Proceedings of the Second Australasian Conference on

ENGINEERING HERITAGE

2000

convened by IPENZ national committee for Engineering Heritage and administered by Continuing Education at the University of Auckland

ipeNz
Institution of
Professional Engineers
New Zealand

The
Institution
of
Engineers,
Australia

Proceedings of
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on
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Auckland
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Edited by:

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Cover photos

Front Cover: General view of Waikato River at Arapuni as preparations are made for river diversion. c.1925

Rear Cover: Detail at bottom left of front cover, showing the downstream portal of the diversion tunnel during construction. c.1925

INTRODUCTION TO THE CONFERENCE PROCEEDINGS

This Engineering Heritage Conference is the second of the Australasian Engineering Heritage Conferences. The first was held at the University of Canterbury from 27-30 November 1994. As with the earlier conference, both IPENZ and IEAust are sponsors.

The Conference Committee has been fortunate to have financial sponsors. The Joint Major Sponsors are Construction Techniques Group (New Zealand) and Remedial Engineering Group (Australia). Holmes Consulting Group and Svedala NZ Ltd are also sponsors.
Their interest and financial support has been important to the conference arrangements.

One of the moving spirits associated with the Christchurch Conference in 1994 was John Scott Pollard (1923-1999). Due largely to his efforts and advocacy, the IPENZ National Committee for Engineering Heritage was formed in the 1980's, and John was the first and long serving Chairman of the Committee. John died a few months ago. His Obituary in the Wellington Evening Post of 22nd July by Miles Kennedy and Bob Norman, titled "Chemical engineer with a concern for heritage", is a fine tribute to his achievements. As a mark of our respect the John Pollard Prize will be presented to the author(s) of the best Conference paper by John's widow, Biddy Pollard, at the Conference Dinner.

We have three Keynote Speakers who have responded to our invitations and are giving generously of their time for our Conference. In advance we thank our Keynote Speakers, Dr Roger Blakeley, Bruce Leaver and Rob Irwin for their contributions.

Also in advance, we thank the Session Chairpersons, since their guiding of the Sessions is so important to the smooth running of the Conference.

Heritage Committee members have spent much effort in arranging the pre-Conference Tour and we are confident that this will be a worthwhile preliminary to the Conference proper.

The present Conference is being held at a very busy time, with other events in Auckland claiming much attention. The most notable of these other events is the defence of the America's Cup, scheduled to begin a few days after this Conference ends.

We wish all our conference goers a successful and worthwhile Conference.

Finally a special thank-you to all our authors for their contributions.

The Conference Committee
January 2000

ALPHABETICAL CONTENTS BY AUTHOR

PAPER SESSIONS DETAIL

MONDAY 14 FEBRUARY

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Baxter	*Redundant Industrial Heritage - The Challenges and the Solutions*
Cox, Rynne	*A Synergistic Approach to the Recording, Interpretation and Conservation of a Built Environment*
SESSION 1B:	**Infrastructure, Power**
Aitken	*The Story of Hydro Electric Development on the Waikato River*
Baker	*Kingston Powerhouse's Past in the ACT's Future*
Clark	*The Benmore-Haywards HVDC Link*
SESSION 2A:	**Heritage: Preservation and Education**
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Beauchamp	*The Victorian Engineers of University Square*
Lowe	*Some Aspects of Australasian Academic Engineering - from Rankine to Southwell*
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Hill	*Clarks Flour Mill and Water Race, Maheno, North Otago*
Hutchinson	*Salvage of the Dredge "Hapai"*
Richards	*Benalla Water Supply*
SESSION 3A:	**Natural Resource Conservation Issues**
Bird	*Restoration of New Zealand's Largest Sawmill Tramway Viaducts*
Barry	*Bucketladder and Paydirt*
Hutton, Knapman	*Mining of Kerosene Shale at Glen Davis - Was it a Success or a Costly Failure?*
SESSION 3B	**Transport, Defences, Timber Structures**
Gamble, Stewart	*Auckland's Electric Tramway Heritage - Celebrating 100 Years*
Veart	*Propping up the Past, Concrete Repair Work at the North Head Historic Reserve*
James	*Survey of Large Timber Structures in Western Australia*

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Leaver	Australia's Heritage System - Building on a Quarter Century of Heritage Achievement
Bishop	William Ferguson, Founding Father of the Engineering Profession in New Zealand
SESSION 4A	**Seismic Influences, Maritime**
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Taylor et al	*Seismic Resistance: Heritage, Architecture and the Post-Colonial*
Laxon	*New Zealand's Marine Engineering Heritage*
SESSION 4B:	**Heritage Buildings - Fire Protection**
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Caldwell, Bowron	*Historic Places Trust Guidelines for the Fire Protection of Historic Buildings*
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KEYNOTE 3

Irwin	Heritage Engineering - Our Professional Obligation; Practical Development in Achieving our Goals
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Pitt	*A Case for Preservation of Historic Machinery with Special Reference to Less Appreciated Items as Refrigeration Machinery*
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SESSION 5B:	**Protecting Heritage Structures**
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Wyatt	*Ralph Symonds' Plywood Factory*
Sandie, O'Neill	*The Hoffman Brick and Tile Company, Melbourne, Australia*
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Thornton	*Early Suspension Bridges in New Zealand*
Norman	*Heritage at Risk: The Rape of Our Resources*

PROGRAMME SESSIONS

Sunday 13 February

4.30pm Registration Opens

6.00pm Powhiri (Welcome)
6.30pm Drinks, Snacks
7.00pm Official Opening
- Mayor of Auckland
- Sir Ron Carter, President IPENZ
- Representative, IE Aust.

8.30pm Close

Monday 14 February

8.00am **Registration**

8.30am **Opening Address**
- Dame Cath Tizard, Chair, Historic Places Trust

8.50am **Address**
- Dr Rob Aspden, Ipenz Heritage Committee
  Introducing Conference Theme "The Past in the Future"

9.00am **Keynote Address**
- Dr Roger Blakeley, Secretary of Internal Affairs

10.00am Morning Tea

10.30am **Papers Session 1 (Parallel Streams)**
- Heritage: Legislation and Policy
- Infrastructure, Power

12 noon Lunch

1.30pm **Papers Session 2 (Parallel Streams)**
- Heritage: Preservation and Education
- Industrial Heritage

3.00pm Afternoon Tea

3.30pm **Papers Session 3 (Parallel Streams)**
- Natural Resource Conservation Issues
- Transport, Defences, Timber Structures

5.00pm Session concludes and Partners Kawau Island Trip returns

5.30pm **Visit to Museum of Transport and Technology.**
Transport and refreshments supplied.

8.00pm Return to City for own (dinner) arrangements

Tuesday 15 February

9.00am **Keynote Address**
- Bruce Leaver, CEO, Australian Heritage Commission
  "Theme: The Past in the Future"

10.00am Morning Tea

10.30am **Address**
- Warwick Bishop, IPENZ
  "William Ferguson, Founding Father of the Engineering Profession in New Zealand"

11.00am **Papers Session 4 (parallel Streams)**
- Seismic, Maritime
- Heritage Buildings - Fire Protection

12.30pm Lunch - A little later than usual

1.30pm Site Visits to places of historical interest.
Afternoon tea included

4.30pm Return to Hotels

7.00pm for 7.30pm **Conference Dinner :**
Theme - Heritage Hats and Headgear
Rose Garden Restaurant

Wednesday 16 February

9.00am **Keynote Address**
- Rob Irwin, Chairman, Construction Techniques Group of Companies

10.00am Morning Tea

10.30am **Papers Session 5 (Parallel Streams)**
- Industrial Heritage
- Protecting Heritage Structures

12 noon Lunch

1.30pm **Papers Session 6**
- Bridge Heritage. Recent Conservation Experience

3.00pm Closing Session, Refreshments

4.00pm Conference concludes

The Story of Hydro Electric Development on the Waikato River

A.W. Aitken B.E.(Civil) F.IPENZ.
Formerly Engineer-in-charge, Waipapa Power Project

Summary

The development of the Hydro Resources of the Waikato river have played a major part in New Zealand's economic growth. Altogether the eight projects built between 1924 and 1964 utilise 89% of the total fall available between Lake Taupo and the sea. This provides a total peak generating capacity of 1,045 megawatts of pollution free renewable energy. Despite the difficulties imposed by the geological nature of the underlying rock encountered, the qualities of which were virtually unknown at the the start, and utilising techniques at the forefront of world technology, the schemes were built and remain testimony to the design and construction capacity of the Ministry of Works (Public Works Department) and the NZ Electricity Department (State Hydro Electricity Department). The primary printed source for this paper, and of figures 1-8, is the book "People, Politics and Power Stations" edited by John Martin, see Reference.

1. Introduction

The potential of the Waikato River as a source of hydro electric energy was recognised right from the earliest days of the development of electricity.

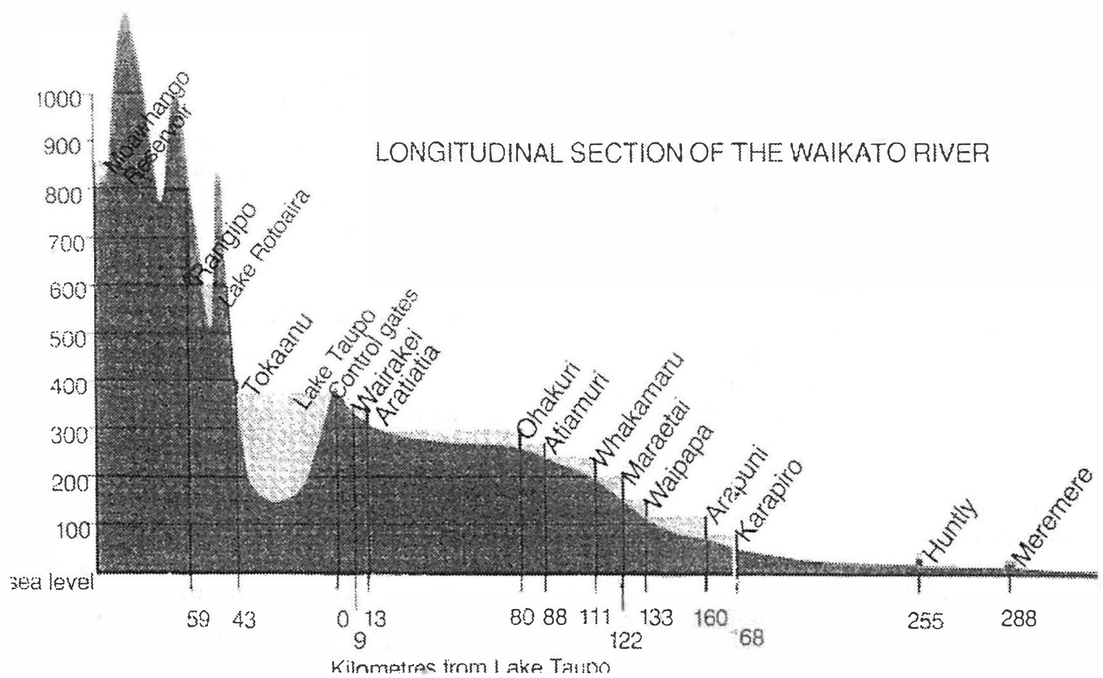
With a total fall of some 357 metres from Lake Taupo in its more than 300 kilometers journey to the sea, interest in its utilisation was first considered by an entrepreneur, Mr. J.C. Firth, in the 1880s. With the requirements of the mining industry in mind he engaged Professor George Forbes, the designer of the Niagara Falls Station, to investigate a suitable site. The report selected Huka Falls as the optimum. However the Government of the day vetoed the proposal, as it would have involved giving a long term water right to British financiers, akin to Niagara Falls.

In 1904 Mr. P.S. Hay, the then Superintending Engineer for the Public Works Department, together with Mr. L.M. Hancock, a Californian consultant, did a reconnaissance trip up the river to assess the potential for power generation. The Hay Report, which has since become regarded as a classic, prescribed most of the sites on which stations have since been built. Huka Falls was regarded as the obvious starting point. However this was not to be.

Horahora

It was not until 1912 that the first power station was built. This was Horahora, a private low head scheme developing 6.3 megawatts for the Waihi Gold Company. In 1919 the Government purchased the station and extended its capacity to 10.3 megawatts.

Horahora continued to supply the National Grid right up to 1947 when it was drowned out by the lake which

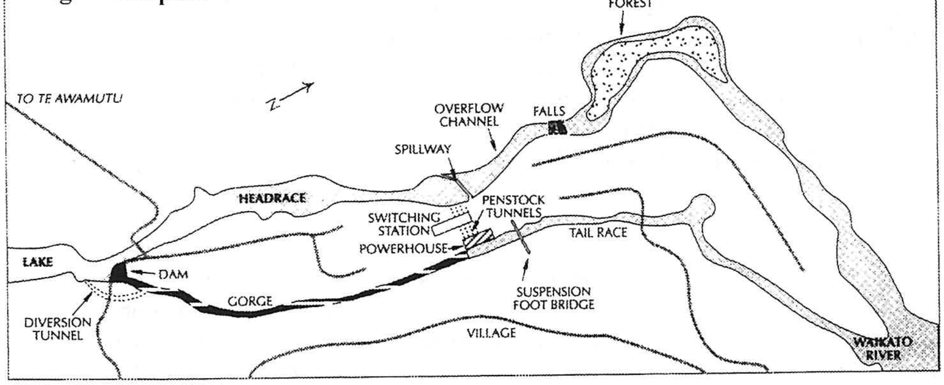


formed when Karapiro Station came into operation.

Arapuni

After the end of World War 1 the demand for electric power was increasing so rapidly that the Government decided to build the Arapuni Scheme. The station, which was large by any standards of the day, was controversial from the outset. It was the first of six

Fig 1 - Arapuni



stations on the river to be founded on ignimbrite rock which presented problems of various sorts with all the schemes where it was involved. Geologists maintain that ignimbrite had been erupted in the form of a viscous cloud of particles, which, on being deposited in sheets (or layers) of varying depth, shrinks and cracks on cooling. The configuration of the underlying country varied and determined the nature of the cracking through differential settlement.

The Project was designed by the Public Works Department. The Dam site was thoroughly investigated but because ignimbrite, at that stage, was more or less an unknown quantity, the PowerHouse site was to prove a major problem. A contract for the complete construction was let in 1924 to the English contractors, Armstrong Whitworth.

After completing the diversion tunnel, the dam and the headworks, the contractor made a start on excavating the PowerHouse foundations. It was at this stage that they declared it was impossible to build, because of the uncontrolled leakage of the cofferdam, and abandoned the remainder of the Contract. The Public Works Department redesigned the foundations and completed the project with their own forces in 1929.

The operation of the spillway revealed another major problem with erosion downstream. Both the rock and the pumice overlay retreated at an alarming rate. The removal of the volcanic material on the alluvial flat where the flow discharged revealed the prehistoric buried forest that is obvious today.

After two years of operation disaster struck. A crack appeared at the intakes, parallel to the river and along the line of the headrace. The station had to be closed down while the headrace, the source of the water that opened up the crack on an old fault line, was lined and the crack pinned and grouted – a major job. This was done on the recommendation of Professor Hornell, a Swedish expert. At the same time the waterfall below the spillway was concreted to halt the horrendous erosion of the old channel.

Power generation was resumed in 1932 and four additional machines were added to the original four so that, by 1946, it reached a total capacity of 158 megawatts. Despite a further crisis in 1958, when an excessive flood ripped out part of the headrace, Arapuni has continued to be a major contributor to the North Island grid.

"Arapuni stands testimony to the ability of early engineers to design and construct a large scheme on a complex site with little prior experience and much more meagre resources than were available to their successors." Ref. P.97

2. Further Investigation

After completion of the remedial works on Arapuni investigation of further sites, both up and down the river, was put in hand. These included Karapiro, Maraetai, Whakamaru, Ohakuri and Waipapa. Access to some of the sites was difficult and conditions for the investigation team of surveyors, drillers, geologists, tunnellers etc were primitive to say the least.

Taupo Control Gates

Control of storage of the river at source, that is Lake Taupo, was a crucial element to the development of the downstream stations. Today Lake Taupo provides 15% of the country's hydroelectric storage. In 1940-41 a control gate structure, which was combined with a bridge for State Highway 1 (the country's main artery) was constructed.

The Lake is controlled over a range of 5 feet which is its natural range of fluctuation.

Karapiro

In the meantime on completion of Arapuni it was decided to proceed with Karapiro as the next major scheme.

Detailed investigation and design began in 1937 and construction by the Public Works Department, later to be called the Ministry of Works, began in 1939 with the building of the 25 feet diameter diversion tunnel. Although Karapiro was the only scheme founded on greywacke rock, the foundations were not without problems and required intensive grouting – that is pumping of cement into the ground to seal the cracks. The diversion tunnel and gate shaft were completed in 1940 when work had to be suspended with World War II and the demands it made on manpower and resources.

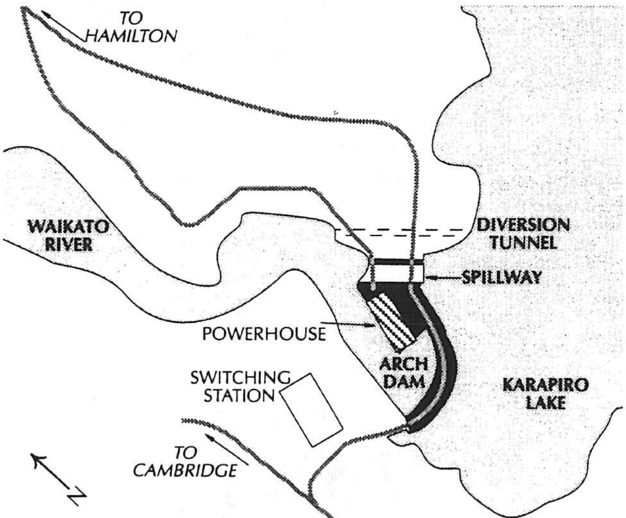


Fig 2 - Karapiro

Work was resumed in 1943 and completed in 1947.

Karapiro has an operating head of 100 feet. It is a concrete arch dam 219 feet high and 1,089 feet long with a gravity abutment taking the thrust on the right bank side and which incorporates the spillway and intake structures. The PowerHouse also forms part of the dam structure. Three 21 feet diameter steel penstocks lead to three Kaplan Turbines, with automatically controlled variable pitch blades, driving 30 M.W. generators with a total capacity of 90 M.W.

The Spillway was designed for a capacity of 25,000 cub. feet/sec. This, as has Arapuni, been subsequently enlarged to take the extra flow in the river with the development of the Upper Taupo resources and the Western diversions that were included.

As has been mentioned the filling of Karapiro Lake drowned out Horahora and part of S.H. 1 but in so doing has created a stretch of water that has become renowned for aquatic sports such as rowing, water skiing and yachting.

3. Mangakino

In 1946 a start was made to construct the town of Mangakino. It was regarded as semi-permanent and prior to a bridge being built was only accessible by barge. At its peak Mangakino had a population of over 6,000 and served as the centre for construction of most of the dams built to complete the harnessing of the River's fall from Taupo to Cambridge. It was regarded as a model town and was a big advance, at the time, on previous construction accommodation.

Maraetai I

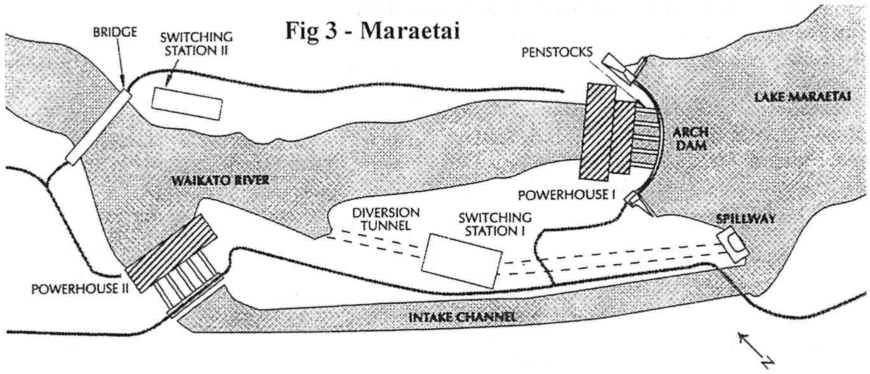
Maraetai some 20 miles up river from Arapuni was the next scheme to go ahead. Starting in 1946 it consisted of a concrete arch dam in the deep and narrow gorge. The PowerHouse took up the full width of the gorge so that the spillway had to be incorporated with the diversion tunnel. The ignimbrite again presented major problems. The driving of the 25 feet diameter diversion tunnel was made extremely difficult by the influx of water which proved a major problem to seal off and required a battery of pumps to keep the water level down. The abrasive nature of the lower rock was also to prove very difficult to excavate. Once again extensive grouting was required including a 180 feet deep grout curtain along the centre line of the dam.

The scheme was completed in 1953. It is described as a concrete variable radius arch dam, 436 feet long, and 285 feet high. Five Francis turbines drive 36 M.W. generators making a total capacity of 180 M.Ws.

Maraetai II

Before completion of Maraetai I it was decided to build a second powerhouse, downstream from the existing spillway tunnel outlet, as a peak load station. Excavation of the intake channel was well advanced when a government decision was made to stop. However, with additional flow into the Waikato with the Western Diversion stage of the Tongariro Development,

Fig 3 - Maraetai



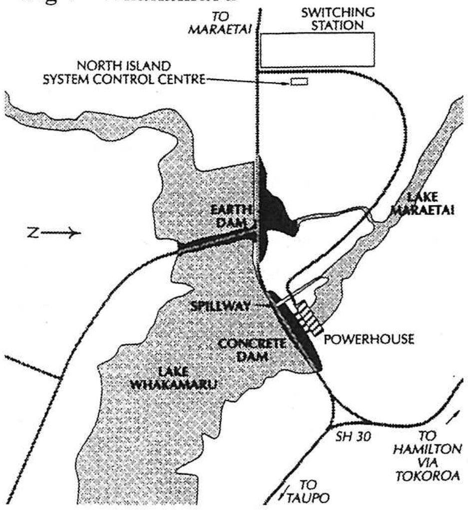
the decision was reversed and the scheme completed in 1970.

Maraetai II power station is identical to Maraetai I and thus gives a combined output of 360 M.Ws. for peak load conditions.

Whakamaru

The Whakamaru station was sited at the head of the 7 mile long Maraetai Lake. Initial investigations were carried out from 1940-44 but, because of the geologically complex structure of the ignimbrite rock, more intensive work was required from 1946-49. Construction proper started in 1949 with the building of the large diversion channel which subsequently forms part of the spillway. There is an earth dam at the western end of the concrete dam which diverts the

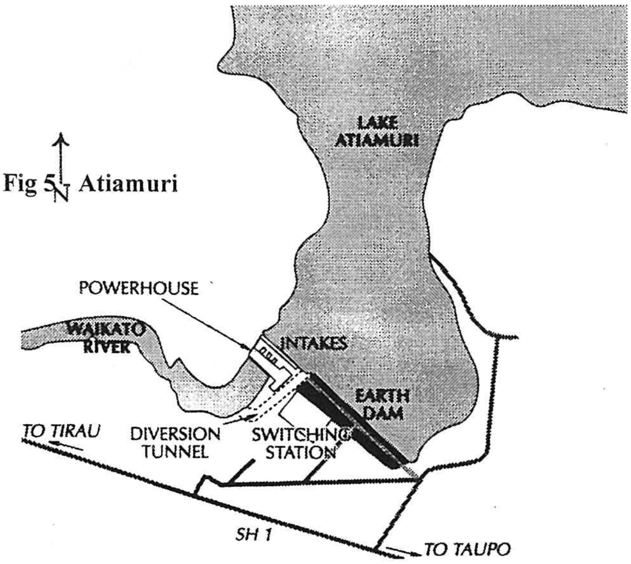
Fig 4 - Whakamaru



Mangakowhiriwhiri Stream in to the main lake. When the riverbed was uncovered it was found that a fault, (or crack,) ran diagonally across the base of the dam. A series of four tunnels at about 20 feet vertical intervals were driven along the fault line. The crack was washed out and filled with grout. The tunnels were then filled with concrete to key the rock together. To reinforce the rock to take the thrust of the gravity dam, inclined tunnels were also drilled below the dam. Work was completed in 1956.

Whakamaru has a central concrete gravity dam 184 feet high, 1,106 feet long and contains 4 penstock intakes and the spillway. The earthfill dam is 1,299 feet long and 93 feet high. The steel penstocks lead water directly to the Powerhouse below the concrete dam with 4 turbines driving 25 M.W. generators for a total capacity of 100 M.Ws. The dam also provides the road link to the west of the River.

Fig 5 Atiamuri



Atiamuri

As the Power Design Office of the Ministry of Works was more than fully committed with stations in both the North and South Island, the design of Atiamuri, the next on the programme, was let to an English firm, Sir Alexander Gibb and Partners. It is situated at the head of the Whakamaru Lake. Work started in 1953 with the building of accommodation, clearing the lake area of pine forest and the realignment of the State Highway. A bridge was built across the river and a road built to connect with Whakamaru and to Mangakino (where some of the work force was still located). Twin diversion culverts, one of which was blocked and the other formed the spillway, were completed by 1956. The concrete gravity section of the dam is 143 feet high and sits on a hard rhyolite rock dome, well grouted. This connects to an earth dam wing 840 feet long. Four steel penstocks take water to turbines driving 21 M.W. generators giving a total output of 84 M.W.

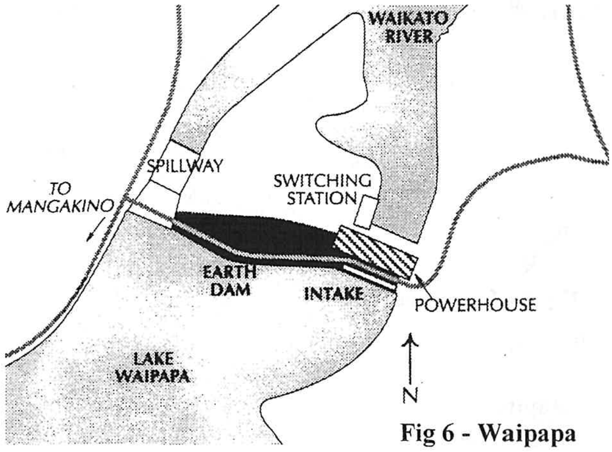


Fig 6 - Waipapa

Waipapa

Waipapa, at the head of Lake Arapuni and seven miles downstream from Maraetai, is the smallest of the Waikato stations. It had been under consideration since 1943 but was extremely problematical because of the difficult foundations in the riverbed. The river had cut its way through the ignimbrite of the area and into alluvial material underneath. Because of the complexity of the site and other priorities, work did not begin until 1955. Ref. p.164

It was decided to site the core of the earth dam on the only rock that crossed the river in the form of a bridge which was overlain by some 20 feet of soft silt. Extensive grouting was again required including a 100 feet deep grout curtain. A 1,700 foot diversion tunnel, which formed the spillway was built in the left bank, and the intakes and Powerhouse on the right bank side with a 121 foot high earth dam 525 feet long spanning between. With a head of 53 feet and with 3 Kaplan turbines driving generators of 17 M.W. Waipapa produces a total of 51 M.Ws.

Ohakuri

The rock of Ohakuri is known as a silicified pumice breccia. It is similar to ignimbrite and could well be the same that has been hydro-thermally altered. It is pink in colour and has been used as a building stone.

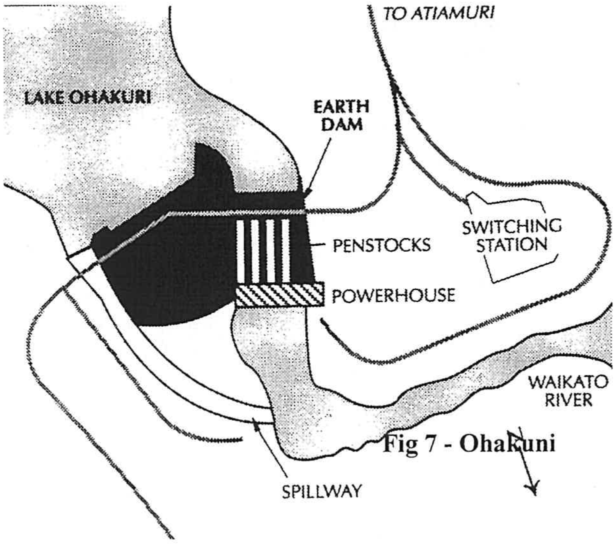


Fig 7 - Ohakuni

The site appeared to be ideal for an arch dam but the strength of the rock for the right bank abutment was doubtful so a gravity dam was considered. Excavation of the river bed revealed a deep hole that had not been identified in the investigation, so it was decided to build an earth dam with concrete spillway in the right bank and intake structures on the left.

Ohakuri was started in 1956 and completed in 1961. Four turbines drive 28 M.W. generators to produce a total capacity of 112 M.W.

Lake Ohakuri is the largest artificial lake in the North Island and is popular for boating. It drowned out much of the Orakei-Korako geothermal activity.

Aratiatia

The construction of Aratiatia, the last of the Hydro Projects, was a very contentious issue because the rapids are such a scenic attraction. After much negotiation it was agreed that a station should be built provided it was made as unobtrusive as possible and would operate the rapids at set hours each day. The site should also be landscaped and replanted in native trees.

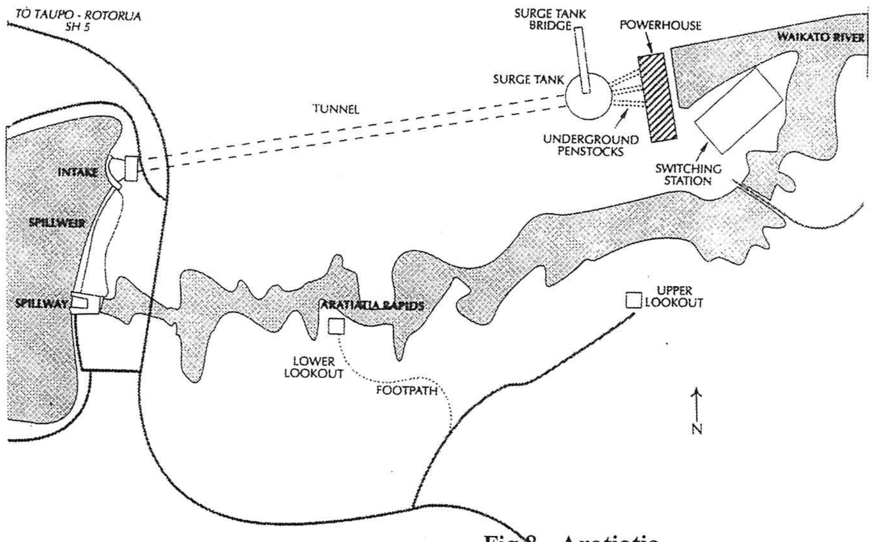


Fig 8 - Aratiatia

Although the Huka Falls had early been considered for hydro development and would have been another contentious environmental issue it was found to have subsurface geothermal energy which made their development, as a hydro resource, impossible.

The construction of Aratiatia meant some 89 percent of the total head available from Lake Taupo to the sea was utilised.

The scheme was designed with a low head dam with a spillway gate at the top of the rapids, the daily opening of which provides a great tourist attraction. A 30 foot diameter tunnel leads to a large surge chamber (120 feet in diameter) and thence to the PowerHouse out of sight from the rapids. With an operating head of 110 feet 3 turbines drive 30 M.W. generators for a total output of 90 M.W.

Construction started in 1959 and finished in 1964.

Thermal and Geothermal Stations

The Waikato also provides cooling water for the Meremere (since decommissioned) and the 1,000 M.W. Huntly Thermal Power Stations as well as the Wairakei and Ohaaki Geothermal stations.

4. Conclusion

New Zealand has indeed been fortunate to have had the Waikato available to develop such a cheap, reliable, environmentally sustainable source of energy. It's good fortune also extends to having had an organisation in the Ministry of Works with the ability and the capacity to design and propagate works in the forefront of existing technology. The NZ Electricity Department, or as it was then called, the State Hydro Electricity Department, also played a major part with the installation and development of the generating machinery and the network distribution of the power produced.

5. Acknowledgements

Thanks are given to Historical Branch, Ministry of Internal Affairs and Mighty River Power Company, for supplying "People, Politics and Power Stations" as the principal source of reference. Also to J.H. Macky C.B.E., B.E., M.I.P.E.N.Z, former Project Engineer, Mangakino, and Commissioner of Works, for supplying much background information.

6. Reference

People, Politics and Power Stations – Electric Power Generation in New Zealand 1880-1998. Editor John E. Martin, Historical Branch, Department of Internal Affairs

Past voices - Future lessons

Rob Aspden, F.IPENZ, FIEAust
Formerly Resource Manager, Power Engineering Group,
Opus International Consultants Ltd

SUMMARY: The technique of oral history is a valuable means of collecting and storing personal history and experience. This paper briefly describes the process and then looks at how the engineering professions have used this technique both in Australia and New Zealand. IE Australia has established an excellent program while nothing equivalent currently exists in New Zealand. However some interviews with engineers has been undertaken in New Zealand and this work is described. The paper concludes with the recommendation that a similar program to the one in Australia be established in New Zealand.

1 INTRODUCTION

"The world is changing" is a truism that seems to have lost its impact through overuse. Yet as shown well in other papers at this Conference, dramatic changes are occurring in New Zealand and throughout the world which make the recording of people's experiences even more vital now than they have ever been in the past. This is particularly true in the engineering field. I won't comment on whether I think the change is a good or a bad thing, but what does concern me is the apparent lack of interest in the past by the people who govern corporate processes.

Oral history is a growing and valuable source of information involving a wide range of people who have helped to build the fabric of a country. It is not necessarily "history" as historians would define it, but is a personalised view of events. The process is ideally suited to the engineering profession, which is not noted for the willingness of individual members to record their lives and describe the history of developments which have had a major impact on the lives and prosperity of people both in Australia and New Zealand.

2 THE ORAL HISTORY PROCESS

A detailed account of the oral history process is contained in the books by Hutching (1) and Fyfe et al (2). Obviously the process must start with the training of interviewers and the purchase of suitable equipment for recording interviews. Given the required equipment and suitably trained interviewers then the process is:

(i) Planning of the project and selection of suitable interviewees (or informants):

First the objectives of the project need to be defined and a decision made as to where the material obtained will be deposited. The selection of people for interview must take into account their significance in the profession, in their community and in the country. It also depends on their willingness to be interviewed and their ability to remember, describe and assess past events and achievements. Obviously since the list will be quite large, a prioritised list needs to be prepared.

(ii) Research for the interview

Before contacting the interviewee the interviewer must have done essential background research relating to the subject. This means, not only the personal milestones of the interviewee, but also the local, the regional, the national and the international events that will have impacted on his or her life. The personal milestones can also be obtained at the preliminary meeting.

(iii) The preliminary meeting

Thus prepared the interviewer is ready to contact the interviewee and arrange a preliminary meeting. At this meeting the purpose of the interview and the procedure to be adopted are explained. Obviously it will also be necessary to obtain the interviewee's agreement to the interview and explain what will happen to the tapes made and their ability to determine the level of access that members of the public will have to the tapes. An agreement form for the interview is then left with the interviewee to examine at leisure.

(iv) The interview and the signing of the agreement form

Obviously good quality recording equipment and tapes are required for the interview, and the interviewer must be confident with the use of the equipment and with recording techniques. Practice in the use is essential! Then comes the interview, using open-ended questions and endeavouring to minimise the amount of time that the interviewer asks questions. The interview needs to be well planned and follow a logical order, starting with basic family information, to allow both interviewee and interviewer to get used to one another. At the end of the interview the Agreement form has to be completed and signed. This form ensures that there is a clear understanding of the potential uses that the tapes may have and the restrictions that the interviewee may wish to impose on their use.

(v) Follow-up to the interview

Essential housekeeping follows the interview:

- completing biological, occupational and genealogical details
- labelling, protecting and copying the tapes and
- writing to thank the interviewee,.

(vi) Preparation of the abstract

A full transcription of the tapes is rarely made. Instead it is usual for an abstract (or "log" as I believe it is called in Australia) is prepared. This lists the subjects described in the interview and gives some basic details, so that it serves to provide a guide to the information contained in the recording.

(vii) Write an interview report and deposit the tapes and abstract in the selected archive.

Finally a report is written and the tapes and abstract deposited in the chosen archive.

3 INSTITUTION OF ENGINEERS AUSTRALIA ORAL HISTORY PROJECT

I actually feel an impostor in presenting a paper on this subject to an Australasian engineering heritage conference. The Institution of Engineers, Australia is way ahead of New Zealand in this regard and the person who should be presenting this paper is Michael Clarke, who manages the very successful oral history program in Sydney for the Institution. He and his team (including a part-timer employed by the Sydney Division) commenced their program in 1991. As at September 1999 they have deposited close to 140 interviews complete with their own logs (or abstracts) in the State Library of NSW (Mitchell Library) in Sydney, and they form The Institution of Engineers Oral History Collection. Details are contained in papers presented by Block (3), and by Clarke (4 & 5). There is also up-to-date information on the IE Australia website (6) and details on costs and the operation of the program have come directly from Clarke (7).

The IE Australia website provides the following information about the program objectives:

The objectives of the Oral History Program are to:

- Record in their own voice, the working history and experiences of eminent and historically important engineers, and of others who have had engineering experiences of historical interest; and in so doing, capture the interviewee's comments and opinions on social, political and work practices applying during their career and the influence of these on society, the interviewee's life and work, and their personal, work and professional decision-making;

- Ensure conservation of the material created as part of the Nation's engineering heritage;

- Encourage use of the material to promote the engineering profession and its contribution to society;

- Subject to any limitations imposed by either the interviewee or the Committee, make the material freely available to libraries and all those with a bona fide interest such as authors, journalists, researchers, historians and biographers.

The current aim of this program is to undertake 50 interviews a year, 30 of these by professional interviewers and 20 by volunteers, depending on the funds available and availability of trained volunteers. The interviews last on the average around two hours and their costs for professional interviewers are around A$220 per interview (including the preparation of the abstract). Their current budget from the IE Australia Engineering Heritage committee is around $3,000 to 4,000 per year and they hope to continue to get a 50/50 heritage assistance funding from the government. They also have a part-time employee who undertakes much of the support administrative load for the project. Michael Clarke considers that without her "his efficiency would be more than halved". It is also necessary to note that as a volunteer he is involved 4 days a week on heritage matters. So the success of the program is due in no small measure to the energy and commitment that he and others have given to it.

4 THE SITUATION IN NEW ZEALAND

An attempt to establish an oral history program under the auspices of IPENZ has been made in the past but it has not made any significant progress through lack of support. However a number of professional engineers, sponsored by other groups, have been interviewed and the resulting tapes and abstracts deposited in the Oral History Centre at the Alexander Turnbull Library (part of the NZ National Library). A disappointingly small list of people described as "engineers" for whom interviews are held at the Oral History Centre is attached as Appendix A (8). It can be seen that of the 52 people listed, 28 were members of IPENZ. Of these IPENZ members, 22 are engineers who were interviewed as part of the Electricity Centenary Oral History Project, described in the next section.

The Radio New Zealand Sound Archives in Christchurch have not been checked but will probably include many engineers. Also for the centenary of the Ministry of Works around 1970 many retired engineers were interviewed. However it appears that only snatches of these interviews remain, contained in a series broadcast on radio entitled "Trailblazers". No doubt there are a few other engineers who have been interviewed and whose tapes are held in other archives in the country, but it is unlikely that there are very many. Certainly the 1992 directory of oral history collections (9) only lists two engineers in the directory.

Major changes have occurred in New Zealand since 1984. In particular, the transformation of the big government engineering departments (New Zealand Rail, the Ministry of Works and Development, the Ministry of Energy, NZ Post Office and NZ Broadcasting Corporation) into government corporations and private companies. These departments were responsible for major infrastructure developments in New Zealand and the story of this development is one which urgently needs capturing and recording. It does not appear that the organisations which have replaced the departments show a great deal of inclination to record the developments which occurred before their time and unless other groups take action, these personal stories will be lost.

5 THE ELECTRICITY CENTENARY ORAL HISTORY PROJECT

The centenary of the electricity industry in New Zealand was celebrated between 1986 and 1988 and as part of the celebrations I had the good fortune to be asked to arrange a series of oral history interviews. An account of this project is given a Works News article (10), and in the end of stage reports prepared by Fyfe et al (11). The project involved the interview of 32 people who had had significant involvement with the industry during the major development period, some dating from the mid 1910s. Twenty two of the interviewees were engineers, seven were technicians or tradesmen, one was a union organiser and two were the wives of two other interviewees who had lived with their husbands on the construction projects. A list of the interviewees is provided in Appendix B.

The electricity industry has changed dramatically over the last ten years and in the last three years the Electricity Corporation of New Zealand (ECNZ), has been split into four generating companies. Also local body electricity supply bodies (power boards and municipal electricity departments) have been merged, corporatised and split into line companies and supply companies. Until 1996 ECNZ was a government corporation and the main generator of the power supply (around 95%). It was formed in 1987 from the Electricity Division of the Ministry of Energy. The primary government involvement in the electricity industry began with the formation of the Hydro-electric Branch of the Public Works Department (PWD) in 1911. This became the State Hydro-electric Department in 1946 but in 1948 the civil engineering design section returned to what had become the Ministry of Works (MOW - formerly the PWD). The State Hydro-electric Department in turn became the New Zealand Electricity Department (NZED) in 1958 and then the Electricity Division of the Ministry of Energy in 1978.

The Public Works Department (PWD) was formed in 1870 and continued as such until just after the Second World War. In 1948 it was merged with the Ministry of Works which had been formed during the war (1943) and became the MOW. This was broadened to Ministry of Works and Development (MWD) in 1973. In turn the MWD was corporatised in 1988 and became a State-Owned Enterprise, Works and Development Services Corporation (NZ) Ltd and then in 1996 its consulting arm became Opus International Consultants (Malaysian owned). Through this time (from 1948) the Power Division and then the Power Engineering Group remained directly involved in the country's power generating system.

Many of the conference participants will have been on the pre-conference tour through the Waikato and seen some of the hydro-electric dams in the Waikato development. As Alec Aitken has explained in his paper on the development, this project was a major post war scheme, actually started (apart from the 1920s construction of Arapuni) at Karapiro in 1940 and completed (apart from Maraetai II) with Aratiatia Power Station in 1964. Other major projects occurred in this period and subsequently up to the late 1980s in the Tongariro (Upper Waikato), and in the South Island on the Waitaki and Clutha rivers. These schemes were major developments for a country in which electricity load growth was increasing dramatically. Their social and economic impact were very large and of a scale, particularly as government agency developments, that will probably not be seen again.

A certain amount has been published on these projects (the best overall book being Martin (12)) but relatively little about the living and working conditions on them. Hence the fact that of the 32 people interviewed, 19 have extensive construction project experience, makes this a very valuable collection. This experience is mainly on the Waikato ("River Men"),- 3 civil engineers, 4 electrical engineers, and 4 overseers. Also two wives (Frances Robins and Ella McLeod) experienced the problems of Mangakino life and record their memories on the tapes. (Mangakino was the project town for the Waikato development). Four were project engineers for a time (McLeod, Macky, Ridley and Smith) and four overseers/ construction supervisors each spent an average of 40 years on various projects around the country.

However the record contained in the collection is very much broader than this. Other aspects covered include:

- One General Manager and one Assistant GM of the NZ Electricity Dept (NZED) (Blakeley and Bambery)
- One Secretary of Energy (Duncan);
- Two Commissioners of Works (Macky and McLeod);
- One Engineer-in-Chief of the Ministry of Works (MOW) (Turner);
- 15 who worked in the design office of MOW or NZED;
- 6 were involved with the operation of the hydro-electric stations;
- 9 were involved with electricity supply bodies;
- 6 who worked as consulting engineers;
- One internationally recognised earthquake design expert (Hitchcock);
- One journalist (Stace);
- One trade union man who became the General Secretary of the NZ Workers Union (Duggan);
- One Rhodes Scholar and Member of Parliament (Ridley);
- Two women who were trained nurses (Robins and McLeod);
- One member of the NZEF (1914/18) (Nicol);
- 12 people who served in the Second World War;
- One of these served in the Maori Battalion (Waiwai);
- At least two were involved with the rebuilding work following the Napier earthquake (Turner and Robins);
- Two had fathers who were senior figures in the early years of the PWD Hydro-Electric Branch (Hitchcock and Robinson);
- One was a key figure in the establishment of the State Hydro-electric Department and the subsequent move of the civil design section back to the MOW (Turner);
- Two were very involved in roading development in NZ (Turner and Macky);
- One was the first Director of the Water & Soil Division of the MOW (McLeod); and
- Two were very competent musicians (Ritchie & Mill);

The collection can therefore be seen to be a wealth of information, not only about the electricity industry but other facets of engineering and life in New Zealand. The material collected is in its raw state and is unedited, and as such is also a valuable record of styles of speech and language of this period. The recordings are available to genuine researchers but because of some potentially sensitive information provided at times, the responsibility for control on access now rests with the Manager of the Power Engineering group of Opus International Consultants Ltd.

It is also worth noting that it was quite an expensive program because a good deal of travelling was involved and because photographs supplied by the interviewees were copied on to archival paper and have been placed with the abstracts. The photographs provide a valuable addition to the collection. The total cost was around $54,000 (including GST) for the 32 interviews.

Sadly, at the time of writing this paper, eleven of these people have died since being interviewed. It is at least rewarding to think that an indelible record of their lives, experiences and achievements will be preserved for the future.

6 THE PRESENT AND THE FUTURE

In the 12 years since the interviews were made there has been limited but very useful access to the tapes. Two post graduate students have used them for background information for their theses. One of these theses was examining the social history of Mangakino Township (1947 to 1967). (I have no reference for this thesis). In addition, I have used the tapes for the preparation of an essay on Charles Turner which is shortly to appear in volume 5 of the Dictionary of New Zealand Biography (13) and also for an obituary for Harry Hitchcock in 1998 (14). Although this is limited use to date, I have no doubt that with time particularly as time passes on the corporatisation and restructuring processes that the electricity industry has undergone the value of this collection will become more apparent.

However the electricity industry is not the only area where major changes have occurred. The whole engineering field has changed dramatically, as will be mentioned by other speakers, particularly the large government engineering departments. As seen in Appendix A, four engineers from the Post Office have been interviewed shortly before it was split into separate components. This is a small number but certainly better than other organisations. However there is a clear and urgent need for a better record to be established of the people who participated in the major infrastructure development in New Zealand following the Second World War.

We have so much to learn from the experience and wisdom of these people that it will be a great loss, not only as a record of our past but even more as lessons to the engineers of the future. The work that Michael Clarke and his team are doing for the Institution of Engineers Australia shows that they have recognised the responsibility that this generation have to the future and are to be applauded for the great work that they are doing. It is time for the Institution in New Zealand to establish and adequately fund a similar program here and I hope that this conference will support this recommendation.

Perhaps then we might be able to echo Hamlet's words (act 3, scene 2), (although hoping that the memory lasts longer than Hamlet suggested!

"Then there's hope a great man's memory
may outlive his life half a year".

7 ACKNOWLEDGEMENTS

I gratefully acknowledge the valuable and willing help given by Linda Evans and her team at the Oral History Centre in Alexander Turnbull Library, and by Michael Clarke in Sydney and Suzanne Mayrhofer in the IE Aust office in Canberra. Thanks also to Tony Pickford, Manager of the Power Engineering Group in Opus International Consultants Ltd for permission to use the material of the Electricity Centenary Oral History Collection.

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Appendix A - Engineers List from the Oral History Centre

Surname	Forenames	IPENZ	Intvw date	Interviewer	Sponsor	Employer
Ashwin	Barry Stuart		16/12/86	Hugo Manson	Fletcher Challenge	Tasman Paper
Bambery	Colin McIntosh	Y	17/02/87	Judith Fyfe	MWD Power	NZED
Barbarich	Anthony Mathew		14/09/89	Judith Fyfe	Fletcher Challenge	Winstones Ltd
Bettany	Roland		8/05/88	Boyack&Tolerton	Boyack&Tolerton	WW1
Blackwood	John Gordon	Y	25/11/85	Hugo Manson	Fletcher Challenge	Tasman Paper
Blakeley	Philip William	Y	20/02/87	Judith Fyfe	MWD Power	NZED
Chapman	Peter	Y	10/09/87	Hugo Manson	MWD Power	NZED
Dalton	Arthur & Constance		4/12/84	Judith Fyfe	NZ Post Office	NZ Post Office
Donaldson	Sir Dawson	Y	5/12/84	Hugo Manson	NZ Post Office	NZ Post Office
Duncan	William Munro	Y	27/09/88	Hugo Manson	MWD Power	MWD/MoE
Ellis	James Douglas	Y	14/09/88	Judith Fyfe	MWD Power	Hutt Valley EPB
Fookes	Bill	Y	30/09/87	Judith Fyfe	MWD Power	MWD
Girardin	Jack		22/09/87	Judith Fyfe	MWD Power	NZED
Harpham	Percy Wadsley		15/05/84	Hugo Manson	NZ Computer Soc	Progeni NZ Ltd
Herbert	John		17/05/92	Evelyn Wright	Hamilton Public Lbry	Dinsdale Community
Hingston	Clifford		9/11/89	Boyack&Tolerton	Boyack&Tolerton	WW1
Hitchcock	Henry Coleridge	Y	19/02/87	Judith Fyfe	MWD Power	NZED
Hughes	Bert		4/11/89	Boyack&Tolerton	Boyack&Tolerton	WW1
Hunter	Jock		27/09/88	Cath Kelly	Trade Union Oral Hist	NZ Engr Indl Union
Jenkin	Ralph		10/08/88	Boyack&Tolerton	Boyack&Tolerton	WW1
Johnson	John Francis		4/08/88	Caitriona Cameron	WTu et al	Friends Ambulance Unit
Livingston	Norman & Susan		7/05/87	Rosie Little	McKee Trust	Golden Bay
Macky	James Henderson	Y	5/12/88	Hugo Manson	MWD Power	MWD
McDell	Tom & Myrl		17/12/91	Vicki Jones	Hamilton Public Lbry	Dinsdale Community
McDonald	Denford		20/08/90	Hugo Manson	Todd Corpn	Todd Corpn Ltd
McLeod	Norman Colin	Y	13/09/88	Judith Fyfe	MWD Power	MWD
Mill	Alexander	Y	12/02/87	Hugo Manson	MWD Power	EDA
Milne	Grant	Y	7/12/84	Judith Fyfe	NZ Post Office	NZ Post Office
Moon	Bruce	Y	21/06/84	Judith Fyfe	NZ Computer Soc	Computer Industry
Natusch	Gilbert Gardner	Y	18/02/87	Judith Fyfe	MWD Power	MWD
Nicholson	Victor		11/08/88	Boyack&Tolerton	Boyack&Tolerton	WW1
Nicol	Stuart Maxton	Y	14/09/88	Hugo Manson	MWD Power	NZED
O'Donnell	James William		18/02/87	Hugo Manson	MWD Power	NZED
Pannett	Ralph	Y	5/11/94	Valerie Craven	Helen Walch	Presbyterian Church
Phillips	Ray		11/09/89	Mark Torley	Massey U, Hist Dept	WW1&2
Reese	Bob		29/11/91	Robert Paton	Trade Union Oral Hist	Labour movement
Ridley	Jack	Y	24/09/87	Judith Fyfe	MWD Power	MWD/ MP
Ritchie	Robert Francis D	Y	19/02/87	Hugo Manson	MWD Power	MWD
Robertson	Bill		13/09/93	David Young	Turnbull Library	Wanganui River boats
Robinson	Geoff	Y	30/11/87	Judith Fyfe	MWD Power	NZED
Robinson	John Vernon	Y	22/05/84	Hugo Manson	NZ Computer Soc	MWD
Rothman	Seigfried		19/11/84	Ann Beaglehole	Ann Beaglehole	Jews in NZ
Sandelin	Sandy	Y	23/09/87	Hugo Manson	MWD Power	NZED
Sands	William		8/05/90	Maurice Gough	NZ WEA	NZ WEA
Smith	Sydney Maxwell J	Y	13/09/88	Hugo Manson	MWD Power	MWD
Stace	Francis Nigel	Y	16/02/87	Judith Fyfe	MWD Power	Engineering Publcns Ltd
Stephens	Cory	Y	23/09/87	Judith Fyfe	MWD Power	Thames Valley EPB
Thompson	Thomas Eric	Y	16/12/85	Judith Fyfe	NZ Post Office	NZ Post Office
Turner	Charles William O	Y	15/12/86	Hugo Manson	MWD Power	MWD
Webb	Norman	Y	24/09/87	Hugo Manson	MWD Power	NZED
Wise	Henry Robert	Y	15/09/88	Hugo Manson	MWD Power	Waitaki EPB

Abbreviations

MWD	Ministry of Works & Development	EDA	Electricity Development Association
NZED	NZ Electricity Department	EPB	Electric Power Board
MoE	Ministry of Energy	WEA	Workers Education Association
MP	Member of Parliament	WW1	World War 1

Appendix B: List of interviewees for the Electricity Centenary Oral History Project

Name	Organisation	On retirement	Project	Engr
Stage I (1986-87)				
C M (Colin) Bambery	NZED	Asst General Manager	Waikato	Engr
P W (Phil) Blakeley	NZED	General Manager	Waikato	Engr
H C (Harry) Hitchcock	NZED	Sen Research Engr	Benmore	Engr
A (Alex) Mill	ESA			Engr
G G (Gil) Natusch	MWD	Principal Invgn Engr, Power		Engr
J W (Jimmy) O'Donnell	NZED	Superintendant, Haywds		
R F D (Bert) Ritchie	MWD	Chief Engr, Power	Roxburgh	Engr
W M (Bill) Robins	MWD	Construction Super, Huntly	Various NI	
F N (Nigel)Stace	Journalist	Mng Director, Tech Publications		Engr
C W O (Charles) Turner	MOW	Engr-in Chief	Waikato	Engr
Stage II (1987-88)				
P W P (Peter) Chapman	NZED	District Engr, Hamilton	Waikato	Engr
R W J (Bill) Fookes	MWD	Ch Design Engr (Power)		Engr
J (Jack) Girardin	NZED	Station Super, Wairakei		
T S (Tom) Jones	NZED	Construction Super, Huntly	Various NI	
J W (Jack) Ridley	MWD, MP	MP, Consulting Engr	Benmore	Engr
Frances M Robins			Waikato	
G H (Geoff) Robinson	NZED	Asst GM (Des& Constn)	Roxburgh	Engr
E G (Sandy) Sandelin	NZED	Chief Engr (Des&Constn)	Roxburgh	Engr
O C (Cory) Stephens	ESA	CEO, Thames Valley Power		Engr
N D (Norman) Webb	NZED	Commissioning Engr		Engr
Stage III(1988-89)				
T R (Tom) de la Haye	NZED	Station Super, Arapuni	Arapuni	
D J (Dan) Duggan	NZWU	Gen Secretary, NZWU		
W M (Bill) Duncan	MWD, Energy	Secretary of Energy	Roxburgh	Engr
J D (Doug) Ellis	ESA	Gen Mgr, Hutt Valley EPB		Engr
C L F (Colin) Lennon	MWD	Construction Super, Clyde	Clyde	
N C (Colin) McLeod	MWD	Commissioner of Works	Waikato	Engr
E M (Ella) McLeod			Waikato	
J H (Jim) Macky	MOW	Commissioner of Works	Waikato	Engr
S M (Max) Nicol	NZED	Regional Engr		Engr
S M J (Max) Smith	MWD	Project Engr, Upper Waitaki	Upp Waitaki	Engr
T N E (Bill) Waiwai	MWD	Construction Super, Ohaaki	Tongariro	
H R (Bob) Wise	ESA	Consulting Engr		Engr

Abbreviations:

NZED	NZ Electricity Department
ESA	Electricity Supply Authority
MWD	Ministry of Works and Development
MOW	Ministry of Works
MP	Member of Parliament
NZWU	NZ Workers Union
Energy	Ministry of Energy
CEO	Chief Executive Officer
EPB	Electric Power Board

Kingston Powerhouse's Past in the ACT's Future

Keith Baker BE, M App Sc., MIEAust: Engineering and heritage management consultant, Canberra.

Summary: *The paper looks at the history of Kingston Powerhouse and the coverage of engineering features in the conservation management plan and proposals for reuse of the building. It found that there was insufficient information provided for interpreting the former engineering function as distinct from the building shell.*

The author describes the oral history project that was undertaken by the Institution of Engineers Australia to obtain more information about the former operation of the powerhouse, and the other sources that he was able to draw on. These tapes, articles, plans and photographs enabled him to gain an understanding of the power generating plant that is no longer in existence, and its relationship to the building features. This information was then built into a computer-based presentation suitable for use by visitors to the building so that they could gain an overview of its former function and explore different aspects depending on their level of interest

The approach taken to the development of the multi-media presentation is discussed and the main features demonstrated.

1 KINGSTON POWERHOUSE HISTORY

1.1 Introduction

Kingston Powerhouse, commenced physically in 1913, was the first permanent building to be constructed in Canberra by the Federal Capital Commission, and supplied electricity to the developing national capital[1]. The project was designed under the control of Col. Percy Owen, Director-general of Works, before the competition for a town plan for Canberra was finalised.

1.2 Design

Specialist advice was obtained in deciding that Canberra would be an all-electric city. To generate the power, coal fired water tube boilers were selected to supply super heated steam to triple expansion reciprocating engines connected to three phase alternators. Mechanised coal handling and heat recovery systems were state of the art for 1911when the design decisions were made, but isolation of the site may have influenced the choice of reciprocating engines when turbines were beginning to take over elsewhere.

The location was selected on engineering grounds alongside the Molonglo River at an existing gauging weir, requiring only a short extension of the railway from Queanbeyan in New South Wales. It was not in the position favoured by prize winning town planner and architect Walter Burley Griffin, beginning a controversy over its permanence, and a long running battle between Owen and Griffin.

The building was designed by government architect John Smith Murdoch to be monumental rather than a temporary galvanised iron shed. His stripped classical style was developed into what became known as Federal Capital architecture in later buildings like the Canberra Hotel and Parliament House.

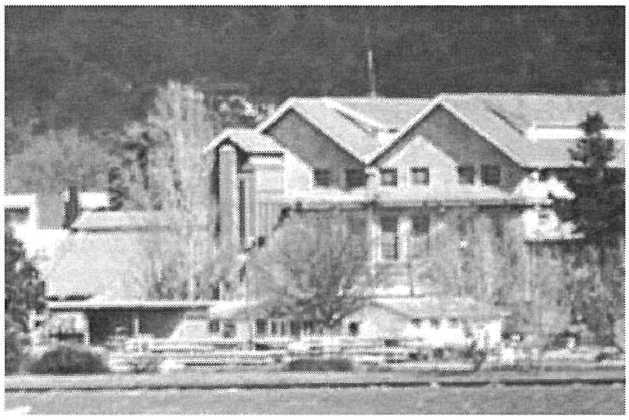

Figure 1 Kingston Powerhouse Exterior

1.3 Construction

Tenders were called for materials in August 1911, and the building was constructed by day labour beginning in January 1913. Boiler plant was supplied and installed by Babcock and Wilcox, the steam engine by Bellis and Morcom, and a 600kW Brush alternator was installed by Gilbert Lodge. The initial installation was acceptance tested in July 1915 and first supplied consumers in August of that year.

1.4 Expansion

Before the first engine and alternator were installed, tenders were called for a second matching set. Tenders were invited shortly after for a smaller second hand set which was required on short delivery. A Robey-Hall set of 150 kW output was thus installed to cover periods of light load.

The growth of Canberra was slow until the events associated with the transfer of Parliament from Melbourne in 1927. A 1500 kW British Thompson Houston (BTH) turbo-alternator was then installed along with a further Babcock and Wilcox boiler to supplement the initial three.

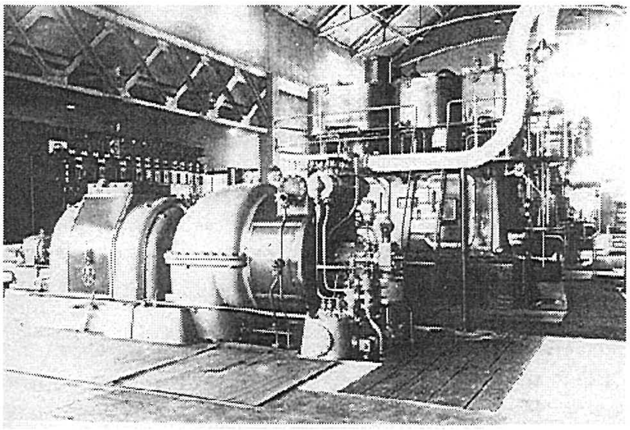

Figure 2 Machine Room with Bellis & Morcom Engines and BTH Turbo alternator

1.5 Demise

In spite of economising features in the installation, generating costs were higher than expected by the designers. When hydroelectric power became available from Burrinjuck in New South Wales in 1929, a 66 kV line was constructed to connect Canberra. The powerhouse then fulfilled only a backup role.

1.6 New Life

Weakness in the Burrinjuck dam that was identified in 1935, and a shortage of power in New South Wales resulted in Kingston being brought back into full service. Shortly after it was augmented by the Electricity Commission of New South Wales through the transfer of two Brush-Ljungstrom turbo alternators and two larger Babcock and Wilcox boilers from Port Kembla. These commenced generating early in 1939.

1.7 Decommissioning

The need for power generation at Kingston reduced as the NSW grid was strengthened, and the station was shut down in early 1942. The BTH turbo alternator was reprieved and placed in service again in May 1942 to supply the Belconnen Naval transmitter. At the end of the war it was shut down. The station was used again from 1948 to 1955, and sporadically until 1957.

Power shortages in the post war period were then addressed by the use of packaged diesel generating plant in a different building on the Kingston site. After that time the remaining generating plant was removed and between 1956 and 1960 the boilers and ancillary plant were scrapped. The coal hoppers and ash disposal hopper and elevators remained in place, probably because their supporting structure was integral with the building. The overhead travelling crane was retained in the machine hall, and the auxiliary switchboard continues in service. Mass concrete machine foundations remain, but the machine floor was levelled to make it more usable. Dampers and ash chutes in the boiler room were sealed to contain asbestos. The chimney stack was demolished to a brick base. The powerhouse building is otherwise unchanged internally and externally from when it ceased operating.

1.8 Reuse

The building continued to be used by the electricity supply authority Actew as a store, workshop and an apprentice training facility. The course of the Molonglo River became submerged in Lake Burley Griffin in 1964, but this had only minor effect on the site, apart from making it more attractive for redevelopment.

2 CONSERVATION AND REDEVELOPMENT

2.1 Significance and Recognition

Kingston Powerhouse has been recognised as a significant building in the Australian Capital Territory. It is classified by the National Trust (ACT) and included in the Register of the National Estate, the ACT Heritage Register and the Royal Australian Institute of Architects Register of Significant 20th Century Buildings.

The Institution of Engineers, Australia has placed a Historic Engineering Marker on the powerhouse. This was unveiled by the ACT Chief Minister in 1998.

2.2 Conservation Management Plan

In 1993 a Conservation & Management Plan (CMP) was prepared by Freeman Collett & Partners[2] in conjunction with the ACT Heritage Unit and ACT Electricity and Water (Actew), under a National Estate Grant. This was a three-volume document that covered the whole precinct. The historical research was thorough and the conservation analysis and management policies were comprehensive regarding the building features. They made reference to an earlier structural engineering report on the powerhouse building, and Actew provided some engineering advice. It had been intended that Mr Alan Jones, former Chairman of Actew would be technical advisor to the team, but he died in late 1992. There was no engineer on the consultant team, and in my view this resulted in the analysis having a strong architectural emphasis but insufficient engineering content for a place that was significant for both architectural and engineering reasons.

The citation for the Kingston Powerhouse for the ACT Heritage Register is based heavily on the Conservation Management Plan and makes direct reference to it with regard to conservation work. The citation recommends that the CMP should be expanded to fully explain the engineering functions and processes of the place. It also recommends oral history interviews to recover memories and attachments.

2.3 Kingston Foreshore Redevelopment

The Kingston Powerhouse precinct and other adjoining industrial buildings, including the site of the government printing works, were identified for redevelopment by the ACT Government in the mid 1990s.

A statutory authority, the Interim Kingston Foreshore Development Authority was set up and a design competition arranged in 1997. The Powerhouse was designated as an essential feature to be retained in what is to become a multi-purpose city development over the next decade.

The planning includes residential, shopping and recreational areas. The Powerhouse will become the centrepiece of a cultural precinct, but the final purpose is yet to be determined. The large volumes of the boiler room, machine floor and economiser room risk being subdivided and losing their evocative feeling unless a suitable use is selected.

3 RECOGNITION OF ENGINEERING OPERATION

3.1 In the Conservation Management Plan

The Conservation Management Plan recognised the original purpose of the powerhouse. This is acknowledged in the Statement of Significance by points which include

- a comparatively early example of steam powered electricity generation
- demonstrating the technology and process of the early electricity generation for the Federal Capital. The plant became essentially redundant within twenty years, hence the shell of the Power House demonstrates an important technology which has been made redundant.
- the earliest examples of steam powered electricity generation plant in New South Wales (sic) and consequently nationally significant.
- A notable example of a Power House facility with all major components and associations (excepting machinery) intact.

This might be considered a fairly major exception in the last point, and the comparative analysis supporting the second last point was incomplete. Clearly significance was considered in terms of engineering function, but the remaining engineering features and evidence were not given equal billing with the architectural features. For example, a series of 12 architectural drawings of the building were included, showing spaces such as the Boiler Bay, Engine Bay and Economiser Annexe. But the coal handling hoppers and conveyor, boilers, steam engines and alternators, condenser, economiser, high voltage switchboard, transformers and the like were incidental to these drawings if included at all.

To be fair, the listing of significant fabric which remains included the engine room gantry, coal hoppers, coal elevator, ash pit chutes and base of stack. My concern is that the entry stairwell and the windows had twice the coverage of the coal hoppers and elevator, which were judged to be highly significant to be retained in situ. The condenser pit and generating plant bases in the lower level were not mentioned, although they have high interpretive value for an understanding of the plant configuration and relationship of the building to the river.

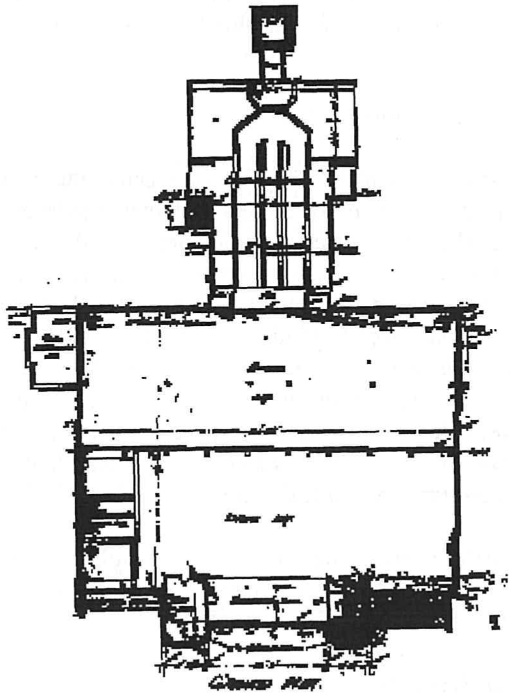

Figure 3 Floor Plan shown in CMP

3.2 In the Proposed Interpretation

The Statement of Significance in the CMP indicates that Kingston Power House Precinct has exceptionally high interpretive value, both as the core of the first permanent Federal Capital development, but also as a benchmark example of a building and architectural type. No mention here of engineering interpretation, probably because the boilers and rotating machinery have been removed.

The Statement of Conservation Policy that follows indicates that it will promote the explanation and understanding of significant precinct buildings and site through the provision of appropriate interpretive material within the buildings and elsewhere. The provenance (origin) and history of the precinct and its components would be explained through the provision of appropriate displays and the maintenance of adequate records. The provision of the display material was beyond the scope of the CMP consultant study.

The 1993 brief for the CMP also proposed an oral history project on the site, but this was not funded by the Commonwealth.

4 OBTAINING MISSING INFORMATION

4.1 Grant Application

After a successful oral history project on ACT Dams, the IEAust Canberra Division Engineering Heritage Panel applied for an ACT Heritage Grant to conduct an oral history project and prepare engineering interpretative material for Kingston Powerhouse. The application was partially funded, allowing the first part to be undertaken. A subsequent request to the building owner Actew resulted in matching funding which allowed the interpretive multi-media presentation to proceed.

4.2 Oral History Project

Canberra historian Matthew Higgins conducted interviews with 12 former employees of Actew and their predecessor organisations who had worked at the powerhouse during the 1940s and 50s. They were able to describe the equipment that they worked on and the people with whom they were associated, in some cases stretching back to the 1920s. They also provided information about the social conditions at the time, and events and understandings which had not been previously recorded. The range of nationalities and accents included give an interesting insight to the employment situation in Canberra around and immediately after WW2.

The tapes have been copied and lodged with the ACT Heritage Library. Extracts from them are included in the audio-visual presentation which will follow.

4.3 Archival Research

The engineering history of the powerhouse had been previously recorded by Alan Jones in his chapter on Electricity in Canberra's Engineering Heritage. Jones had worked at the powerhouse from 1928 when he joined the Federal Capital Commission as a cadet, and continued his association through to his retirement, culminating in his period as Chairman of ACT Electricity Authority from 1963-75. His history was concise, but needed to be supplemented to give a more complete picture of physical arrangement of plant in the powerhouse.

Archival research in a range of places gave considerably more information than had previously come to light. The Mildenhall Collection of photographs held by Australian Archives and other photos held by Australian National Library revealed more of the building exterior, the boilers, and the small generating set. Some original design drawings held in microform by Actew gave more information about the boiler plant and ancillaries.

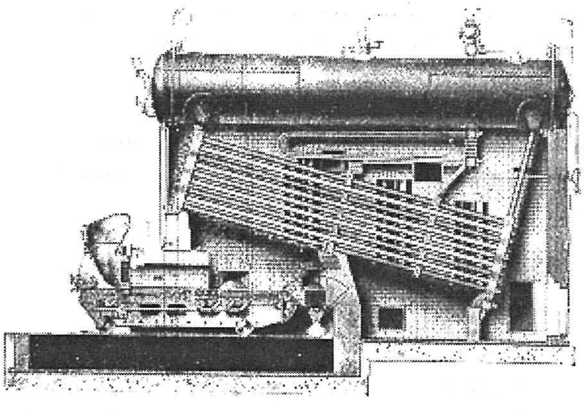

Figure 4 Section Through Typical Babcock and Wilcox Boiler of the Time with Chain Grate Stoker

Textbooks of the period held by the National Library gave illustrations of some of the plant, which was not specific to the Kingston installation, but representative of the manufacturer's similar models. Illustrations of Babcock and Wilcox boilers, Bellis and Morcom engines, and Greens economisers[3] were most useful in this regard.

The Film and Sound Archives, now known as Screensound Australia, were also searched for film footage of early Canberra showing the Kingston Powerhouse and related subjects. This was not particularly fruitful, but some other power stations of the period and relevant events and effects were found that could be potentially used.

The ACT Heritage Library, Actew file archives, the National Trust files and the photographic collection of the Canberra and District Historical Society were also useful.

Government Gazettes from 1912 to 1915 in National Archives were useful in tracing the sequence of tenders advertised and accepted, and seeing the way materials and works were packaged. And a gem that was discovered in the National Library was the original specification for the Power Generating Station Plant for the Federal Capital Site, consisting of sections on the Boiler House Plant, the Engine Room Plant, and the Alternator and Exciter.

4.4 Site inspection with photographs

Part of the process of understanding the configuration of the plant was to view the site with historic photos and put oneself in the place of the photographer. Aspects of remaining features such as steel columns, concrete bases, stairs, windows, roof trusses and coal hoppers could be identified in the photos and the position and orientation of plant items could be confirmed. Obtaining photos, site verification and taking present day photos became a somewhat iterative process.

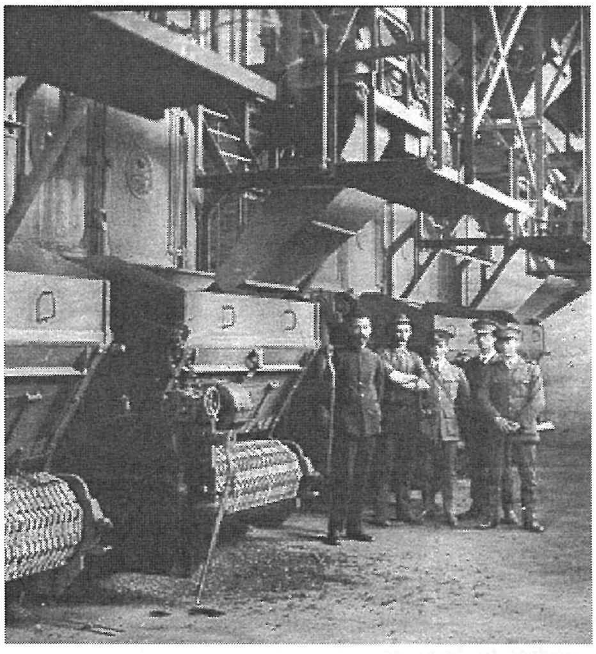

Figure 5 Babcock and Wilcox Boilers with Chain Grate Stokers at Kingston Powerhouse

It was interesting to note that some features such as the reciprocating engines and the turbine were frequently photographed, while other aspects such as the condenser, economiser, coal conveyor and ash disposal were apparently less glamorous and no photographs have been identified. The alternators and high voltage switchboard tended to be captured with the engines, and two photographs exist of the boilers.

4.5 Feedback

A useful exercise was to give an illustrated lecture on the project to an audience which included several of the former employees who had been interviewed in the oral history component. Some additional insights were obtained during discussion and question time, and it was reassuring to not have much disagreement with the authenticity of the material I was able to present.

5 PREPARING THE MULTI-MEDIA PRESENTATION

5.1 Rationale

The original idea had been to prepare an audio visual presentation with slides and a script, and separately to have photographs mounted for viewing. The material was to be presented in a way that could be turned into a computerised touch screen display. As the research progressed it became obvious that there was a large amount of material that would be of interest to some people but not to all. Most people would require a general overview of the history and operation of the place, some would want more social information, and some would need to have the technical processes explained, while others would want to go to the technical details. An interactive computerised display seemed most appropriate to allow views to tailor the parts of the presentation to their own experience and interest. Multi-media software would allow this to be made more interesting with sound and movie clips.

5.2 Inputs

The range of inputs included

- Historic black and white photos
- Present day colour photos
- Historic documents
- New text written for the purpose
- Plans and other drawings
- Movie clips
- Oral History interview extracts
- Sound effects
- Recorded commentary

5.3 System Software

The decision on software was not easily made. The first inclination was to use Microsoft Word and Powerpoint with which I was reasonably familiar. Powerpoint is commonly used for computer based slide presentations. This gives scope for inserting photos and diagrams as well as text, sound and video. However Adobe Acrobat provides similar features, is reputedly more efficient in computing resources, and is more universally acceptable for file transfer between computers. Other web page authoring products were also considered. Development work has been done in Word, Powerpoint and Acrobat, with Acrobat used as the final form for the presentation.

5.4 Result

The audiovisual presentation has been produced so that it can operate on a stand-alone personal computer, be projected as a slide show, or transferred on the Internet.

It commences with a general historical and technical overview which can be played as an automatic sequence, and is followed by a series of buttons from which viewers can select the type of information they require, and go to the level of detail that they consider appropriate. Pages are linked so that individuals can go backwards and forwards to suit their interest and understanding.

The audiovisual package will be demonstrated as a major part of the delivery of this paper.

6 CONCLUSIONS

The presentation should be suitable for visitors to the redeveloped powerhouse building to use interactively in small groups to understand the history and former functioning of the building. If any further professional editing is required, the necessary technical information will be there. This should enable the people involved in the redevelopment, as well as future visitors and regular users to more fully understand and appreciate this part of this part of Canberra's past.

The case should also highlight the need when studying the conservation of industrial facilities for the professional team to include a member with an understanding and strong interest in the former technical function. This would assist in producing a balanced assessment of the engineering significance along with the building elements, and provide for future interpretation of the industrial function.

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[2] Freeman Collett & Partners Pty Ltd, *Kingston Power House Precinct, Kingston ACT, Conservation & Management Plan,* , June 1993
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[3] Cressy, Edward *A Hundred Years of Mechanical Engineering*, Duckworth, London 1937, and McDonald, CGH *Lectures Delivered at Firemen's Instruction Classes, Newport Power House*, Victorian Railways, 1917

Bucketladder and Paydirt

Engineering Heritage of Gold Dredging on the West Coast, South Island, New Zealand.

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Summary In the late eighteenth century New Zealand was a world leader in the application of electricity to mining, the introduction of the cyanide process of gold extraction and the adaptation of the bucket ladder dredge to the extraction of gold from alluvial deposits. This paper discusses the history and features of the New Zealand style dredge and its influence on later American designs. Advances in gold dredge design are illustrated by the Kohinoor dredge, Redman's Creek and Rimu dredge. Both operated on the West Coast, South Island, New Zealand. Although New Zealand's progress was eventually supported by the agricultural and pastoral industries the gold mining industry of which dredging was an integral part provided markets for the fledgling farming industry, generated overseas capital, encouraged investment and attracted the man power necessary for growth.

1 INTRODUCTION

Dredging evolved from the miners' determination to profitably extract gold from low grade or water saturated placer deposits which were unworkable by hydraulic or underground means. At first the shallow, rich gold accumulations ("paydirt") on river beaches, bars and terraces of Otago, the West Coast, Nelson and Marlborough were worked by individual miners with pans, cradles and "long toms". Upon the exhaustion of the dry or shallow river gravels the miners experimented with methods which would allow extraction of gold from deeper water. As early as the early 1860's the miners would wade out into the current and "blind stab" with a shovel, especially when the rivers were low. The beds and banks of some rivers were then worked by the use of "wing dams" which partly diverted the flow and primitive pumps but these were ineffective in the deep, fast flowing rivers of Otago and the West Coast. The object of this paper is to describe how the bucketladder dredge overcame these difficulties and show that gold dredging was a significant contribution to world mining technology and New Zealand's economic development.

2 NEW ZEALAND TYPE DREDGE

2.1 Evolution

The first stage in the development of the New Zealand gold dredge was the evolution of spoon dredging from "blind stabbing" in 1863, just two years after the Gold Rush had commenced at Gabriel's Gully (Fig. 1). A spoon, consisting of a leather bag tied to an iron hoop on a long pole, was carried out into the river then dragged back to shore while being held down into the river bed. Soon the spoon was mounted on a punt moored further out into the flow. The spoon was dragged from bow to stern and then lifted to the deck by a crab winch. By mid 1864 there were as many as 15 spoon dredges between Clyde and the Tuapeka River (1). Further early developments were, stakes or spuds sleeved to the hull and pushed into the river bed to anchor the punt, a central well in which the spoon was dragged, and the spoon "was given a sharp, hardened steel, cutting edge" (2). In 1866 a spoon dredge known as the "Moa" powered by a paddle wheel or "current wheel" at the bow was launched (1).

Spoon dredging was slow and laborious, and applicable only to relatively calm, shallow water but operations were widespread and many were very successful. However, depth and power limitations, and the build-up of tailings in the riverbeds from sluicing claims along the banks led to a rapid decline in the spoon bagger fleet from 1870.

Attempts to overcome the tailings problem had begun in 1868 when the spoon dredge "Moa", already powered by current wheel, was converted to bucket ladder, which was in fact its original 1865 design (1). This system furnished a continuous supply of gravel to the gold recovery apparatus by an endless chain of buckets turning around a rigid ladder. Continuous digging also minimised the backfilling of the dredged zone by tailings. However, this was not seen as the answer because the "Moa" was the sole bucket ladder dredge amongst spoon baggers for some years (1) and after 1870 considerable effort was applied to building and testing rather more complicated devices. These included the "Salamander", a steam powered spoon dredge (!), a compressed air caisson device, two submersibles, diving bells and an auger. All were found to be totally inadequate (3).

The next current wheel bucket dredges appeared in 1876 when the "Salamander" was converted from spoon dredging, and 2 new craft were built (3). By 1879 dredging was at a low ebb

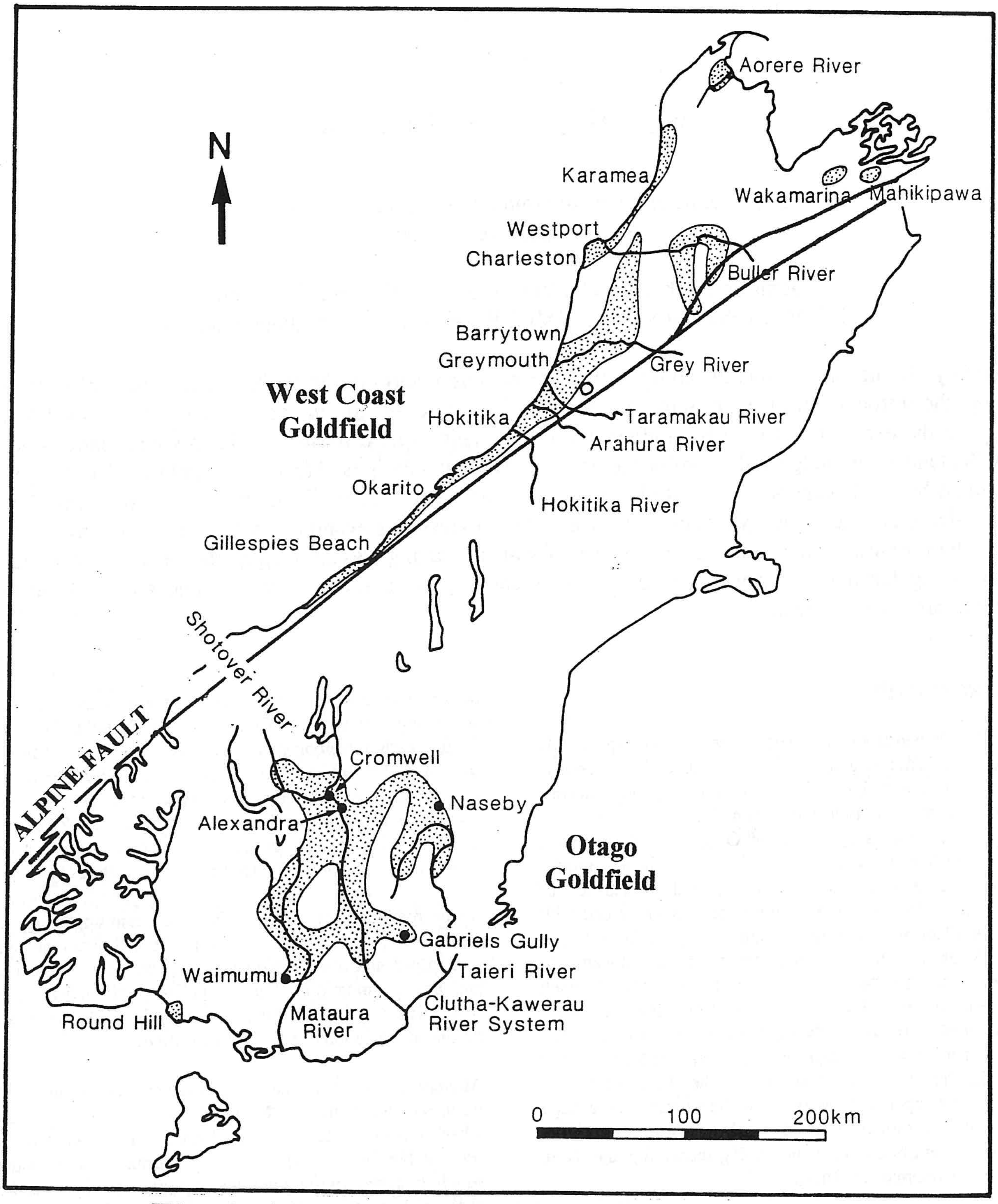
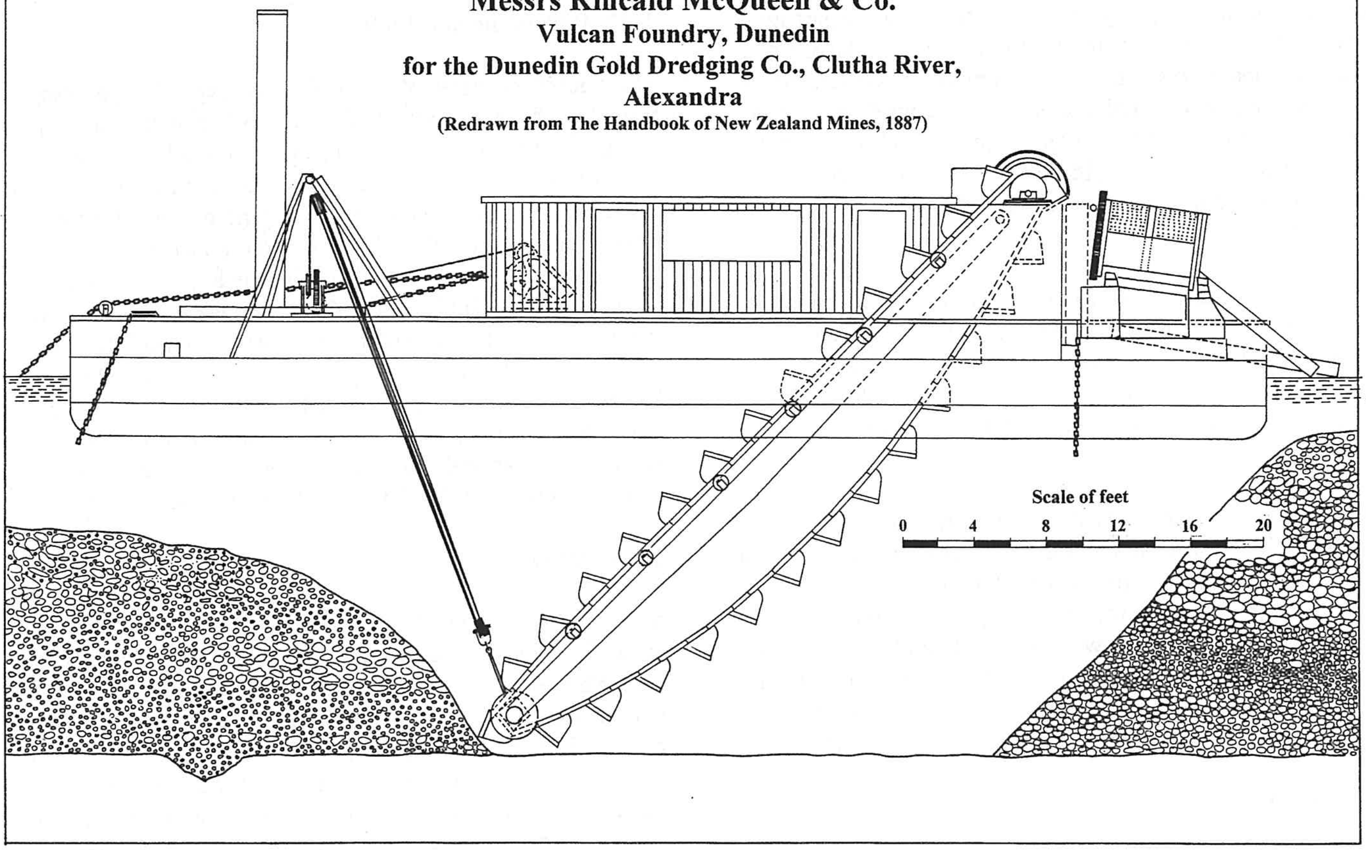


Fig. 1 Alluvial Goldfields of the South Island.

as there were only 4 current wheel bucket ladder dredges and 1 spoon dredge at work. While the manning requirements of current wheelers were low and no fuel was required they could not follow runs of gold into calm water as they could only operate where the current was strong. Furthermore they were underpowered for work in deep water, thick wash and hard or bouldery ground. Continued build-up of tailings in the rivers was another impediment to successful operation.

A steam powered bucket ladder dredge worked on the Otago Harbour as early as 1867 (1), and current dredges had shown that auriferous gravel could be mined by the continuous bucket ladder. In spite of this there was strong resistance to the use of a steam powered bucket dredge to recover alluvial gold, and projects in 1873 and 1878 did not eventuate. Eventually the coal supplies and other factors improved and remarkably in 1881, no fewer than four steam bucket ladder dredges were launched on the Clutha River. Two 30 ton boats with 10 hp boilers were launched near Tuapeka Mouth in May by a Port Chalmers syndicate (1). One ran aground in December, while the other achieved only limited success.

Fig. 2 Dredging, Washing & Sluicing Machinery Constructed by
Messrs Kincaid McQueen & Co.
Vulcan Foundry, Dunedin
for the Dunedin Gold Dredging Co., Clutha River, Alexandra
(Redrawn from The Handbook of New Zealand Mines, 1887)



In July 1881, the "Eureka" was launched above Alexandra at a cost of £3,000. However, the boiler and engine were "old worn-out ...much too large" and buckled the pontoon. Coal consumption was also excessive. As a result the "Eureka" was soon converted to a current wheeler (1).

The fourth dredge was the "Dunedin" (Fig.2), which was launched upstream from Alexandra in late 1881. Designed by Charles McQueen and built new by Kincaid and McQueen, it cost between £5,500 and £10,000. With a steel hull and ship's prow, it had many similarities to the harbour dredges the company had built. The dredge had a 70 ft x 15 ft x 9 ft deep pontoon and a 30 horsepower boiler. Two bucket ladders, mounted port and starboard, in order to reach closer to shore, were a highly distinctive feature (1). Each ladder carried 31 2 ft^3.buckets. However, the twin ladders and prow caused stability, manoeuvring, and production problems. After various modifications, including the addition of outrigger pontoons, the two ladders were removed in 1891 and replaced with a single ladder in a central well (3). The dredge was then moved downstream to Coal Creek where it rewarded the shareholders with £15,270 in dividends over the next 10 years. In total the "Dunedin" recovered 16,966 oz of gold (3).

With the demise of the other steam bucket dredges and the 9 year dearth of profits from the "Dunedin" current wheel dredges were predominant through the 1880's. Following this, trials of suction dredges and barge mounted grabs, cranes and hydraulic elevators showed that at best these devices could only work in very restricted conditions (3). It was becoming clear that nothing could match the capabilities of the steam powered bucket ladder dredge, especially in deep, tight or bouldery ground. As a result the steam bucket fleet slowly increased.

A further limitation was emerging. Steam dredges could follow leads into the river banks but were then becoming entrapped, as the river often could not wash the tailings away. In 1894 the Cutten Brothers invented an elevator which carried the tailings up and away from the dredge. It consisted of a set of trays on an endless belt, supported by a wooden or light steel frame ladder rising at 45^0 from the stern. The tailings elevator allowed the dredge to manoeuvre, generate its own pond and dig deeper ground. It was quickly realised that as long as the ground held water, no river was needed, and thus a huge addition was made to the gold resource accessible to mining. With this advance the New Zealand Gold Dredge was essentially complete.

The effectiveness of the steam driven bucket ladder dredge was finally brought home by spectacular results from Choie Sew Hoy's dredges at Big Beach on the Shotover River in

1889. A dredging boom followed in which the number of steam powered bucketline dredges increased from 14 in 1889 to 80 in 1899. At this point a second, sharemarket based boom exploded, ignited by returns exceeding 600oz per week obtained from 1897 onwards by the dredges of the Electric, Magnetic, and Hartley and Riley Companies working in the Kawarau River above and Clutha River below Cromwell (4). Then came the record breaking weeks in 1900 when the Hartley and Riley dredge obtained 1,187 oz (of which 1,157 oz was dredged in 4 days) and the Lady Ranfurly recovered 1234 oz!

Gold dredge numbers peaked at 201 between 1902 and 1903 and thereafter declined to 4-5 between 1924 and 1932. During the boom gold recovered by New Zealand style dredges operated by registered companies rose from 21,862 oz in 1890 to 124,660 oz in 1906 and then declined to 8953 oz in 1930.

The "Dunedin" is now considered to be the prototype of the global dredging fleet which dominated alluvial gold, tin, and platinum mining prior to World War II. Bucket ladder dredges by their continuous system of mining, processing and placing of tailings are the lowest cost method of mining known and with their power and strength can work tight bouldery and saturated deposits in rivers, flood plains and in any form of alluvial terrace or flat as long as a pond can be maintained.

2.2 Design

2.2.1 Hull and Superstructure

Usually the pontoons were made of wood although steel was sometimes used. Australian hardwood was found to be ideal for the framework which was often planked with kauri. Typically the pontoons were 70-100 ft long, 30 ft wide and 5-6 ft deep. The ladder well, an opening along the centreline, extended about 40 ft back from the bow. The hull was rectangular in cross section with a slightly crowned deck. Diagonally braced thwardship frames consisting of deck and bottom beams separated by side posts were the primary structural elements. Fore and aft strengthening timbers were bolted inside the frames where the posts joined the deck and bottom beams. Bottom, deck, side and ladder well planking was spiked to the frames. In an alternative stronger method of construction the thwardship frames were laid on and bolted to fore and aft stringers. The bottom planking was then laid thwardships instead of fore and aft. All planking was corked with oakum and the seams pitched. Hatchways were provided for hull access and cowls for ventilation (5).

Support for the forward end of the ladder was provided by the bow gantry. In early New Zealand style dredges this was made of stout, timber beams inclined forward for a more direct pull on the ladder. The bucket drive and aft end of the ladder were supported by the main gantry, a substantially built diagonally braced structure. Posts were often placed under each bearing. The stacker ladder was attached to the stern with the outer end suspended from the stern gantry. This gantry generally consisted of two posts with cross timbers and diagonal braces. Both the bow and stern gantrys were guyed with steel cables to each other and to the main gantry (5).

2.2.2 Bucketline and Ladder

The bucket capacity of New Zealand type dredges ranged from 2 - 3 ft^3 in the early dredges up to 7 ft^3 in the later types. The body of the bucket was built up from steel plate and fitted with a renewable hardened steel lip. Each bucket was riveted on to steel links bushed with manganese steel. Connecting links which separated the buckets were joined to the buckets with manganese steel pins. Typically the buckets were carried on a plate girder ladder about 40 ft long which was pivoted at the top end while the bottom end was suspended by sheaves and wire rope from the bow gantry. It was raised and lowered by the ladder winch. The bucket line formed an endless chain which rested on rollers on the top of the ladder, passed over a square or hexagonal cast steel upper tumbler and back in a catenary curve to a circular flanged lower tumbler.

2.2.3 Power

Steam power was chiefly used to operate the dredges although some, Waipori, Golden Beach and Teviot in Otago, and the Five Mile Beach dredge at Okarito were driven by Pelton wheels. Compound, condensing, vertical or horizontal engines ranging from 20 - 50 horsepower were used for digging and pumping. Energy was transferred by ropes or belts to the bucketline via a gear train on the main gantry. Winches and electric lighting plant were often run by separate engines.

Steam was generated by locomotive type boilers burning about 2.75 cords of wood, 1 ton of lignite (Otago) or 0.5 tons of bituminous coal (West Coast) per day. The boilers consisted of a large diameter, unlined furnace and a smaller diameter tube shell which terminated in the smoke box. Most of the engines and boilers on the early New Zealand type dredges were imported from Marshall and Sons Ltd., Gainsborough, England (7).

New Zealand was in the forefront in the application of electricity to dredging as the Sandhills dredge which worked in the Upper Shotover between 1891 and 1899 was electrically driven (8).

2.2.4 Gold Recovery

The wash was dumped from the buckets, at a discharge rate of about 10-12 (later 16) buckets per minute, into a drop shute lined with wear plates which delivered it into a sluicebox or an inclined revolving screen. The screen was about 20 ft long and 3.5 ft in diameter. Jets of high pressure water from a sparge pipe washed the gold bearing fines through the screen perforations into a distributing box which partitioned the fines evenly between port and starboard gold saving tables. The gold tables were from 12 to 18 ft wide and 16 to 18 ft long and were divided into sections (3). Each section was covered with plush, felt, calico or hessian mats overlain by coconut matting and expanded metal. Waste fines passed from the tables into riffled sluices which discharged overboard astern of the dredge. Where the current was strong enough the screen oversize was discharged astern via a short "nugget"sluice.

2.2.5 Tailings Disposal

River dredges working mid stream had little trouble with tailings as they were washed away by the current. However where the current velocity was low tailings would accumulate astern of the dredge, eventually backfilling the pond. Compared with a sluicebox dredge which required 20% more space for tailings a dredge with a revolving screen needed about 33% more room because of the increase in volume caused by the separation of fine and coarse material. The problem of tailings disposal was overcome by Cutten's tray elevator. Like the bucketladder the elevator could be raised or lowered, the angle depending on digging depth and bank height. This invention enabled the dredge to move away from the rivers on to the adjacent flats and terraces taking its pond with it by digging into the face and stacking the tailings behind.

2.2.6 Operation

By means of lines from winch barrels passing around fairleads at the four corners of the pontoon, through shore blocks attached to "deadmen" (shore anchorages) the dredge could be winched into any position. In the case of the bow lines these returned to an attachment fitting on the ladder near the bottom tumbler. A winch barrel was also provided for a resilient headline. Anchored hundreds of feet ahead of the dredge this line was led aboard through headline sleeves. In the early New Zealand dredges the face was "opened out" by lowering and digging the ladder to bottom. After the bottom was thoroughly scraped the dredge was moved 1 to 1.5 ft sideways by loosening the lines on one side and hauling in on the other. A fresh area of bottom was then "cleaned up". On reaching the end of the cut the headline was shortened by 1 to 4 ft and the buckets worked to bottom as before (9). In this method of working most of the material was lifted from the bottom of the face.

Otago dredges were worked by a winchman and an engineer 24 hours per day on a three shift roster for 6 days per week. A crew of 7 was required for continuous operation.

2.3 Manufacture

Dunedin became the world centre of dredge design and construction. Manufacturers included A & T Burt Ltd., Kincaid and McQueen, Joseph Sparrow and Sons, R. S. Sparrow (later The Dunedin Foundry and Engineering Co.), Cossens and Black Ltd., all of Dunedin, Morgan and Cable (later Stevenson and Cook), Port Chalmers, Joseph Johnson and Son, Invercargill and Andersons of Christchurch (7). Prominent, Dunedin based, dredging engineers included Charles McQueen, Edward Roberts, F. W. Payne, Cutten Bros., John McGeorge and Robert H. Postlethwaite (8).

3 NEW ZEALAND TYPE DREDGE ON THE WEST COAST

3.1 West Coast Alluvial Goldfield

The West Coast Alluvial Goldfield comprises land in the catchments of the rivers flowing west from the South Island main divide from the Haast River in the south to the Karamea River in the north. The goldfield is situated west of the Alpine Fault, a convergent plate boundary, east of which rapid uplift is taking place (Fig. 1). Moisture from the Tasman Sea is precipitated by the high fault uplifted terrain and rainfall is extreme. Consequently the West Coast rivers are large, steep and vigorous. The ensuing high rates of erosion together with the effects of Quaternary glaciations have eroded auriferous quartz reefs in the Southern Alps to form large rich alluvial gold deposits in a variety of geomorphic settings (10, 11). The characteristics of these deposits and the terrain are quite different from those in Otago, which is the mirror setting of the West Coast, being on the eastern side of the Alpine fault and in the rain shadow of the Southern Alps (10). Hence the West coast alluvials are typically far more bouldery, tighter (hard to dig) due to the presence of glacial silts and contain buried tree trunks, while the terrain is more rugged, bush covered and more inaccessible than Otago.

3.2 Development of Dredging on the West Coast

The first dredge on the West Coast was a spoon dredge which prospected the Buller River near Murchison about 1881 (12). The next attempts were aimed at the unique beach deposits. Amongst the first was a Mr Brooke-Smith who used a small Ball dredge (a suction pump with rubber lined impeller to minimise wear) to prospect the Five Mile Beach south of Okarito (13). Later, starting in 1889, a number of projects targeted the back beaches between Westport and Ngakawau. In that year Kincaid and McQueen commissioned a bucket dredge with giant 9 ft^3 buckets and custom designed gold winning circuitry. Only a small amount of gold was recovered (14). Through to 1891 at least four other projects on these leads failed. (15).

Further south around Greymouth in 1889 Taylor's rail mounted "dredge", on a fossil beach lead, had not only a suction pump for the finer gravels but also a Priestman grab (clamshell) for the coarser material. Brown's "dredge" at Paroa was equiped with a gantry mounted American Cataract suction pump with underwater rakes to remove stones. Further south again a Welman dredge was set up on the Saltwater Lagoon, between Waiotahi and Wanganui Rivers (13). Other projects included suction dredges at the Three and Five Mile Beaches (Okarito) and at Gillespies Beach (14). None of these, nor other later beach lead suction projects achieved any major success.

From 1891 onwards the development of dredging on the West Coast was a case of adapting the New Zealand type dredge, now almost fully developed in Otago, to the local conditions. In 1891 the Whitecliffs dredge commenced at Berlins on the Buller River with 2 ft^3 buckets and a digging depth of approximately 18 ft. The Buller catchment was more rugged, and floodprone than the Clutha. As a result dredging activity was characterised by floods washing dredges downstream, changes of ownership, moves and rebuilds of the dredges, heavy wear and tear, and normally a low success rate. After just such a life and ending with 4 ft^3 buckets, the Whitecliffs dredge was scrapped in 1905. However, although it dug too shallow in many areas it was one of the successes in the Buller, producing 4,139 oz of gold and paying the first dividends on the river (16, 17). Only two other dredges appear to have worked in the Buller River catchment in the period up to 1899. These were located at Fern Flat and on the Matakitaki river, both near Murchison. Over the dredging boom and after, up to 9 dredges worked in the Buller producing 31,365 oz (17).

There were no dredges working elsewhere on the Coast in 1898 but with the boom pending, all potential ground was pegged and many dredges were being built. The first of these began in 1899, on the Totara river near Ross. Designed by Cutten Brothers it had 160 ton displacement (pontoon 75 ft x 39 ft x 6 ft) and was regarded as a modern machine (18). In 1900 there were 18 dredges working on the West Coast and 20 under construction. The Totara was having problems with the heavy wash and was obviously too light for the job. It ceased working by the end of 1901.

The boom peaked with 50 dredges recorded in 1902. By now they were working in all kinds of alluvial environments as well as rivers - creeks, terraces, flood plains, and the tricky beach leads, from the Buller to the Mikonui and Okarito. Around 30 were in the Greymouth district. It would be only around this period that the New Zealand type could be said to be well established on the West Coast. Dredge numbers on the West Coast then declined to a single unit in 1920 (19). Increases after this reflected the incoming American type dredges that will be discussed later in this paper.

The official output of NZ type dredges on the West Coast up till 1935, excluding some private groups which didi not have to report their results, is estimated at 279,000 oz (17). The 176,428 oz output of the American Rimu dredge is also excluded and it is assumed that production from any other American style dredges to 1935 was minor and balances the private gold not reported (17). The biggest gold producers were as follows, and all except one of them was in the Middle to Upper Grey Valley.: Worksop No 2 in Antonio's Creek, 25,766 oz; Notown No 1, 19,648 oz; Five Mile Beach near Okarito (beach gold recovered from 1931-1940) 17890 ozs; the Pactolus Company in Nelson Creek, 33,118 oz (2 dredges); Nelson Creek No 1, 14,668 oz; and Blackwater River, 14,295 oz.

West Coast dredges were designed by Dunedin engineers, (Cutten Brothers, F. W. Payne, and E. Roberts) except for 8 designed during the boom by a Mr James Bishop. He produced some imaginative work including the short lived Mahinapua "dry land " dredge as well as the Kohinoor which will be discussed in the next section. The dredges were commonly 85 ft – 100 ft long, drew 6 ft – 7 ft, had 4 – 5 ft^3 buckets, and were fitted with 20 – 30 hp boilers. Crewing on the West Coast dredges was of necessity greater than the 2 man shift crew in Otago, due to the necessary firewood cutting and clearing the dredging land of heavy timber. For these reasons and for the heavy wear and tear, costs on the dredges were higher than in Otago. Between 1901 and 1904 overheads averaged £2,500 - £3,000 per year for wages, fuel, repairs and maintenance, and administration, or 15 – 20 oz for 40 operating weeks per year (20, 21) The Otago cost was broadly equivalent to 10 – 15 oz per week.

While the best properties returned great riches, there were many failures, and the Mines Department considered that the dredges were frequently underdesigned for the tight, bouldery and abrasive West Coast alluvials. In comparison, bearing in mind the later American type dredges that were generally successful, it could be argued that the the physical and economic limits of the wooden, steam driven, New Zealand type dredge were reached in the West Coast ground. Another cause of failure, which was not limited to the West Coast, was placing dredges on poorly prospected ground.

3.3 Kohinoor Dredge

3.3.1 Background

The first goldfield declared on the West Coast was found in 1864. By 1866 rich surficial gold deposits had been discovered over a wide area including Squatters and Redmans Creeks and Italian Gully, small tributaries of the Mikonui River south of Ross. The upper portions of these creeks were worked first, by hand methods followed by paddocking in the middle reaches. Finally shafting was attempted on the Kohinoor Terrace, adjacent to the Mikonui River and Redmans Creek, where the wash was under overburden up 40 ft thick. When recovered the wash was of almost legendary richness, returning grades of 8-10 g/m^3, worth approximately \$100 per m^3 today (22). However, the underground workings were below the level of the river and in places extended out under it. Water inflows through the permeable overburden proved uncontrollable notwithstanding many attempts with increasingly bigger pumps. Underground mining was abandoned in the 1870's. Nevertheless, the presence of paydirt at relatively shallow depth suggested that the lower reaches of Redmans and Italian Creeks could be an attractive dredging proposition.

The Kohinoor Gold Dredging Company Ltd, registered on 15 February 1900, secured the ground and commissioned James Bishop M.I.M.E. to design a suitable dredge.

3.3.2 Technical Details

Figure 3 shows the layout of the "Kohinoor". dredge. The pontoons, built of locally milled timber, were 104 ft long with a beam of 32 ft and a depth of 7 ft. A 6 ft wide forward well was provided for the 60 ft long ladder and a short stern well for the elevator tumbler. The open-connected bucket line contained 35 buckets of 5.5 ft^3 capacity. Buckets discharged into a 60 ft long, 6 ft dia. screen with a short discharge chute

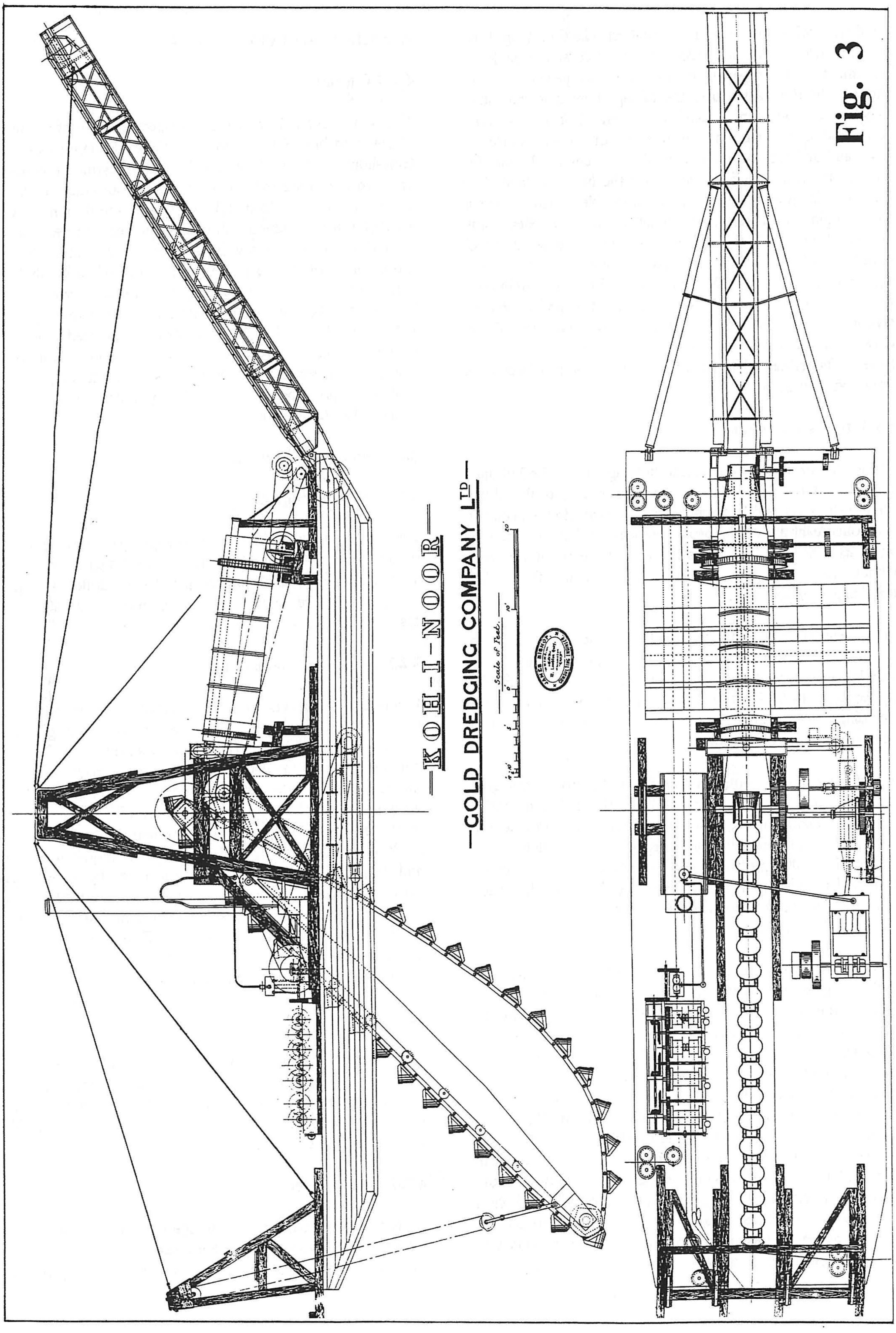


Fig. 3

fitted with riffles to recover nuggety gold. The 60 ft long, tray, elevator was of lattice girder construction and capable of stacking to a height of 32 ft (18). The tray elevator system allowed the dredge to stack the tailings behind it and move freely in the pond. The bucketline, screen, 12 inch centrifugal pump and stacker were driven by a 20 horsepower Ransome, Sims and Jefferies compound condensing engine. Power for the winch which contained barrels for the headline, ladderline and four sidelines was provided by a double cylinder vertical steam engine also by Ransome, Sims and Jefferies. Steam was generated by a 30 horsepower locomotive style multifuel boiler. Total weight of the dredge and machinery was approximately 200 tons. Messrs Luke and Co., of Wellington were awarded the contract for hull construction and machinery erection. The estimated cost of the dredge was £8,900. A crew of 8 was employed comprising a 2 man shift crew on three shifts per day while the other 2 men may have been on a firewood contract.

3.3.3 Dredging Results

The Kohinoor dredge commenced digging beside the Mikonui River in early 1902 before advancing out into the river. Mostly the river bed is dry but bank to bank floods occur at least once each year. The dredge appears to have reached as much as 200m, or 2/3 across the river from the north bank without protective stopbanks or bunds– a major feat in the flood prone Mikonui.

In the year to 31 March 1903 744 oz of gold was recovered worth £2,920, while costs were £5,687 (23). In the year to March 1904 it recovered 1,318 oz of gold worth £5,170, against costs of £4,779 (24). At this point the cumulative loss including capital was £12,032. The company was put into liquidation on 13 April 1904.

An estimate of the volume and grade of the ground dredged, calculated from boreholes drilled from the 1930s onwards, indicates a maximum likely volume of say 400,000 m^3 with a grade of approximately 200 mg/m^3. This would have contained 2,500 oz of fine gold. In comparison, the grade estimated by Bishop was 1,000 mg/m^3 (22). If this had been obtained the gold recovered would have amounted to something like 7,600 oz worth nearly £30,000.

Why did the dredge not obtain the expected gold grade? Its gold saving equipment was not greatly at fault as 2062 ozs or 80% of the gold in the ground was recovered. However, drilling has since shown that the first 2 metres of rich wash lay at an average depth of 40 ft, the limit of the Kohinoor's dredging depth. A small amount of wash along the river banks inland was shallower, but further out the rich wash deepened and would have been completely out of reach. Hence the dredge recovered mostly low grade overburden. L&M Mining Ltd profitably mined material under the old dredge tailings in 1996 and 1997, by using mobile diesel powered earthmoving equipment to strip the overburden, followed by a floating wash plant fed by a hydraulic excavator to process the paydirt. An essential aspect of this operation was a large complement of pumps to dewater the workings.

4. AMERICAN TYPE DREDGE

4.1 Evolution

The first bucketladder dredge to operate successfully in the U.S.A. was built for the Bannock Gold Dredging Company, Grasshopper Creek, Montana by the Bucyrus Company in 1894. In 1896 the Risdon Iron Works of San Francisco built a number of New Zealand style dredges to the design of R. H. Postlethwaite, a Dunedin dredging engineer formerly of the New Zealand Engineering and Electrical Company. Although this dredge sank during a flood in the Yuba River in 1897 (25) a number of New Zealand type dredges were subsequently built by the Risdon Iron Works ,(12 were working in the U.S.A. in 1899 (18), and successfully operated below the gorge of the Feather River, Butte County, California. Californian engineers assimilated the best features of both designs to produce the Californian type dredge which soon became the global standard.

4.2 Technical Information

4.2.1 Hull and Superstructure

Until 1912 the hulls of American dredges were mostly built of wood. After this standard, riveted, compartmented, steel hulls were used. The steel shapes and plates were drilled, set up for inspection in the engineering shop, dismantled and finally assembled at the construction site.

4.2.2 Bucketline and ladder

Whereas the buckets in New Zealand style dredges were separated by links the buckets in American designs each bucket was connected to the bucket ahead by a nickel-chrome pin with a lug at one end which fitted into a machined slot in the bucket base. The American buckets consisted of a cast manganese steel base to which a renewable manganese steel lip was riveted. Bucket capacity of American dredges in New Zealand varied from 12 ft^3 (Rimu) to 18 ft^3 (Ngahere, Kanieri and Arahura). The bucketline was supported by either a steel plate-girder or a lattice-girder ladder. Although the lighter lattice-girder ladder was as strong as the heavier plate-girder ladder the latter was preferred for New Zealand conditions. To accommodate increased power the bucketline was driven by gears at each end of the upper tumbler shaft.

4.2.3 Power

In Californian dredges electricity was generally used. Where electricity was unavailable it was sometimes generated on the dredge or on shore by steam or diesel generators and transmitted aboard by an armoured, rubber covered trailing cable supported by floats.

4.2.4 Gold recovery

As in the New Zealand style dredge the alluvial material was dispersed and sized in a revolving screen with a sparge bar. Screen undersize was evenly distributed between the gold

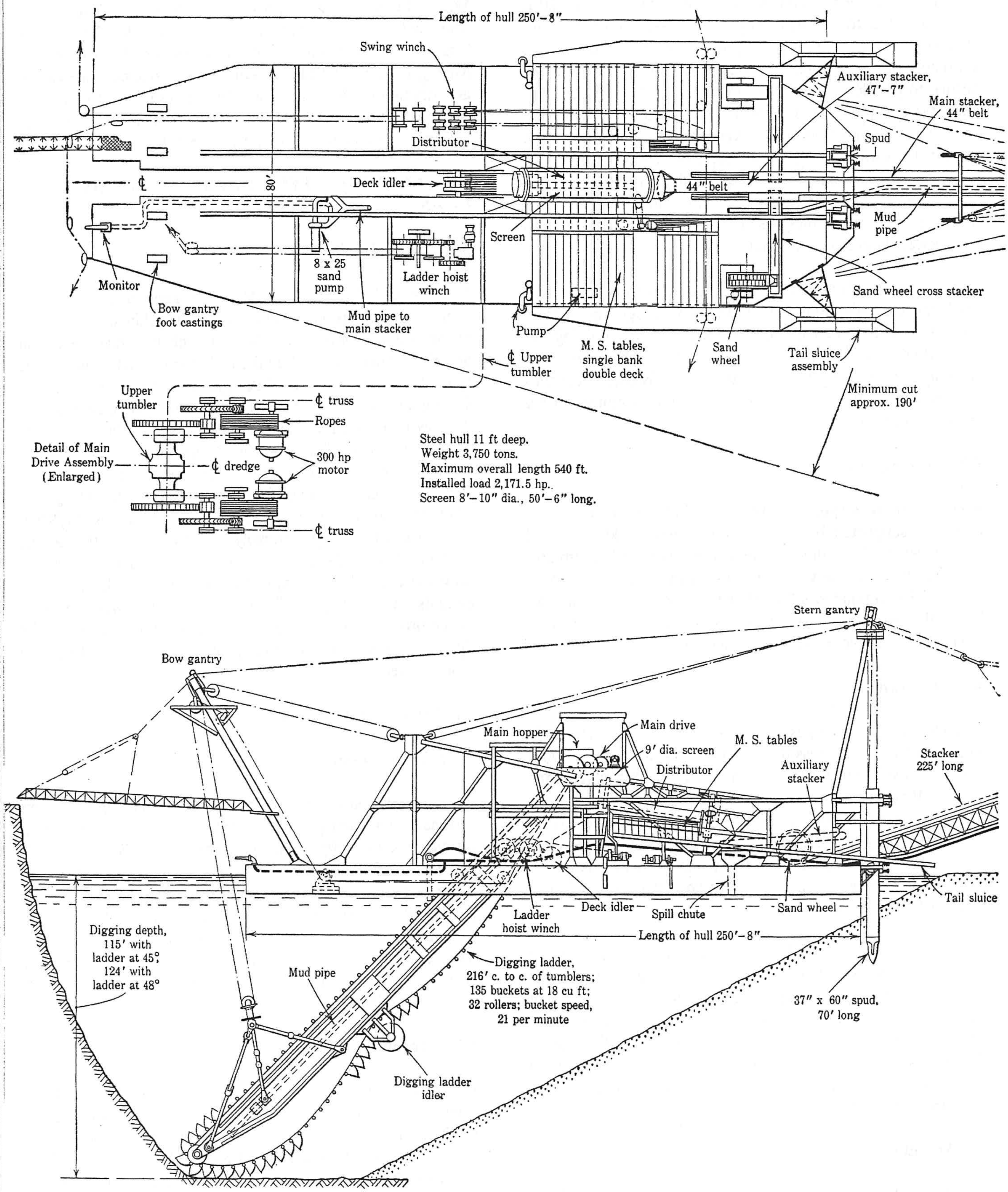


Fig . 4 Plan & Elevation of 18 ft^3 American Style Gold Dredge equiped with tables designed by the Yuba Manufacturing Company.

saving tables by a distributor and the gold recovered on wide inclined wood or mild steel tables placed on both sides of the screen. Each table was divided into 6 to 8 sluices, 16 to 20 ft long and 2.5 ft to 4 ft wide sloping outwards at 1:8 to 1:10. Hungarian or rail riffles, the primary gold saving device, consisted of rectangular or square wooden slats oriented normal to the slurry flow. The riffles were often capped with mild steel or angle iron and made up into frames which were bedded on coconut matting and wedged under brackets on the sides of the sluice. As a general rule Californian dredges with tables only were equiped with 200-500 ft^2 of riffled tables per ft^3 of bucket capacity (26). The outer ends of the tables discharged into the tailings sluice that was often riffled to catch escaping gold or amalgam.

On the large dredges of American design on the West Coast the Rimu Gold Dredging Co. Ltd's first dredge had a table area of 4800 ft^2 whereas the Grey River Gold Dredging Co Ltd's dredge was provided with 2000 ft^2 of tables. The Australian designed Kanieri, Arahura and Ngahere dredges were equiped with tables and mechanical gravity concentrating devices called jigs.

4.2.5 Tailings disposal

Screen oversize disposal in American dredges was by a belt conveyor supported by two parallel cross-braced structural steel trusses. Although the belt conveyor had a greater capacity and better servicability it could only elevate up to an angle of 20° compared with 45° with a tray elevator. Stacker length depended primarily on the digging depth, the nature of the material and the amount of swell (26).

4.2.6 Operation

Characteristically dredges of American design were held against and moved across the face by the bow sidelines about one of two steel poles or spuds, lowered from the stern of the dredge. When using the spud for "stepping up" (advancing) the dredge was swung on one spud to two thirds the arc of movement, the other spud was then dropped. The spud which served as a pivot was then raised, the dredge winched back portion of its travel, the original pivot spud was dropped once more and the holding spud raised.

In the American system the face was worked in a series of shallow benches commencing at the surface and proceeding downwards by successive cuts to bottom. Movement backwards and forwards across the cut was controlled by the bow sidelines while the bucketline was held against the face by the pivot spud. At the end of each cut the ladder was lowered and a return cut excavated. This cycle was repeated until "bottom" was reached.

4.3 Manufacture

The status of American designers and manufacturers at the end of 1915, is shown by the fact that of the 225 dredges operating in the world 166 were in the United States and only 11 of the total were not American made (27). American dredgemakers, who supplied complete dredges or machinery worldwide, included Bucyrus-Erie Co., South Milwaukee, Wis, Marion Steam Shovel Co., Marion, Ohio, Yuba Manufacturing Co., San Francisco, and the New York Engineering Company, New York. In the 1930's Alluvial Mining Equipment Ltd., of Sydney, who planned the Kanieri and Arahura dredges, was the principal designer of dredges in Australia. A 12 ft^3 gold dredge designed by the Yuba Manufacturing Company is shown in Fig. 4.

5.1 AMERICAN TYPE DREDGES ON THE WEST COAST

5.1.1 Introduction

As early as 1893 Alexander McKay suggested that extensive deposits of auriferous gravels could exist within an old channel of the Hokitika River (28). Along the channel margins recent gravels had been worked by the early miners and some terrace faces along the Hokitika River had been mined by shafting, driving and sluicing. Further development was constrained by the lack of water, the tight bouldery nature of the channel fill and the presence of water in the deeper parts of the channel. About 1909 claims on the Rimu Flat were consolidated into four properties and drilled by Rimu Options Ltd. The group of claims known as Rimu No. 1 were purchased by the Rimu No. 1 Gold Dredging Company who transported the dredge "Glasgow" from Sandy Point, Otago to the site. This steam powered New Zealand type dredge with 7 ft^3. buckets was commissioned during April 1917. The venture was shortlived as the dredge was not large or powerful enough to work the tight, bouldery, iron cemented, ground. A total of 980 ozs of gold was recovered.

5.2 Rimu Gold Dredging Company

5.2.1 Background

After completion of the drilling in 1917 Rimu Options were fortunate in attracting the attention of Robert E. Cranston, a prominent Californian dredging engineer. With Bulkeley Wells of Denver, Colorado, Cranston drilled a further 110 bores on Rimu Options Ltd., and Rimu No. 1 Gold Dredging Ltd's properties. A comprehensive report was prepared and Cranston returned to the USA to raise capital. The support of The General Development Company of New York was secured and the Rimu Gold Dredging Company Ltd. registered in Wellington on 12/07/20.

5.2.2 Technical Details

Compared to the early New Zealand type dredges the Rimu dredge contained many new features. Built at a cost of about £100,000 it was the first of the large Amercan type dredges which were to dominate the New Zealand alluvial mining scene for the next 60 years. The dredge was designed and the machinery supplied by the New York Engineering Company.

Because of a post World War 1 steel shortage, material for the pontoon and superstructure was not immediately available and as the Directors were anxious to commence gold production the design was revised and the pontoon and superstructure built of oregon pine. The hull, 35.2m long, 15.2m wide and 3.25m deep, was heavily braced and covered with thick planking. The 41m long digging ladder, of plate girder construction, was fitted with a hexagonal upper tumbler, and a round lower tumbler and the close connected bucketline carried 73, 10 ft^3 buckets. These dumped at the rate of 19 buckets / min. into the main hopper which discharged into a 14m long x 2.1m diameter revolving screen. Oversize passed from the screen on to a conveyor belt supported on a 41.1m long lattice girder stacker (29).

Gold recovery was effected by 4,800 ft^2 of wooden riffle tables with most of the gold being recovered on the upper tables close to the distributor box. Manoevering was accomplished by two 17m long spuds each weighing 18 tonnes and four sidelines. Dredge operations were controlled from a pilot house on the upper deck behind the main gantry. Dredging commenced on 12th of September 1921. Operations were carried out on 3 shift basis with an average staff of 37. Electricity was generated by a subsidiary company, Kanieri Electric Ltd., at the Kanieri Forks station which was originally built by Ross Goldfields Ltd.

5.2.3 Dredging Results

In the first full year of operations (1922-1923) 1,147,790 yd^3 was dredged from which 10,163 ozs of gold was recovered (360 mg/m^3). Between 1921 and 1930 an average of 10,408 ozs of gold was recovered. Dredge availability exceeded 80% of the possible digging time and the digging rate (1928-1930) varied from 255-318 yd^3/hr. By 1930 the wooden pontoon had developed a pronounced sag towards the ladder well and had arched longitudinally. As much ground remained to be worked the management decided to reconstruct the dredge on a steel pontoon and upgrade the machinery. Plans and specifications for this work were prepared by Paul R. Parker, formerly chief engineer for the Yuba Manufacturing Company in California and the construction contract was awarded to Hansford Mills Construction of Wellington (30).

The dredging programme was organised so that the old dredge reached the new pontoon just as it was completed. The new steel pontoon was launched in March 1931, the two were moored together and the machinery transferred between June and October. Comparison of the volume dredged before and after reconstruction indicate a 14% increase in digging rate. Further efficiencies were achieved in 1933 when the bucketline speed was increased and bucket capacity enlarged from 10 ft^3 to 12 ft^3. Between 1932 and 1938 the average digging rate was 422 m^3/hr decreasing to an average of 312 m^3/hr from 1941 to 1953 in tight bouldery ground. Of the total time available for dredging between 1932 and 1938 the dredge operated for an average of 87.5% of the time. From 1941 to 1953 dredging time decreased to an average of 77.8% as a result of difficult dredging conditions, lack of spare parts and electricity supply problems.

In the 31.5 years of operation an area of 878.5 acres was dredged and 62,550,000 yd^3 of gravel treated from which 319,345.3 oz of gold was recovered. A total of £759,802 was returned to the shareholders (30).

By American standards the Rimu dredge was not unusually large as the 18 ft^3 Yuba No. 20 operated by the Natomas Company near Hammonton, California could dig to 124 ft below water level and work against a bank 50 ft high. When compared to the New Zealand type dredge it was stronger, more durable and was sufficiently powerful to economically dig the very tight, low grade, bouldery West Coast gravels. Other improvements included the close connected bucketline, use of a conveyor belt for stacking and the application of spuds instead of a headline. All the machinery was independently powered by electric motors and the dredge was controlled from a central position above the deck.

6 CONTRIBUTION OF DREDGING TO THE NEW ZEALAND ECONOMY

The importance of gold in the development of New Zealand has been well documented and researchers agree that gold mining assisted the early European development of New Zealand by stimulating the growth of agriculture, providing employment, improving communications and promoting the creation of towns and businesses (4, 31). This was especially evident in Dunedin which was, for a period after 1871, the commercial centre of New Zealand. By 1861 gold exports comprised 55% of export earnings. After 1870 gold diminished in importance as the value of wool increased (31). Peak gold production years were in 1866 and 1906 when 735,376 ozs and 562,843 oz of gold were exported (Fig. 5). Within this period gold returns from listed public dredging companies increased from 21,862 ozs in 1890 to 124,660 ozs in 1906, the zenith of the first dredging boom, when the gold dredging yield amounted to 22% of declared gold exports.

On the 31st March 1900 81 dredges were working in Otago and Southland and 4 on the West Coast. A total of 159 dredges were under construction, 101 in Otago plus 58 on the West Coast. Apart from the men employed in dredge building each Otago dredge had a permanent crew of 6 while additional men were required on most West Coast dredges for land clearing. In addition each dredge indirectly employed at least 11 men, including coal miners, wood cutters, carriers, and engineers (19). In Dunedin a healthy industry developed around the design and manufacture of gold dredges for local use and export. According to Warden McCarthy the number of men employed in Dunedin foundries to fill orders for dredging machinery increased from 1016 in January 1898 to 1630 in the same month of 1900 (19). The relation between employment, the number of dredges and gold produced is shown in Fig. 6.

After the first dredging boom gold produced from quartz mines steadily declined as the gold resource diminished but the period 1931 to 1934 saw another expansion in alluvial mining due to an increase in the price of gold from £3/15/0/oz to £8/4/0/oz. Rising gold prices were also responsible for a revival of interest in the extensive, low grade, alluvial gold

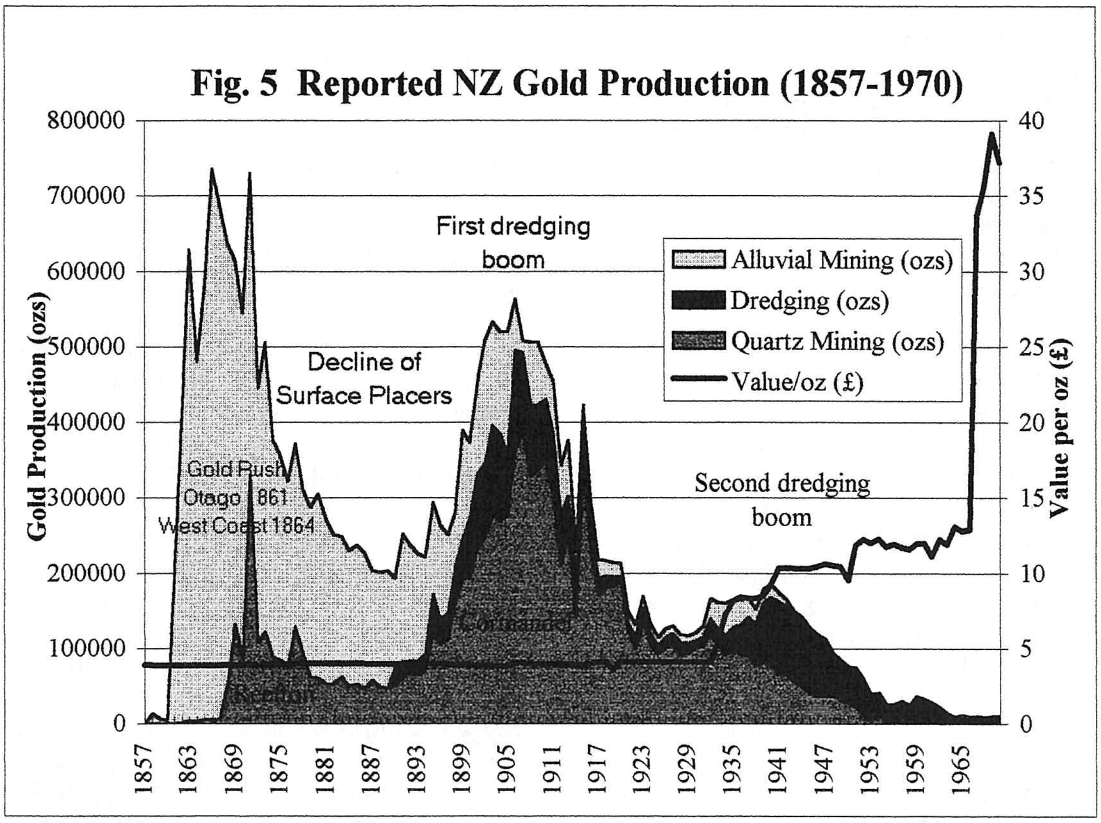


Fig. 5 Reported NZ Gold Production (1857-1970)
Gold Production (ozs)
Value per oz (£)
First dredging boom
Decline of Surface Placers
Gold Rush Otago 1861 West Coast 1864
Second dredging boom
Alluvial Mining (ozs)
Dredging (ozs)
Quartz Mining (ozs)
Value/oz (£)
800000
700000
600000
500000
400000
300000
200000
100000
0
40
35
30
25
20
15
10
5
0
1857
1863
1869
1875
1881
1887
1893
1899
1905
1911
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1923
1929
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1959
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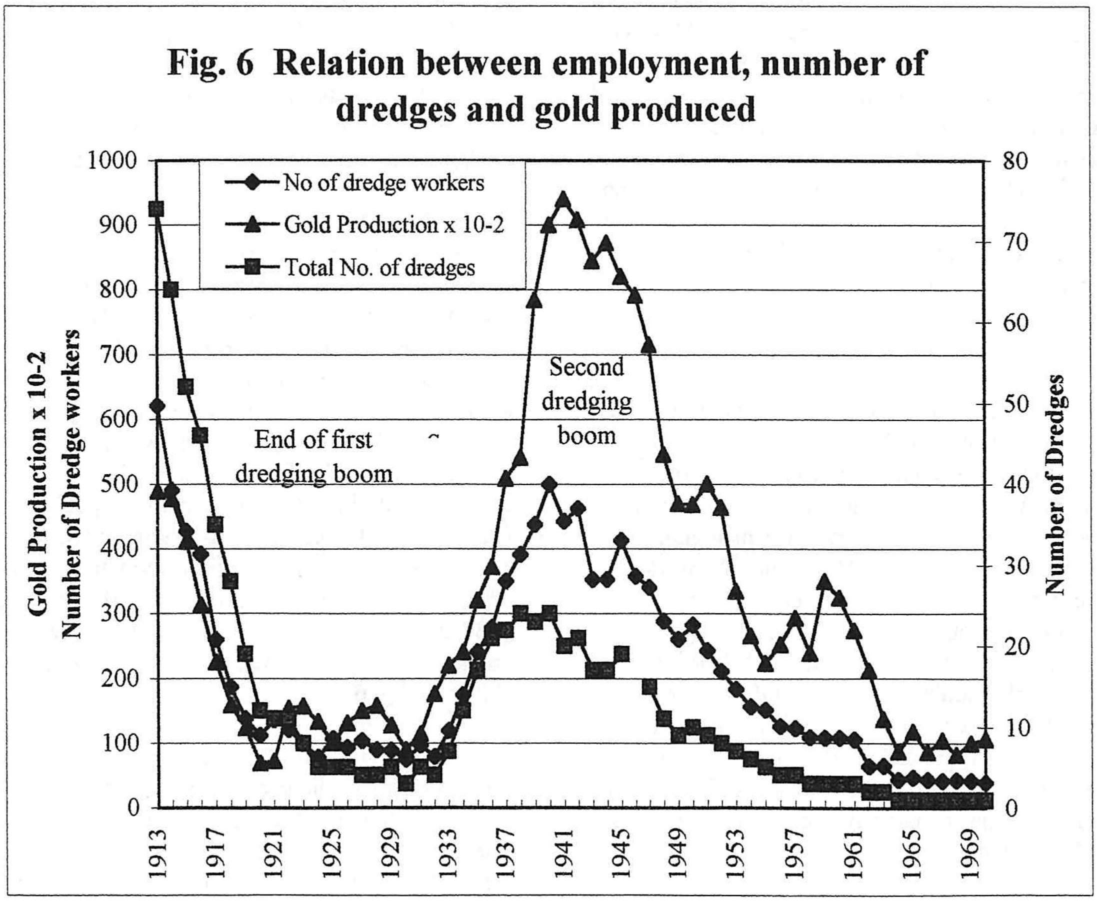

Fig. 6 Relation between employment, number of dredges and gold produced
No of dredge workers
Gold Production x 10-2
Total No. of dredges
End of first dredging boom
Second dredging boom
Gold Production x 10-2
Number of Dredge workers
Number of Dredges
1000
900
800
700
600
500
400
300
200
100
0
80
70
60
50
40
30
20
10
0
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969

deposits of Otago and the West Coast. The success of the American Type dredge working on the Rimu Flat, south of Hokitika, attracted the promoters' attention and many giant American type dredges and smaller, electrically powered New Zealand designed craft were commissioned. In 1936 the 37,269 ozs recovered by 21 dredges, exceeded the amount of gold recovered from all other alluvial activities (Fig. 5). At the height of the second gold dredging boom in 1941 the 94,059 ozs, worth $56.4 million (NZ) with gold at $600/oz, from 19 dredges exceeded the yield of the Waihi quartz mines (Fig. 5). From 1947 the annual quantity of gold dredged began to decline and the number of operating dredges decreased from 14 in 1947 to 2 in 1955. Sole survivor of the dredging fleet in 1961 was the Kanieri dredge on the Teremakau River.

Over the period 1861-1970 the reported New Zealand gold production amounted to 27.3 million ozs worth $16.4 billion at a gold price of $600 (NZ) per oz. Of this about 3.5 million ozs (15%) was recovered by bucket ladder gold dredges. Although New Zealand's progress was eventually supported by the agricultural and pastoral industries the gold mining industry of which dredging was a part provided markets for the fledgling farming industry, generated overseas capital to assist the internal economy and attracted the man power necessary for the "creation of the nation" (32).

8 ACKNOWLEDGEMENTS

We would like to thank L & M Mining Ltd., for access to Kohinoor resource data, staff from the McNab room at the Dunedin Public Library and the Stephanie Van Gaalen from the Nelson Provincial Museum, who willingly recovered the heavy volumes containing the Mines Statements that record much of the dredging story. We also acknowledge, the painstaking work of John Caygill who was commissioned by the Department of Lands and Survey, Dunedin to research the history of the gold dredge in Otago and Mr Syd Griffiths for information on the Bucyrus Company.

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Redundant Industrial Heritage: the challenges and the solutions!

Ian Baxter, Director, Heritage Council of Western Australia

SUMMARY

Over the past few years considerable effort has been made around Australia to identify, list and conserve places of industrial heritage significance that have played a major role in the economy and development of the Country.

There are some excellent examples around Australia where this has been achieved such as in the case of the Powerhouse Museum in Sydney and the old Melbourne Sewage works at Spotswood now part of the "Scienceworks"museum.

These, are however the exceptions. Today the challenge is to conserve places that have little potential for government funding either capital or recurrent, are often in private ownership and can only be conserved in the context of an economic return often against quite extraordinary odds.

This paper sets out the fundamental issues involved and how they have or can be addressed in respect of any place, using specific examples from Western Australia.

1.0 INTRODUCTION

Redundant buildings, structures and sites present one of the most difficult challenges for conservationists in the next Millennium.

They are inevitably ugly to the common eye; rundown, are often situated on prestigious sites capable of redevelopment and greater financial return as clear sites rather than restrained by the physical limitations associated with their original functionality and condition.

Alternatively, as in the case of mining sites and sites associated with timber milling, they can be remote from centres of population and therefore subject to vandalism and neglect.

Then there are those places that, for one reason or another, lack the political support or the owners' willingness to consider alternative development options that could, with some lateral thinking, lead to their conservation.

Despite this, industrial facilities represent the core of a nation's economic development and can therefore be of major historical and social significance and more often than any other place satisfy all of the four basic heritage criteria relating to aesthetic, historic, social and scientific values.

In Western Australia there are a number of industrial sites that have been converted to accommodate new uses. This paper is dedicated to advancing the knowledge and understanding of the issues associated with the successful and not so successful conservation of places in the interests of retaining some of the tangible evidence of our past industrial endeavours.

Long-term thinking is lacking; some places will need ten, maybe twenty years to make projects work. Often the pervading market conditions are prejudicial to viable redevelopment; take the Swan Brewery, for example, in Mounts Bay Road in Perth. This redundant industrial complex (has) stood still for three years, awaiting a change in the market sufficient to warrant further substantial capital expenditure.

Many examples will be used in the presentation to graphically demonstrate the way many of these places have been adapted. For every situation there can be a solution. The challenge is not in coming up with the ideas, although this in itself requires creative thought and imagination, but in delivering the idea.

Marketing the idea is the key. Gone are the days when one could rely on governments to fork out huge sums of money, not only in capital but also in recurrent funding, to support yet another museum. These days we all have to satisfy the ideals of the economic rationalists and produce solutions that work at minimal cost to the community in both the short and long term.

Therein lies the challenge: How to retain the past meaningfully, and yet do it in such a way that the financial burden is acceptable.

We have already lost too much and as time goes on I believe that we will regret not making a greater effort now to retain the heritage that still remains. So while we still have a chance to conserve our industrial past, let's do it!

Understand the problem and you will understand how to arrive at the solution!

2.0 THE ISSUES

What are the characteristics that epitomize the redundant heritage site?

2.1 Location

Industrial sites seem to be either very close to Town centres or in extremely remote locations.

This tends to create problems of viability relating to a lack of economic return to simply an inability to make the place readily accessible.

Sites located within urban areas will be under pressure to maximise the area available for new redevelopment and retention of existing buildings will be challenged, as it will be seen as a liability.

A location close to water is typical of many industrial sites such as Power Stations because of the roles water played in the manufacturing process. This aspect may help in the conservation of the place because it will provide opportunities for exploitation of the setting.

The remote site may be difficult to conserve because of its lack of supporting infrastructure, but if it is on a tourist route there may be other opportunities for conservation as in the case of the *Cheynes Beach Whaling Station* near Albany in Western Australia, or the steam driven pumping station at *Dedari* near Kalgoorlie.

Then there are the numerous stamping batteries that were located near mining sites in the Goldfields and the steam powered timber saw mills such as *Donnely* in the heart of the State's South West near Manjimup.

Each of these quite diverse locations provide opportunities as well as challenges for conservationists.

2.2 Condition

Many places present challenges because of the poor condition they end up in after years and years of neglect, making the conservationists' task all the more difficult.

This is most often a conscious decision of the management who may be faced with declining demand for their product, or may need to expand beyond the limitations of their current site and upgrade to new technology such as in the case of the Swan Brewery in Perth where they were forced to relocate elsewhere.

Whatever the reason, structures, sites and buildings are often left in a thoroughly degraded condition.

Services such as the electrical supply to the buildings and the site may be substandard, even dangerous. Stormwater drains and sewage systems may be derelict. Structural fabric may be deteriorated beyond economic repair, for instance steelwork may be heavily corroded and require total replacement, asbestos roofs may require removal and walls may be ridden with concrete cancer.

Conditions such as these can be found on many redundant heritage sites all over Australia and many sites such as exist at East Perth have all the problems on the one site.

2.3 Large Scale Sites

One aspect common to many industrial sites is their large size which is usually a direct consequence of the scale of the operation that is or was carried out.

This can have significant advantages in terms of redevelopment options, however it also means that decisions on reuse will involve more complex planning and servicing issues such as whether areas of the land can be utilised for housing, or whether parts can be turned over to public open space.

Decisions will therefore involve a multiplicity of agencies, extensive community consultation and potentially more substantial infrastructure and development cost.

Large scale areas like East Perth 1 km from the centre of Perth which contained a multiplicity of industrial sites, have benefited from major injections of capital funds such as those provided through the Commonwealth Better Cities Program.

Yet, in the case of East Perth the agencies charged with redeveloping the area have failed to provide any priority to places such as East Perth Power Station, arguably one of the most significant and widely representative Stations of its time still substantially intact in Australia.

2.4 Environmental issues

Many sites have occupied prestigious locations for decades and have undertaken operations that have been unfriendly to the environment. Examples abound where toxic waste has been stored or buried on site leaving an expensive legacy for future generations to remediate.

It is another major hurdle to overcome and in fact is often one of the most expensive elements associated with the redevelopment of industrial sites, irrespective of whether the buildings are removed or not.

In some cases such as the State Engineering Works in North Fremantle in Western Australia, site remediation required all buried wastes to be excavated and transported to a new location.

There is also the relationship of the site to the surrounding environment. Midland Railway Workshops for example falls within a proposed new flight path for Perth Airport and within close proximity of a cattle saleyards, creating limitations in terms of development options.

South Fremantle Power Station site occupies an area planned for redevelopment as public open space, creating a dilemma between retention of the building and improved public amenity. This station and East Perth are adjacent to major open air electricity transmission stations which are still operational and therefore are considered hazardous in close proximity to built up areas. In both cases the transmission stations have many years of useful life ahead of them and will cost many millions of dollars to relocate.

In the case of the grain silos in Fremantle, the structures occupy a significant footprint within the existing harbor land based operational area. They are now redundant and the land is required for the construction of new container facilities. They fall within the highest risk contour for safe port operations and therefore cannot be converted to uses such as apartments that might otherwise be viable.

On many occasions there is conflict between conservation and the provision of new roads. One such case relates to a site of national significance located in close proximity to Perth City where a suite of Beehive Kilns and tall chimney stacks are under threat from proposed new roadwork.

The Beehive kilns at Ascot are believed to be the largest set of kilns of this type still surviving in Australia, and as such are considered by the Heritage Council to be worthy of conservation.

An alternative road design has been proposed that would see the kilns retained, however even if this proves successful what does one do with 8 kilns and 5 stacks to ensure they are maintained in the future and remain accessible to the public for interpretation purposes?

Perhaps the answer lies in the comprehensive redevelopment of the site and a requirement for the developer to incorporate the conservation of these structures into the overall management of the place in a creative manner. Only time will tell!

2.5 Compatibility of use versus integrity of place

How far do we go in adapting places before the changes that are necessary compromise the heritage values to a point where there is a significant loss in integrity?

I will quote a number of examples where quite different approaches have been taken and yet the results, in my view, have achieved a worthwhile conservation result.

Three flourmills that fall into this category are Katanning, York and Cottesloe.

The first two are situated in the country and therefore different environmental factors are at play.

Katanning flour mill some 200 kms from Perth, was constructed in 1891 but ceased operation in 1981 This has been conserved with all its original equipment intact so that it is possible to fully understand the operations of the flourmill to the present day. York, a heritage town close to Perth also has a redundant flourmill. This been adapted to a new but quite compatible use as a fine furniture factory and sales office, which leaves the primary fabric intact and retains many of the bits and pieces that were part of the original machinery.

At the other extreme is Cottesloe Flour Mill (1902), which is within 10 kms of Perth. This has now been converted into 13 luxurious apartments but still retains the primary internal and external fabric. Extensive physical interpretation of the previous function of the place has been provided to ensure its history can be understood by future generations.

The extent of remaining fabric and the viability of retaining original fabric and equipment within a new function often dictate the level of adaptation.

In the case of the Swan Brewery in Perth for instance, when purchased by the State Government, the building was an incomplete shell, cleared of 99% of its working machinery.

The decision made here initially was to convert to office and commercial uses, however market conditions prevented this from happening and only recently has a controversial decision been made to convert to residential accommodation.

2.7 Timing/Political Support

Often the decision to conserve or not is dependant on prevailing market conditions and political policies of the Government of the day.

Timing is everything. In Perth there has been a glut of office space for the last ten years, developments that were viable in 1989 are still not viable today. Offsetting this however is a new interest in inner city living, which has created a demand for housing not seen in the inner city for a century.

Suddenly, opportunities for adaptation of redundant heritage buildings and sites have appeared that did not exist 5 years ago. Some buildings like the Cottesloe Flour Mill have been waiting for 8 years for the right time and would have disappeared had there been no heritage legislation in place.

Many larger sites are government owned and are subject to the political whim of the day. In Western Australia there has always been a strong "development at any cost" mentality and this has resulted in much of our precious heritage being lost to future generations.

This is critical; the longer a site or building remains unused the more it will deteriorate and the harder it will be to remediate and achieve a cost effective solution as in the case of the East Perth Power Station.

3.0 SOLUTIONS

There is no magic formula that will apply to every site nor every building or structure. Each will require its own unique solution. It is likely, however, that the issues outlined above will apply to many places of an industrial nature.

In Western Australia there have been a number of very successful projects completed that demonstrate what can be achieved through some lateral thinking and resolve by the parties involved.

In some cases government funding has been a significant factor in getting the project off the ground, in others, the commercial return has been sufficient to enable the project to be undertaken without financial support. In all cases, however, there has been a strong community interest in the retention of the buildings or structures and some compulsion to find solutions that work.

I have chosen a range of examples to demonstrate the diversity of some of the sites and the solutions found and follow with some comments on the strategies that can be employed to achieve these results.

3.1 Joe White Maltings Perth

My first example is an inner city industrial site that has recently been redeveloped in close consultation with the Heritage Council. The Joe White Maltings, is a complex of buildings and industrial structures dating from 1899, which was still in operation up until 1998 producing malt for brewing.

Whilst a number of concessions had to be made to achieve a viable development, this project in my view is an excellent example of how conservationists and developers can come together in a collaborative way to achieve a win-win position.

The best solutions come from collaboration

Early discussions with the developer resulted in the preparation of a comprehensive conservation plan and video recording of the manufacturing process prior to cessation of production.

A scale model of the manufacturing process was commissioned and as the project progressed a scale model of the whole site was constructed to explain to potential purchasers how the buildings were to be adapted to fit in residential apartments and community facilities.

The conservation plan identified the most important elements of the complex as well as those that are more readily adapted to new uses. In this way it was possible to retain not only the landmark value of the place but also important elements of the manufacturing process such as the innovative sub-floor ventilated Malthouse from 1899.

3.2 'E' Shed Fremantle Harbour

The Port of Fremantle has been undergoing constant change since CY O'Connor first engineered it in 1897. As an operational Port the Port Authority have had to continue to implement changes to improve the way goods are handled and the way the Harbor is utilised to ensure that it maintains its competitive position.

As part of this change process it became necessary to relocate or demolish one of the goods sheds to make way for other operational facilities.

The Port Authority involved the community in the process to elicit ideas for its retention, and after some debate it was decided to call for expressions of interest to relocate the structure to an area of the wharf that is not required for expansion and will become a discrete heritage precinct.

A viable use as a shopping market was identified and the structure subsequently relocated and the severely deteriorated external fabric replaced.

The basic timber structure, which is of grand proportions, remains intact and today the structure lives on with an exciting range of new uses including offices for the Rottnest Island Authority.

Coincidentally it became necessary to relocate a Luffing Crane, one of many that used to grace the Port. A prominent position was found for this piece of maritime history alongside the relocated 'E' Shed.
This is the front runner of a major project announced by the State Government that involves the construction of a new maritime museum to house Australia II and conversion and restoration of many of the industrial buildings and structures within the historic precinct of the Fremantle waterfront.

3.3 Cheynes Beach Whaling Station Albany

Remoteness of industrial sites has been mentioned as a difficulty but one such site is near Albany, and understood to be the last intact Whaling station in Australia. It has been conserved through the intensive efforts of a local group of volunteers.

Tourists can now experience through a very graphic audio-visual display and the intact physical remains the whole whale processing operation.

This would have to be one of the most successful examples of conservation of an industrial site that I have seen and have been involved in supporting through recognition on the State Register and provision of grants.

The group has even managed to acquire and restore one of the Whale Chasers, which is now available for inspection as part of the whole experience and understanding of how this facility operated in its heyday.

3.4 Swan Brewery-Perth

This is another industrial complex located on the Swan River with spectacular views of the City and the backdrop of Kings Park.

In the 1980's it was decommissioned, purchased by a private developer, subsequently transferred to the government of the day and leased to another developer for a 65 year period with a requirement written into a heritage agreement with the Heritage Council of WA to undertake certain prescribed works in accordance with a Conservation Plan.

Seven years later after a period of no activity, the project is now nearing completion, having undergone extensive restoration of the external fabric and construction of new buildings a car park and a jetty.

Public accessibility to the ground floor areas of the buildings was a major requirement of the brief and this will be achieved through the provision of restaurants and office spaces.

Interpretation of the site is a requirement of the brief, and given the high level of community interest in the site this remains one of the more important outcomes from a heritage perspective.

3.5 Fairbridge Farm-Pinjarra

Located some 70kms distant from Perth, Fairbridge is somewhat outside the usual notion of industrial heritage, yet this farm which is made up of some 52 individual buildings and many acres of farming land represented a major conservation challenge.

Originally built by Kingsley Fairbridge in 1913 as a place where underprivileged children from Great Britain could be educated and learn basic farming skills, the complex was virtually unused in the late 80's and in jeopardy of becoming just another abandoned site.

A group of old Fairbridgians in association with the Masonic Lodge and the mining company Alcoa developed a plan to raise $6m over a period of 4 years, and subsequently appointed a young, enthusiastic chap to run an intensive fund raising campaign.

In less than 2 years the Association received pledges and firm commitments in excess of the $6m target from State and Federal Governments, the Lotteries Commission and the Community! The funds to be used towards the restoration and conversion of the complex as a training centre for youth with particular emphasis on the conservation of the environment.

Work is now well advanced on the conservation and conversion of the buildings for their new use in complete harmony with a conservation plan and the original purpose.

4.0 STRATEGIES FOR CONSERVATION

4.1 Security and Documentation

One of the most important first order principles to be followed in my experience is to secure the site. So often we come back to find much of the intrinsic value of a place is lost through vandalism and sheer neglect willful or otherwise.

Most heritage legislation is ineffective against willful neglect, meaning that just because a place is on a register it doesn't provide protection from doing nothing!

In Western Australia we have a number of good and bad examples of this. Take the Midland Railway Workshops for instance, very early on it was decided to undertake a full survey by Industrial Archaeologists to determine the significance of plant and machinery much of which was still original.

The resulting schedule of items has served to guide the retention and disposal policy of Westrail, the agency responsible for the decommissioning of the site.

Occupation is the best security!

A perimeter fence was immediately installed around the core buildings and arrangements made for volunteer groups such as the Machinery Preservation Society and the Railway Historical Society to use the buildings in conjunction with 24hr surveillance. The establishment of a TAFE college annex was also agreed to.

This has prevented any major catastrophe and will continue until an alternative long-term use can be found for the place.

By contrast, East Perth Power Station has been left to the vandals who have destroyed much of the interior fittings and plant.

Often simple methods are all that is required to maintain security, in other cases electronic surveillance and physical barriers are necessary.

4.2 Conservation Planning/Development

The development of a conservation and management plan and physical record of the place is one of the next steps towards a successful conservation outcome.

Armed with conservation plan and a management strategy one can start to negotiate with the parties responsible and consider acceptable uses that will least compromise the place.

Plan to understand!

If the site is large and complex such as Midland then a development plan will probably be required and it may be necessary to change the use zonings for the land.

Heritage Agreements are a useful tool if the site is to be sold off and guarantees may be required to ensure appropriate conservation strategies are employed in the future.

If the climate is right the next step might be to call for expressions of interest in redevelopment.

For developers to express an interest it is preferable that as many uncertainties as possible are removed before venturing out on the open market.

If the development involves government funding then it is likely that up to 3 years prior notice will need to be given to arrange allocation of funds and a clear mandate given by the State Cabinet.

If the circumstances call for a large injection of funds from a diversity of sources, a funding committee should be set up and a full time person appointed to run the campaign.

Employ a "Champion"

It is also advantageous to appoint a "champion" for the cause, someone who is well connected, influential and committed to the conservation of the place, as per the Fairbridge example.

4.3 Exploring options

Often it becomes necessary to become pro-actively involved in the exploration of options for re-use of a redundant site and this can be done informally or formally by seeking expressions of interest.

Before this is done, however, it is essential that as many barriers to development are removed so that the proponent has confidence in investing time and resources into the proposal.

Challenge the preconceptions!

Issues such as road reservations, height limits on new development, car parking requirements, zoning for other uses, density of development, all these can be challenged!

In the case of the East Perth Power Station, a site of great industrial heritage significance, located adjacent to the Swan river, an option was identified which involves the relocation of "Scitech"; an already established interactive science based educational facility somewhat comparable to the Powerhouse in Sydney or Scienceworks in Melbourne.

In some cases options have been driven by tourism, in others a demand for CBD located higher density residential accommodation.

CONCLUSIONS

Managing the process of redundancy is complex and challenging, it often depends on good luck rather than good management and it is certainly sensitive to the political environment and market conditions prevailing at the time.

If there is community resolve to support conservation then the opportunity for success is enhanced. Education and an understanding of the significance of our industrial past are fundamental to this support and wider collaboration amongst the heritage bodies in spreading this message is essential.

In Western Australia we have a very committed group of Engineers who have established an industrial Heritage Strategy for WA in association with the Heritage Council. I commend this initiative to others interested in advancing the cause of industrial heritage conservation.

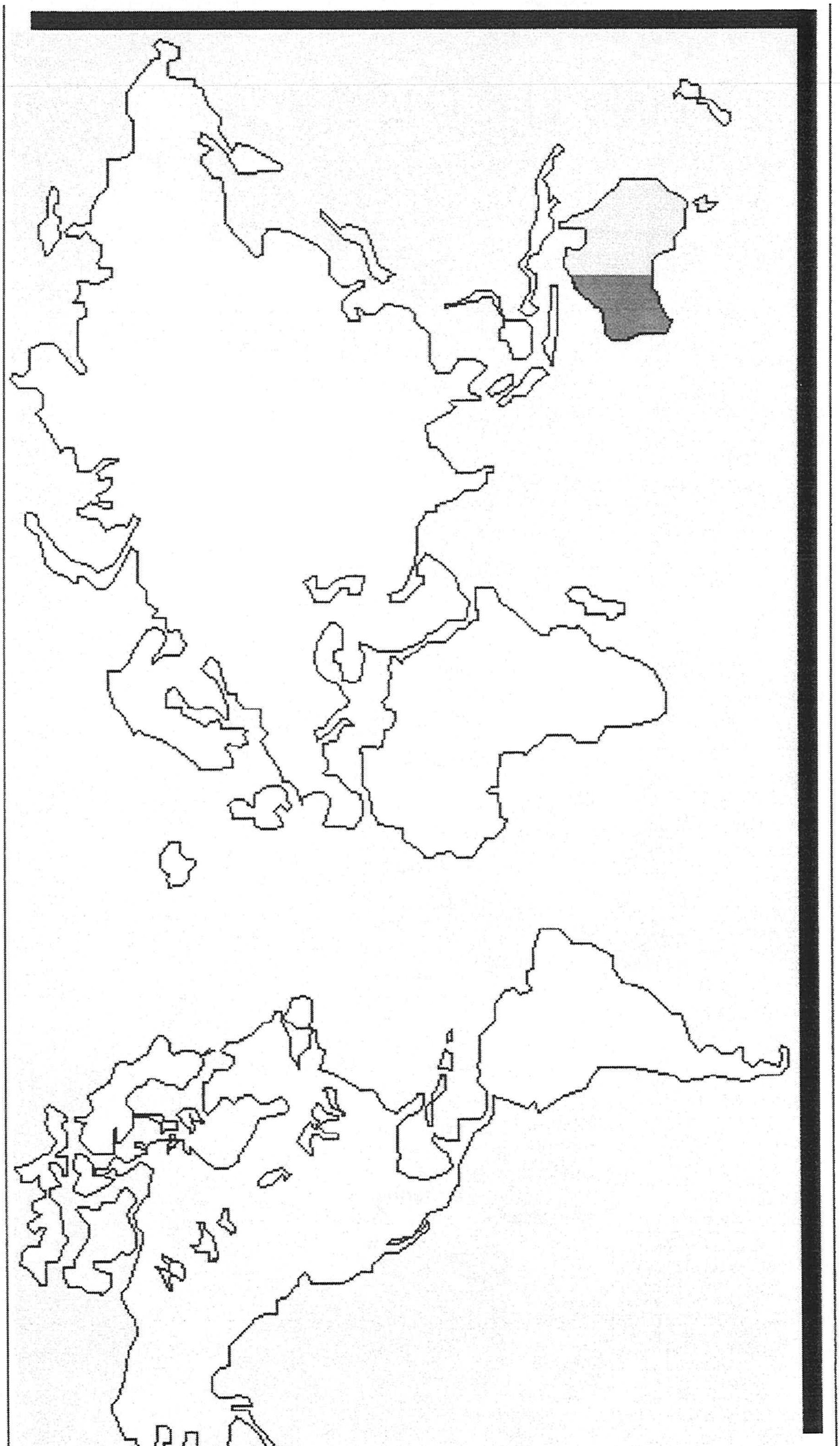
The Heritage Council has also developed a Mining Heritage Strategy in association with the Peak bodies and key stakeholders, in an endeavour to identify and protect our significant mining heritage.

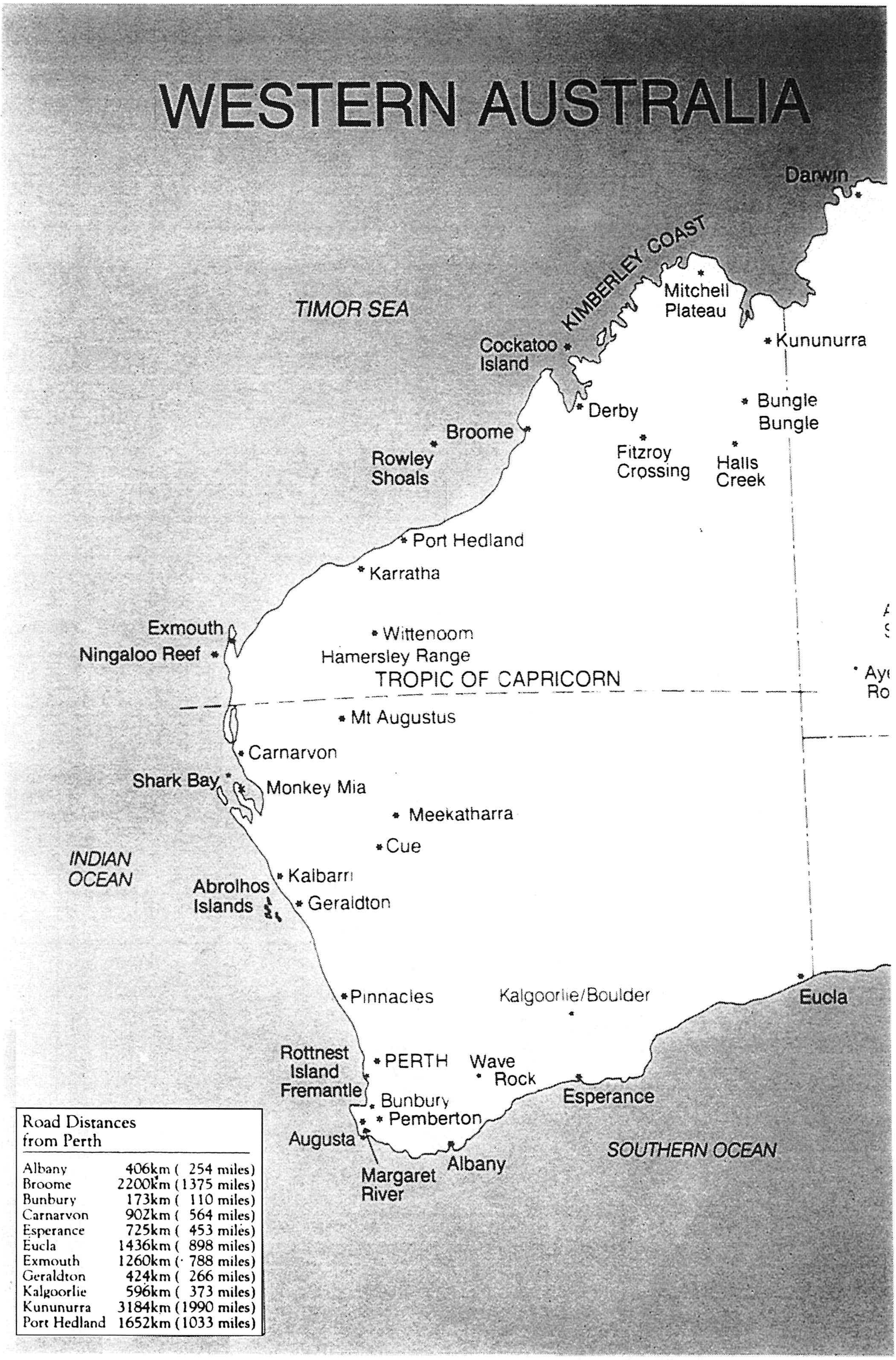
The principles as outlined in this paper are essentially quite simple: -

- Understand the problem
- Identify the significance
- Implement holding strategies
- Develop short and long term plans for conservation
- Explore and pro-actively pursue options and funding strategies

Having determined a course of action review the potential outcome to ensure that the cultural heritage integrity place is not compromised to the extent that that result is unacceptable.

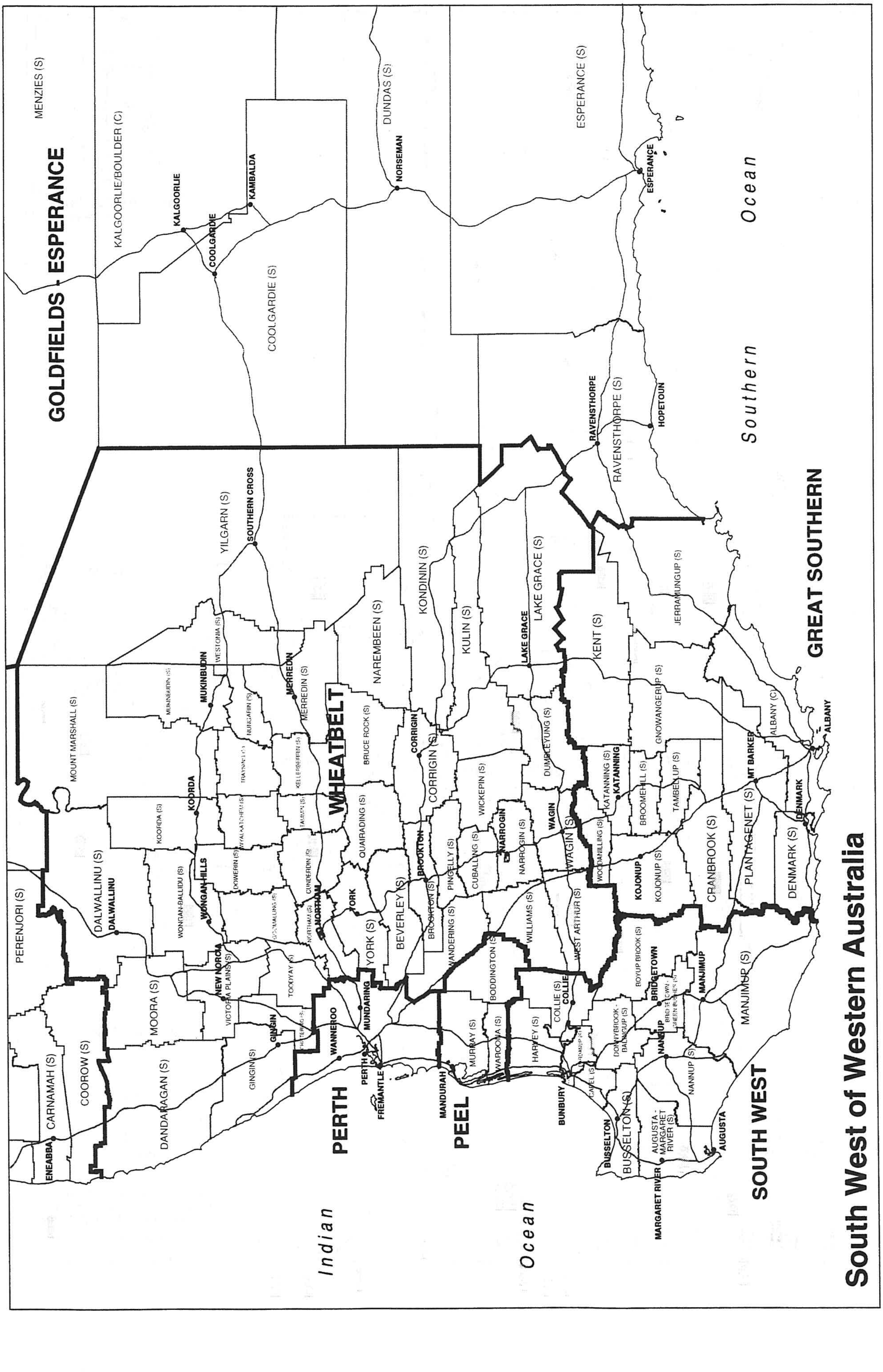
In other words, that a good balance has been achieved!





Road Distances from Perth

Albany	406km (254 miles)
Broome	2200km (1375 miles)
Bunbury	173km (110 miles)
Carnarvon	902km (564 miles)
Esperance	725km (453 miles)
Eucla	1436km (898 miles)
Exmouth	1260km (788 miles)
Geraldton	424km (266 miles)
Kalgoorlie	596km (373 miles)
Kununurra	3184km (1990 miles)
Port Hedland	1652km (1033 miles)


South West of Western Australia
GOLDFIELDS - ESPERANCE
WHEATBELT
GREAT SOUTHERN
SOUTH WEST
PEEL
PERTH
Indian
Ocean
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MENZIES (S)
KALGOORLIE/BOULDER (C)
KALGOORLIE
COOLGARDIE
KAMBALDA
COOLGARDIE (S)
DUNDAS (S)
NORSEMAN
ESPERANCE (S)
ESPERANCE
RAVENSTHORPE
RAVENSTHORPE (S)
HOPETOUN
YILGARN (S)
SOUTHERN CROSS
MOUNT MARSHALL (S)
WESTONIA (S)
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MERREDIN
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KONDININ (S)
KULIN (S)
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KENT (S)
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GNOWANGERUP (S)
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WICKEPIN (S)
DUMBLEYUNG (S)
KATANNING (S)
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PERTH
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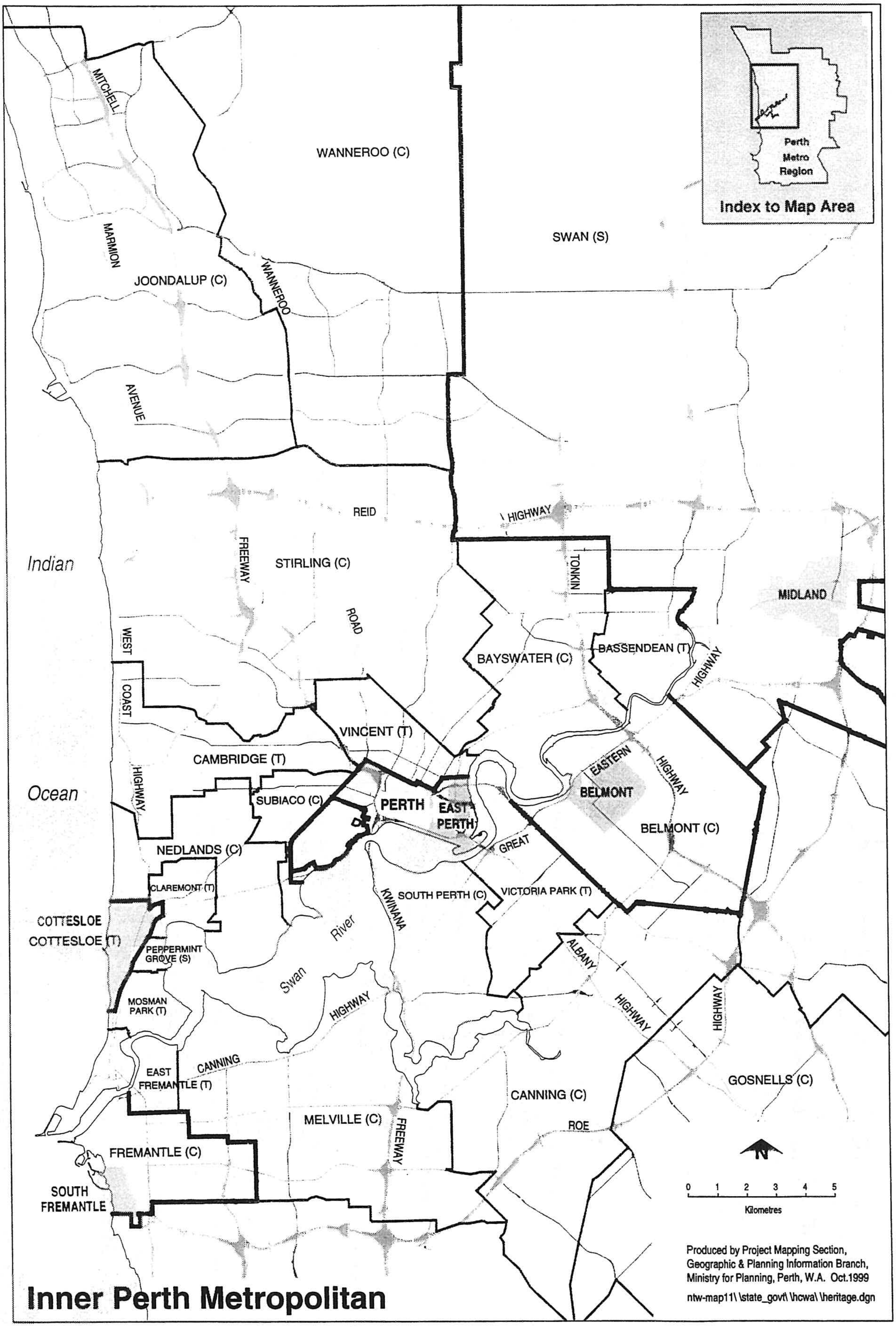

Index to Map Area
Perth Metro Region
WANNEROO (C)
SWAN (S)
MITCHELL
MARMION
JOONDALUP (C)
WANNEROO
AVENUE
REID
FREEWAY
STIRLING (C)
ROAD
HIGHWAY
TONKIN
MIDLAND
Indian
Ocean
WEST
COAST
HIGHWAY
BAYSWATER (C)
BASSENDEAN (T)
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VINCENT (T)
CAMBRIDGE (T)
EASTERN
HIGHWAY
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BELMONT (C)
SUBIACO (C)
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EAST PERTH
GREAT
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EAST FREMANTLE (T)
CANNING
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MELVILLE (C)
FREEWAY
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Inner Perth Metropolitan

The Victorian Engineers of University Square

David Beauchamp BE, MIPENZ, MICE, MIE Aust

Summary This paper looks at the lives of three prominent Victorian engineers all of whom at some stage of their lives resided at University Square, Carlton in the City of Melbourne. Alexander Kennedy Smith trained in his father's firm in Scotland, he built Melbourne's first gasworks and then went on to be a successful consultant, designing and building many other gasworks in Australia and overseas. Professor William Charles Kernot was Australia's first academically trained engineer, the first Professor of Engineering at the University of Melbourne and educated many of Victoria's engineers. He undertook a long battle to change the bias in government departments and the engineering profession against academically trained engineers. Mephan Ferguson was a self taught engineer, an inventor and a manufacturer of bridges, pipes and other equipment. His factories helped provide much of the infrastructure for Melbourne, Victoria and Australia.

1 INTRODUCTION

The second half of the 19th century was an exciting, challenging and profitable time to be an engineer in Melbourne. In 1851 the Port Phillip District separated from New South Wales to become the Colony of Victoria and in the same year gold was discovered at three locations in Victoria. In the next forty years Melbourne changed from a frontier town with a population of 23,000 to a metropolis with a population of 500,000. Roads were paved, bridges built over the Yarra River, railways were built linking Melbourne to the gold towns of Ballarat, Bendigo and Castlemaine as well as to Adelaide and Sydney. A proper water supply was provided, the streets were lit with gas lights, cable trams and railways linked the city with the suburbs and the grand buildings of Melbourne, Parliament House, the Royal Exhibition Building, the Supreme Court and the major banks were built. The one thing missing from Melbourne's infrastructure was an underground sewerage scheme, which resulted in the city being labelled "Marvellous Smellbourne".

Just to the north of the central business district foundries, factories and workshops were built to provide the pipes, girders and machinery needed for Melbourne's rapid expansion. Many of the owners of the foundries and factories lived close by at University Square, an ornamental reserve surrounded by two-storey terrace houses. Three of the residents of University Square were engineers, Alexander Kennedy Smith, a civil and consulting engineer who owned a nearby foundry, William Charles Kernot, a lecturer and later the first Professor of Engineering at the University of Melbourne, just to the north of the Square and Mephan Ferguson, industrialist, inventor and engineer who bought Alexander Smith's foundry after his death.

2 ALEXANDER KENNEDY SMITH

The first of the engineering residents of University Square was Alexander Kennedy Smith who rented 1 Summerhill Terrace at 114 Leicester Street, Carlton from 1868 to 1879.

The young Alexander Kennedy Smith

He was born at the Cauldmill, Roxburghshire Scotland, on July 7th, 1824. In the Smith family there were eight sons and four daughters. Six of the sons became engineers and all held responsible positions both at home and abroad.

A. K. Smith began his indentures with his father, James Smith at Harwick and completed them with a Galashiels firm. In 1846 he joined the Great Western Railway Company and worked in their Locomotive Works at New Swindon, both in the factory and in the drawing office. In 1848 he was recommended by Isambard Kingdom Brunel for the position of Devonshire County Engineer. For some years he practised as a civil and practical engineer in Exeter dealing with rope works, gas works and paper-making machinery. He also held the position of engineer to the Bath and West of England Agricultural Society. [1, 2]

In 1853 the City of Melbourne Gas and Coke Company advertised in England for a suitably qualified engineer to erect and manage the first gasworks proposed for Melbourne. The liberal salary for the position attracted sixty four applicants from the United Kingdom and Europe. Alexander Smith was selected from all the applicants and was engaged for a five year contract starting on September 21st, 1853. After ordering all the necessary equipment for the construction of a large gasworks from suppliers in Manchester, Newcastle, Edinburgh, Leith and Glasgow, he sailed on the *Croesus*, leaving on January 11th, 1854 and arriving in Melbourne on April 8th. Twelve ships were needed to transport all of the components for the gasworks. Smith also ordered 1000 tons of English coal, 300 tons of Scottish cannel coal as well as nineteen miles of pipes together with all necessary bends, T pipes, water-traps, etc.

At a Special General Meeting held on the 2nd of November 1854, Smith explained to the shareholders that the plant expected to cost £25,000 would actually cost £40,000. He then convinced the shareholders of the need for extra capital pointing out that the bigger and more expensive plant ordered allowed for the whole of the city to be supplied with gas rather than the one-quarter originally planned.[3]

The foundation stone for the Melbourne Gasworks was laid on the 1st of December 1854, the day of the Eureka Rebellion at Ballarat. The band of the 40th Regiment marching in the procession was suddenly withdrawn from the parade and despatched to Ballarat. In October 1855 the Works chimney was topped out and a small champagne breakfast was held for the Directors and friends at the top of the 195 foot high shaft. The guests *'were conveyed in proper cradles to the top of the shaft by means of a small steam engine'* [4] and toasts were drunk to A.K. Smith and others. On the 17th of December 1855 the Governor, Sir Charles Hotham, lit the first fire at the Gasworks, caught an extremely bad cold because of the foul weather and died on New Year's Eve just before the commencement of the supply of gas on New Year's Day 1856.[5]

In 1857 Smith recommended the extension of the gas mains to Richmond, Prahran, Windsor, St. Kilda, Emerald Hill and Sandridge. In order to meet the demand of the expanded system gas production and storage capacity had to be increased. A 350,000 cubic feet gasholder was ordered from England and a third retort house was proposed to give an annual gas production capacity of 300 million cubic feet of gas. New shares were issued to cover the cost of the works plus an additional forty miles of gas mains.

In 1859 A.K. Smith, having fulfilled his contract to construct and commission the Melbourne Gasworks, left to set up as a civil and consulting engineer with his own foundry at 41 Leicester Street, Carlton. In 1866 the foundry was moved to 54-56 Leicester Street. Smith built gas works at Ballarat, Castlemaine, Sandhurst (Bendigo) and Newcastle. He reported on and in some cases supplied plans and specifications for the supply of gas to Bathurst, Goulburn, Shanghai, Yokahama, Auckland, Dunedin, Hokitika, Nelson, Hobart Town, Maryborough, Creswick, Kilmore, Portland, Warrnambool and Stawell. He designed, made and erected mining machinery, waterwheels, and sawmills. In the 1860's he was engineer for the South Yarra Waterworks and was also the consulting and locomotive engineer for the Melbourne and Suburban Railway Company. Smith had some input into reports on the Coliban and Sydney water supply systems.

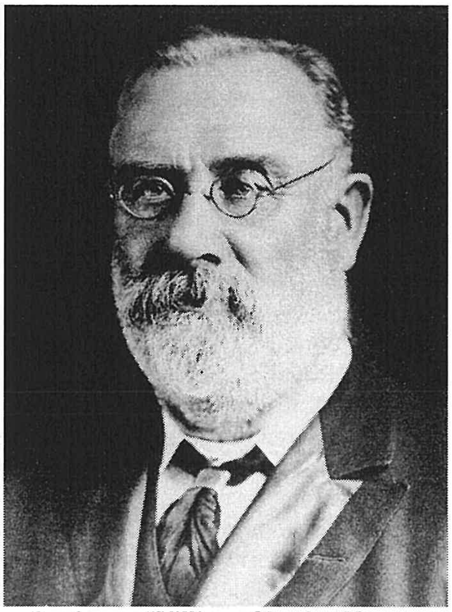
Apart from his engineering practice Alexander Smith was active in a wide range of other spheres. He was a captain in the first volunteer rifle corps and in 1863 became a major in the Victorian Volunteer Artillery Regiment. Smith was an office bearer in the Royal Society and gave papers at the Society. The Mining Institute of Victoria and the Humane Society were other bodies he belonged to, as well as being a prominent Freemason under the Scottish Constitution. For fifteen years he represented the La Trobe Ward in the Melbourne City Council and was mayor in 1875-76. He was elected to the Victorian Legislative Assembly in 1876 and remained a member until his death in 1881.

Alexander Smith was said to exemplify *'Scottish engineering and mechanical expertise and business acumen'* [6]. Another view was that he was a man with an eye on the main chance[7] and certainly controversy surrounded some of his dealings in the gas industry. He was accused, while still working for the Melbourne Gas Company, of importing gas fittings, exporting rags and bones, trading in pipes and using company equipment for his own use. In the 1870's there were several gas companies in Melbourne, each undercutting the others to get a bigger share of the market with a resulting loss in profits. As a consequence it was proposed to amalgamate all the gas companies to create a monopoly and restore profits. Smith played a variety of roles in the amalgamation. He was a substantial shareholder in two of the companies, consulting engineer to the South Melbourne Gas Company and technical adviser to the parliamentary agents for the Bill to allow the amalgamation. In the Legislative Assembly he spoke persuasively in favour of the Bill. As a Melbourne City Councillor he should have been endeavouring to obtain the best price for the supply of gas both to the City of Melbourne, whose street lights were a major user of gas, and to the ratepayers he represented. *'To discharge all of these responsibilities, Smith had to extract a better deal from himself, for himself, or vice versa.'* [8] A Select Committee of Parliament later found that Smith had accepted £210 from the newly amalgamated company after the passage of the bill for, as *The Age* put it, *'professional services very easily rendered.'*

In 1880 Alexander Smith moved from Carlton to Rochester Street, Studley Park where he died of heart disease on 16 January 1881. He was survived by his wife Isobel (nee Cochrane), whom he had married in Wiltshire when he was 22, and by two of his four daughters. His estate was valued for probate at £12,537 and included shares in six Victorian gas companies.

3 WILLIAM CHARLES KERNOT

The second engineer to move to University Square was William Charles Kernot who rented 1 Cree Terrace, 110 Leicester Street from 1872 to 1879. Living with him for some of those years was his brother Maurice Edwin Kernot, who was listed in the Sands & McDougall directories of the day as draftsman in the Mines Department. W.C. Kernot was listed both as a lecturer at the University of Melbourne and as working for the Victorian Water Supply Department.



Professor William Charles Kernot
M.A., M.C.E., M.Inst.C.E., M.Am.Soc.C.E.

William Charles Kernot was born on June 16th, 1845, in Rochford, Essex. He came with his parents and his sister, Mary June, to Geelong in 1851 on the *Duke of Wellington.* Seven other siblings were born in Australia but only four of these survived.

His father, Charles Kernot, set up business in Geelong as chemist, printer and stationer. In three years he had made enough money to retire as a chemist and enter local and later state politics. He was a Dissenter, a radical and strong on 'mutual improvement'. Charles Kernot had a great taste for amateur engineering and maintained a first-class home workshop.[9] It is not surprising that three of his sons became engineers. One son, Maurice Kernot, became the Sole District Engineer for the Construction Branch of the Victorian Railways.[10] The youngest son, Wilfred Noyce, born 23 years after W.C. Kernot, became a mechanical engineer, taught first at the Working Men's College and then at the University of Melbourne where he was Dean of the Faculty from 1932 to 1936.

William Charles Kernot attended the University of Melbourne when he was 15, gaining his B.A. in 1864, his M.A. and his certificate of civil engineering in 1866 to become the first qualified engineer produced by the university. In 1898 he gained his Master of Civil Engineering. His thesis was entitled **Prevalent Errors in the Design of Iron Girder Bridges and Suggestions for the Improvement of Existing Structures.** This was published as the book **On Some Common Errors In Iron Bridge Design** which went to at least two editions.

After completing his certificate of engineering William Kernot tried to get a job in industry but his academic qualifications were regarded as being of no use at all. As the Victorian Government was the main employer of engineers he applied for a position in the public service but again his university qualifications were not recognised and he had to sit the Civil Service Examination which he found to be *'a very elementary examination requiring but little knowledge, but demanding a high degree of mechanical proficiency in spelling and simple arithmetic'*[11] After considerable delay and only with the help of an influential acquaintance he obtained a position in the Department of Mines, where the work consisted of checking mining leases. His qualifications were *'as useless as a punkah would be at the South Pole or a pair of snowshoes in the Red Sea'*[12] and when work diminished he was the first person dismissed after the most unpleasant eighteen months he had ever spent .

In 1867, with the help of a politician, the Hon. James Balfour, he was appointed to Water Supply Works where he worked on the Coliban, Geelong and Echuca Water Works making trial surveys, taking water levels, computing capacities of reservoirs, discharge of pipes and channels etc. He discovered a serious flaw in the design of the mechanism of to open a large valve from the Castlemaine reservoir and when he suggested to the resident engineer that the machinery, as designed, would not work was told to 'design a machine that would answer'. He then proceeded to check the mechanical details of other schemes and found similar errors The engineers he worked with were experienced, careful men, well acquainted with all routine engineering business but who '*as far as I could discern were perfectly unconscious of physical laws.'*[13].

In 1870 he moved to the Department of Railways for six months. There he found that the Engineer-in-Chief, T. Higinbotham, '*never missed an opportunity of impressing upon me the uselessness and undesirability of University training for engineers.*'.[14] After six months in the Railways Higinbotham told him he had arranged for him to go back to the reorganised Victorian Water Supply, saying '*Your scientific knowledge Mr. Kernot is of no use to us but possibly may be of some value to the Water Supply.'*[15] It must have been a sweet revenge when years later he found that the Railways' locomotives were so poorly balanced that they jolted along the rails at slow speed, used excessive fuel and drew light loads. Applying the mathematics he first learnt from Professor Wilson, he calculated how the locomotives could be balanced, which resulted in savings of £20,000 per year. This advice Kernot claimed he could have given the Railways twenty years before when he worked for them as a junior engineer.[16]

In 1868, while still working for Water Supply, he was appointed by the university as part-time lecturer in surveying and the next year received a similar appointment in civil engineering. In 1875 he resigned from public service and was appointed full-time lecturer in Engineering and acted in the role of Lecturer-in-charge until 1882 when he was appointed Professor of Engineering. In 1883 the degree course was instituted and the first degree, the Bachelor of Civil Engineering, (B.C.E.) was conferred in that year.[17]

Apart from lecturing on surveying, roads and bridges, harbour works, lighthouses, boilers, pumps and other machinery, he was asked, in 1888, to give the natural philosophy lectures because of the illness of the lecturer.

It was because of Kernot's urging that John Monash finished his engineering degree in 1890.[18]. Another of his early students was William Thwaites, the first Engineer-in-Chief of the Board of Works.

Kernot undertook a series of experiments at Melbourne University on the question of the minimum weight of steel needed to give the maximum strength and rigidity for a truss structure. Two recent graduates from the university then working as junior engineers in the Victorian Railways, Messrs. Fraser and Chase, used these experimental results in 1882 to design the Victoria Street Bridge. The result was a highly effective design with the 55 foot span girders weighing only 3 $^1/_4$ tons.[19]

Prejudice in government departments against academically trained engineers was still common in 1899, with students complaining that little recognition was given to their degrees. This attitude started to change after Professor Kernot discovered a serious weakness in the great Moorabool Viaduct on the Geelong-Ballarat railway. In lectures to final year students he would give telling examples of mistakes made by experienced practicing engineers with little or no theoretical training: *'We have in this Colony numerous structures three times as strong as they need to be, according to the best authorities of engineering science, we have others that are deficient in strength to the extent of 50%. With reference to these your lecturer is happy to say that he has been the means of the prevention of the erection of two, closing a third and drawing attention to the weakness of others.'*[20]

In addition to twenty three hours a week lecturing or tutoring students, Kernot undertook much outside consulting work which proved very profitable. He helped Louis Brennan develop a steerable torpedo (the Brennan Fish Torpedo) by making the calculations for the working model. After Brennan received £110,000 when the torpedo was accepted by the War Office, he sent £500 to Kernot for his assistance. Kernot was a member, along with Professor Warren of Sydney University, of the 1884-86 New South Wales Royal Commission on Railway Bridges and in that capacity examined, tested and reported on a large number of iron bridges and several thousands of feet of timber viaducts. In 1886 he reported on the stability of several important railway bridges in Tasmania and South Australia. He undertook an inquiry for the Victorian Government on the placing of telegraph and telephone lines underground and gave evidence at a Royal Commission on the Sanitary Condition of Melbourne. He tested oil engines for the Government and private firms, gave advice on pelton wheels, and designed a large steel framed grandstand at Flemington Race Course. In 1882 he introduced electric light to Melbourne through the New Australian Electric Company and was chairman of the company from 1882 to 1900.

After the 1907 Quebec Bridge disaster, when 19,000 tons of steel crashed into the St Lawrence River killing 75 of the men constructing the bridge, Kernot was asked by the Canadian Government to help investigate the failure.[21]. The report on the failure found that buckling of the connection plates at the ends of the compression members was one of the chief causes of the failure. The design of the compression members and the connecting plates was based empirical design rules developed for much smaller structures. One of the joints that failed had only 30% of the strength of the compression member it was connecting; also two rivets were used in the joint instead of the eight needed. The report found that the stress-analysis theory used in the design was inadequate to predict the failure.[22]

Other activities included successfully arbitrating the end of the sixteen day Wharf Labourers' strike of January 1886. After hearing evidence the union was granted an eight-hour day and slightly lower wages than they had sort. He was president of the Royal Society of Victoria from 1885 to 1900 and was part of a committee of three set up by the Royal Society to report on the controversial subject of cremation. The committee's report came out strongly in favour of cremation as the best solution on hygiene, sentimental and economic grounds. He was active in the Victorian Institute of Engineers (president 1886, 1890, 1897-98 and 1906-07) and the Victorian Institute of Surveyors (president 1883-84). He was also Chairman, for ten years from 1889 of the Working Men's College where his brother Wilfred was a member of staff. In 1903, he offered his students' services as strike-breakers during the railway engine-drivers strike, and gave instruction on the Westinghouse brake to volunteer engine drivers. Although he did state his sympathy was *'with all the wants, ambitions and trials of the so-called workingman.'*[23]

Kernot was very generous to the University of Melbourne, giving large sums of money for scholarships as well as £1,000 to equip the metallurgy laboratory and to pay for a lecturer and a demonstrator. He had even proposed to build, at his own expense, a new engineering school for the university but lost so heavily in the 'Land Boom' crash that he had to withdraw the offer.

Kernot's other interests included cycling (he claimed the record for a penny-farthing journey to Geelong, a distance of 75 km), he was an enthusiast for ballooning and he owned a steam-powered car that he used to drive in student processions disguised as a locomotive.[24]

Kernot was a stern critic of the engineering profession's lack of theoretical knowledge, its reliance on empirical rules and rule-of-thumb methods of design. He criticised government and municipal engineers when he found fault in their designs and referred to the *'ordinary ignorant emperic who calls himself an engineer.'*[25] Although he became an associate member in 1885 and, in 1901, a corporate member of the Institution of Civil Engineers

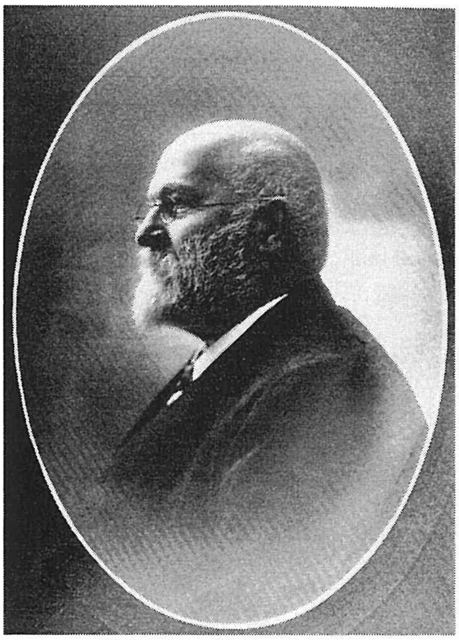
(U.K.), he conducted a lengthy campaign against the anti-academic bias of the Institution. He also fought against the unscientific and anti-theoretical approaches of government departments in appointing and promoting engineers and surveyors. He claimed to be '*the first man that the University sent out to attack single handed the fortress of professional ignorance and prejudice.*'[26]

In 1880 he built a large, comfortable house, *Firenze*, in Royal Parade, Parkville where he lived unwed but with other members of his family until his death in 1909.

4 MEPHAN FERGUSON

The third engineer to move to University Square was Mephan Ferguson who, in 1885, moved to 2 Summerhill Terrace and lived there until he and his family moved to Royal Parade, Parkville in 1888.

Mephan Ferguson was born on July 25th, 1843 at Falkirk, Scotland. In June 1854 he arrived with his parents, his sister and two brothers in Melbourne aboard the *Admiral Boxer* after a three month voyage from Liverpool. The family settled at Emerald Hill (South Melbourne) until late in 1856 when they moved to White's Flat in Ballarat. There, at the age of 13, Mephan Ferguson went to work as an apprentice for John Price, whose business was advertised as 'Coopers Carpenters, Blacksmiths and Mechanics'. The firm produced rocking cradles, ripple boxes, amalgamators, pumps, tanks, trucks, barrows and cages for miners.[27]



Mephan Ferguson
A.M.Inst.C.E.

In 1873 John Price won the tender to fabricate and erect the ironwork for a new bridge over the Leigh River, at Shelford in the Western District of Victoria and Mephan Ferguson was sent to supervise the work. After the box girders were fabricated, instead of building timber falsework to support the girders as they were pulled into place, Ferguson launched the girders across the 60 foot gap between the abutment and the central pier using ropes and chains working over shear legs fixed in the river bed. '*It was estimated that at least £300 was saved for his employer by the talented young engineer whose services they were fortunate to secure.*'[28]

At this time Ferguson was courting Agnes Shand, who had come out on the same ship to Australia. To see Agnes he had to walk the 40 km to Geelong and walk back the next day. His courting was successful and the couple were married on April 7th, 1893 at the Ryrie Street Congregational Church in Geelong.

After the completion of the Shelford bridge Ferguson moved on to Rochester to be the resident engineer for a new railway bridge over the Campaspe River. Agnes and Mephan lived in a tent at the site and their first child, Ernest Rochester Ferguson, was born at Rochester.

In 1875 Ferguson and his father-in-law W.A. Shand bought the girder making plant from John Price and in June 1876 they were awarded the contract to build a replacement iron bridge at Johnston Street, Collingwood for the sum of £7,366-18s-7d. This was the start of many government contracts for bridges, some of which are listed below.

Bridge Location	**Date Built**
20 bridges for the north-east railway line to Wodonga	Prior to 1888
8 bridges for the Clifton Hill railway line	Prior to 1888
Brunton's Bridge over the Thompson River, near Walhalla	1887
Duplication of Flinders Street railway viaduct	1914
Cordite Avenue Bridge over the Maribyrnong River	1905
Saltwater Bridge over the Maribyrnong River	1911
Greensborough Siphon Bridge over the Plenty River	1891
Banksia Street Pipe Bridge over the Yarra River	1892

In 1878 Mephan and his family moved to Erskine Street, Hotham Heights (North Melbourne), there a back yard workshop was set up and between 1881 and 1884 2,000 tons of bolts, screw couplings, dog spikes, fish plates, etc, were made.

A second child, Albert George Hotham Ferguson, was borne at Erskine Street, but with an expanded family and an increasing amount of work there was a need for more room and manufacturing capacity. Mephan Ferguson purchased the Carlton Foundry, presumably from the estate of A.K. Smith, in 1883. The works consisted of a foundry, machine shop, carpentry shop and space for fabrication, assembly and storage. In addition there was a skilled work force that had been trained by A.K. Smith.

Ferguson owed his early success to his entrepreneurial and technical skills and to the government's protectionist policy of awarding contracts to local firms. By 1885 his firm was well established. In that year, Alfred Deakin, the then Minister for Public Works and Water Supply in the Victorian Government, returned from California and made the decision that wrought-iron pipes should be used instead of cast-iron pipes in the Melbourne water supply. Ferguson acted quickly, winning a government contract for the supply of 3 km of 762 mm diameter wrought-iron riveted pipes. He purchased the Glasgow Iron Works in West Melbourne and 400 m away at another site a tar coating and testing works was established. He imported the latest hydraulic machinery and designed a plant said to be the match of any in the world. [29] With this plant and equipment Ferguson monopolised government contracts for the supply of pipes and by 1888 he had been awarded contracts for 7,000 tons of wrought-iron pipes varying in diameter from 305 mm to 1,350 mm. [30] The Mephan Ferguson works also supplied pipes to various Victorian Water trusts and to the Chaffey brothers who had come from California to pioneer irrigation at Mildura and Renmark.

By 1888 the premises in Carlton and West Melbourne had become too small and 10 acres (4ha) of land was purchased in Footscray where a new factory was built. By 1899 all the operations were transferred to this site and the other properties, including the head office in Collins Street, were sold.

In 1892 Mephan Ferguson patented the spiral riveted pipe which, because stresses on a inclined joint are less than on a longitudinal joint, allowed thinner material to be used in the pipes. Hundreds of kilometres of these pipes were produced over the next forty years.

When steel plates are joined by riveting a hole has to be punched through the plates, this decreases the strength of the plates. Ferguson reasoned that if he could design a joint that transmitted the full strength of the plate he could make a thinner pipe that would have the same pressure capacity as a spirally riveted pipe. In 1896 he got the idea for the lock bar pipe and after testing the idea quickly patented it.

The lock bar joint works by compressing a slotted piece of steel onto the enlarged or 'upset' edges of two sections of semi-circular curved plate to form a longitudinal joint that can transmit the full strength of the plate. Forge welded steel rings were used to join the pipes, the 6 mm clearance between the pipes and the rings was first filled with hemp packed into place and then molten lead was poured into the remaining space.

The first lock bar pipe contract was awarded in 1897 for a 2 km water main from Darlington to Grange in Adelaide. These pipes were still in service in the 1990s. The longest use of the lock bar pipe was the 576 km of 762 mm diameter pipes supplied for the Coolgardie water scheme in West Australia. To make the pipes plant was shipped from Melbourne and steel was imported from the United States and Germany.

The lock bar pipe was so successful that Ferguson won contracts in New Zealand. The necessary machinery to make the pipes was made at Footscray and shipped to Wanganui and Lower Hutt. A contract was also won to supply pipes for the Mond Gas Company at Tipon, South Staffordshire, England. Plant again was shipped from Footscray to make the pipes. The U.K. rights to manufacture lock bar pipes was sold to Stewarts and Lloyds and the U.S. rights to the East Jersey Pipe Company, which was controlled by the Carnegie Trust.

As well as bridges and pipes the Mephan Ferguson works undertook many other contracts, including the manufacture and erection of 1,300 tons of cast-iron and wrought-iron work for the Newport railway workshops, the iron works for the Maryborough and Seymour engine-sheds and the tunnelling shield for the Hobson's Bay sewer main under the Yarra River.

Mephan Ferguson was largely self taught, he had no formal training as an engineer either academically or by being indentured to an engineering firm. He erected bridges, designed equipment for his factories as well as inventing the spirally welded and the lock bar pipe systems. He was elected an Associate Member of the Institution of Civil Engineers in 1907. His application was signed by, amongst others, (Sir) John Monash and Maurice Kernot. In the description of his engineering experience there is the statement that between 1873 and 1907 his business carried out works to the value of £5,000,000. '*Some of these works were designed by the Candidate and include wrought-iron and steel bridges, Government engine-sheds, railway station buildings, irrigation and water supply works, machinery of all descriptions, and the design and manufacture of shields and other plant for sewerage works.*' [31]

Apart from being president in 1892-93 of the Victoria Bowling Club, which was situated in the northern part of University Square, Ferguson had few outside involvements, devoting all his energies to the development of his very successful business.

In 1888 Mephan Ferguson and his family moved to a new house, *Falkirk,* that he had built in Royal Parade, Parkville. He lived here until his death, in 1919, leaving an estate worth £14,000. He was survived by his second wife, Margaret (nee Kennedy), three sons and three daughters, one other son being killed in the First World War.

After Mephan Ferguson died the firm was run by his sons and after their deaths it was sold, in 1950, to Tubemakers of Australia Ltd.

5 CONCLUSIONS

Each of the engineers of University Square had different training and very different careers and each made major contributions to Melbourne, Victoria and Australia.

A.K. Smith was trained in the traditional British system where most, if not all the training, was by working as an apprentice to an engineering firm. Using the experience he had gained in the United Kingdom Smith became a very successful engineer in Melbourne, designing and building many engineering works. In addition he was very active in the public sphere in various scientific and technical societies as well as in local and state politics.

W.C. Kernot was Australia's first academically trained engineer and had to battle for many years the prejudices of traditionally trained engineers who had few analytical skills. He doubtless made himself unpopular by pointing out the deficiencies in the designs of these engineers. Like Smith, Kernot was very active in the scientific and technical societies of the day.

M. Ferguson was largely self taught but in his patents for the spirally riveted pipe and the lock bar pipe he demonstrated his grasp of technical matters. The pipe technology he developed was so successful that it monopolised pipe production in Victoria and was exported to many other countries. Unlike Smith and Kernot he appears to have little involvement in outside matters devoting all of his energies to the successful development of his firm.

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Restoration of New Zealand's Largest Sawmill Tramway Viaducts

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Summary In 1994 the Southland community restored New Zealand's tallest timber trestle bridge, the 36m high Percy Burn viaduct. This derelict sawmill tramway bridge dating from the 1920's is now part of a popular tramping track. More recently, during 1999, three smaller viaducts nearby were similarly restored. This significant project is even more impressive considering the magnitude of the re-building necessary and the remoteness of the work-site in southern Fiordland, eight hours walk from the nearest road-end. The four timber viaducts are the most visible relics of the indigenous logging and milling operation carried out at Port Craig, once home to New Zealand's largest and most technologically advanced sawmill, and now a ghost town. Although Port Craig lasted only a little over 10 years the steam-powered logging and milling equipment introduced there set the standard for indigenous logging for almost 30 years - equipment which has, like the township, now passed into history. This paper outlines the restoration of the massive timber viaducts together with details of the logging and milling technology that were such a feature of the venture.

1. INTRODUCTION

The Percy Burn Viaduct and its sister bridges are magnificent monuments to one of New Zealand's heroic failures. Conceived as the largest indigenous rimu sawmill in the country, the Port Craig mill was intended to satisfy the expected timber famine at the end of World War One. Instead the enterprise suffered in 1917 the tragic drowning of its founder and manager, John Craig, after whom Port Craig takes its name. As the company struggled to find its feet and limp towards opening day in 1921 the timber boom passed them by.

Port Craig is located in the far south-west corner of New Zealand's South Island, now part of Fiordland National Park. Backed by the Waitutu Forest and fronted by Te Waewae Bay, the town has never had any road access, all inwards and outwards traffic being by sea. Port Craig was typical of hundreds of NZ frontier towns during the early years of this century, yet the operation was untypical because it introduced greater sophistication and heavier investment than was normal for the period. Because of its total isolation and short life span the town represents a fascinating case study.

2. THE ENTERPRISE

Everything about Port Craig was on a grand scale. The sawmill plant - described as "a revolution in sawmilling in Southland" - introduced for the first time modern, high-capacity American milling machinery and timber handling systems.[1] On the bush tramway ran New Zealand's largest geared steam locomotive over four large viaducts, including the now famous Percy Burn Viaduct – at 36m height the highest timber trestle in New Zealand (perhaps the world) today. In the bush a mighty steam hauler, "the Lidgerwood", brought logs in to the bush tramway along an 800 metre overhead cableway. A similar overhead cable was used in later years to sling sawn timber from the Port Craig wharf to sizeable Union Steamship Company steamers moored in the bay.

2.1. Historical Context

By the early years of the 20th century most easily accessible native forests around New Zealand were either milled or under license for milling. Milling ventures were typically low-capital family affairs or partnerships. As the easily won timber was worked out there came a need for increased investment to work more remote forests. This was typically achieved by the formation of milling companies, which became increasingly common from about 1910 onwards. Exactly these circumstances led a group of Christchurch merchants and builders to form the Marlborough Timber Company, which would subsequently build Port Craig, in 1908.

The increased capital available through the new companies allowed more remote bush areas to be penetrated by extensive bush tramways. Sawmills became more technically sophistocated and permanent. From this period on mills were typically located near centres of population rather than being continually relocated to ever more remote bush areas. While Port Craig was not an existing town, it was expected to become permanent, ultimately serving the prosperous rural hinterland that would follow in the wake of forest clearance.

2.2. Bush working

By 1920 mechanisation was starting to impact on bush operations. While the axe and cross-cut saw were still the main tools of the fallers, steam power was replacing horse and bullock power for log extraction. Low powered steam portables with one or two winch drums were being commonly used elsewhere to winch logs out of the bush to the tramway. Port Craig management introduced a giant technological leap with the use of an American Lidgerwood hauler. This massive vertical-boilered machine powered an overhead cableway on which logs were extracted from the bush and brought to the tramway from up to 800 m away. An added advantage was that trees were delivered to the tramway largely clean of mud and gravel (which was damaging to the mill saws), and loading of tramway bogies was facilitated by using a convenient guy-line spanning the tramway. The machine was technically brilliant, but less than ideal in Port

Craig's sometimes sparse bush. It required a team of specialist riggers, who were not easy to find and retain in the NZ back country. Overhead logging was uneconomic at Port Craig but still occupies a niche place in logging today.

Port Craig management withdrew the Lidgerwood after only a few years and replaced it with seven ground haulers. Once again sophisticated compared to their peers, these haulers winched logs along the ground from the tree site to the tramway. While they were more flexible in operation their shorter 'reach' required additional branch tramlines to be laid. Seven six-man ground hauler teams replaced the 17 men required to operate the Lidgerwood.

2.3. Tramways

NZs native forests were normally accessed by bush tramways – lightly laid railways, which were laid and re-laid as necessary to reach the particular bush being worked.

Port Craig tramways were more elaborate. To carry the massive 80 tonne Lidgerwood log hauler the company opted for a high standard of construction, necessitating substantial earthworks and expensive bridging. This was perhaps understandable on the 15 km main line, which was expected to have a long service life, but even temporary branch tram lines often included significant earthworks. No machine tools were available in the Port Craig bush; indeed mechanical excavators were only just starting to appear on major projects closer to civilisation. All excavation was by hand into horse drawn or man-powered trolleys. Extensive use was made of explosives to break up harder rock, but all drilling was carried out manually using sledge hammer and drill rods.

Propulsion of log trains during the period was normally by small, geared steam locomotives, chosen because they gave good power at low speeds, they were forgiving of steep grades and irregular track and had a light axle loading.

The locomotives utilised at Port Craig for haulage were relatively powerful and fast by comparison with their peers. For instance the Ar locomotive built by Prices of Thames in 1926 was the largest geared steam locomotive to work in New Zealand, and its gearing ratio made it significantly faster under load than other geared locomotives.

Four deep gullies were bridged by substantial timber trestles. The company could alternatively have installed winch-operated inclines to lower log loads down one side and haul them back up the other. They could even have built a line sidling around the head of the gully (although this would have required heavy earthworks due to the steepness of the gullies). Instead the four viaducts were built, reflecting the philosophy of the project promoters: to build permanent structures for an anticipated long life. The highest bridge, the Percy Burn viaduct, was recognised as the tallest timber tramway bridge in the country when it was opened in 1925. It took a year to build, involving the use of 167 m^3 of Australian hardwood.

2.4. Milling

It was the American equipment in the Port Craig sawmill that provided the most marked contrast to other operations. (A useful short guide to American sawmill practice of the period can be found in reference 2.) The sawmill itself was constructed spanning a gully so that the saw floor was comfortably below the surrounding terrace to facilitate log entry. Another floor below contained the belt drives for the steam powered machinery, together with the 'hogger' which minced up waste wood to augment the feed to the boilers. 'Dutch-Oven' type boilers fired on sawdust were introduced at Port Craig in place of conventional mill boilers fired on mill slabs. The stream in the gully floor provided a convenient means of disposal for the firebox ash.

Typical sawmills of the 1920's comprised a breaking down bench and one or two breast benches, and produced up to 23 m^3/day. By contrast the Port Craig mill included a breaking down bench, a secondary 'pony' bench and an edger (which was later replaced by four conventional breast benches and a deal frame). The Port Craig mill was said to be capable of producing 94 m^3/day although little better than half this figure was actually achieved in practice.

In contemporary sawmills the log carriage was winched through the breaking down saws manually, whereas at Port Craig the cable that hauled the log carriage was steam powered. A 'nigger' – a large toothed ram powered by underfloor steam cylinders – was introduced for turning or kicking the log. Unlike other mills of the day it was seldom necessary to handle logs manually once they entered the mill, as all logs and sawn timber were transferred automatically by spiked rollers or toothed chains. Retractable underfloor docking saws were installed to trim finished timber to length, while a battery of overhead saws were available to swing down to cut waste timber (slabs) for disposal. While most sawmill machinery was powered by underfloor belt drives, the pony saw bench was notable for being operated by its own steam cylinder, 75 mm dia and 15 m long – the so-called "shot gun feed". Old hands claim that no modern machine could match the pony bench for speed, particularly on the return stroke.

Some of the American equipment proved unsatisfactory. The edger, which sawed multiple boards at once, lacked the flexibility to saw its way around the shakes and defects of typical NZ saw logs. The edger was replaced with standard breast benches, which permitted a flitch to be turned between sawcuts to maximise the quantity of good timber extracted.

In the saw doctor's shop a gulleting machine for sharpening and setting saw teeth was another feature brand new to New Zealand.

Many of the above operating systems were to become commonplace in New Zealand sawmills over the next quarter century. The most significant developments that were *not* present at Port Craig were the introduction of band saws, electric power, and the move towards timber drying and treatment, all of which were to become established practice over the next few decades.

While steam provided the motive power for milling and ancillary operations at Port Craig, electric power made a tentative first appearance in the form of a tangye steam engine and dynamo for lighting the wharf where loading was often carried out at night.

2.5. Dispatch

Sawn timber left the mill via a chain conveyor to the beach area where it was tallied, hand-stacked and stored. During the 1920's timber seasoning was not yet common practice, and all Port Craig timber was shipped green. While timber treatment was the subject of much research around the world the technology was not yet practicable, and no treatment was carried out. Each time a ship called, packets of timber were drawn out onto the wharf on a horse-drawn trolley, craned into a large wooden lighter and then transhipped at shipside out in the bay. The packets of timber were broken up and individual planks were loose-stacked in the ship's hold.

Unfortunately there was insufficient deep water for ships to berth at the Port Craig wharf, so that lightering was essential. In later years a tower was constructed on the end of the wharf so that packets of timber could be sent out to the ship via an overhead cable. It was quite an achievement to build a system that could load timber safely on deck, regardless of the rolling of the vessel. The secret was, of course, that the cable was not fixed to the ship but merely ran through a block on the ship's derrick away to a seabed anchor beyond. In this way the cable was always held at the correct height directly over the ship' hold.

2.6. Closure

Unfortunately the quality of the Port Craig bush never lived up to expectations. The large Port Craig mill also failed to realise the economies of scale intended. The onset of the Great Depression was the final straw. The mill closed in 1928, and again in 1930 for the final time, with the town being abandoned nine years later. Today the site comprises rusty relics and moss-covered ruins, a fascinating world to explore, just six hours easy walking from the road-end at Bluecliffs Beach, west of Tuatapere. The viaducts are 2 – 3 hours walk further on, so that both the town and the viaducts can be inspected in a two or three day trip.

3. VIADUCT RESTORATION

Western Southland has struggled to keep its feet in recent years with the decline of indigenous sawmilling and poor returns from farming. Fortuitously the area is en-route to the Fiordland tourist area, and enthusiastic locals are keen to exploit the area's tourist potential. Part of their strategy includes the development of a world-class walking track (due to open in 2000) taking in the scenic highlights of Te Waewae Bay and southern Fiordland together with the historical features of Port Craig and its viaducts.

Seventy years of neglect had however taken their toll on the viaducts. By the early 1990s the tallest, the 36 m high Percy Burn viaduct, was derelict and in danger of collapse. Council engineers assessed the condition of the structure in 1992 and reported that all that stood between the viaduct and total collapse was one winter storm.[3] Fortunately that storm held off long enough to permit a major fund-raising campaign (which raised $275,000 in the space of 11 months) and full restoration.

3.1. Getting the Community On-Board

No one in New Zealand had ever before attempted to restore four huge timber bridges in such a remote site. It was obvious from the start that a major community fund-raising campaign would be necessary. Getting the public 'on-board' incorporated several key elements:

- Stressing the uniqueness of the viaducts. There are no others like them, and they are (or were) in danger of falling down. Major play was made of the Percy Burn viaduct's 1990 IPENZ commendation as one of NZ's most notable engineering achievements. Similarly a NZ Historic Places Trust survey report[4] and the subsequent classification of the Percy Burn viaduct as a class 1 historic structure were used to reinforce the importance of the relics.

- The Viaducts' Trust sought to establish the credibility of the project early on by winning the support of a major corporate donor. They then used this early momentum to gain additional corporate support and promote community fund-raising. The track record established through the restoration of the first viaduct was then used as leverage to win additional support to restore the remaining three bridges.

- Constant publicity. Every opportunity was taken to promote the area and the project through every available media. Feature articles were syndicated to newspapers throughout the country. A variety of magazines ran features and local and national television followed the restoration. Major sponsors were supplied with publicity photographs, which are displayed with pride in their head offices today.

- Involving high profile public figures was important in capturing the community's (and the media's) attention. At different stages throughout the process appropriate cabinet ministers, local politicians and the Governor General were flown in to inspect the site. Prominent artist Jonathan White was flown in to paint a view of the Percy Burn viaduct, the sale of which subsequently raised $40,000 for the project.

- Related projects. The viaduct restoration has a symbiotic relationship with the Hump Ridge Track Trust, which is developing a major new tramping track incorporating Port Craig and the viaducts together with the adjacent Hump Ridge (which gives spectacular views of the mountains and lakes of southern Fiordland). The viaducts' restoration served as the catalyst to kick-start the track project and they will in turn become key attractions. Track development to date has involved $2 million of community fund-raising and 4500 hours of labour (as at Oct 1999), however the track promises to create the equivalent of 15 full-time jobs and return $1.4 million per year to the local economy.

A concession has been obtained from the Department of Conservation for development of what is effectively a private walking track through their estate – believed to be a first for New Zealand. Resource consents are currently being obtained for the principal buildings and facilities. In conjunction with the main track it is hoped to construct an interpretative walk around the historic relics at Port Craig.

- The promise of economic development. The Southland community are proud of their heritage and strongly supportive of any initiative that promises economic development for their region. The viaduct restoration and Hump Ridge track projects combine a unique blend of history, scenery and tourism.
- Perhaps the key ingredient was to make the project fun! Trust members used every opportunity to make the project enjoyable for those involved, from flying in 170 people to a reopening ceremony for the Percy Burn viaduct to providing fresh paua steaks for the workers at the bridge site.

3.2. Logistics of working at a remote site

The logistics of working at a site eight hours walk from the nearest road-end and 50 km from the nearest town presented a number of unique challenges. At the start of each major restoration project all equipment, materials, and accommodation facilities had to be shipped from Bluff to an anchorage about 800 m off the South Coast at the mouth of the Percy Burn. All goods and materials were then trans-shipped by helicopter to the Percy Burn base camp and to the other viaducts as appropriate. The 1999 exercise involved 32 one-tonne helicopter loads, including two large portacom buildings.

Two key factors in the success of the project were effective off-site management and good communications. Side band radio provided links between the individual viaduct work-sites, together with twice daily radio schedules with civilisation to plot progress and order supplies. The number of supply trips had to be strictly controlled as helicopter hire comprised a significant part of the project budget, and uncontrolled use of helicopters could have quickly blown out costs.

A temporary base camp was established at the Percy Burn for the 1994 restoration of that bridge. A permanent building was established on the same site in time for the 1999 restoration of the other three bridges, supplemented by extra portacoms.

An extra difficulty for the 1999 project was that the other three bridges to be restored are spaced 15 - 30 minutes brisk walk apart. This difficulty was overcome by using four-wheeled motorbikes along the old tramway route to transport personnel and light equipment. Temporary 'bush' bridges had to be constructed over a number of washouts to make the track passable.

3.3. Method of restoration

The fact that the viaducts were originally constructed of Australian hardwood has no doubt contributed to their longevity, however after more than 70 years of neglect many structural members on all four bridges were in advanced stages of decay. Many piers were rotted virtually right through at their base and the only reason that two of the bridges still stood was the steel rail diagonal bracing that held each bent together.

The Percy Burn viaduct had the additional disadvantage that it had suffered an arson attack some 30 years earlier, and several trestle members had been completely burnt through - all four legs of one bent were severed in this way. Far from carrying log trains and an 80 tonne log hauler, the Percy Burn had reached the stage where it could barely even carry its own weight, and had developed a distinct bow to one side.

The repair strategy involved clearing vegetation from around the bridges to permit light and air circulation, spraying and injecting preservatives into the bridge timbers, and replacing damaged or rotting bridge members. It was apparent that new 300 x 300 hardwood sections would be prohibitively expensive yet similar sections in radiata pine would be difficult, if not impossible, to procure and still require much heavy lifting. The Viaducts' Trust adopted a pragmatic solution involving the use of four 300 x 75 laminates of radiata pine, bolted together to achieve the full cross section of the trestle members. The original bridge builders used hardwood because indigenous timbers of the period lacked the necessary durability and suitable timber treatments were not yet available. Hardwoods also possessed the qualities of high strength and dimensional stability. The radiata replacement timber is expected to have ample strength for the bridges' new role as footbridges, and with modern timber preservatives should last many years.

The smaller laminates permitted the replacement timbers to be prefabricated at ground level before being lifted into position and reassembled. Once in place the laminates were bolted together onto a tongue cut out of the original hardwood. It was estimated that 10% of the Percy Burn bridge timber required replacement in this way. All four legs of one trestle had to be lifted by jacking at mid-height to permit replacement of a rotten waling. Another trestle had all four wasted legs replaced at one time, requiring a specially fabricated steel truss to support the bridge deck off the bent either side.

3.4. Resourcing the Restoration Project

It quickly became apparent during early project planning that the restoration of large bridges in a wilderness area would require specialist skills. Working at heights with large timber members meant that it was impractical to use voluntary labour in anything other than a support role. The project was therefore drawn up as a commercial construction contract, with various support and unskilled labour inputs supplied by volunteers. Such was the enthusiasm of the Southland community that the supply of volunteers exceeded demand and willing volunteers had to be turned away. One of the very satisfying aspects of the project was the way volunteer and contract staff worked alongside one another without significant difficulties.

The Viaducts' Trust was fortunate to receive the support of the Southland District Council (fortuitously the viaducts are located mostly on road reserve) whose engineers carried out structural analysis and bridge reporting. The Council further assisted by drawing up contract specifications and providing contract administration.

3.5. The Future

To date a total of 9240 hours have been logged on field work in connection with bridge restoration. This does not include the substantial fund-raising and project management functions carried out back in town. Restoration of the four viaducts has cost at least $600,000 in contract labour, transport and materials (but excluding voluntary labour). The viaducts are now fit for another 15-20 years service in a rather more public role as footbridges on a major walking track. They are rapidly becoming nationally recognised icons symbolising the Western Southland/southern Fiordland area.

The next phase is for the Viaducts' Trust to compile a Management Plan for the ongoing maintenance and use of the viaducts. They are hopeful that ongoing maintenance costs can be met through a suitable arrangement with users of the new Hump Ridge tramping track and facilities.

4. CONCLUSION

Indigenous logging and milling technology is a field that has been relatively poorly researched and published to date. The Port Craig operation is significant nationally because of the 'leading edge' technology introduced there, which marked an important new phase in New Zealand sawmilling. While few intact relics remain at the Port Craig town site the historic precinct provides an important glimpse at the layout of a steam-age sawmill township.

The four Port Craig viaducts are the most significant sawmill tramway relics remaining in New Zealand today. They are also the best preserved, thanks to the recent restoration efforts of the Southland community.

5. ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of the Port Craig Viaducts' Charitable Trust in the preparation of this paper, and in particular the input of Trust member Stephen Canny. The assistance of Graham Jones of Southland District Council is also acknowledged.

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William Ferguson, Founding Father of the Engineering Profession in New Zealand

Warwick T Bishop - F.IPENZ , FIEAust. FIEE - CEO IPENZ

Summary: In a recent tidy-up of the Wellington offices of the Institution of Professional Engineers New Zealand (IPENZ) an old oil portrait of a *William Ferguson* was discovered wrapped up in corrugated cardboard in the top of a cupboard where it had lain for over thirty years. Although in poor repair and unsigned it appeared to be of good quality. At the same time a bundle of hand written correspondence from the early 1950's was found. These letters helped explain some of the intriguing history behind the painting, the subject, and the "anonymous" artist. While researching the background to the portrait the author gained an insight into not only the interesting and varied career of the "founding father" of the Institution of Professional Engineers New Zealand but also the unhurried and very polite society that surrounded the profession some fifty years ago. The fully restored painting will be "unveiled" to the profession in Auckland in February 2000 along with the artist's motivation, name, and position.

INTRODUCTION

"I can well understand Miss Warne's preference for painting men. They are certainly less beautiful, but usually - though not always - more interesting. I share her preference. That is where my part in this business really began - a surprise meeting with W.F., about 1930, outside 54 Molesworth Street; It happened thus: A lady - no doubt Miss O'Hara Smith - entered "Sec.'s" room. She looked slightly troubled, as when she mentioned that she had a number of engineering volumes for our library, her discontent needed no explanation to anyone knowing the 54 Molesworth Street stairwell. Elderly Members, having toiled up, were glad to take a spell at ease in the Council chairs.

"Vulgar telegraph and errand boys scribbled rude remarks on the plastered walls, about the lifts - or the need for one ... " Sec.", naturally, bounded forth, to save the lady the trouble of carrying the books up (if indeed she had even thought of doing so), or at any rate to indicate how glad we were to get them. She had not mentioned that the donor - Mr William Ferguson - was himself in the car below.

"He evidently had heard me clattering down the steps, for his head was somewhat inclined forward, enabling him to see us and be seen clearly as we emerged through the doorway of No 54. But to me it was a complete surprise to meet suddenly that kindly, quizzical, interested and very interesting face. Naturally posed, seen against a dark background, and accidentally but perfectly framed in the aperture of the car-window, it was very striking - especially the eyes. One could never forget it."

The above extract is from a letter dated 27 January 1951, written in Nelson and sent to a Mr MacLean* in Wellington. It holds the key to an intriguing sequence of events that led to the Institution of Professional Engineers New Zealand becoming the owners of the rather magnificent portrait you see before you today.

* Francis William MacLean, a former President of the Institution, displayed exceptional devotion to the profession of engineering and to his fellow engineers. His memory is perpetuated with the award, from time to time, of the **MacLean Citation**

The National Offices of the NZIE (now IPENZ) as discussed in the various letters in this paper. This building at 48 to 56 Molesworth Street housed the Institution from 1929 to 1939.

HISTORICAL BACKGROUND

William Ferguson was born in London on the 15th of June 1852. In his youth he was educated at King Edward VI Grammar School at Burton-on-Trent and then Rathmines Private School, Dublin. At the early age of thirteen he was indentured as an apprentice with Courtenay Stephens and Co. for five years. He ultimately became Chief Draughtsman with Ross Walpole & Stephens North Wall Foundry before attending University at Trinity College in Dublin. In 1877 William Ferguson gained his BA, followed two years later with a BAI (Engineering) and then in 1880 an MA.

While undertaking these academic courses he was also engaged in a number of interesting projects helping to design waterworks, bridges and railway extensions. While studying for his MA and for a while thereafter William Ferguson acted as assistant to the Professor of Civil Engineering at Trinity College, Dublin. For six months during 1882 he even undertook all the tuition because of the Professor's ill health.

In July 1883, with his mother and younger brother - Dr H. Lindo Ferguson - he sailed from the Clyde on the *s.s. Takapuna* for Dunedin, New Zealand. Then in the following year in May he was appointed Engineer and Secretary to the Wellington Harbour Board - positions he retained, along with that of Treasurer, until February 1908 when he voluntarily retired. After taking six months leave of absence he took up a role of Consulting Engineer to the Board for a further five years.

Interestingly William Ferguson and his wife were passengers on the *SS Wairarapa* when this ship was wrecked on Great Barrier Island on 29 October 1894. Two little girls were orphaned that night and they were subsequently brought up and put through both school and university by William and his wife.

From 1908 until 1917 he acted as General Manager then Managing Director to the Wellington Gas Co. Ltd. during which time completely new works were designed and erected at Miramar for the supply of gas to Greater Wellington.

There were many other important works and roles undertaken by Mr Ferguson during his working life. With others he helped devise the scheme that became the main drainage system for the City of Wellington. He was also involved in advising a number of the Harbour Boards around the country such as Napier, Auckland, Lyttelton, Wanganui, Gisborne, etc. and even as a consultant to the Port of Melbourne, Australia - about facilities management as well as dredging and the maintenance of deep waterways. Other centres called on him for advice on the construction of canals and the silting of rivers. In 1914 he wrote a report on the feasibility of the proposed Waikato-Manukau and Manukau-Waitemata Canals.

Just before the start of the First World War he was asked to be Chairman of a Commission to investigate the Parapara iron sands deposits. This Commission reported confidentially to the government on the feasibility of proposals made by a financial syndicate to start an iron and steel industry in New Zealand.

Towards the end of that decade William Ferguson worked on increasingly varied projects: from the viability and ownership of tramways in Auckland and Christchurch to the investigation of sickness in Trentham Military Camp; from concrete failures in the Gisborne district to dam sites for the generation of electricity; from new rail links to gas works.

He was also called to help with investigations into the financial affairs of the Wellington Farmers Co-op (Waingawa) freezing works and then acting as one of the Receivers and Managers of the Paparoa Coal Mining Co. Ltd. William had a real passion for the Wellington dry dock project and was very instrumental in this project's success. William also served as Honorary Chairman of the National Efficiency Board from 1916-1920. This Board played a key role in allocating key resources during and after the First World War

William Ferguson also served on the Board of Public Health and was a Member of the Council of Wellington's Victoria University College for several years. He retired from nearly all public duties in 1924, at the age of 72, because of ill health.

PROFESSIONAL MEMBERSHIPS

William Ferguson was a Life Member of the Royal Dublin Society, was elected an Associate of the Institution of Civil Engineers of Ireland in 1873, an Associate Member in 1899, a Member in 1916 and - after 50 years connection with the Institution - he was made an Honorary Member in 1923.

He was elected a Member of the Institution of Mechanical Engineers in 1881 and for many years acted as its Corresponding Member and Chairman of the Local Advisory Committee in New Zealand. Mr Ferguson was also elected an Associate Member of the Institution of Civil Engineers in 1880 transferring to Member in 1893. He acted as a Member of the Council of the Institution from 1912 to 1914 and for many years was the Chairman of the Local Advisory Committee in New Zealand.

He joined the Institute of Local Government Engineers, New Zealand, in 1912. Under his strong leadership negotiations resulted in the founding of the New Zealand Society of Civil Engineers in 1914 and then the merging of the Institute of Local Government Engineers into this new Society.

William Ferguson can thus be regarded as the actual founder of the present Institution - IPENZ, formerly NZIE. He was Hon. Secretary from 1914 to 1918, President from 1919 to 1920, and a member of Council from 1920 to 1924.

It would be difficult to exaggerate either the influence he exerted upon the Society and on the engineering profession in New Zealand, or the profound personal regard which he inspired in all who came in contact with him. William Ferguson died at the age of 83 on the 20th of June 1935.

THE MEMORIAL

A little of the history behind the painting of William Ferguson, which now hangs in the IPENZ meeting rooms in Wellington, is well described in the following extract from the Minutes of the Annual Meeting of the New Zealand Institution of Engineers 15th April 1943:

"P.p. 54/55 William Ferguson Memorial

"Mr F W MacLean drew the attention of Members to the gallery of portraits of previous Presidents. He said that shortly after Mr Ferguson's death, the Council discussed the matter of whether they should have some sort of memorial of the late Mr William Ferguson. Several suggestions had been made; one was to have a painting of Mr Ferguson, and another to have a bronze bust. A small Committee had been formed to deal with the matter, and Mr MacLean said it was just as well to confess that they had fallen in rather badly. They had decided to consult the late Mr Ellis who had been a friend of Mr Ferguson for many years. As a result, Mr Ellis had offered to make a model and have a bronze casting made. Mr Ellis had actually prepared a model for inspection, but the Committee had not approved of it at all. A plaster bust had been made later, and the earthquake in June solved the problem as far as that was concerned. The matter had been left for further consideration, and various proposals were put before the Committee.

*"A painting of Mr Ferguson was available, and it had been hung in the room for members to see. It had been painted by a lady - Miss E Baldwin-Warne - who was a pupil of the celebrated painter and sculptor, Sir Hubert Von Herkomer, and if members looked at it closely, they would see Mr Ferguson to the life. Certain unofficial conversations had been held with Mr W D Ferguson, (*William Ferguson's son*), and he had said that if the Institution could get an artist to copy the portrait, he would be glad to present it to the Institution.*

The difficulty had been to get an artist who knew Mr Ferguson personally and someone in whom they had sufficient confidence to contract the work. Subscription had been asked for a memorial fund, but the matter had hung fire, so that the Committee had to consider cost. Artists charge high fees and object to copying another artist's work. Finally, (quoting from a letter received from the Secretary of the Institution) an "unpretentious artist" had been found who would do the work, and the painting had been completed.

"Mr and Mrs W D Ferguson were completely satisfied with the painting, and with Mrs Ferguson's consent, arrangements had been made to have the original portrait and the copy brought down to the Institution's office.

"The artist who had done the copy of the painting desired to remain anonymous.

"Mr MacLean then asked the Secretary to bring the copy into the room for inspection. He said that the Committee had examined the painting and were entirely satisfied. Mr MacLean thought that a portrait of Mr Ferguson would be a fitting memorial. Mr Ferguson was really the founder of the Institution, and it was due to his wise guidance and generosity that the Institution was in the position it was at the present.

"After the copy had been examined, Mr MacLean informed the meeting that the artist who had done the painting (of the copy) was Mr Cole. He said that few members realised what a treasure they had in that respect in Mr Cole. As Secretary, he had been a perfect marvel, and Mr MacLean considered that the Institution had been very lucky indeed to have him. Mr MacLean said he objected to Mr Cole remaining anonymous in respect to the painting, and he did not think he should make a presentation of it. The Institution had not been appealed to for the Ferguson memorial before, and he was sure that members would feel it a privilege to subscribe a satisfactory sum to avoid Mr Cole's generosity. It was only just that the name of the "unpretentious artist" should be

revealed to the members even though he had expressed the wish to be anonymous.

"Mr H L Cole said he wished to make it quite clear that so far as he was concerned, no expense had been incurred. All expenses had been covered by others. He hoped that the suggestion that a fund be built up for some trust by which the memory of Mr Ferguson would be perpetuated would be followed up. Mr Cole said he was sorry that Mr MacLean had betrayed his trust and given away a secret vice from which he later hoped to obtain a good deal of entertainment in writing up and illustrating his memoirs.

"The Chairman moved: THAT this meeting places on record our appreciation of Mr Cole's action and expresses our admiration of his work."

Carried by acclamation."

FURTHER NOTE from F W MacLean:

I wrote to Mr Cole on 22.1.51 sending him a copy of the Report in the Proceedings of the NZIE Vol.29. 15.4.43 p.p.54 & 55 with reference to the Presentation of the copy, by Mr Cole (as Secretary of the NZIE) of the original portrait of William Ferguson, my remarks thereon, and Mr Cole's rejoinder.

Mr Cole *"hoped that the suggestion that a fund be built up for some trust by which the memory of Mr Ferguson would be perpetuated, would be followed up"*

The foregoing with reference to the "William Ferguson Memorial" which still appears among the financial statements of the NZIE and its obligations. With regard to Mr Ferguson's views about "decorations" and presumably of "memorials," the following may be of interest: -

I remarked to the late Sir Lindo Ferguson, Mr William Ferguson's brother, that it seemed very strange to the Engineering Profession that his brother had never received any "decoration" considering the extent to which New Zealand is indebted to the Engineering Profession, and to Mr William Ferguson being looked on by Engineers as the Head of the Profession.

To this, Sir Lindo Ferguson - he having had no scruples (and in my opinion rightly so) to accepting his knighthood - replied: -

"His brother was Chairman of an Advisory Commission in connection with World War No 1 and did very valuable work.

"It was desired by the Government to ask Mr Ferguson to accept a decoration (the particular nature of this not stated but presumably a knighthood) the Governor General (Lord Liverpool) having been asked and having agreed to recommend this to the King.

"Mr Ferguson declined any decoration for his services. Lord Liverpool saw Mr Ferguson and pleaded with him to reverse his refusal - a member of the Commission of which Mr Ferguson was the Chairman, particularly desired to have a decoration, and Mr Ferguson was putting him (His Excellency) "in a devil of a hole" as obviously the subordinate member could not be "decorated" if he (Mr Ferguson) declined.

"Mr Ferguson was sorry, but he could on no account accept a decoration."

Signed:
F W MacLean, 39 North Terrace, Wellington

Mr F W MacLean then wrote to Mr Cole - who by this time had retired to Nelson:

129 Upland Road
WELLINGTON W.1.

24 January 1951

My dear Mr Cole,

I hope you will forgive my recalling to your memory the abortive scheme for a memorial to William Ferguson, as the founder of the NZ Soc. C.E. which came to such an inglorious end. We were badly "let down." It is with regard to subsequent events, in which you came to the rescue, that I now write to you.

In the various visits which I made to Mr Ferguson at his home at Silverstream I was greatly impressed with what, to me, seemed a very admirable and characteristic portrait of him which I understood had been painted by a lady, a pupil of an artist of considerable repute in England. After Mr Ferguson's death, and the failure of the "memorial scheme" it occurred to me that a copy of this portrait might form a suitable memorial, and sought the assistance of Mr Ferguson's son.

He was very cordial, and in fact, told me that he had thought of presenting the portrait, which he had in his house in Wellington, to the Institution, but naturally, desired to retain it during his lifetime. He would willingly give permission to have a copy made of the portrait if a suitable artist could be found able and willing to make a copy. Mr Ferguson expressed great pleasure at the desire of the Institution to honour his father.

Mr Ferguson could tell me little of the identity of the lady who painted the portrait, as he was in England at the time (in 1911/12). He thought she was a Miss E. Baldwin-Warne, but had never met her, as she was in New Zealand only while he was in England. She had been a pupil of Sir Hubert von Herkomer he believed.

Under ordinary circumstances, the preparation of a copy of a portrait would be subject to the consent of, or by the undertaking of making the copy, by the artist who painted the original. The artist was no longer in New Zealand and could not be communicated with. The owner of the portrait had willingly given his consent to a copy being made provided a suitable artist could be found, able and willing to make the copy.

A Miss O'Hara Smith, until recently living at Silverstream, was, for a considerable time a member of the late Mr Ferguson's household and would be likely to have definite information about the name of the artist, of the date when the portrait was painted, and, probably, of the circumstances under which the portrait was painted.

I wrote to Miss O'Hara Smith, who has given me the following facts: -

The portrait was painted when Mr and Mrs Ferguson lived in Hill Street, Wellington, and was an excellent likeness of Mr Ferguson at that time, the date as stated by Mr W D Ferguson (1911/12).

Miss Baldwin-Warne and her friend (whose name Miss O'Hara Smith has forgotten) stayed with Mr and Mrs Ferguson while the portrait was being painted. Miss Baldwin Warne would not paint Mr Ferguson's face if Mrs Ferguson was not in the room too, as his expression was much better if she was there. The background, etc. was painted when Mrs Ferguson was not there.

Miss O'Hara Smith states - "I should say Miss Baldwin Warne was between forty and fifty years of age at the time. She did other portraits while in New Zealand, preferred to paint men, but she did paint a portrait of the late Judge Chapman's daughter. She also did miniatures very beautifully. She was proud of being a pupil of Sir Hubert von Herkomer."

An artist was found who was prepared to paint a copy of the original portrait, and both portraits, - the original and the copy side by side - were shown at a special meeting of the Council of the Institution, the copy was then presented, this received with great enthusiasm, the merit of the copy esteemed to be on a par with the original, that, considered to be great.

These conditions have been observed though I have been told that the identity of the artist who painted the admirable copy of Mr Ferguson's portrait which hangs in the Institution Rooms is no longer a close secret.

I have not been able to understand why the copy of the portrait has not been accepted officially as the "memorial."

In the yearly accounts of the Institution there appears, under the heading of "Liabilities" - "William Ferguson Memorial Fund," the same amount stated year by year.

I ventured recently to call the attention of the Council to the position and suggested that the "amount at credit" should be placed to the credit of the Benevolent Association of the Institution, in which Mr Ferguson was interested and to which I understand he had bequeathed a legacy.

The suggestion has been agreed to by the Council, and that effect will be given to this in the accounts. So far so good but what about the "Memorial."

A younger generation of Engineers is arising since the death of Mr Ferguson in 1935. To many of these, there is little knowledge of the man himself, and less, of the valuable work he did for the N.Z. Soc. C.E. (now the N.Z.I.E.)

My own feeling is that there should be a clear indication in connection with the portrait now hanging on the wall of the Institution; its nature as a memorial and to whose memory and for what service; the name of the artist who painted the original; and the name of the artist who painted the copy.

The Benevolent Association of the Institution has been referred to in connection with the Memorial Fund. Mr Hugh Vickerman and I are the sole Trustees of the Fund at the present time. I referred the suggestion as to the transfer of the existing balance of the Memorial Fund to Mr Vickerman who cordially approves of that, and of the further proposals.

In the foregoing statements, I have tried to place the whole matter before you, and trust that you will feel able to support the proposals and to release the condition of anonymity on your part, in the interest of the Institution and in justice to yourself.

With best regards and apologies for the length of the letter.

Yours very sincerely,

Signed:. F.W. MacLean.

Meanwhile Mr Cole was responding to a previous letter from Mr MacLean at the same time:

H.L. Cole
"Woodfield"
17C Brook Street
NELSON

23rd January 1951

Dear Mr MacLean

This is a short interim reply to your letter about the Ferguson Memorial - a somewhat longer one, more explanatory, is on the stocks and will follow, I hope, in a day or two. In the meantime, for your immediate information.

There was more than one reason for the "Week-end Dauber's" anonymity - in the first instance - "Wee Ken Dawber" might have been quite a good pseudonym, by-the-way! However, the need has passed, and I gather that the veil of anonymity has worn too thin to be effective now, anyway. So that's O.K. and can pass.

As to the balance of the Ferguson Memorial Fund: Don't worry Bedingfield about it, but I left a memo with him, mentioning that a little further expenditure would be needed to have a suitable "label" or small panel, attached to the bottom of the frame suitably inscribed with W.F.'s name, presidential date, and "PRESENTED BY W.D. FERGUSON" shown on it. This is because W.D.F. insisted on giving me a cheque much in excess of the few pounds which I estimated, represented my maximum costs (exact computation of course was impossible), and he wished to be the donor. This, I felt and I feel, was a great compliment to my effort, and it is in fact the only thing that could please me better than my own original wish (and intention) - subject to the work being approved by W.D.F. and yourself - which had been to present it to the Institution, myself.

No doubt the Council would agree to financing the necessary inscription from Institution funds instead of from the balance of the original Memorial Fund - which, as you suggest, might most suitably be transferred to the Benevolent Fund. Yes, W.F. did make a request to the Benevolent Fund.

I am writing and posting this in a hurry, so please forgive this awful scrawl. We have had a couple of accidents - one to my wife and the other to myself. She (in my absence) intervened to check what looked like developing into a real fight between two of our bull terriers - Lady "Pixie" Champagne, the Mamma, and Miss "Sprite" Champagne - rather tough daughter and quite the Modern Child, but a very fine 11 months old pup. Result - a bite on the back of Mistress's hand, though intended for Mamma. Mistress's hand is still in a sling - "it" happened a week ago, but the hand got bumped later and that didn't help matters.

Then, on Friday, I skidded on a surface pipe-line while carrying a box of spare honey-sections under my arm, after mucking about with one of the hives. I fell on my side - the side carrying the box of course, it would be! The box was smashed. My ribs stood up to it better than that, but Doc says one is cracked and I've got to go and be x-rayed today. I can't laugh, sneeze, cough or even blow my nose in comfort at present, but I don't think there's much wrong, actually. My wife is the worry - she won't rest her arm as much as she ought to, and so still runs a bit of a temperature which should have disappeared before now. She is very insubordinate.

Otherwise all fit and recovering reasonably well from Christmas visit of part of the family .... No more now - must post.
We hope that yourself and Mrs MacLean are keeping fit. Your letter is right up to F.W. Mac form in all respects and that was always first-rate. I like it so much that I'm going to keep it in our private archives. But I hope to add one or two details in another - and more legible - reply, later. All the very best to you both - and all!

Yours very sincerely

H L Cole

A few days later he sent a fuller response to Mr MacLean:

H.L. Cole
"Woodfield"
17C Brook Street,
NELSON

27 January 1951

My dear Frank

Your latest letter (24 January) again upbraids me for using the offensive 'Mr' when writing to you, but as it does not indicate a preferred alternative, it puts me "on the spot". Thus - even with your repeated requests to "drop the 'Mr' " in mind, it feels greatly daring - even presumptuous to barge my way into that intimate circle entitled by more ancient friendship, or even closer ties, to address you as "Frank". On the other hand, while the words "Old Mac" have naturally become a term of affection and respect and always refer specifically to Francis W MacLean,

among your friends of (round about) my own generation, I cannot see myself adding you to the considerable list of mere acquaintances whom I could address familiarly as "Mac". "Of course there are other "Macs", "but this is THE 'Mac'", I might explain - and rightly! But it's not good enough.
In this dilemma, anxious not to offend you either way - or perhaps even more frightened of offending Mrs MacLean! - I have promoted myself to stand alongside ("with but after" is the formula used in the "Warrant of Precedence") such a one as James Marchbanks in addressing you as "Frank".

J.M. was such a good and congenial friend to me himself, that I hope his spirit does not resent the obvious corollary to this - that is if he were still with us in the flesh, I might speak to him as 'James'.

As to the Ferguson Memorial portrait - your letter of 24 January tells me that the information in my previous note settles the whole question - Good! However, I can add an item not mentioned in your account, relating to Miss Baldwin Warne: She did a portrait of Mrs Ferguson, too. W.D.F. has it, and I understand from him that while the artist was most anxious to paint William Ferguson's portrait, W.F. himself refused to sit for it unless Miss Warne undertook to do a companion portrait of his wife. So she had to comply - or else forego her chance of doing W.F.'s portrait. Incidentally - on the back of Mrs Ferguson's portrait, there is a rough sketch which I took to be (probably) a preliminary study for the William Ferguson picture - perhaps to try out an idea for the post, or the spacing.

I can well understand Miss Warne's preference for painting men. They are certainly less beautiful, but usually - though not always - more interesting. I share her preference. That is where my part in this business really began - a surprise meeting with W.F., about 1930, outside 54 Molesworth Street; It happened thus - A lady - no doubt Miss O'Hara Smith - entered "Sec.'s " room. She looked slightly troubled, as when she mentioned that she had a number of engineering volumes for our library, her discontent needed no explanation to anyone knowing the 54 Molesworth Street stairwell. Elderly Members, having toiled up, were glad to take a spell at ease in the Council chairs.

Vulgar telegraph and errand boys scribbled rude remarks on the plastered walls, about the lifts - or the need for one..... "Sec.", naturally, bounded forth, to save the lady the trouble of carrying the books up (if indeed she had even thought of doing so), or at any rate to indicate how glad we were to get them. She had not mentioned that the donor - Mr William Ferguson - was himself in the car below.

He evidently had heard me clattering down the steps, for his head was somewhat inclined forward, enabling him to see us and be seen clearly as we emerged through the doorway of No 54. But to me it was a complete surprise to meet suddenly that kindly, quizzical, interested and very interesting face. Naturally posed, seen against a dark background, and accidentally but perfectly framed in the aperture of the car-window, it was very striking - especially the eyes. One could never forget it.

Years later, when the choice of a Memorial was being considered by the special committee, I myself rather favoured the idea of enduring bronze, especially when it transpired that Ellis, the Wellington Art teacher and sculptor, had known William Ferguson well for many years, and could be expected to make a good job of a portrait - bust. But Ellis was a sick man. The plaster model, after long delay, was made, but not to the satisfaction of W.F.'S son or of his closest friends. The question of getting it cast - or not! - became shelved, perhaps on the outbreak of World War II, since Ellis himself had stated that the plaster model would have to be sent to Belgium for the casting to be made.

Then occurred the earthquake, which - some said providentially - settled the matter by throwing the unfortunate plaster model from its perch onto the floor of the Institution's Library. It was irreparably broken - and Ellis himself was dead.

And that was that. I do not recall that anyone expressed, or showed any violent grief at the loss of the bust. On the other hand, there was no great clamour for the meeting to be held to consider a substitute. It was impossible to contemplate another attempt at a bronze bust though it seemed to me that the idea of a bronze plaque, perhaps with the head in profile, need not be ruled out. However, I felt sure that you, and probably others, would be more in favour of the original alternative; namely, a copy of a certain portrait; a portrait which those best qualified to judge - including W.F's son - regarded as excellent. You had often spoken of that portrait. In all the circumstances, it now seemed to offer by far the best solution - but for one snag finance. Any professional artist in good standing would be entitled to expect a fee much in excess of the small balance remaining in the Memorial Fund.

I am sure that we all felt that another appeal to members was unthinkable. As to Institution funds, the body was not so opulent, and its membership was much smaller than it is today. (One tends to forget that it was born in 1914, built up during World War I, struggled through the Depression - "carrying" a number of its less fortunate members - and was again in the midst of another long war, with many of its members overseas).

But something had to be done. With the vivid impression of my first (and only) meeting with William Ferguson in my mind. I "felt it in my bones" that there was another possibility - if "Wee Ken Dauber" could obtain permission to make the attempt. I did not know "young" Ferguson. I should have to make the approach through yourself, and I did not know how you might view the idea. Moreover - and this was important - I had not seen the portrait, myself. Would it reflect the personality of the William Ferguson that I had seen looking at me out of his car window that day at 54 Molesworth Street? If so, I felt little doubt about making a success of the work. if not, - well; I might not have attempted it at all!

It was the eyes that mattered most.

You know the rest. You were so good as to take me along to see W.D.F. - and the portrait. Both W.D.F. and the portrait put me at my ease. However, I asked for secrecy until the result should have been approved by both yourself and W.D.F.; and anonymity until at least it should have been accepted by the Institution.

Moreover I determined that failing your approval, then with a large pot of paint and a house painter's brush, I would swiftly obliterate the whole thing, murmuring the while - "It is a far, far better thing that I do now than I have ever done before " - or words to that effect. However, it came off; and I was very happy. Especially when W.D.F. was pleased.

This is a terribly long-winded account of my side of the story. My cracked rib is to blame for that - because it doesn't allow me to go forth into the jungle with scythe or battle-axe; though it's not serious. Wife's hand also nearly healed.

"Sea maw" got me beat in your letter of 24th January. You see I'm only 2s/6p in the Scotch; that is by extraction (my maternal Great-grandfather's name was Lundy) and my co-efficient of absorption is not what it used to be when the Punjab Clube's excellent Keith Jopp Whisky could be bought @ 2/8 (then = 3s/4p) per bottle. Happy days! Whisky is absent from our cellar now - except when my young brother (a kid of 54) comes over for a few days and brings a bottle of - Australian!

I see that something about "a" spot is mentioned at the start of this letter. It is appropriate to close on (or near) the same note. Nelson beer "is not such awful swipes" - to quote Alderman Twyford late Lord Mayor of London - as most other N.Z. beers, and there is something left in a 2-gallon jar still ....!

Enough to drink a health to Absent Friends; especially at 129 Upland Road. All the best to you both, from both of us.

Yours H Cole.

HAROLD LINTER COLE (OBE, MNZIE, M.I.Mech.E)

Mr Cole served as secretary of the N.Z.I.E. for a number of years before retiring to Nelson where he kept up his interest in painting and was a well-known member of the group that formed the Suter Gallery.

Originally a mechanical engineer from Glasgow in Scotland he trained in locomotive engineering and became the Asst. Loco. Superintendent to the Indian State Railways in 1901. By 1910 he was the Assistant Secretary to the Indian Railways Board.

The First World War interrupted his service with the Board and he became a Captain of the Railway Construction Troop rising to Major in 1917. He retired in 1919 as a Lieut. Colonel having being thrice mentioned in despatches and awarded the OBE.

Mr Cole returned to the Indian Railway Board as Secretary for three years. He was then loaned to the Bengal-Nagpur Railway, first as Assistant then finally as Chief Mechanical Engineer.

He retired from the service of the Government of India in 1928, having previously, during a furlough, established his family in New Zealand.

THE MASTERPIECE LOST & FOUND AGAIN

H L Cole's painting hung in the Institution's offices at 54 Molesworth Street for the next 15 years or so.

When the Institution moved to Molesworth House at number 101 Molesworth Street in 1966 someone decided that the painting looked "too old fashioned" for the "modern" decor! It was wrapped in cardboard and placed on the top shelf of a cupboard off the stairwell.

Thirty-one years later it was found again when the building was being tidied up in readiness for the sub-letting of more space. By now the painting was in poor condition and in urgent need of attention.

RESTORATION

Heather McCaskey - A Wellington-based Paintings Conservator, trained in Europe and of considerable skill - was engaged to bring the fifty-year-old work back to its former glory. This task was completed in late 1998 and you see the full results of that restoration work before you today.

CONCLUSION

The Institution is very fortunate to have re-discovered, and been able to fully restore, this "memorial" portrait of its founding father. The painting will be featured in a prominent position within the IPENZ meeting rooms along with a suitable plaque as originally envisaged some fifty years ago. As Frank MacLean so aptly put it in 1951:

"It would be difficult to exaggerate either the influence he exerted upon the Society and on the Engineering Profession in New Zealand, or the profound personal regard which he inspired in all who came in with him."

Constructing our past - the importance of New Zealand's Engineering Heritage

Roger Blakeley, Secretary for Internal Affairs

New Zealand's engineering heritage provides an exciting window into the dominant forces of our history and identity over the past 200 years.

During the 19th century Pakeha colonists set out to settle the country with enormous energy and were primarily interested in exploiting the country's primary materials. Building bridges and tunnels for the communication infrastructure became a primary goal.

By the turn of the century New Zealand had become the offshore farm of Britain. Our aim was to feed Britain's people and serve Britain's imperial aims. This was reflected in new engineering efforts such as the development of ports or the use of traction engines on farms. New materials such as concrete emerged and this country became a pioneer in its use.

From the mid 1960s New Zealand has had to adjust to a new economic world and develop new products. The jet boat, the bungy jump, the glass tower, the sports stadium and the computer screen became symbols of this new economy and identity.

Since our engineering history tells us so much about who we are as a people, it is very important that we preserve the visible reminders of this heritage. The establishment of the Ministry for Culture and Heritage has signalled central government's recognition of the importance of our heritage and provides as opportunity for a strategic look at the whole area.

In addition the Historic Heritage
Management Review has indicated that the Resource Management Act 1991 will provide the major mechanism for protecting heritage sites and buildings, but the details of how the new system will actually function in practice is still being worked through. The long-term future of the Historic Places Trust is still to be determined.

There is also a review in process of the Antiquities Act and recent examples of the export of traction engines, an important part of our engineering heritage, has pointed up the urgent need for new legislation. So there is much change in the wind with respect to government's policy and role in this area.

The Lottery Grants Board, which is serviced by the Department of Internal Affairs, continues to provide considerable support for the preservation of our heritage under its Environment and Heritage Committee.

At the dawn of the third millennium, New Zealand is literally *First to the Future* Our innovations in engineering and science are leading edge worldwide. Engineering has helped shape our sense of identity, from rugged pioneers to revolutionaries in the knowledge society

Recycling Hamilton's Historical Bridges

Cliff Boyt, Design Services Manager, Hamilton City Council

1 INTRODUCTION

Hamilton is a City of 120,000 people located in the heart of the Waikato region – a region that is a very rich agricultural area and which is intensively farmed having a strong emphasis on dairying.

Being located 125 kilometres south of Auckland it is really the transport hub of the North Island.

The city sits astride the mighty Waikato River with about 60% of the people living on the Eastern side and most of the industrial and commercial activity and about 40% of the people on the West of the river.

It is hard to say whether the bridges across the river were built to provide a transport link between the two halves of Hamilton or whether the building of the bridges has promoted the split development. Either way the bridges provide the vital arteries that connect the two halves of this thriving city. They are essential to its commercial and social well being.

The city is currently serviced by six vehicular bridges, one railway bridge and one services bridge across the Waikato River. The first of the present bridges was opened for traffic in 1910 and the others have followed at regular intervals since then.

This paper reviews the development and usage of the bridges and their importance to and influence on the city. It discusses the historical importance of three of the bridges and discusses problems that this creates for the City.

The paper concentrates on the technical problems in keeping the 3 oldest and most notable bridges operating to cater for modern transport needs. It discusses upgrade works carried out on these 3 bridges and recounts some of their history.

The paper concludes with a crystal ball look into bridging for the future.

2. A POTTED HISTORY OF HAMILTON'S BRIDGES

Hamilton was established as a permanent european settlement in about 1864. Initially it was serviced solely by river traffic and all cross-river transport was by punt.

2.1 The Union Bridge

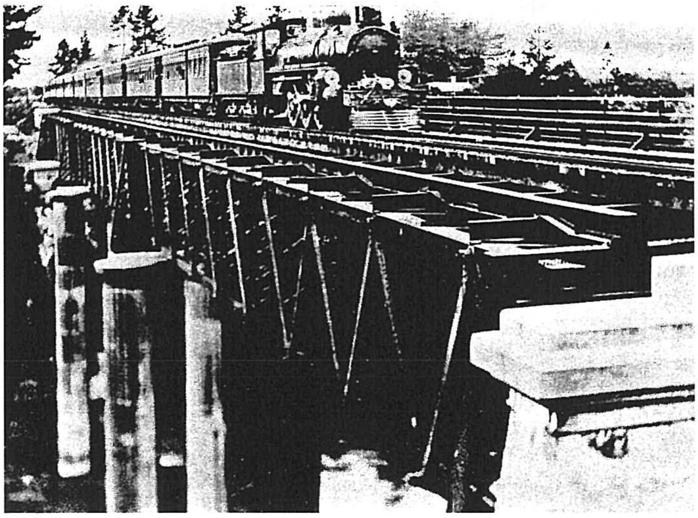
The first bridge across the Waikato River, built in 1878, was a timber structure built from kauri and called the Union Bridge. It provided a one-lane crossing for horse and cart traffic and was initially a "toll" bridge. It served the City until 1910 when it was demolished after the "new" Victoria Bridge was opened immediately alongside. The kauri timber was reused in houses – Stan West who was Drainage Engineer from 1966 to 1974 discovered that his home in Firth St was constructed with timbers from the Union Bridge.

Union Bridge

The timber piles were cut off at "bed level" and are still there today – they can cause a problem for unsuspecting boaties when the river level is very low.

2.2 The Railway Bridge

The second bridge across the river was the high level railway bridge which opened in 1884. It was widened in 1908 and then converted to a road bridge in 1966.



Old Railway Bridge

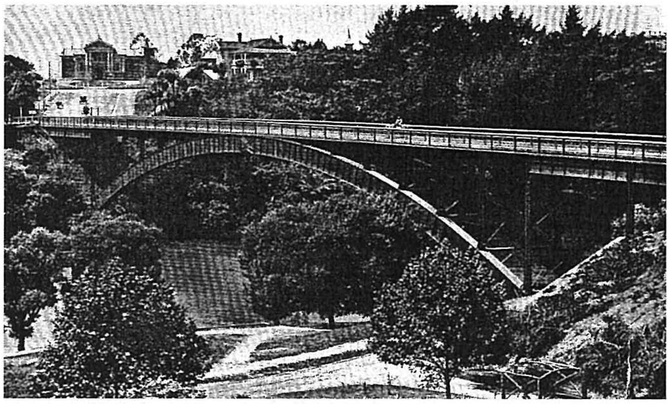
After the 1908 widening the bridge provided a key pedestrian link for residents living on the Eastern side to get to shops and secondary schools on the western side of the River.

The development and maintenance history of this bridge is discussed in more detail later in this paper.

2.3 Victoria Bridge

The Victoria Bridge was built and opened in 1910 to replace the Union Bridge which was becoming quite "rickety".

Victoria Bridge is a 3 pin steel arch bridge that is featured in many photographs of Hamilton. During its 90 year life it has been redecked twice but the sub-structure is essentially as originally built.

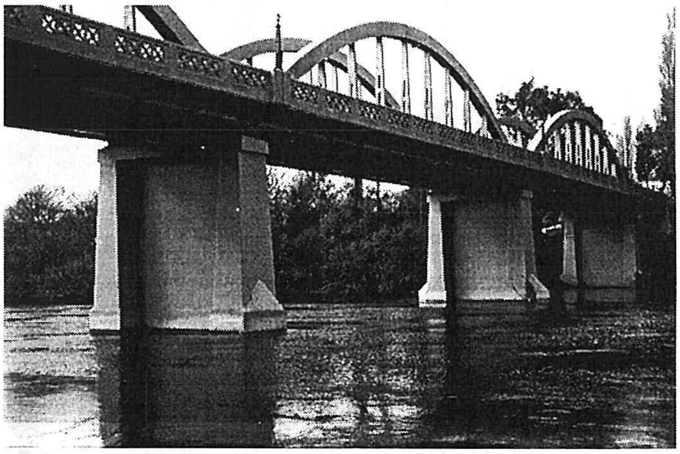


Victoria Bridge

The technical issues with keeping the Victoria Bridge operational are discussed later in this paper.

2.4 Fairfield Bridge

The Fairfield Bridge is a 3 span concrete bowstring arch bridge that was opened in 1937. It was the fourth concrete bowstring arch traffic bridge in New Zealand, the others being at Tuakau across the Waikato River; the Fitzherbert Bridge across the Manawatu River at Palmerston North and the Balclutha Bridge across the Clutha River. The Fitzherbert Bridge has been demolished.



Fairfield Bridge

The Fairfield Bridge was built by the Waikato County Council and was promoted by Caesar Roose who had a lifelong involvement with the river and ran the Roose Shipping Company.

When the Fairfield Bridge was opened it was "out in the country" but it is now right in the heart of the City.

The opening of the Fairfield Bridge in 1937 allowed for the Victoria Bridge to be closed for urgent major repairs.

2.5 The More Modern Bridges

Since the early 1960's there have been five more bridges constructed across the Waikato River in Hamilton and the old Railway Bridge has been converted to a road bridge.

The five "new" bridges listed in order of construction are discussed briefly below:

i) Low Level Railway Bridge

As the City grew, the level crossing at the main shopping street became intolerable. In the early 1960's a project to lower the railway, including a new bridge across the Waikato River was undertaken.

The new railway bridge is a very slim concrete box girder construction on 2 distinctive "V" shaped piers. It was opened in 1964 and the old bridge was gifted to the city and converted to a road bridge.

ii) Cobham Bridge

In the mid 1960's a new arterial road was constructed providing much improved access to the central area from the South Eastern suburbs and all points South. The Cobham Bridge was constructed as part of this development and was opened in 1966. It is a simple steel beam/concrete slab bridge.

iii) The Sewer Bridge

This is a concrete box girder bridge that was built in the mid 1970's expressly for the purpose of carrying all of the wastewater from the Eastern side of the City across the river (at grade) to the treatment plant on the Western side. The bridge provides key links for all other infrastructural services – water and gas pipelines and electricity and tele-communication cables. It also provides a key pedestrian link.

The possibility of a combined road and services bridge was investigated but too many compromises would have been needed.

iv) Whitiora Bridge

The Whitiora Bridge was opened in 1978 and connected between existing streets on either side of the river.

It is a box girder prestressed concrete bridge of modern design.

v) Pukete Bridge

The Pukete Bridge was opened in 1997 and is located at the Northern end of the City. It is part of a comprehensive route development joining the Te Rapa industrial area and State Highway 1 with the rapidly developing residential suburbs in the North Eastern corner of Hamilton.

It is also a box girder prestressed concrete bridge of modern design.

3.0 THE HERITAGE BRIDGES

Three of the bridges as classified by the Historic Places Trust as being of historical significance. These are:

- Victoria Bridge
- The old railway bridge now called Claudelands Bridge
- Fairfield Bridge

The heritage classification brings special considerations when it comes to planning for the future of the bridges. There is a requirement to retain the bridges as part of the City's heritage so that replacement at their current site is not an option. All repairs and maintenance must be done in a way that retains or enhances the heritage value of the structure.

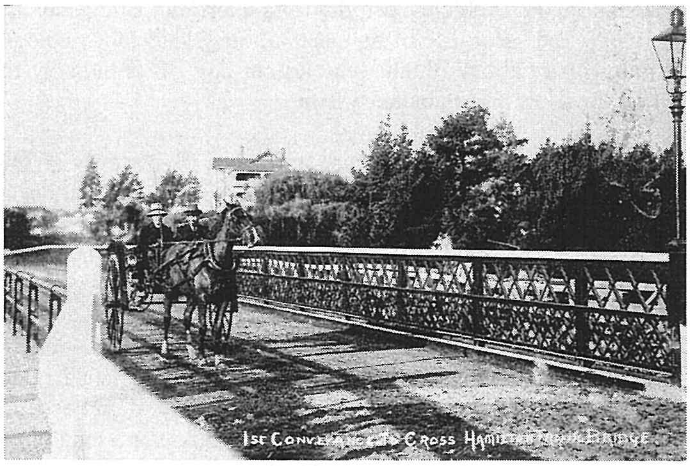
Recognising the importance of these three old bridges, and the high cost of creating a new cross river link, there is a real pressure on the City to look after them.

In the following sections I discuss key works that have been carried out on each of the bridges.

3.1 Victoria Bridge

Victoria Bridge has an interesting history. While the arch and support structure are more or less as original the deck has been replaced twice.

When the bridge was constructed in 1910 it had a very heavy deck of hardwood timbers and "earth". Apparently this first deck caused an overload on the foundations of the arch. The western arch block was pushed back into the ground with a result that the centre pin of the arch dropped by about "2 or 3 feet". Attempts to strengthen the foundations by "soil petrification" (presumably pressure grouting) were only partly successful.



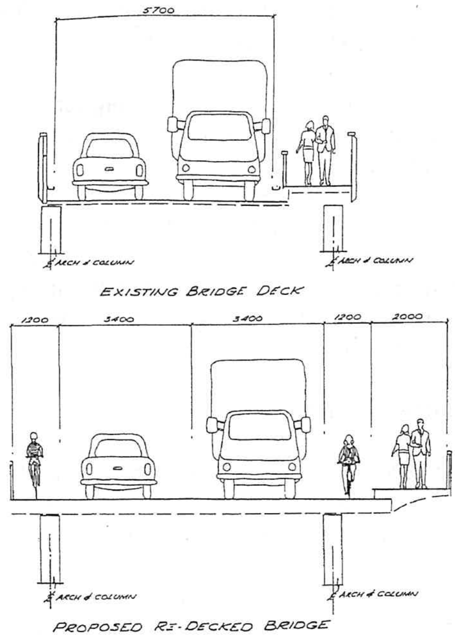
Victoria Bridge on "Opening Day". Note rise to centre of bridge. The bridge is now virtually "flat"

By about 1932 the condition of the bridge was causing concerns and Council proposed to the Railways Department that the railway bridge be converted so that it could also be used for road traffic. This was declined so that Victoria Bridge had to be nursed through until the Fairfield Bridge was opened in February 1937. At that time Victoria Bridge was closed for redecking.

Accounts suggest that when the heavy deck was removed the centre of the bridge recovered "6 to 8 inches" which was not lost again with the replacement deck. The replacement deck was a thin steel grid (egg crate) with concrete infill. It weighed less than 60% of the old timber deck. The carriageway dimensions were the same as for the original bridge and the original handrails were retained.

Apart from a tidy up and repaint every 15 to 20 years the bridge performed well through the next 55 years. However as traffic volumes grew the narrow deck became less popular and particularly unsafe for cyclists. In 1990 studies showed that the deck was nearing its calculated fatigue life whereas the sub-structure was still quite sound. Also in 1990 the bridge was given a B classification by the NZ Historic Places Trust.

In 1992 the bridge was redecked again. The specification was for a deck "about 50% wider than the old deck but weighing no more". The solution was to use an orthotropic steel deck with a thin (25mm) bitumen mastic surfacing. New handrails were manufactured to be close replicas of the originals and lights that look similar to the original gas lamps were installed. Both handrails and lamps required special dispensation from modern standard requirements to be able to preserve the heritage appearance. Paint colours were chosen for their heritage appeal.



Victoria Bridge Deck

During the project the arch and columns were repaired with corroded steel being cut out and replaced. The removal of the old deck allowed access to some areas, particularly around the central hinge, for the first time in 55 years. Around the central hinge there was a significant amount of deterioration caused by the effect of pigeon droppings. In these areas measures were taken to eliminate ledges where pigeons may perch.

A rigorous analysis showed that the arch members needed strengthening over the mid section between pins in order to provide a fatigue life in excess of 40 years. The strengthening plates were attached to one side of the arch after the deck load had been removed from that side only (i.e. while the top flange was in the minimum compressive stress case). The other side was strengthened after the deck was removed and the new deck had been installed to the other half.

The redecking has been very successful and popular with the public. It was amazing how many people said that it was good to be able to see the river while driving across. Really the only difference was that drivers were too scared to look before with the very narrow deck.

Technical details of the redecking project can be found in the paper presented at the 1993 IPENZ Conference by MJ Bloxam and C Boyt.

3.2 The Old Railway Bridge

The railway bridge was originally built with 2 rows of trusses on two iron cylinder piers. The bridge was quite "whippy" transversely and was fitted with four steel wire ropes as windstays.

During the first 20 years the number, and particularly the weight, of trains increased rapidly and the bridge needed to be strengthened. In 1906 a third row of trusses and support cylinder piers was added. This allowed for the wind stays to be removed. The rail lines were moved to being central on the 3 trusses and the long awaited footbridge installed. The upgraded bridge was opened in 1908.

In 1967 the rail tracks and footway were removed and a new orthotropic steel deck was fitted to convert the bridge to be used for road traffic. As part of this project the steel trusses were tidied up, repaired where necessary and repainted. Considerable analysis was carried out to assess the impact of slightly different properties between the original 2 iron trusses and the third truss which is steel. It does not appear to be a major problem. The bridge has a permanent weight restriction applied.

3.3 Fairfield Bridge

Fairfield Bridge is a concrete structure built in the mid 1930's. Like many concrete structures of that era it suffers from alkali-aggregate reaction (concrete cancer). By the early 1990's it was starting to cause real concerns. There was concrete spalling off in many places leaving reinforcement exposed and there were a couple of places where impact from vehicles had knocked big chunks of concrete off.

Studies showed that the action of the concrete cancer could be inhibited by keeping the concrete completely dry. A project to restore the bridge to its original glory was undertaken. The work comprised several stages:

- cutting out spalled and poor concrete back to fully expose the reinforcement
- where the reinforcement was badly corroded it was cut out and a new piece of reinforcement welded in
- where the reinforcement only had surface rusting it was cleaned by sandblasting and coated with an anti-corrosion product
- replacement of concrete using proprietary materials
- installing new lights with cables set into a groove chased into the concrete and resealed
- special attention was paid to drainage to ensure rainwater did not puddle and wet the concrete
- all of the historic concrete ballustrades were cut out and replaced using sprayed concrete
- the entire bridge was waterproofed using a "Barracryl Elastic" coating system.

The upper structure from deck level upwards was repaired and coated in the summer of 1992/93. The underside was left uncoated for a full year to allow the concrete to completely "air dry". The underside of the bridge was repaired and the waterproof coating completed in the summer of 1993/94.

The Historic Places Trust took an intense interest in this project and was keen to have the bridge restored to its original appearance. Attention was paid to the ballustrades and lighting but one feature that they wanted to replicate was the planking marks in the concrete surface from the original timber formwork.

The bridge should now have a service life of at least another 50 years so long as attention is paid to looking after it and particularly to ensuring the integrity of the waterproof coating.

Technical details of the restoration of Fairfield Bridge can be found in the paper presented at the 1993 Conference of NZ Cement & Concrete Association by Leroy Leach and Robert Robinson.

4. LOOKING TO THE FUTURE

At present there are 6 road bridges across the river and they carry 120,000 vehicles every day. Victoria Bridge carries about 28,000 vehicles per day and Fairfield Bridge about 19,000 vpd. Because of its location, the Claudelands Bridge only carries about 10,000 vehicles per day. It is unlikely to ever be a key bridge in the system.

The growth rate for cross river traffic has been steady at 3% per year for a long time. If this rate continues then another 2 lane bridge (or widening one of the existing bridges to 4 lanes) will be required by about 2004 and another by about 2010 and so on.

Being located in key positions relative to the city's commercial area, both Victoria Bridge and Fairfield Bridge are extremely important cross-river links. Hamilton needs to keep them both operating as key roading links for a long time. Recognising their heritage value, the City won't be able to demolish either bridge and build a replacement. Building a modern replacement bridge alongside is also not a realistic option. Therefore Hamilton really must look after these bridges. Regular inspections, painting and repairs as needed will be required. The type of traffic using these two bridges needs to be carefully monitored and if necessary a heavy vehicle restriction imposed.

New bridges will (and must) come but these 3 historical bridges – Victoria and Fairfield particularly – will always be important features for the City.

5. CONCLUSION

Hamilton City has 3 fine examples of historic bridges – Victoria Bridge; the old Railway Bridge, now Claudelands Bridge; and Fairfield Bridge. All 3 have a B classification from the NZ Historical Places Trust.

During the 1990's both Victoria Bridge and Fairfield Bridge have been extensively restored and Claudelands Bridge was restored in 1967 when it was converted to a road bridge. As a result, all 3 could be expected to last for at least another 40 years so long as they are well maintained.

It is so important that the bridge owners, whoever they may be in the future, understand the key features of these bridges and pay attention to their maintenance. For both Victoria Bridge and Claudelands Bridge the key criteria that will affect their life are metal fatigue and localised corrosion. For Fairfield Bridge it is maintaining the waterproofing to keep the concrete dry and inhibit the concrete cancer.

I really hope that future generations treasure these bridges. If they are looked after they will continue to be features of the City while continuing to serve as key components of the transport network.

Historic Places Trust Guidelines for the Fire Protection of Historic Buildings

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SUMMARY

This paper presents a process to evaluate and implement fire requirements in historic buildings. The process is to; Assess Heritage Significance, Develop Fire Safety Objectives, Qualitatively Assess the Fire Risk, Fire Design to meet the BIA Acceptable Solutions, Fire Design as an Alternative Solution, Identify and Evaluate Fire Safety Options within a Conservation Context, Obtain Building Consent, Implement the Chosen Fire Design, Meet Compliance Schedule Requirements. The best approach is a team approach, with all parties involved at the outset. This team approach continues through to installation and making sure the installation contractor is aware of the goal and limitations of the project. The Robert McDougall Art Gallery in Christchurch is a purpose built art gallery that also has a heritage one classification. The Gallery was only provided with an automatic heat detection system, with manual call points and sounders. A significant fire protection upgrade to install fire separations, specialised smoke detection, an automatic sprinkler system and smoke exhaust capability was undertaken over approximately three years using this process.

INTRODUCTION

The Historic Places Trust recognises the importance of protecting historic buildings, and those who use them, from the effects of fire. Historic buildings present particular problems in terms of fire safety. First, they often incorporate construction features that are a risk, such as exposed timber floors, walls lined internally with combustible materials, and wooden mouldings. Second, there is potential for conflict between the measures that are needed to protect an historic building from fire and the retention of its heritage character and value. The fire safety and fire protection of historic buildings calls for a process that, in addition to being legal, is creative, logical and guided by expert opinion. The Historic Places Trust has published a brochure called "Guidelines for the Fire Protection of Historic Buildings".

STATUTORY REQUIREMENTS

Two main pieces of legislation have an impact on the fire safety of buildings: the Building Act 1991 and the Fire Service Act 1975.

The Building Act

The Building Act 1991 has two requirements for fire safety:

1. If a building is being altered (but the use is not being changed), the local authority must be satisfied on reasonable grounds that after alteration the building will comply with the provisions of the New Zealand Building Code for means of escape from fire 'as nearly as is reasonably practicable, to the same extent as if it were a new building'; and

2. If the use of the building is being changed, the building must comply with the provisions of the Building Code for means of escape from fire, protection of other property, and structural and fire rating behaviour 'as nearly as is reasonably practicable, to the same extent as if it were a new building'. This means that in addition to the means of escape, the spread of fire must also be addressed.

Your local authority has the power to decide what is 'reasonably practicable' and section 47 of the Building Act lists factors for the local authority to consider in coming to a decision. Of most relevance to historic buildings is s. 47 (j) which states that local authorities shall have due regard to 'any special historical or cultural value' that a particular building might have. This gives local authorities some discretion where, for example, strict compliance with the Building Code might conflict with and compromise heritage values. Any variation from compliance with the Building Code requires a formal waiver to be issued by Council.

Finally, s. 64 of the Building Act deals with dangerous buildings. Dangerous buildings can include those that are deemed to be hazardous due to fire. Responsibility for identifying dangerous buildings lies with local authorities. Local authorities can seek the advice of the New Zealand Fire Service in identifying dangerous buildings. They can then require that dangerous buildings be made safe or boarded up to prevent entry. If the owner does not take action, then the authorities can require that the building be demolished.

The Fire Service Act

The administration of the Fire Service Act 1975 is generally the responsibility of the NZ Fire Service and the Fire Service Commission. Of particular interest to building owners is s. 21A of the Act. It discusses the types of buildings for which the building's owner is required to provide an evacuation scheme. In 1992 the Fire Safety and Evacuation of Buildings Regulations were introduced with the fourth schedule of the Building Act. The Regulations are applicable to most buildings, including historic buildings, that are used by the public. Any building where more than 10 people are employed, where more than 100 people assemble, or where accommodation for more than 5 persons is provided, requires an evacuation scheme. If the subject building does not have an approved sprinkler system, then the evacuation scheme must be approved by the NZ Fire

Service. There are some other specific occupancies which require approved evacuation schemes.

Compliance with the NZ Fire Safety and Evacuation of Building Regulations 1992, and liaison with the NZ Fire Service is recommended as part of the development of the fire safety design for any building. However, the NZ Fire Service cannot require any fire safety features in excess of the requirements of the Building Act / Building Code, as explicitly stated in s. 7 of the Building Act.

THE PROCESS

Before considering the project in any detail, consult your local authority to find out if your building is listed as a heritage item on its district plan. You will be advised whether a land use resource consent and/or a building consent will be required for the project.

Then follow the steps outlined below to ensure that an optimum fire safety solution is found for your historic building.

1. Assess the Heritage Significance of the Place

It is only by fully understanding the significance of our legacy from the past that the clearest idea will emerge of which parts of an historic building can and cannot be changed without impairing the heritage values of that building.

If the provision of a fire safety system is part of a larger project, or the building is one of outstanding heritage value, it may be necessary to employ a consultant to prepare a cultural heritage assessment. Depending on available resources, it might be a full-scale conservation plan that is commissioned. The process of conservation planning is discussed more fully by Greg Bowron and Jan Harris in *Guidelines for Preparing Conservation Plans* (Wellington: Historic Places Trust, 1994, 2nd ed. 1999). Often, though, a one or two paragraph statement about the significance of the building and its spaces will be sufficient to explain the heritage value of a place.

The assessment or statement of significance should identify the spaces and elements that make a particularly important contribution to the overall significance of the place. Every effort should be made to minimise damage to the materials and features that have been identified as being of the highest heritage value. Secondary spaces and elements should also be identified. These areas can often be altered without compromising the significance of the place as a whole.

2. Develop Fire Safety Objectives

It is important that the fire safety objectives for the building are clearly defined at the outset of any fire improvements. The question to ask is 'what level of fire loss is acceptable?' In order of increasing fire safety, these are as follows:

- Meet the minimum fire requirements of the NZ Building Code. This provides the minimum statutory life safety and protection of *adjacent* property.
- Limit damage to the fire compartment of origin
- Limit fire damage to the room of origin
- Limit fire damage to the absolute minimum possible.

The fire safety objectives and criteria for assessment should be agreed through consultation with stakeholders, including the property owner and manager, NZ Fire Service, Territorial Authority, Historic Places Trust and the fire engineer.

In all cases, the minimum requirements of the Building Act will have to be met to obtain a building consent. These requirements are primarily related to life safety protection of the occupants and NOT property protection of the building.

<u>Limit Fire Damage to the Absolute Minimum Possible</u>: In order to limit the fire damage to the absolute minimum, four systems are recommended:

1. Good housekeeping and building management - to limit the incidence of fire;
2. Very early warning smoke detection system - to detect the fire;
3. Automatic suppression system - to limit the growth and spread of the fire; and
4. Fire compartmentation - to limit the spread of fire effects.

Obviously, limiting the fire damage to the absolute minimum will cost more than the other options.

3. Qualitatively Assess the Fire Risk

A fire engineer can qualitatively assess the risk of fire in a particular building (Deterministic Methodology). The level of fire risk will be the result of a complex interaction between a variety of factors including the start of the fire, the growth and spread of the fire, the response of the building components to the fire, the response of the occupants in the presence of fire, and the response of the fire fighters. This qualitative assessment is not a necessity. However, it is a good exercise to consider the potential ignition sources and the various paths fire can spread in a building. The fire risk depends on the likelihood of fire occurring in a particular building, and on what the consequences of a fire in the building will be. To assess the consequences of a fire, the fire engineer will develop a credible fire scenario based on the installed fire safety systems and the physical features of the building.

An alternative approach is quantitative risk assessment (Stochastic Methodology). This approach assigns probability to events and is very complicated and expensive. It is not covered in any detail in the Guidelines for the Fire Protection of Historic Buildings. For information on it, see *Fire Engineering Guidelines* (Sydney: Fire Code Reform Centre Ltd, 1996).

4 a. Fire Design to Meet the Requirements of the Building Code

Three main objectives emerge from the fire requirements of the Building Code: (i) to ensure that the occupants of the building are able to escape from it in event of fire; (ii) to make allowance for fire fighters to enter the building to undertake search and rescue operations; and (iii) to limit the spread of fire from the burning building to neighbouring properties.

The Building Act provides two methods of achieving compliance with the fire requirements of the Building Code: (i) compliance with the approved solutions for fire; or (ii) providing an alternative fire solution. The approved solutions are the prescriptive approach and the alternative fire solution is a performance approach. There are a variety of solutions available for fire safety. It is difficult to make generalisations about which solution will be the most appropriate in a given situation. Thus the heritage values and the fire safety requirements of individual buildings should be considered on a case by case basis.

4 b. Fire Design to Meet BIA Acceptable Solutions

The BIA, which administers the Building Act, has developed prescriptive fire documents. They are called the Acceptable Solutions. The titles of the documents are:

- C1/AS1 Outbreak of Fire;
- C2/AS1 Means of Escape;
- C3/AS1 Spread of Fire; and
- C4/AS1 Structural Stability During Fire and the Fire Safety Annex.

The applicable specific fire requirements of the BIA Acceptable Solutions should be identified. The impact they have on the building can then be assessed. They often have strong fire compartmentation measures. This means that open stairwells may not be permitted, doors may have to be upgraded to fire doors, and selected walls may have to be upgraded to fire walls.

4 c. Fire Design as an Alternative Solution

Alternative Solutions will deviate slightly from the BIA Acceptable Solutions. Your local authority must be satisfied on reasonable grounds that the proposed Alternative Solution will comply with the Building Code. Thus the Alternative Solution must demonstrate equivalency with the BIA Acceptable Solutions and meet the performance objectives of the Building Code.

Alternative Solutions can be particularly useful for the fire protection of historic buildings as they allow for flexibility (and often cost savings) in situations where the retention of heritage character and value is an additional parameter. The impact upon the building can be minimised with an Alternative Solution.

Examples of Alternative Solutions accepted in the past include:

- The installation of a sprinkler system to permit existing non-fire-rated doors to bedrooms to be used and not upgraded;
- The installation of a sprinkler system to permit open stairwells and low levels of fire compartmentation to remain as is;
- Management control on door arrangements to allow doors to swing inwards instead of being re-hung to swing out;
- The installation of a suppression system to permit plain glazing to be retained instead of being replaced with wired glass.

A team approach is often needed to achieve an Alternative Solution:

<u>Local authorities</u>: Local authorities vary in their acceptance and knowledge of Alternative Solutions. It is important to involve the local authority in the fire design solutions at an early stage. The Council will be responsible for issuing the building consent for any work on the building. If it is not satisfied, then work cannot proceed. The Council may require that another fire engineer 'peer review' the fire design.

<u>NZ Fire Service</u>: The Fire Service administers the Fire Safety and Evacuation of Building Regulations. It is also the organisation that will respond to a fire in your building, and it can be important to understand how the Fire Service would approach the building in the event of fire. Ensure to liaise with them at an early stage of the design process, to enable agreement to the proposed scheme to be available.

<u>Conservation Architect</u>: A conservation architect needs to be involved in the development of Alternative Solutions. He or she can assist in determining which fire design solution will impact least upon the heritage building fabric.

<u>Fire Engineer</u>: The fire engineer's role is to develop the fire safety strategy and fire safety system design for the historic place in consultation with other members of the project team. The fire engineer will advise the team members of design options and the pros and cons of those options in a fire safety context. The fire engineer will also make recommendations on the options.

5. Identify and Evaluate Fire Safety Options within a Conservation Context

Once heritage significance has been considered and fire objectives determined, ways of protecting the building from fire can be developed. Remember, the aim of this exercise is to provide the greatest level of fire safety without compromising the heritage significance of the place. Modifications can often be phased in over time as funds become available.

Identifying and evaluating fire safety options within a conservation context means giving due consideration to conservation standards at every stage of the project. The most appropriate conservation standards in use in New Zealand are those contained in the *ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value* (1993). Copies are available from the Historic Places Trust Head Office (PO Box 2629, Wellington) and from ICOMOS NZ (PO Box 37 428, Parnell, Auckland). The *ICOMOS NZ Charter* has been formally adopted by the Historic Places Trust and a number of local authorities. The following recommendations are consistent with the principles of the charter.

Minimal Change: The provision of fire safety should involve the least possible loss of significant heritage fabric. Building fabric of heritage value should be retained where practicable and the opportunities offered by the existing structure and fabric should be carefully utilised.

Sensitive Change: Changes to historic buildings should be sensitive to the heritage character and value of the place. This generally means that alterations will be visually compatible with the old building, be of an appropriate scale and not be intrusive. New material should be discrete rather than dominant.

Distinguishing New from Old: Growth and change are natural parts of the life of any building. Matching the materials of the new work with those of the existing building is one option but, as historic buildings were generally not designed with fire safety systems in place, the equipment will be new and it is acceptable that it be designed to read as new work rather than as part of the original building fabric. The new work should be careful, honest and unambiguous.

Reversible Work: Where possible, new work should be reversible, so that the place can be returned back to its earlier form, if desired, in the future. Recycle or store early fabric that has to be removed, and make new junctions with the old fabric as light as possible.

Documenting Changes: Changes should be fully documented using drawings and photographs, with the latter taken before, during, and after, any changes are made. A thorough photographic record will be invaluable if there is a move to return any part of the building to an earlier form or appearance. New materials should also be identified by a discrete date stamping.

Heritage Professionals: You should seek the advice of an architect and a fire engineer who are proficient in the specialist field of the conservation of historic buildings. The same applies to builders and contractors - those who have experience with historic buildings and an understanding of conservation requirements are more likely to produce a better end-result than those accustomed to working solely on new or recent buildings.

6. Obtain Building Consent

A building consent must be obtained for most work on a building. A fire report is required to obtain the building consent. It must identify if the work is an alteration to the building or a change of use, and it must detail how compliance with the Building Code 'as nearly as is reasonably practicable, to the same extent as if it were a new building' is achieved. With the team approach noted above, the local authority should be familiar with the proposed fire design solution before the application for consent is lodged. Note that there are only two parties involved in the consent process, being the owner and the local authority / building certifier.

7. Implement the Chosen Fire Design

After acceptance of the fire design by the relevant parties involved, the fire design must be implemented in a way that has the least impact upon the building. This means that prior to any work commencing on site, proper planning is accomplished. The fire engineer, owner, and conservation architect need to walk through the building to determine the best method to proceed. Based upon this discussion and site visit, it may be desirable to develop design drawings for a contractor to bid to. The design drawings should show where each device is expected to be installed and the location of wiring and piping. It is important that the drawings note the applicable installation standard/s the contractor is to comply with. It is beneficial for the fire engineer, owner, conservation architect and fire contractor to walk through the building after completion of installation drawings but prior to commencing installation. This helps to improve communication and limit misunderstandings during installation.

8. Meet Compliance Schedule Requirements

Section 44 of the Building Act deals with Compliance Schedules. If a building contains any of the systems or features listed in s. 44 (this includes the components of a fire safety system such as suppression systems, fire doors, fire hose reels, fire alarms and emergency lighting), it must also have a Compliance Schedule. Compliance Schedules are issued by local authorities and specify the inspection, maintenance and reporting procedures that are to be followed by the independent qualified persons for each of the systems and features.

In addition, the local authority provides a Statement of Fitness which must be displayed publicly in the building for the first 12 months after a new building is constructed or an old building upgraded. At the end of that period, it is replaced by the first of the annual Building Warrant of Fitness. On the annual anniversary of the issue of a Compliance Schedule, the owner must supply the local authority with a Building Warrant of Fitness, stating that the requirements contained in the Compliance Schedule have been fully complied with during the previous 12 months. A copy of the current Warrant of Fitness must be displayed publicly in the building.

FIRE MYTHS

Sprinklers Do More Damage than the Fire

Sprinklers operate one at a time and ONLY when they get hot enough from the fire. The water spray pattern is very localised when compared with NZ Fire Service hose streams that would be used to fight the fire. With sprinklers, the fire will be minimised as the sprinklers will control the fire. Items that get wet can be salvaged, whereas items that are burned are lost forever.

The NZ Fire Service Can Make a Difference

The NZ Fire Service cannot be depended upon to arrive before fire causes damage. If it is after-hours the only way they are alerted is by the fire burning through the roof or window or if there is an installed fire/smoke detection system. The fire continues to burn while they drive to the scene, unload their gear, make entry to the building and search for the fire. All of the actions of the Fire Service take time, and time is the ally of the growing fire.

The installation of a suppression system which automatically operates is far preferable to relying on manual intervention.

Fire Won't Happen Here

This is certainly a common thought, fire won't occur here in my premises. It is true that as curators of a building everything possible can be done to prevent fire occurring. However, there is still the problem of arson and other unforeseen fire initiating events.

ROBERT MCDOUGALL ART GALLERY FIRE PROTECTION UPGRADE

Heritage Significance

The building was constructed in 1932 as an art gallery. The majority of construction is concrete, including some of the interior walls. The outside of the structure is brick. Interior walls in the north wing are painted burlap. A key feature of the design is the window system that reflects light to the interior of the building. However, this system is no longer in use and has been removed from the north wing. In 1960-61 the night entrance and workshop were added. The Administration wing was added in 1983.

Currently the value of the building is about $10 million and the contents are about $30 million. This does not include special travelling exhibits. The building has an Historic Places Trust classification of 1, this is the most significant classification. It is considered to have national value for conservation as opposed to just regional or local interest.

Develop Fire Safety Objectives

The Christchurch City Council recognised that they needed to improve the fire protection measures at the Gallery. They had allocated a sum of money for this purpose. The reality was to do the best available within the funds allocated.

Avoiding property damage was very important for both the contents and the structure. This is due to the irreplaceable nature of the artwork and the building. The objective was to provide for the absolute least amount of damage from fire within the budget available. Recognising this primary goal of minimising property damage, there were several other important aspects considered;

- Life safety (achieved by meeting NZ Building Code requirements)
- Minimal interruption to the Gallery during installation of fire safety systems
- Involvement of the Historic Places Trust
- Cost effective solutions
- Staged implementation.

Issues were discussed with the TA and NZ Fire Service to ensure they were satisfied with the requirements.

Fire Design As An Alternative Solution

The building is considered CL purpose group, Crowd Large on the ground floor. The first floor spaces are considered intermediate floors, WL purpose group. The basement is a combination of WL and IA purpose groups. The Gallery was lacking in egress capacity as it originally existed, some additional egress was added. After the installation of sprinklers the egress was not considered as much of an issue.

The majority of the design was above NZ Building Code requirements due to the objective of property protection.

Identify and Evaluate Fire Safety Options within a Conservation Context
The fire safety options identified for the Gallery are:

- Compartmentation – firecells created of basement storage areas
- Active suppression systems – sprinklers throughout the building
- Early warning systems – VESDA air sampling smoke detection system in all areas of the building except office and roof space
- Smoke management systems – provided for exhaust capability throughout most of the basement
- Administrative – housekeeping, hot work/welding, control over interior finish materials
- Exterior exposure protection – the risk evaluation identified this is not an issue

All concerned parties; Gallery staff, Christchurch City Council conservation department, fire engineer and contractor reviewed the installation of these systems. The basement where much of the work occurred was not considered to have strong heritage significance. Therefore the compartmentation activities that occurred in that area were acceptable.

The installation of the sprinkler system and VESDA smoke detection system were accomplished with very little impact on the building. Some sprinkler piping was installed above the roof to limit the exposed piping inside the building. Other various ledges and hidden vertical shafts were used to limit the visual impact of the fire protection system.

Obtain Building Consent

The fire report prepared was submitted to the Christchurch City Council for approval.

Implement the Chosen Design

The team approach worked well at the McDougall Art Gallery fire upgrade, in Christchurch. The owner, fire engineer, smoke detection system contractors, and sprinkler system contractor met to discuss the installation. In this case there were no design drawings provided to the fire protection contractor. There was an onsite walk through and discussion prior to the installation commencing.

As with any project there were some unforeseen events. Also, as is often typical of these types of buildings, there are few to no drawings available with pertinent information. For example hidden in the wall were electrical conduits that were cut during the core drilling. Their repair investigation found a hidden space that was previously unknown.

In another area, the installation of an oversized fire door created the need for a structural review of an area of the building after the door opening was enlarged.

Meet Compliance Schedule Requirements

The ongoing maintenance of the fire protection systems has been picked up by the Gallery. They ensure that the systems are tested and maintained as required.

The Benmore - Haywards HVDC Link

J. M. Clark, BE (Hons), ME, MIPENZ
Transpower New Zealand Ltd

SUMMARY

In the early 1960's, after a period of intense debate, the NZ Electricity Department commenced the construction of a 600 MW high voltage direct current (HVDC) transmission link between the North and South Islands. The scheme was the world's fourth HVDC link, and the third to include a submarine cable. In addition to the 40 km cable crossing of Cook Strait, the scheme required the construction of 570 km of overhead transmission line between Benmore in the South Island, and Haywards in the North Island. Since the completion of the original HVDC scheme in 1965, 20 - 30 % of the North Islands annual electricity requirements have been met by transfer from the South Island. After more than 30 years service, the original Cook Strait cables have been replaced, but the majority of the original converter station equipment is still in service. The scheme has always been one of the world's best performed mercury arc valve HVDC links.

1. INTRODUCTION

In 1950 M. G. Latta, Chief Engineer of the State Hydro-electric Department, produced a paper on the future supply of power in New Zealand. Latta argued that the effective limit of hydroelectric capacity in the North Island would be reached when the load was about two and a half times its present level. From 1925 to 1949 the average annual rate of increase in the energy generated in the North Island was 9.7 per cent, a figure similar to that in other countries. Assuming that the best guide to the future was the long-term past trend, Latta made assertions that lay at the heart of New Zealand power planning: load would continue to grow and the North Island's hydro-electric capacity would be fully developed in the foreseeable future. The North Island's hydroelectric resources would be exhausted as early as 1959 if the annual growth rate was 10 per cent, and a decade later if it was 5 per cent.

2. A COOK STRAIT CROSSING ?

Were it not for the existence of Cook Strait, Latta argued, South Island hydro-electric stations could supply the southern half of the North Island and ensure that the country's load was met for many years to come. A single generating system would have other advantages. The South Island lakes offered a large potential for storing water, and the peak river flows in the two islands were complementary. In the North maximum flows came in winter, but there was little long-term storage capacity. In the South Island high-country snow and ice melt created maximum flows in late spring and summer in rivers such as the Waitaki, which offered huge storage potential. A cable across Cook Strait and the development of this storage capacity would allow the transfer of considerable energy to the North Island in winter.

Latta believed that the technology of high-voltage DC transmission that would be needed to overcome the barrier would soon be available. He referred to the undersea cable link between mainland Sweden and Gotland, which was to transmit 20 MW DC at 100 kV over 96 km. The best way to transmit large amounts of power over long distances, particularly when submarine transmission was involved was by high-voltage DC. But energy had to be converted from AC to DC and back again. High power DC conversion had been made possible by the development in the 1930s of the mercury-arc rectifier, and DC transmission had been pursued in Sweden, Germany and the Soviet Union. The problem was that in the early 1950s, conversion equipment for large amounts of power at very high voltages was still not very reliable.

3. INVESTIGATIONS BEGIN

In 1950 the government invited to New Zealand the Chief Engineer of British Insulated Callender's Cables Ltd (BICC), a company with unparaleled experience in both manufacturing and laying submarine cables. He reported in July 1951 that the scheme was possible but extremely difficult, and BICC proposed that it should investigate the project's feasibility further, including manufacture and tests of a trial length of cable. This was not given the go-ahead.

The timing of Latta's report had been very awkward politically. South Island consumers were acutely aware that they would suffer power shortages until the Roxburgh hydro power station was commissioned. Indeed, A.E. Davenport, the General Manager of the State Hydro-electric Department told one South Island conference that the government would not run a cable across Cook Strait 'to take power to greedy neighbours in the north'. For some years the idea of the cable faded from view as attention was directed towards the Meremere thermal power station and geothermal development. But Latta did not give up. On several occasions, he urged unsuccessfully that BICC be awarded the investigation contract, and he kept careful track of overseas developments. By 1954, the Swedes had successfully commissioned the link to Gotland, and other schemes were in progress.

Latta went overseas in 1955 to investigate gas turbine plants and managed to keep up with submarine cable developments by visiting various countries. On his return he reiterated his previous arguments and urged that the proposal be investigated by BICC. The crucial factor in many respects was not so much the cable itself, which could be laid quickly, as a large new hydroelectric power station on the Waitaki river at Benmore, which would take a long time to build.

Cabinet was persuaded, and in early 1956 BICC at last got its contract to report on the feasibility of the scheme. The contract included the design, manufacture and testing of samples of cable, and extensive surveys of the seabed and tidal currents, and of shore conditions on the proposed routes.

For reasons of cost the State Hydroelectric Department was very anxious to use the 40 km route from the reasonably sheltered and sandy-bottomed Fighting Bay, northeast of Blenheim in the outer Marlborough Sounds, to the exposed Oteranga Bay, on Wellington's rugged southern coastline. A longer alternative route might have an easier sea floor but would be very much more expensive. AC transmission remained an option in theory, but would be at least 30 per cent more expensive than DC, and there seemed to be growing evidence from the Gotland experience that the Swedish ASEA Company could provide reliable mercury-arc rectifiers.

In December 1956 BICC reported that the project was 'thoroughly practicable'. They recommended the Fighting Bay-Oteranga Bay route and DC transmission of 600 MW over two cables with a third as a spare. Assurances were given that it would be possible to make repairs if faults developed.

Many remained sceptical, including some Post Office and Ministry of Works engineers, and opposition to the cable emerged. As early as August 1956 the Commissioner of Works, F.M.H. Hanson, stated publicly that the need for an inter-island link was not urgent because of the prospect of geothermal steam becoming available. In July 1956, Hanson and his Engineer-in-chief had been appointed to the Combined Committee on the New Zealand Electric Power Supply. They would go no further than approve the cable in principle, with testing to continue, arguing that the only information received had come from the likely contractor. They had two major objections: that BICC might have underestimated the cost and time involved in a major repair, and more importantly, that the proposed Oteranga Bay route ignored many years of Post Office experience that indicated that serious chafing on rock would probably be caused by tidal currents. Davenport insisted that the cable would move far less than the Post Office cables because of its armouring and its greater ratio of weight to diameter. The Combined Committee on the New Zealand Electric Power Supply reported in March 1957, recommending approval of Benmore as soon as possible and approval in principle for the inter-island link.

The criticisms made the State Hydro-electric Department consider a cable route ending at Lyall Bay, as used by the Post Office. This route was nearly twice as long as the route to Oteranga Bay, much more expensive, and raised problems with transmission from Lyall Bay to Haywards.

The debate delayed Cabinet agreement to the manufacture of cable and the laying of trial lengths until August 1957. Two 0.8 km lengths of cable were eventually laid off Oteranga Bay in 1958. Meanwhile in October 1957 the Benmore project (with two generating units) was approved. Later that year Labour became the government and the balance of political influence shifted away from the State Hydro-electric Department towards the Ministry of Works when Hugh Watt became minister of both portfolios. Because Labour favoured the development of North Island hydro-electricity, and because of economic constraints and interdepartmental conflict, Watt's August 1958 White Paper announced the deferral of the cable for a year.

Lack of resources needed for data collection meant that there continued to be uncertainty about currents on the seafloor and their effect on the cable. In November 1958 the British firm of Preece, Cardew and Rider was asked for an independent report on the feasibility of the scheme.

The Preece, Cardew and Rider report was received in October 1959. It argued that the scheme recommended by the 1957 Combined Committee was the 'simplest and most economic scheme' which was 'practicable to construct and will be reliable in operation'.

The report favoured the short route while acknowledging that further investigations were needed and suggesting that tidal patterns and the sea-floor conditions for other routes should be looked at. Captain O R Bates of the British General Post Office had previously recommended an alternative route from Cloudy Bay to Fitzroy Bay, but it was noted that this would cost more than twice as much, allowing for additional electrical losses.

However, in March 1960, the Labour Cabinet accepted the Ministry of Works' recommendation that a decision on the scheme be postponed for a year in view of the deteriorating economic situation.

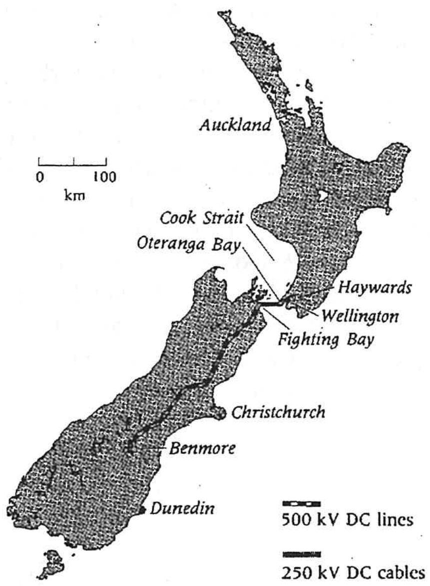
In the early months of 1960, the lengths of cable laid nearly two years previously were recovered and found to be in excellent condition, while further underwater photography reduced the fear of rock formations on the seabed. At a meeting of power planners in May, Latta argued that all the reports and evidence indicated that the short route was practicable. But Watt was still chairman of the Power Planning Committee, and Ministry of Works and Treasury representatives outnumbered those from the Electricity Department. The committee merely agreed that it could do nothing until the uncertainties about the reliability of the cable issue were resolved.

Before the end of the year, however, National was returned to office and Goosman, whose sympathies were more with the Electricity Department, was back as Minister. He reconstituted the Power Planning Committee and made Davenport its chairman, and also made it clear that it was free to recommend the cable if it thought fit. To demonstrate the cable's durability, Goosman obtained a 41 kg sample, staggered across the floor of the debating chamber and deposited it on the table of the House. But the cable still had many political opponents, and Goosman, who remained a little uncertain, asked Hanson for an independent report on the project.

4. THE DECISION TO PROCEED

The Power Planning Committee met for two days in January 1961. One of its two Ministry of Works members argued that the cable would actually move more than smaller and lighter ones. The question was not resolved until a BICC team came to New Zealand in February for final discussions on the cable and asserted that they were confident of its success. After an entire day of debate the cable received majority approval. For a time a Ministry of Works minority report seemed possible, but the Commissioner of Works gave up under pressure from Goosman. By now the ministry was less confident about further North Island hydroelectric development and geothermal development at Wairakei no longer looked as promising.

The committee reported on 1 March 1961, asking for approval for the link and the addition of four generating units at Benmore to bring the station to its full capacity. On 13 March Hanson submitted his report, which supported the committee's recommendations. At the end of March Cabinet approved the laying of the cables and the construction of the high-voltage DC transmission line that would take power almost 600 km from Benmore to Haywards, as well as the conversion equipment at both ends of the line and the four additional generators at Benmore. The target date for completion was April 1965. Time was short.



Route map of HVDC from Benmore to Haywards

BICC and ASEA were awarded major contracts for equipment. ASEA was to provide the high-voltage DC converter plants at Benmore and Haywards, and BICC was to provide the cables for the Cook Strait crossing.

5. COOK STRAIT SUBMARINE CABLES

BICC manufactured three unjointed lengths each of more than 40 km of specially designed cable, one cable being a spare. The voltage between the two operational cables was 500 kV. The cables were 13 cm in diameter with a conductor cross sectional area of 5.16 cm^2, paper-insulated and pressurised internally by nitrogen at approximately 30 bar to cope with the water pressure at the deepest point (243 m). Each cable weighed 1,500 tonnes. They were the longest and heaviest submarine cables ever manufactured to that time. The cables also had by far the greatest capacity of any submarine cable yet made, and were the first to be gas-pressurised. In addition to the main lengths of submarine cable, short lengths of land cable were also manufactured. These were designed with a larger conductor cross-sectional area to ensure that the maximum temperature rise was no more than in the submarine cables.

6. THE LAYING OF THE CABLES

The cables were laid one at a time in late 1964. They were installed in parallel with a spacing of around 900 m. The laying was surprisingly quick, and was not seriously affected by the notorious Cook Strait weather. The bulk carrier MV Photinia was specially converted for cable laying, fitted with a bow propeller, and provided with the latest precision radio-navigation aids for precise fixing of position. The laying of the first cable began at Oteranga Bay at noon on 12 November. Each cable was coiled in a separate hold, out of which it was drawn over a bow sheave. A 'floating head' was used to land the cable end on the shore from the Photinia. Floats supported the cable during this process. After six hours the shore end laying was completed and the ship was able to move out into Cook Strait. The Photinia crossed the strait within six hours and reached Fighting Bay at midnight. A further six hours from first light was spent laying the Fighting Bay end. This process was repeated for the other two cables. The second cable was laid after a ten-day delay caused by bad weather, and the third was laid by 13 December. All went well, except that the last cable developed a kink when unexpectedly powerful currents moved the ship. This was only discovered during testing, and after many problems, between March and May 1965 a new section was spliced into the cable to replace the damaged section.

7. CABLE TERMINAL STATIONS

In addition to the laying of the cables, cable terminal stations had to be built on each side of Cook Strait to manage the transition between the submarine cables and the overhead HVDC transmission line. At each site, a joint pit was constructed in the beach to accommodate the transition between the submarine cables and the short length of land cable between the beach and the terminal station switchyard. The site at Oteranga Bay posed particular challenges because of the difficult access, and the extreme weather. During severe storms, wind speeds of over 140 knots have been recorded near Oteranga Bay, and salt is continuously deposited on all surfaces, including outdoor HVDC insulation. An automatic washing system was eventually implemented to keep the insulation relatively free of salt pollution and minimise flashovers.

8. CONVERTER STATIONS

Besides the standard outdoor high voltage substation equipment at Benmore and Haywards, it was necessary to install HVDC converter stations, each housing 28 special mercury-arc rectifying valves.

The mercury arc valves convert power from AC network voltages to 500 kV DC at Benmore and reverse the process at Haywards. The valves themselves consist of a horizontal steel cylinder with a cathode pool of mercury in the bottom, and four anode columns and anode voltage dividers mounted on top. Each anode column consists of a heavy upright cylindrical porcelain which provides the insulation and supports the anode, the grading electrodes and the grid. A current divider is suspended above the four anodes to ensure proper current distribution between the four anodes. The cathode tank and anode columns are evacuated to a high degree of vacuum, maintained by mercury diffusion vacuum pumps, and the temperatures of the cathode tank and anodes are closely controlled.

The mercury arc valves at Benmore and Haywards are arranged in four groups each containing seven valves, forming a 3-phase bridge arrangement with a bypass valve. The valve groups are connected to the AC network via converter transformers.

In addition to the valves and transformers at each converter station, there are large DC smoothing reactors, static capacitor harmonic filter banks, damping resistors, surge diverters, high voltage isolating transformers, and a wide variety of special measuring and protection equipment.

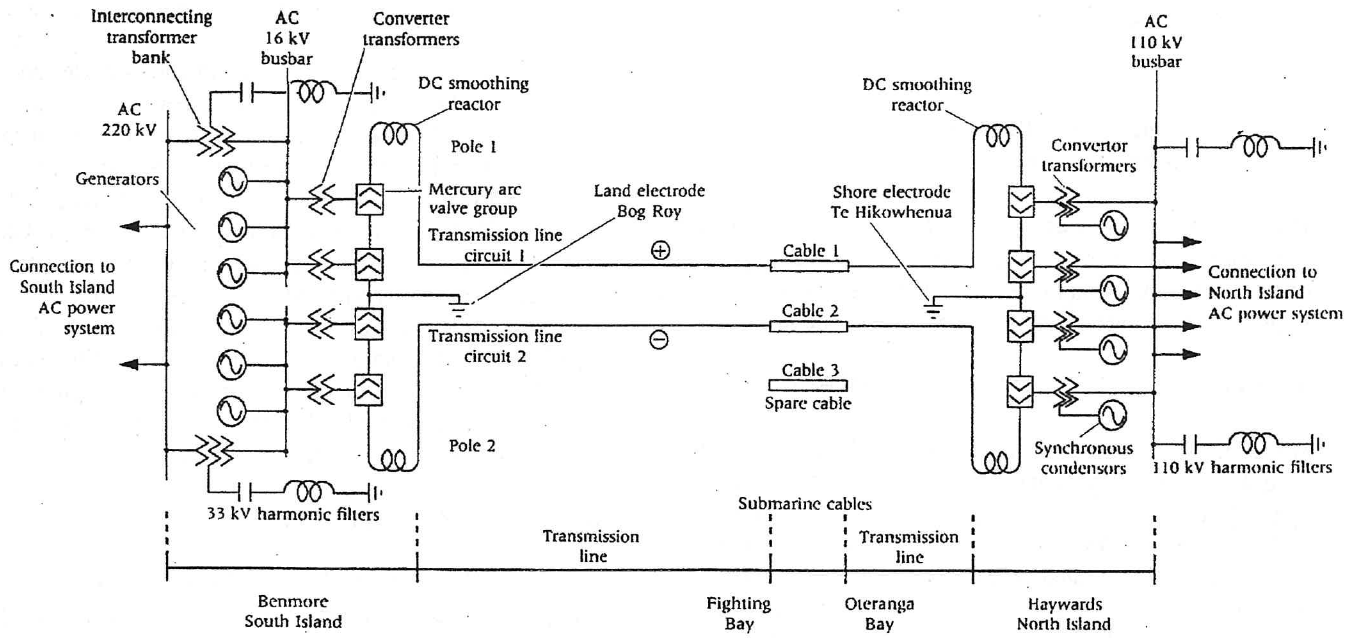
The converter station buildings are air-conditioned for temperature control and to keep the air free of mercury vapour and dust. The buildings are equipped with special clean workshop facilities for the maintenance and refurbishment of the mercury-arc valves. Particular care was taken in the design of these facilities to provide an environment that would help protect the safety and health of the workers who maintain the valves and ensure that they were not harmed by exposure to mercury vapour.

9. EARTH ELECTRODES

The HVDC link is bipolar, using two separate cables as conductors of opposite polarity. In emergency or fault conditions the link can operate at half capacity on one pole using one cable as a conductor, with the earth itself used as the other conductor. This required the design and installation of sea and land electrodes to provide the connections to earth. The land electrode is near Benmore and the sea electrode on the coast north of Oteranga Bay near Makara. The electrodes were themselves major design achievements with little previous experience as a guide. At both electrode stations, steps were taken to ensure that no hazard to personnel or grazing stock would be created by the operation of electrode station. In some cases, it was necessary to segment and insulate short sections of fence.

10. TRANSMISSION LINES

The project also required the construction of 570 km of high-voltage DC transmission line including 1,623 steel towers. The majority of the line route is in the South Island at heights of up to 1,280 m, traversing some particularly difficult country in northern Marlborough. More than 400 km of access tracks were required, and several major bridges, including six span bridges up to 75 m long. The average span of the transmission line is 356 m between towers, although the longest span is 1119 m near Port Underwood as the line approaches Fighting Bay. The construction of the transmission line employed more than 350 men. Specially designed aluminium and steel transmission line conductors were manufactured in a factory in Auckland. The insulation used on the line varies between the coastal and inland sections. The insulation strings on the coastal sections are more than 5 m long to help avoid flashovers resulting from salt pollution. By early 1963 more than half the towers were up and a start had been made on stringing the lines. The line was completed in January 1965, an astonishing achievement.



New Zealand HVDC Scheme - Simplified Single Line Diagram

11. COMMISSIONING

The project was commissioned on schedule on 1 April 1965. The Prime Minister, Keith Holyoake officially opened the HVDC scheme and Benmore Power Station on 15 May 1965 in the presence of many distinguished guests including the Chairman of BICC, the Chairman of ASEA, Crown Prince Bertil of Sweden, and Dr Uno Lamm, the developer of the high voltage mercury arc valve.

For the year ending March 1966, 13.3 per cent of the North Island's energy was transmitted via Cook Strait.

The link was working well, albeit at half capacity because of a problem with harmonic interference to communication circuits. The harmonics generated by conversion into DC interfered with telephone toll circuits, street lighting and hot water control systems, particularly in the north of the South Island. This problem was resolved with the installation of additional harmonic filtering equipment at Benmore.

At the land and sea electrode stations, few difficulties were experienced, although some pipework in a farm close to the land electrode station suffered electrolytic corrosion and had to be replaced.

12. UTILISATION AND AVAILABILITY

After an exceptionally dry winter in the North Island in 1969, the HVDC link supplied 38 per cent of the island's needs between September 1969 and March 1970, and up to half the total load at times during that period. For the year ending March 1973, 32 per cent of the North Island's energy consumption was supplied via the cable, again because of drought.

In 1976 the system was modified so that up to 400 MW could be sent from north to south, and this was immediately taken advantage of in the dry seasons of 1976 and 1977, and to help with the filling of Lake Pukaki.

The HVDC link has regularly supplied 20-30 % of the annual North Island energy requirements since commissioning, and has usually achieved better than 93 % annual availability. The average annual load factor or utilisation is around 50 %. In recent years, the annual availability of the mercury arc converters has exceeded 95 %, which is comparable with the best performed HVDC schemes in other countries.

13. OPERATING EXPERIENCE

In 1968, some major problems with mercury-arc valve performance became apparent. An extensive programme of corrective work was commenced and by 1972, the performance of all valves had been greatly improved.

Also in 1968, a number of HVDC transmission line towers were damaged during the *Wahine* storm. In 1975, seven DC line towers in Canterbury were blown down during 185 km/h winds.

The wisdom of providing for a spare cable was amply demonstrated by 1976. The first cable fault occurred in 1973 at the Fighting Bay shore joint. A similar problem arose with the second cable in 1976, and again in 1980. In 1976 the cable that had to be repaired at the time of initial laying again experienced problems. The Photinia was recalled and in June 1977 another complex splice, similar to the original one, was made to replace the repair joint.

The lengths of the cables suspended over rocks near Oteranga Bay are subject to tidal action. The first problems came in 1981 when gas leaked from the jointed cable. This was repaired over the summer of 1982-83. When a further leak was detected subsequently it was decided not to undertake a much more difficult repair, but rather to use the cable only in emergencies and at half capacity.

In May 1988 the sealing joint at the Oteranga Bay end of one of the good cables exploded. An urgent repair was commissioned and completed within a few months.

In 1991, Cable 2 suffered an electrical fault in the middle of Cook Strait in deep water. Subsequent investigations indicated that the cable was probably struck by a fishing trawl. Cable 1 failed in 1992 during the upgrade of the HVDC link described in the next section.

Finally, in 1996, it became necessary to abandon Cable 3, the last of the original Cook Strait cables, after more than 30 years service. By that time, sections of the cables in the Terawhiti Rip south of Oteranga Bay had become very severely eroded by the constant movement of seabed material across the surface of the cable. This phenomenon was observed and recorded with the use of time-lapse video equipment placed on the seabed in the areas of highest tidal current flows.

14. UPGRADING THE INTER-ISLAND LINK

In order to fully utilise new hydroelectric power being developed in the South Island, it became apparent in the late 1980's that extra inter-island transmission capacity was needed from the early 1990s. The possibility of increasing the capacity of the link was investigated from 1987, and it was decided to expand and upgrade the link to operate as a hybrid system, with new converter stations operating at – 350 kV. The existing mercury arc converter stations were to be changed to + 270 kV instead of ± 250 kV. The total capacity was to be increased from 600 MW to 1,240 MW.

In February 1989 a contract was let to ABB High Voltage Cables and Alcatel/STK to design, manufacture and install three new 350 kV undersea cables. In March, another contract was let to Asea Brown Boveri for two 'solid state' thyristor converter terminals - the modern equivalents of the mercury-arc rectifiers - for the new link, together with a new control system for the existing mercury-arc rectifiers.

A Norwegian cable-laying ship, the Skagerrak, arrived in February 1991 and successfully laid the three new cables in February and March. The upgraded 'hybrid' HVDC link was fully commissioned during 1992, and was immediately used to help manage a period of low hydro inflows in the South Island.

15. FUTURE LIFE OF ORIGINAL EQUIPMENT

The majority of the original converter station equipment commissioned in 1965 is still in service. The mercury arc converter stations are relatively maintenance intensive, and there are concerns about the future reliability of some of the major items of plant. The insulation of original converter transformers is now significantly deteriorated and some failures must be anticipated.

The mercury arc valves themselves are at the heart of the existing converters. This technology became obsolete in the 1970's with the development of reliable high power semiconductor thyristors. There has been no support for mercury arc valve technology available from manufacturers for many years, although an international user group provides a valuable forum for sharing experiences. There are also very few spares available, but Transpower has taken advantage of the decommissioning of other schemes to purchase some critical items. It is possible that New Zealand may be one of the last countries to continue to operate a mercury arc valve HVDC scheme. Transpower faces continuing challenges in ensuring that there is a sufficient pool of experienced personnel available to continue the maintenance and refurbishment of the valves.

The recent reforms in the New Zealand electricity industry are also having an impact as patterns of HVDC transfer become more variable. This is leading to increasing switching frequency and thermal duty cycles which may shorten the ultimate life of the equipment.

As yet no clear end-of-life can be determined, and at an operational level, every effort is made to maintain the present high level of availability. Transpower is continuing to assess the market requirements for inter-island HVDC transfer capacity, and closely monitor the condition of the plant.

16. HERITAGE STATUS

The exceptional characteristics of the New Zealand HVDC scheme were recognised in March 1962 by the Swedish Royal Academy of Engineering Sciences. The Academy invited Arthur Davenport, the General Manager of the New Zealand Electricity Department, to Stockholm to deliver the prestigous Axel Ax:son Johnson Lecture and receive a plaque "for outstanding achievement in the application of engineering science research in the service of mankind". This was a very significant tribute to the engineering profession in New Zealand.

In 1990, the Institution of Professional Engineers New Zealand, recognised the original HVDC scheme as a very important part of New Zealand's heritage. The citation recognises that with its rating of 600 MW, 500 kV, the link was the world's first major undersea power cable link.

The interconnection of the two islands has proven to be an outstandingly successful project and of enormous value to New Zealand. Latta's vision has been fully realised.

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A Synergistic Approach to the Recording, Interpretation and Conservation of a Built Environment

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Summary
The heritage of a built environment is a legacy left to us by successive generations of engineers, architects and contractors, using a combination of skills. Progressive legislation, recently introduced in the Republic of Ireland, has re-defined the heritage of the built environment and promises to provide improved levels of protection for a broad range of heritage, including engineering, industrial and architectural. The authors suggest that a synergistic approach to the recording, interpretation and conservation of this heritage is more appropriate than individual groups working in isolation. The authors review the nature and extent of the heritage of the built environment in the Republic of Ireland and examine the methods currently being employed to record, interpret and conserve such heritage.

1 INTRODUCTION

A built environment may be defined as the accumulation of the results of man's interaction with his natural surroundings. Lasting monuments to the skill of our ancestors are evident in the multiplicity of elements which make up our present built environment. These elements have frequently been grouped to form human settlements, industrial sites, or transportation networks.

Synergism, the interaction or co-operation of two or more organisations to produce an enhanced effect compared to their separate efforts, is derived from the Greek word *sunergos*, meaning working together.

In a country such as Ireland, with a small geographical area and limited indigenous resources, the need to avoid duplication of effort is therefore of some importance.

Elements of the built environment have, in the past, been categorised for convenience, and the understanding of their historical significance has often become the preserve of specialist historians working in relative isolation. Thus, we have industrial archaeologists, architectural historians and civil engineering historians, each concerned with different aspects of the same built environment. A synergistic or co-operative approach to the recording, interpretation and conservation of the best elements of this built environment is, it is suggested, desirable and ultimately more productive.

Although personal contacts between professional historians are vitally important, it is suggested that future co-operation should be formalised on an inter-institutional basis.

New heritage legislation, recently introduced in the Republic of Ireland, promises to provide the catalyst, which it is hoped will result in the development of a more synergistic approach to the study of all aspects of the heritage of the built environment in the country.

2 HERITAGE LEGISLATION

2.1 Early Legislation

Until recently, the Local Government (Planning & Development) Act of 1963 obliged each planning authority to maintain a development plan for its area, setting out certain mandatory development objectives. Local authorities were thus able to provide a limited degree of protection for designated structures in formulating their development plans. In general, structures included in the so-called 'List 1', were those for which preservation was considered essential. For those in 'List 2', preservation would be considered only if and when a planning application was made (usually too late for an informed opinion regarding historical significance to be communicated to the relevant authorities). 'List 1' generally contained sites of early archaeological significance (up to 1700) and rarely included more utilitarian structures such as bridges, waterways and industrial buildings.

In any event, planning authorities were, under no statutory obligation to list structures, and, probably even more importantly, there was no obligation on the part of an owner of a listed structure to maintain it. Neglect of a listed structure was not an offence punishable by law.

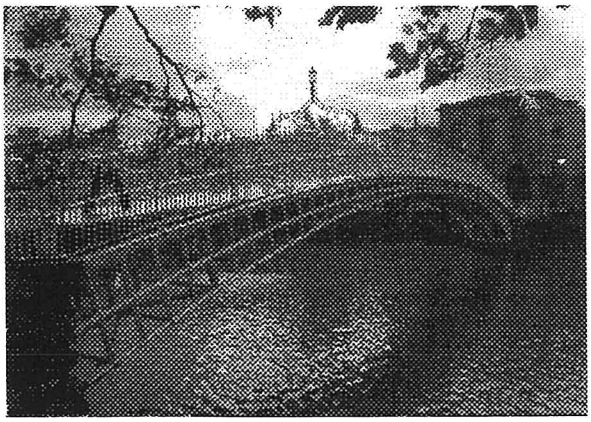

Fig 1 Liffey Footbridge, Dublin

Between 1930 and 1994, there was also a series of National Monuments Acts, which provide for a Register of Historic Monuments, mostly of medieval or earlier date. In the case of a minority of structures considered to be of national importance, a government minister is empowered to make a preservation order.

A National Heritage Council was established in 1988 as a non-statutory body operating under the Office of the Taoiseach (Prime Minister). It *"formulated policies and priorities for the preservation and enhancement of Ireland's heritage."* The Council's areas of responsibility included architecture and certain inland waterways, but it's brief was by no means comprehensive. However, some funding was obtained from the Council in 1988 to enable a start to be made on the recording of civil engineering heritage sites and the establishment of a National Engineering Heritage Database. This project received further funding in 1991. The National Heritage Council also contributed in 1991 to a survey of the industrial archaeology of Cork city and its environs.

2.2 Local Government (Planning & Development) Act 1999

Mounting pressure from conservation groups, and a growing public awareness of the value of our extant built heritage has resulted in a major change in government attitudes towards the study and appreciation of this heritage.

In December 1994, the government, in a major policy document, entitled *"A Government of Renewal"*, stated its intention to *"improve the protection for listed buildings, including placing the system of listing of buildings on a statutory basis and introducing incentives for proper upkeep and maintenance."* It was also intended to *"undertake a full national architectural audit."*

In the following March, an inter-departmental working group was set up to advise the Minister for Arts, Culture, Gaeltacht & The Islands and the Minister for the Environment on ways of implementing this policy. In its report, *"Strengthening the Protection of the Architectural Heritage"*, published in June 1996, it was envisaged that *"all facets of the architectural heritage, including areas such as industrial archaeology and vernacular architecture"* would be addressed. The planning authorities were consulted and the existing heritage legislation of Northern Ireland and Scotland was also examined.

Significantly, architectural heritage was defined in much broader terms than hitherto and was deemed to include *"all structures, buildings and groups of buildings, including streetscapes and urban vistas, which are of historical, archaeological, artistic, engineering, scientific, social or technical interest, together with their setting, attendant grounds, fixtures, fittings and contents."*

The main recommendations in the report (which have been reflected in the subsequent Act) were:

- Legislation for the preservation of architectural heritage should stay principally within the Planning Code which, with appropriate amendments, should operate alongside complementary legislation, such as the National Monuments Act and the Heritage Act;
- Listing should remain a function of planning authorities and should be a mandatory and statutory function of such authorities;
- Buildings should be listed in their entirety, including interior and curtilage;
- National inventory of architecture to be completed and given legislative recognition;
- Heritage should be categorised as being of Regional, National or International importance; and
- Financial and tax incentives should be provided for preservation of heritage.

The new Local Government (Planning and Development) Act 1999 recognises that the existing protection for our built heritage under the 1963 Act was not sufficient. The new Act, which came into force on 1st January of this year (2000), provides the necessary support legislation to oblige and facilitate local authorities in the protection of their designated heritage items.

The Department of the Environment, whose minister was the chief promoter of the new planning and development legislation, played a key role in ensuring that all aspects of the legislation relating to the recording, interpretation and conservation of the built environment were fully understood by, and acceptable to, local government and planning authorities. However, responsibility for formulating heritage policy lies firmly with the Minister for Arts, Culture, Gaeltacht & The Islands. The Act, in general, provides the mechanisms for the successful implementation of that policy and increased protection for the heritage of the built environment.

2.3 Heritage Bodies

The Heritage Act of 1995 established the Heritage Council, as an independent, but statutory, body with the following remit:

"To propose policies for the identification, protection, preservation and enhancement of the national heritage, including....architectural heritage" and to "promote interest, education, knowledge and pride in, and facilitate the appreciation and enjoyment of the national heritage." In this role, the Council advises the Minister for Arts, Culture, Gaeltacht & The Islands on all heritage matters.

The Heritage Council is in the process of compiling a national list of 'buildings at risk' in an effort to identify which structures of national importance are under threat and deserving of funding for conservation.

What is of interest for all those involved in the conservation of the built environment is the schedule of building types being used. This includes structures associated with transportation networks, such as roads, canals, railways and airports, as well as dams and harbours - all clearly elements of civil engineering heritage. Industrial heritage is represented in the schedule by water mills, windmills, tidal mills, and buildings associated with a range of industries, for example brewing, distilling, and electricity generation. Last, but by no means least, most of the building types listed may be considered as part of our architectural heritage. It can thus be seen that a co-operative or synergistic approach to the recording, interpretation and eventual conservation of the built environment (as

defined above) would appear to benefit all those involved - the industrial archaeologist, the civil engineering historian, and the architectural historian.
However, at the same time, civil engineering heritage should not be confused with industrial heritage (also referred to as industrial archaeology) which deals with all aspects of the history of technology and surviving evidence of industrial activity. Nor should it be confused with architectural heritage, an area where different assessment criteria apply and much emphasis is placed on the artistic and aesthetic qualities of a structure.
The Heritage Council recognises that there are close links between heritage conservation and sustainable development. The concept of sustainability offers the built and natural heritage something much more than can be offered by static preservation.

2.4 National Inventory of Architectural Heritage

Towards the end of 1998, the Department of Arts, Culture, Gaeltacht & The Islands (DAHGI), in accordance with the government's Action Plan for the Millenium, initiated the preparation of a National Heritage Plan, the aim being to *"develop a national plan for the protection, conservation, management and presentation of the natural heritage, the architectural and archaeological (movable and immovable) heritage, the inland waterways of the State, and documentary and archival heritage."* The DAHGI is responsible for heritage policy, the National Inventory of Architectural Heritage, and for guidelines on listing and work on listed buildings.
A National Architectural Inventory was commenced by the Office of Public Works (OPW) in 1990 as a consequence of the signing by the Irish government in 1985 of an European Union initiative for the protection of Europe's architectural heritage (the Grenada Convention). Whereas the aim of the Archaeological Survey of Ireland was to provide a Sites & Monuments Record for all sites dated prior to 1700, the aim of the National Inventory of Architectural Heritage is to provide a detailed listing of all post-1700 structures. A database is maintained of buildings (structures) of architectural merit in various towns in Ireland. To date, some 30 towns have been surveyed.
Dúchas - The Heritage Service, established in December, 1997, is the State body responsible for the protection and conservation of Irish natural and built heritage. It operates under the aegis of the DAHGI and has now been given responsibility by the Minister for the completion of the National Inventory of Architectural Heritage begun by the OPW.

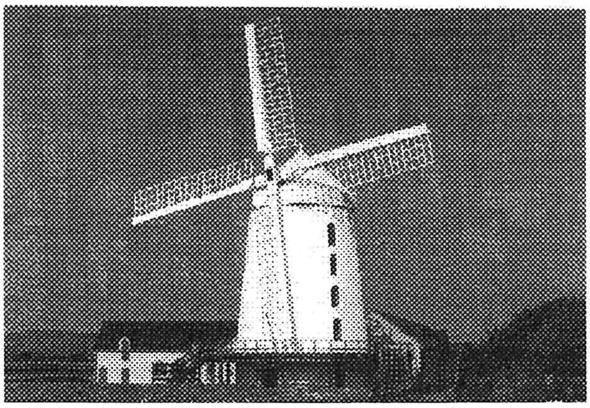

Fig 2 Blennerville Windmill, Tralee

3 CIVIL ENGINEERING HERITAGE

Civil engineering heritage may be defined as the surviving works of past generations of civil engineers. Until the creation of the separate discipline of mechanical engineering in the mid 19th century, civil engineering, as distinct from military engineering, encompassed all engineering work. Thus historically, civil engineering may be interpreted in the broadest sense to include structures built in support of industrial development and extractive industries, including power generation, as well as transportation systems and public health works.
In order for local government and planning authorities to identify, and list for conservation, elements of civil engineering heritage, it was first of all necessary to understand their local and national significance. This could not be achieved without a nation-wide survey

and the establishment of a database within which comparisons could be made of the relative importance and landmark value of individual or groupings of heritage sites. Landmark value has always been regarded by civil engineering historians as of great importance in any studies of the historical development of civil engineering design and construction methods. Ireland, although never industrialised to anything like the same extent as Britain has, nevertheless, played a part in such development.

The approach to the recording of civil engineering heritage has developed in a somewhat different way from that adopted by industrial archaeologists. This has, to a large extent, been influenced by the resources available and the way in which the now wider interest in civil engineering heritage has grown only slowly over the years.

Efforts have been concentrated on recording the extant heritage, and less on what existed in the past. For example, the history of a timber bridge is interesting, but it is difficult for the general public to relate to something which no longer exists. Industrial heritage surveys, on the other hand, like architectural heritage inventories, tend to be all embracing, albeit concentrating, in the first case, on the extant remains of industrial sites and, on the other, on the exterior and interior of buildings, including vernacular architecture.

Major transportation routes, such as canals, railways and roads, are, by their nature, linear features and may extend for many miles. The recording of such features cannot be regarded as solely the recording of a number of individual elements, such as locks, station buildings or bridges. In order to understand the historical or landmark value of such a civil engineering project, it is necessary to consider the concept, survey, design, construction and maintenance of the project in its entirety. It is, of course, possible, and in fact desirable, to single out particular elements in the transportation route for special attention, e.g. a major bridge of some landmark value, such as largest span, first use of a particular material, only example in the area, etc. This is vital for the assessment of the importance of items deemed worthy of conservation. Realistically, only a few structures will attract public (or private) funding for their conservation and/or restoration, thus it is even more important that the assessment is founded on sound historical facts and expert opinions.

The recording of civil engineering heritage in Ireland has until now been carried out in a subjective way and has not been all embracing. Nevertheless, map studies have been carried out for the whole country and each county has been visited at least once during the field recording work associated with the project. All significant transportation routes and associated infrastructure have been surveyed and their elements recorded. This subjective approach was necessitated by the limited resources available for field work, but this was offset to a large extent by access to expert local knowledge in the engineering departments of local authorities.

Fig 3 Lucan Bridge, Dublin

A National Engineering Heritage database has been in existence foı a number of years and is updated and expanded on an on-going basis.

The recording methodology adopted was similar to that employed by the Panel for Historical Engineering Works (PHEW), an activity of the Institution of Civil Engineers (London), but the criteria used were modified somewhat before being applied to the Irish situation.

The setting of such criteria is always the subject of great debate amongst engineering historians and the wisdom of selecting a particular item or site for further study was of necessity bound to be somewhat subjective at the outset of the project. Nevertheless, it was possible to lay down a number of criteria which were deemed to be appropriate to the local conditions. The recording methodology and selection criteria are discussed in COX & GOULD (1996).

This selective recording of the Ireland's civil engineering heritage led to the publication of *Civil Engineering Heritage : Ireland* (COX & GOULD, 1998)

4 INDUSTRIAL HERITAGE

4.1 Extant Heritage & Conservation

The essence of industrial archaeology is the study of the material remains of past industries - our industrial heritage. Industrial heritage is seen as including sites and machinery relating to extractive industries (e.g. mines and quarries), manufacturing (e.g. corn and textile mills), service industries (e.g. water, gas , electricity), power (windmills, watermills, steam engines) and transport and communications (e.g. roads, bridges, railways, canals, harbours, airfields). Again, the definition of industrial heritage overlaps in many ways with civil engineering heritage as defined by the PHEW.

The potential for Ireland to industrialize in the 18th and 19th centuries was never realised. While the greater part of Ireland never experienced the changes which industrialization wrought in many European regions, industries of both national and international significance did become established. In real terms, Belfast (now within Northern Ireland) was the only Victorian industrial city on the island; the economic fabric of both Dublin and Cork was essentially commercial rather than industrial. Small pockets of dispersed industrial activity became established near the ports and larger country towns, such as Dundalk, with varying degrees of success, but overall this patchwork of industry can in no way be characterized as large-scale industrialization. Ireland's predominantly agrarian society also presents rather different challenges to Irish industrial archaeologists in regard to defining the relationships between the pre-industrial elements of the 18th- and 19th-century Irish landscape and those associated with Irish industry, especially as industry was not the dominant activity in many parts of Ireland well into the 20th-century

There are around 100,000 sites and monuments of industrial archaeological interest on the entire island of Ireland. The largest single grouping comprises agricultural and industrial lime-kilns, but transportation networks, such as sections of the inland waterways and railway systems can also be considered industrial archaeological sites in their own right. In general terms, the single most important facet of Irish sites is the high level of preservation. Large numbers of early industrial buildings have survived in Ireland within the immediate environs of its larger towns.

Unlike the surveys carried out within Northern Ireland (GREEN,1963; McCUTCHEON,1970), the only industrial archaeological surveys carried out within the Republic of Ireland have been those (of a preliminary nature) covering a number of counties, carried out in the 1970's for the National Institute for Construction Research & Planning (An Foras Forbartha) by Bowie and Courlander, and the more recent more detailed surveys of county Kilkenny (HAMOND, 1998) and the city and county of Cork (RYNNE, 1999)

In the absence of statutory protection for industrial archaeological sites up until the enactment of recent legislation, a building had to demonstrate strongly that it could be adapted for modern use to ensure its continued survival. In normal circumstances this had an important bearing on planning decisions. However, even with improved protection afforded by the new legislation, the extent to which the planning authorities will be prepared to force developers to adapt existing buildings, rather than allowing them to demolish and build anew, is another matter. Regardless of its state of preservation, a prospective developer may be reluctant to adapt an historic building when the option to demolish is available, if they can demonstrate that the building is manifestly unsuitable for the planned purposes. A stipulation to have an 'archaeological record' (generally unspecified) made of the building before demolition is often the only avenue open to the planning authorities, unless a government agency such as Dúchas takes a firm stand. The de-commissioning of public utilities and components of the public transport system also present special problems, in that many of the decommissioned elements, such as waterworks, electricity generating stations, railway stations and so forth, will themselves be of interest to both industrial archaeologists and civil engineering historians.

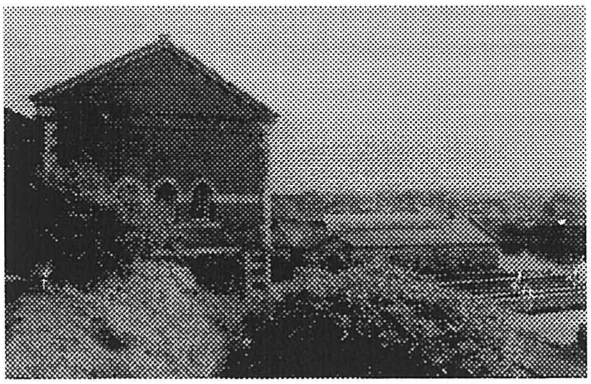

Fig 4 Lee Road Waterworks, Cork

Water distribution networks will generally be controlled by either municipal or county authorities, but there are, at present, no policy guidelines on their recording, conservation or adaptation. Similarly, the ESB (The Electricity Supply Board), Iarnród Éireann (Irish Rail) and the Defence Forces are not statutorily obliged to heritage manage the sites of industrial archaeological interest under their control.

As with all historic buildings, those associated with industrial heritage sites require extensive research to provide a detailed outline of their development through time. Extensive recording of the surviving fabric is necessary, in order to facilitate conservation and repair work. Rarely, however, is such research undertaken for such structures, as traditionally they have not been seen as important as sites of other periods of industrial activity. For conservation and repair work on most historic buildings before 1700, the consent of Dúchas is necessary. There are, however, no firm statutory guidelines on how such works should be undertaken.

4.2 Recording of Archaeological Heritage

In Ireland Dúchas acknowledges three levels of recording. They are:

Level One: A basic 'paper survey' identification of sites of probable archaeological interest using ordnance survey maps, aerial photographs, etc., which may or may not be supplemented with a survey of secondary documentary sources. This information is generally used to compile a Sites and Monuments Record (SMR), which consists of a printed list of archaeological sites and monuments. This is accompanied by a series of control maps; upon which the sites are carefully marked and numbered (normally on 6-inch OSI (Ordnance Survey Ireland) maps, although urban archaeological surveys and industrial archaeological surveys require 25-inch maps for control purposes).

Level Two: Using the data compiled from a level one appraisal, the site is visited, detailed written descriptions are made, basic dimensions are taken and a photographic survey is made. In most cases secondary documentary sources only are consulted. This data is considered sufficient for compiling an inventory account, which forms the basis for the Dúchas published inventories.

Level Three: A large scale instrument survey of the site is made in order to produce plans, sections and elevations, at scales dictated by the extent of the surviving, buildings, earthworks and so forth. Interior features such as decoration and machinery are also drawn and photographed in great detail, at appropriate scales. Primary documentary sources such as surviving title deeds, business records, auction notices, and valuation survey notebooks, are all consulted to produce a comprehensive account of the physical development of the site. Under normal conditions, surveys of this type are generally carried out, either to facilitate archaeological excavation and general research, or for site management purposes, such as conservation or repair.

For most works involved in the adaptation for modern purposes of an industrial building of archaeological significance, recording to level three will be necessary. Even if the work requires only partial repair to part or parts of the existing structure or structures, a full archaeological survey of the building to level three standard will be required.

The Industrial Heritage Association of Ireland (IHAI) was formed in 1996 to foster a greater awareness and appreciation of Ireland's industrial legacy, both North and South. The aim of the IHAI is to promote a nation-wide inventory, survey and record of all industrial sites.

5 ARCHITECTURAL CONSERVATION

To the conservation architect, the conservation and protection of the built environment presents a number of challenges, which clearly distinguish it from the more mainstream effort of maintaining buildings and landscapes of particular architectural significance. In recent years, there has been a growing realisation of the cultural value of this inheritance.

The surviving remains of past industries and communications range from products of basic engineering, modest, but often in a well-built vernacular style, to structures which embody engineering and design innovations unique to their era. The most ambitious or prosperous industries erected buildings of substance and up-to-the-minute style, emulating the taste of their bankers and stakeholders. Even simple urban warehouses could wear the stylish ornament of main street commerce.

6 A SYNERGISTIC APPROACH

A synergistic approach to the recording of the built environment is evident on an examination of the various inventory schedules currently being used. The national inventory of architectural heritage includes most, if not all, those elements of the built environment of interest to civil engineering historians and industrial archaeologists, as well as satisfying the requirements of architectural historians and conservationists.

A specific example of the increasing synergistic approach to heritage conservation is contained in the Heritage Council's recently published policy document on the future of Ireland's inland waterways. (HERITAGE COUNCIL, 1999).

The overall aim is stated thus:

"The inland waterways and their corridors should be developed in an integrated broad-based way, conserving where possible their built and archaeological heritage features and protecting their unique ecological systems, to enhance the enjoyment and appreciation of that heritage now and for future generations."

This recognition of the importance of conserving the best features of the built environment of inland waterway corridors is in marked contrast to previous more narrowly defined approaches, such as the maintenance of navigation or the protection of wildlife habitats.

A new waterways body, hopefully to become a cross-border merger of the Waterways Division of Dúchas-The Heritage Service with the Rivers Agency in Northern Ireland, should have responsibility for co-ordinating the functions of all departments and agencies involved in the management of Irish inland waterways. It should also have professional staff to look after strategic planning, navigation and engineering, planning and development, natural and man-made heritage, education, promotion and marketing.

The built environment of Irish waterway corridors includes structures of interest to a range of heritage study groups. Civil engineers designed and supervised the construction of the canal and river navigations and left behind monuments to their professional skills.

Many industries were dependent on the waterways for the movement of raw materials and finished products. The architectural value of the major aqueducts and bridges is well recognised.

Recording methodologies and schedules of structures used by industrial archaeologists, civil engineering historians, and architectural historians exhibit many similarities. It is envisaged that the data from the various regional and national surveys of the elements contributing to the built environment, currently underway, or proposed, may prove equally beneficial to all those working in the area of heritage management of the built environment.

7 CONCLUSIONS

The built environment in Ireland has been defined as the accumulation of the results of man's interaction with his natural surroundings. The heritage of the built environment handed down to us is an amalgam of the efforts of successive generations of engineers, architects and contractors, using a combination of skills.

The study of this heritage has been undertaken over recent years by a number of professional and amateur historians and several publications have ensued from their research.

There is now a greater public awareness of the value of our heritage and a desire to know more about the achievements of our ancestors and the history of the structures, which contribute to the present built environment.

Closer co-operation between researchers (industrial archaeologists, civil engineering historians, and architectural historians) has led to an enhanced body of knowledge and a greater appreciation of the heritage of the built environment within the country.

Vastly improved planning and development legislation has recently been enacted and promises to provide for greater protection and conservation of the heritage of the built environment.

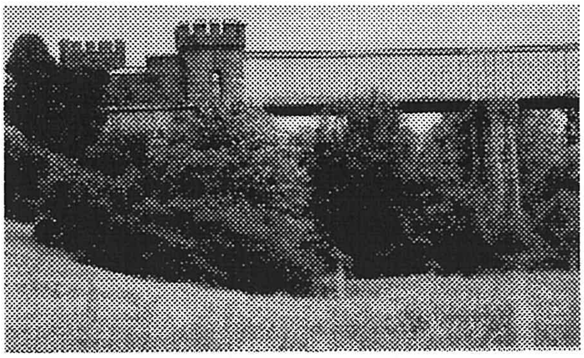

Fig 5 Cahir Rail Viaduct, Cahir, Co.Tipperary

As with our cultural and natural environment, the built environment can enrich our lives, but only if we can learn to appreciate its richness and diversity. This can only come from a better understanding of the historical significance of the various elements making up that environment.

A synergistic approach to the recording, interpretation and conservation of the built environment can aid that process.

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A history and development of fire and life safety in Australia

ANDREW J ELLIS BE (Mech), Grad IEAust, Grad AIRAH

Many of us grew up wishing that we could be a fireman when we were older. However, as the time has passed, most of us have moved on from that childhood dream and chosen another profession to follow. Still, there are those few who have chosen a career in the area of fire and life safety. The work of a fire engineer is full of excitement and challenges with many stringent code requirements demanding consideration in every single design solution.

The aims of a fire and life safety package are twofold. First and foremost is the protection of people from fire and smoke - also known as life safety. Secondly, it is important to minimise damage to buildings, their surrounds and everything contained therein.

Today, there are many aspects of a fire services package, each with an important place, in the protection of life and equipment. The Building Code of Australia and assorted Australian Standards call upon tools such as sprinklers, hydrants, hose reels, extinguishers, smoke exhaust fans, building occupant warning systems, smoke and heat detectors to be used. They also address items such as fire compartment sizes, structural integrity and paths of escape or egress from the building. All of these things form part of the fire services package.

The fire and life safety package is always individually tailored to meet the application. For example, offices, prisons, shopping centres, hotels, hospitals, apartments and factories all have different needs and requirements depending on size, classification and construction.

We have much to learn from our past tragedies. This paper addresses the code current requirements and considerations of a fire and life safety package in the light of these past tragedies and developments.

1. INTRODUCTION AND SCOPE

This paper serves as a kind of basic introduction to the profession of fire engineering, looking at the many tools available to the fire engineer in designing a building to be "fire safe". The paper considers some of the early disasters and lessons learnt in and through Australian fires.

The paper focuses on fire services in commercial buildings, and does not consider domestic or bushfires. Examples are mainly taken from Adelaide, South Australia where the author has spent most of his life.

This paper refers to many codes and standards. This is not intended to form a design brief and the author strongly urges that the Building Code of Australia and Australian Standards be read in conjunction with this paper.

2. DEFINITION AND NOTES

Abbreviations:

FIP - Fire Indicator Panel

BCA - Building Code of Australia

AS - Australian Standard

NZS - New Zealand Standard

l/s - litres per second

kPa - kilopascals

SAMFS - South Australian Metropolitan Fire Service

Definitions

Prescriptive design approach - designing items which form part of a system to a set of given requirements. For example, the number and spacing of extinguishers is identified in AS2444 for a certain type of hazard and sized area.

Performance based design approach - designing (usually) a total system to a certain set of key parameters, but with the freedom to select an overall best solution for the money spent and performance required.

Classification - a building is classified under the BCA according to its type of usage. For example, offices, homes, underground car parks, schools, hospitals and restaurants are all classified differently. The classification determines many of the requirements for fire protection.

Notes

Throughout this paper, the Building Code of Australia and Australian Standards have been referred to. In some cases the Australian Standard and New Zealand Standard are one and the same document, however, there are other areas where the Australian and New Zealand standards and building codes may differ

3. A HISTORY OF FIRE FIGHTING IN AUSTRALIA

"The drama and danger of a blazing building always draw the crowds and when the Old Government House burned in January 1841 they came running from all over Adelaide.

There was no hope of saving the building because it was constructed from sun-parched pinewood and roofed with thatch. It made an exciting spectacle as flames and sparks gushed up into the hot summer night."

Interestingly, one of the earliest fire engines reported in Adelaide was a horse-driven cart lodged at the Mounted Police barracks in 1845. It was used by the police, since there was then no fire brigade. Whenever a fire broke out, a messenger would have to run to the police barracks, where the police would harness the horses and prepare to go to the fire. Such was the nature of the fire engine that the officers could not ride on it, but rather had to run alongside of it. Where today's fire engines and fire brigades will generally respond to a fire within ten minutes, in the earlier days it normally took in excess of thirty minutes. Newspapers of the time applauded the police for their prompt action, however, they were rarely present early enough to save a building from total destruction.

Such was the life of the early colony in Adelaide (and indeed the other major cities also). The people lived with fire - open fires for cooking and heating, candles for light, steam powered mills with furnaces and boilers, blacksmiths forges and so on. Fire was a necessary part of life even though its danger was obvious.

Figure 1: Fire!

One fire worth noting occurred at the Wyatt Street Cold Stores in Adelaide early this century. Such was the time of year that the cold stores had much meat and apricots in storage at the time. This multi-storey cold store kept the apricots on a higher floor than the meat. When the building burnt down, the apricots melted, soaked through the wooden floor boards and ran through the bags of meat, giving it an apricot smell and taste. The damage done was quite massive and took many dollars and months to rebuild. Fortunately, the fire took place out of normal business hours and no one was harmed. This fire was typical of many where the wooden buildings were no match for the fire.

Modern day design considerations

In the world of fire engineering we have learnt much from our predecessors about ways of protecting ourselves from fire and there are continual developments. Items which the fire engineer must consider in the light of a total fire services package for a building are discussed in the following section.

4. FIRE SERVICES EQUIPMENT AND INFRASTRUCTURE

There are a number of elements which make up the fire services package of a building. These can be classified as follows:

	Automatic	**Used by general public**	**Used by fire-fighters**
Detection / warning systems	Smoke and heat detectors	Manual call points	FIP (to locate)
Fire-fighting systems	Fire dampers, smoke spill/exhaust fans, sprinklers, fire pumps	Hose reels, extinguishers, fire blankets	Hydrants, boosters

It could also be argued that there are other more passive elements which contribute to the fire protection of a building. In current building practices, it is normal to construct buildings of materials which reduce the spread of flame and fire. For example, plasterboard and brick are much better at restricting growth of a fire compared to the wooden buildings which were much more common earlier this century. Air conditioning systems can also be used to prevent the expansion of a fire.

We will now discuss each of the above measures and their reasons for use.

Smoke and heat detectors

There have been many advertisements on television lately calling for the use of smoke detectors to be fitted in our homes. Their use is in the early detection of smoke to warn people of the eminent danger of a fire. Domestic smoke detectors can be fitted quite cheaply, with battery operated detectors available from hardware stores for under $20. Larger buildings often make use of detectors connected together in zones, which are linked back to the FIP giving fire brigades a more exact indication of the location of the fire. In a domestic setting the detector beeps loudly when it is set off. In a commercial or industrial setting the detector sends a signal to the FIP and will often initiate the building occupant warning system.

Heat detectors are used in various places in larger buildings, sometimes in plant rooms, switch rooms, etc.

Manual Call Points (MCPs)

Manual call points are easily recognised as a small red box mounted on the wall, usually adjacent to the fire exit or stairwells and paths of egress. They are operated by a person walking past hitting it to break the glass and set it off. MCPs are generally used in larger buildings and will send a signal to the FIP to set off the building occupant warning system in much the same way as detectors will.

Fire Indicator Panels (FIPs)

The FIP is perhaps one of the most important aspects to a fire services package as it enables the fire brigade to quickly and accurately locate a fire. FIPs are normally located close inside the main entrance of a building, perhaps inside a clearly marked cupboard. Occasionally in large hospitals or shopping centres, the FIP is located inside its own room with other fire and emergency control equipment, drawings and layouts of the site.

The FIP lists the different fire zones on the site with a red light indicator for each. When a detector or MCP in a zone is activated, the red light on the FIP illuminates indicating the location of the fire. A signal is sent to initiate the building occupant warning system, an alarm which rings throughout the building to warn its occupants. In larger and more complex systems, often times a signal can be sent direct to the local fire station, upon which they will react immediately.

Fire dampers

Australian Standards for the use of fire dampers have been in existence for more than 25 years and their use is widespread through mainly multi-storey buildings and hospitals. They are used in air conditioning duct work where the duct penetrates a wall or floor from one fire compartment to another. They serve as a barrier to reduce and hopefully stop the spread of fire from one fire compartment to another.

Smoke dampers

Interestingly, the smoke caused by a fire is usually more deadly than the flames. Smoke dampers are similar in principle and operation to fire dampers, however, they act to reduce the spread of smoke throughout a building. Again their use is mainly in multi-storey buildings and hospitals where required by the building code or standards.

Smoke spill and exhaust fans

The use and role of (major) air conditioning systems will be discussed later in this paper, however, it is worthwhile noting at this point that there are times when smoke spill and smoke exhaust fans and systems are required by the codes and standards. This is often the case in larger shopping centres, stadiums and hospitals. The design and installation of the smoke spill / exhaust system can be quite complex as the duct work and fans usually need to be specially made for high temperature air and smoke.

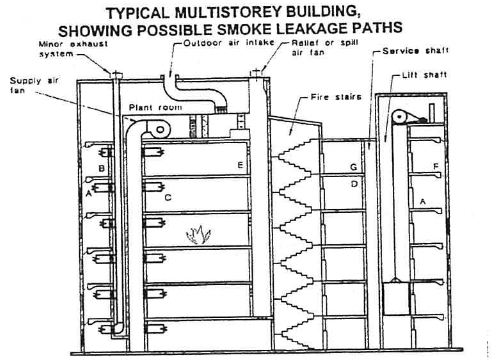


Figure 2: Smoke leakage paths

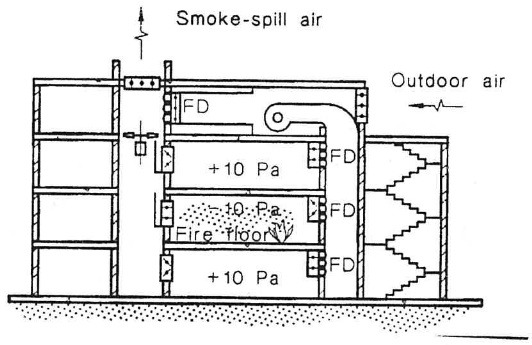


Figure 3: Smokespill fans and arrangement

Sprinklers

Sprinklers are perhaps the most well known and widely recognised of all the fire services equipment used. Sprinklers are used in medium to large sized buildings to extinguish fires. They are activated individually when the temperature beneath the sprinkler reaches a point high enough to burst the bulb, allowing water to flow through. Sprinklers usually require a high amount of piping and other infrastructure which can make a fire sprinkler system quite expensive. Whenever a sprinkler is activated and a pressure drop is sensed in the pipe line, a signal can be sent to the FIP and also to the fire pumps for them to start. Infrastructure including fire pumps will be discussed in the next section.

There are many different kinds of sprinklers used including exposed, concealed and sidewall. There are domestic, commercial and industrial types with different flow and spray characteristics for all applications.

Fire pumps and mains water

Often times in large buildings, the mains water needs to be pumped in order to meet the pressure requirements at the furthermost point. Different types of fire pumps are used and include jacking, electric and diesel. In the event of a fire the control system would initially turn on the electric pump to pump water through the sprinkler and/or hydrant system to the fire. If the electric pump fails to turn on - possibly caused by a mains power outage - the diesel pump will turn on and operate. Both pumps are capable of the same duty The jacking pump is usually much smaller and cycles on and off to maintain the pressure in the system when and where small flows are used - for example, the use of one hose reel.

Depending on the size, location and type of the site, the fire mains may be arranged quite differently. On smaller sites, the fire mains are taken directly from the mains water in the street. Large site like hospitals and universities often use a ring main which is supplied from two or more sides of the campus. In the case of an emergency/fire where one of the water supplies is cut off the other is able to meet the required demand.

Fire hose reels

Fire hose reels are generally located throughout most medium to large sized buildings. Their use is intended mainly for bystanders to try and put out small fires before they take hold. Hose reels give a bigger coverage than (water type) fire extinguishers and can be used for much longer given the "unlimited" supply of water. Unfortunately, they are perhaps the most misused of all fire services equipment, with some people using them for hosing and cleaning car parks, etc or being played with by children and teenagers.

Fire extinguishers (and blankets)

Extinguishers are perhaps the best known tool used to fight (small) fires and are used domestically, commercially and industrially.. They are generally used by one of the bystanders shortly after a fire starts rather than the fire brigade responding to the incident. Extinguishers range in type and size depending on the type of hazard present - for example water or carbon dioxide extinguishers are used in offices where the main hazards are for either paper or electrical fires. Clearly, the water extinguisher would be used on the paper fire (eg files) and carbon dioxide on an electrical fire (eg computer or switchboard).

Other types of fire extinguishers include chemical, foam, powder and halon which may be used on fire hazards such as oils, fats, flammable gases and liquids and the like.

Fire blankets are generally used in kitchens and serve as a rather cheap, effective tool against small fires.

Fire hydrants

Fire hydrants are used primarily by the fire brigade on large fires where a large amount of water is required. The fire brigade, with their hoses, are able to deliver 10 l/s of water compared to much less than 1 l/s from a hose reel. The pressures used through the hydrant is very high. Different states and regions have different requirements. For example, the SAMFS is able to deliver water at 10 l/s and 350 kPa or 5 l/s and 700 kPa when boosted.

Air conditioning systems

Ducted air conditioning systems form one of the greatest potential dangers in a fire. Depending on their design and use, they have the ability to spread or remove smoke from a building, to greatly increase or decrease the likelihood of danger to people. AS1668 part 1 (1998) describes the new code requirements for fire and smoke control for use mainly in multi-storey buildings. The code looks at the use of fire and smoke dampers, heat and smoke detectors in the air handling units and ducts and smoke exhaust.

Much has been learned of the role of air handling systems since the 1970s. In 1980 it was said "For many years safety regulations have required that plant be shut down and fire dampers be closed when fire is detected in a building. It was hoped that this action would retain heat and smoke within the fire compartment. Experience has demonstrated that this practice builds up the pressure differential between the fire compartment and adjoining compartments and forces the flow of heat and smoke through openings and shafts for services and up lift shafts and stair shafts. This uncontrolled flow of smoke has required complete evacuation of buildings during relatively minor fires and has resulted in multiple fatalities."

The use of fire and smoke dampers may be used in air conditioning systems, and their use has already been discussed.

Maintenance of fire services

Historically, one area where cost cutting has been made in businesses has been in the area of regular maintenance to plant and equipment. Fire services plant and equipment has not been exempt of this. Through reduced maintenance, the reliability of the equipment generally decreases.

Australian Standards exist which define the required maintenance procedures for fire protection equipment. They cover maintenance of each item listed in this paper including air handling systems, extinguishers, hydrants, sprinklers and detectors.

5. RECENT INNOVATIONS

Three notable areas where recent innovation has taken place include computer modelling of pipe flow calculations, communications technology and in the area of air handling systems under fire conditions as demonstrated by the recent re-issue of AS1668 Part 1.

Hyena is a computer program used for water pressure and flow calculations which has been developed by ACADS/BSG - an industry body which has introduced many computer programs as design aids in the building industry. The current revision of the program is DOS based and can be programmed with all of the components of the piping system to analyse the flow and pressure drop through different fittings and loops, sprinklers and orifice plates. Hyena is also used to determine the pump characteristics required for the flow and pressures needed.

Communications technology has enabled direct wiring of alarms to the local fire service. The ability of a FIP to receive a signal from the detectors, MCPs or sprinklers has already been discussed. The FIP can also send a signal further on through a phone line to the fire brigade enabling prompt response. Such technology has existed for some time now, however, it is a vast improvement on the earlier mentioned way of sending a messenger to run to the local police station in order for a fire brigade to be sent on its way.

In 1998 a new edition of AS1668 part 1, covering fire and smoke control in multi-compartment buildings was issued. This was issued with nation wide industry training courses on its use and application. The standard calls for a more prescriptive approach in the design of a fire services package with fire engineers looking at cost effective, well engineered solutions. It covers the code requirements for smoke control, protection of openings, zone pressurisation, fire-isolated exit pressurisation, lift shaft pressurisation, system shutdown and other minor and miscellaneous requirements.

6. CONCLUSIONS

Much has been learnt of fire and life safety since the turn of this century. The tragedies of our past have contributed greatly to our current knowledge of fire and life safety.

Fortunately, we now live in a society which is much more aware of the risks associated with fire and with the methods for putting it out. This paper has moved from the past tragedies, through the current fire services equipment used, with a little of a look into the more recent advances. It is anticipated that more advances will be made in the years to come, with the ultimate winner being mankind as we live and work in buildings which are much safer than they used to be.

Our world is a much safer place to be because of the advances made in area of fire and life safety learned through and from the experiences of the past.

REFERENCES

The following books have been used in compiling this paper:

1. Standards Australia, SAA MP47 Part C1 - Fire Precautions in Buildings with Air Handling Systems, (1980)
2. SAMFS, Muscle and Pluck Forever! SA Fire Services 1840 - 1982 (1983)

Current and now superseded editions of the following standards have been used in compiling this paper:

1. AS1851 Maintenance of fire protection equipment
2. AS1682 Fire dampers
3. AS2444 Portable fire extinguishers - selection and location
4. AS1221 Fire hose reels
5. AS1670 Automatic fire detection and alarm systems - system design, installation and commissioning
6. AS1603 Automatic fire detection and alarm systems
7. AS/NZS1668 Mechanical ventilation and air conditioning code
8. AS2941 Fixed fire protection installations - pump set systems

Auckland's Electric Tramway Heritage – Celebrating 100 Years

Bruce R Gamble and Ian W Stewart
MOTAT — Auckland's Museum of Transport, Technology and Social History, New Zealand

Summary: At its inception (1899-1902) Auckland's electrified transport system was the largest municipal engineering project undertaken in New Zealand and the only large tramway in the country built by private enterprise. However, the electric tramway era in Auckland (1902-1956) has passed with little published recognition of its engineering significance. This paper traces the early conception and design. We examine the sources of engineering expertise and the problems that were solved, including project management and construction methods. The growth of the system and its impact on Auckland are described briefly. We conclude that the remaining artifacts (including the Western Springs Tramway at MOTAT), documentary archives and skills are important historical, educational and technical resources. These resources are fragile but at present there is no mechanism in New Zealand that will ensure preservation of this heritage.

1 INTRODUCTION

The advent of the "electric street railway" throughout the world heralded a solution in the long quest for an optimum form of mechanised public transport. The 1870s had seen steam-powered cable traction begin to displace the horse – a fascinating balance between high initial cost for cable technology and high operating costs for "horse-power". Punctuated by forays into steam locomotion, the 1880s was a period of intense experimentation with electric traction. It was marked by E W Siemens' demonstration in Berlin in 1879 and culminated in Frank Sprague's Richmond, Virginia system in 1887. Sprague contrived the first successful integration of four vital tramcar elements: the series-wound direct-current motor; the "wheel-barrow" motor-drive arrangement; the resistance-controller method of voltage/speed control; and the under-running trolley pole as a means of collecting current from an overhead conductor;

As the major economic and other benefits of electric traction overcame initial scepticism, the new technology blossomed. Quickly it swept aside the earlier modes. By early 1888 there were 21 electric trolley systems of the Sprague type in the USA. Within the decade there were many hundred. The first system using an overhead conductor in Europe was Leeds in 1891 (although this was preceded by a short-lived "conduit" system in Blackpool in 1885). In the UK there were 200 electric tramcars by late 1891, but 6000 by 1901.

Commercial ventures with the aim of exploiting the new tramway technology formed rapidly. The great British Electric Traction Company and its associates, among others, began to build, buy and operate systems throughout the UK and to supply tramcars and other plant. Its sights turned overseas as reports of ripe opportunities flowed back home from reconnaisance trips by engineers and others. Emile Garcke, founder of the BET, determined that theirs was an "octopus" policy: "to go into every corner... and do work which until [the BET] came was neglected."

Thus in 1899, the BET Co purchased the ailing Auckland City & Suburban Tramways (12.4 km of horse tramway), bought out the Auckland rights of the NZ Electric Light & Traction Co (a London syndicate, hastily formed to gain concessions in New Zealand for electric lighting and tramways) and incorporated the Auckland Electric Tramways Company Limited.

The Auckland Electric Tramways was to be the largest municipal engineering project undertaken in New Zealand. It was the only large tramway network built here by private enterprise. By 1904, investment in the system had reached £600,000 (about $110 million in 1999 terms[(1)]), a sum that climbed steadily over the following years – see Table 1.

The population of the Auckland isthmus in 1899 was less than 60,000, but as time would prove, the venture was a sound one in every way, despite the large investment and risks.

The rest of our paper draws on early records to show how the vision was converted into reality. We see that the process was not without political hurdles, engineering or logistical problems. These were solved predominantly by men with engineering skills. Their endeavours resulted in a large, vital and heavily-used public utility. We also describe what now remains of the Auckland electric tramway system.

We conclude that the remaining artifacts (including the Western Springs Tramway at MOTAT), documentary archives and skills represent important historical, educational and technical resources. Unfortunately the present cultural-political climate represents a severe threat to this heritage.

2 A FEASIBILITY STUDY – 1900-STYLE

One of the most important documents of the pre-electric era – what we would call today a feasibility study – has fortunately survived. It dates from 1898 when W Gentry Bingham, a representative of the NZ Electric Light & Traction Co prepared a penetrating comparative account of urban transport in the four main cities and revenue opportunities from electrification. Bingham is described as the company's attorney, but the technical fluency and detail of his report betray a tramway engineering background.

The greater part of Bingham's report dealt with Auckland – based upon the perceived high potential for traffic growth, the city's evident prosperity and the existing poor level of service. Dunedin and Wellington were also reckoned to be good candidates, but Christchurch was expected to be the least remunerative of the four.

(1) Our research indicates that after conversion to $ from £ (2:1), a factor of 90 is appropriate for escalation of construction and wage costs during the period from 1899 to 1999.

For Auckland, Bingham anticipated at least 6,000,000 fares annually (i.e. >100 trips per capita) and revenue of £50,000 (say $9 million in 1999 terms[1]). He expected to be able to reduce fares from an existing average of 3d to 2d (from $2.25 to $1.50). The cost of building the system and buying out the existing assets would be £192,000 ($34.6 million). Annual working costs were estimated to be £30,500 ($5.5 million) including the employment of 98 staff. One hundred years later, the detail given in reaching these estimates is particularly fascinating to the transport historian.

In engineering terms, Bingham's assessment translated into a system of 21.5 route-km serving Queen, Customs, Wellesley and Symonds Streets, Parnell, Newmarket and Epsom, Karangahape Road, Ponsonby, College Hill and Jarvis (sic) Road, and branches into Mt Eden and Mt Roskill. There would be 36.9 km of track (21.5 route-km) and 42 tramcars (7 in reserve), each with a capacity of 40 persons and requiring two 30-HP (22-kW) motors. The power-house, ideally to be located at the corner of Symonds St and Karangahape Rd, would have three coal-fired steam-engines (one in reserve) each of 350HP (260kW), coupled to dynamos. The overhead was to be carried on poles spaced at 27m and fed from a comprehensive set of feeder cables, those in the central area being placed in underground conduits.

It seems that the BET generally accepted Bingham's findings in making their own assessment. The initial system as built had several similarities to Bingham's draft scheme – indeed he was retained for short time by the AET Company as a consultant. As it turned out, however, the Company's plans were bolder and more heavily engineered. This was just as well, for the traffic generated quite outstripped all projections. From the very start of electric service in late November 1902, the Company became hard pressed to meet its obligations – see Table 1.

3 CONSENTS – THE LOCAL BODY HURDLES

The legal framework for the construction of New Zealand street tramways at the end of the century was the 1894 Tramways Act. This provided local authorities with powers to construct, purchase, operate and regulate tramways within their districts. The Auckland City Council had been wooing prospective electric tramway partners since 1895, amidst heated debate as to private or municipal ownership. When the time came for the Auckland Electric Tramways Co to exercise its hard-won concession, the Council was able exert leverage under the Act.

In the process of agreeing the terms of an enabling Order-in-Council and the Deed of Delegation (of its powers to the Company), the City Council, the Public Works and Post & Telegraph Departments were all able to impose significant conditions on the tramway's construction, operation and service. These included such things as: routes, hours of operation, service frequencies and fares; maintenance of the roadway; street-lighting; behaviour of passengers; licensing of tramcars, land rents and allocation of nett profits; compliance with British Board of Trade tramway regulations in regard to the use of electricity; guard wires for overhead telephone circuits; electrolytic effects; compulsory purchase by the local authorities; penalties for late construction; etc..

As if the Auckland City Council's conditions were not enough, lines beyond the City's boundary required individual negotiations with the suburban Boroughs of Parnell, Newmarket, Onehunga, Grey Lynn and (later) Mt Eden, and the Boards of the Remuera, Epsom, One Tree Hill, Mount Roskill, Eden Terrace and Mount Albert Road Districts. All, to some extent, attempted to squeeze the Company and in some cases this had engineering implications. Signing off the Deed with Onehunga, for example, was greatly protracted by the Borough's insistence on the use of steel, not timber, poles.

Several of these provisions were, in retrospect, excessive and without fundamental reason. Despite the impacts on design, and service efficiency, they were used nonetheless to keep an upper hand over the AET Company.

Of course the Company countered with unashamed lobbying In Company papers (discovered recently in an east London laundry!) we find original receipts from: the Mayor of Auckland for a "Presentation Seat for Albert Park" (£3-10-0) (say $630 today); from H E Partridge & Co (tobacconist) for "One Pipe in Case for Chief Reporter NZ Herald" (£1-17-6); from Pullan, Armitage & Co ("Livery & Bait Stables, Victoria St") for cab fares in "Calling on various Mayors & Chairmen of Districts"; from a Mr A Fisher, among other things, for "obtaining 83 extra signatures of ratepayers…" of the Remuera district (£14-10-0); and a subscription to the Liberal and Labour Federation of NZ.

Scheme promoters, engineers, politicians and the bewildered public 100 years later will recognise that not much has changed under our "modern" Resource Management Act!

Table 1: Growth of the Tramway

	Isthmus population (approx 1000s)	Routes in service (km)	No. tramcars in service	Tramcar running (1000 car-km)	Passengers carried (1000s)	Trips /capita/annum	Route-km/capita	Employees	Capital invested (£1000s)	Passenger receipts (£1000s)
Horse tramways (1902)	60	12.4	33	354	2,240	42	1:4840	110	30	20
Bingham projections	70	21.5	42	1,580	>6,000	>100	1:3260	98	192	50
1903 (1st yr of electric trams)	70	27.5	43	2,100	13,540	193	1:2550	218	550	82
1909	84	35.7	92	3,570	28,740	327	1:2350	530	690	181
1919 (ACC purchase)	140	43.5	154	5,340	43,790	312	1:3220	700	1140	300
1929 (ATB control)	170	52.5	194	9,360	59,400	349	1:3240		1600	613
1939	180	71.7	232	10,050	58,800	326	1:2510		2000	641
1944 (maximum traffic)	200	71.7	232	11,570	99,400	497	1:2790	1400	2130	1071

4 DESIGN – THE SOURCES OF EXPERTISE

The agreements between the Auckland Company and the BET included the appointment of the BET as consulting engineers. With some 30 undertakings (mainly British) under its control by 1900, the BET was well-equipped to provide such a service. There was a London group of some 60 engineers and support staff covering electrical power supply, permanent way and rolling stock. They were assisted by a strategic "Parliamentary" section. Calling on these resources was an Auckland project team under C W G Little. Then aged 33, Little had spent 10 years with the Thompson-Houston Electric companies, notably with T-H International in Boston, Massachusetts, and in France, before joining the BET consulting group.

Among the BET staff engineers at the time was J J Walklate who later, in 1907, became General Manager & Engineer of the Auckland system. Walklate retained this position even after the Council took over in 1919 and he served both in this role and as Auckland Town Clerk until his death in 1922, then aged 52.

Walklate gained his early experience on British steam and cable systems. But in 1893 he was engaged with the pioneer electrical firm of Mather & Platt as resident engineer on the Douglas & Laxey Tramways, Isle of Man. (This operation still runs today, using some the original 1893 cars. It is an enduring tribute to early tramway engineering.) Walklate took charge of the Brisbane horse tramways in 1896 and, in the course of its electrification, visited USA and Canada to inspect the latest developments. With this experience he joined the BET engineering group in 1899. He was General Manager of the Potteries Electric Traction Co (a BET concern centred on Stoke-upon-Trent, Staffordshire) for six years before taking up the Auckland position.

There was yet another New Zealand link at the BET in the person of Frederick Black. Black graduated in engineering from Canterbury. By the age of 24 he had packed in much experience in the USA and with Siemens Brothers at Woolich before joining the BET in 1898. His return to New Zealand around 1907 was to private practice. In this he pioneered many electrical and tramway investigations and installations, including the Napier Tramway system design (1911) and the first New Zealand trolley-bus installation, on the Hutt Road, Wellington (1924).

At an early stage the AET Co also retained the services of a local consultant, James Stewart, and appointed Mathew Carey as its Electrical Superintendent.

Carey arrived in Auckland on 18 June 1901, having been transferred from the tiny Nelson [British Columbia] Electric Tramway – the BET's most far-flung operation at the time. He was a Canadian, educated in Montreal. He trained with the Edison Company and spent nine years with the successor General Electric Co and other firms on tramway and electrical transmission work in the USA, South America and western Canada before joining the BET for the Nelson project. Carey took the role of overseeing the Auckland electrical installations – possibly assisted initially by W G Bingham. (Bingham's consulting role with the AET Co became rather tense and ended in 1904 with an out-of-court settlement for fees and commissions.) After operations began, Carey largely managed the engineering and traffic side of the tramway. In his case too, tension with the directors grew. He left the Company rather abruptly, near the end of 1906. (J J Walklate was sent out from England to take over – with a distinct change in management style.)

Civil engineer James Stewart's involvement with electrification of the Auckland tramways had begun in 1896 when he visited England. In response to the Auckland City Council's 1895 overtures, Stewart returned from overseas representing Parrish Brothers, an English contractor, and managed to obtain an agreement with the City. This fell through, however, when its terms became the subject of much criticism. (shades of Britomart?) Later, in 1897, Stewart argued strongly for municipal ownership of the tramway system.

Born in Scotland in 1832, Stewart's New Zealand career began with a distinguished design for the Auckland waterworks in 1860. He surveyed the Auckland-Drury railway about the same time and in 1863 became Engineer to the Auckland City Board of Works. The next 33 years saw his involvement in many civil works, particularly those undertaken by the Provincial Government: the Auckland-Mercer railway (1872); the Bean Rock lighthouse (1872); District Engineer for the Railways Department (1874); the Thames Valley & Rotorua and other railways (from 1881 as a private consultant). His involvement with the Auckland horse tramways began in the 1880s and he continued on as civil engineering consultant to the AET Co until 1911-12 (aged nearly 80) when A G Walker took over this role. Stewart's last major work for the Company was documentation in 1907-8, for the Mt Eden and Mt Roskill (Dominion Rd) extensions.

5 FRUSTRATIONS IN MOVING AHEAD

Until the Auckland venture, the BET Co's sole experience of electric tramway construction outside of Britain had been confined to the small system of 4.8 km and three cars in the mountain town of Nelson, British Columbia in 1899. For this project eastern-Canadian resources were engaged.

Constructing a system the size of Auckland's, however, half a world away from London and within the time constraints imposed, was something else. Transport and communications were major factors and the South African war was in progress. Letters relaying instructions from London, via the San Francisco mail boat, took at least four weeks each way. Morse telegraph, via cable, was available but expensive. (An elaborate system of code words, usually sent ahead by mail, was set up to anticipate various situations.)

The authorising Orders-in-Council of April 1900 specified that work was to start by 1 June 1900 and be completed by 1 June 1902, subject to a penalty of £5 ($900) per week. The Council increased the pressure by specifying in the Deed of Delegation liquidated damages of £1000 ($180,000) for failure to start work within the year before 1 June 1901 and £50 ($9000) per week for late opening. The deal giving the Auckland Electric Tramways Company Ltd a conditional 32-year right to operate was signed off on 26 June 1900.

The Company engineers wasted no time in indenting rail and other supplies for the first 8 miles (13 km) of track, through an associate English firm, Rowell Stuart Kelman & Co, requiring delivery in early 1901. Also they placed an order with another associate, the Brush Electrical Engineering Co, Loughborough, for 43 tramcars: six double-deck bogie cars seating 80 passengers; 19 single-deck bogie cars seating 48; and 18 single-deck 4-wheelers seating 32. The total price was £55,578-13-1 ($10.0 million).

Negotiations began with J G White & Co (a London contractor with offices and staff in New York) for the permanent way, power-house and electrical equipment.

Progress was frustrated, however. During the first part of 1901, the Company's local director, Paul M A Hansen, found himself much occupied in placating the city councillors with a raft of reasons why work could not begin on time: tramway construction was in a boom throughout the world; the South African war and formation of steel cartels had reduced supply and increased rail prices; there were delays in approvals from the Council's Engineer; approved plans had taken eight weeks to reach England instead of four, and so on. Hansen explained that the order for rail had been transferred to the Lorain Steel Company in Pittsburgh, but they had failed to perform and, when they did, only a slow boat (the SS *Cereda*) to New Zealand was available.

By this time (May 1901) the main contract still had not been sealed. J G White & Co had needed to visit Auckland for inspections and had been pricing subcontracts with many other suppliers. Ultimately, with a contract sum of £260,167-11-7 ($47 million), the work included:

Permanent Way

- John McLean & Son (an Auckland firm) sub-contracted to remove 7.75 route-miles (12.4 route-km) of horse tramway, prepare the formation along 17.2 miles (27.5 km) of street, and lay 29 miles (46.4 km) of track. About 5000 tons of rail, fixings and special-work supplied by Lorain Steel Co.

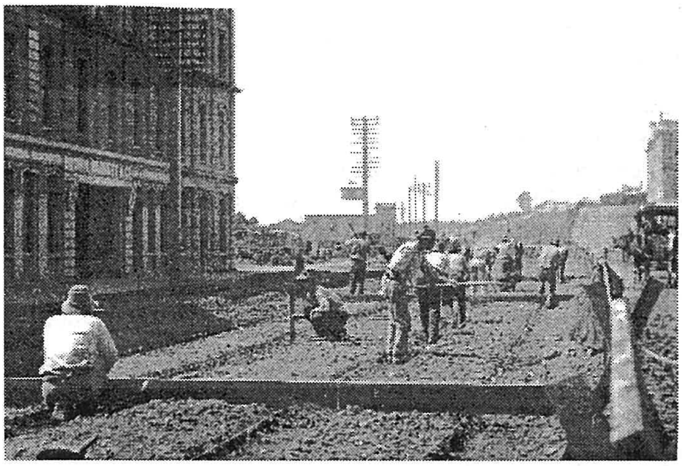
Power-House & Motive Power

- Local sub-contractors to prepare the foundations. Labour engaged by J G White & Co to erect steel-work (shipped prefabricated from USA) and lay brickwork.
- Boilers (4 x 2100 ft^2 (195 m^2) heating surface) supplied by Babcock & Wilcox Co, England. Green's Economiser (360 tubes). Erected by local agents.
- Engines (3 x horizontal cross-compound Corliss-type of 475 hp (355 kW) normal output, 700 hp (520 kW) maximum output, at 150 lb/in^2 (1000 kPa) and 100 rpm) supplied and erected by Cole Marchent & Morley Ltd, England.

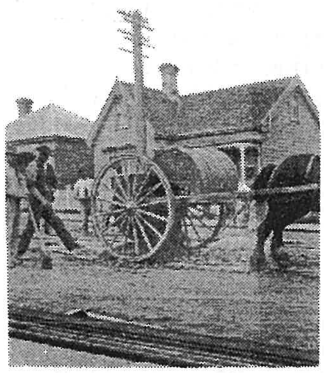
Electrical Equipment & Reticulation

- Generators (3 x 300kW at 550V direct-current, compound-wound, 8-pole, capable of 50% overload), boosters (4 x motor-generator sets to correct either rail or overhead voltage drop) and switchboards (blue Vermont marble) supplied by General Electric Co, New York.
- Underground cable conduit (4 miles (6.4 km) mostly 2 to 6 ways, earthenware, Camp system) laying sub-contracted to John McLean & Son, Auckland
- Feeder cables (vulcanised-bitumen-insulated where in conduit) supplied and installation supervised by Callender's Cable & Construction Co, England.
- Steel poles supplied by John Spencer & Co, England.
- Overhead conductor (00 B&S gauge) and fittings, sourced from British and American suppliers, erected and supervised by J G White staff.

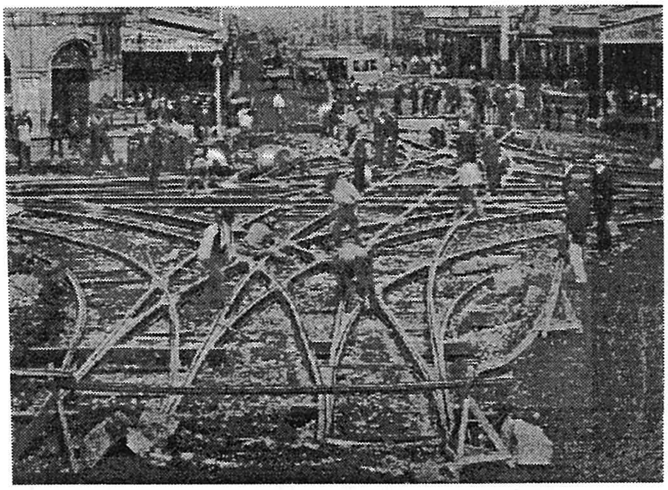
When White's construction supervisor, W S Turner, arrived in Auckland on 18 June 1901, he found practically nothing in the way of plant or materials to



A grading gang at work in Customs Street East. Trenches are being excavated for the longitudinal concrete stringers supporting the rails. This form of permanent-way construction was not successful and was eventually replaced by transverse timber sleepers.



Left: Filling the concrete mixer. Right: After taking the horse for a walk, the concrete is dumped to form the longitudinal stringers



Laying out the many components of the "grand union" at the junction of Queen and Customs Streets. Trams approaching in any direction could turn left, right or continue straight on. Grand unions were rare even in large tramway systems. Another was installed at Queen and Wellesley Streets in 1916 with the construction of the upper Queen Steet section.

hand. Not until 19 July was the first 1000 tons of rail from the Lorain Steel Co unloaded from SS *Cereda* (by primitive means). A formal ground-breaking ceremony took place at the foot of Hobson Street on 1 August 1901, but rail-laying did not start until 3 September.

6 CONSTRUCTION – HARD LABOUR

Despite the initial difficulties, the contractors made spectacular progress during the 14 months from September 1901 to November 1902. They completed over 27 miles (43 km) of track, built the power-house and reticulated the electrical supply. The rate of progress seems all the more remarkable through present day eyes because of the lack of construction machinery. Photographs show the extent to which the work relied on manual labour.

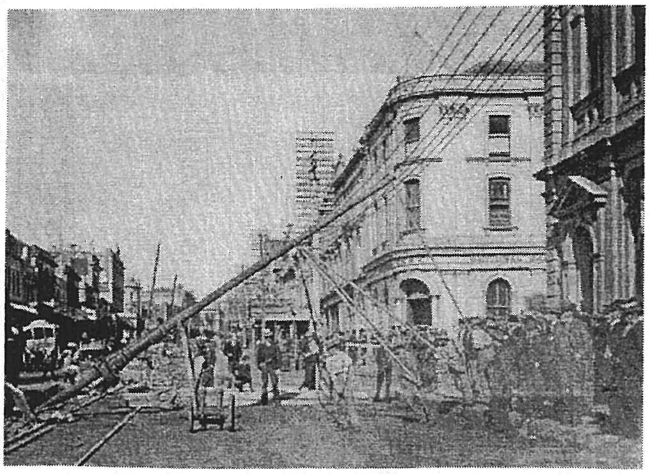
One invoice details the effort put into excavating about 1300 yd^3 (1000 m^3 or about one-third of the total) of clay spoil from the power-house site in lower Hobson Street. The 1000 m^3 took four weeks (of 5½ days), using 6 to 7 men with picks and shovels, and 4 to 5 drays (with drivers). The contractor charged out each man at 10½d ($7.88) per hour and the drays at 12/6d ($112.50) per day. The total bill, rendered by Mr E Pasco of the Kyber Pass Stone-Breaking Works (sic) for May 1901, was £114-18-11 ($20,700). Thus it took each man about one hour to dig and load one cubic yard. The cost amounted to about 1/9d per yd^3, or $20.70/$m^3$. Such work would be accomplished much quicker today but at a surprisingly similar cost.

Laying the track entailed similar manual effort. First the gang broke up the road and lifted any old horse tram rails and sleepers. After re-grading to new levels, a trench 18" wide x 16–19" below finished grade was opened out for a continuous longitudinal mass-concrete stringer below each rail. Concrete mixing was primitive, and only partly assisted by horse power, as shown in the illustrations.

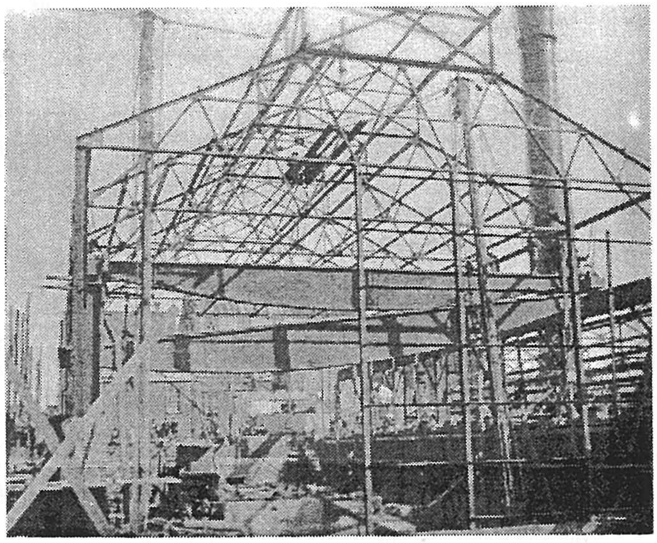
Steel poles to carry the overhead were wheeled from the wharves on handcarts. Although 32 feet (9.8 m) long and weighing up to 1435 lb (650 kg), they were erected, sometimes even through shop verandahs, with nothing remotely resembling a crane.

At the power-house, the riggers used an elementary derrick to raise the pre-fabricated steelwork (which did not arrive until 18 July 1902) including the 20-ton overhead gantry. Only then could the fitters erect the massive engine castings, dynamo parts and boilers. In these circumstances the completion of the power-house and the generation of power by 10 November 1902 must be considered a most creditable performance, even by today's standards.

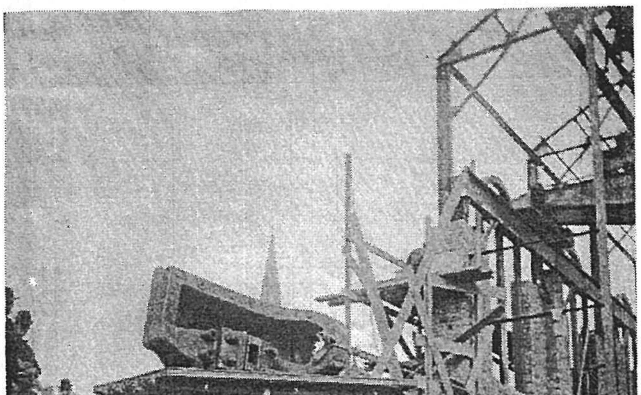
The erection of cars (broken-down into kitsets after completion at the Brush works) took place at the Ponsonby depôt, the first shipment having arrived in mid-June 1902 aboard the *Niwaru.* Messrs S A Mahood and James of the Brush Co came out to supervise the work and the first trial, using one of the 4-wheel cars was made on 13 November, shortly after the power-station became functional. About ten of the cars were ready for use by the intended opening day 17 November 1902. But fate had one more delaying tactic for the AET



One of the steel centre-poles being erected at the foot of Wyndham Street



The power-house was erected and completely fitted out with the generating plant in four months. A simple derrick was used to lift all the building components, including the 20-ton gantry girders as shown here.



An engine frame is delivered to the power-house by J J Craig. It will be lifted into place with the newly installed gantry.

Co: the steamer *Elingamite,* carrying eleven ex-Sydney motormen who were to take up similar duties in Auckland, was wrecked at the Three Kings Islands on 9 November with serious loss of life. The inauguration ceremony was held, but the public had to wait until 24 November to try out the new wonder.

7 CHALLENGES & LOCAL SOLUTIONS

From the outset the Auckland designers faced a number of challenges - some obvious, some not. With their diverse backgrounds and experience (see section 4) the design team was drew on a mixture of current British and North American tramway practice in meeting these.

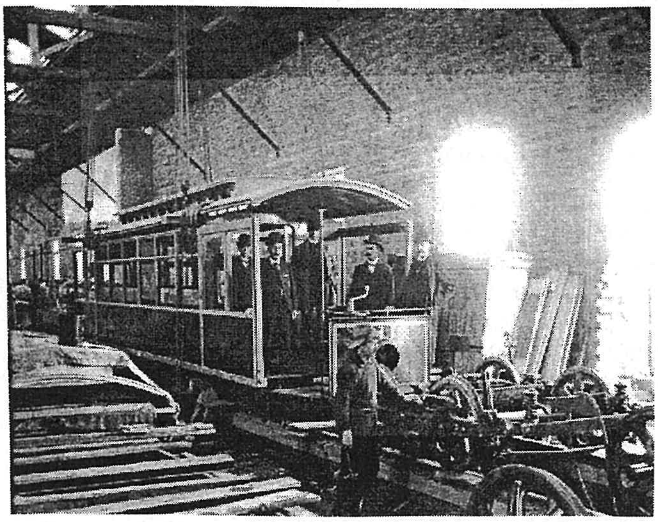
Auckland's streets were quite broad in comparison to most British towns. But our central business area was surrounded by steep climbs (Wellesley Streets East and West, Parnell Rise and College Hill). The long runs (e.g. out to Onehunga – the first "coast-to-coast" tramway) called for fast running speeds. Thus the Auckland cars were longer, wider and more powerful than the usual British tram of the time. The end-entry saloons ordered were typical of American practice. Only six double-deck cars were ever ordered – these were a good solution for events such as race-days, or to get high capacity as in cramped British cities, but they were slow to load and unload.

At the turn of the century, braking systems were still evolving. The Auckland cars, as built, were fitted with two manually-applied service brakes and a crude electric emergency brake. The "goose-neck" brake handle for the wheel-brake can be seen in the photograph of car No.1. The other was a hand-applied track-brake. Bringing one of the double-deck cars down Parnell Rise (1: 8.8 or 11.4%) with 80 passengers and a gross weight of 25 tons, on hand-applied brakes alone, must have called for some nerve. It was not until 1911, after much official enquiry into the pros and cons of magnetic-rheostatic and air-assisted brakes, that the Auckland fleet was fitted with air-brakes. Surprisingly, during the first 10 years, there were no significant instances of brake failure, although the dramatic 1903 Kingsland accident highlighted the need for training.

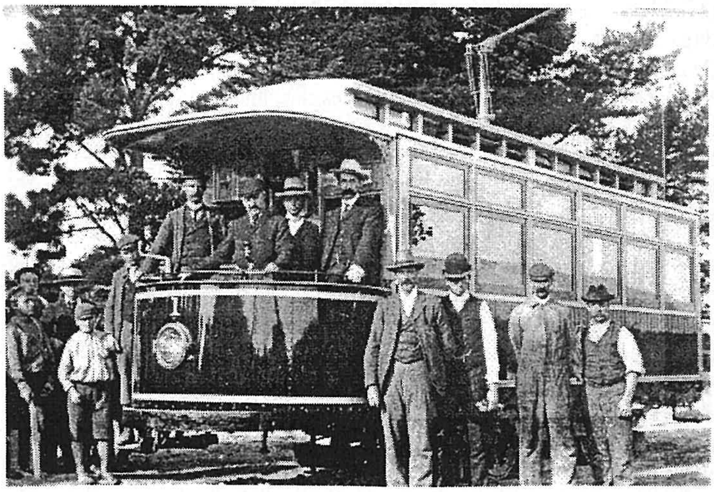
One of the less obvious challenges was permanent way design. The designers (and this may have included James Stewart) chose to use longitudinal mass-concrete stringers under the rails with no great emphasis on the foundations below this level. This may have worked well in British cities where many years of road formation had resulted in a well-compacted base. But in Auckland generally it did not work well, and in Queen Street, an old stream bed, it was a massive failure.

Initially a series of "boosted" feeders supplied power to the outer reaches of the system. One such feeder went out to Epsom, but with traffic growth, this was soon found inadequate. Plant providing 5500V a-c was installed at the powerhouse about 1911. A substation built at Epsom used motor-generator sets to supply 550V d-c. Feeders along Greenlane and Balmoral Roads then supplied the other radial routes.

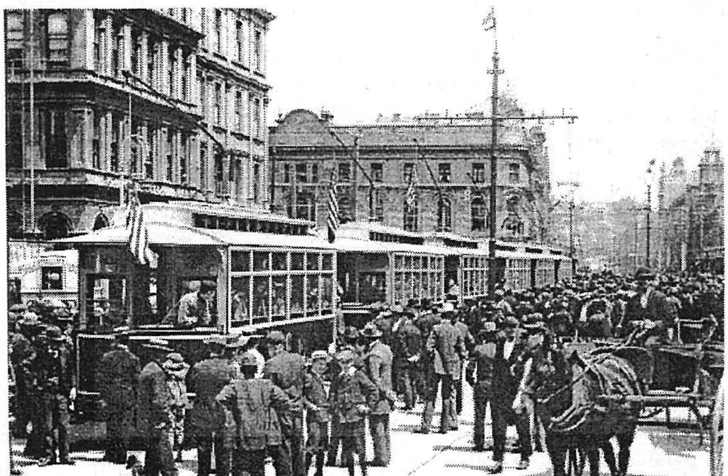
The tramway was also a victim of its own success in the matter of electricity supply. The capacity of the power-house had to be doubled by 1909 and increased over 6-fold by 1919.



The first car to be erected at Ponsonby Depôt was 'Combination' No.11. Present in the photograph are Messrs T C Duncan (AET), S A Mahood (Brush), M F Carey (AET), X James (Brush) and W S Turner (White).



"Dinghy' No.1 being readied for inauguration day. Present on the car are Messrs X James (Brush), S A Mahood (Brush) at the controller, F N Smock (White) and J Reed (White). The occasion, near the Ponsonby depôt, is attended by a curious crowd of local boys anxious to be in the photograph.



The inguration of the system on 17 November 1902. After the opening and starting of the first car by Sir John Logan Campbell, a group of official guests was taken via Wellesley Street and the Symonds Street branch to a luncheon at the Choral Hall (now part of the University) on the corner of Alfred Street.

8 EFFECTS – BROAD & LONG-LASTING

Once the initial system was built, the tramway became a "home-grown" industry, designing and building almost all of its expanding fleet and network through local designers, suppliers and skilled contractors. Little of that industrial base or skill now remains in Auckland.

The subsequent growth of the tramway and its traffic is shown by Table 1. The expansion of the system was not merely reactive: "tramway suburbs" developed all over the Auckland isthmus partly because cheap, rapid transport was available. For example, the Mt Eden – Mt Albert area, between 1906 and 1926, grew in population from 10,471 to 38,236. At the same time Remuera grew from 3,802 to 11,821. When the tramway was at its zenith, in 1940–50, we have calculated that approximately 80% of the Isthmus population was within 500m of a tram-route, and most of those much closer. Except during the 1919–29 period of City Council ownership, there was roughly one kilometre of tramway for every 2500 residents. Thus the tramway became an essential component in most Aucklander's social, recreational and working lives – this is shown in Table 1 by the annual number of trips/capita.

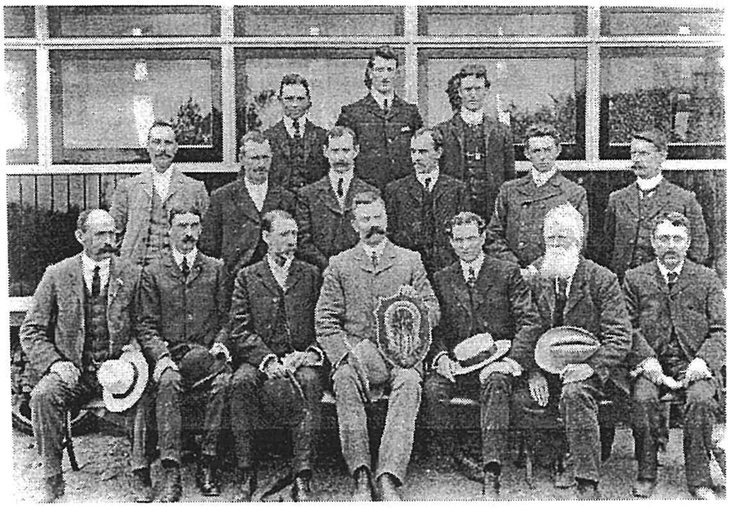
9 REMAINING HERITAGE – MOTAT'S ROLE

The intensive use of the tramway during the 1939–45 period (see Table 1) resulted in a severe run-down of the tramcars and track. The electrical system continued to rely on much of the original cabling and this was also nearing the end of its economic life. After several years of debate and analysis of the options, the Auckland Transport Board took the decision to scrap the system. The first closure took place in 1949 (College Hill – Herne-Bay) and the system closed entirely on 29 December 1956 (City – Onehunga). All the tracks were taken up after closure.

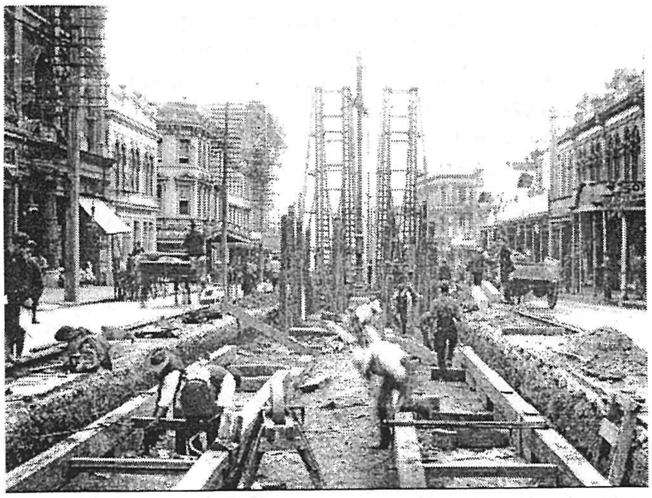
Reminders of the system existed for years afterwards, particularly as the electric trolley-bus system (1949–1980) used much the same power supply, reticulation network and workshops. Most of the tram-bodies, including some of the original 1902 cars, were carted off – sans running gear – for use as sheds, baches, etc. Even today, of the fleet totalling roughly 260 bodies, remnants of about half can be found scattered about the upper North Island, particularly in the Thames-Coromandel region. These still provide information and the occasional part needed for MOTAT's tramway.

Other infrastructure is disappearing quickly. The first Company office building (at the corner of Hobson and Customs Streets) remains, as does a fine waiting-shed and toilet block (of 1910) at Grafton Bridge. The Epsom administration and staff recreation building (c.1920) still exists, next to the site of the now-demolished car barns in Manukau Road. But recent casualties have included the evocative 1902 power-house in lower Hobson Street (just one victim of the mindless 1980s boom) and quite recently (1996) the 1914 tramway workshops at Royal Oak (a superb example of early 20th century industrial design and innovation).

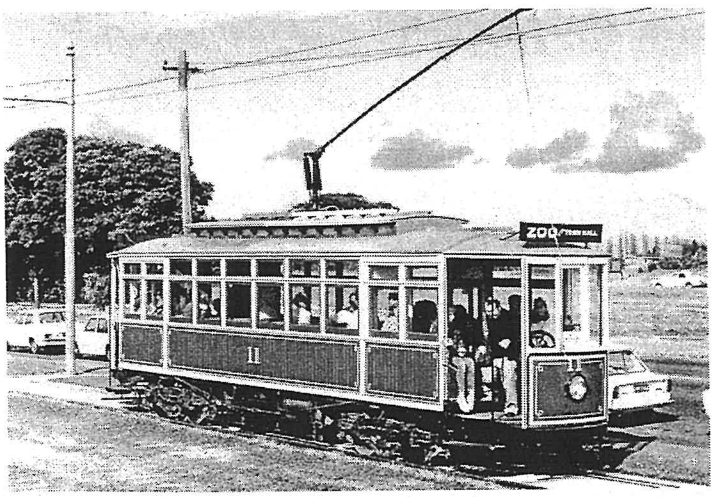
Fortunately not all has been lost and a good collection of artifacts exists, mainly at MOTAT. This collection was formed within the decade after system closure



Members of the Auckland Electric Tramways Co and contractors pose with one of the new double-deck cars in November 1902. Among them are: (3rd from left front) W S Turner (J G White & Co manager), Paul Hansen (centre, local director and BET representative), Mathew Carey (AET electrical superintendent), James Stewart (civil engineering consultant) and S A Mahood (Brush Electrical Engineering Co representative).



Not all of the original work was a success. Major foundation problems in Queen Street required extensive piling in 1906 – shown here. Failure of concrete packing beneath the rails entailed more major remedial works in 1913.



One of the original 1902 Brush cars, No.11, continues to operate on the Western Springs Tramway 98 years later.

thanks to the foresight and effort of a number of individuals and groups such as the Old Time Transport Preservation League.

The first car to be erected at Ponsonby depot in 1902, No.11 (built by the Brush Co at a cost of £1399-2-1 ($250,000)) is at MOTAT, restored to its 1912 state and in operating condition. This car runs on original Brush D-type bogies, which are thought to be the only examples remaining anywhere. Other examples of the early Auckland tramcars at MOTAT include No.44, a 1906 4-wheel "Dinghy" (being restored) and No.17, one of the six 1902 Brush double-deckers. Replica bogies, using No.11's as patterns, will allow this fine example of late-Victorian tramway engineering to be returned to operation in its 1902 condition in time for its 105th birthday.

The museum also has representative examples of later Auckland tramcars, including the once numerous "M-class" which absorbed most of the huge increase in traffic between 1908 and 1921 (see Table 1), and the structurally-innovative "Semi-steel" type (with "deco" style bodies, locally-built from 1923). The final "Streamliner" 1934–37 design, using light-weight Electro-Mechanical Brake Co bogies, is represented by cars 248 (in operating condition) and 253.

10 THE WESTERN SPRINGS TRAMWAY

The Western Springs Tramway was set up, over 30 years ago, to provide a demonstration of electric tramway technology – using ex-Auckland and other scrapped equipment. (At the time those involved were regarded widely as eccentric.) The line now runs between museum site at Western Springs and the Auckland Zoo, about 1.1 km away. Approximately 140,000 one-way fares are collected annually.

The WST not only fulfils a useful and friendly transport function. It is an important shrine for folk whose family members worked on or used the trams, sometimes for a lifetime. It is an educational resource, heavily used by students in a spectrum of fields from physics to sociology. For many visitors, the now rare sight of a large but simple direct-current machine at work (in contrast to modern solid-state a-c technology) gives their first real understanding of the principles of electricity and magnetism.

Visitors are also intrigued by old skills being applied to restoration of the trams and in the maintenance of the power-supply and track. Some of these skills have been passed on, but many, over a period of 30 years, have had to be re-learned in order to keep 100-year old technology safely functioning

11 OTHER SURVIVING TRACES – UNDER THREAT

In addition to the "hardware", some documentary records of the system have also survived, but these are very widely dispersed. Practically none of the information in this paper came from institutional souces in New Zealand. Meagre remnants of official records have been discovered in obvious places such as the Auckland City Municipal Archive and the National Archive (where materials from the former Public Works Department and the Auckland Transport Board were deposited). There have been pleasant surprises and bitter disappointments concerning records. The most remarkable good luck in 1994 uncovered a mass of records from the BET stored in a laundry in London. (Over a period of 90 years, the BET had progressed from a multinational transport operator to an owner of a roller-towel operation!) Amongst these papers were many very early items relevant to the fledgling Auckland Electric Tramways Co Ltd. None of these had surfaced previously in New Zealand.

Trade journals current in the formative period of the tramway are also a mine of "lost" information. But there are almost no copies of the British or American tramway journals extant in New Zealand, most having been discarded as "no longer relevant". Fortunately the National Tramway Museum, Derbyshire, UK has comprehensive holdings of these.

Record losses occurring in early days are understandable. But we have been disturbed to find that the destruction (or near destruction) of some invaluable records has been quite recent. For example, a number of Company drawings originally sent to the PWD were accessed and copied for us during the 1970s, courtesy of the Ministry of Works & Development. Now, after the break-up of the MOWD, significant numbers of those records and others can no longer be found, despite extensive searching among items actually deposited with the National Archive.

Another "horror story" concerns irreplaceable records dating from the earliest days of the Company that should have been archived by the Auckland Regional Authority. Some years ago a phone call was received late in the week: "If you want this old stuff [several cubic metres] come and get it, otherwise it will go to the destructor on Monday morning".

Yet another inexcusable loss occurred when the Auckland Regional Authority's bus transport division was split off as a result of Government legislation: James Stewart's original civil engineering drawings of the tramway had been carefully kept by successive administrations for over 80 years. These venerable relics were sighted in the mid-1980s but, by 1989, were nowhere to be found.

Not surprisingly, we hold many unique and valuable documents ourselves, unwilling on the basis of experience to entrust these to public institutions, yet fearful of the risks that attend private collections.

12 CONCLUSION

Auckland's electric tramway system was a grand engineering achievement for its time, one that had broad and long-lasting community benefits. Through the remaining artefacts and records, knowledge of the tramway commands respect for those who conceived, designed, built and operated it.

Unfortunately the remaining traces are fragile – neither fully nor widely appreciated. At present in New Zealand there is no mechanism that will ensure preservation of this heritage.

ACKNOWLEDGEMENTS

We acknowledge the effort that early members of the tramway heritage movement have made in keeping something for future generations to learn from. The archival material gathered by Graham Stewart is particularly noted, as is his willingness to share it. Similarly the work undertaken by members of the National Tramway Museum, Crich, UK, in preserving important archival materials relevant to New Zealand must be mentioned. We also thank our volunteer colleagues at MOTAT, past and present, for their contributions to this paper.

REFERENCES

The information in this paper has been drawn from many primary sources, too numerous to fully list here. We would be pleased to assist anyone wishing to find access to these sources.

CLARKS FLOUR MILL AND WATER RACE MAHENO, NORTH OTAGO

R.F. Hill B.E. (Civil) F.I.P.E.N.Z. Retired

SUMMARY

This paper describes the strengthening and upgrading carried out by David G. Cox for the Historic Places Trust on the Maheno Flour Mill.

Flour Mills were an important part of the local economy and were common throughout the East Coast of the South Island of New Zealand in the 1800's. They represented the interface between industry and agriculture and required considerable venture capital to set up.

Flour Mills were large buildings from 4 to 6 stories high with machinery generally driven by water power to grind the wheat for flour or the oats for oatmeal.

The Historic Places Trust bought the Maheno Mill in 1977 as an example of the larger country waterpowered flour mills that were once so common. The mill is a 4 story structure with load bearing walls of local Oamaru limestone and timber floors. The mill race comes from the Kakanui River and originally drove an overshot water wheel.

The building was in serious disrepair when bought by the Historic Places Trust and David G. Cox, a structural engineer experienced in providing structural strength to historic buildings, was commissioned to carry out the repairs. This involved strengthening the limestone walls by placing a reinforced concrete shear wall inside the limestone facing and providing floor bracing to make the structure capable of resisting seismic loads.

The paper describes the innovative means of providing structural strength without changing the appearance of the building.

INTRODUCTION

Clarks Flour Mill was built in 1867 and bought by the Historic Places Trust in 1977 who commissioned a report from David G. Cox, a structural engineer experienced in providing structural strength to historic buildings. He inspected the building in early 1977 and his proposal was accepted by the Historic Places Trust.

In order to understand the reasons for the Historic Places Trust buying this building we need to understand the importance of flour to the community and hence the importance of flour milling.

History of Flour

Flour comes from ground wheat and was one of the earliest activities of the food gatherers. Wheat had its origins in Mesopotamia growing wild in the Euphrates and Tigris valleys, but it was growing in all European and Asian societies, having been found in the Swiss Lake dwellings and in China 3000 B.C. It was the main crop in ancient Egypt and Palestine and it spread across the developing world with major growers in 1939 in descending order - Russia, India, Canada, Australia, the Danube Basin and Argentina.

The wheat plant consists of stalks supporting heads called spikes in which flowers and kernels are formed. The kernels or grains are enclosed in seal like coverings called husk or chaff but the seed instead of being free like a walnut is fastened to the inner wall of the shell and it is not easy to separate them. Mans effort to do this and to grind the corn by mechanical means has led to the development of flour. The wheat grain consists of the endosperm, the germ and the bran but white flour comes only from the endosperm which has almost no nutritional value. It is the germ which contains the growing power of the seed - the oil. The bran is the outer layer which provides the fibre and is essential for good health. From one wheat seed 4 spikes can grow, each containing 100 kernels of grain.

The grinding of wheat grain may have been the first step in engineering where early man used his ingenuity to find the means and then steadily improved on them over the centuries. The first was a pestle and mortar referred to by the Greek writer Hesiod in 8th Century BC then the pestle was refined by notching the bottom and the grain was grated rather than pounded. This developed the circular action and a handle was added to the top of the pestle so that it might more easily be driven around in a circle and the mortar was thus converted into a handmill, later horizontal shafts were added to the mill so that it might be driven by slaves or cattle. Then came the Quern, a rotating upper stone on a bell shaped lower stone. In a baking house in Pompei a quern was found with an iron pivot to support the upper stone to reduce friction. The quern was followed by revolving millstones powered by windmills or more commonly water wheels.

The millstones have a carefully designed series of furrows and lands cut into them, leading from the centre or eye to the outside edge. The furrows act as air conducting channels and distributors and provide a cutting edge. In the process of grinding, the furrows in the upper stone cross those of the lower stone in a scissor like action, the edge of the furrow meeting the land causes a cutting or opening out action, the land acting as the grinding medium. While the bedstone tended to hold the grain, the runner stone acted as a grinder and the grain having to pass from the centre to the periphery was subject to the action of a considerable area of grinding contact.

The millstone in 1866 was the quintessence of the experience and knowledge of many generations of millers and millstone builders. Many early New Zealand stones were made of French Burr and imported from France. Consider the degree of mechanical perfection involved in getting a millstone 1.2 metres in diameter and weighing 600 kilos to revolve for 6000 hours per annum in balance generally on a single point so closely to a sister millstone that they touch the wheat grain simultaneously on both its inner and outer sides without unduly pulverising it or without coming into contact themselves. Consider the amount and intensity of the friction involved - one stone stationery and the other revolving at a periphery speed of 500 metres per minute.

Up to the end of the 16th Century, there was only one method of reducing the grain to flour by passing the grain through the machine once and grinding it up into wholemeal.

A new system was published by Bouquet of Lyons in 1760 consisting of passing wheat three or four times through millstones and after each grinding, the broken stock was sifted on a fine reel separator to take out the flour whilst the overtails went to the next pair of millstones to be reground. The first millstones were set "high" so only slightly grinding the wheat and succeeding stones were set successively closer so that the overtails of the last separator consisted only of bran. This was the start of the gradual reduction process and the flour obtained was whiter than the single grinding system.

In New Zealand wheat was introduced by Captain Cook in 1773 in his garden at Ships Cove Queen Charlotte Sound.

The Bay of Islands Chief Ruatara returned to New Zealand from Sydney in 1813 with tools and grain which he distributed to his friends. Ruatara ground the wheat in a steel mill and baked a cake in a frying pan. The chiefs were impressed and all wanted more seed and Ruatara stated

"I have now introduced the cultivation of wheat into New Zealand. It will be a great country, for in two years I shall be able to export wheat to Port Jackson in exchange for hoes, axes, spades, tea and sugar."

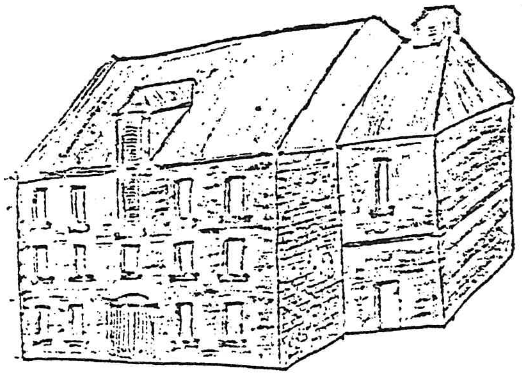
In 1833 a water-powered flour mill was built at Waimate. By the 1850's Maori were growing wheat in considerable quantities. One year 50,000 bushels were sent to Auckland and a single district in the Waikato had 2,500 acres of wheat under cultivation. In the middle of last century there were 236 water flour mills in New Zealand and 81 were owned by Maori. Maori also owned cutters and scows to take the flour from their mills to the major settlements in New Zealand and to Sydney.

The History of the Mill

The Maheno Flour Mill was built in 1866 by the two Campbell Brothers for Mathew Holmes and Henry Campbell lessees of the nearby Totara Estate. It was sold to the New Zealand and Australian Land Company who had bought Totara Estate in 1867. Three years later it was being operated by Anderson and Mount, Otago flourmillers and in 1901 it was bought by Alexander Clark and called the Maheno Valley Roller Flour Mills. In 1868 the area was flooded and the water level reached the 1.2m level of the second story forcing the evacuation of all the workers on that shift. The flour produced by the mill was known as "Snowdrift flour", while the oatmeal was branded "Muscular".

The water wheel was later replaced by a 25h.p. turbine and the millstones by steel rollers. In 1967 the turbine was replaced by an electric motor.

Alexander Clark's sons and grandsons continued milling until the end of 1976 and early in 1977 the mill was bought by the Historic Places Trust so that it could be put in sound structural order and maintained as an example of the larger country water powered flour mill that were once so common. Its Schumacher plant is still in working order.



Sketch of Mill from South East.

The main mill building is an unreinforced masonry structure four storeys high with internal dimensions of 16.5m x 9.1m.. The internal floors are timber on joists supported by large timber beams which bear on the internal wythes of external walls and columns of cast iron at approximately mid span. The roof is corrugated iron on timber trusses. An Oatmeal House abuts the east end of the building some 6m x 6m internally in plan. Its floors and roof are of similar construction to the main mill building. Water to power the original overshot water wheel originates from the Kakanui River which has a dam of limestone blocks to provide a mill pond and the water flows from the mill pond through a small rock tunnel to an open channel to a culvert under the main State Highway No.1 and thence in a concrete race up to the mill building to a wooden flume to the overshot water wheel. The race and tunnel were dug by hand in total the race is 700 metres.

THE CONDITION OF THE MILL IN 1977

David G. Cox was asked to inspect the mill by the Historic Places Trust. He inspected the building on 17th February 1977 and reported as follows.

MAIN BUILDING

Walls

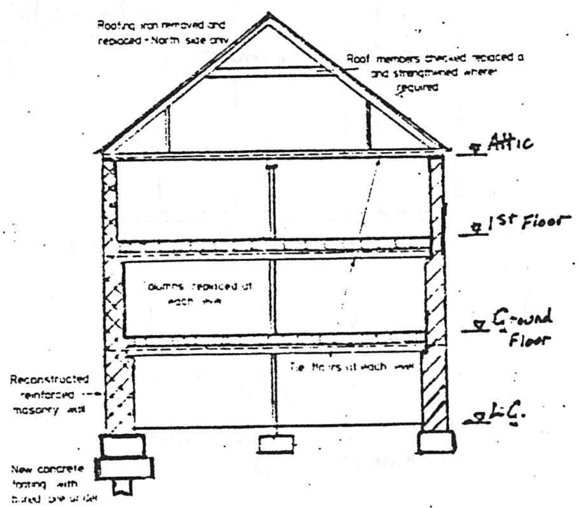
Major cracks are evident to the east and North walls particularly near the N.E. corner. Some of these cracks appear to run for the full height, particularly near the middle of the East wall, some being up to 50 - 80 mm wide in places, with one in particular as much as 150 mm wide. The gable to the East wall is extensively cracked as can be readily seen from inside the Oatmeal House at 2nd floor level - this crack is up to 80 mm wide.

The West wall is free of major cracks - in fact, even hairline cracking is not obvious. The South wall shows some minor cracking internally, particularly in the upper storey. Some of these cracks have been repaired previously, but they show little evidence of recent movement. The outside of this wall has been plastered in relatively recent times and consequently there is not much external cracking evident. There are no interior masonry cross-walls and generally corners to walls are not well bonded.

Typical wall thicknesses are:-

Bst. - Ground	-	750 - 900.
Ground - 1st	-	600 - 700
1st - 2nd	-	450 - 500
Gable ends	-	600

Walls are limestone blocks and lime mortar in two wythes of varying thicknesses with cavities between wythes largely filled with rubble or small pieces of limestone. It seems probable that all limestone blocks were hand-hewn and adzed. It appears that the North wall may have moved outwards by up to 70 - 80 mm at the top and correspondingly lesser amounts at lower levels. Capping stones to gable ends are obviously loose and in some places noticeably displaced.



TYPICAL CROSS SECTION

Floors

Floors are timber planking on timber joists supported by large (310 x 310) timber beams (probably matai). Main beams are built into external walls at each end and rest on columns between floors at approximately mid-span. It is fairly certain that these columns are cast iron - they are some 75 - 100 mm in diameter, tapering slightly with height. Floors are generally uneven, have many holes through them (mostly for pipes and ducts) and do not appear to be tied to exterior walls in any way. Joists to 2nd floor are bolted to roof rafters, but not fixed to walls. Basement floor is uneven and broken up in N.E. corner where it has subsided markedly.

Roof

Roof framing (i.e. rafters etc.) appears to be in reasonable condition. Iron to South elevation is also reasonable. To North elevation, iron is more rusty, showing some holes and is sagging noticeably under the weight of a thick brown deposit (presumed some type of flour residue) which is probably more than 300 - 400 mm thick at the West end near the flu outlet.

OATMEAL HOUSE

Walls

The North and East walls of the Oatmeal House are extensively and severely cracked, particularly around the N.E. corner where some stones have become dislodged near basement level. The South wall shows some cracking but not extensive wide cracks as for the other two walls. The West wall is in fact the East wall to the Mill building already mentioned above. Some bolts and straps evident at approx. 1st floor level suggest previous attempt to tie walls together.

Floors

Access to lower floors is awkward and upper floors are covered with rubble and rubbish. It is thus difficult to comment on their condition but it is suggested that due to lack of use for some time, some areas of these could need replacing. It is fairly certain that floors are not positively fixed to walls.

Water Race

The existing water race on the East side of the main Highway is concrete. Base seems to be in reasonable condition. This may have been helped by the fact that it has been flowing a few inches deep more or less continuously. Upper sections of walls above ground show significant vertical cracks at fairly regular intervals. Walls show significant deflection and deviation from what was presumably a reasonably straight line originally.

Portion near Mill has been lined (possibly aluminium) and appears in reasonable condition, but this should be checked in detail.

Dam

Part of the dam has been breached and portions of concrete in this area washed away. It is a low dam anyway and is still holding sufficient water to feed the water race through the intake gate further North from the dam itself.

POSSIBLE CAUSES OF PRESENT CONDITION

Main Building

The primary cause of cracking to walls is undoubtedly settlement in the N.E. corner probably caused by scouring of material around inadequate foundations. Water from the water wheel, and later the turbine, would have flowed past this corner virtually continuously for many many years.

Other contributing factors were probably temperature movements and considerable vibrations during Mill operation. However these factors appear quite secondary to the settlement mentioned above. The lack of effective tying together of walls and floors has probably further contributed to the damage now evident. There is little direct evidence of damage caused or accentuated by seismic shaking, although this could have aggravated existing cracks.

Oatmeal House

As for the main Mill building, the primary cause of damage is settlement along North and East walls particularly near N.E. corner created by water scouring around foundations. Other factors as above may well have aggravated existing cracks.

Water Race

Exposure to weather with corresponding temperature induced movements have probably aggravated previous cracking. This would be accentuated without water flowing at depth within the race, which has probably not happened for at least ten years. Where it may have had minor leaks previously, these could well have become quite substantial. This can really only be proven by actual test.

Dam

The breach in the existing dam wall was probably caused by severe flooding and associated undermining of the wall face. It is likely that future flooding could inflict further damage, thus reducing the capacity of the dam and possibly affecting the amount of water which can be diverted into the water race through the existing intake gate.

ASSESSMENT OF SEISMIC RISK

There is no doubt that the building in its present state is a significant seismic risk. In particular, the Oatmeal House is quite dangerous. An assessment was made using the Code of Practice "Recommendations for the Classification of High Earthquake Risk Buildings", a publication by the NZ National Society for Earthquake Engineering. This indicates a Life Evaluation for this building as a potential museum (Type 2) of approximately six years with a review period of six months - one year. This means that it is a high risk requiring early attention to particular hazards such as cracked walls, high gable ends, loose capping stones, etc.

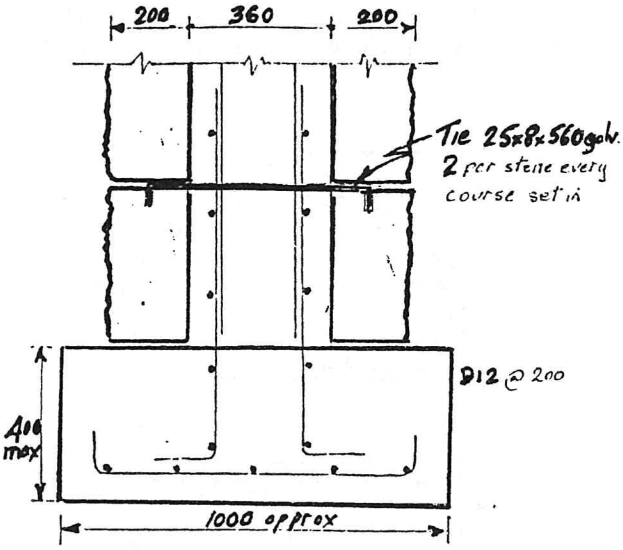
The Oamaru area is classified in Seismic Zone B which is the middle of the three zones used in New Zealand. It is of interest to note a recent paper by W.D. Smith "Statistical Estimates of the Likelihood of Earthquake Shaking throughout New Zealand", Bulletin of N.Z. National Society for Earthquake Engineering, Vol. 9, No. 4, December 1976. This paper attempts to estimate the approximate return periods for earthquakes of varying intensities at various locations throughout New Zealand. By interpolation, the return periods for the Oamaru area are approximately eighty years for MM VI and 400 years of MM VII. Corresponding figures for Wellington are 6 years MM VI and 20 years MM VII and Dunedin 150 years MM VI and 800 years MM VII. While these figures must be interpreted with some caution since they are predictions based on a limited history, they do give a basis for comparison, confirming that the Oamaru area is of relatively low seismicity compared with most other parts of the country. This should be recognised when considering the risks involved. On the other hand, a moderate earthquake shaking the building as it is would probably demolish the Oatmeal House, and could inflict severe damage to the North and East walls of the Mill building.

The central cast iron columns are probably brittle and would have little or no resistance to lateral movements - they should be removed and replaced..

RECOMMENDATIONS FOR STRENGTHENING AND UPGRADING

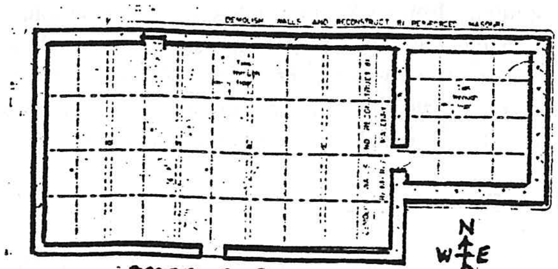
The following outlines a suggested approach to strengthening and upgrading the existing structure. This is based on an initial inspection only and could well be modified by more detailed study at a later date. However, it is considered that the broad approach would remain similar. Recommendations are as follows:-

1. Demolish Oatmeal House and lean-to structure over water turbine (North Elevation).
2. Scaffold and support North East corner and most of North and East walls - ditto to floor supports internally.
3. Carefully demolish most of East wall around North East corner and approximately half of North wall right down to founding level, dam and divert water away from building.
4. Place new concrete footing with small diameter bored piles under, taken down well below scour level.
5. Rebuild walls in reinforced stone masonry using existing stones i.e. two skins with a reinforced concrete cavity between. Rebuild only to ceiling level, not including gable.



TYPICAL RECONSTRUCTED WALL
BASEMENT TO GROUND

6. Demolish West gable and parapet stones to ceiling level.
7. Remove North section of roof - strengthen timbers and replace with sound iron (could be second hand).
8. Strengthen remainder of roof structure and tie to walls - this may require new steel or timber trusses each end.
9. Replace gables in lightweight construction e.g. galvanised iron on timber framing.
10. Prop main beams, remove existing columns, place new footing and erect new steel or reinforced concrete columns.
11. Tie or stress in both directions at each floor level ensuring positive and effective connections of floors to walls.



FIRST FLOOR PLAN.

12. Strengthen existing corners to main building.
13. Replace selected portions of floors and renail all floors.
14. Remove plaster to South elevation.
15. Clean stone work, touch up generally, paint timber etc.
16. Repair cracks to water race.
17. Repair breach to Dam.

FURTHER CONSIDERATIONS

The above proposals imply an acceptance of a slightly changed exterior appearance. It is considered almost impossible to effectively strengthen this building without showing some features externally, but this would be minimised as much as possible. The Oatmeal House could in fact be rebuilt if desired, but this would have to be done in reinforced masonry as outlined in items 4. and 5. above, and this in turn would add considerable expense. Likewise, it is possible to reinstate the end gables in reinforced masonry (re-using existing stones where possible,) but we would recommend against it, suggesting that this would not seriously detract from the appearance. The natural desire to regain the original appearance is appreciated, but this must be tempered with the need to effectively strengthen. The decision as to whether the plastered surface to the South elevation (14. above) should be removed back to original stonework should also be viewed in this context.

After reinstatement, the building will effectively become a museum open to the public. As such, any scheme for strengthening and reinstatement must be approved, not only by he Waitaki County Council, but also by the Ministry of Works and Development. The M.W.D. have a planned policy of eliminating unreinforced masonry buildings which come under their jurisdiction throughout New Zealand as soon as practicable. The new loadings code N.Z.S. 4203:197 General Structural Design and Design Loadings for Building does not in fact allow for unreinforced masonry, which means in effect that this cannot be applied to older buildings such as this. However, M.W.D. have some sympathies with the retention of selected worthwhile historic buildings, and it is considered that a scheme such as that outlined above would prove acceptable to them on the basis of a low occupancy as a museum, and therefore a correspondingly low risk. However, it must be recognised that each such proposal must be considered on its own merits, and thus close consultation with M.W.D. personnel would be necessary during the development and preparation of final proposals. It is probable that once accepted by M.W.D., approval from the local authority would follow without difficulty. It is appreciated that this work will take considerable time as the Trust will presumably want to spread the financial burden over several years. While some of the particular hazards should be treated as soon as possible, some of the later work could be staged as a progressive upgrading. It would be desirable to establish and confirm the total programme before commencing work on site. Obviously the risk of an earthquake occurring during reconstruction works increases with the length of time taken to complete, but as pointed out above, this risk is considered very low. Repairs to the dam and water race could be deferred until the building works have been completed.

SUMMARY

This report outlines possible means of strengthening, repairing and reinstating the building, water race and dam following an initial site inspection. It is considered feasible, but it will prove expensive and relatively slow as much of the work involved is labour-intensive. It is emphasised that any scheme will require approval in principle by M.W.D. and the local authority before commencement. Considerable further study and documentation is required before actual details of a firm proposal can be finalised.

David G.Cox
18 March 1977

THE RECONSTRUCTION

The Historic Places Trust accepted David G. Cox's report and started on the reconstruction which was to be staged over a five year period and cost more than $100,000. Only the first stage, the strengthening of the walls of the flour mill and oat house has been completed, the second stage involving the restoration of the milling machinery to full working order has still to be started. By December 1979 contracts had been let to W.J. Dooley for the masonry work and Winsley Construction for the reinforced concrete foundations and walls. "Ted Hyland, a stonemason of 40 years experience with 6 able bodied young men and a rather antiquated crane" were reported as carrying out the work.

The reconstruction work consisted of taking down the masonry walls of the Main Mill and the Oathouse numbering each block in the process excavating for new foundations and where necessary due to soft ground boring small diameter piles. These reinforced piles were placed under the North and East walls then the reinforced concrete foundations laid and the masonry work could begin. The wall reconstruction required each block in the North and East walls to have a section cut off the back of the block so that when it was back in place there was a cavity of 360mm at basement level, 300mm at ground floor level and 200mm at 1st floor level between the inner and outer limestone blocks. Steel ties 25mm x 8mm were set 50mm into the top face of each block to hold the blocks as shuttering for the reinforced concrete wall poured between. These ties were at 600mm centres or 2 per stone. On the South and West walls the limestone blocks were replaced in their original position with mortar between the blocks. The mortar used to bed the limestone blocks was 6 parts sand, 1 part hydrated lime, 1 part cement. The mortar used to point the limestone blocks was - 4 parts fine white sand from Mt Somers, 2 parts hydrated lime, 1 part Oamaru limestone dust, 2 parts white cement.

The reinforced concrete wall between the limestone blocks on the North and East walls was continuous from the foundation to the full three story height of the walls with a return of 2.6 metres around the South wall. This provided shear walls in two directions at right angles over the fall height of the building.

New steel columns were placed on a reinforced concrete footing to supporting the main 1st floor beams. The timber floors were repaired and steel tie rods placed below the floor spanning the width and length of the mill building at approximately 2 metre centres across the building and three metre centres along the building. These rods were embedded in the wall at one end with a washer and nut on the outer face of the building at the other.

The roof timbers were repaired and new corrugated iron placed where necessary. The gable ends which had previously been limestone blocks were replaced with timber panels.

CONCLUSION

Flour to produce the daily bread was vital to the early community in New Zealand and once wheat growing had started in New Zealand grinding the grains for flour locally became important and economical compared with sending the bags of wheat away and then sending the flour back.

A flour mill represented the interface between agriculture (farming) and industry (manufacturing) and was a major undertaking requiring considerable venture capital. There were men like Mathew Holmes and Henry Campbell who were entrepreneurs and prepared to provide that venture capital. It is estimated that in today's money the Maheno Mill would cost over $1,000,000 to build with the full cost of machinery on top of that. The later owners, the Clark Family, had emigrated from Southland after farming in the Orkney Islands, settled in Maheno district and had a number of agriculture contracting businesses.

Because flour mills were such a vital part of early communities in New Zealand it is important that typical examples are protected for future generations to see and through the building gain an understanding of their heritage.

The Historic Places bought the Maheno Mill at auction in 1977 having registered it as a place of historic importance in 1974. The Mill buildings were dilapidated and David G. Cox provided a means to bring the building's structural strength to a level to resist likely earthquakes and comply with the latest building codes. The real art in this design work was to ensure that the reconstruction work not be apparent either externally or internally. This has been brilliantly achieved with the only sign to the naked eye being the steel tie bars immediately under the floor beams and these appear a natural part of the building. The work is a credit to David G. Cox and a fitting momento of his life as a Structural Engineer caring for Heritage Buildings.

References -

N.Z. Industrial Heritage by Geoffrey G. Thornton
Brickell, Moss, Rankine & Hill by David G. Cox

SALVAGE OF THE DREDGE "HAPAI"

P.S. HUTCHINSON and C.F. MEAD
A.M.I.C.E., A.M.N.Z.I.E. B.E., A.M.N.Z.I.E.
Engineering Staff, Auckland Harbour Board at the time of the salvage

SUMMARY

In June 1957 the Auckland Harbour Board's bucket dredge Hapai over-turned and sank, in the Rangitoto Channel just outside Auckland Harbour. She was found lying with a considerable portion of her hull above water level at low tide.

As no special salvage equipment or lifting vessels were available in New Zealand or Australia, the job was tackled using standard gear and winches which were readily available, together with lifting camels designed and built for this one job.

This paper was published in New Zealand Engineering, February 1959 and presented to an Annual Conference of the New Zealand Institution of Engineers.

The Dredge commenced working again in 1958 and continued dredging until 1965.

1. INTRODUCTION

In the early morning hours of Monday, June 24, 1957, during a north-easterly gale, the Auckland Harbour Board's bucket dredge *Hapai* overturned and sank in the Rangitoto Channel, in about 26 ft of water.

The *Hapai* had been dredging sand three-quarters of a mile off Cheltenham Beach for the placing of a sand mattress in connection with the construction of Freyberg Wharf. The crew had left the dredge, moored for the weekend, at midday on Saturday, with a caretaker on board, a partially loaded 450 cu.yd hopper barge moored alongside to starboard, and a half-full 100cu.yd hopper barge on the port side.

It was about 5 am on the Monday that the signalman at Mt Victoria noticed that the riding lights were extinguished but as he was still able to locate the dredge by radar, took no action. (It was the *Hapai's* bottom returning the echo). It appears that the watchman noticed nothing unusual until he awoke in the early hours to find the ship with a large list. He had time only to grab a lifebelt and jump before the *Hapai* turned turtle.

The *Hapai's* crew left Auckland at 7 am for their day's work and discovered the sunken dredge in the early morning light. The watchman was found clinging to the hull. The small barge was still held one end, by the mooring lines, but the larger barge had broken adrift, and was taken in tow later in the morning, just before it struck the rocks off Rangitoto Island.

The dredge was lying on her starboard bulwarks and the top of her tower, the bottom of the ship being at an angle of 3O° to the vertical. The bulwarks were resting on the harbour bed from the stern to amidships, but from here to the bow the dredge was unsupported. The *Hapai* had capsized into the cut she had dredged previously. The bulwarks were resting on the undredged bottom at 26ft below L.W.S.T while the tower had fallen into the cut 5 ft deeper. The weight supported by the tower amounted to 350 tons, and this heavy load broke one of the large bucket drive gear wheels.

2. PARTICULARS OF THE DREDGE

The dimensions and tonnage of the dredge are as follows:

Length:	B.P. 205 ft, overall 210 ft 9 in.
Breadth moulded:	40 ft 0 in.
Depth moulded:	14 ft 9 in.
Tonnage, gross:	870 tons.
Working draught:	Empty – fore, 9 ft 0 in;
	Aft, 11 ft 6 in.
	Loaded – fore, 11 ft 6 in;
	Aft, 13 ft 6 in.

Working displacement empty, approximately 1,400 tons. Two engines triple expansion, condensing, of 400 hp each. Two multitube oil burning marine boilers. Buckets 1 cu. Yd capacity, normal speed 12 per minute. Weight of tumblers, buckets and ladder complete, approximately 150 tons.

Built by Fleming & Ferguson at Glasgow in 1908.

Major overhaul during 1955 when new bucket ladder complete with buckets was fitted and boilers altered to oil burning.

3. METHOD OF RIGHTING

The Auckland Harbour Board decided to obtain the services of a salvage expert. On July 6, Captain JN Edwards, Chief Salvage Officer for the Port of London Authority, arrived.

Prior to Captain Edwards' arrival, a scheme for righting the dredge had been prepared, and after some discussion, the method was approved and the Board gave the word to proceed with the salvage.

It was calculated that a maximum moment of 28,800 foot-tons would be required to right the dredge. This moment was a maximum at the commencement of movement, decreasing as the dredge rolled on her side, then increasing again to roll the dredge over her bilge, and again decreasing till the dredge finally fell under her own weight.

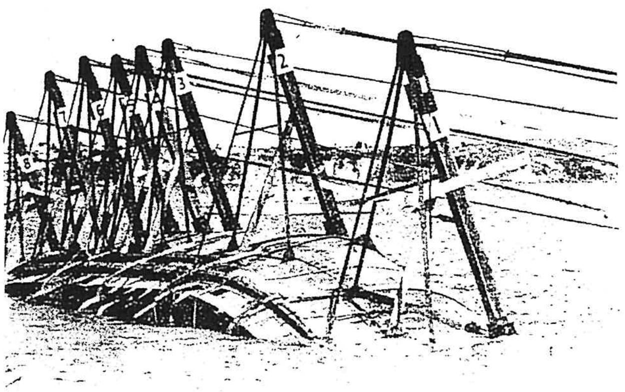


Fig . 1: Eight frames 20 ft high in position on the hull (October 1, 1957); pull of 320 tons causing initial rotation. - "N.Z. Herald" photo

To obtain this moment it was decided to use eight frames 20 ft high erected on the side of the dredge. A force of 60 tons at the top of each frame then gave the required moment, and was adopted as the nominal load for the design of frames, anchors and pulling gear.

4. RIGHTING FRAME

The construction of the righting frame can be seen in Fig. 1. The forces transferred from the frames to the dredge amounted to some 120 tons from the strut at the start of movement and 120 tons in the tie when the dredge was rolled over her bilge. These loads gave very low local stresses in the hull when spread to three hull frames beneath the strut or to the deck, which acted like a deep girder for the tie. This check was confirmed when a load of 77 tons was applied to frame No. 1, during the righting, producing a downward force of 135 tons on the hull. No sign of failure was apparent.

The struts were made of hardwood as this was readily available from stock. The base of the timber strut was housed in a steel chair which spread the load over three hull frames. To take the tensile load, the 12 in. x 1 in. steel tie from the head of the frame was bolted to the deck and 5 in. x ½ in. side braces were provided to take a deviation of pull of 10° should the ship slew during the operation.

To obtain a joint to transfer a force of 120 tons on to the deck, great care was taken in bolting the 12 in. x 1 in. steel ties. Rivets were blown out, then drilled and reamed with the tie plate in place. A hole was cut in the deck to enable the high tensile bolts to be placed and the nuts were tightened with an air impact wrench. This work was perhaps the most difficult of any and could be carried out only at low tide, and for those near the bow and stern, at low spring tides.

5. TACKLE

To provide the 60 ton pull to each frame, heavy sheave blocks were purchased from a local shipping company. We are indebted to this company, as no suitable blocks were available elsewhere, and it was necessary for them to dismantle the heavy lifting gear on several of their ships. In all, 16 blocks were required with at least 5 sheaves per block. Regardless of the number of sheaves, all blocks were reeved with $3^1/_8$ in. wire to give an eleven-fold purchase so that pulling speeds would be similar.

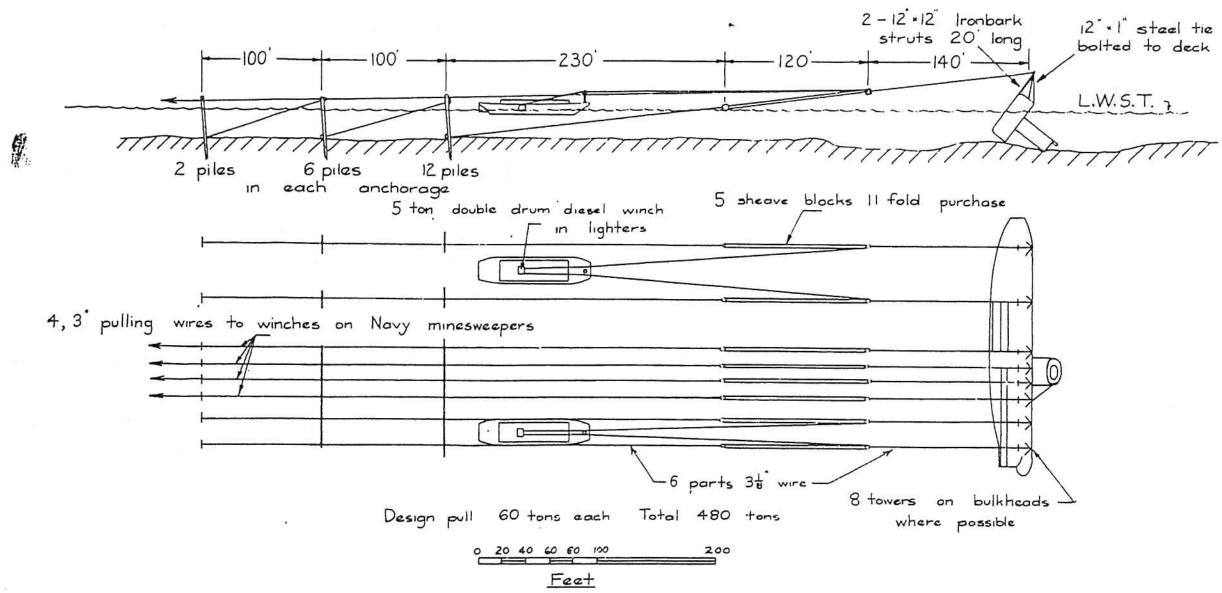


Fig. 2: Layout of equipment for the righting operation.

During the rolling-over movement, the length of arc covered by the top of the frames, from the initial position to the point where movement continued under gravity alone, was 72 ft. A length between blocks of 120 ft was provided to allow for any sliding or slewing. The pennants connecting the blocks to the frames and the anchorage were made up of several parts of 3 in. or 4 in. wires to give a factor of safety of 2, that is, a breaking load of 120 tons. So that individual wires would render and carry an equal load, 7 in. diameter pins were provided at all end fixings. The pennants were made up on shore and the wires held in place with light mild steel straps.

Some fear was held that the blocks might twist. However, no preventative measures were taken and there was little sign of twisting.

6. ANCHORS

From soundings bottom samples dredging and prickings to hard, it was known that the harbour bottom was a fine sand with many large and small shells with layers of fine sand and silt one to three feet thick on or near the surface. A firm layer existed about 15 ft below the surface and the piles usually pulled up at this depth. The anchors were designed for normal working stresses in the timber piles and values of $\varnothing$ = 35° and W = 56 with a factor of safety of 2 for movement against passive soil pressure. To obtain the most soil resistance, the piles were arranged in a line, at right angles to the direction of pulling. The anchor for each frame was a separate unit and consisted of 3 rows of piles 100 ft apart, the front row of 12 piles being tied back at half tide level to an R.S.J. laid on the harbour bed behind the next row of six piles, the heads of which were in turn tied back to two piles. This system is, in fact, a large version of an army picket anchorage. A broad flanged beam was laid behind the front row of piles and connected to the pulling gear through a gap in the centre of the row.

Each anchor consisted, therefore, of twenty piles, so some 160 piles were driven in the main anchorage. Two similar sets of 20-pile anchors were driven on the far side of the *Haipai*. These were anchors for the parbuckle holding wires prevented the *Harpai* sliding along the bottom, or slewing, during the righting operation.

7. WINCHES

No suitable steam winches were owned by the Board or were available for hire or purchase in the North Island. The final arrangement consisted of two new Navy double drum diesel winches with a hydraulic coupling and a total pull of 10 tons each mounted in two lighters moored ahead of the main anchorage, and two similar steam winches on the minesweepers H.M.N.Z.S. *Stawell* and *Echuca* which were moored on dolphins behind the main anchorage. These circular dolphins consisted of nine perpendicular piles and in addition three-pile anchors were driven off the bow of each minesweeper to take the 10 ton winch pull. The layout of gear for this operation is indicated in Fig. 2.

8. GAUGE

To measure the loads on the eight tackles a simple wire load gauge (Fig. 3) was positioned on the hauling wires ahead of each winch drum. The gauges were calibrated from 3 to 7 tons and worked well with an accuracy of about ½ ton on stationary and moving wires. They were the means of keeping the load spread evenly on the floor double drum winches. Without these gauges it would have been possible to overload one tackle with perhaps, disastrous results.

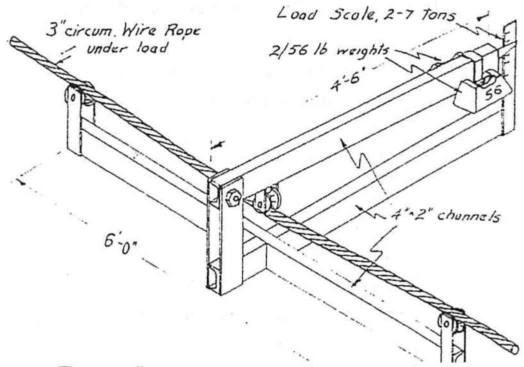


Fig. 3: Isometric view of wire load gauge.

9. THE PREPARATIONS

Soundings showed the dredge was in such a position that, when righted, it would have listed 5° to 10° into a previous cut. Approximately 1,000 cu.yd of sand were dumped into this hollow to build up a level bed, and measurements taken after righting showed that the final list was less than 1° to port with the keel at the bow about 1 ft higher than the keel at the stern.

A platform 8 ft high from which the operation was controlled was built on a punt and moored off the bow of the *Hapai*. R/T sets were used to convey all orders and messages to and from the winches, with Navy semaphore signalmen on hand in case of breakdown. Flag signals were used to co-ordinate all winch operations and provide a visual indication of the load conditions at any time. The system worked well; the flag instructions used were as follows:

Control	Winches
Green Flag Raised	
I have an R/T order for all winches.	I have understood the order and am ready to carry it out.
Green Flag Lowered	
Carry out order.	I have finished carrying out order.
Red Flag Raised	
Stop pulling, apply brakes (Obey on sight).	I am unable to pull on one or both wires.
Yellow Flag Raised	
Prepare to let go.	I have less than 3 tons on one or both wires.
Yellow Flag Lowered	
Let go.	

10. THE OPERATION

On Monday September 30, the two Navy minesweepers *Stawell* and *Echuca* were brought into position. A test was carried out using the *Echuca's* winches and a load of 4 tons on each of the two hauling wires was obtained and held simultaneously.
The next morning, October 1, the lighters were towed in and moored in position. Just after midday, all was ready. Quite an array of large and small vessels were on hand to witness the result of three months' planning and preparation.

The operation was controlled by the Foreman of Works, F.H. Tackaberry. A short summary of the record of events follows:

Time: 12.23:	Pulled up to 3 tons per winch (total pull – 240 tons).
12.58:	Pulled up to 4 tons per winch (total pull – 320 tons).
13.08:	Pulled up to 4½ tons and tried to maintain. Movement commenced (total pull – 360 tons).
13.15 – 13.20:	Stopped pulling to even up wire tensions.
13.21 – 13.32:	Rotated through 35° to bottom vertical.
13.32 – 13.40:	Evened up wire tensions and pulled up to 4½ tons (total pull – 360tons).
13.40 – 13.49:	Rotated through 90°, last 35° by gravity.

Figure 4 shows the pull required during the rolling over.

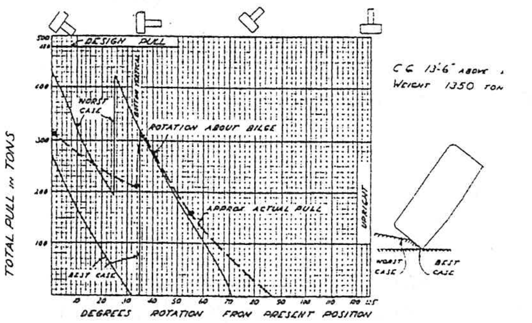


Fig. 4: Graph of rotation/pull.

Everything went smoothly and accordingly to plan, no unforeseen difficulties arising. Three months of hard and painstaking work and borne fruit.

11. METHOD OF LIFTING

The following methods were considered: Cofferdam, hopper barges, lighters, deck cofferdams, jack-off piles, and camels (the adopted method).

11.1. Cofferdam

In this scheme, it would be necessary to build a double-walled or cellular steel sheet pile cofferdam to surround the *Hapai* completely and to withstand pressures due to a difference in water level of 38 ft. When pumped dry, it would be possible to make any necessary repairs and then float the ship with a controlled inflow of water. This scheme was not accepted owing to the time necessary to obtain the materials and build the cofferdam and because of the high cost, estimated at £300,000.

11.2. Hopper Barges

The two hopper barges used by the *Hapai* would lift, with sealed doors, a total of 1,400 tons approximately. This would be sufficient total lift, but the difficulty was to position the barges over the *Hapai* and attach wires in a suitable manner for lifting. If all gear was removed down to the *Hapai's* deck level by divers, a sufficient lift could have been obtained to place the ship in dock. The scheme was not accepted owing to the tedious and difficult work necessary by divers.

11.3. Lighters

Twelve cargo lighters 90 ft long by 22 ft beam were available. Consideration was given to lifting over the bows of the lighters, so enabling a direct lift at several points along the sides of the *Hapai* to be obtained. A lift of 20 tons could be supplied by each lighter, and this lift could be increased to 60 tons, if the after crew compartment was filled with water. The scheme was not accepted owing to the uncertain stability of the lighters with a load over the bow, and because a lift of only 5 or 6 ft could be obtained on each tide.

11.4. Deck Cofferdams

A conventional method of raising a sunken ship, is to seal all small openings, and building cofferdams from one or two of the larger openings to above high water level. The hull can then be pumped out through these cofferdams until sufficient buoyancy is obtained to raise the ship to the surface. This scheme was not adopted owing to the large amount of diver time required, and the uncertain stability of the ship when buoyant, with free water inside.

11.5. Jack-off Piles

A unique suggestion was put forward to dive piles at various points around the hull and then, using 100 tons jacks, lift the ship inches at a time, taking the weight on to the piles, until the deck was above water level. The scheme was not accepted owing to the unorthodox method and the difficulty of finding sufficient jacks.

11.6. Camels

In this scheme cylindrical pontoons were constructed to give sufficient buoyancy to lift and move the *Hapai* to shallower water, when, with the deck above water level, the hull could be pumped out and the ship refloated. The diameter of the camels was determined by the buoyancy required to be spaced out along both sides of the ship. The displacement of the *Hapai* is approximately 1,400 tons and the submerged weight 1,150 tons. After some consideration, the dimensions decided upon were: 12 camels, 17 ft diameter, 24 ft long , weight 18 tons, 138 tons net buoyancy each, 1,656 tons total net buoyancy.

It was considered by some that the heavy bucket line, bucket ladder and tumbler gear should be removed before any attempt was made to refloat the dredge. The total weight to be removed amounted to about 150 tons, and this would have the effect of lowering the centre of gravity from 14 ft to

11 ft 9 in. above the keel. As this would not have improved to any great extent the good stability provided by the camels, it was decided to lift the dredge as she stood.

12. CAMEL DESIGN

The pressures acting on the walls of the submerged camel under load were calculated and an additional 5 lb/sq.in. added as a contingency. The resultant pressure is independent of depth. Ring girders were provided at 4 ft centres, and bending moments in these were calculated by the column analogy, 4 in. x 3 in. R.S.J.'s being sufficient.

Shell thickness was calculated from stresses due to circumferential, longitudinal and bending tensile forces, these being 2,080 lb/sq.in., 2,080 lb/sq.in. and 4,160 lb/sq.in. respectively for ¼in. plate. The plate thickness was considered to be the smallest desirable to withstand subsequent handling and local loading. The shell was also checked for crinkling through bending as a beam by a formula from Conway's *Aircraft Strength of Materials*.
The load on the flat ends of the camel was taken by:

(a) 3 pairs of boiler stay tubes extending end to end.
(b) 3 vertical internal 10 in. x 5 in. R.S.J.'s.
(c) 7 horizontal external 4 in. x 3 in. R.S.J. stringers at centres , varying from 1 ft 9 in. at the top to 2 ft 6 in. at the bottom. Plate thickness was calculated to be 5/16 in. from Crashofs, Pounders, Bach's and Timoshenko's formulae.

It was originally intended for simplicity and cheapness to construct the camels as simple cylinders.

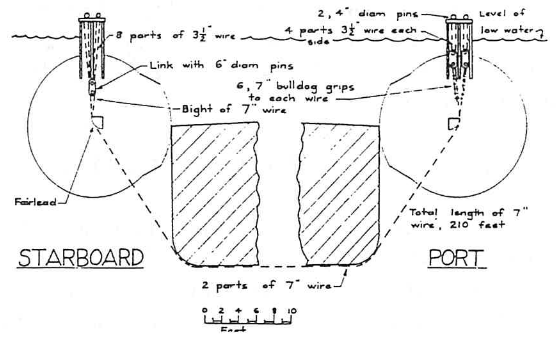


Fig. 5: Attachment of camels.

However, it was shown that this shape is unstable longitudinally when partially filled with water, and a central bulkhead was provided giving two completely separate compartments. The central bulkhead was of similar construction to the ends.

The weight of each camel was 18 tons approximately, including over ½ ton of ballast. Towers consisting of two 10 in. x 3 in. channels with a central 10 in x 6 in. R.S.J. and extending 4 ft above the camel were constructed at each end to enable the fixing of lifting wires to be carried out above water level at low tide.

The lifting wires were led around a fairlead at the centre of each end of the camel. Thus the towers could be maintained vertical (or at any required angle) without imparting a rotational force to the camel.

Buffers were provided at each end to keep the thin shell away from the hull and to transfer all the heavy loads through the ends. The buffer width was 12 in., 18 in., or 24 in. depending upon the curve of the belting of the *Hapai* in the vicinity.

Calculations for the size of valves were based on the use of one 250 cu.ft/min compressor per pair of camels. This required a 6 in. water valve at the bottom of each compartment and a 1 in. inlet valve and air hose. With this arrangement a pair of camels could be blown out to full buoyancy without undue pressure drop through the 6 in. valve, in about 40 minutes. Finally, ¾ in. hose was used for the central eight camels, and an extra 1 in. valve was fitted to each camel compartment to prevent air locking. Safety valves were included and these could be opened when faster sinking was desired.

13. AIR SUPPLY

To enable full buoyancy to be obtained in less than 1 hour, a total of 6 compressors with capacities from 155 cu.ft/min to 250 cu.ft/min were accommodated in a cargo lighter moored alongside but held clear of the camels, by two piles fitted each end with rubber buffers, and hung horizontally between the *Hapai* and the lighter. Individual 1in. hose led from each compressor to the control device called "the organ", situated on a temporary bridge constructed on the *Hapai's* upper works well above water level. From a common 3 in. pipe manifold, 15 ft long, blowing and venting valves and 0-15 lb/sq.in. pressure gauges, were arranged to allow the control and measurement of buoyancy in all 24 compartments of the camels. From a measurement of the camel freeboard or submergence, together with the internal air pressure, the buoyancy to the nearest ton could be obtained from a table. The internal air pressure could be read only when blowing or venting was stopped.

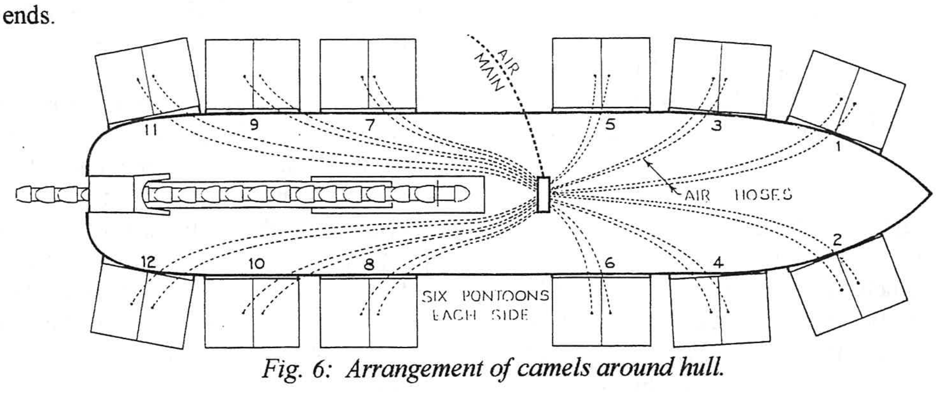


Fig. 6: Arrangement of camels around hull.

14. ATTACHMENT OF CAMELS

The largest wire available in New Zealand in sufficient quantity was 7 in. circumference 6/37 galvanized wire. This was cut into lengths of about 230 ft to pass, doubled, around the hull of the *Hapai* opposite each end of each camel. Before the dredge was righted, the ends of the wires were coiled as far under the ship's side as possible, and the wire laid around the upturned hull. After rolling over, both ends were then available.

Perhaps the most vexing problem of all, was how to fix the 7 in. wires to the camels (Fig. 5.) A tapered stopper was designed but the total cost of local manufacturer for 48 off was in the vicinity of £10,000. Carpenter stoppers for 7 in. wire rope were available in England at a cost of £420 each. Finally conventional dog clips were made in aluminium bronze, 5 of these withstanding the test load of 70 tons.

A doubled 7 in. wire was provided for each end of each camel, the bight being on the starboard side and the two loose ends being on the port side of the ship. The loose ends were turned and clipped off with the dog clips to give the correct length of wire. The loops were then placed around one pin of a large link and several parts of 3 ½ in. wire rope taken from the other pin of the large link to two 6 in. diameter pins bolted to the top of the camel tower. A breaking strength of 260 tons was then available at each end of each camel against a maximum working load of 100 tons. The pair of camels was then evened up to the correct height with the assistance of a floating crane on each side, and a full buoyancy test carried out. The friction of the wire against the hull was relied upon completely, to prevent rendering, and it was necessary, during the test and subsequently, to ensure as near as possible, the same buoyancy in each camel of the pair. The camel turned out to be a temperamental creature, and it took several days to learn how to keep them in hand. On one occasion a camel moved astern under load, bent the buffer and opened up a few small holes, requiring major surgery.

The arrangement of camels around the hulls is shown in Fig. 6.

15. ANCHORAGES

To prevent the dredge from floating up harbour on the incoming tide, anchorages were driven about 1,100 ft from the bow, forming the centre of an arc along which movement inshore to shallower water took place. Two such movements were carried out. The anchorages consisted of two 14 in. x 12 in. B.F.B.'s 45 ft long driven 100 ft apart into the sandstone bottom. A wire passed from the top of the forward pile to the rear pile at sand level. Two 4 in. wires formed the 1,100 ft long pennant from the anchorage to the *Hapia* bow.

16. THE FIRST LIFT

(March 1, 1958)

The previous day, the camels had been left in position with about half maximum buoyancy. Blowing of the camels commenced at 9.05a.m. and the bow rose about 2 ft at 9.35 a.m. when the total buoyancy was 1,014 tons. Blowing was continued on the camels near the stern and at 10.19 a.m. the stern rose about 4 ft. The *Hapai* was then towed inshore by four small tug boats as the tide rose, just touching the bottom all the way. Approximately 3 ½ hours later, when she was in the planned position, the camels were vented. She was then in 18 ft 6 in. of water (below L.W.S.T.) a vertical lift of 8 ft having been obtained.

17. THE SECOND LIFT

(March 26, 1958)

The portion of the dredge now showing above water was hosed down with a water jet supplied through a fire hose and nozzle from a 3-stage diesel-driven pump. An extension piece 4 ft high for the camel towers had been fabricated, and these were bolted to the towers along the port side with the camels resting on the bottom. The 7 in. wires were pulled through under the hull and re-clipped to the tower extensions. By this means, all work could be done above low water level.

At the first light of dawn on March 26 blowing was commenced on all camels. After a lift of about 2 ft at the bow, the camels on the port side reached sufficient buoyancy to come to the surface and produce a list to starboard of 8°. With blowing continuing on the starboard side, 20 minutes later a movement took place resulting in a list of 8° to port.

These movements were anticipated by those planning the operation, but caused great anxiety to others watching. Finally, at 6.40 a.m., the *Hapai* reached an even keel and began to be towed inshore on the rising tide. To reduce the draught further at the stern, the two after chain lockers were pumped out, and the *Hapai* settled in the planned position at 9.48 a.m. The decks which were covered with 2 in. to 3 in. of silt were hosed down during the next few days. A vertical lift of 9 ft 6 in. had been obtained leaving the decks a little below half-tide level.

18. PUMPING OUT AND FLOATING

It was decided not to use any big pumps as sufficient capacity could easily be obtained from 2 in. and 3 in. sizes. The pumps were arranged to draw the water down at approximately the same rate in all compartments. A total of 23 petrol, diesel, and air pumps were used, giving a combined capacity of 7,000 gal/min. With all pumps working to capacity, the hull could be pumped out in about an hour, whereas there was about four hours available from the time the tide left the deck till it returned. Several holes were cut in the deck to allow direct access for the suction hoses. The pump discharges were left open on to the deck and the water ran out the scuppers.

The eight central camels were left in position with about 50 tons buoyancy in each as it was feared that the ship might take an unhealthy list if some free water still remained in the bilges. With the camels in position, it was possible from their buoyancy readings to anticipate any list. The camel buoyancies on the two previous moves inshore had shown a difference of about 60 tons between the port and starboard sides. Water was now left in the *Hapai's* port buoyancy tank and this corrected the list that otherwise would have been there.

A comprehensive lighting system was installed to provide sufficient light to work the pumps before dawn, and to light the inside spaces after the bulk of water had been pumped out.

At 5.45. a. m. on March 31, the pumps were placed aboard as the tide ran off the decks, and pumping out commenced. By 7.30 a.m. most of the water had been removed, and work was continued with air pumps to remove the last few inches of water in the bilges. At 10.30 a.m. the *Hapai* was just afloat without showing any list, and the camels were gradually vented. By 3 p.m. the camels were on the bottom, and the *Hapai* afloat once more on her own account. Much discussion had previously taken place as to whether the camels should be completely removed from the area, but it was decided to attempt to pull the dredge clear of the camels and lifting wires, with tugs. Initial pulling showed that the dredge was held by the 7 in. wires caught on underwater projections from the hull. The 7 in. wires were cut with the gas, and fell to the bottom. Finally at 6 p.m., under the combined pull of the two Board's tugs together with three smaller tug boats, the *Hapai* came clear and was towed to her berth at the Western Viaduct.

19. COSTS AND ECONOMICS

The 49-year-old dredge had undergone a major overhaul two years previously and the book value stood at £150,000. A considerable amount of new gear had been added and she was in quite good working condition. When the Board considered the future of the sunken dredge, there were three courses open:

(a) Leave the dredge where she lay. This, they decided, could not be tolerated mainly for aesthetic reasons.

(b) Break up by explosions placed by divers and remove piece by piece. This method was sometimes used during and after the war in English ports, but proved to be an expensive procedure. In the case of the *Empress of Canada* which capsized in the Liverpool Docks after an outbreak of fire, it was considered cheaper to roll her over, and refloat, prior to handing her over to the ship-breakers, than to cut her up where she lay. Within a day or two of the *Hapai's* capsize, a bucket dredge similar to the *Hapai* capsized in an Australian port and was broken up and removed as she lay. As far as can be ascertained the cost of breaking up this dredge will prove to be of the same order as the cost of righting, refloating and docking the *Hapai.*

(c) Salvage and refit. This has proved to be the wisest decision from almost all points of view. A new dredge of the same type as the *Hapai* would cost today something like £750,000 with a three year delay before delivery.

The cost of the salvage operations was in the vicinity of £110,000 and the cost of cleaning and refitting amounted to about £50,000. The refitting progressed satisfactorily, and the dredge was working again by October, 1958. Although most of the working parts of the dredge had lain underwater for nine months, the work necessary has entailed little more than that required for a major overhaul.

20. CAUSE OF CAPSIZE

While it is possible that sufficient water could have entered an open porthole during the rough weekend to cause instability, the actual cause of capsize in not known. The dredge has, for lists up to 15°, a high metacentric height of 4 to 5 ft, and has always shown herself to be a stable ship.

21. CONCLUSION

It has been shown that, in the absence of heavy salvage and lifting vessels, the design, fabrication and use of special lifting gear with the co-operation of men of all departments – draughtsmen, crews of floating plant, fitters, welders, riggers, plumbers, shipwrights, divers, contractors and others – has brought about a completely successful salvage operation.

22. ACKNOWLEDGEMENT

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Heritage Engineering - Our Professional Obligation; Practical Developments in Achieving our Goals

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Summary

Heritage Engineering involves the preservation of structures built by our ancestors, used by present generations and preserved for the good of our children. It necessarily combines an understanding of what our forebears created and intended, with the requirements of present day engineering codes. It involves the close working together of the architect, structural engineer and the specialist contractor charged with carrying out the works. Understanding what was intended is the prerequisite to a satisfactory solution. However, changes in design methods and laws have seen the necessity for new techniques for the upgrading of the structures, especially where the upgrading is required to involve strengthening.

This paper attempts to set the scene of what we have inherited and offers modern solutions for overcoming the problems which arise in any upgrading project. Many of the methods described as modern day tools have been introduced to Australasia by the author's associations, who have pioneered the development of the systems and their successful application. An excellent three dimensional non-linear structural analysis programme is described and its use in several projects is illustrated. In all, the paper attempts to set before the interested conservation engineer or architect a taste of what can be achieved in the new millennium, with the hope that it will provide some stimulus and inspiration to push the standards we have set to an even higher plane.

1. INTRODUCTION

Most people today have one particular job in society: a person is an engineer, architect, soldier, or bricklayer and so on. Many professions are themselves sub-divided and these specialities are followed as quite separate careers. Thus an engineer will be either a civil engineer or an electrical engineer, a mechanical or some other type of specialist engineer. Each will belong to a specialist technical institute, undertake quite different work and only have a limited knowledge of the other's trades. All this was much less true in the ancient world. An engineer would deal with both fixed works and mechanical devices. Today a distinction is also made between civil engineers and architects. Architects are concerned with the arrangement, appearance and finish of all kinds of buildings, whilst civil engineers become involved in buildings only when structural problems have to be solved or special foundations are needed. In the Egyptian, Greek and Roman civilizations, all these activities would have been the concern of the same person.

Heritage Engineering, as we know it at the beginning of this new millennium, seeks to find ways to preserve the magnificent works of those who came before us. Traditional methods of restoration used 2000 years ago need constant modification as environmental conditions become more severe and demanding. The concept of seismic engineering has posed a huge challenge to the heritage engineer as society demands that we bring structures up to present day code requirements largely without disfiguring either the outside or the inside of the structure. The harnessing of earthquake forces created in the structural elements of a structure, caused by the violent movement of the supporting ground and, to all intents and purposes, concealing the retrofitted members which carry these forces, are major challenges to both the architect and the engineer.

The period since the Second World War has seen not only a rapid development of the technology of conservation but also a matching development of the philosophy and ethics of conservation. In this same period, the term "conservation" has been adopted to refer specifically to the professional use of a combination of science, art, craft and technology as a preservation tool. The conservation of historic buildings or buildings of heritage value has thus developed into an extremely complex process involving a team of many professionals, specialists, trades and craftsworkers.

In Australasia, we are not troubled by the conserving of structures more than two hundred years old. We are mostly looking at structures half of this age, many of which are constructed in stone and concrete. Our philosophies and methods do not greatly differ from those of our European cousins and many of the techniques used in preservation are sourced from Europe. Notwithstanding, in a continuation of the true pioneering spirit shown by our ancestors who left the various motherlands, we have developed unique technologies which are suited to the Kiwi and Aussie way. This paper is an attempt to describe how the author's company assisted with some of these processes coming into being.

2. PART 1: A VERY BRIEF LOOK AT THE PAST

While the saying *"we did not inherit the world from our ancestors; we borrowed it from our children"* is very true, it is important we understand how the structures we strive to preserve today were created and what legacy our ancestors left us to pass on to our children. Understanding the intentions and skills of those who came before, creates the inspiration which drives our obligation.

2.1 3000 BC – 1000 BC: The Egyptians

The greatest legacy from this long engineering period is, of course, the great Pyramids. We can still marvel how the people of these times built these massive structures, although much scrutiny and study of the methods has failed to fully explain this in detail. One authority estimates that 100,000 workers spent 20 years building the Great Pyramid; when you consider that this was 5000 years ago, this is an engineering feat, even by modern standards, of gigantic proportions. That the limestone from which the structures were built is still largely intact today shows us that the Egyptians not only knew how to construct, but had a good feeling for durable materials.

2.2 1000 BC – 200 AD: The Greeks

From an engineering point of view, the best legacy to come out of this period is the development of mathematics, philosophy and architecture. The names of great Greek philosophers, such as Apollonius, Archimedes, Euclid, Plato, Pythagoras and Socrates still permeate our basic engineering learning today. Geometry was their particular strength. The cutting of precise volumetric shapes from large blocks of stone, to minimise wastage and preserve uniformity of texture and colour, was the motivating force behind these early engineers.

2.3 200 BC – 400 AD: The Romans

Whilst this era overlapped that of the Greeks to a certain extent, the Roman influence grew quickly and spread throughout Europe and Northern Africa. It is in this period that the great civil engineering works, many of which can be seen today, were created. Roman roads were constructed to allow access of their legions to the conquered regions. Roads of comparable quality and durability were not to be built again for more than a thousand years. The massive aqueducts built to bring water to their cities, were major works, even by today's standards. It is interesting to note that Roman architecture relied heavily on the Greek theory of architecture and surviving works such as the superb group of buildings on the Acropolis, in Athens. It was engineer-architect Vitruvius who created the norm for those who followed. His Ten Books on Architecture, published about 20 AD set the standard of much which was to come. From an engineering perspective, the Roman period was one of intense development of construction techniques, which illustrate the excellent understanding of basic principles the engineers-architects of the time possessed. Aqueducts, roads and bridges all demonstrate the Romans' grasp of the basic principles of engineering. They appreciated the importance of sound foundations and the equally important need, especially when building roads, to protect the foundations from water. In perfecting the arch, they realised that careful shaping and accurate cutting of the voussoirs would allow that a semi-circle of stone would carry any load forever (fig 1).

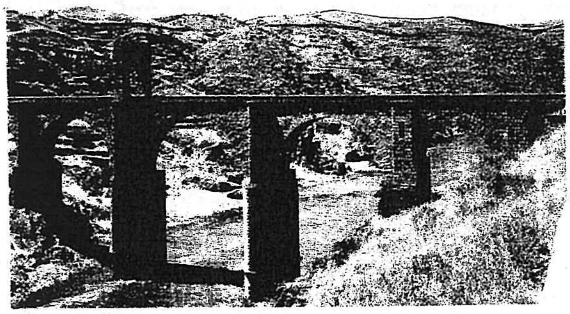

***Fig 1:** The Romans took the semi-circular arch and made it the most characteristic feature of their architecture. This splendid example is the triumphal arch of the emperor Trajan, built about the middle of 2 AD.*

The application of these principles produced a vast amount of work to a formidably high standard. But does history repeat itself? Sometimes construction in Roman times did fall below standard. The ever vigilant Pliny reports such a case to Trajan: *"the citizens of Nicomedia have spent staggering sums on an aqueduct, twice begun, twice demolished, but still they have no water supply!!"* Ancient writers complain, too, of the dishonesty or carelessness of the jerry-builder; his enthusiasm for tall insulae far outran his observance of structural principles, with disastrous results. Have we heard this before? It seems that nothing changes!

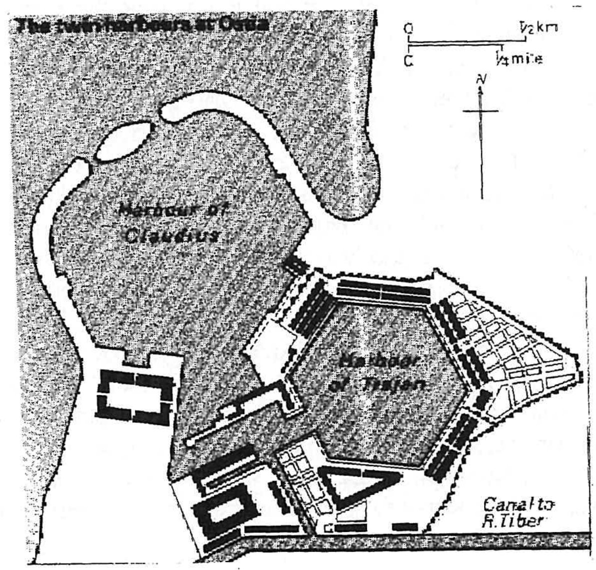

***Fig 2:** The port of Ostia. There were mooring facilities for more than a hundred ships in Trajan's basin. Goods were stored in the surrounding warehouses. The lighthouse probably stood on the island between the two moles.*

The Roman engineers' confidence in their knowledge and ability is magnificently expressed in such remarkable structures as the Colosseum and the Amphitheatre at Pozzuoli (fig 3). Here a most skilful combination of arch and vault has produced arenas in which many thousands of spectators could sit, and – more important– move to and from their seats with ease (the designers of Eden Park's new ASB Grandstand could learn a lot from this!!). The boldly executed harbours of Ostia (Rome's original seaport) , the outer one built under Claudius, the inner under Trajan, were inspired by this same confidence (fig 2). But even the Romans could not predict everything accurately; miscalculations did occur as Tacitus tells: *"When the tunnel from Lake Fúcino was opened, the flow of water was much greater than expected that it swept away the ceremonial banquet arranged to celebrate the opening!".* [3]

2.4 400AD – 2000 AD: Post Roman

This paper is not a lecture in history; the brief comments on the three early periods are meant to set the scene for the discussion on present day heritage engineering. Thus I do not intend to cover the intervening post-Roman periods, known as the Early Medieval Period (400AD – 1000 AD, the Cathedral building period (1000 AD – 1449 AD), the Byzantium period (400AD – 1400 AD), The Renaissance (1450 – 1599), the Seventeenth and Eighteenth Centuries (1600 – 1749), the later Eighteenth Century and Early Industrial Revolution (1750 – 1799), the later Industrial Revolution (1800 – 1849), the second half of the Nineteenth Century (1850 – 1899), and the first half of the Twentieth Century (1900 – 1949). Reference [1] gives a concise history of these periods, which engineers will easily understand.

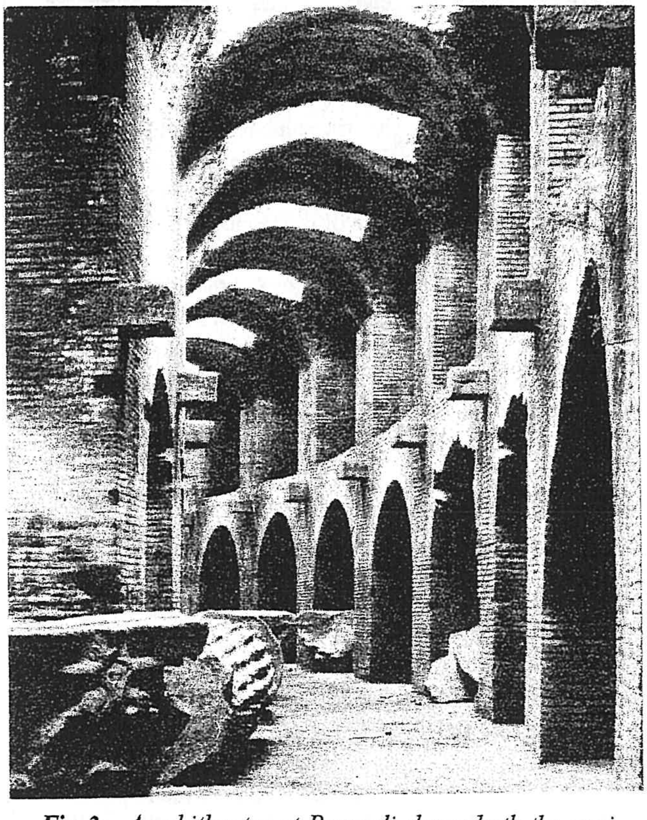

Fig 3: Amphitheatre at Pozzuoli shows both the engineers' highly developed use of arches in their design and the strength of their concrete standing firm after 2000 years even if some of the brick facing has fallen

It would, however, add to the scene setting of the present day to describe briefly the development of the engineering infrastructure in Australia and New Zealand over the first half of the twentieth century. It is this infrastructure which we are charged with preserving and much of the work in the early part of this new century (twenty first) will see continuing restoration and preservation of these works. By Infrastructure is meant the man-made permanent structures, such as buildings, roads, power stations, dams, railways and the like. The engineering profession and industry were the source for these achievements. What was different in Australasia to the countries of Europe was that there was no significantly older infrastructure present. Thus resources were mobilised to create new structures without having to rehabilitate the old. In the field of roading and bridges, NZ and Australia followed a similar path, as it did for water supply structures and hydro dams. The same can be said for marine structures – there is little difference between the types of wharves built in the two countries. Mostly, structures were built of reinforced concrete and their inherited problems are much the same. Both countries are surrounded by the oceans, with concentrations of populations near to the sea. Thus the cause of deterioration of the structures invariably comes from the salt contaminants present in the air and (in some early instances) in unwashed beach sands used to make concrete. Australia constructed more brick structures than New Zealand probably because NZ was always aware of the lack of strength of such structures under seismic conditions.

It is in the field of buildings that we see quite a difference in construction methods and materials used between the two countries. Prior to the 1970s, in both countries (indeed in the whole world) structures were designed according to the strength method allowing only for the performance of the structure within its "elastic" range. Essentially many buildings were just gravity structures, with moments in horizontal elements created by the vertical loads. Due to the natural presence of good building stone, Australian cities featured more stone buildings than did New Zealand cities. In NZ, concrete, in conjunction with timber, prevailed as the predominant form of construction, although some structures were built of imported stone (the Ferry Building in downtown Auckland, built of Sydney sandstone, is an example of this).

The advent of the capacity design philosophy, introduced to the world by Park and Paulay of New Zealand in the early 70s, saw a very rapid change to building design and construction methods (also, to a certain extent, to those other important structures, such as dams and bridges). Capacity design requires an analysis of the structure in the post-elastic range, so that the structure's behavior in an unusual event such as an earthquake, is predictable. The aim is to ensure that a structure will not collapse when such an event occurs, even though it might sustain considerable damage. Buildings designed according to the strength method invariably were not "flexible" enough to enter the post-elastic range, because they were too stiff and did not possess enough ductility in their critical members. As new codes evolved around the world (initiated by NZ, Japan and California) building control authorities declared that structures had to be upgraded to code requirements or be demolished. This saw major changes in cities such as Wellington, where about 60% of its large office building stock disappeared over a 10 year period to be replaced by earthquake resistant buildings. Those structures of heritage significance were strengthened and it is here that the techniques discussed later in this paper were developed. Other major structures, the bridges and dams, were analysed for seismic strength and because the cost of replacement was prohibitive, were also strengthened to meet the then current code requirements.

Thus the design and construction methods used in NZ and Australia set off on different paths and have continued to do so ever since the 1970s. I well recall my first visit to Australia in the late 60s and observing the smallness of the columns on the major buildings being constructed in Sydney at the time, when compared to those in NZ. For seismic resistance using the strength method of design, circa 1970, it was not uncommon to see ground floor columns in Wellington measuring 2m x 1m, whereas the equivalent in Sydney might have been 500 mm x 500 mm, or even less. Fortunately today, using capacity design methods creating ductile frames, the size of members has been reduced to something more acceptable.

However, the point of the matter is that these valuable structures pre-1970s, must be preserved, which means strengthening. It is the methods which have been developed since the early 1980s, to satisfy the requirements of these changing codes, which I want to make the main feature of this paper.

3. A WORD ABOUT MATERIALS

Any conservation project depends to a large extent on the studies of the original building materials and particularly on their method of manufacture, the sources and extraction of their raw materials, and their deterioration generally and specifically in the instance under study. Furthermore, the strengthening of a heritage structure, to bring it up to present day code requirements, requires a very intimate knowledge of the original materials and their behaviour when subjected to present day loads (which might be quite different to those at the time they were designed.)

In comparison to Europe, we are fortunate that our structures are not constructed of many varying types of materials. NZ has very few stone and brick structures and most structures are made from concrete, timber and artificial masonry (concrete blocks). In Australia, there are many more stone and brick buildings, as well as the concrete and masonry structures.

The Romans considered stone as their most important building material and indeed it is quite remarkable how much was done with nothing but dry stone. Foundations were laid, water-channels, walls, bridges and vaults built, and roads surfaced. All this reflects the great skill and care the Romans applied to quarrying and shaping. In one way, their eventual progress to mortar jointing was a step backwards for the mason's art; they no longer needed to cut and shape so easily. From the earliest days the blocks of stone were laid in varying lengths and widths with their vertical joints staggered at random. A wall would be weaker if the vertical joints were directly above one another. Only the depth was kept the same. The variety of widths of the stones did not matter, since a wall was usually built with two skins of stone, each with a flat outer face and the cavity between was filled with loose rubble. Mortar began to be used in joints about 2 BC. Early mortar was weak and spread thinly between accurately dressed blocks. However, when the Romans had discovered how to make stronger mortar, stones no longer needed to be carefully cut. This new mortar, which had great bonding power, gave a number of smaller stones the strength of a large block.

The magic material which gave the Romans the everlasting reputation for strong mortar was called *pozzolana*. As it was a volcanic ash, they found that strong mortars could be made from pozzolana located near a volcano and much further away, the material produced only weak mortar. The Romans used pozzolana as we use sand; three parts of pozzolana added to one part of lime was their "secret" mixture. Roman concrete was not suddenly invented; it developed from the practice of building walls with a rubble core. The addition of good quality mortar to the rubble filling made the wall much stronger; in due course, this process became systematic and carefully controlled so that the same high quality could be reproduced every time. Where concrete was being placed between brick or stone facework, no ramming was used as this would have moved the face of the stonework outwards.

Wherever there was a suitable clay and the climate was sunny enough, early civilisations made crude bricks baked in the sun. Vitruvius instructed that a good sun-baked brick should be exposed for two years. Kiln-fired bricks, first used to make roofing tiles, became the predominant form of construction dwelling houses in early Roman times.

Nineteenth and twentieth century materials used in Australasia consist of stone, timber, brick and concrete. Stone is now rarely used as a construction material, due to the high cost of labour required to produce, shape and place it. But heritage structures constructed of the other three materials abound. When strengthening of brick and timber is required, usually other materials are used in conjunction with the original; concrete to strengthen brick and stone walls; steel to strengthen timber structures. But there exists a variety of new ways of strengthening concrete structures, some which appeal to the conservationist because of their lack of bulk, thus preserving the original form of the element strengthened. These are covered later in this paper. Reference [2] gives a detailed treatise on techniques and materials used in the conservation of buildings and is recommended.

My company's interest in materials for repairing concrete structures dates back to about 1980. At this time, problems associated with spalling of concrete due to rebar corrosion were not understood anywhere in the world. This is an interesting fact which is borne out by texts on concrete at that time. Concrete was the ever durable material; "build in concrete and it will be there forever". Spalling which did occur, was invariably patched with epoxy mortar, the "cure-all" sold by material suppliers, without giving a thought to determining or treating the cause. But people were starting to realise that the very high quality (and expensive) epoxy mortar being promulgated as the answer to a maiden's prayer, seemed to "pop-off" the concrete after a relatively short space of time, for some unknown reason. But notwithstanding, cubic metres of this material with a cost close to that of gold, continued to be sold, for want of an alternative. It is fair to say that it was also realised that patching spalled concrete with cement mortar did not work either.

From 1980, for three years, my colleagues and I experimented with what we termed "resinous concrete", as a repair material. The term resinous was used to differentiate the binder in the mortar from epoxy. Acrylics (polymers) were experimented with as binders and the object was to develop a mortar which could be easily applied to old concrete, would stick like the proverbial to a blanket and which had physical properties very close to that of the old concrete (coefficient of thermal expansion, tensile strength, flexural modulus). It was also important that during its curing period, it did not expand or contract extensively. I presented a paper entitled "*Repair of Concrete Structures in Marine Environments*" at the NZ Concrete Society's Conference in 1982, setting out the scant knowledge we had developed in-house at that time [5]. This was 5 - 7 years before the proprietary cementitious mortars which abound today were available. I am amazed, nearly twenty years later, that our simple and crude experimentation was so close to the mark of what is now accepted common practise. This was the birth of the Concrete Repair business in Australasia, as it is known today.

The modern concrete repair material has little changed since those early times. It is available today in various forms; as a hand patching mortar, a pourable micro-mortar and a sprayable mortar, but essentially the important properties outlined from our early experimentation are still the crucial ones.

4. DIAGNOSTIC TECHNIQUES

In the mid-1980s, the need to diagnose the cause of concrete deterioration became necessary. The cause of deterioration of other materials, stone, brick and timber, had been well understood for many decades. Concrete, the wonder material, had not been part of this understanding. Researchers worldwide, realising that the potential repair market exceeded that of the new construction market, turned their attention to the causes of concrete deterioration. The reasons why rebar corroded and caused the concrete to spall were quickly understood; the reasons why the rebar corroded in the first place were studied in detail. The terms "carbonation" and "chloride ion attack" became household words in the laboratories of the concrete technologists. By early 1990, hundreds of concrete repair conferences were being held and thousands of papers had been written. Today, the causes are know by every engineer, but it was not the case a little over 10 years ago.

Diagnostic techniques are now available to measure the depth of carbonation, the level of chlorides in the concrete at various depths, the porosity of the concrete, the insitu strength of the concrete, the rate of corrosion of the rebar etc, etc. There are many types of instruments available for measuring these properties.

5. ELECTROCHEMICAL REPAIR

In the late 1980s, the electrochemical behaviour of the rebar immersed in concrete became better understood. While the US had been using electrochemical methods of repair for some 10 years, on their salt laden bridge decks, this knowledge had not spread to other types of concrete structures. The cathodic protection of rebar became a practical reality around 1988 and the first structure of importance in Australasia, an apartment building in Auckland, was cathodically protected in 1989. The principle of changing the potential of the reinforcement within the concrete to a point where corrosion cannot take place is termed cathodic protection (CP). The concept has been well understood for steel in a submerged condition, for many years. In this case, the electrolyte which enables positive and negative ions to move freely between anode and cathode is

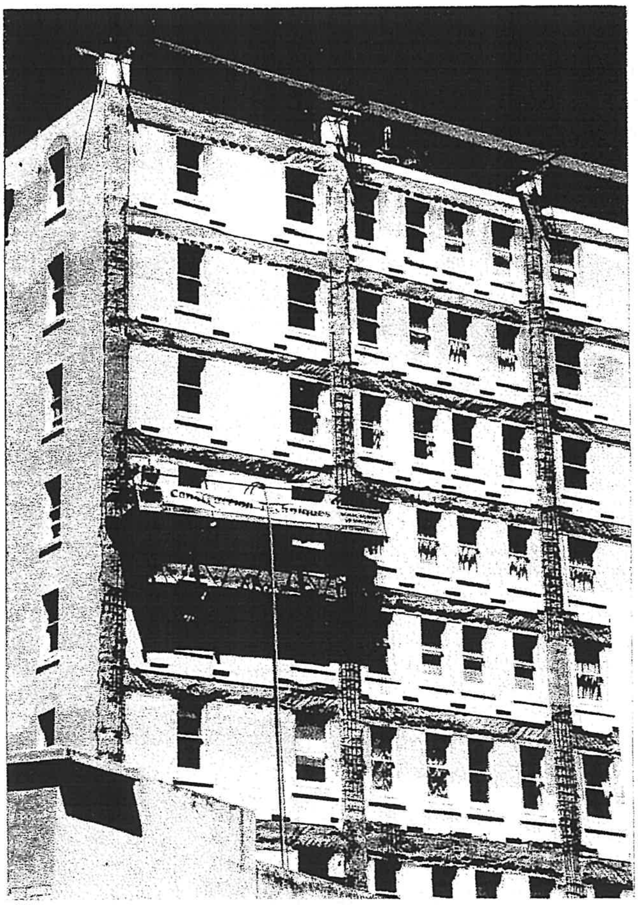

Fig 4: Westminster Court Apartment – state of the concrete and reinforcement prior to the repair and application of a CP system – 1989

water, which is a good conductor. The difference in natural potential between steel and another more noble metal (usually zinc) is used to "drive" electrons from the anode to the cathode, the more noble metal being termed the anode and the steel the cathode. As it loses electrons (corrodes) the anode is consumed and needs replacing.

Not so in concrete. Being a relatively dense material, the electrolyte in this case is the moisture which is ever present in the concrete's pores and capillaries. The resistance of the small waterways is known as "resistivity" and this varies according to the quality of the concrete and the available moisture. Thus to overcome this resistance, the electrons must be "driven" through the electrolyte, to achieve a circuit. This is done by joining a small DC current in the circuit, usually by way of a rectifier which converts AC to DC.

So a method of stopping the corrosion of concrete (and hence the disfiguring spalling which results from this) was born. This was a major step in the science of rehabilitation of concrete and meant that important structures showing degrees of decay, could have the process easily stopped, in theory, forever. Indeed this process, after a shaky and slow start due to the huge numbers of disbelievers, is now an accepted and proven method. In Australia, there are more than 40 major structures now protected by CP; NZ has less but the number is about 10. The historic and important Wellington Carillon has recently been protected by this method

Electrochemistry as it applies to concrete has been forced upon civil engineers who have accepted it with reluctance, mainly because they have difficulty understanding it. After all, most civil engineers chose to go down the civil path because of their loathing for chemistry and electricity! But it is not all bad. Anode materials have greatly reduced in cost in the 10 years of CP's practical existence. 50 years of life (or) more can now be assured from titanium oxide coated anodes. Australasia's first CP project, the Westminster Court Apartment building (fig 4) is now in its 10th year of service and has required no maintenance what-so-ever during that time. Winner of the NZ Concrete Society's Award of Excellence in 1990, the judges' citation read *"this remarkable advancement in the science of concrete practice will be watched with interest by owners and engineers in the years to come, to determine if the intended life will be achieved"*. The confidence placed in my company by the building owners and its consultants has been justified and we see no reason why the system will not continue to work as has for the last 10 years, in the years to come.

Two variations on CP for concrete are available in the market place, these being *realkalisation* and *chloride extraction*. Both work on the same principle as CP but are cures which are applied to concrete over a short period of time, instead of forever, as is the case with CP. Realkalisation consists of electrochemically drawing positive alkali ions (K^+ and Na^+ mostly) into the concrete to surround the reinforcement with an alkaline environment. A "reservoir" containing an alkaline solution is used as the anode and during the flow of an applied current, the positive alkali ions move towards the reinforcement (the cathode) and create an alkaline solution in the rebar vicininty. Chloride extraction is the reverse. An temporary artificial anode is applied to the surface and the impressed current causes the negatively charged Cl^- ions which are located near the rebar, to migrate to the anode where they are absorbed and discarded when the temporary material is removed. The latter of these methods has a limited application in Australasia, because of the presence of chloride laden air in our cities near the sea. Chloride extraction can only be applied where there is a limited chance of further chloride contamination.

Electrochemical methods are the only ways of stopping rebar corrosion and its associated spalling forever. All other methods are either temporary or have a minimum life.

6. STRUCTURAL STRENGTHENING TECHNIQUES

The post 1970s strengthening techniques have evolved as the demands to bring structures up to changing code requirements have been implemented. Many methods have been employed, mostly using traditional principles. In the field of foundations, additional load carrying capacity or the need to found a structure in a different layer of material, has seen piling used in all its forms. External piles and internal micro-piles transferring loads to new pile caps, which in turn have loads transferred to old foundations have been used. The use of new piles does not affect the heritage engineer keen to hide his work, because most can be hidden below ground or floor level.

Above ground, it is a little more difficult. Our architect colleagues want nothing of the original form changed; our engineers, responsible for directing the new forces down through the structure to the foundations, struggle to do this through the existing members. Ten years ago, steel framing was thought to be the most inconspicuous way of creating paths for these forces. A variety of structures were strengthened this way, one notable building being the original University of Auckland Building and tower. A steel frame was used to strengthen the stone tower and loads were carried towards the foundations by steel members concealed within the walls. New pile caps located on micro-piles below the floor level, received the steel members. This very neat concealment satisfied all parties, the architects, engineers and owners.

In the 1980s, many cavity brick structures were strengthened by the creation of new reinforced concrete walls within, but attached to the masonry walls. Dowel bars were drilled and grouted into the brickwork and these were tied to new reinforcement of the wall. The wall was created by wet-mix spraying of concrete (fig 5). They were located on extended foundations, which often contained new piles to carry the additional loads. Many notable structures were reinforced in this way, Scots College, Wellington being the first (circa 1982), with the High Court, Auckland, Auckland Grammar School and Baradine College being other good examples. Possible several hundred structures have been strengthened this way in NZ and this type of work continues today.

The advent of a three dimensional, nonlinear time history analysis package, developed by Holmes Consulting Group, has created a new dimension in the strengthening of concrete and masonry structures requiring earthquake retrofit (fig 6). Whereas traditional methods analysed the behaviour of certain elements when subjected to earthquake loads and resulted in the weakness of a single member being used as a basis for strengthening all of the like elements of the structure, the Holmes method provides a more detailed approach to the response beyond the elastic limit by accurate modelling of the element force deformation behaviour. This enables the actual strength of the structure to be accurately assessed and also ensures that the existing elements are used in parallel with strengthening elements to ensure an optimum retrofit, using materials which are compatible, both physically and visually, with those of the structure under consideration. The procedure has been used to evaluate numerous unreinforced masonry buildings, concrete frame structures, combined frame/shear wall structures and base isolated structures.

In practical terms, by subjecting a modelled structure to various known earthquake patterns, realistic indications of demands on individual components which are loaded significantly beyond the elastic range are obtained. The individual member may then be strengthened and the programme re-run to gauge the effect on the rest of the structure. The overall result is that only the members which require strengthening are retrofitted and the changed effect of this is accurately seen throughout the structure. Economies are thus made which are significant.

This evaluation process has been applied to numerous projects throughout New Zealand and include such structures as Christchurch Arts Centre, Armagh Street Tower, Christchurch Cathedral, Wellington Maritime Museum, Auckland Civic Theatre, Auckland Custom House and Auckland Railway Station. Pictorial examples of this process will be given in the presentation. Details of one project, now under the stage of being retrofitted, are given below:

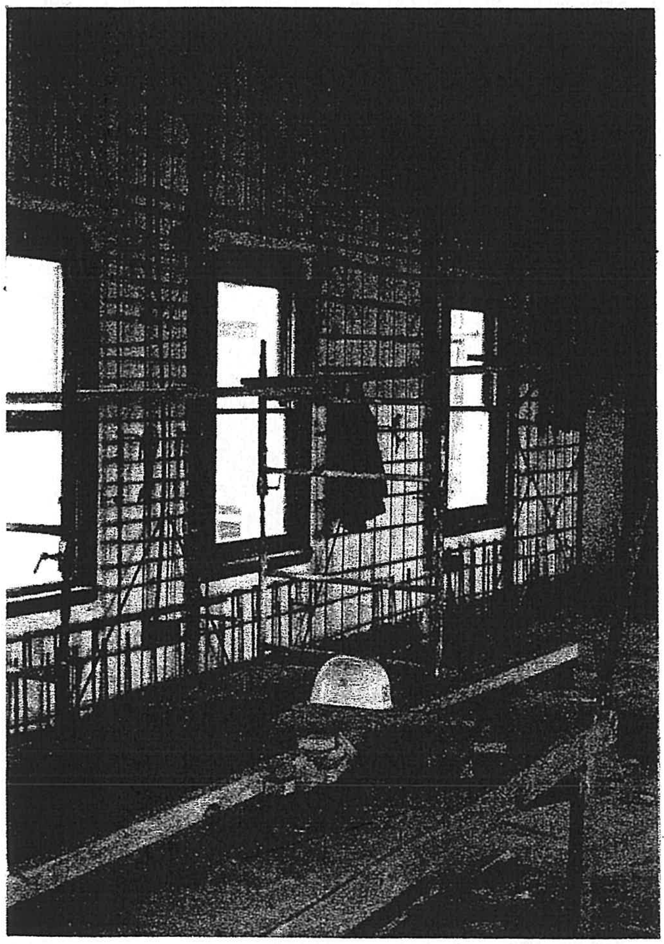

Fig 5: Typical preparation of a masonry walled building prior to the construction of new reinforced concrete walls to which the masonry walls are attached. Wall construction is by sprayed concrete – Baradene College, Auckland

Christchurch Cathedral

The Christchurch Cathedral (fig 7) is an unreinforced masonry building constructed in the early 1900s. The building is located in a moderate seismic zone and has suffered minor earthquake damage. The building has survived an earthquake only 30% of that required for a new building, with a peak ground acceleration of 0.10g. Failure occurred from a shear fracture in the flying buttresses of the West face of the building adjacent to the main entrance. The longitudinal nave walls have large openings. The columns along the aisle are flexible and so resist very little earthquake loads. The roofing is not stiff enough to transfer the nave wall inertia loads to the exterior walls and so the stiff flying buttresses resist most of the earthquake loads. This causes the buttresses to fail at the top. Remedial measures undertaken during strengthening were to add concrete skin walls to the Trancept and gabled end walls and to add bracing to take loads to the side walls (see illustrations)

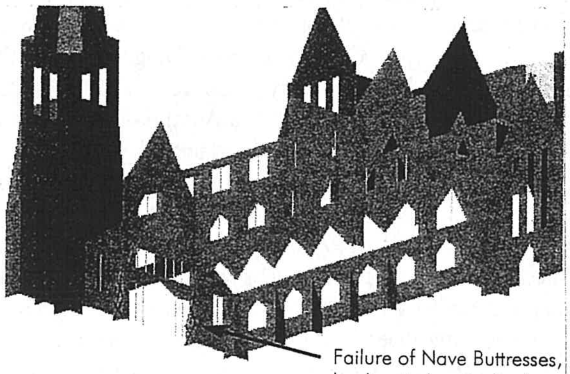

Fig 6: ***Christchurch Cathedral*** *– time history nonlinear analysis identified weakness in the Nave Buttresses which would lead to longitudinal collapse. Columns in the aisle are flexible and so resist very little earthquake loads. Roof not stiff enough to transfer the Nave wall inertia loads to the exterior walls.*

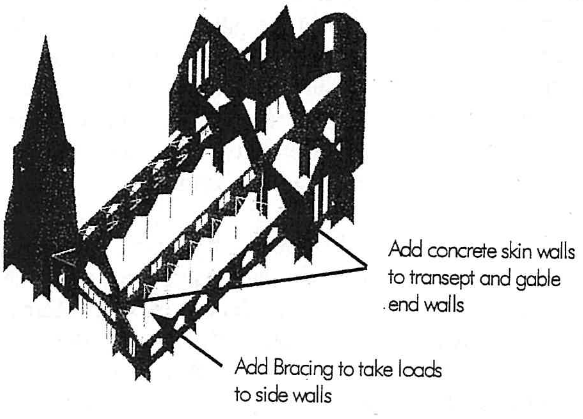

Fig 7: ***Christchurch Cathedral** – remedial solution: addition of concrete skin walls to Transcept and gabled end walls and bracing to take loads to side walls*

7. ADVANCED COMPOSITE MATERIALS

The use of Advanced Composite Materials (ACMs), was introduced as a retrofitting technique in California around 1993. The initial development and testing work was carried out at University of California, San Diego, under the supervision of Dr Nigel Priestly. Contech and Remedial Engineering introduced ACMs to the Australasian market in 1995 and since that time a large number of projects have been strengthened using these materials. Initially developed for the provision of additional confinement to bridge columns, ACMs can be used for providing additional flexural and shear strength to beams slabs and walls in concrete, masonry and timber structures. ACMs consist of E-glass or carbon fibres embedded in an epoxy matrix. Research has demonstrated that remarkable strengthening can be obtained

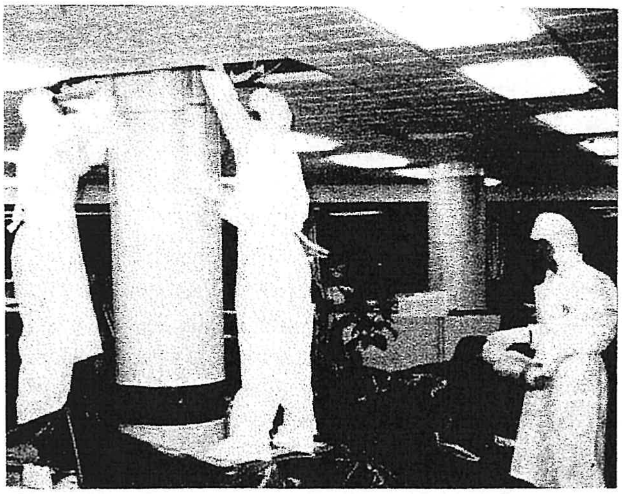

Fig 8: *Application of pre-saturated ACM to interior column of a multi-storey building*

with these materials in combination with the original material. Design concepts are based around strain compatibility, similar to that for reinforced concrete. ACMs of varying E-modulus and strength are available in the market place and these provide a wide range of choices for various applications.

The obvious advantage of ACM as a retrofitting tool is its weight/strength ratio. The resulting strengthening is virtually inconspicuous and adds little additional weight to the structure. Its relative ease of application to all sorts of element shapes, with only small portable equipment makes it very popular for working on the inside of buildings.

Extensive research into the effects of confinement of highly loaded columns, of bridge beam shear and flexure enhancement and the solving of rebar curtailment (lap) problems in beams and columns has been undertaken at Canterbury University over the past years. A much better understanding of design and performance matters relating to ACMs with reinforced concrete has been obtained. [6], [7], [8] & [9]

A number of unreinforced masonry buildings have been strengthened using ACMs. These include the Auckland Railway Station, where the Holmes Consulting Group analysis programme chose certain wall areas which required reinforcing to bring the structure up to earthquake code requirements. This is a good example of where the weak parts of a structure only required strengthening, rather than the "belt-and-braces" method of casting new concrete walls within the brick structure, as was the norm up until 5 or so years ago. The future of ACMs looks very bright for the retrofitting of buildings, as it does for bridges, reservoirs.

8. ANCHORING AND CONNECTING MASONRY STRUCTURES

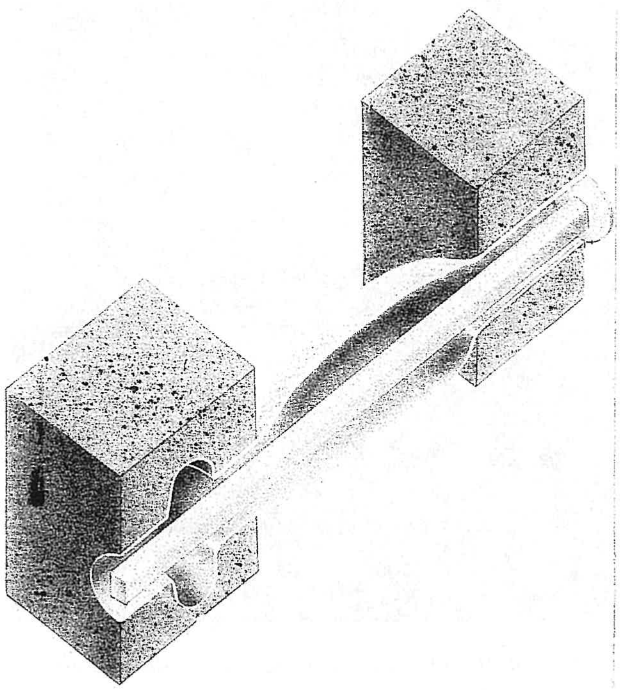

Fig 9: *Basic type of Cintec Anchor, comprising stainless steel anchor and fabric sock which expands inside the cavities of the masonry*

One of the most dramatic recent advancements in masonry preservation technology focuses on strengthening and connectivity. In the face of seismic forces, wind loads, vibration from vehicles and machinery, inadequate original design, new adaptions and ageing, stabilising masonry is becoming a more critical element of rehabilitation and historic preservation efforts.

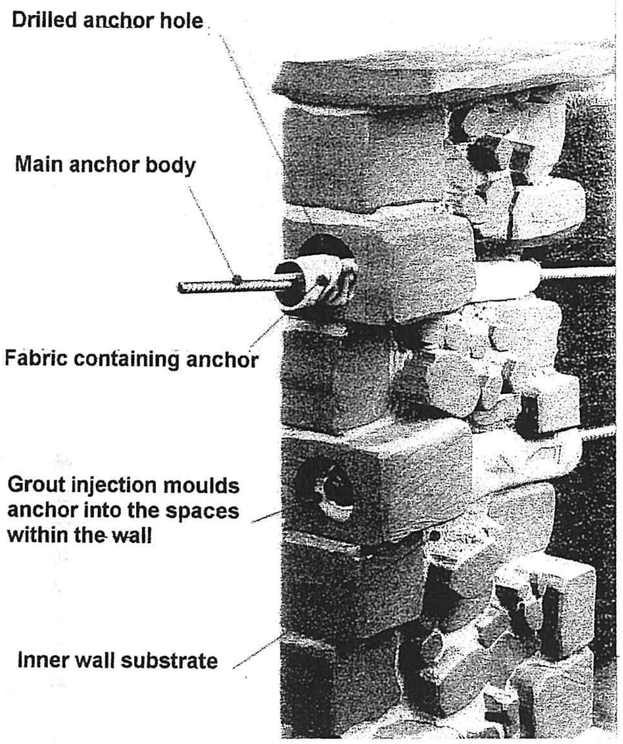

Fig 10: Functioning of standard Cintec anchor within a masonry wall.

The Cintec Designed Anchors Systems offer an innovative alternative to invasive or unsightly structural strengthening systems (fig 9). The Cintec anchor is embedded within masonry walls and can be installed with relative ease and speed. Developed in the UK and instrumental in the recent post-fire restoration of Windsor Castle, Cintec anchors are deceptively simple. A steel rod wrapped in a fabric sock is inserted into a predrilled hole in the masonry. Once in place, ultra fine cement grout is pumped from the remote end of the anchor into the sock. As the sock fills, the entire assembly inflates like a balloon under the pressure. The excess grout milk and bonding agent is forced through the sock, creating a chemical bond between the anchor and the substrate. The small exterior hole is then patched. The nylon sock has the ability to expand and fill the cavity until it is completely wedged in (fig 10). The large surface area of the anchor, in conjunction with the pressurised grout create an anchor system that dispenses with the need for unsightly patress plates on the exterior of the structure, creating a near invisible mend. Monuments, churches, bridges and buildings have benfitted by the use of this system. Perhaps the most famous example in Australasia is the restoration work done on the Christ Church Cathedral, Newcastle, as a result of damage sustained in December 1989 by an earthquake of magnitude 5.6. Over 4 km of anchors were installed to reinforce walls and piers, both horizontally and vertically. The Cintec anchors used ranged from 215 mm long cavity ties to 32 m long anchors in the naive

Cintec anchors offer excellent solutions for reinforcing, stitching, tying and supporting of all types of masonry elements.

9. OTHER METHODS

Space does not permit details of the other methods used to strengthen structures. Such methods include:

- external post-tensioning as a means to increase the flexural strength of beams, particularly in the case of bridge beams. Numerous bridges in NZ have had their load carrying capacity increased by this method.
- bonded steel plates for increasing flexural and shear capacity in beams and slabs – (to a large extent, this technique has been replaced by the use of ACMs).
- circular steel jackets on circular bridge columns – steel provides increased flexural strength as well as confinement; ie, two directional strengthening.
- the use of large capacity ground anchors drilled and installed vertically through concrete dams into the rock beneath, to increase the overturning resistance due to horizontal seismic forces and wave action resulting from earthquake effects.
- vertical post-tensioning of masonry buildings, by drilling and installing vertical tendons anchored into foundations.

10. CONCLUSIONS

The heritage engineer and architect have available a variety of methods of preserving their structures. New Zealand and Australia have kept up with, and to some extent led the world in the application of methods to strengthen and restore important structures. Many of these methods have been pioneered in our countries and certainly in the field of earthquake strengthening, we are world leaders.

Rapid changes to our building stock, brought about by the requirements to upgrade to present day earthquake codes, have seen many buildings demolished to make way for earthquake resistant structures. Notwithstanding this attack on our precious heritage, many structures of importance have been retained and brought up to the requirements without suffering too badly by disfiguration.

We have an obligation to those who came before and those who will carry on, to provide solutions today which will endure for years to come, yet which will still enable the structures to be modified again and again, if the occasion demands it.

Engineers and architects must work together with a similar goal; we must make the bearers of the purse strings aware that our heritage must be retained and preserved. We owe it to our children and their children in turn.

11. ACKNOWLEDGEMENTS

The author wishes to acknowledge the research assistance provided by Jeremy Salmond of Salmond Architects and Holmes Consulting Group, who made available in-house reports on several of their retrofitted projects.

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Large Timber Structures in Western Australia

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SUMMARY

"As the result of a AU$11,000 Grant through the 1993/94 Australian National Estates Grant Programme, the members of the Engineering Heritage Panel of the Western Australia Division of the Institution of Engineers, Australia, have completed a five volume survey and recording of a number of Large Timber Structures in Western Australia which was initially started by the late Mr Denis Cumming in 1993.

The survey covered Road Bridges, Railway Bridges, Footbridges, Timber Company Bridges, Forestry Department Bridges, Jetties, Air Transport Structures, Maritime Structures, Military Structures, Mining Structures, Railway Water Tanks, Forestry and Timber Milling Structures, Water Supply Tanks and Major Timber Power Lines.

Some 850 structures were listed of which 139 have been selected as having a high degree of engineering heritage which should be considered for State Listing.

The Paper covers the process by which this project was undertaken, the documentation and final presentation of the survey."

STUDY OBJECTIVES

The aim of the study was to make a survey of the whole range of Large Timber Structures in Western Australia, which represented the output of an industry which was of great importance to the development of the State of Western Australia.

These structures also represented the result of the design and construction skills of a range of government instrumentalities, including the Public Works Department, the Main Roads Department, the Western Australian Government Railways, the Forests Department(latterly the Department of Conservation and Land Management), as well as those of timber milling companies, building and civil engineering contractors and the Australian Army.

Such large timber structures are under-represented in the registers of the National Estate and the Heritage Council of Western Australia and often differ considerably in design and construction from those of similar types in the eastern states. A further aim was to prepare an initial list of large timber structures that are considered to have outstanding heritage value.

TYPE OF STRUCTURE

The most significant type of large timber structures considered in the study was the bridge, which was dealt with under five categories; Road Bridges, Railway Bridges, former Timber Company Tramway Bridges, Forestry Bridges currently in use, and Footbridges.

The Jetty was another type of large timber structure which has been of great importance to the State in the past and which was included in this report in a supplementary manner to a report prepared by Mr Denis Cumming in 1994/95 entitled "Port-related Structures in Western Australia".

Other types of large timber structures considered were associated with transportation; namely Airport Hangars, Railway Goods Sheds, Tank Stands, Signal Boxes and Port Storage Sheds,

Industrial use structures include Mining Headframes, Ore Bins, Timber Mill Sheds and Forestry Fire Observation Towers, with other forms of infrastructure, such as Power Transmission Towers, Water Supply and Flood Control structures, and former Military Wartime Storage Sheds were also surveyed.

Other types of buildings, built largely of timber, such as Agricultural and Pastoral Sheds, Factories and Warehouses, were not included as a survey in each of these areas would be a major undertaking in itself.

JUSTIFICATION

Many of the structures considered in the study were nearing the end of their useful lives. Some were being considered for replacement and were to be demolished, abandoned or put to other uses. Others, such as timber company tramway bridges and the older jetties have already been abandoned.

The remains of these vary in condition, from structures that have only recently become unserviceable, to impressive ruins with the skeletons of their main structural members still intact, and to other remains, the evidence of which is barely discernible to the general public.

The operating and owning authorities and those with control of land containing redundant structures, need some guidance as to the importance of such structures, and also in the procedures for selecting those which can be retained and conserved, and in managing ruins in such a way that their rate of deterioration is slowed, and so that they do not become unreasonable dangers to the public.

2.4. PROCEDURE

In 1994-95 Denis Cumming made inspections of jetties and maritime structures throughout the State in conjunction with work on other studies, and also inspected a number of important road and railway bridges, and other railway and water supply structures for his study. His findings have been incorporated in the report.

The Working Party was fortunate enough to be able to call upon the services of three experts in particular fields covered by the study; Mr Bill Larke, former Westrail Chief Engineer Civil, Mr Lloyd Margetts, Main Roads Western Australia Bridge Engineer with particular expertise in the interpretation and maintenance of timber road bridges, and Mr Max Anderson, former Chief Engineer of the Harbour and Rivers Branch of the Public Works Department. These gentlemen have been able to supplement Denis' work with their extensive professional knowledge of the structures covered by the study.

As far as timber company tramways are concerned, we have been fortunate in receiving the assistance of Mr Jeff Austin, who in 1994 prepared a report, "Sawmilling, Firewood and Other Tramways" for the National Trust of Australia (Western Australia), and who made supplementary notes for this report in 1995. No further inspections of tramway bridges have been possible and much remains to be done in this important field of industrial heritage.

For information on the Department of Conservation and Land Management's forestry bridges, we have relied upon a 1994 Bridge Inspection Report which the Department kindly made available. The larger bridges in that report have been included as a tentative, preliminary, measure. Their inclusion will highlight the fact that some of them may, at some future date, be classified as items of industrial heritage as a means of interpreting how forestry workers of the day went about their business. Without them, no report on large timber structures in this State would be complete.

LARGE TIMBER BRIDGE INVENTORY

In 1996, the Working Party decided that if the maximum benefit was to be gained from this exercise, the study report should contain as full an inventory as possible of all the major bridges in the State. The detailed criteria for inclusion in each bridge category are discussed in the introduction to each section on bridges. Several factors contributed to this decision.

Firstly, the large number of timber bridges in the State, and their dispersal over such a large area, made the identification of those with heritage value very difficult without having the benefit of a systematic revue of all bridges, even for those with a lifetime's experience in the field.

One of the aims of the study was to prepare an initial list of large timber structures which were considered to have a high heritage status. In future it was hoped that, when this first cohort has been fully documented and registered, there will be a demand for the registering of further examples. To provide as full an inventory of bridges at this stage will make future registrations a far easier task and will negate the need for another broad review.

Another factor of importance was the closure of Westrail's civil engineering design section, and the reorganization of its archives and divisional inspection services. It seemed prudent to access all the relevant information required on the Westrail bridges using familiar sources, as this would undoubtedly prove more difficult in the future when much of the material may be of no further value to Westrail.

At the same time, Main Roads Western Australia had increased the coverage of its inventory of timber bridges so as to make an inventory of all major bridges a possibility.

The production of an inventory of major timber bridges throughout the State has been no small task. However, with the exception of a handful of railway bridges on several poorly documented closed lines and bridges on the Trans-Australain Railway, the task has been completed despite funding limitations.

It should be remembered, however, that some aspects of the study had, of necessity, been limited to a desk exercise. In the future, when nomination forms are being completed for the heritage registration of those structures that are to be recommended by the report, it may well be necessary to make a thorough site inspection of each of the recommended structures.

HERITAGE ASSESSMENT

All items in this report were assessed for their heritage value as structures in terms of the recognised criteria of importance; namely, aesthetic, historic, technological, and social together with the degrees of significance being rarity, representativeness, condition, integrity and authenticity.

Most of the structures listed in Volume I of the total five-volume report, are of importance from at lest two or three of these aspects. Where the technological and historical importance of a structure has been emphasized, it has been considered from the viewpoint of how best it interprets the work of those who built and used it in their work. If less emphasis has been given to the aesthetic consideration of a structure, it was because it was assumed that the beauty and integrity of a bridge or jetty or the timber frame of a large building needs no advocate.

HERITAGE VALUES OF ASSETS STILL IN USE

During the working life of different classes of government-owned assets, such as bridges or dams, it was considered that managers should be encouraged to identify specific examples which are outstanding, or typical examples of particular types, and which, in the future, could be retained as heritage items.

This would enable future generations to better interpret how instrumentalities carried out their important statutory functions on behalf of the State, and would also help them to appreciate skills and crafts possibly no longer in use, together with the beauty and functional aesthetics of their products. When such assets are in the latter parts of their working lives, maintenance on them should be continued so that, when no longer in use, they do not deteriorate so rapidly that authorities feel obliged to "make them safe" by demolition. Assets which were identified in this way should be eligible for special maintenance grants to owners from heritage authorities. Where such assets are sold to private companies, or reserves containing them are leased to other authorities or companies, the State Government should be encouraged to include in the sale or lease agreement caveats requiring retention of these structures and controlled public access to them.

RANKING SYSTEM

ROAD BRIDGES

The first substantial road bridge in Western Australia at Drummond's Crossing at Guildford, was built in 1835. Only a handful of other road bridges were completed in the period up to 1850, when the first shipload of convicts arrived.

The arrival of the first contingent of Royal Engineers, in December 1851, meant that the convict labour could be adequately supervised, and that the construction of public works (including roads and bridges) was greatly accelerated. The effect of using this small group of engineers, combined with the ready availability of good bridge timber, was that simple standardized structures were usually built.

The evolution of the Public Works Department saw the reinforcement of the trend towards simple, easy-to-build-and-maintain bridges. The main differences between the timber bridges were either evolutionary improvements or were aspects of standard solutions related to parameters, such as height and foundation conditions.

Significant detail changes over time have included the general change from round timber fullcaps over the piles at each pier, to the more-easily maintained sawn timber halfcap system. Early bridges rarely used corbels, but the use of these to support stringers over piers was almost universal by the 1890s. Sawn jarrah stringers were normal between the 1890s and the late 1920s - when round stringers were adapted for their greater strength. A different superstructure system - that of supporting longitudinal decking over transverse bearers, on wider-spaced round stringers - was adopted for a period during and immediately following World War Two. Many other minor details are characteristic of particular time periods.

The years have seen major changes in the approach of durability requirements to timber bridges. Initially, the bridges were built as "craft" items - with natural drainage optimized and surfaces sloped to shed moisture. Ironwork fastenings were usually pickled in tar before use in timber. In time, bridges were built faster and more cheaply - but with less durability. The economic imperative of recent years has seen a return to the concept of structural timber durability - this time, achieved by the synthetic means of applied waterproofing materials, diffusible chemical fungicides, and reinforced concrete deck overlays.

The development of new preventative maintenance techniques to extend the service life of road bridges in use in Western Australia has automatically increased the options available for conservation of heritage-related structures. It is expected that appropriate application of preservation technology will allow many structures to survive safely with minimum expenditure, while decisions are made and funds are found for the full-scale conservation of those items identified to be of special importance.

There are approximately 1,500 bridges in service on public roads in Western Australia plus approximately another 150 on roads reserved for the use of the Water Corporation and the Department of Conservation and Land Management. In addition, there are over 20 closed road bridges and ruins of bridges which are of heritage importance. This section of the report surveys 282 of these bridges (but excludes CALM bridges in the south western forests which were dealt with in another section). It was intended that all significant timber road bridges in the following categories be included:

1. Historic bridges including those no longer in service,

2. Major bridges of more than 4 spans,

3. Bridges with significant heritage features,

4. Bridges on sites that are of historical importance, particularly those sites using early pre-convict or convict labour.

5. Bridges that are of significant local interest, particularly in urban areas.

A ranking system is used for most road bridges to help give each a heritage significance where:

1. There is limited individual significance,

2. The feature(s) of some significance,

3. The timber bridge history is important at the site,

4. The current bridge, which is in use and is being maintained, has significant features,

5. The current bridge has significant features but work needed for public access to be maintained.

Fifty bridges have been given Rankings 4 or 5 and were considered to be of major heritage importance and data sheets and photographs for these bridges are contained in Volume 1 of the report as well as in Volume 2. In addition 47 bridges are on sites that are historically important as timber bridge sites (Ranking 3) and a further 45 have features of significance (Ranking 2).

RAILWAY BRIDGES

With the advent of railway construction in Western Australia for timber exploitation and agricultural development in the last quarter of the nineteenth century, there was no local iron production or fabrication industry. All railway construction iron work had to be imported fully fabricated. With the resulting high cost and time delays, engineers quickly turned to exploiting the abundance of hardwood for their bridge construction. At first, they used carpentry technology developed for European softwoods but very quickly developed a technology with designs suitable for Western Australian hardwoods.

In the 1950s, with the increasing availability of good quality steel and cement after the Second World War, Westrail embarked, upon a bridge replacement programme using steel and concrete. This replacement programme was necessary because many bridges were around fifty years of age and larger postwar rolling stock had begun to stress bridges above their earlier design loads.

One of the consequences of this was that bridge maintenance, together with the bridge gang workforce, was allowed to run down. By the early 1970s, when a steel and concrete bridge at Tenindewa washed away in a cyclone and had to be replaced urgently in timber, Westrail could only just muster sufficient skills to undertake the work. In recent times, Westrail has only undertaken minimal maintenance and has usually contracted Main Roads Western Australia to undertake any significant bridge work.

These circumstances have resulted in a steady decline in the number of timber bridges. This has been exacerbated by a reduction in open railways from 7,000 kilometres in 1938 to 5,800 kilometres today of which 900 kilometres is relatively new railway built without timber bridges. Of the open railways, approximately 600 kilometres is non-operating, leaving 5,200 kilometres of working railway. The result is that Westrail has roughly only 80 timber bridges on their working railway with approximately 90 on the non-operating railways. The number still existing on abandoned railways is not known but the study has identified about 130 that may still exist.

Over this period of decline, all the large timber Howe `through trusses' that were once the hallmark of timber bridge building in Westrail, have gone. Only two bridges that have trusses still exist, these are at York and Capel. Gone also are examples of the earlier bridge building technology using crown stayed stringers with straining beams and thrust abutments; the last being the Midland Railway Company's bridge at Mogumber. Luckily, an originally crown stayed, but now altered, bridge over Ringa-Ringa Brook at Toodyay still stands. Some small examples and ruins exist on the Geraldton-Northampton Railway.

It is ironical but fortuitous that some large bridges remain on Westrail's lightly trafficked railways because the high replacement capital cost of steel and concrete cannot be financially justified without corresponding requirements for axle load increases. Smaller bridges have been replaced long ago using lower capital cost solutions, such as culvert pipes. In these circumstances, it could well be in Westrail's interest to apply the latest technology in preservatives and preservation techniques together with advances in construction techniques. In this way, it should be possible to achieve low cost piecemeal replacements as and when required, so keeping bridges operational without large capital injection.

However, not only operating bridges are at risk. Out of service and redundant bridges face natural risks such as fire and floods, development pressures and ignorance of industrial and engineering heritage values. In respect to their circumstances, one inexpensive outcome of this review should be to ensure that these bridges appear in the Municipal Inventories that the Shires are required by the Heritage Council of Western Australia to be prepared and kept up to date. This would be a logical step towards planning priorities to place bridges on the Heritage Council of Western Australia's Register of Listed Places.

Timber bridges and other large timber structures on the Trans-Australian Railway within Western Australia have not been included on the survey.

DEFINITION

Definition of a large timber bridge.

A judgement was made to define a large timber railway bridge as a structure with 7 or more openings or 30 or more metres in overall length or having a height greater than 3.5 metres, provided the bridge has 3 or more openings.

All bridges meeting this criteria have been recommended for either further assessment or listing. Lesser bridges have been recommended on criteria such as age, engineering uniqueness or rarity associated with historic events, persons, precinct etc. In general, only current existing bridges have been recommended but some important sites of ruins have also been recommended for attention.

The span of a timber railway bridge normally means the clear span between half cap edges. Height is measured between the stream bed and soffit of beams (water level for permanent water). Overall length is usually taken as over the extent of decking.

RANKING SYSTEM

A numbered ranking system has been devised to indicate the industrial heritage status of timber railway bridges and sites. The system also indicates a recommended course of action and indicates priority and importance by ascending number order. The categories used are described hereunder:

1. Where no industrial heritage value exists or where it does not fit into the defined category of a large timber structure. Also, those sites already destroyed beyond interpretation.

2. Where there is a bridge of limited industrial heritage significance but should not be replaced or altered or the remains of ruins should not be destroyed without further assessment or recording.

or

Where the bridge does not fit the defined category of a large timber structure but should be recorded and maintained as being most significant to industrial heritage.

3. The bridge ruin is beyond useful repair or site of significance industrial heritage with a location or circumstances such as the heritage value can be usefully displayed.

4. Register and maintain as an important industrial heritage structure. For abandoned bridges, seek alternative uses or means of preservation; for bridges in service, seek the owner's cooperation to retain and maintain it.

5. As for 4 but urgent assessment is required as the bridge is subject to alteration, demolition or various types of damage or destruction.

Eighty-one bridges have been given Rankings 4 or 5 and were considered to be of major heritage importance. Of these bridges, 50 have been classified as being of very high heritage value. Twenty-five of these 50 have been given "very urgent" priority status. Data sheets and photographs of the 50 very high value bridges are included in this volume and the 25 recommended for urgent attention were also identified and marked with a double asterisk on the data sheets.

CLASSIFICATION OF RAILWAYS

In the report, Government Railways were classified Open, Non Operational or Closed.

Open Railways.

These are railways currently being operated by Westrail. Each Section of Railway has a Section Number which is shown on the Data Sheets. These Section Numbers appear on publicly available Railway System Maps for the location and identification of individual railways.

Non Operating Railways.

These were railways for which Westrail management suspended operating services for an indefinite period. Legally, they remain open railways and the fixed assets remain in place unless the Government Minister responsible for Railways has given permission for their removal.

Closed Railways.

These were railways that have been closed by Parliament through a Discontinuance Act. This was usually combined with, or followed by, a Revestment Act vesting the land in the Crown for other specific uses. In a number of cases, no revestment has taken place leaving the legal ownership of redundant assets unclear.

DISTANCES

Distances on Bridge Data Sheets.

For open and non operating railways, kilometrage cited for a bridge is the distance of that bridge from the start of the relevant Westrail Section. For closed railways, mileage cited for a bridge is the shortest distance of that bridge from Perth or Geraldton along existing or former Westrail lines.

RAILWAY BRIDGES NOT DEFINED AS LARGE TIMBER STRUCTURES

All railway timber bridges meeting the definition of the large timber structure and for which data was available, were expanded into data sheets. A large number of smaller bridges not meeting the criteria were also expanded into data sheets. The heritage status ranking system identifies these.

To complete a record of government railway timber bridges currently existing, both in service or unused, a list was appended at the end of the section identifying other timber bridges that were not expanded into data sheets. These bridges did not meet the defined criteria for a large timber structure and were, therefore, considered not to have industrial heritage value.

RAILWAY BRIDGES NOT RESEARCHED

There were a number of closed sections of Government railway for which data was not readily available. These were not researched for the report. These bridges were also listed to provide a complete record.

RAILWAY BRIDGE PLANS

Plans of 112 of the bridges in this section have been included in the Report as Volume 5 - Appendix. Where a bridge had plans included in Volume 5, this was indicated on its data sheet under "Notes and references".

FOOTBRIDGES

Prior to the Second World War, nearly all suburban railway stations had a pedestrian footbridge, generally constructed of timber. The dramatic decline in passenger traffic after the war, coupled with the ageing of these structures, resulted in them being replaced with level crossings for pedestrians.

Today, only five bridges remain and most of these have either been partially replaced in steel or have been strengthened in steel. In 1988, the timber truss at Meltham was removed for electrification works and, with the exception of Claremont, the others are under threat. In particular, the East Perth timber truss, built in the late 1940s, will be removed for the City Northern Bypass works.

Non-railway footbridges were also listed in this section, including the Munday Brook Bridge, formerly a Mason and Bird Timber Tramway Bridge, and believed to be the longest surviving all-timber bridge in Australia.

Both the Collie Footbridge and the Poole Footbridge are of considerable heritage significance and have been placed on the Register of listed Places by the Heritage Council of Western Australia. The shortest of footbridges considered to have high heritage value have been limited to the two most important ones, being the West Leederville Footbridge which is on the Register of the State Heritage Council, and the Munday Brook Bridge.

TIMBER COMPANY TRAMWAY BRIDGES

In the hundred years from 1870 over 6,600 kilometres of steam powered tramways plus scores of kilometres of horse-drawn tramways were built by timber companies into the forests of the south west.

Called `tramways' to distinguish them from the government railway system, the steam tramways differed very little from some sections of the government system, using similar locomotives, wagons and loadings and an identical rail gauge. In some instances, tramway locomotives even hauled their own wagons on the government system.

Although the main arteries of the tramway system remained in place for a number of decades, and some were taken over and incorporated into the government system, most of the tramway lines existed for only limited periods. They were built into areas of virgin forest and were removed after logging had been completed, and were then re-laid into new areas. Many were remarkable feats of construction, especially as they were built largely by pick and shovel. They ran through heavily timbered forest, often on steeply sloping ground, or alongside, and repeatedly crossing, rivers and creeks. A number of the main arteries of the tramway systems have been made into roads and many others can still be found in the forests with some mapping guidance. The most dramatic reminders of the tramway systems are, however, the remains of the bridges. Some, such as the magnificent Long Gully Bridge in the Boddington Shire, are now road bridges, whilst others, such as the Mason and Bird Bridge over Munday Brook, which may be the oldest surviving all-timber bridge in Australia, are now used as footbridges.

The majority of those remaining are now disused and the more important of them now require urgent stabilization if their deterioration is to be controlled. Some of these, such as the bridge over the Gardner River at Northcliffe, are amongst the most impressive railway bridges in the State, while the remains of other impressive ones, such as those in the St John Brook Conservation Park and in the Lane Poole Reserve, occur in areas of high conservation importance.

It was not possible to inspect any of the tramway bridges as part of this study. However, in 1993-94, Mr Jeff Austin prepared a report for the National Trust of Australia (Western Australia), entitled "Sawmilling, Firewood and Other Tramway" (February 1994) in which he gives details of the history and location of Western Australian sawmills and their tramways and remaining rolling stock, and also of the evidence still visible of the tramway formation and associated bridgeworks.

Mr Austin had also prepared supplementary notes for this study (dated January 1995) giving further details of these bridges. Extensive use of these two documents was made in preparing this section of the report. Most of the known tramway bridges or their remains have been listed, including those of quite small spans, where they were considered to be of historic or interpretative value. There are probably other less well known tramway bridges which should be listed, particularly in the Die-back quarantine areas of the forest, but their identification was beyond the scope of this report.

Former tramway bridges which are now used as road bridges or foot bridges were listed under their current use. Trestles of the colony's first railway bridge to be used by a steam locomotive, which was at Wonnerup Inlet, have been incorporated into the Vasse River Flood Gates.

In the report, it was only possible to make a preliminary review of timber company tramway bridges. It was considered that enough evidence had been provided to indicate clearly that these bridges were an important part of the State's industrial and social heritage, which deserves greater attention than hitherto given to it. It was recommended that a more comprehensive technical study should be made of these bridges to determine how they can be economically managed in such a way as to ensure that their heritage values are retained or enhanced.

FORESTRY BRIDGES, DEPARTMENT OF LAND MANAGEMENT. (CALM)

A survey of large timber structures in Western Australia would not be fully comprehensive without the inclusion of timber bridges used for forestry operations in the State Forests of the south west, which were built for, and maintained by the Department of Conservation and Land a Management (CALM). The Department's bridge inspection report, dated 20 October 1994, covers 112 bridges located in eight CALM districts of Busselton, Collie, Harvey, Jarrahdale, Manjimup, Nannup, Pemberton and Walpole. No bridge inspections are listed in the Dwellingup district. Only three are trestle bridges, the remainder are low level bridges with abutments and intermediates supports of bed logs, and with logs as stringer superstructure. Forty-nine of the bridges are decked.

The 17 bridges listed in the report have been included because they were considered significant as large timber structures. This assessment was based on the somewhat arbitrary criteria of bridges with single spans of 10 metres or over, and for multiple span bridges of 20 metres or more in length. The 17 bridges noted are by no means a comprehensive list. For 39 of the 112 CALM bridges, there was insufficient data in the inspection reports to determine whether or not the bridges satisfied these length criteria.

All 17 of the bridges listed are in the Manjimup and Nannup Shires. Two significant groups of bridges consist of five along the Donnelly River and seven along Pine Creek Road in State Forest No. 35.

It was not possible to determine within the scope of the study whether any of the 112 CALM bridges might have potential heritage significance. None of the bridges listed were inspected for this report.

JETTIES

Since 1832, when the first timber jetty was built at Fremantle, timber jetties have played a very prominent part in the development of the State from Wyndham in the north to Eucla in the south. All of these structures were of a basic design, generally using Western Australian hardwoods for the components of the jetty.

Unfortunately, the life of the timber in these jetties was limited due to marine borers, decay and termites, apart from the relentless pounding of the sea, which claimed not only many a vessel, but also many a jetty, sometimes even before it was able to berth a ship.

Of the eighty or more timber structures, built, modified, extended or replaced in the period from 1832 to 1942, only four, Esperance, Busselton, Bunbury and Carnarvon, still remain in part or in full. None of them are being used for their original purpose as a cargo handling pier.

These four jetties represent the major type of maritime timber structure which was used for the transport of cargo between the ship and the shore during the first hundred years or more of settlement in Western Australia. They were greatly valued as an important community asset, being recognised both locally and regionally.

Generally, most of the original components of a timber jetty which continued to be used until the 1960s would no longer be present in the ruins or in the structure, having been replaced at least once since the jetty was built. However, the ruins of some jetties, which only had a limited period of use, may still contain some original components.

The nominations for registration that were made or endorsed in the 1995 report, "Port Related Structures on the Coast of Western Australia" by D A Cumming, D Garatt, M McCarthy and A Wolfe were noted and have been endorsed. Of the 21 large timber structures recommended for registration in the Cumming et al report, the Albany Town Jetty, the Carnarvon Jetty and Tramway, and the Bunbury Timber Jetty have been placed on the `Interim List' of the Heritage Council of Western Australia.

No photographs were included for jetties as they had already been supplied with the report by Cumming et al.

INDUSTRIAL, MILITARY, AND SERVICES SUPPLY STRUCTURES.

Introduction and comments.

Until well into the 1960s, timber was the main construction material for most industrial and infrastructure developments in Western Australia. A considerable number of large timber structures were built for industrial, military and service supply purposes, of which many still exist. The report presents a preliminary inventory of such structures in eight categories: air transport, maritime and port-related structures (excluding jetties which had already been covered), military, mining, power supply, railway, timber milling and forestry, and water supply and control.

The three major categories of large timber structures which it has not been possible to include in this study are pastoral and agricultural sheds, timber framed warehouses and factories (except for railway goods sheds and harbour sheds) and other buildings with large span timber roofs. These are important parts of this State's heritage and studies into each of the three is strongly recommended.

With one important exception, research into structures in this section has been largely a desk exercise to coordinate and extend work already commenced by others. The items listed hopefully include most of the important examples in each category, but in many cases, they were only a small representative proportion of the total number of examples in the State. It is hoped that the review will encourage others to carry out more extensive research into areas which have only been sparsely covered.

The observation fire tower is another important type of large timber structure in this section which was surveyed in the field. During 1997-98, the most important remaining examples of timber fire towers and tree lookouts in the south-western forests were inspected by Mr Lloyd Margetts of the Heritage Panel,s Working Party, and a preliminary short list of those with important heritage value made.

Several important large timber structures, such as the two hangers at the former Maylands Aerodrome, and the Nungarin Army Store, have been included in the report in outline only as they have already been assessed by others. They have been included in this report because, in addition to their importance as fine examples of buildings of this type with important historical associations, they are also important as outstanding examples of the structural use of timber in very large military and aviation buildings.

AIR TRANSPORT

The only items included are the two hangers at the former Maylands aerodrome, both of which are of great historic and technical importance. Other timber airport buildings may exist at other aerodromes used during the 1930s or were built during the Second World War and subsequently used for civilian purposes.

MARITIME AND PORT RELATED STRUCTURES

These include a number of unusual structures, such as the Albany Floating dock, which came to light during Mr Denis Cumming's studies of maritime structures and light stations. Also included were large timber warehouses at ports, and bridges and other structures on various tramways that served a number of Western Australian ports.

MILITARY

The former No 5 Base Ordinance Depot (BOD5) building at Nungarin, which may be the largest building with a fully timber framed structure in the State, is a magnificent example of typical military timber construction. There may well be a number of other significant large timber structures built for military purposes still existing in the State, some of which may still be used for defence purposes.

MINING

The boom in gold mining in the 1980s and 1990s has unfortunately resulted in the loss of most of the old timber headframes and other mining structures. Two very important examples of early Golden Mile Headframes and an ore bin have been preserved and reconstructed at Hannans North Mining Historic Mining Reserve. The Sons of Gwalia Headframe has also fortunately been reconstructed at Gwalia. Other examples of timber mining structures may also exist in less well known mining centres. Several small headframes have been listed in the Northampton Mineral Field , and others may exist in other base metal mining centres. Because of the comparative rarity of timber mining structures, the term `large' in this sub-section was applied quite liberally.

POWER SUPPLIES

Large quantities of timber have been used in this State for the transmission and reticulation of power supplies. The `pi' structure, which was used for several major long distance transmission lines, was the largest of all timber structures used for transmission lines in this State and relevant examples were included in the report.

RAILWAY

One large timber structure that figures prominently is the water supply tank which has long been the point of identification of many rural communities as well as being of major importance for supplies to steam trains. In many instances, railway tanks are now used for local water supply purposes which has assisted in their retention. A large number of timber framed goods sheds and several signal boxes were listed, and although not a particularly large structure, a timber derrick of the standard type was included, as it is probably the last example of its type left in the State.

Only large timber railway structures, which are more than 30 years old have been included in the report. In preparing this section, Ms Phillippa Uhe's report prepared for the National Trust of Australia (WA) and entitled "Survey of Railway Heritage in Western Australia" (2 parts) proved most useful.

RAILWAY GOODS SHEDS

Westrail have used standard forms of goods sheds. All have timber superstructures and were sheeted with either weather board, corrugated fibro-cement or galvanised iron. There were five sizes, the two largest having trussed roofs and the smaller ones with skillion roofs. Only the trussed buildings were considered to meet the criteria of `large timber structures'.

All attended stations throughout the railway system had goods sheds, including those in the metropolitan area. All major towns and junctions used the large size. Most of the larger towns, and many of the metropolitan stations, used the second size. There were probably about 100 of the larger two sizes on the total system. These sheds remained in use until Westrail relinquished its common carrier charter and abandoned less than wagon-load traffic in the early 1970s.

The goods shed was arguably the most important building in most Western Australian railway yards. In the 1994 report `Survey of Railway Heritage in Western Australia Vol 1 - South of the 26th parallel' prepared for the National Trust of Australia (WA) by Ms P Uhe, goods sheds were dealt with in a cursory manner. The report's only recommendation specifically related to goods sheds that were considered for assessment as part of station yard complexes, notably at Narrogin, Mukinbudin, Donnybrook, Pemberton and Bridgetown, together with an example of one small country goods shed. Whilst the heritage registration of railway yard complexes is considered the most desirable method of recognition of the heritage of railway buildings, it should be noted that a number of goods sheds that are of value, both as railway heritage and as local community assets, occur outside potential railway heritage complexes.

The goods sheds in the report were generally those in the two largest categories, each with trussed roofs. The locations have mostly been taken from the 1993 Westrail report Asbestos/Historical Register of Westrail Properties. This list does not include goods sheds on closed railway lines. Of the 42 listed, 17 were not included in the 1994 National Trust Report. It was recommended that a further examination of the heritage value and existing status of these buildings be made, particularly those that do not exist within the recognised railway heritage complexes.

RAILWAY TANK STANDS

In 1938, when the railway network had expanded to a maximum, there were approximately 250 water supply installations. These installations were normally self contained with catchment and storage dams, pumping equipment, holding tanks with stands and delivery systems to locomotive water columns. Even the external sources of water were available, such as in the city. The requirement of quick filling of locomotives from a 150 millimetre diameter supply water column required the use of high stands to provide the necessary pressure and volume. Most early tank stands were constructed of timber.

The introduction of diesel locomotives in 1953 heralded the staged abandonment of railway water supplies, initially in the dry Northern and Eastern Districts, and finally in the South Western District in the early 1970s. The water supplies were then gradually handed over either to the Country Water Supply Department for regional schemes, or the Public Works Department or Lands Department. Some of these are now in Shire ownership for landscape reticulation.

Although this inventory was not complete, it included a number of examples of large timber tank stands which remain in various states of repair.

FORESTRY AND TIMBER MILLING

Over fifty-five observation posts have been built in the forests of the South-West of Western Australia in the last 60 years in the form of timber towers, lookouts on tall trees, and steel towers or huts on elevated ground.

There are nineteen significant timber towers or lookouts. The towers are large timber structures by any standards and tree lookouts have been included because the construction of lookouts on trees of over 20 metres in height were in themselves not inconsiderate feats of timber construction.

Factors considered in the short listing of these structures for heritage assessment were:

1. Technical interest. Height Innovation (including timber splicing) Construction techniques (including hand axe-work).

2. Age.

3. Maintenance features. Whether still used
Public accessibility (if easily accessed and quite "public", vandalism would probably become a less serious a problem).

4. Dieback Restriction. It would be hard to justify heritage/Area Status. "tourism" funding for a structure to which general access is prohibited.

5. Originality.

Over sixty sawmills operated in the south west in the hundred years from 1870, most of which were housed in large timber buildings. Few of these remain. Many were burnt down and others were moved to new sites. The few important examples remaining were listed but a fuller inventory of all aspects of timber industry heritage is badly needed.

The fire tower was another important type of structure included in this category.

WATER SUPPLY AND CONTROL

One type of large timber structure in this class which was omitted because of time limitations was the timber support structure for roofs to service reservoirs and rock catchment collection tanks, of which there are a considerable number in the State. A further study of these was recommended.

Two large timber flood control structures are included but irrigation control structures have not been researched.

CONCLUSION

In total, some 850 structures were listed of which 139 have been selected as having a high degree of engineering heritage which should be considered for one or more official `Listing'.

The report covers a very broad spectrum of `large timber structures' in Western Australia. The main focus was to initially identify those structures that met the criteria of a `large timber structure' and then to document them before they became either redundant and were replaced or deteriorated to the stage of becoming ruins.

Structures that were deemed to have a high degree of heritage significance were singled out for recognition either on the National Estate, listing by the Heritage Council of Western Australia, or by entry on the Municipal Inventory of all Local Government Authorities.
`Time' was an essential element in the preparation of the report as it was felt important to have it completed before too many of the structures `disappeared'.

In total, some 850 structures were listed of which 139 have been selected as having a high degree of engineering heritage which should be considered for various degrees of `Listing'.

The completed report covers five volumes. Volume 1 lists the procedure adopted together with the details of the 139 structures recommended for listing. Volume 2 covers the Road bridges with Volume 3 covering the Railway bridges. Volume 4 covered all the other types of structures with Volume 5 supplying detailed drawings of many of the Railway Bridges.

In presenting this paper, I cannot stress too strongly the necessity for all areas of both Australia and New Zealand to make an immediate effort to identify and document their `large timber structures' before it is too late.

Finally, I would like to acknowledge the great effort put in by the late Denis Cumming in starting the project in the first place, and, following his untimely sudden death in January 1995, to the members of the Editorial Committee of the Western Australia Division of the Institution of Engineers, Australia, Heritage Working Party and the many other helpers who collected and collated the data into the final report, which I have used extensively to supply most of the contents of this paper.

Mining of Kerosene Shale at Glen Davis - Was it a Success or a Costly Failure?

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Summary: The decision to establish the National Oil Pty Ltd company, in 1937, to produce petrol from kerosene shale at Glen Davis was an Australian Commonwealth Government decision. With the threat of World War II, and the threatened interruption of overseas supplies, it appeared that Glen Davis would provide a vital and much-needed resource for a sea-locked country at war. However, with the pressure of war gone, Glen Davis was living on borrowed time. Production expectations were well below maximum and, with many other factors appeared to work against the venture and the company ceased operations in June, 1952. Three of the main problems, the darg, water shortage and floods, are reviewed in this paper. The discussion of these problems will show that many seemingly logical and technical considerations were changed, delayed and even ignored. The question arises then as to why the Glen Davis operation was set up in the first place when throughout its relatively short life it appeared to have been doomed by the very same organisation that brought it into the world, the Commonwealth Government of Australia. Hindsight suggests Glen Davis was simply a political exercise. It did not matter what technologies were used and nor how the miners operated, Glen Davis could not succeed.

1 INTRODUCTION

Glen Davis is located in the Capertee Valley, itself located 40 km north of the relatively small New South Wales country town of Lithgow which is 160 km west of Sydney. It would seem on the face of things, that with Glen Davis, close to Australia's largest city and thus a large population base and a large market, was ideally situated to take advantage of an indigenous industry that would be of strategic value in case of war and at least of value in reducing exports of an ever increasing imported commodity.

During the 1930s, the Newnes Investigation Committee (NIC) was commissioned to determine if oil shale mining and a petrochemical industry was again viable at Newnes, and especially as to whether petrol of a satisfactory quality could be produced in NSW from the kerosene shale. On economic grounds, the Committee felt the establishment of the industry was not warranted. An oil shale industry could only be justified, if at all, on the basis of national consideration for developing an Australian oil industry. Thus any agreement to again operate an oil shale industry would be on strategic grounds, not economic grounds. Furthermore, the Committee emphasised that such a project could only be undertaken by a private organization, not as a Government enterprise, and only with the help of experienced personnel.

In 1936, the Commonwealth Government of Australia publicly invited tenders to develop a shale oil industry in either the Wolgan Valley or Capertee Valley in accordance with the recommendations of the NIC, recommendations that were four years out of date by 1936. Capital and operating expenses had escalated well above the NIC estimates. This is perhaps the first time that viability of a Glen Davis shale oil should have been questioned.

With the exception of one offer that lacked substance, the Commonwealth received no response to its public invitation. At the request of the Minister for Development, Senator A J McLachlan, and Sir Herbert Gepp, a member of the NIC, Sir George and Chris Davis, and their Davis Gelatine Company business associates were invited to submit a tender to finance and direct the revival of the shale industry of NSW. The invitation was declined. It was the challenge of making something out of nothing, or taking the dying and making it live again, that had drawn McLachlan to the Davis brothers. He was aware of their success in developing an international gelatine business and in turning the Commonwealth's unprofitable Cockatoo Island dockyard into a flourishing ship building and engineering concern.

In this paper we look at a number of the problems that beset the Glen Davis project. Looking back with hindsight, it is clear that the best options were not always taken. 'Things' probably would have been different if other options had been taken. Perhaps the most far-reaching decision was to take the project out of the hands of private industry and place it in the hands of politicians. Hands that, at the best of times, have difficulty not interfering in what they know not.

2. WHAT IF?

As early as 1942, the closure of Glen Davis was inevitable even though in later years, both Labor and Liberal Governments would do their utmost not to close NOP (and lose votes over the issue). Many circumstances conspired against the success of the company. The Commonwealth Government was impatient with the financial impasse, technical delays and the shortage of skilled labour for the shale mine.

With the demise of Glen Davis, another oil shale era met a sad end and people once again walked away from their jobs and homes with nothing. Many questions can be asked, most remain unanswered. Perhaps things could have turned out differently if:

- different mining techniques had been used and different equipment had been used in the mine;
- there had been no mining darg;
- there had been no wartime restrictions, and petrol and rationing restrictions had not been enforced;
- there had been no shortage of water, equipment and labour, and no delays because of flooding;
- NOP had stayed as a private company and it had not been rushed into production by the Commonwealth Government before testing had been undertaken;
- Estonian retorts had been built as requested by Sir George Davis;
- petrol had not been changed from 70 to 80 octane (thus reducing the yield);
- the Commonwealth Government's anxiety not to be involved in competing with private industry had not resulted in a limitation of ½ price on by-products; there was no competition;
- tank storage had not been taken over by the Commonwealth Government and filled with white products removed from Sydney in case of bombing during the war.

Three of the above will be examined in more detail - the strikes and the Darg, the lack of water and flooding

3 THE DARG AND MINING PRACTICES

It was in the mine that major problems arose, and soon after mining commenced. Glen Davis could only have been a successful operation if production had met targets. The first step in this chain was the mine and miners. If the miners did not meet the targets set, then the downstream operations could not possible meet their targets.

Two factors mitigated against full capacity from the mines – mining practices and the darg. It can perhaps be said that miners are a hard-nosed bunch of operators who believe they know best. For example, management tried to introduce pillar extraction by machine. The miners opposed pillar extraction by this method. It was claimed by outsiders the miners' objections were rooted in a perceived danger that only existed in the minds of the union leadership. The unionists and some of the miners claimed that when the extraction of pillars was carried out by hand, the miners could hear warning noises and creaks before a roof collapsed, thus allowing time to get out. Machinery, it was claimed, drowned out these warning sounds, thus increasing chances of the men being trapped. On the other hand, many men believed that the pillars could be extracted by machines with safety.

At one stage, 218 men met at the pit top to resolve whether they would extract the pillars by machine on condition that the work was carried out under competent supervision. Sixteen deputies who heard the resolution took umbrage and walked off the job throwing the mine idle for days during this strike.

3.1 Strikes

Strikes caused untold damage to the fledgling industry, especially as productivity was not achieving anywhere near the desired targets. In August, 1940, the first petrol was produced at Glen Davis and the historic occasion was celebrated by the residents with a carnival at night and a sporting event the next day[1]. These celebrations were short lived. When the Government assumed control of NOP in 1941, one of the first actions of the Minister for Supply and Development, John Beasley, was to inquire into the position of the company. He felt that progress was disappointing although experience was being gained by NOP. There was no indication as to the additions and alterations that were necessary to improve production. He said it was a condition of the NOP agreement in 1937 that by January 1, 1940, the works would be capable of, and properly equipped for, producing petrol and oil from shale.

As early as April, 1940, delays caused by a coal strike resulted in approximately 1,500,000 gallons of oil waiting to be converted to petrol. The House of Representatives was told that the company could not give a forecast of the volume of its production until the conclusion of the strike[2].

In December, 1941, fitters, boilermakers, riggers and electricians went on strike for more than a week. Clem Norcross, the manager, and staff did their best to do the every day running repairs and adjustments necessary. The main breakdown during this period was the shale handling equipment where ropes on the dragline broke. Only riggers could splice and repair the ropes. This interruption saw mine production reduced. Also, several retorts were out of commission because the ironworkers were on strike[3].

Frequently, the retorts were affected by strikes set to cause the most damage, usually when the retorts were coming into operation. One such strike lasted seven weeks with the retorts fully loaded with shale. Another strike occurred the day the rebuilt retorts were commissioned in February, 1947. The new retorts had been heated up over a six week period. During this strike, the unions withdrew the safety men, men who were employed to ensure that safe operations were maintained at all times. The Company emphasised that the action of the men in bringing about the stoppage, was unwarranted and indefensible. The strikes were over disputes related to the domestic management of the hostel and the lessee, nothing to do with the works. By withdrawing the safety men, the Glen Davis Trades and Labor Council had committed a flagrant breach of an undertaking given previously to the management. There was grave danger of damage to valuable and essential equipment. If it became necessary to close down all retorts, it was unlikely that the units could have been fully recommissioned for at least three months, maybe longer. The action of the Unions in withdrawing all the members from the mine and the retorts, caused the plant to suffer yet another setback and one that threatened the future of Glen Davis[4].

By mid 1949, Glen Davis was again in danger of being ruined when a nation-wide coal strike was called. More than 300 men were stood down and drastic measures were adopted to keep the retorts in operation. Throughout the strike, NOP managed to keep 12 retorts working using a skeleton staff.

3.3 The Darg

The darg was a partisan agreement within a group of miners, and unofficially sanctioned by the miners' union, to limit the output. The limits on output could be controlled by a number of work practices such as a reduction in the time spent on the job or in the mine, a slowing down of the work rate and use of poor practices. The darg was an almost impenetrable block or barrier to increased production and was very difficult to control or eliminate. On the one hand, the miners and the union claimed that a darg did not exist at Glen Davis but on the other hand every one in the town knew otherwise.

At Glen Davis the mine was highly mechanised and very little reason could be given for a darg. In September, 1941, mine manager, Harry Dalziel resigned and John Daniel Bowdler became manager. Bowdler found that boring the seam prior to shotfiring was the most difficult of all operations in the mine. It was reported that at the mine face, a pair of miners could machine bore a set of holes in approximately two and a half hours yet commonly it took a whole shift if hand-held drills were used. The miners had in effect imposed a limitation on the number of holes drilled, simply by using hand-held machines. This is an example of the darg in practice.

The output of shale from the mine was insufficient to maintain full supplies of feedstock to the retorts although this was not apparent until 1946 when the retorts were completed and capable of operating at their maximum capacity. Again, hopes for increased productivity were raised in 1947 when the miners consented to the mechanical extraction of pillars. However the Miners Federation continued its own method of reducing mine output - enforce the darg on machines and shotfiring.

When new mine manager Mr Moore took over, he was not happy with the men coming out of the mine early and thus imposing a limit on the number of holes being bored. He wanted more practical work, but the men continued with their disappointing practices[4].

In May, 1948, Mr E J Kenny wrote to Senator Ashley reporting on some of the problems:

"Your attention has been drawn on several occasions to the existence of limitation practices, notably the boring darg, which constitute a major, though not the only, factor in the restriction of shale output. The Company's efforts to overcome, or at least to modify these practices have proved so far unavailing. Some increase in shale production was expected as a result of the recently introduced mechanical extraction of pillars, but the system has now been in operation sufficiently long enough to indicate that no significant improvement in output or cost is likely to arise from the practice. We regret to report, there is no evidence of any appreciation by mine employees that, in their own interests and those of the industry, a greater degree of co-operation is essential, or by failing to give a reasonable day's work for a good day's pay they endanger the very existence of the industry"[5].

It was said that man cannot beat machines, but that did not seem to hold true at Glen Davis. Results show that when the machines were accepted as instrumental to raising output, with less sweat and less drudgery for the men, marked improvements in production were obtained. Far too often, the machinery was deliberately slowed down to the pace of manual machines. Below are given other examples of how to enforce a darg.

- Men would take longer crib hours than they were entitled to take;
- Often skips were sent out of the mine only partly filled;
- Late starts were very popular; a common activity was to call a pit top meeting before work began
- Strikes took place just as the retorts were ready to start causing weeks of disruption.
- Frivolous strikes took place with any reason sufficient varying from bad food at the hostel to the men wanting a man reinstated after being sacked for constantly going to work drunk; drunkenness was in itself a safety problem.

Closely related to the darg, if not part of the darg, was the problem of absenteeism in the ranks of the single men who lived in the Government-leased hostel. Every now and then these men 'took off' to Lithgow or Sydney for a few days, thus leaving the mine undermanned and not capable of attaining optimum productivity.

4 WATER AND FLOODS

4.1 Early Problems

The decision to build Glen Davis in the Capertee Valley ignored one important factor, the lack of a permanent water supply. The Capertee River was not a permanent stream, unlike the Wolgan River at Newnes. This problem was to revisit the new township and its fledgling industry, again and again, until such time as the Fish River Scheme was finally completed many years later.

In June 1933, the Newnes Investigation Committee received a report from the Mining Sub-committee in which it was suggested ample supplies of water for condensers could be obtained by sinking bores along the Capertee River. It also felt that supplies of good fresh water were available from Running Stream, a tributary 3 km downstream from the MP1 tunnel. The report suggested that by constructing a dam on this stream would allow water to be piped to the works site[6].

The lack of water for both domestic consumption and industrial use was a major problem, almost from the time the first sod was turned. Whilst the work site of NOP was being surveyed, a water-boring plant was sent into the valley to search for much needed water to supply the township as well as the works. The water obtained was highly mineralised and extensive treatment had to be undertaken before it was useable in concrete construction. Even whitewashing of buildings was delayed for the want of water. By the end of 1938 a tank to supply the mine and bathrooms and another tank at the sanitary depot had been built. A number of bores were put down and a well sunk at the brickworks. Tanks were situated on the hillsides to give pressure when being used for plant construction. The water was found to be hard and unsuitable for domestic purposes. The capacity of the bores was good but the water required the addition of silicate of soda or other salts to render it useful. One of the bores produced 6,000 to 10,000 gallons of water per hour according to seasonal conditions and a second successful bore gave a smaller flow. The water contained sufficient dissolved solids to be classified as saline. Water was also hauled by truck from Running Stream.

In 1939 Sir George Davis received a report from his construction engineer, H I McGuigan, that he was looking at Running Stream as a reservoir site. The scheme was to dam Running Stream to impound 120,000,000 gallons of water and to supply 500,000 or 1,000,000 gallons per day to the works at an estimated capital cost of £45,000. The scant data to hand placed the stream as a constant storage source. It was hard to estimate maximum flows, but flood marks pointed to a flow in the order of 300 million gallons per day. It was concluded that sufficient water would flow through Running Stream for all of NOP needs. Unfortunately no action was taken on this scheme[7].

Tests were conducted in January, 1942, on various bores around the valley. The Mines Department geological surveyor, Mr C S J Mulholland, was asked by NOP to investigate underground water in the Capertee Valley. This was with a view to possible augmentation of supplies for the Glen Davis works and householder requirements. From the 13th to 16 January he examined the Company records, conducted field investigations and selected sites for further exploration.

Mulholland's report stressed that any of the proposals advanced must be regarded as a temporary measure to assist operations in times of emergency when water from other sources was reduced. He felt that requirements for the plant would not be obtained from wells and bores. He concluded that the only satisfactory solution of the water problem for the works was a scheme to impound run-off.

Bores were sunk but because the flow from the best bore was small compared with the anticipated requirements of 750,000 gallons per day for the works.

Dry conditions continued until 1944. At this time, no water was available from Running Stream and local bores were drying up. To relieve the position a tanker load of drinking water was purchased from the Railway Department and carted to Glen Davis from Capertee. Another scheme was to install a tank to take condensate from the main engine in the power house, the water was then left standing for a few hours to allow oil to float to the top of the water. It was not very palatable for drinking but was satisfactory chemically and bacteriologically. Water was soon being carted by truck into the valley and sold by the gallon to residents. During the sparse rainy period, dishes, buckets and anything that would hold water, was spread around houses to catch a few precious drops.

4.2 Later Water Supply Schemes

It became obvious after much dilemma that a permanent water supply scheme was needed for the town and for the works site. A number of possibilities were considered but it was many years before any scheme was put in place. One scheme was to supply water from thee Wolgan River at Newnes. In January, 1940, the mine manager Mr Dalziel started driving the MP1 tunnel through the mountain to the Wolgan Valley to pump and pipe water back to Glen Davis. Before the three miles long tunnel was completed the Wolgan River ran dry for the first time; all plans for the tunnel were dropped[8].

In January 1942, the surveyor for the Public Works Department, Mr Butler, spent 10 days surveying a pipeline from the junction of the Wolgan and Capertee Rivers to Reservoir Hill above the Glen Davis township.

The next attempt was a pipeline supply from the Wolgan River and Rocky Creek at Newnes[10]. The flow was good enough to run continuously out of a six-inch pipe. It was found that the water disappeared underground after it left Rocky Creek[9]. This plan also was dropped.

By December, 1944, the water position was critical and thoughts were turning to pumping water from Newnes through the petrol line when it was not in use. Within weeks of arranging pumps the Wolgan River was practically dry. Nothing would be gained by installing the pumps[11].

Another scheme suggested was a storage dam on Coco Creek in the Capertee Valley. This project did not go ahead and many other schemes had to be implemented before the Fish River was in operation.

The first indication of a water scheme on the Fish River, near Oberon, and piping water to Glen Davis was in a letter from the principal engineer of Water Supply and Sewerage in January 1942. Temporary supplies of water would be brought by rail from the Fish River to Glen Davis to help during the drought. The scheme was to consist of a small weir on the Fish River and a pumping station to service a reservoir at Oberon, 3 km away. These were to be designed and constructed so that later, they would be part of the main Fish River Scheme.

From the service reservoir water for Glen Davis was to be delivered by railway trucks with rail cartage involved for a distance of between 40 to 50 miles to a suitable point near Ben Bullen. From here, the water would be discharged through a pipeline to the Glen Davis service reservoir. Most of this line would then form portion of the main Fish River Scheme[9].

By mid 1942 the NSW Government had planned a central water supply scheme for the Blue Mountains area, to Lithgow, Kandos and as far as Glen Davis. The Oberon site was chosen because it was just over 1000 metres above sea level and water would flow downhill to consumers. The dam was to be built on the Fish River with a sixty-mile pipeline to Glen Davis. NOP's contribution would be £160,000 and the total cost of water delivered at Glen Davis would be about 1s 3p per thousand gallons.

Although the scheme had been before both Governments for months no announcement was made for or against it. Because of the difficulties experienced by NOP and its importance in the war effort, the Commonwealth Government finally gave its support to the scheme. From State and Shire records it is obvious that local governments in the Blue Mountains used Glen Davis as bait for Canberra to get their water supply through. In October 1943, work finally started with a gathering of politicians, councillors and citizens to celebrate the reality of a reliable water supply for the Blue Mountains, and at the end of the line, Glen Davis. The Fish River dam was the first slab and buttress concrete dam built in NSW.

As there were no celebrations or official opening of the Glen Davis water supply, no completion dates have been found although water was available to the works area by 1947. It was 1949 before houses were connected and it is ironic that within the next few months floods would isolate the valley on many occasions.

4.3 Floods

For Glen Davis, it was a case of not enough water on the one hand but too much water on the other hand. If Glen Davis was to be brought on stream in this day and age, the mine probably would be located where it was but the infrastructure and processing facilities undoubtedly would have been placed elsewhere. A modern environmental impact statement would have investigated the potential for floods and the need for a permanent and adequate water supply. Although the last major flood at Glen Davis, prior to the shale oil operations, had been in the 1920s, floods were uppermost in the mind of Dai Davies as he planned the new works. Hindsight shows this was not enough. In May, 1938, Davis applied to the Lands Department for contour maps and flood levels of the valley. These were not available. Ironically heavy rain fell for weeks with flood waters covering part of the flat near the works site. The rain was short-lived and drought conditions once again prevailed.

Below is a list of the more destructive floods that caused damage and delay from 1939 to 1952.

- 02.11.39. Loads of machinery were stranded for six weeks on the road near Glen Alice because of flooded causeways. Boring machinery near the works was moved to higher ground.
- 05.04.42. This flood was one of the largest with access into the valley cut. Damage was caused at the pumping plant at Running Stream were it was necessary to sheet pile the stream bank to prevent further erosion near the race. The power house was damaged.
- 12.11.42. The Running Stream pipe line was again disabled whilst the Tank Farm at NOP was inundated to a depth of two feet. Many tanks floated from their bases, damaging retaining walls when unexpected floods hit. Partly filled tanks had water added to keep them down. If tanks were empty they would be opened to allow water to enter, stopping them from lifting off their bases.
- April 1944. Seven inches of rain fell within days with only about half an inch for the rest of the year. Roads were again blocked.
- 12.01.46. A violent thunderstorm produced two inches of rain in 45 minutes and washed the Running Stream pipeline away in places. Damage was caused around the works site.
- August 1948. During floods, two sections of the refinery cooling tower collapsed. Throughout the following summer months only half the tower was usable.
- 20.06.49. Glen Davis was again cut off. Sections of the works were damaged including the power plant and supplies were cut off to the works and township. Until all damage was repaired blackouts were introduced to help prolong the electricity supply. All street lighting was off and electricity was limited to 6am-8am and 5pm-8pm. The foundations of two huge petrol storage tanks were damaged when they were lifted but they were prevented from being washed away by large pipe stays.
- 06.07.49. By July, 48 inches of rain had fallen. Due to flood waters reaching the works, exchange technicians had to install a new telephone exchange. Complete rewiring was necessary to both telephones and 52 extensions.
- 20.1.50. The works were isolated, power again disrupted and over 250 workers were without jobs until flood waters receded and the damage repaired. "Practice makes perfect' and this proved true as the months went on and flooding continued. During the first floods it took quite a while to move motors and build levee banks but this changed with each flood. Eventually a routine plan came into action. Everyone was allocated a job and rescue work became quicker with each flood.
- 6.2.50. Six feet of water had staff working around the clock to effect repairs. Salvage work at the office included valuable records being stored above water level to prevent their destruction. Electricity was again cut off with workers and rescuers using torches, hurricane lamps and candles as they worked.
- 19.2.50. Electricity was again cut. Boilers, engines and electrical equipment had to be dried with repairs to the retort brickwork. Office furniture, records and walls were damaged with faulty underground cables in the flooded area presenting many problems.
- 26.02.50. Flood waters lifted tanks in tank farm and dumped them at random around the grounds. The power house was flooded and electricity was off until motors dried out.
- 02.04.50. Floods on the 2nd and 3rd of April damaged the Running Stream bore, motors, pumps and the residual pipe line connecting to the works. A levee was started around the works site to protect it against future floods. During the floods that came it was not a success. An all-metal 14 foot skiff was purchased and kept at the entrance to the works, This skiff looked flimsy when one considered the force of the floods which buckled the massive steel tanks in the tank farm.
- 11.07.50. Floods held up work on the damaged refinery cooling tower and three partially empty residue tanks were lifted. It was estimated that two weeks fine weather would be required to effect repairs. This seemed to be a tall order as the wet conditions and floods had continued for so many months.
- 20.07.50. As flood waters rose to 11 feet above the bridge the works were inundated once again. The retort section had 18 inches of water through it, power was again cut off and the coal mine isolated.
- 04.08.50. This flood brought to 17, the number of times that the valley had been hit be floods. This flood claimed the life of Keith Harrower when he tried to swim home after water had covered the bridge near the hostel. Whilst not as bad as the February floods, water again entered the works and caused inconvenience rather than damage. Landslides cut off

the Fish River Water Supply. Consequently water was supplied and supplemented from a six-inch pump at Running Stream after the floods subsided.

- 27.10.50. Floods slowed work on the levee around the works. At this time plans were drawn up to divert the course of the Capertee River in three places near the work site.
- 22.11.50. As Sydney experienced its worst rains in 90 years Glen Davis felt the effects of yet another flood. Telephone communications to the works were cut when water interfered with the switchboard at the works office. With water swirling through the office and laboratory, staff lifted machinery and stored records and files in the ceiling above water level. The levee that was partly built around the works had offered a large measure of protection and it was felt that it had reduced the water level by up to two feet. The works manager Mr Christie reported at this time that the company expected to complete the wall by the end of February 1951. It was hoped that the wall, that would be up to 12 feet high in places, would prevent any further flooding of the works.
- 14.8.52. This flood was described as the worst floods since 1926. Torrential rain lashed the valley once again isolating the township, works and coal mine. The power house again was flooded cutting supplies to the works and the township was without lights and cooking facilities.

In defiance to future floods, a levee of ash up to eight feet high in places was built at the works site. It was hoped this would give a measure of protection against further floods. When the levee was constructed it did not make any special provision for gas and flare pipes or water supply and ash disposal pipes. The levee covered all existing drainpipes with provision made for renewing them in the future by leaving three concrete tunnels under the levee. At several points a trench was dug to the level of the lowest drain. A concrete circular, semi-circular, or domed concrete duct was poured into the trench then covered over and the end sealed. The duct was large enough to carry all drainage pipes requiring renewal.

It was considered that the river was too close to the plant for the levee to be continued along the alignment of the river. A plan was drawn up to divert the course of the Capertee River by constructing three diversion channels and a levee on the rivers edge. The diversion would straighten the river and move it 30 yards away from the boundary of the works. The diversions were to be 35 feet across 12 feet deep and level with the existing riverbed that would be filled with earth from the new workings. The plan was to close off the bends, cut through the bank in a straight course for about 380 yards and lift out 26,900 tons of soil. When the three bends were cut off and the water diverted it was hoped that the levee banks would help protect the works. The plans were approved by the NSW Irrigation and Water but never built.

5 CONCLUSIONS

Strikes, the darg, lack of water for industrial and domestic use, and many floods were just a few of the problems that beset Glen Davis. No one factor can be said to be the cause of the closure of Glen Davis. Indeed, when the end came, it could be argued that the Government made the right decision, albeit a political one when it came.

The problems listed above all contributed to the demise of Glen Davis in some small way. One question will always be asked. "What if things had been done differently?' Perhaps the demise could have been delayed and the hurt experienced by the people of Glen Davis ameliorated in some small way. Perhaps the only factor in favour of Glen Davis from the start was the strategic factor if and when Australia went to war. Perhaps the Davis family would like Glen Davis to be remembered in this and to their credit, they knew this and did the best that could be expected of them.

Was the mining of kerosene shale at Glen Davis a success or a costly failure? Alas, history says failure! However, in no way should this failure be attributed to either the Davis family who were cajoled into starting the enterprise, and were then given a heavy boot when a scapegoat was needed, nor the residents of the township. The government and the miners must equally shoulder the blame.

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C.R. Ford's Contribution to Seismic Engineering in New Zealand

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Summary: New Zealand's first national recommendations for seismic engineering practice were prepared by the Building Regulations Committee of 1931 immediately following the February 1931 Hawkes Bay earthquake. Some of the recommendations reflected technical discussion in the 1926 book by C.R. Ford published in New Zealand on the basis of a lecture to the Engineering and Architectural Society of the University College of Auckland. This appears to have been more comprehensive than previous publications in English on structural engineering design for seismic load. In it Ford advocated the establishment of a seismic code of building practice for New Zealand; a plea which was not to be realised until the earthquake of 1931 provided the political will for such. Having published his book and stimulated pressure on the Government to take action on this matter it is somewhat surprising that Ford was not invited to be part of the Committee. However, he did inspect the earthquake damage and make a submission to the Committee, and later served on the Model Building Code Committee of 1934. Aspects of Ford's book *Building and Earthquake Construction*, and his life and personality make an interesting backdrop to early building code developments in New Zealand.

1 THE BUILDINGS REGULATIONS COMMITTEE

"In the winter of 1931, in the depths of a world depression, rigid economy was a necessity.", so says Burdon (1) was one aspect of the underlying atmosphere during the deliberations of the Building Regulations Committee, and subsequently the New Zealand Parliament, on the formulation of building regulations. The Committee had been convened on the 17th of February 1931, just 14 days after the Hawkes Bay earthquake, and in June of that year its report was tabled in Parliament for the presentation of a Building Construction Bill. Certainly, a severe event, estimated to have been 7.8 on the Richter scale, had revealed a keen need for the regulation of construction in New Zealand, but also the hard conditions of a world depression were equally present in the minds of all and, in view of the expense of implementing it, the Bill was allowed to lapse. It might be thought that the Committee's effort had been wasted, but it had brokered the provision of urgently needed advice on rebuilding in the immediately affected regions and it had informed the debate on the immediate revision of schools in particular then under construction or in planning. Most of all, in the urgent atmosphere energised by the recent earthquake, it had committed to print building recommendations of an order of more detailed than had previously been available in New Zealand, and which bore fruit when the topic was revisited three years later.

The Committee was set up under the joint control of the Public Works Department and the Department of Scientific and Industrial Research (see Minutes of the first meeting) and presumably selection of members of the Committee was decided by the Heads of these Departments, F.W. Furkert and Dr E. Marsden: Furkert attended the first meeting on the morning of the 21st February and Marsden the second, in the afternoon of the same day. Not unnaturally, chairmanship went to Professor J.E.L. Cull, who, as Head of the Civil Engineering Department in the then National School of Engineering and with a background in structural engineering, held high technical standing in the civil engineering community in New Zealand. Further representation was made up of 6 engineers, 2 architects, 2 contractors and one architect/engineer. Eight were based in Wellington, and to these fell extra work because they could meet more easily. Neither Furkert nor Marsden was on the Committee. At the first meeting, when Cull appeared unsure what their aim should be precisely, Furkert told the Committee in direct terms that the Government would look to them to formulate legislation, and appeared to be speaking as one confident of the sentiment of the Government.

Circumstances surrounding the setting up of the Committee are depressingly familiar in that the similar situations arose in Japan and in California. Seismicity in Japan and suggestions for construction precautions had been documented by Milne (2), for example, in 1885; ending with a note that to his knowledge the Local Government of Manila alone had provision in its Building Acts for seismic design and that this was only a consequence of an earthquake of 1880. Milne, in effect, was an early "prophet" calling for the formulation of seismic building codes. Arguments raised by Milne, placing light flexible frames in opposition to heavier rigid frames, seem to only finally be settled and codified following the 1923 Kanto earthquake. In California there was a disastrous earthquake and fire in 1906 and the Santa Barbara earthquake in 1925 before the Long Beach Earthquake of 1933 provoked emergency legislation which initiated a building code, albeit only for school buildings in the first instance. In both regions there had been committees investigating earthquakes, and consequent publications, going on for some time before the final event crystallised matters.

Of course, it should also be noted that coincidentally analysis of framed structures was coming of age in the early 1930's, as witnessed by the extensive ground breaking work of the Steel Structures Research Committee in the United Kingdom, between 1929 and 1936. To a large extent, prior to this such structural analysis as existed had not been seriously set in order. In addition, important new ideas, on the design of "real" struts, realistic floor loading and the analysis of structural frames using the moment distribution method emerged during this period. So it could be argued that prior to 1930 a code committee would have been working with a good deal less knowledge and writing a code for an industry largely unprepared for information that was only then being formulated. The final report of the SSRC was not made until 1936, and even that committee, which had been in the forefront of ideas for seven years, contained several members said by one commentator to have been "punch drunk" from the barrage of new ideas. Therefore recommendations to be expected from the Buildings Regulations Committee in New Zealand in 1931 have to be seen in the light of a climate of quite limited information by modern standards. That is not to say that useful and relevant building information could not possibly be formulated before, say, 1930: it could, but it would be expected to be more practical than technically detailed. Cull telegraphed the SSRC who advised that in 1931 they had nothing in final form but would supply him with what they had of relevance if he could be specific: no further contact is recorded in the notes of the meetings of the Committee.

Also a "prophet", Charles Reginald Ford, in the winter of 1925 gave a series of lectures to the Engineering and Architectural Society of the University College on the question of earthquake resistant construction. Out of this came his book *Earthquakes and Building Construction* published by Whitcombe & Tombes, Auckland, in 1926. One source of inspiration was Ford's recoil at the quaint remark appearing in the New Zealand Yearbook of 1921-22 and attributed to Mr G. Hogben, late Government Seismologist, to the effect that earthquakes were "...rather a matter of scientific interest than a subject of alarm." The remark is repeated in subsequent years but not made again after the report of the Murchison earthquake of 1929; though the annual report continues to refer to the chimneys which have fallen down over the years in a deprecatory way as "(for the most part badly constructed ones)", and this latter remark is only discontinued after the Hawkes Bay earthquake of 1931: the whole sequence betraying a reluctance to admit to concern. But disapproval alone could not have inspired a lecture series, let alone a book, had there not been Ford's keen interest in the subject resulting from his study of contemporary Japanese and American writers, his correspondence with them, his own architectural and structural understanding and his first hand experience of earthquake damage. It was a topic which exercised to the maximum Ford's diverse interests: at the time of writing he already held memberships in the Royal Geographical Society, the Royal Institute of Architects, the New Zealand Institute of Architects (past President), the Institution of Structural Engineers (London), and the Seismological Society of America. He wrote and published other tracts but this was his major publication.

That the Buildings Regulations Committee were aware of Ford's book is fairly sure: it had been available for five years before they met, the University of Canterbury Library copy is Cull's own, and other copies are held in four Wellington libraries including the Parliamentary Library and the Turnbull Library, three Auckland Libraries and the Dunedin Public Library; though dates of acquisitions are not able to be established. To some extent it is therefore surprising that Ford did not serve on the Committee, and that his work was not acknowledged by that Committee. The Californian standard code, as far as it had been prepared, is acknowledged, and Mr Henry Dewell of San Francisco and Professor Bailey Willis of Stanford University. Ford also acknowledges these sources and others, and the Committee may therefore have felt justified in bypassing him to acknowledge the primary sources; and also that in its findings it went further into technical detail than Ford. Nevertheless his collection and arrangement of information from many sources had already been made and must surely have been very convenient at least.

2 LIFE OF C.R. FORD

In two places an article profiling Ford in *The Weekly News* of January 30, 1963, has him use the word "romance"; and it is one word which may contribute much to understanding the events in his life. These are ably summarised by Lowe (3) in the Dictionary of New Zealand Biography, vol 4. Born in 1880, he is thought to have gone from school to the Royal Navy. He then volunteered for the first of the Royal Geographical Society's National Antarctic Expeditions led by Scott during 1901-1904, and thereby had his first introduction to New Zealand. Returning to New Zealand in 1906 he was a land agent in Christchurch, where he married in 1908. Perhaps because of having native ability at drawing he prepared himself for architecture, and in 1919 was practising as an architect in Wanganui. By 1921 he was President of the NZ Institute of Architects for the Annual Meeting, which was held in Wanganui that year. He then moved to Auckland and in 1923 began in partnership with W.H. Gummer, which relationship continued for the rest of his working life.

Each of the career moves above was characterised by success. In the Navy he was absorbing "a wonderful spirit" in which boys were trained not to think "I can't" but rather "I'll try". This was a service still basking in the afterglow of Trafalgar. To go to the Antarctic with Scott was a "wonderful romance". This particular expedition ended well, with Scott engaged in a lecture tour and Ford accompanying him. In Christchurch, with characteristic energy it seems, he soon established his own Land Agency business, Ford and Hadfield, which continued to operate until very recently, well after he had moved on, and indeed after he had died. In Wanganui, in a short time he had established a partnership and was President of the NZ Institute of Architects, and had made sufficient impact for his future partner Gummer to describe him as: "most refreshing. I did not know him until he commenced his term of office, and I would like to give my personal testimony to the regard I have for him and his outlook on affairs." (Petry (4)). And with Gummer, Ford then consolidated what became, according to Lowe: "the most successful architectural practice in New Zealand between the two World Wars."

Ford is characterised in the obituary in the NZIA Journal, 20 July 1972 as "one of our first architect administrators, who ran a practice on strict business lines, working successfully alongside the more sophisticated designer and theory men." Petry notes that both Ford and Gummer moved easily in the plush atmosphere of the Northern Club, the Auckland Society of Arts and similar groups where "personal contacts contributed to Gummer and Ford gaining many large scale commissions, and ...the firm was able to establish a reputation of professional competence. .... Therefore the practice was sustained by a group of influential clients and supporters who socialised and developed a shared 'vision' of the future." We do not know what opportunities Ford might have had in Britain. After a short attempt to establish himself in Canada he quickly discovered that conditions were not favourable for Englishmen in French dominated Ottawa, and he soon moved on to New Zealand. Conditions here obviously were favourable and the picture emerges of a successful architect and businessman. But before we fix him thus, there was another more contemplative side to Ford.

It appears first in three anti-war publications in 1911 and 1912. Given his background in the Navy, and the general mood of the community before and during the First World War towards pacifism, these are surprising. He does not seem to have persevered with this point of view. However, he also had a very close friendship with Archbishop Liston, for many years Catholic Bishop of Auckland. It began on a professional basis but developed beyond that as indicated when Archbishop Liston wrote movingly in the New Zealand Herald on Ford's death: "Forty seven years of my life in Auckland have been enriched in the friendship, close, strong and unclouded, of C.Reginald Ford.": going on to describe him as a man with "concern for the primacy of the spiritual in the life of man.". That he also had a passion for antiques, and for the Auckland Museum, is evident in his pamphlet on "Collection of old English pottery and porcelain, with a note on Meissen and Sevres" published by the Auckland Museum, to which he bequeathed much of his personal collection. His obituary in the NZIA Journal of the 20th of July 1972 notes that he held strong views on the education of architects: particularly that they should be widely knowledgeable in cultural and economic matters and imbued with social responsibility. He is variously said to have been widely read, and in an unpublished note J.B. Gummer remarks that he was a fluent speaker and writer, from time to time contributing articles to NZIA meetings and the press. Presumably because of his strong views on education, he did get himself elected to the Auckland University Council.

3 *'EARTHQUAKES AND BUILDING CONSTRUCTION'*

The *Weekly News* article also records that as a young person in the Navy, Ford saw at first hand complete destruction resulting from an earthquake when visiting a Greek island in the Aegean Sea, and that Scott put him in charge of a seismograph carried with the Antarctic expedition. No doubt these were, in retrospect, useful experiences. Data he mentions in regard to the Lisbon earthquake of 1755, and Japanese and Italian earthquakes he attributes to the Bulletin of the Seismological Society of America, though he may have visited some of these places during his service in the Navy. He did, however, visit California in 1922 between leaving Wanganui and settling in Auckland, and the bibliography in his book indicates a comprehensive reading programme including works published around this time. It therefore seems possible that he met architects in California with heightened awareness of earthquake construction requirements, and possibly seismologists, through his membership of the Seismological Society. It would be interesting to know if he had planned his visit to California for a purpose such as this, and if the visit marked the commencement of his membership of the Seismological Society of America. It is possible that his serious interest in earthquake resistant construction arose when he found himself an architect, and a member of the Institution of Structural Engineers, in an earthquake prone country, but he does not reveal the origin.

The preface to his book suggests that he had "some years ago" intended to produce a larger work, and the implication is therefore that the present publication has been hastened by the occasion of delivering "a lecture" to the Engineering and Architectural Society of the University College of Auckland. There is evidence right throughout the book of material written as though for an audience: and, given the range of material covered, if only one lecture was presented, it would have been a long one. In parts the haste of the preparation of the text are obvious, and that is a disappointment. On the other hand the material is densely packed and much ground is covered, albeit hastily.

The limited state of knowledge on structural engineering prior to 1930 is mentioned above. Ford's book must be seen in that context. He made no claim to originality, yet he was excellently positioned to write something useful on the subject because many of the improvements possible in seismic construction at that time were in practical construction details, more immediately accessible to an architect than an engineer, a seismologist, a geologist or any other with an interest in the subject. The most obvious attribute that we can apply to him is that he, by his own self education, had made himself familiar with aspects of these other disciplines. It is tempting to claim that his interest in seismic matters outside narrow architectural confines, is impressive. He is willing to use the mathematics of physics and seismology that he has found in scholarly reports. He constantly returns in argument to examples and reasons founded in dynamic structural behaviour rather than be satisfied with the application of static horizontal load. As consequences there emerge several practical suggestions such as the desirability of avoiding structural types which promote torsion in horizontal loading: and the absolute need to tie sub structures together very purposefully where this might occur. In this vein he also draws attention to the performance of various foundation materials under dynamic load, and the dangers of particular site locations: beneath high cliffs for example. His appreciation of the need for increased frequency of ties to confine primary reinforcing near the ends of reinforced concrete columns appears to go beyond that of the Buildings Regulations Committee, which contained several engineers; and embraces ideas which were being aired in reinforced concrete research papers beginning in the latter 1920's; noted for example in Glanville and Thomas (5) in 1936.

It may be useful to present in table form a variety of ideas which arise in Ford's text, and note how these are treated by the Buildings Regulations Committee:

Table 1 Concrete and Steel Framed Buildings

Building and Earthquake Construction	**Report of the Building Regulations Committee**
Care in construction joints: failure can occur at the base of columns where dirt has settled prior to concrete laying.	Before setting any concrete, previously set concrete to be roughened and cleaned.
Concrete beams should note be allowed to set before slab concrete is poured.	Before setting any concrete, previously set concrete to be roughened and cleaned.
All reinforcement should be adequately anchored.	Not discussed.
Haunches should be used	Not discussed.
Column stirrups should be closely spaced at top and bottom of columns.	Not discussed.
Facing material must be secured to structural frame.	All veneer-finish and ornamental details shall be securely and permanently attached.
Buildings with parts having different periods must be avoided (i.e. building must act as a unit).	Buildings must be firmly bonded and have parts tied so to act as a unit.
Concrete floor slabs must be reinforced at exterior angle corners as the slab acts as part of the bracing in the horizontal plane.	Bearing walls to be tied in to floors at each level.
Buildings with re-entrant corners of L and U shape to be avoided.	Buildings to be simple in layout. Bracing systems should be symmetrical to avoid induced torsion.
Diagonal bracing to be used.	All corners of external walls to be diagonal braced in the horizontal, partition walls and gable roofs to be braced also.
Heavily tiled roofing to be avoided on light frame buildings.	Not discussed.
Substantial foundations.	Continuous concrete foundation walls not less than 8 inches thick. Concrete, timber piles used. Outside foundations sunk ≥ 18 inches. In poor ground, reinforced concrete with ¾ inch diameter steel rods embedded in top and bottom.

Table 2 Masonry Buildings

Building and Earthquake Construction	**Report of the Building Regulations Committee**
Lime mortar not to be used, bricks must be wet to get good bond.	Only 1/3 lime to be allowed. Bricks must be saturated before use.
The need for good workmanship and supervision is most important.	Working stresses will be reduced if supervision and workmanship can be approved.
Tie rods should be used in arches (designed for vertical forces, not for horizontal forces).	Follow British code.
Use continuous horizontal concrete bands reinforced at the top and bottom of openings to prevent diagonal cracking.	Lintels to have 9 inches bearing at each side and be anchored into the wall.
Japanese suggest that iron bonding strips should be 2× ¼ inch bar iron.	Not discussed.
Damp proof course: use asphaltic material in a keyed joint.	Damp proof course to have strong adhesion.
Floors, walls and roof should be well framed and braced together so the whole structure acts as a unit.	Buildings must be firmly bonded and have parts tied so as to act as a unit.
Brick only suitable for 3-4 levels: reinforced concrete band must run around top of walls (New Zealand by law): timber plate bolted to reinforced concrete band.	The maximum height of brick bearing walls to be 40 feet. Reinforced concrete tie beam required at each floor level. Timber top plate to be bolted to wall.
Parapet walls and cornices in New Zealand are dangerous and heights should be lowered or removed.	Parapet walls to be only 3 feet above roof.

Table 3 Chimneys

Building and Earthquake Construction	**Report of the Building Regulations Committee**
Reinforced concrete chimneys lined with terra cotta pots, best option, should be compulsory.	Fireclay liners to be at least 1 inch thick.
If brick then only cement mortar used.	Joints filled with lime mortar and gauged with cement.
Two walls of flue to be 9 inches thick.	Wall thickness: reinforced concrete 6 inches, brick or plain concrete 9 inches.
Vertical steel rods to run in joints, wire hoops every fourth course.	Vertical rods 5/8 inches diameter, no. 8 wire, wire hoops every 12 inches.
Coke breeze with cement mortar.	Pumice concrete offers great possibilities.

The above is no more than a selection of topics, and does not pretend to be comprehensive. We suggest only that Ford had provided a lead on some topics which the Committee had to consider: and it should be appreciated that there were other details decided by the Buildings Regulations Committee that had not been considered by Ford.

One final striking item of agreement arises in the remark almost at the end of Ford's book: "It has been suggested (H.M. Hadley) that buildings should be designed to resist an earthquake producing a dynamic effect in a horizontal direction equal to one-tenth of the weight of the structure." And the Committee reports: "This draft requires....that all new buildings shall be designed to withstand a horizontal acceleration equal to one-tenth of the acceleration due to gravity." Their submission reflects some concern about the variation in risk throughout the country by going on to suggest that this represents a "minimum force" and they have: "...left to local authorities the duty of requiring a higher value in their own districts". Subsequently it seemed that successive code revisions were loath to depart too far from this magic figure even after accelerations of 0.33g had been recorded in the ground at El Centro, California; eventually having recourse to the concept of "ductility" to bring some rationality to a vexing situation.

We have not been able to find a specific note by Hadley supporting 0.1g. In a private communication T Toshinawa has supplied a translation of a 1983 commentary in Japanese on *The Modified Design Law for Urban Structures* (1924) (Japan) which states:

> "In 1924, the lateral force of 0.1g was determined in *The Modified Design Law for Urban Structures*, this value being decided on for the first time in the world. The reason for this choice is mentioned by Kitazawa (1957) as follows:
>
> i) During the 1923 Kanto earthquake, ground-motion intensity was estimated to be 0.3g in Tokyo and 0.35g in Yokohama.
>
> ii) In order to prevent structural collapse under this level of loading, the lateral force of 0.1g is considered reasonable for design."

As an emergency measure for guidance to owners of damaged buildings in considering reconstruction, at the first meeting the Committee, largely directed by Cull, made four recommendations which loosely summarise to:

1. That ornamentation in the form of cornices, parapets be avoided.
2. That note be taken of structures which have survived the earthquake.
3. That competent advice, and supporting calculations, be sought in planning reconstruction.
4. That simple non-composite structural forms be followed.

Ford attended the meeting of the 14^{th} of April. The immediate impressions he reported were: he would not allow two storey brick construction, heavy concrete floors had caused damage when combined with brick construction, the design of shop fronts would have to be materially altered, in many cases party walls had not been adequately braced.

4 THE BUILDING CODE COMMITTEE OF 1934

In June 1931 the Building Construction Bill before Parliament was allowed to lapse. When the worst of the depression had passed the Government felt able to revisit the subject, and did in 1934 in association with the N.Z. Standards Institution. A general committee with wide representation was formed, and two smaller committees: the Technical Committee and the Bye-laws Committee. The Technical Committee was charged with bringing the report of the 1931 committee up to date and the Bye-laws Committee with producing a code in appropriate form taking into account legal requirements. The Technical Committee consisted of two architects, two engineers and two building contractors; and Ford was elected one of these. Deliberations proceeded for over a year before the Code as it then stood was ratified at a plenary meeting of all committees: proposed Furkert (Chairman), seconded Ford. It must be generic for all code producing committees to feel anxiety that the document before them cannot be perfect and immutable for all time, and that is apparent in the minutes of this meeting. The Committee was also unsure how a code might be implemented in different regions of the country, and aware of clear differences in seismicity in different regions. So, in fact, being in the stage of inaugurating building regulation, they had no clear model of how the legislation might work out in practice, and therefore how they should present it. The question of regional differences was not settled before strong protest from Otago and a stand off between seismologists and geologists brought in to help settle the matter some years later.

Clear acknowledgement is given to the value of the 1931 report in providing the basis for the work of the Technical Committee. In recognition of this Cull was seconded to meetings of the Main Committee even though he had declined, for reasons of work pressure at the University of Canterbury, to be a regular member.

It is interesting that in the correspondence associated with these committees an article by Scott and Glanville is mentioned by Ford .These authors were associated with research into the need for increased frequency of ties near the ends of columns as noted above by Glanville and Thomas (4). In another letter to Ford in reply to his mention of the method of Morch (sic), the writer was confessing unfamiliarity with it. This may have referred to the 1902 publication *Der Eisenbetonbau* by the German author Morsch or to a 1924 publication by him. It is implied that Ford was reading the specialist literature in reinforced concrete construction; some of it being in advance of contemporary practice.

This would appear to be entirely characteristic of Ford. Given that he did not have extensive formal schooling, that he came into architecture without an extensive formal background, that he gained membership of the Institution of Structural Engineers also without formal training as and engineer, that he held membership of the Seismological Society of America, again without formal education in seismology and he belonged to the Royal Geographical Society without having any formal connection with geography we can assume that he was in fact a highly intelligent and energetic person. His self-motivation was excellent, and produced an admirable total contribution to earthquake engineering in New Zealand.

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New Zealand's Marine Engineering Heritage

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It was with some hesitation that I agreed to accept your organisers' invitation to present a paper to this conference on New Zealand's marine engineering heritage. I am very conscious that I possess no qualifications whatsoever in the engineering field and I am therefore venturing into the lions' den in appearing to speak before an audience of professional experts. Perhaps the only mitigation I can offer is that both my maternal great-grandfather and grandfather were marine engineers. Regrettably somewhere in the following two generations the purity of the bloodline went astray.

New Zealand is a small island nation for which during the first 70 years of European settlement the only practicable means of communication was for the most part by water. Initially this was by wooden sailing ships which are outside the scope of this paper and I begin my story in 1851 with the construction of the first locally built steamer. The hull, being wooden, need not concern us, but the construction of the engine and boiler provide the opening scenario for marine engineering in NewZealand. The engine was a product of Bourne's Foundry, the pioneer metal working enterprise in Auckland but at first it appeared as though construction of the boiler was to be an insuperable obstacle. Just when matters were grinding to a halt it was discovered that a recently arrived American by the name of Brown had previous experience of boilermaking and it seemed that the difficulties had all been removed. Unfortunately the equipment necessary for the task, although common in the United States, was completely lacking in Auckland. The problem of shaping boiler plates was solved by constructing a clay mould and bending the heated plates to form the cylindrical shape. Punching the holes to rivet the plates together proved another challenge but eventually an advertisement for "strongest man in the town" provided a suitable candidate who punched all the holes by hand. The result of this enterprise was the successful trial trip of the "Governor Wynyard" on January 19, 1852 though regrettably the economics of the Auckland Province at that stage were insufficient to support a steamer and she soon crossed the Tasman to Melbourne where gold discoveries provided more rewarding employment.

Gold discoveries were to be the platform from which much of New Zealand's marine engineering development sprang. Although there was some alluvial gold, most gold in New Zealand was found in quartz which required expensive and complicated crushing machinery to extract it. The engineering works which were founded to produce this kind of machinery inevitably also became involved in marine engineering and ship building because much of the plant required was equally adaptable for both purposes. In the latter part of the 19th Century there also developed a great demand for dredges to work alluvial deposits in rivers, particularly in the South Island. The building of dredger hulls and machinery involved much the same kind of skills as building coastal steamers and most firms were involved in both aspects. Moreover it gave rise to one of New Zealand's earliest exports of plant and know-how when the techniques used in building gold dredges were exported to Malaya in the first decade of this century to exploit the alluvial tin deposits in that country.

In making this survey it is matter of choice whether the approach should be chronological or geographical. At the risk of being categorised as parochial I will opt for geographical and begin in Auckland. As is so often the case, the first catalyst for development was an outbreak of war, in this case the land wars in the Waikato. The river of that name was to prove vital to the eventual success of the British forces and the outfitting and servicing of the river fleet brought the first concentrated demands for engineering services. These were first based in Onehunga where George Ellis undertook the task of fitting out the coaster "Avon" as a gun boat. The work included cladding the hull in iron plating and running a perforated steam pipe round the bulwarks to repel boarders.

It was soon realised that Onehunga was too distant for the needs of the river fleet, particularly as the passage involved an open sea voyage and the crossing of two inhospitable river bars. A Government shipyard was therefore established a Port Waikato from which the engineering requirements of the river fleet were met. The close of hostilities brought this early engineering facility to an premature close and attention moved across to the east coast where gold was discovered at Thames in 1867.

The demand for machinery to service the gold fields soon attracted other enterprises to Thames, among them one of the best known engineering firms in New Zealand, A & G Price. The brothers Alfred and George Price had established themselves in business at Onehunga in 1868 specialising in flax dressing machinery. The call of the gold fields persuaded them to move their works from Onehunga to Thames in 1871 and although they are probably more associated with the construction of railway locomotives, it should not be forgotten that their marine engineering business was equally important during the 19th Century. Their first set of marine engines was a compound plant for the re-engining of the coastal steamer "Durham" in 1875, the work also including the casting of the propeller and the screw shaft. The Waihou River was the principal artery leading from the Firth of Thames into the Ohinemuri gold fields and Prices constructed a number of compound engines for river craft during the 1870s and 80s. In 1881 they moved a step further to ship building by launching the iron paddle steamer "Patiki" which was followed in 1883 by the screw steamer "Despatch" both the hull and engines of which were Price products. The company then tended to concentrate on engine rather than hull building with many familiar coasters being propelled by Price engines. Among the best known were the Northern Steamship Company's "Taniwha" of 1898 which sailed passed her engine builders daily on her regular run between Auckland and Paeroa and Bradney & Binns' Riverhead ferry "Onewa" of 1910.

Prices were also involved in a notable day for Auckland marine engineering when on 20 November 1876 the first locally built iron steamers were launched within an hour of each other. Prices supplied the machinery for the second into the water, the 80' "Kina" built by R H Yeoman. She had been preceded by an hour by the "Rotomahana" which was both built and engined by another leading Auckland engineering works, that of Fraser & Tinne who were to build a number of ships for the coastal trade to the turn of the century. George Fraser also brought his engineering skills to bear on other marine related areas, the most notable of which was the refloating of the large overseas steamer "Triumph" which had gone ashore immediately beneath the lighthouse on Tiritiri Island in December 1883. Having got her successfully back to Auckland, Fraser was faced with the dilemma of carrying out repairs to the damaged bow as the then Auckland graving dock was too small to accommodate her. The problem was resolved by constructing a cofferdam round the stern leaving the bow at the head of the dock able to be worked on.

Although most steamers built in Auckland over the next 40 years were wooden hulled, a notable exception was the 422 ton PUTIKI built in 1904 by Seagar Bros for Wellington owners, the machinery being supplied by Robertson & Co of Wellington. Other Auckland builders of marine steam engines during this period were SMcCoskric & Son, C Hawkswood and Vickery & Masefield.

In Wellington the marine engineering scene was dominated by S Luke & Sons who in 1885 built and engined for Captain W R Williams' West Coast coal trade the 275 ton "Maitai" the largest steamer yet built in the country. By the turn of the century though the principal marine engineering firm was William Cable & Co Limited, originally established in 1854 by E W Mills as the Lion Foundry. Cables did not build ships but were largely involved in the repair business and in the building of some machinery. They supplied the engines for the Auckland built KAPANUI of 1898 which subsequently found their way into the HAUITI of 1911 after the former vessel had been burnt. In 1949 they amalgamated with A & G Price to form Cable Price Limited although by that time the connection with marine engineering was a very small part of both businesses.

In the north of the South Island, the Nelson marine engineering world was dominated by the Anchor Foundry which had been established in 1866, principally to repair and maintain the vessels of the associated Anchor Steam Packet Company. The Foundry carried out some major engineering works in the 1880s including the lengthening and conversion to screw steamers of the paddle steamers "Charles Edward" and "Wallace" and then in 1906 the assembling of the screw steamer "Koi" which had been brought out from Scotland in sections. The importance of the Anchor Foundry both for marine work and in Nelson generally was illustrated in 1901 when it and the shipping company were amalgamated under the title of the Anchor Shipping & Foundry Company Limited.

In Lyttelton John Anderson's foundry was early on the scene, constructing a set of engines for the locally built "Maid of Avon" in 1866. His business had begun in Christchurch as a smithy in 1851 and in 1891 completed the iron steamer "John Anderson" for the Banks Peninsula trade. Thereafter it was principally involved in ship repairing rather than construction.

The part of New Zealand which received the greatest impetus from the gold discoveries was the Province of Otago where ship building began in earnest in 1862, the year after the first discoveries. These were mostly small vessels of less than 100 tons, many assembled from imported parts and some destined for reassembly after daunting overland transport to Lake Wakatipu. The three major Dunedin engineering works were all established in the 1870s, Kincaid & McQueen leading the way in 1873 with an "export" order, the steamer "Fairy" for Napier owners. The paddle steamer "Mountaineer" was delivered in sections for Lake Wakatipu service in 1879 and the coaster "Invercargill" in 1885. Meanwhile the second major firm, R S Sparrow & Co had delivered another Lake Wakatipu steamer, the "Jane Williams" later known as the "Ben Lomond", in 1872 followed by a notable export order the 108 ton "Port Jackson" in 1884 for Sydney ferry service, the first steel steamer built in NewZealand.

The last and most prolific of the Dunedin ship builders was John MacGregor & Company which came into its own in the first 15 years of this century during which it delivered the steel hulled Clutha River stern wheel steamers "Clyde" and "Clutha", the harbour ferries "Waikana" and "Waireka", the tug "Dunedin", the coaster "Waipu" and, best known of all, the lake steamer "Earnslaw" which is still in service today on Lake Wakatipu with her original 1912 hull and engines.

So far this paper has concentrated on the ship building and engineering side. There is also a major story to tell in 3 other areas. The first is ship salvage. The earliest major feat of this kind was the salvage of the 415 ton steamer "Taranaki" which had sunk in 100' of water after striking a rock in Tory Channel at the entrance to the Marlborough Sounds. Salvaging of so large a steamer from such a depth was generally thought to be beyond local capabilities but two Wellington engineers, Messrs Seagar & Thirkell, were not daunted. They formed the Wreck Recovery Company, constructed four pontoons, two on each side of the wreck joined by wooden cross beams from which were dropped rods secured to the hull and with the raising momentum provided by screws. Two months of effort eventually brought the vessel into shallow water where the holes were plugged and she was then towed back to Wellington for permanent repairs.

Another notable 19th century salvage feat was that of the Union Company's coastal passenger steamer "Mapourika" which stranded just north of the entrance to Greymouth only five weeks after entering service in 1898. Salvage into the open Tasman was deemed impossible, so the engineering solution found by the Union Company engineer, Mr Daniels, was to cut a hole in the northern breakwater through which the vessel was successfully relaunched in the Grey River. Many more examples could be given of successful marine salvages but these two incidents well illustrate the application of Kiwi ingenuity in sites far removed from the major resources available overseas.

The spotlight naturally falls on the building and engineering of new ships but it was also vital in a country separated by 1200 miles of often stormy Tasman Sea from its nearest neighbour to have the ability to provide normal survey and maintenance facilities as well as those needed by ships which had met with mishaps. Dry docking facilities were early on the agenda for most ports. The first to be provided was the 170 foot floating dock ALPHA at Port Chalmers in 1868. It soon proved inadequate and in 1872, the Otago Dock Trust commissioned a 330' graving dock, capable of dealing with the largest vessels trading to the country. In its turn, it proved too small particularly to service the growing fleet of the locally based Union Steam Ship Company and in 1909, the 500' Otago Dock was opened, remaining in commission until buried in reclamation for the container terminal in the 1970's.

Canterbury too had to have its dock and the 450' Lyttelton Graving Dock was opened in 1883. It is still in service today but its size limits its usefulness. In Wellington, the only ship repair facility for many years was the patent ship in Evans Bay opened in 1873. A second larger slip was constructed in 1922 and between them they could cope with most vessels in the coastal trade but the Wellington Harbour Board saw the need to provide for overseas vessels too and in 1931 the Jubilee Floating Dock capable of lifting vessels up to 17,000 tons arrived under tow from Britain. It remained a feature of the Wellington scene for many years at its berth off Aotea Quay, one of its best known and largest inhabitants being the trans-Tasman liner WANGANELLA after she had struck Barretts Reef in 1947. At the end of its useful life, the dock was sold to overseas buyers but broke in two and foundered in the Tasman in 1989 on its way to Bangkok.

Auckland had more varied docking facilities. The first graving dock at the corner of Quay and Albert Streets was opened in 1878 but was soon unable to accommodate the larger steamers then beginning to arrive regularly. The Auckland Harbour Board decided to take the plunge and in 1888 Calliope Dock at Devonport on the north side of the harbour was completed. At 525 feet in length, the new dock was the largest in the southern hemisphere and with several subsequent extensions at the head remains in commission today. With the building on the western reclamation of a 600 ton shipway in 1915, the work available to the original graving dock disappeared and it was filled in.

Despite this chronicle of achievement in dock construction and the associated repair plant, it has to be acknowledged with concern that there is today not one dry dock in the country capable of stemming the majority of the ships engaged in our overseas trade. The successful salvage of any ship meeting with disaster around our coasts depends entirely on it being seaworthy enough to make the trans-Tasman passage to Sydney or Brisbane.

The last of the other areas of which I wish to speak is that of harbour construction. New Zealand is endowed with relatively few natural harbours in the right places, Auckland and Wellington being the only two in this category. All of the others required extensive engineering works in the way of breakwaters, training walls and the like before they were both secure harbours and able to accommodate ships of any size. Because of the widespread nature of this problem and inevitable high cost involved, the New Zealand Government decided in 1877 that expert assistance was required. The eminent British engineer Sir John Coode was engaged and he arrived in New Zealand in 1878. Sir John had a previous connection with this country when he had been engaged by the Canterbury Provincial Council to report on the construction of a breakwater harbour at Timaru. He did not come to New Zealand then but sent his assistant, Whately Eliot, out to investigate. It was doubtless the difficulties arising from this process that persuaded Sir John to come in person for this large assignment. Inevitably against the time pressures involved, some of the Coode plans proved less than ideal but it was an enormous achievement to have produced such wide ranging schemes. Leaving aside the minor ports which fell by the wayside, Coode produced plans and recommendations on which the present day ports of New-Plymouth, Gisborne, Napier, Timaru, Otago and Bluff are still largely based. Finance of course proved the major obstacle in carrying out what were by any standards major works in inhospitable surroundings and it was well into this century before most were completed.

The years between the two World Wars were unremarkable in the marine engineering sense. Virtually no vessels of any consequence were built locally and it was only the outbreak of the Second World War that brought into focus the need for local marine engineering capability. At first this consisted of adaptation work where the machinery of two out of commission Northern Steamship Company coastal vessels was installed in composite hulls (wooden planking on iron frames) of minesweepers built in Auckland. A more concentrated effort was called for though, and it was decided to build steel Castle class minesweepers in Auckland, Wellington and Port Chalmers. Fourteen vessels were contemplated but only nine were actually completed, seven by Stevenson & Cook at Port Chalmers, one by Mason Brothers at Auckland and one by the Wellington Patent Slip Company. Construction of the engines was shared between A & G Price and New Zealand Railway Workshops at Lower Hutt, the boiler plates being supplied from Britain.

After this burst of activity steel ship building in New Zealand went into the doldrums again until Mason Brothers completed at Auckland in 1961 the largest steel ship yet built in the country, 627 ton Foveaux Strait ferry "Wairua" for the New Zealand Government. A & G Price returned to shipbuilding at Auckland with the construction in 1962 of the pontoon for the Auckland Harbour Board's diesel electric floating crane HIKINUI, the crane machinery being supplied from Germany. This work was carried out at Westhaven just west of the harbour bridge approaches but most of the company's shipbuilding in this decade was tugs and fishing trawlers built in its yard on the Western Reclamation. A more unusual task in 1967 was the lengthening of the Islands trader TAGUA which was cut in two amidships and a new 18 foot Price built centre section installed.

The spotlight for New Zealand marine engineering then moved north to Whangarei where Whangarei Engineering & Construction Limited began building in 1964. Although it turned out hopper barges, dredgers, ferries and trawlers its principal claim to fame was in the construction of tugs using Voith-Schneider cycloid propulsion. Before 10 years were out, tugs of this kind were to be found in most New Zealand ports and the company continues in business today, now a subsidiary of the Northland Port Corporation. It at present has under construction new tugs requiring only a two man crew, compared to the previous four or more, for the Auckland and Tauranga Port Companies.

Whangarei is also the current location of a very different type of marine engineering activity, the construction of modules for the Anzac frigate project. These prefabricated units weigh hundreds of tonnes and are then shipped by barge across the Tasman to be assembled on the slipway at Williamstown in Victoria. It is generally not known that the Royal New Zealand Navy's latest frigates, although built in Australia, have many of their parts originating from New Zealand. The large barges of 7,000 tonnes or more which ship them across the Tasman plus the tugs that tow them are also products of Whangarei ship builders.

Tug construction in more recent years was not confined to Whangarei though. Sims Engineering at Port Chalmers produced the GODLEY for Lyttelton in 1977 and the RUPE for New Plymouth in 1984. Less happy were the events surrounding the construction of 2 new tugs for Port Chalmers in the early 1970's. The Otago Harbour Board was satisfied with none of the tenders it received so decided to build the tugs with its own engineering staff. Despite this unlikely beginning the RANGI and KARETAI of 1974/75 have proved very successful and are still in service today.
It will have been noted that although I have made comment on many New Zealand firms involved in the building of marine steam engines I have said nothing about diesel machinery. Virtually no diesel plant of any size has been built in this country. Yet New Zealand engineers were prominent in the construction of "oil engines" which comprised both hot bulb or semi-diesels and full diesels in the first two decades of this century. Most of these were produced in Auckland, the leading plants being those of W R Twigg & Co who marketed their engines as "Twigg" and Hoyland & Gillett who produced the "Zealandia". These engines powered many of the local work boats and fishing fleet but the depression of the 1930s killed off production which was never resumed.

I am conscious that this review is very much "once over likely" and that I have had to omit many aspects of New Zealand marine engineering history to bring this paper within the required length. I trust though that what I have been able to cover will demonstrate clearly the rich heritage that this country enjoys in marine engineering.

Australia's Heritage System– Building on a quarter century of heritage achievement

Heritage – linking the past and the future

Keynote speech by Bruce Leaver, Executive Director, Australian Heritage Commission, First Assistant Secretary, Australian & World Heritage Group

"The engineer has been, and is, a maker of history"

-James Kip Finch

Professor of Engineering, Colombia University (1960)

The theme of this conference draws attention to a key aspect of heritage - heritage is not just about the past. Its about what we aspire to be as a culture. The complete heritage of the Australian nation lies in the full range of its natural environment, its indigenous living culture, its immigrant culture and its social history.

Key features of Australia's heritage are:

- It is the only developed country in the world whose biodiversity is defined as megadiverse.
- The oldest evidence of life on earth is found in the Australian continent
- It is home of the oldest continuous culture on earth, having been occupied by Aborigines for more than 60,000 years.
- It has a rich and varied history of European settlement over the last 200 years.
- And it has become the home of people from every culture in the world, with a consequent richness of tradition and cultural diversity.

Engineering heritage is an integral part of the 'picture' of Australia. Like New Zealand, Australia since colonisation has rapidly developed an infrastructure which has taken other countries centuries to evolve. That infrastructure, much of it engineering, is expensive to build and difficult to coordinate given the size and population of our country.

It would therefore make sense to preserve what we already have where a suitable use exists. And given our short history, what we do have is all the more important. For our own sense of cultural identity and our sense of social and political place in the global context, it is crucial we conserve as much of our natural and cultural heritage, including our engineering heritage, as possible.

These engineering facilities have harnessed our natural environment and encompass bridges, pipelines, harbours, railway stations, power stations, factories, pump stations, weirs, mine sites, buildings and others.

What we chose to conserve reflects our nation's values. Heritage is about all of us today, and in the future. Since its foundation in 1976, the Australian Federal Government's heritage adviser, the Australian Heritage Commission, has played an essential role in identifying and promoting the protection of Australia's natural and cultural heritage, and in pioneering good practice in its conservation. In its Strategic Plan for 1999-2002 "Our Heritage –Our Future", which highlights the linkages between the past and the future, the Commission has stated its mission as taking a leading role in safeguarding those parts of Australia's natural and cultural environment that have special value for current and future generations. The Commission's vision is a future in which heritage in Australia, in all its diversity, is valued and conserved by communities and governments.

Achieving this vision in the current social, economic, and policy environment, is the challenge facing the

Commission. After a quarter century of heritage achievement, the Commission is an active player in shaping a new heritage regime in Australia. Australia's heritage management for the coming decade is being reshaped by a major new initiative – the National Heritage Places Strategy. When agreed between the Commonwealth, State and Territory governments, this Strategy will be underpinned by new heritage legislation that will establish the new regime.

On the cusp of major change, it is useful to reflect where we have come from.

Today, more than ever before, Australians from all walks of life understand the importance of our natural and cultural heritage. The pivotal role of the Australian Heritage Commission has been to show leadership in this change in the national psyche - to one in which the conservation of our heritage has become a matter of public practice rather than an isolated afterthought to other processes.

Developing a heritage ethos

Australians have not always appreciated and protected their heritage places. The rapid development/destruction phase of post-World War Two brought us many losses of nationally, regionally and locally important places. Losses like Lake Pedder , Sydney's Regent Theatre and much of the WA mallee heathland shocked Australians into fighting for their National Estate.

In the early 1970s, the government of the day called for a committee of inquiry into the condition of our heritage and the response was overwhelming with more than 650 submissions from the community, led by the National Trust, trade unions, resident action and conservation groups.

The upshot was the identification of a **'great public concern for the conservation and presentation of the National Estate,'** and the birth of the Australian Heritage Commission in 1975.

This movement had bipartisan support in Parliament. Leading Country Party Member, farmer and future Minister, Ralph Hunt, captured the spirit of the moment when he said during the second reading of the Australian Heritage Commission Bill in 1975:

'The environment, and for that matter the National Estate, surrounds all of us. It belongs to all of us. It is not the monopoly of any one man. It is not the monopoly of one generation, one group, one party, one government. It is ours to pollute, to destroy, to desecrate, or it is ours to value, to preserve, to protect, to hand on to the next generation.'

With the establishment of the Commission came the Register of the National Estate—Australia's first official inventory of its special heritage places—both natural and cultural. The Register now comprises more than 12,000 places around the nation.

Since the Commission's foundation, States and territories have followed suit, introducing their own legislation and establishing their own heritage councils and bodies. Where 25 years ago, we only had community support, today Australia has a substantial network of legislation, registers bureaucracies, specialists and owners all working for the conservation of our heritage places.

Heritage System and Industry in Australia

There are a number of Commonwealth agencies and programs which deal with the environment and natural heritage, but not so many which focus on non-indigenous cultural heritage. There is a big emphasis on a coordinated approach so that heritage is considered in the broad range of Commonwealth government policies and programs.

• The Australian Heritage Commission is the government's chief adviser on heritage, bringing natural, indigenous and historic heritage issues together in a single agency.

Major functions of the Commission include:

1. Compiling the Register of the National Estate as a comprehensive inventory or reference point of Australia's natural, indigenous and historic heritage places – this includes some 800 places listed as public utilities, rail, road, air and water transport, maritime industry, shipwrecks, lighthouses, mining and mineral processing and manufacturing and processing.

2. Advising the Commonwealth Minister responsible for the environment, and other Ministers and Commonwealth Government authorities, on all matters concerning the National Estate – and especially referrals of proposed actions and decisions by the Commonwealth that might adversely effect places on the Register. The Commission advises that it is in the best interests of departments to try to integrate procedures for heritage protection into their day to day operations rather than having them as an add-on to other decision making.

3. Developing policies and programs for public information and education, research and professional training - for example, the Commission funded the

development of the Mining Heritage Places Assessment Manual to be jointly published with the Australian Council of National Trusts which administered the grant.

Administratively, the Commission is an agency of Environment Australia, and is part of the Australian and World Heritage Program. This program area also has responsibility for the Historic Shipwrecks Act and the Aboriginal and Torres Strait Islander Heritage Protection Act.

. Australia ratified the World Heritage Convention in 1974 and remains a strong supporter and advocate of the Convention and its implementation. Australia was a member of the first World Heritage Committee established under the Convention, has since been re-elected to the Committee on two further occasions, and is a member of the current Committee. Australia has 13 World Heritage listed properties and has been involved in developing nominations, planning and management of World Heritage places for almost two decades.

The World Heritage branch develops nominations of places of outstanding universal heritage value to the World Heritage List and funds programs for the management of listed World Heritage places in Australia. They are currently working on nominations for the Greater Blue Mountains in NSW and a serial nomination of Australian convict sites. Consideration has been given to a nomination of the Sydney Opera House in its Sydney Harbour setting with the Harbour Bridge. Late in 1999, at the request of the World Heritage Committee, Australia set up a website as a focal point for World Heritage activities in the Asia-Pacific and to foster cooperative programs

• The Australian and World Heritage Group works closely with other parts of Environment Australia to incorporate heritage considerations into the broad range of policies and programs within the department. For example, a major program to identify and conserve the environmental and heritage values of Australia's major native forest areas has been under taken in recent years. Comprehensive regional studies have been used to plan for enhanced conservation balanced with sustainable use of the timber resource through Regional Forest Agreements entered into by governments and supported by community interest groups. As a result of the RFA program, there will be major new listings of national estate forests and many high value conservation areas, including historic sites with values related to engineering heritage, such as mining structures, water catchment and transport systems, will be protected.

• Environment Australia also includes major program areas with responsibility for biodiversity and wildlife protection; environmental impact assessments, the marine environment and Australia's Antarctic territories. Heritage considerations are often relevant to these programs, especially issues relating to indigenous and geodiversity heritage. Australia's Antarctic Territories have a collection of important heritage sites related to the exploration of this remote area, including Mawson's hut.

• Since 1996, State of the Environment reporting undertaken by Environment Australia has included an assessment of the current state of cultural and natural heritage. The next -State of the Environment Report is due in the year 2000. Indicators for the natural and cultural heritage theme have been developed to present supporting data for the Report. A number of the indicators will depend on data harvested from the Register of the National Estate Database.

The Environment Protection and Biodiversity Conservation Act received Royal Assent in July 1999. The EPBC Act provides a stronger role for the Commonwealth in the protection of the environment, and especially in matters of national environmental significance such as Australia's World Heritage properties, Ramsar wetlands of international importance, and the Commonwealth marine environment. The EPBC Act will take effect on July 16th 2000.

We hope that new heritage legislation will better define the Commonwealth's role in national heritage. There is a good opportunity for heritage legislation to be an addition tothe EPBC Act. The new heritage legislation will provide for a list of national heritage places over which the Commonwealth will have protective powers

• Of course, recognising and conserving heritage in its broadest sense also requires linkages with the museum sector, community arts and educational media. At the Commonwealth level, the Department of Communications, Information Technology and the Arts is responsible among other things for legislation which protects Moveable Cultural Heritage, and for supporting the development of AusHeritage – an export network of the cultural heritage industry in Australia.

• In partnership with Environment Australia, they also deliver the $70.4 million Federation Cultural and Heritage Projects Program which celebrates the centenary in 2001 of the federation of the Australian colonies. Grant funding has been allocated for community projects including history studies, conservation works at heritage places, and education and presentation projects, including establishing regional heritage trails and networks of museums as the focus of enhanced tourism activities.

All states and territories now have heritage legislation, departments and authorities. The roles of these are, generally, to identify, conserve and promote the heritage of the state or territory, although there is often a focus on the historic environment and on places of state significance. They develop and administer a broad range of programs, including the compilation of a register, publications and community awareness programs and grants programs.

They also act as land managers in providing advice and permits for actions directly impacting upon heritage registered places. There is often blanket protection of indigenous sites at the state level, with a permit system to limit actions to destroy or damage sites. Few states maintain registers of natural heritage places and values, although these values are often protected within the conservation reserve system and by off reserve management.

The longer term directions for the states and territories vary. Those agencies which administer more recent legislation are concentrating on identification and assessment programs to build up their registers, while others are looking more to dealing with the ongoing management of large numbers of places. Education and community awareness programs, grants programs and a focus on local government are generally priorities for all agencies.

The third tier of government, local government, also has responsibility for heritage, generally that of local significance. Councils develop local registers, administer building permits and often support free advisory services of conservation architects or heritage advisors to their local community.

The heritage system in Australia is developing a stronger reliance on local government actions and responsibilities. For example, local and regional environment plans are increasingly seen as the most effective ways of conserving our heritage. Local knowledge, commitment and responsiveness to local issues are seen as key resources.

These governmental systems are supported by many other systems, for example community advocacy bodies such as the National Trust, professional bodies such as Australia ICOMOS, industry bodies such as the Royal Australian Institute of Architects, The Institution of Engineers and many local interest groups, community action groups and concerned individuals. The National Cultural Heritage Forum, which advises the Minister on historic and Indigenous heritage places, and of which the Institution of Engineers, Australia is a member, is another mechanism which provides professional and community heritage interests with direct input to heritage policy-making.

Over the last two decades, there has been a great rise in skill, interest and commitment to heritage by governments, practitioners and the community at large.

By 1996 the Commission (and others in the heritage field) recognised that this growth had been somewhat *ad hoc*, the result being a plethora of different laws and processes relating to heritage and the environment at all levels of government. This had created duplication of effort in some areas, and had left complete gaps in others causing confusion and unnecessary conflict in the past. Work to correct this started on a number of fronts.

The Commonwealth Government, for example, has been progressively implementing two important reforms since 1996.

The first of these was the Review of Commonwealth/State Roles and Responsibilities for the Environment conducted by the Council of Australian Governments or COAG, and the second was the reform of Commonwealth environment and heritage legislation referred to earlier.

One of the outcomes of the 1997 COAG review was an Agreement to rationalise existing Commonwealth/State arrangements for identifying, protecting and managing places of heritage significance. This was to be done through the cooperative development of a **National Heritage Places Strategy**—the first ever for Australia.

The agreement sets out the key matters that the National Strategy will address. These include looking carefully at the role of each level of government, exploring the possibility of a National List and developing and agreeing on national principles and standards for managing our heritage places. To achieve the goals of the agreement it may be necessary for governments to adopt new responsibilities. It will also become necessary to amend existing legislation or develop new legislation altogether.

The overall objective of the agreement is to ensure that heritage systems are compatible, complementary and streamlined across all levels of government. Duplication must be minimised and certainty provided to property owners, decision-makers and the community.

In April 1999, the Commonwealth Minister for the Environment and Heritage released a **Commonwealth Consultation Paper on the National Heritage Places Strategy**. The Strategy focuses on the need to set out roles and responsibilities of the Commonwealth and the States. It also seeks to improve protection of heritage places at the national, State and local level using a number of mechanisms such as agreed national standards and Commonwealth compliance of State heritage and planning laws. The Strategy will also establish national and Commonwealth heritage lists and a one-stop-shop heritage database known as the Australian Heritage Places Inventory.

Developing the Strategy has involved consultations with State and Territory government Ministers and officials. This consultation paper contains a specific section on principles that would be used by the Commonwealth and the States in implementing the Strategy. The 12 principles build on those agreed by Heritage Ministers in October 1997 and by the National Heritage Convention which was held in Canberra in August 1998.

The Convention, affectionately known as HERCON, was the first national gathering of people from the full range of heritage perspectives: historic, Indigenous and natural. It brought together over 220 people from around Australia, including heritage officials and professionals, Indigenous, community and industry leaders, to debate and resolve critical issues facing Australia's heritage.

The Institution of Engineers, Australia (IEAust)participated in HERCON and made submissions on the National Heritage Places Strategy Consultation paper when it was released. IEAust recognised that the National Heritage Places Strategy has the potential to provide a better public understanding of the responsibilities of the various spheres of government when it comes to heritage.

IEAust was particularly keen to see a linked Australian Heritage Places Inventory which could help identify places in all relevant government jurisdictions. Most importantly, such an inventory could assist organisations like IEAust to nominate places and for those places to receive much wider recognition.

The Australian Heritage Places Inventory

For those of you who may not be aware, the Australian Heritage Places Inventory is a data repository of information collected from heritage lists across the country. It is being developed in consultation with State and Territory agencies and non-voluntary organisations to provide a central point of access to Australia's heritage places via the Internet. During the year, agreement was reached with State and Territory governments to proceed with the project, and an initial repository of data was established with information obtained from the Register of the National Estate Database.

The repository will be publicly available from the Internet site 'Australian Heritage Websites' during 1999-2000.

Commonwealth Heritage Properties

A Committee of Review into Commonwealth owned heritage properties has resulted in a draft Heritage Asset Management Manual to assist Commonwealth property owners and managers to identify, assess and manage properties with heritage values in accordance with best practice. These properties include munitions and ammunitions sites and aviation heritage such as RAAF Amberley.

Commonwealth disposal of heritage property is subject to section 30 of the AHC Act 1975. The Commission encourages Commonwealth agencies to comply with their obligations under the Act and ensure that a property's heritage value is protected under future ownership.

National list

A key component of the new heritage regime is the proposal to establish a list of nationally significant heritage places that better define the national interest and role in heritage management. The list will form a tier between places of world heritage significance and state and local heritage significance. It would provide the Commonwealth with a clear basis, if necessary, to take steps over and above those available to the individual states and territories to conserve places on the National List for the Australian community.

Current thinking is that the National List should consist of places that reflect the Australian experience - places that we can collectively acknowledge as being important contributions to the nature of the continent on which we live, and which reflect the diverse experience of our occupation of it.

Undoubtedly, engineering heritage places and themes will be a key aspect of this list, reflecting the role of engineers in the creation of the Australian nation and landscape. This could include aspects such as irrigation and water management, defence heritage, transport, including construction of ports, road and bridges, communications, such as the Overland Telegraph, or radio telescopes, power stations, mining sites and structures – much engineering heritage is evident already in the Register of the National Estate and State and Territory registers.

This work to date provides a good basis for thinking about national significance – perhaps the Snowy Mountains Scheme, or 'Snowy', one of the largest engineering schemes ever built in Australia. Completed in 1974, the scheme employed over 100,000 people from thirty different counties, and had a major role in post war cultural development. Other contenders would surely include national icons such as the Sydney Harbour Bridge, and sites around the continent related to the Australian Gold Rushes. The Institution of Engineers, Australia has already provided a level of recognition for engineering sites through a plaquing program which recognises two levels of significance- National Engineering Landmarks and Historic Engineering Markers. Sites recognised include the Sydney Harbour Bridge, and the Coolgardie pipeline.

There is much work to be done, in consultation with professional groups such as the Institution of Engineers, to develop a credible National List that is supported by expert opinion. I am hopeful that the National List will have strong relevance to groups such as your's, and that you will contribute your expertise to the process of developing the list.

There are many challenges to be faced in implementing the new heritage regime proposed in the NHPS. These include:

acknowledging the heritage conservation needs of heritage places cared for by all levels of government, so that enhanced conservation outcomes apply broadly to the nation's heritage

addressing gaps in protection (especially for many natural areas);

unifying criteria and protection mechanisms across natural and cultural heritage;

improving processes for consultation with stakeholders, including Indigenous people, and

finding creative ways of dealing with insufficient funding for conservation – economics and heritage is a key area of interest for the future, including the untapped potential of heritage tourism and the economic benefits it can bring when it is properly managed.

Experience tells us that when economies are struggling, particularly in rural areas, heritage places are the first things to suffer. Yet shrewd investment in conserving and promoting heritage places can be the key to a tourism-led recovery. The Heritage Commission has recently initiated a joint study with the Co-operative Research Centre on Tourism at the University of Canberra titled "Tourism-generated Economic Benefits from National Listing of Places of Cultural Heritage Significance". The study will identify key values of a selected class of cultural heritage places, assess the economic impacts of tourism visitations and estimate regional and local impacts on income and employment.

This type of study has shown encouraging results overseas. The New Jersey Historic Trust in the US has recently completed one of the most comprehensive analyses of the economic benefits of conservation-related activity. This research found that $US55 million (Aus$86 million) in preservation grants leveraged around $US403 million in historic rehabilitation efforts, 6200 jobs, $US222 million in income and $US307 million in GDP for New Jersey residents.

In conclusion, I would like briefly to summarise achievements to date and look at where we want to be in 10 years time.

What we currently have is:

- heritage legislation in every state;
- Australian-developed models or approaches for identifying and managing both cultural and natural heritage places which are internationally recognised as best practice;
- active community interest and work in the heritage field with groups such as Bushcare, Coastcare, the Indigenous Heritage Officers' Network, the National Trust, local historical societies and other conservation groups, putting their energy into safefuarding our heritage places, and
- a climate in which government, communities, individuals and industry have started talking to each other and taking into account varying points of view.

The States and the Commonwealth are settling details of the National Heritage Places Strategy. The States broadly agree with the National List, the Commonwealth List and the concept of the Australian Heritage Places Inventory. Once the NHPS has been finalised, we will be in a better position to decide on the appropriate legislative vehicle for the Strategy and, consequently, appropriate changes to heritage legislation.

We have travelled a considerable distance in the last half of this century. We have managed to pull out of a spiralling disregard for our heritage to a point where we have a range of systems in place to help protect our special places. But can we see a horizon for our heritage which is positive and achievable?

Where do we want to be in 10 years time?

I am sure that some of our goals will remain constant. **In 10 years time** we should be confident that Australia's invaluable heritage places are safe-guarded for the future.

Consequently, we would all want to see governments of all levels, the community and industry regarding the conservation of our natural and cultural heritage as a **mainstream activity** and not an add-on.

> To do this would mean that we would need a streamlined, consistent and interlinking national policy framework underpinned by an agreed set of best practice principles and standards. This means that **in 10 years time** we should have an effective national strategy covering policies and programs as well as complementary legislation between all levels of government.

In 10 years time we should have embraced the notion that proper respect for indigenous heritage is one of the key elements necessary for reconciliation. This means acknowledging that heritage is different for different cultural groups—and that this diversity is one of Australia's strengths worth celebrating.

But I very much hope that **in 10 years** time we have matured enough as a nation to at last acknowledge that what we value cannot always be measured on a ledger. There are often strong economic benefits for heritage conservation. But a society of any cultural depth must have the courage to conserve its heritage for reasons which transcend economics.

Over the next few days, I will be interested to compare notes with delegates at this conference about the directions and challenges in conserving heritage in New Zealand. We share many of the same issues – perhaps there are common solutions on which we can work together.

The Overland Telegraph Station Alice Springs - A Conservation Study

Neville Leybourne-Ward
B Arch, B App Sc (Biology), Dipl Conservation Studies, FRAIA, RIBA

SUMMARY

The telegraph repeater station at Alice Springs, Central Australia, was a major station on the Overland Telegraph Line constructed from 1870 to 1872, an engineering project of national significance. It was in continuous operation from 1872 until 1932 a period of 60 years during which time it was expanded both in building fabric and in technology. There were five distinct periods of occupancy up until the present date with varied uses including housing the so called 'stolen children'. In the late 20th Century some conservation was attempted with dreadful mistakes. It is now a government owned tourist venue. The first (1872) building could be a subject for restoration to the original form and serve as a museum of 19th Century telegraph technology and include an engineering heritage plaque.

THE OVERLAND TELEGRAPH

The Overland Telegraph Line (OTL) was constructed out of necessity. Communication with Britain by sea was too slow for commerce and the threat of Russian invasion accelerated the political will of the Colonies. There was intense rivalry between Queensland and South Australia which then extended from the southern to the northern shores. South Australia won the day through the efforts of Charles Todd, the Superintendent of Telegraphs and Observer, with the strong support of Governor MacDonnell. The OTL took 23 months to build and included 12 stations over 1765 miles (2824 km)

THE FIRST BUILDING

The site for the first or main building was that chosen by Todd's overseer, William Whitfield Mills, for what was known as Section C. Mills had passed through the Waterhouse Range from the south and arrived at a waterhole on 11 March 1871 which he named **Alice Spring** in honour of Todd's wife Alice[1].

By December 1871 Mills had finished Section C line work so it is probable that the permanent repeater station stone buildings began about that time. The main building was the station when the line went into operation on 21 October 1872 (See Figure 1).

There was a nucleus of four structures at that time: the main building, the police house, the store (under construction) and a shed or temporary house plus the important stockyard for horses and the telegraph line entering from the west.

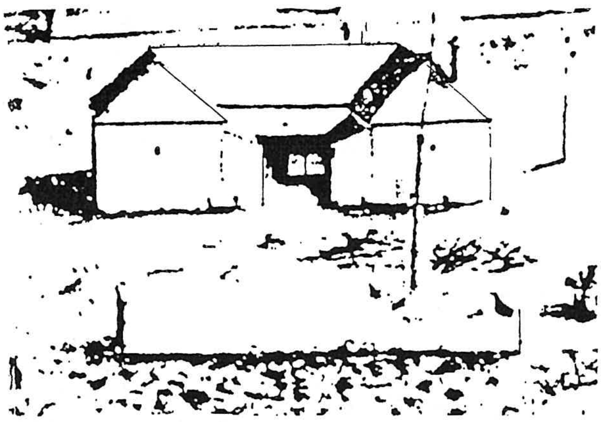
This principal building housed all functions: kitchen, telegraph offices, battery room and staff accommodation. From a conservation and museum point of view the extant structure would be suitable for restoration to the 1872 condition for there is nothing else left on the OT Line available for this type of interpretation and in a central and accessable location.

At first the technology was simple and the traffic low but as these both developed there was a need for increased staffing and changes in accommodation. A survey of historic photographs has shown that, with each stationmaster appointed, there were major changes in the use of the structures with alterations, additional buildings and demolitions.

At one stage there was a roof fire in the main, or original station building and, although photographs were not properly dated, it is reasonable to deduce that it was about 1886 during station master Flint's tenure (1879-1887). Batteries were not necessarily to blame as the principal cell was the Meidenger but probably there were some LeClanche cells in use.

Surveyor C Winnecke visited the site in 1881 and recorded the new buildings such as the long stone structure divided into two rooms known as the Men's Hut and the new Telegraph Office and a residential building divided into two rooms (See Figure 5, buildings 3, 4 and 5 respectively). Along with other buildings and the knowledge in changes in telegraph technology there is evidence of a rather large development of operations from 1879 to 1887.

Figures 2, 3, & 4 show some of the stages of "development" of the first building, the one that is of interest to us. In the 1880s the door to the first telegraph office can be seen as well as the kitchen chimney (on the left) and the office chimney. During the 1916-20 period the office chimney was extant, the roof had been rebuilt with a lower pitch and verandahs had been added (Figure 3) but in the 1950s many internal alterations had taken place including the demolition of the office area and its chimney (Figure 4).



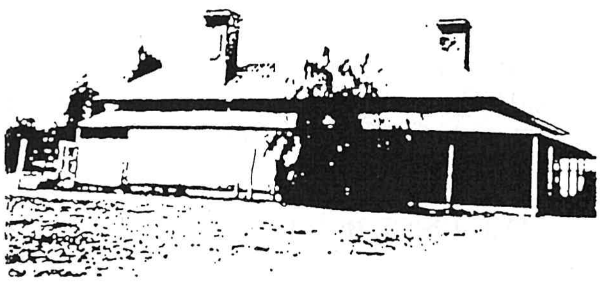
VIEW FROM THE NORTH 1872 ARTIST UNKNOWN 1

VIEW FROM THE WEST 1880s PHOTOGRAPH 2

PERIODS OF OCCUPANCY

The first period from 1872 to 1932 saw eight station masters in occupancy, the first being Johannes Ferdinand Mueller and the last Ernest Allchurch. Thomas Andrew Bradshaw (1899-1908) is, perhaps, the most notable: his daughter, Doris Blackwell, recorded the events with some detail and accuracy[2].

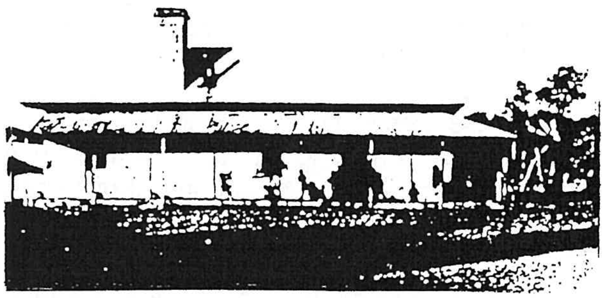
However, the administration was the preserve of the State of South Australia up to 1911 when the Commonwealth of Australia took over. The beginning of the 20th Century saw the growth of Stuart Town nearby with roads for heavy transport and motor vehicles and great changes in the function of the telegraph station - it operated as a post and telegraph office.



VIEW FROM THE WEST 1916+ PHOTOGRAPH 3

With the advent of the rail service a new office was constructed in Stuart Town and took with it the name Alice Springs which it bears to this day. Closure of the station on 20 January 1932 meant that another use needed to be found.

That year the Commonwealth proclaimed the 674 acres telegraph station an Aboriginal Reserve.



VIEW FROM THE WEST 1955 PHOTOGRAPH 4

Figures 1, 2, 3 & 4

The Aboriginal School

A new use for the old telegraph station had its genesis in the 'half-cast' problem which confronted the Commonwealth when it took over the Northern Territory of South Australia in 1911 and later declared a policy to collect all half-casts from native camps at an early age. In Stuart Town in 1914, Topsy Smith, an Aboriginal woman who came from the Arltunga goldfields, was in charge of a children's home, an iron shed at the back of the then police station and near the hotel toilets, This became known as the "bungalow". The school was moved to Jay Creek then to the telegraph station.

Pressure was put on the Commonwealth Postmaster General who eventually relented and the move was made on 17 November 1932. The story has it that the Jay Creek building materials were used to construct a new structure at the telegraph station.

This was a structure known as the 'bungalow' north of the first building (See Figure 5) probably a dormitory. Building 3 Figure 5 was also used as class rooms. Building 1 would have been for kitchen, dining and classes.

The school was well run, the children healthy and they received a good education[3].

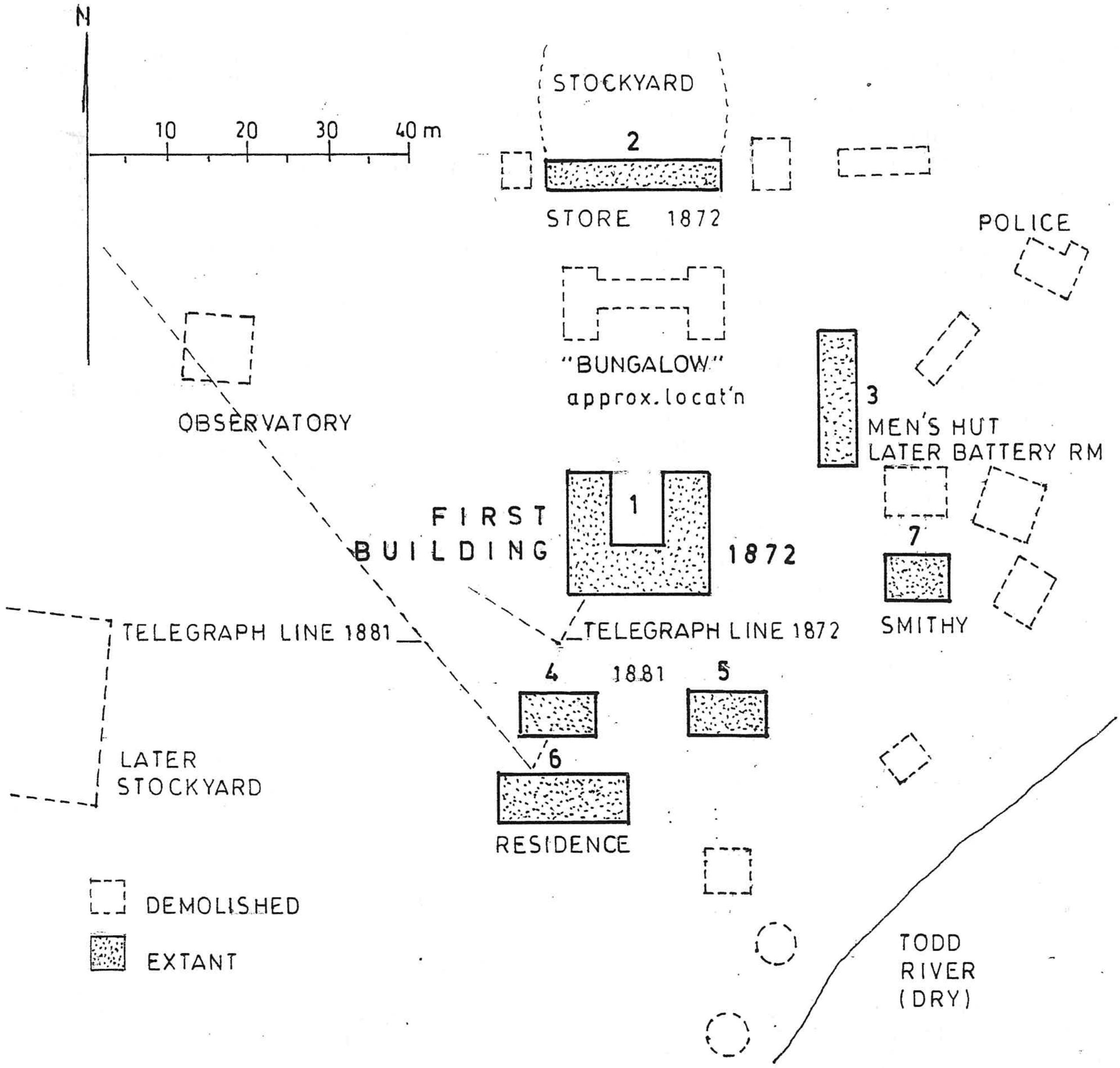


FIGURE 5 *ASTS SITE PLAN – HISTORICAL*

Department of Defence

The second world war put further demands on the old telegraph station and it is believed that it was used for a native labour headquarters. During this period the historic fabric fell into further disrepair.

The attitude of the Commonwealth Department of Works during this and the previous native school occupation was not one of interest in the telegraph heritage. The Department made alterations and would have caused further destruction had it not been for the budgetary constraints. It is on record that it was noted that the buildings were of stone and would be very difficult to alter[4].

An Historic Reserve

A change of attitude next: on 25 October 1962 the Commonwealth proclaimed, under s.103 of the Crown Lands Ordinance, that the station and its lands had become a Reserve for "Historical and Recreation Purposes"[5].

Then began a sorry tale of 'restoration'. The reserve was in the care of the Northern Territory Reserves Board. The first attack was by Adelaide architects Bullock and Burton in 1964. The Bradshaw residence (Figure 5 No 6) had its south verandah removed and the stone plinths rendered. The Board then employed contractor J Taylor to repair the residence and the kitchen (Figure 5 No 4) both buildings having new verandahs out of historic character. By 1969 the stone verandah flagging was replaced by concrete and external walling was repaired. And so it went on.

The work was reviewed: The Governor-General wrote to the chairman of the Reserves Board saying that it was "...one of the finest restoration projects I have seen..." That was 26 September 1969. Then, on 2 March 1971 the President and Director of the Royal Australian Institute of Architects paid a visit. The Director said "...it looked like a stage set rather than the way it originally looked"[6]

The Board affirmed its practice of 'restoration' by adopting a policy to fix the dates between 1895 and 1905.[7] The execution was too zealous; for example the stone joints were ruled and painted black and this they called 'tuck-pointing' an error repeated by other authorities into the 1990s.There is no evidence of tuck-pointing in the historic photographs. All verandah posts were replaced with 4" x 4" jarrah; not historic as there were a variety of posts including Oppenheimer telegraph line poles.

Conservation Commission of the NT

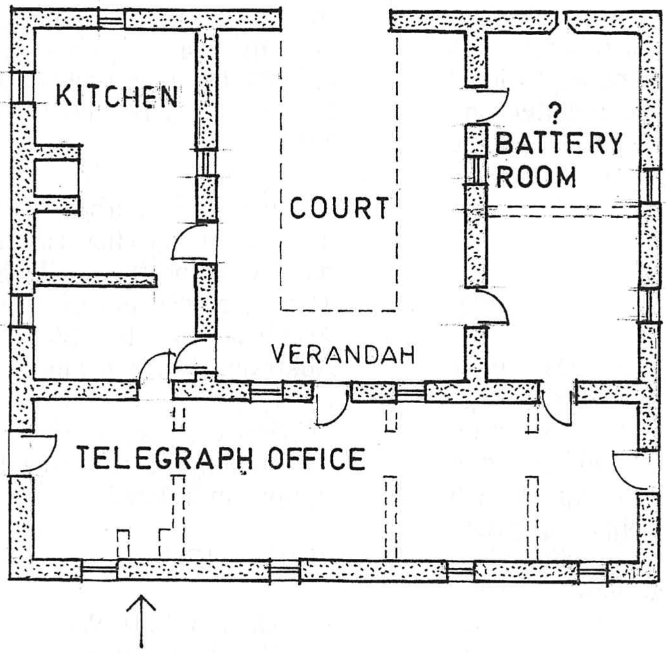
The Government of the Northern Territory took over the Reserve on its formation in 1978 and in 1980 all the extant buildings were measured and drawings prepared by the Conservation Commission of the Northern Territory. This documentation made matters even worse as the record then showed heavily stylised design and total consistency in materials and finish over all buildings. The diverse historic character was lost and the public misled - extremely unfortunate. Now, the site really does look like a stage set.

THE TELEGRAPH SYSTEM

The first technology used was the 'simplex' whereby a single current (15 to 20 mA) was used by the Morse Code sender. Because of the long distances the signals were received on a relay then through a local circuit (known as 'local working') before being sent on the the next repeater station some 150 to 200 miles away (240-320 km), a distance dictated by the technical limits. By 1876 the system in South Australia changed to the 'duplex' which was a single current system but allowing simultaneous transmissions in opposite directions - two messages on a single wire.

Line operation changed to 'quadriplex' then to automatic morse transmission invented by Charles Wheatstone and using a perforated tape, a system introduced into South Australia in 1905 (During Bradshaw's time as stationmaster). This was later improved by the printer made by the English firm of Creed; the printed strips were pasted on to a telegram form. Further development was a carrier system, in 1927, based on the use of thermionic valve amplifiers and with the 'Murray Multiplex' of NZ origin with time division multiplexing and page printing and capable of sending eight messages, four in each direction, at 40 words per minute on a single wire[8].

ALICE SPRINGS
TELEGRAPH STATION
1872 RECONSTRUCTION



APPROX LOCATION
OF FIREPLACE: SEE
SKETCH 1876 BY
W R POUNSELL

PARTITION LOCATIONS
APPROXIMATE BUT
DERIVED FROM
LOCAL INFORMANTS

EXTANT STONE WALLS

PRESUMED PARTITIONS

N

DRAWING: N LEYBOURNE-WARD JULY 1999
SCALE 1:200

FIGURE 6

Some notes on line and equipment

The early single line was 6 swg galv. wire from Darwin south (from stocks in Port Adelaide) and 8 swg elsewhere (manufactured by Johnson and Nephew) The line had a deflection of 3 feet (900 mm) in every 4 chain (80 m) span[9].

Local working was to magnify or intensify the strength of the signals received and to transmit on to the next repeater station - therefore eleven times from Adelaide to Darwin. One end of the line was connected to the tongue of the relay and the other end to the front stop of the relay; there was a local battery (usually 3 cells) a tape register and sounder combination for reception of the morse signals either by tape or sound[10]. Reception by sound meant writing down the message for retransmission.

Batteries

The early line batteries were Meidenger which Doris Blackwell describes as wet cells each in a large glass jar containing a solution of water and magnesia and a lead and zinc plate. Fitted neck down into the top of each jar was a bottle containing copper sulphate commonly known as bluestone. A small glass tube in the cork of the bottle allowed drops of copper sulphate to fall on the lead plate which gradually became coated with copper. Insulated wires from the zinc and copper allowed the hundreds of cells to be linked together. Every few months the batteries were recharged with the addition of new copper. The telegraphists had to maintain the batteries, about 500 of them[11]. A very observant young Doris Bradshaw.

Line voltage was 120 to 140 therefore there were probably four banks of 125 cells in series, the banks being in parrallel (Meidenger voltage was 1.1). This arrangement would leave one bank out for maintenance.

The Meidenger cell was used up until 1925. C Leonard (ND) noted that telegraph engineer Fred Simmons visited all stations north of Port Augusta in 1925 upgrading the installations replacing the Meidenger primary batteries with Leclanche[12]. Batteries for local working were 'Gravity' (Meidenger?) type or Leclanche[13].

RECOMMENDATION

In 1998 a draft conservation report was prepared for the Parks and Wildlife Commission of the Northern Territory in which the opinion was given that the first building, the original telegraph station (1872), be restored to its initial form. There could be early telegraph systems on display with Meidender and Leclanche cells in what was the battery room.

There is much equipment held in Adelaide by the Telecommunications Museum (TMA) not currently on display. If the NT government accepts the recommendation the TMA or SA History Trust could be approached for help.

Further, this author prepared a submission in 1995 for an Historic Engineering Plaque to be fixed in the original telegraph office. That material is now lodged with the Senior Archivist at the State Library of South Australia; Denis Cumming collection.

Therefore it would be appropriate to have the building restored to 1872 and fitted with equipment related to early telegraphy- Fig 6

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Some Aspects of Australasian Academic Engineering -from Rankine to Southwell

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Summary: The education and training of the young engineer in Australia and New Zealand has been strongly influenced by British and other practice and experience, and yet has evolved in a distinctive way. Here some of those influences are discussed, and the local distinctive aspects related, particularly in the context of some of the individual engineers and educators who contributed to the development of academic engineering in Australasia.

1 INTRODUCTION

The engineering professions in Australia and New Zealand were amongst the first in the English-speaking world to require a university degree as the educational prerequisite for eventual corporate membership of the professional body. (Here *Australasian* is taken to mean, *-referring to New Zealand and Australia.*) Even earlier, influential engineers, especially those in Government employment and responsible for recruitment into their respective Departments, often favoured and encouraged the young engineers to follow an academic path into the profession [1].

The same may not have been true of engineers in private practice at the earlier times in relation to their own recruiting of staff. Often the effects were the same, however, because the self-employed consulting engineers had themselves started their careers in the profession as employees of Government Departments, either national or local.

Engineering Schools in the modern sense were established remarkably early in Australasia, most notably in the Universities of Sydney and Melbourne, and soon followed by others.

Here we describe some of the background events that contributed to these early educational experiments, and the outcomes for the engineering profession.

2 EARLY DEVELOPMENTS

Academic engineering courses and qualifications in the Western world have developed over about a two hundred year period – from the last decades of the eighteenth century until the present day.

The early leaders were the French and the stimulus was from the military[2]. Some of the German states followed soon afterwards, to be followed somewhat later by Great Britain, the U.S.A. and Japan. In technical and scientific terms, Russia was also an early leader through patronage by the Tsars and Tsarinas of the mid eighteenth century, but the process was not continued and their Institutes and Schools of Engineering re-emerged in modern times in a leading role.

For the purposes of this paper, since we are primarily concerned with the Australian and New Zealand experience, the starting point for academic engineering experiment and experience will be taken as associated with the appointment to the Regius Chair of Civil Engineering and Mechanics at the University in Glasgow in 1855, of William John Macquorn Rankine (1820 – 1872). This was one of the earliest Professorships associated specifically with Engineering education in the English speaking world. Rankine was the second appointee to this chair: The first holder of the Regius Chair was Lewis Gordon who occupied the post for about fifteen years, from 1840.

3 SOME BACKGROUND

There were relatively few Professors or staff of any sort at the Universities at that time. Indeed there were very few Universities[3]. The Regius Chairs were a new departure at the time, and were most often established in more mainstream academic subjects such as History or Theology. Even so, there were very few in all. So it must have come as an unpleasant surprise to the other professors when a new discipline such as Engineering was mooted. Indeed, when Gordon resigned and Rankine was proposed for appointment to the Glasgow Chair there was move by other professors to have the appointment deferred and the chair suppressed.

These were and are called Regius chairs because they were sponsored by the Crown, in this case by Queen Victoria and more particularly, by her husband, Prince Albert. Albert was German speaking and had experience of the German technical and engineering environment. He used his influence to promote technical and engineering education in the U.K. The Great Exhibition in Hyde Park in 1851, which Albert was closely associated with, had a strong technical content and the profits were to be applied in education.

Even earlier there had been the Mechanics Institutes and bodies such as the Society for the Diffusion of Useful Knowledge which sort to raise awareness and themselves published some excellent books and journals as well as mounting courses for the less well off. Many of these courses and publications had technical and engineering content.

The British Association for the Advancement of Science held well attended annual conferences, at a different city, and even country, each year. The BAAS began in the 1830's and continues at the present day. Rankine and other leading engineers and scientists in the early years were actively involved. The ANZAAS is a related body.

There were and are important differences between the educational systems in England and Scotland. Some of these differences were exported to Australasia. Very roughly the differences centred on an elite role for education in England as compared with an egalitarian role in Scotland. In the Scotland of Rankine, industrialisation was taking place at a furious pace, more furious than in England as a whole. The old city of Glasgow, which had for generations been a local centre for education, based on the ancient University in the city, and also a religious centre based on the more ancient cathedral, became the hub of the Scottish industrialisation based on local coal, iron and human resources.

The iron workings produced wrought iron, and later in the century, steel. Ship-building, based on the new technology of wrought iron and steel, grew up on the banks of the Clyde, from the city of Glasgow right out to the Firth of Clyde. James Watt, a primary figure in the age of steam, came from Greenock, down the Clyde from Glasgow, and in early life was employed as an instrument maker at the University. He migrated to England, as did many of the other key people. But not so Rankine. After some incomplete studies undertaken in Edinburgh, Rankine gained experience in the practical side of railway engineering. This was at that time a rapidly expanding industry and technology. Indeed, the practice was well ahead of the theory, and Rankine was to be a key figure in the linking of the Practice with the Theory.

By the time Rankine joined the University in Glasgow, first as a stand-in for Gordon, and then as his successor, William Thomson, later Lord Kelvin, was already in post as Professor of Natural Philosophy, that is Physics in Scottish terms. Both Rankine and Thomson contributed in a fundamental way to the progress and understanding of thermodynamics in the middle of the 19^{th} century. As a measure of the importance of these two colleagues in the University at Glasgow, we note that the (only) two absolute temperature scales are expressed either in degrees Kelvin or degrees Rankine!

Kelvin was to contribute in a fundamental way to electrical engineering, telegraphy and much more but we are unable to discuss his contributions here. Rankine, within months of his appointment to the Regius chair in 1855, started publishing drafts of what became his textbooks. It is these works which are the main focus here.

The numbers of students who chose to study engineering in Rankine's time were very small, and the salary conditions for the professors were dependent to some extent on the numbers. Rankine tried all the means available to him to have a degree in engineering established, but was not successful. The first engineering degrees at Glasgow, Melbourne and elsewhere in the English-speaking world were awarded in the 1880's.

4 THE RANKINE *MANUALS...*

By the time he died in 1872 Rankine had published five major textbooks: a sixth appeared a few months after his death. The first was his *A Manual of Applied Mechanics*, which appeared in 1858. This was a comprehensive work of more than 600 pages. The content spanned the familiar through to the totally novel. This and his other works were to remain in print long after his death. The publisher's records [4] show that the last copies were sold as late as 1944.

The next of his textbooks was *A Manual of the Steam Engine and other prime movers,* published in 1860. Then came *A Manual of Civil Engineering* in 1862 and *A Manual of Machinery and Millwork* in 1868. These works were all of roughly equal length and importance in the respective branches of engineering, with *Civil Engineering* standing out just a little. They all remained in print well into the twentieth century and were expensive purchases at the time. The cost of *CE* was 16/-; the others cost 12/6. These prices were of the order of one months wages for a trades person in the later nineteenth century, and remained unchanged during a period of deflation late in the century.

In this century there has been an explosion of textbook numbers, and so it is necessary to consider the conditions at the time. Rankine's texts were not the only engineering texts available, but they were the most successful of the time. Educational opportunities of the type available today were not available then, and so self-study through reading from Rankine's *Manuals,* or some other source, was about the only option available for the many who sought technical knowledge. There were other comparable works in other languages, particularly in French and German, such as the book 'Theorie der elasticitat fester korper' by A. Clebsch (1862), and the 1883 French translation of this by B. St. Venant. In addition to the translation

St. Venant added annotations which about doubled the length of the book. These works were a sort of European counterpart of Rankine's *Applied Mechanics* and may have been the model for Love's *Elasticity* (see later). The Clebsch books were very theoretical and difficult, but important books for the serious student. They were printed in small editions and neither work was ever reprinted, despite their undoubted value.

Rankine's books, in contrast, were reprinted frequently. Every reprinting seems to have been called a new edition, and the demand was such that a new edition appeared ever few years. When the copies are compared from edition to edition we find that small amounts of new material were introduced into the appendicies at the ends of the volumes. The main body of the text remained unchanged, apart from misprint corrections, throughout their whole publishing history. The *Manuals...* were also quite demanding reading in the theory they presented, but they did not employ the 'state of the art' mathematics of the day, whereas the Clebsch works did. Rankine was quite well informed about the mathematics that was new at the time, but he presumably took the decision to employ less modern, more widely known methods on educational grounds.

Few other texts were as comprehensive in both theory and practice as the *Manuals*. Rankine's books were trend-setting and exerted an almost unrivalled influence, in the English speaking world, on the young who were starting their studies and also those already working in the various branches of the evolving engineering profession. Quite a good archive of materials from Rankine's publishers, Charles Griffin and Company Limited, The Strand, London, has been deposited in the St. Brides Printing Library[4]. It is clear, although the detailed numbers have not been compiled, that many thousand copies of most of the *Manuals....* were printed.

There is quite a lot of evidence to back-up the supposition that the influence of the *Manuals* extended to Australia and New Zealand. In some of the library collections there are association copies, of '*Civil Engineering*' in particular. Copies of Rankine's works that belonged to the Kernot brothers in Melbourne are deposited in the Baillieu Library [5]. J.J.C. Bradfield's copy of *CE.,* acquired when he was a student at St. Andrew's College, Sydney University, is in the Fisher Library. There are other association copies known that were used by engineers of the day in both NZ and Australia

An interesting photograph, which is reproduced in the Histories of St Andrew's College, of a student's room in the 1890's, has been identified, and is certainly that of an engineering student, since Rankine's *CE* and other engineering works are clearly visible.

In addition to the *Manuals* Rankine also wrote a very large number of fundamental research papers which dealt with new developments at the time. The subjects dealt with also spanned a surprisingly wide range, including thermodynamics, mathematical studies of materials as well as his well known writings on geo-mechanics.

5 THE UNIVERISITIES – THEIR STRUCTURE

The structure of the Universities that developed in Australasia was largely derived from a Scottish model, meaning that the Faculty was the primary unit, and the Institution was largely civic, that is city based. Cambridge and Oxford, which have had such a dominant role in the English tertiary education scene, and still do at the present day, were, until the series of Reforms in last century and this, almost a collection of mini, autonomous institutions, the Colleges, where the greater part of the considerable wealth and power resided. The central administration which is now the University is a relatively modern construct, and the faculty groupings , including Engineering , are quite recent developments.

The Scottish Universities are not as ancient as some, but they are, nevertheless. very venerable. Links, both political and cultural, ensured that European influences were felt in Scottish life, and education. When it is noted that the Australasian Universities have primary structures that are derived from Scottish models, this also implies European influence via Scotland. The phenomenon of the Regius Chair at Glasgow, and the contribution Rankine made to engineering tertiary education while the holder of it, could easily occupy us for the rest of this paper. But we must move on.

We should remember that the social conditions in early nineteenth century Europe were of uncertainty and rebuilding following the revolutions, in France in particular, and the Napoleonic wars early in the century.

The *Industrial Revolution*, too, was bringing about massive changes in Society and the countryside, and in education. Many cities grew, almost uncontrollably in some cases. In others there was closer control exercised. City planning, when well executed, produced some of the architectural masterpieces of the age. After the period of canal building as providing transport needs there followed the rapid expansion of the railways, first in Europe and later in North America. Some of the engineers of the day occupied very high profile positions in society, and most career engineers had the satisfaction of seeing great works being planned and executed in their working lives. Railways played a substantial role in Australasian engineering.

The nineteenth century was the period when the *IR* had the greatest impact in western countries. Mid century, 1851, was the year of the *Great Exhibition of the Industry of all Nations* [3]. This was the extravaganza in Hyde Park on the west side of the rapidly growing capital city of the Empire, London. It

1960 period. J. (Jack)W. Roderick (1913 – 1990) arrived in Sydney in 1951 to take up post as Challis Professor of Civil Engineering. For some years prior to 1951 he had been John Baker's research coordinator at Cambridge. Their association had begun earlier, at Bristol. Roderick's 27 year tenure of the Sydney post was a period of quite intense structural research into a series of related developments which had links back to the Baker 'School'. There was a somewhat similar series of developments and research activity at Melbourne and to a less extent at Adelaide and Perth. The Roderick period was in some respects a modern day equivalent to the early influence of W. H. Warren, the first Challis Professor of Engineering at Sydney. Warren was also the founder President of the I. E. Aust in 1919. It was also during Roderick's tenure that the role of Warren was reassessed. The Warren Centre is the tangible outcome of this process. This is an interesting outcome since from [5] it seems that for many years Warren's status and contribution was not well documented or appreciated.

The Cambridge engineering course is classified as being of engineering science type, though the words have a different meaning to the same words used to describe one of the departments in the Engineering School at Auckland. Most departments in the present-day UK are more directly career (vocationally) oriented than are the engineering science type departments. Virtually all the Australasian University Engineering Departments, Faculties and Schools are approximately intermediate in emphasis between the engineering science type and the (majority) professionally oriented Schools in the UK.

Another category of engineer from Australasia went for their initial studies to other countries and returned, often to leave again. Examples are G.T Murray (1859 - 1947) and Sir William Hudson (1896 - 1978). Both were NZ born and sought their engineering education in U.K.- Murray went to Edinburgh University and Hudson to University College, London. William Hudson's career is well documented [11]. His name is most closely associated with the Snowy Mountains Authority. Murray [12] was not as high profile an engineer, but in his own way was important.

8 A FUTURE INITIATIVE?

At the present time much change is being wrought in educational circles, and more, no doubt, will occur in the new Millennium. The Internet and e- whatever will be drivers. What should the professions associated with heritage issues be aiming for in the immediate future?

In the early years of the engineering professional body formation in New Zealand there was a proposal to found a National Library Collection for Science and Technology, [13]. This did not happen but the New Zealand Society of Civil Engineers, the professional body now the present IPENZ, did accumulate a sizeable in-house library. This continued to be the policy until sometime in the 1970's when the policy changed and the collection was dispersed.

Today the only substantial Library collections of engineering materials fully in the public domain in NZ are in the Engineering Faculties at Canterbury and Auckland Universities. The Canterbury collection is the larger and better housed. There is also the Architecture Library in the Faculty at Auckland, and another collection in the Victoria University in Wellington.

Despite all the power to search and other features which the Internet and Data Bases offer, there will never come a time when the physical collection of materials in an actual Library will become redundant. Indeed, those collections that do survive and continue to expand will become the key sources for reference in the future.

Surely the professionals need access to a comprehensive library of physical materials? Why then do we not plan for the establishment of a National Library of Architecture, Engineering, Science and Technology? Revive the 1919 proposal! Just as heritage buildings and infrastructure need conservation so to do library collections. Apart from Government archives that are covered by an Act of Parliament, many other desirable archives are probably being lost on a regular basis because of the lack of a secure receiving library or body. It is a sad fact that the heritage/archival materials in most working Libraries are often the least well provided for sections of the total collection. Couple with this is the very high, no, unrealistically high, cost of new serials to most libraries. The result is that far too much of the available funding is spent on serials, and we have a serious viability issue. Another question to consider is should a National Collection, if established, be a copyright deposit library? When we look around the world at some of the great libraries we almost always see that they have been accorded some special status.

Those bodies which in the past have provided library resources for us to consult, and the Universities are a good example, may well in the future be unable to continue such a policy. As Professionals we will need to take an initiative if the resources are to be available. Some private collections have found their way into public domain libraries, and this is to be encouraged. Long-term security for our collections is needed. The track record is not good, at least in New Zealand. Below is reproduced the personal book-plate from a volume which was previously in the NZSCE library. During the 1970's this library was closed and the contents were passed to other collections. More recent actions by Government and others have had the effect of further reduction in the Engineering Library collections in the public domain. The whereabouts of much of what was in the NZSCE collection is now unclear. We need to do better by the *Past in the future*.

9 CONCLUSIONS

Here a very brief outline has been given of the development of academic engineering in Australasia. The emphasis has been on the personal rather than the institutional aspects, and in particular on Rankine's role through the medium of his textbooks.

No comprehensive biography of Rankine has ever been completed. Further study of the role of Rankine is suggested as a priority. There are several valuable studies of aspects of Rankine's career and importance. For example his geo-mechanical contributions are discussed by Prof. Hugh Sutherland [14], and his thermodynamical innovations by Dr. Keith Hutchinson [15]. There is scope for further studies.

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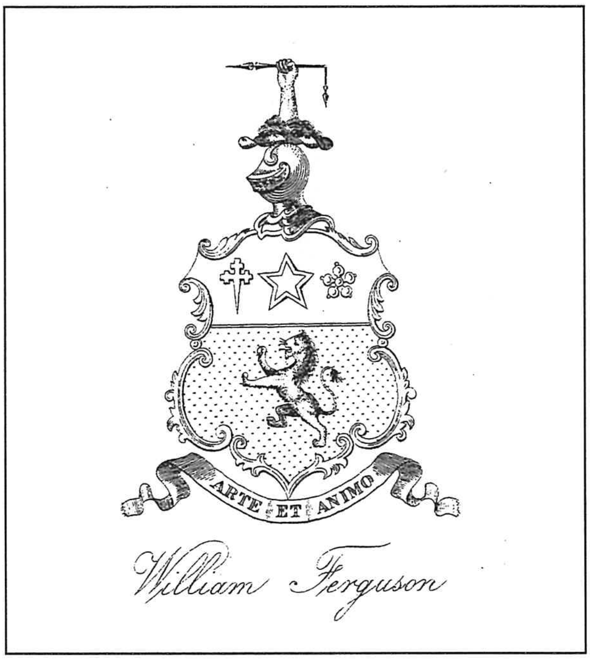
11 APPENDIX

In our section **8** some observations are made about engineering and technical library resources: their conservation and future prospects. Below is shown a relic from a private collection whose present status is not clear.



The William Ferguson Bookplate, from his copy of *Engineering Education, 1891*, Institution of Civil Engineers, London, which was formerly in the Library of The New Zealand Institution of Engineers. See also the Paper in this Conference relating to William Ferguson by W.T. Bishop.

Heritage at Risk : The Rape of our Resources

Robert G. Norman Q.S.O., B.E.(Hons), M.Sc.(Hons)
Past President and Distinguished Fellow
Institution of Professional Engineers N.Z.

Summary: Our engineering heritage is the accumulation of all our knowledge and engineering practice. An historical perspective is most important, and we must learn from the past. Everything stems from design, and this is effectively a continuum of activity, drawing on the knowledge bank and replenishing it. The present trend to dispose of public assets such as our energy system, forestry, and roads is a betrayal of a sacred trust – a heritage of 150 years now at risk under administrations with three-year time horizons and no concern for the long term future. The paper makes a plea to oppose these developments "with vigour, even with passion."

This address is going to take about 40 minutes.

Let me tell you about one or two of the things which will be happening in this country of ours during the next 40 minutes while we are sitting here.

- Five people will be born and five will die.
- Our cars will burn enough petrol to take three car-loads of us from here to the moon and back.
- Six hundred pairs of shoes will be worn out.
- Our poultry will lay 150,000 eggs.
- Our great pine forests - the largest man-made afforestation in the world - will grow 70,000 super feet of timber.
- Our electricity resources will generate enough power to make 300 million cups of tea.

To round off this picture, let me tell you one thing more. The main land mass of New Zealand has existed roughly in its present form for about 100 million years. For all but an instant of that time, none of the things I have mentioned ever existed. The whole of these great developments have occurred in only about a one-millionth part of the life span of this country.

All the artefacts of our heritage have been the product of independence, initiative and improvisation. Because of this, we are now blessed with a legacy of achievements which are in world class. We have been pioneers in things like agricultural aviation, earthquake engineering, universal computerised banking, and many aspects of pre-natal and pediatric medicine. All this has happened because people of great courage, wisdom and skill kept reaching out for the unreachable star. Most of these people have been New Zealanders, and much of the work has involved engineering.

Rich indeed is this country's engineering heritage, and one could wax with enthusiasm about a galaxy of projects which grace this land. But there are some other things that need to be said, and the warning bells need to be sounded.

I put it to you that our engineering heritage is not just a priceless possession to stand back from and admire. It is the accumulation of all our knowledge and engineering practice. We have no other tools or instruments for the future - except guesswork and trust in God.

Our present is but an instant of time - ephemeral, evanescent. It is merely a short step between the great travels (and travails!) of our engineering past, and the uncharted paths that lie ahead. So we must maintain the gift and discipline of recall, because all our completed works are of inestimable value in equipping us for to-morrow.

We neglect history at our peril. Lord Rayleigh once observed that lack of understanding of history meant that the heights of technical achievement were reconquered again and again at great intellectual expense. Similarly the great Danish engineer Neils Plum said : "Read the literature : it will save repeating mistakes and enable a much more accurate aiming at the target." So our engineering heritage is much more than an asset we can observe with nostalgia and pride. It is the very core of that intelligence which we owe to our practice and to our client society.

To eschew such precious intellectual capital is to invite disaster. The most spectacular engineering failures in world history have not occurred because engineers ventured into the unknown. They usually happened because of errors in design or in risk assessment, ***and because people forgot things that had already been learned.***

The Tacoma Narrows Bridge in Washington State is surely an object lesson to us all. To explain this, let me take you back in history.

In 1854, the world's longest suspension bridge at Wheeling over the Ohio River in West Virginia collapsed in a storm. It was far too slender, being 1,000 feet long and only 20 feet wide. Aerodynamically unstable, it fluttered like a ribbon and fell into the river.

The cause of the failure was immediately apparent to one man - the greatest suspension bridge designer and builder of all time. This was Johann August Roebling, who had already developed the rules and parameters about stiffening such structures against vibration. His work culminated in the Brooklyn Bridge, opened in 1883, and in my view the most inspiring and graceful creation of its kind ever built.

Then half a century later, people forgot the lessons learned so long ago. The Tacoma Narrows Bridge design overlooked the teachings of Roebling and others. Its proportions were wrong, it lacked stiffness, and it employed virtually no bracing against vibration. Like the Wheeling Bridge over the Ohio nearly a century earlier, it tore itself to pieces, and its death throes were filmed in detail and seen by the world.

Other failures of great public works are closer to our own time. The Lions Gate Bridge in Vancouver failed during construction because somebody made a mistake in designing a temporary support structure and the calculations were not independently checked.

The Westgate Bridge in Melbourne fell down because people forgot that if you weld bits of steel together they change in length, and you had better leave them room to move.

The two-level Cypress Avenue Freeway in Oakland, California, became a concrete sandwich in the recent San Francisco earthquake because designers overlooked the unacceptably high bond stresses in the reinforced column caps.

Disasters in other engineering fields would be the Titanic - a hull design failure ; HMS Hood - armoured for horizontal fire and sunk by a vertical shell ; the unbelievable human tragedy at Bhopal due to the failure of a chemical plant ; and Chernobyl - where an entire nation - the Ukraine - is still coming to terms with the fallout from a poorly-designed pressure and containment system.

We owe it to society to do better than this. If we fail to profit from the history and performance of our works, then we shall indeed be slow learners.

But are we learning from the past? Are our works secure under their present ownership? Will our future generations be equipped to use them wisely, care for them intelligently, and maintain them to the standards to which they are entitled? Will our future engineering work have available to it all the lessons, all the precepts, all the records of our achievements to date? To address these crucial questions let me deal with a few examples.

First could we look at the philosophy of design.

All our engineering work starts with design. Now there is a point about the design process which is frequently misunderstood. This is the mistaken notion that our engineering projects involve in turn an orderly progression of research, discovery, application and development.

In fact, this is more the exception than the rule. A project usually starts with a dream or a concept, and the engineer draws on the reservoir of existing knowledge to put the dream into reality.

Some way down the track, he then encounters a problem which cannot be solved with the information available, so he has to acquire more. This calls for research, and this could cover a whole lot of activities ranging from a simple literature search to hiring professional expertise over an extensive period. In due course the problems are solved and the project completed.

What has our engineer done?

He has drawn from the whole of the existing store of knowledge at the start of the project. And at the end of the day he has replenished that stockpile with new understandings.

This is the continuity - the continuum - of our engineering work. In this respect, we are really going back to the future. It demonstrates the unmeasurable value of our technological heritage in guiding our future development.

A large part of this design philosophy has to do with quality and standards. We now live in a consumer-oriented society, trying to come to terms with the fact that there are now very few checks and balances to ensure things like durability and safety. At the same time, competition is strong, and great strides are being made to do things better, more quickly, and more cheaply. New Zealand has always been at the forefront of new developments, and for us to continue to prosper, we must be sure of the limits to our designs. In this respect, may I put to you an engineering paradox.

You can only be liberal in your creative efforts if you are conservative and careful with the burdens you place on your works. The world's greatest engineering works stand the test of time because they have margins of strength and durability to cope with the unknown demands of the future. The surest path to technical anonymity of any new system is failure because the margins were not available.

Here again, we learn from the past. Let me drive with you over our highway system, and have a look at our bridges. Here is a system of engineering facilities where safety is a first priority, while the bridges are getting older all the time.

Over this century, the design loadings for highway bridges have changed no less than five times - from a horse-drawn wagon to the modern tractor-trailer rig.

We now have 3,000 bridges on the state highway and motorway system. About one-third of these were designed for loads which are well under the legal limit. Only a few of these have load or speed restrictions.

Contrary to what alarmists might think, this is a perfectly normal and acceptable situation. As the demands of society change, and as the bridges get older, there is a progressive up-grading going on.

To let this happen without disruption calls for good engineering design, with appropriate margins to bridge the gaps in later life between the design capacity of structures and the loads imposed on them.

So that's what good engineering is all about - sensible, conservative designs so that our works will be safe and durable in their unknown trials ahead. This has always been the hallmark of the greatest works of our engineering heritage.

Now let me put to you a question. What if we no longer control that heritage - that infrastructure - that legacy to the nation of our dreamers and builders? What if now, beguiled by the gnomes of the financial bazaars and the temples of Mammon - we have taken our thirty pieces of silver and handed that legacy to others who care little for its long-term future?

Make no mistake - this is happening now.

Last year, the government passed legislation to dismember the New Zealand Electricity Corporation. The arguments presented for the case were poorly researched, shallow and spurious, but notwithstanding this the act became law, and the government has now been engaged in splitting up the corporation.

On 2 April I wrote a letter to the Minister of Energy. It began with a quote from the opening words of that epic poem of William Morris entitled "The Haystack in the Floods".

Had she come all the way for this,
To part at last without a kiss?
Yea, had she borne the dirt and rain
That her own eyes might see him slain
Beside the haystack in the floods?

Then this is what I wrote :-

> Not long ago we celebrated our sesquicentennial. Many of us in the public arena were involved over our whole working lives in the energy, forestry, public works, transport and communication sectors. We took time in 1990 to look back with pride at a whole galaxy of world-class achievements - a heritage of natural and man-made

resources which represented the very best of planning, design, construction and maintenance.

New Zealand's energy system has been one such example. The subject of frequent visits by international experts in the energy game, it has been rated as the most well-conceived and developed energy system on this planet. It was built in the most hostile, physical and topographical environment ever to be encountered. In terms of numbers we are an insignificant group of people - yet our works belie our size. We have put together hydro-electric, coal-fired steam, oil-fired steam, gas-fired steam, gas turbines, geothermal systems, wind turbines and the world's largest submarine DC power linkage. Not only that, but we were able to integrate things into the power system like security of catchments against flooding, recreational resources, and the balancing of load sources, power demands and line losses.

Why was it so successful? It worked because the people who ran it had a stake in it - the people of New Zealand. Holistic management and long-term data collection and planning had been the key. Now it is all at risk. Why? ***Because politics is about making change.*** Never mind that it has been a superb resource. Its public, holistic ownership and management do not line up with the shibboleths of the gnomes of the Treasury, the Round Table, and others who prostitute our heritage before the altar of Mammon.

It was Hegel who said two hundred years ago :

What experience and history teach is this - that people and governments never have learned anything from history, or acted on principles deduced from it.

It is said that we get the government we deserve. But do we really deserve all this?

It would have been nice to have had a response to this letter, but a year later I still await one. My regretful conclusion is this :-

You and I over the years, through a normal democratic process, have empowered a motley crew of political ideologists to trash the world's most brilliantly-conceived and managed energy system.

So much for what we had, and what we are now squandering away.

What about the things we were capable of doing, but have turned instead to the soft path of doing nothing?

The national hydro-electric system was planned and developed on a fifty-year time horizon. This was the time needed to get the information about things like rainfall, storage and landform, so the best bets for hydro schemes could be put in a logical order. But the current political system, surviving as it does on a three year time frame, operates on quite a different astral plane. It can only understand short-term solutions, and consequently major hydro-electric development has virtually ceased.As a result, New Zealand is turning its back on its huge reservoir of intellectual capital on hydro - the best in the world - and grubbing around for more fossil fuel. This is no less than a betrayal of our children and grandchildren, who will be denied the options of choice as our fuel reserves inevitably decline.

On the upper Clutha, at Luggate and Queensbury, are two major hydro opportunities which met all the formal requirements of the Commission for the Environment. On the Lower Waitaki is a huge potential of power, of the order of at least 600 megawatts, which has been carefully researched and would have presented untold opportunities for energy, land conservation, flood protection, irrigation and recreation. None of these projects have ever got off the ground.

There will always be critics of plans for hydro energy. A common complaint is the disturbance to the natural environment, and the loss of some amenities. But look back at the heritage of our hydro works. Who could disagree that the benefits far outweigh any deleterious effects of change? The outcomes of this heritage are some of our country's best conservation and recreational resources.

The selling off of our energy infrastructure has had another unfortunate outcome. Many generations of New Zealanders have worked on, lived with, argued about or witnessed a succession of outstanding energy works, be they hydro, geothermal or fuel-powered. Great care was taken by the national generating authority to present to the public the stories of its works, and to enable our people - who after all were the owners - better to understand their artistry and ingenuity. Well-equipped information centres and effective access and signage were the hallmark of these works, and they have given pleasure and enthusiasm to millions of visitors over the years. But no longer. Shackled by the bonds of the profit motive, the power companies are no longer interested in such trivia - they have other business to do. So we have seen the demise, for example, of the unique and exciting modelling and presentations of the Tongariro Power Development at Turangi. This brilliant engineering concept, albeit a controversial one, incorporated a giant ring drain around the central mountains and changed the whole face and the security of the North Island's energy system. Not far away is Rangipo, the underground power station fed by a partial diversion of the Tongariro River. To get to the headrace of this brilliantly-designed and executed project, you now bump your way along a seedy access road crumbling at the edges, and you will be lucky indeed to find the place.

The squandering of our energy assets is but one chapter in the tragedy befalling our infrastructural heritage.

New Zealand's erstwhile national forest system was another example of long-term planning and investment, and world class engineering associated with sustainable management of stocks and product development. You may well respond : "Why pick on the forests? They are still being managed and developed by other competent groups." But there is more to it than that. Long term projects can thrive only under long term continuity of ownership and management. In this paper I have already placed great store on the value of an historical perspective, especially in the disciplines of research, quest and discovery. Can this be maintained under the bewildering kaleidoscope of changes of ownership of our forest resources, or will people once again forget the lessons which have already been learned?

May we turn now to another aspect of heritage engineering - the development and maintenance of our nation's national parks and walkways. None of us can ever forget the Cave Creek tragedy where an engineering failure cost the lives of so many young people, and prompted the resignation of a minister and a top public servant. In the flurry of the patently predictable political polemics one cause stood out clearly. Emaciated by the penny-pinching of a succession of political administrations, the highly-respected National Park Service could no longer provide the engineering services so vital to public safety. The new administration of the service is tackling this well, and one precept which is paramount has been taken aboard. If you hire technical advisers, then you had better be part of the team. So the service has now put together a core of engineering expertise "within house" to help it plan feasibly, hire the right people, and keep an eye on the results.

This seems almost so obvious as to be trifling. One has only to look back at some of our past technological successes. New Zealand has had outstanding results in the development of natural gas because the government set up a New Zealand-based construction project, and recruited into it for the long haul one of the best American pipeline technology companies. The entire technology was transferred to our engineers, and it is now a normal day-to-day operation.

The Vogel Computer system, the government's erstwhile prime technical and engineering computer and data processing facility, was not just purchased from and installed by an overseas supplier. An entire division of a government agency was set up and trained, and then worked continuously with the suppliers over the years as a progressive up-grading of the system went on. As a result, contractual arrangements for programme sharing were set up with engineering agencies throughout the world, and the Centre became a reputed international resource.

With those kinds of lessons, one would have thought that both our government and the private sector would have had the intelligence to take them aboard. But what have we witnessed over the last few years? Time and again, agencies have brought in consultants not only to provide technical resources to deal with their problems, but also to tell the agencies what their problems are. Add to that the unconscionable acts of administrations for which long-term planning is a no-no, and you have the standard recipe for chaos, cost over-runs and unfulfilled promises. Then the lawyers get into the scene and confuse the issues still further, so that when you look for bottoms to kick, all you find are shapes vanishing into the mist.

One other quite extraordinary and shining example of our engineering heritage needs mention. This is our telecommunications network, incorporating over the years virtually every system which had been invented and developed here and overseas. For example, New Zealand's first commercial telegraph system operated between Christchurch and Lyttelton in 1862, only 18 months after Morse's line in the USA. The first telephones were made in this country in 1877, only 6 months after the publication of Bell's invention, and only 18 months later telephone calls using the Bell system were made between Dunedin and Milton. All the artifacts of these and subsequent systems are in storage. Yet their preservation is at risk because modern commercial networks either forget they still exist or are busy with other things. The IPENZ Heritage Committee is working to ensure that this priceless collection be protected and displayed, but we are by no means out of the woods yet. Much more support is needed, at both government and commercial level, or one of the world's foremost collections of communication technology will be lost for all time.

One last comment to conclude this cry from the heart. Our outstanding heritage of engineering achievements is not for this generation to trifle with. Produced by our forebears who toiled unstintingly for the good of this nation, they should remain in trust for the care and concern of present and future generations of New Zealanders. In this, there is indeed a spiritual context. Neither we, nor the governments we empower, have any God-given right to acquit ourselves of this sacred trust. I have spoken of the inroads already made, and the dangers ahead of leaving our resources to organisations which have neither the understanding nor the historical perspective. If we are to take notice of the lessons of the past 150 years, we must oppose with vigour - even with passion - the plaints of those purveyors of public asset stripping for cash rewards. With their myopia and amnesia, the prostitution of our heritage would leave their uncomprehending and shrunken consciences entirely unmoved.

In the epilogue of a book I published recently is a stanza of mine which represents my entire philosophy on engineering.

> ***Let's not forget the end - a builded work***
> ***That serves us well, and in good cost and time,***
> ***And in so doing, graces our surrounds***

Our forbears did this so well, and they have pointed the way.

Now it's up to us to follow.

Fire Safety Upgrades of the Oamaru Historic Precinct, Excelsior Hotel, and Bangor Homestead

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Summary
This paper presents the fire engineering analysis and alternative solutions presented by Caldwell Consulting Ltd for three projects involving historic/feature buildings. The fire reports for each of the projects developed the fire safety objectives and the fire design to meet the New Zealand Building Code. This involved the use of alternative solutions to resolve a variety of non-complying issues. The results showed that with the proposed fire protection features the objectives of the NZ Building Code for means of escape and spread of fire were achieved and the life safety of the occupants could be maintained, while retaining the individual feature of each of the buildings.

1 INTRODUCTION

Heritage and feature buildings present particular problems in terms of fire safety. Not only do these buildings contain construction features that can be a fire risk, but often the use of the building can be changed to that for what it was originally designed for. The aim of the fire design is to provide a solution that meets both the New Zealand Building Code as well as providing fire protection features that protect the building from fire while retaining its heritage features. The following outlines fire engineering analysis and alternative solutions presented by Caldwell Consulting Ltd for three projects involving historic/feature buildings.

2 PURPOSE OF THE FIRE REPORTS

The purpose of the fire report is to satisfy Council that after the proposed alterations or change of use the building will comply with the provisions of the building code for means of escape from fire and spread of fire as is reasonably practicable, to the same extent as if it were a new building.

The Council is unable to issue a building consent, unless they are satisfied on reasonable grounds that the means of escape from fire and spread of fire would satisfy the requirements of the current New Zealand Building Code, NZBC.

2.1 Design Philosophies

New Zealand Building Code compliance is generally demonstrated using the BIA *Acceptable Solutions;*

- C1/AS1 Outbreak of Fire
- C2/AS1 Means of Escape from Fire,
- C3/AS1 Spread of Fire,
- C4/AS1 Structural Stability During Fire and the Fire Safety Annex

However where compliance is not met with the BIA Acceptable Solutions, which is often common in historic buildings, an alternative solution can be submitted.

The Alternative Solution provides the fire safety features of the building to meet the requirements of the NZ Building Code. The primary objectives of the NZ Building Code are:

- Protect occupant life safety
- Protect neighbouring property
- Provide for some safety for fire fighters
- Protect the environment

With the installed fire safety features proposed in each of the buildings in this paper the objectives of the NZ Building Code were achieved.

3 OAMARU HISTORIC PRECINCT - OAMARU

3.1 Introduction

The Oamaru Historic Precinct consists of two street blocks encompassing 16 heritage buildings. These buildings were built originally for a variety of uses, from a Hotel, Warehouse, Department Stores, Grain Store, and Oamaru Mail Building etc. Constructed from Oamaru stone with wooden roof trusses, columns and wooden floors these buildings were recognised by the Oamaru Whitestone Civic Trust as having a great historic value. They also recognised that fire presented the single biggest risk to the buildings.

Alterations and structural strengthening to some of the buildings as well as a review of the fire protection to the precinct required fire reports for all the buildings. Caldwell Consulting Ltd was brought in to provide fire engineering services for the project. An evaluation as to the best fire protection for the buildings was done by Caldwell Consulting Ltd. This was done to ensure the building could be used for the widest range of purposes as possible.

The installation of a sprinkler system was proposed as providing the best future proof protection for the buildings. This was due to the nature of the construction of the buildings eg. Oamaru stone walls with unknown structural performance, as well as timber trusses and floors. Penetrations between buildings and fire exposure from the adjoining buildings also made the sprinkler system option the wise choice.

An alternative solution was submitted and accepted by the Council to allow the use of the existing two storey Criterion Hotel's open stairwell. The fire reports utilised the installation of a sprinkler system with quick-response sprinklers throughout all the buildings as well as smoke detectors in the Hotel.

3.2 Fire Safety Precautions and Alarm Type

Due to the height and type of activities in some of the buildings eg furniture manufacturer, wool storage over 3 m in height, and that freedom was required to allow most purpose groups to occupy the buildings an Automatic Fire Sprinkler System incorporating a manual fire alarm system was installed.

A smoke detection system was also installed in the Criterion Hotel.

3.3 Means of Escape

Generally the egress from each of the buildings was satisfactory. Some of the buildings with secondary egress through a small wicket door, were required to install a full sized door.

Due to the narrow footpath the some of the main entrance doors also open inward. However with the installed fire protection features these could be retained without being rehung in the direction of escape.

The more complex issues were with regards to the bar and sleeping accommodation for the Criterion Hotel building. As the second floor of the Criterion Hotel was an open intermediate floor, the area between the top of the balustrade and the ceiling, or the underside of the floor above were to be enclosed by a smoke separation. A smoke separation was provided at the base of the stairs and smoke detectors were also be provided in the internal stairway. All the doors opening into the internal stairwell on the ground floor were replaced with smoke stop doors fitted with self-closing devices. A non-combustible imperforate barrier was to be provided on the open side of the floor. The existing wooden open railing did not comply but was addressed by the alternative solution.

The Criterion Hotel also required the bedrooms to be separated from other spaces on the intermediate floor by fire separations having a FRR of no less than 30/30/30. The walls of the rooms on the first floor were lathe and plaster. Those linings in good condition would reasonably meet a 30 minute Fire Resistance Rating. However those in need of repair were required to be replaced.

The bedroom doors were therefore required to be 30 minute fire doors with self-closers. The existing doors were wood panel doors which would reasonably achieve a 15 minute Fire Resistance Rating. The alternative solution submitted addressed the use of the existing doors

3.4 Alternative Solution for the Criterion Hotel

An alternative solution was submitted to permit the use of:

- the existing wood panel doors with self-closers instead of fire doors
- an open railing instead of a non-combustible imperforate barrier on the intermediate floor.

The alternative solution evaluated the overall fire protection features for the facility.

3.5 Fire Protection Features Installed

To support the alternative solution the following fire protection features were installed.

3.5.1 Automatic Sprinklers

The building was fully protected with an automatic fire sprinkler system with quick response heads and incorporating a manual fire alarm system.

The quick response sprinkler heads have a low RTI, response time index. The sprinkler standard NZS 4541:1996 Automatic Fire Sprinkler Systems required quick response sprinkler heads only in the sleeping areas. As all of the spaces throughout the entire building had quick response sprinkler heads this was in excess of the sprinkler standard requirements and provided added protection.

3.5.2 Smoke Detectors

Photoelectric smoke detectors were installed in all the upstairs rooms with ionisation detectors throughout the remainder of the building where applicable. It was recognised that due to false alarms, smoke detectors may not be located in some of the ground floor areas eg. the bar. However this did not affect the outcome of the fire scenarios or the life safety of the occupants. The smoke detectors interfaced with the detector panel and the alarm did not go to the Brigade.

3.5.3 Doors

All the doors opening into the internal stairwell on the ground floor were replaced with smoke stop doors fitted with self-closing devices. The existing double doors into the bar were replaced with a single leaf door.

The existing bedroom doors were wood panel doors which would reasonably achieve a 15 minute Fire Resistance Rating. As the building was to be provided with an automatic fire sprinkler system with quick response heads, incorporating a manual fire alarm system and an automatic smoke detection system it was therefore reasonable to allow the existing doors to remain.
The above fire protection features exceed the BIA Acceptable Solution requirements.

3.5.4 Scenarios

Worst case scenarios were addressed for the alternative solution. They were as follows;

- Upstairs Room - Smouldering Fire
- Upstairs Room - Flaming Fire
- Bar/Restaurant/Internal Stairway - Smouldering Fire
- Bar/Restaurant/Internal Stairway - Flaming Fire

The worst case scenarios evaluated the time that detectors activated the possibility of life threatening conditions and the egress time. With the fire safety features in the building, escape was shown to occur without compromising the life safety of the occupants.

3.6 Installation and Completion

The installation was carried out in two stages, one for each of the street blocks. The fire protection installation was coordinated by Caldwell Consulting with both the contractor and the Oamaru Whitestone Civic Trust to develop an installation that was non-intrusive and in keeping with the heritage aspects of each of the buildings.

The Oamaru Historic Precinct were provided with fire protection features that not only provide the best life and property protection, but also allows the freedom to be able to use any of the buildings for the widest range of purposes. The historic feature of each of the buildings were also retained.

4 EXCELSOIR HOTEL - CHRISTCHURCH

4.1 Introduction

The Excelsior Hotel was an existing three-storey historic hotel building which underwent earthquake strengthening and renovations. The Excelsior Hotel has Bar/Restaurant/Café tenancies on the ground floor and a 120 bed backpackers on the upper floors. The existing egress from the upper accommodation floors was via a main internal stairwell and two non-connected internal stairwells. External balconies formed a major part of the existing egress and were proposed to be removed. The buildings construction was of brick and lathe and plaster. The existing bedroom doors were four panel wood doors

The Christchurch Heritage Trust wished to return the building back to its former glory. Internal alterations and continued use of the building required an upgrade of the fire protection system. The existing heat detection system was replaced with a sprinkler system throughout the building and smoke detectors were installed in the bedrooms. The builders work and fire protection upgrade were completed in approximately 6 months.

Caldwell Consulting Ltd was brought in to provide fire engineering services for the project. Due to the historic nature of the building an alternative solution was submitted and accepted by the Christchurch City Council.

4.2 Fire Safety Precautions and Alarm Type

The appropriate fire safety systems and alarm types based upon the BIA Acceptable Solutions for this buildings height and occupancy were as follows;

- A Fire Resistance Rating of 60 minutes between the ground and first floor,
- A Fire Resistance Rating of 30 minutes between the first and second floor,
- An Automatic Fire Sprinkler System incorporating a manual fire alarm system,
- Emergency lighting in exitways.

4.3 Means of Escape

Egress from the upper floors was via the main entry stairwell that spaned the three floors of the building. The secondary egress was via two stairwells, one which spaned the top two levels, and the other which spaned the ground and first. These two stairs were disjointed from one another and required the occupants to enter the first floor corridor for connection access. As this was not ideal the ground/first stairwell was relocated to an external location accessible from the first/second secondary stairwell. This resulted in the secondary stair exiting on the first floor, but allowing access to the external stair without entry to the first floor corridor.

With the installed fire protection features the external balconies/escapes on the frontages of the building were allowed to be removed.

4.4 Fire/Smoke Separations

A Fire Resistance Rating of 60 minutes was required between the ground and upper floor. It was reasonable in this existing building being fitted with sprinklers to allow a Fire Resistance Rating of 30 minutes. A Fire Resistance Rating of 30 minutes was also required between the first and second floors. With the installed sprinkler system, the existing timber floor and lathe and plaster ceiling reasonably met this requirement.

Each of the bedrooms and corridor were to be fire separated with the fire separations having a FRR of no less than 30/30/30. Those walls in a good condition reasonably met the 30 minute Fire Resistance Rating. However those walls in a state of disrepair were required to be replaced to achieve the 30 minute Fire Resistance Rating.

The bedroom doors were required to be 30 minute fire doors with self-closers. The existing bedroom doors to the corridor were typically four panel wood doors without self-closers and the doors to the internal stairwells were typically wired glass doors on self-closers. The alternative solution submitted addressed the use of the existing non-fire-rated doors. With the installed fire protection features these doors were allowed to remain with little upgrading.

4.5 Alternative Solution

An alternative fire engineered solution was provided to allow the use of:

- the existing construction between floors as a fire separation
- the external fire escapes to be removed
- the use of the existing stairwell doors and non-fire rated bedroom doors.

This alternative solution utilised the installation of a sprinkler system with quick-response sprinklers throughout the building and smoke detectors in the bedroom areas.

4.6 Fire Protection Features Installed

To support the alternative solution the following fire protection features were installed.

4.6.1 Automatic Sprinklers

The building was fully protected with an automatic fire sprinkler system with quick response heads and incorporating a manual fire alarm system.

The quick response sprinkler heads have a low RTI, response time index. The sprinkler standard NZS 4541:1996 Automatic Fire Sprinkler Systems required quick response sprinkler heads only in the sleeping areas. As all of the spaces throughout the entire building had quick response sprinkler heads this was in excess of the sprinkler standard requirements and provided added protection.

4.6.2 Smoke Detectors

Photoelectric smoke detectors were installed in all the bedrooms. The smoke detectors interfaced with the detector panel but the alarm did not send a signal to the Brigade.

The smoke detectors were not required by the BIA Acceptable Solutions. They alert the occupants to a fire in the building much earlier in the growth of the fire and evacuation can begin much sooner.

4.6.3 Emergency Lighting

Emergency Lighting was provided in the corridors on the first and second floors, in the stairwells, and on the external escape route.

4.6.4 Doors

The bedroom/corridor doors and the stairwell doors were required to be 30 minute fire doors with self-closers. However as mentioned the existing bedroom/corridor doors were typically four-panel wood doors without self-closers, and the doors to the internal stairwells were typically wired glass doors on self-closers. The bedroom/corridor doors also had flush panel attached on either side. This could be removed in keeping with the historic nature of the building.

The Fire Protection Handbook from the NFPA, USA p. 6-85-87 discusses fire doors. Fire doors are generally permitted to have less fire resistance rating than the wall. Easily ignited combustibles are not located directly against the doors. With the early detection and suppression features available in this facility, it is reasonable to use the existing doors.

The existing doors, in conjunction with the sprinkler system using quick response sprinklers provides for occupant life safety. The objectives of the NZ Building Code can be maintained with the use of the existing doors.

All the doors opening into the internal stairwell on the ground floor were fitted with self-closing devices and smoke seals and checked to ensure that they latch shut. All the bedroom/corridor doors were fitted with self-closing devices and smoke seals.

The above fire protection features exceeded the BIA Acceptable Solution requirements.

4.6.5 Scenarios

Worst case scenarios were addressed for the alternative solution. They were as follows;

- Upstairs Bedroom - Smouldering Fire
- Upstairs Bedroom - Flaming Fire

The worst case scenarios evaluated the time that detectors activated the possibility of life threatening conditions and the egress time. With the fire safety features in the building, escape was shown to occur without compromising the life safety of the occupants.

The sprinklers will activate very quickly and control/suppress the fire. However, it is unlikely that the sprinklers will operate prior to the smoke detectors. When the sprinkler activates the building audible fire alarm sounds and the Fire Service is alerted.

4.7 Installation and Completion

The fire protection installation was coordinated by Caldwell Consulting with both the contractor and the Christchurch Heritage Architect to develop an installation that was non-intrusive and in keeping with the heritage aspects of the building.

The Excelsior Hotel was able to return to its former glory while keeping it safe for the occupants. The installed fire protection features were utilised by Caldwell Consulting Ltd to allow the existing features of the building remain.

5 BANGOR HOMESTEAD - DARFIELD

5.1 Introduction

The Bangor Homestead is an old two-storey old wooden building with a basement. It is an isolated homestead relying on water supply from ground water wells situated in the country at least 20 minutes from the nearest volunteer fire brigade. The Bangor Homestead changed the use of the building from a private homestead to a bed and breakfast. Due to the change of use of the building, the council required a fire report detailing the means of escape and spread of fire requirements.

The owner of the Bangor Homestead wished to keep the historic nature and atmosphere of the building intact.

The ground floor contains the dining, entertainment rooms, and kitchen for the guests and the owners. Three bedrooms to be used as the owner's accommodation were also located on the ground floor. The first floor contained four guest accommodation bedrooms. Access to the first floor was via an open staircase from the main entrance hall on the ground level. There was also an escape ladder located off the first floor balcony. Two separated buildings were located beside the main building. These were to be used as a garage and disabled guest accommodation bedroom facility. The basement of approximately the same size as the ground floor was only for use as storage. The building is of timber construction, with ceiling and wall linings of lathe and plaster. Some wood panelling is located around the main stairwell

Caldwell Consulting Ltd was brought in to provide fire engineering services for the project. Due to the historic nature of the building an alternative solution was submitted and accepted by the Selwyn District Council.

The outcome of the project meant that life safety of the occupants was upheld and the heritage nature of the building was left intact.

5.2 Fire Safety Precautions and Alarm Type

The appropriate fire safety systems and alarm types based upon the BIA Acceptable Solutions for this buildings height and occupancy were as follows;

- A Fire Resistance Rating of 60 minutes between the ground and first floor,
- No alarm system required, as there were fewer than 20 beds in the building.

Due to the presence of wood panelling around the stairwell, the installation of a sprinkler system was beneficial to not require the striping and application of intumescent paint to the wood.

5.3 Means of Escape

There was only a single escape route from the upper level via the stairwell. The BIA Acceptable Solution required two escape routes from the upper level. However, as the facility was to be sprinklered it was shown by alternative solution that the building code could be met without the need for a second escape route.

5.4 Fire Separations

Each of the bedrooms was to be a separate firecell with the fire separations having a FRR of no less than 15/15/15. With the installed sprinkler system, it is reasonable to allow a minimum of 9.5 mm GIB or lathe & plaster walls up to a standard GIB or lathe and plaster ceiling. The sprinkler system will control/and suppress the fire. The smoke detectors installed in the bedrooms provide early warning of a fire.

The bedroom doors would be required to be 15 minute fire doors with self-closers. The alternative solution submitted addressed the use of the existing non-fire-rated doors without self-closers

5.5 Alternative Solution

The alternative solution submitted allowed the use of

- The open staircase between the ground level and the upper level;
- The existing non-fire rated bedroom doors without self closers;
- The existing non-fire rated ground floor sitting/dining room doors without self-closers.

This alternative solution utilised the installation of a residential sprinkler system with optical smoke detectors in the bedrooms, stairwell and the halls leading from the stairwell.

Because of the isolation of the site, the sprinkler system was designed to suit the situation. This meant a water supply tank and pump were installed. The sprinkler system and the smoke detectors were not connected to the New Zealand Fire Service, as this was not a practical option.

With a residential sprinkler system installed throughout the building, and smoke detectors installed in the stairwell and in all bedrooms the Alternative Solution submitted showed that life safety objectives of the New Zealand Building Code were met.

5.6 Fire Protection Features Installed

To support the alternative solution the following fire protection features were installed.

5.6.1 Automatic Sprinklers

The building was fully protected with a residential automatic fire sprinkler system with quick response heads and incorporating a manual fire alarm system. Residential sprinklers were to be installed throughout the building (eg. basement, ground and first floors). Intermediate response sprinklers were installed throughout the ceiling spaces. Due to the buildings remote location a tank was to provide the water to the sprinkler system. A 5000 gallon tank was anticipated to be installed to provide domestic water supply as well as a supply to the sprinkler system.

The residential sprinklers installed have passed special testing requirements in order to be called 'residential sprinklers'. For sprinkler heads to be classified as residential heads standard testing must be undertaken to show that a sprinkler maintains tenable temperatures in the surrounding environment. Therefore it is expected that tenable conditions are maintained in the bedroom.

The effectiveness of Residential type sprinkler systems at preserving life when an occupant is in the same room as the fire has also been well documented by H.W. Marryatt in his book " Fire - A Century of Automatic Sprinkler Protection in Australia and New Zealand".

The documented situations show residential sprinkler systems are capable of saving the lives of occupants directly exposed to the fire. In some cases the sprinkler system has saved the lives of occupants who have *deliberately started fires* in their room.

The BIA Acceptable Solutions prescriptive requirements for the fire separations and door closers would have no effect on the occupant life safety in the room of fire origin. If there is a fire in one of the bedrooms the installed sprinkler system is capable of saving the life of the occupant in the room and containing the fire in the room. The prescriptive requirement for fire separations is to contain the fire in the room of fire origin or to prevent spread into an adjacent space. The fire separations do nothing to maintain tenable conditions within the room and so are incapable of preserving the life of the room's occupants.

5.6.2 Smoke Detectors

Photoelectric smoke detectors were installed in all the bedrooms, the stairwell and the hallways off the stairwell and on activation alarmed throughout the building.

With the presence of the smoke detectors in the bedroom units, it is expected that the occupants will be alerted to the presence of a fire well before the sprinklers are activated.

Neither the sprinkler system nor the fire alarm system were connected to the New Zealand Fire Service.

5.6.3 Scenarios

Worst case scenarios were addressed for the alternative solution. Each fire scenario was addressed in two parts as shown below;

- a smouldering fire in a bedroom
- a flaming fire in a bedroom
- a smouldering fire in the Sitting Room or Dining Room
- a flaming fire in the Sitting Room or Dining Room.

It was anticipated that these fire scenarios gave the worst case situations for the occupants of the building, in particular the occupants of the upper floor. The location of the fires in the scenarios were chosen to provide a worst case for the occupants on the upper level. This is due to the single escape route from the upper level to the ground level. Smouldering and flaming fire scenarios were presented on the upper floor to show threats to the occupants in the initial stages of the evacuation. A fire on the ground level in either the Sitting Room or in the Dining Room shows the threats to all occupants, especially to the occupants from the upper level during the later stages of their evacuation.

5.7 Installation and Completion

The fire protection installation was co-ordinated with the contractor. With alterations that were taking place the sprinkler piping could be concealed and Bangor Homestead was able to convert into a bed and breakfast operation while retaining its historic nature.

The alternative solution showed that with the installed fire protection features the life safety of the occupants could be maintained with the open staircase and non-fire rated doors.

6 CONCLUSIONS

The three case studies involving alternative solutions by Caldwell Consulting Ltd have shown that it is possible to provide a level of fire protection that not only meets the New Zealand Building Code, but also retains the heritage features of the buildings. With the installation of a sprinkler system many of the fire compartmentation requirements of the New Zealand Building Code can be reduced allowing a more sympathetic approach to fire protection in historic buildings.

A Case for the Preservation of Historic Machinery with Special Reference to Less Appreciated Items as Refrigerated Machinery

William H. Pitt BE, MIEE, MIMechE, MIPENZ

INTRODUCTION

Much early machinery is intimately associated with the history and development of a nation and thus forms a very tangible record of that history and development. It gives as it were a face to history. Once such machinery is destroyed this tangible record is destroyed and is lost for all time and nothing short of the expensive process of replication can in anywise recover it. Even this expedient is only partially successful in that many of the materials and processes used in the original are no longer available. Collections of such machinery have tourist potential. To avail of this potential such exhibits need to be housed and displayed appropriately. All this requires financial resources. A national policy for the preservation of such is then imperative.

SOCIAL HISTORY

The industrial revolution was a vast stride forward in social history. This was, as is generally appreciated, greatly facilitated by the invention of the steam engine. Fortunately steam engines have an inherent fascination for many people and so there is a strong incentive to preserve these as is evidenced around the world.

Greatest ever stride forward in social history was made by the invention and particularly development of refrigeration. This fact is not well appreciated I suspect by the present generation. Not only did this enable an epoch making advance in the development of the economies of our two countries but also of Argentina and the rest of the world for that matter. I have to confess to my own shame that I was until recent years not aware as I ought to have been that this development led to an almost meteoric rise in the awareness around the world of the continent of Australasia tucked away down in the south pacific. Such was the calibre of work donE by and persistence of James Harrison of Geelong in Australia that he received international acclaim.

I have been recently involved in the restoration of the winding machinery and a car and trailer of the original cable car installation in Wellington City which was designed in 1901. This is another interesting example of the impact of engineering input to social development and the preservation in tangible form of that input. You will almost all be well aware that in Wellington the flat land available for building on is very limited and from the turn of the century we have been limited to two choices of building sites, in the harbour or on the hillside. Our colourful politician Robert Semple had not as then driven a bulldozer over a wheel barrow and in consequence modern earth moving machinery was not available to facilitate filling in the harbour so a company was formed to subdivide the hill country immediately behind the city centre and to facilitate access constructed this original cable car. It is of further interest and a valuable record of the development of a nation in that it was designed by one of the first engineers to be fully trained in NZ. From this artefact thus can be developed an interesting facet of the nation's development and the subsequent arising of a branch of a noble world wide profession and from which branch has flowed a stream of Engineers who have made distinguished contributions in the world wide sphere. How many I wonder of our citizens are aware that the Managing Director of the largest steam boiler manufacturer in the world was for many years a New Zealander or that the second head of the Snowy River Authority was a New Zealander. Add to this that NZ have led the world in the design of gold dredges and geothermal steam power stations, not to mention the development and application of refrigeration, and we sense what great achievements originate from humble beginnings. I find that most of our citizens to whom I have pointed out these facts have been totally unaware of them and are amazed. No doubt those of you from Australia have similar exploits to tell of.

TOURIST POTENTIAL

Agriculture in New Zealand, Australia and Britain in particular and in fact around the world has been revolutionised by the invention and development of the agricultural tractor. Consequent upon the fact that we in NZ have only ever manufactured literally one such tractor for sale, we have imported machines from all over the world. Fortunately these are easier to restore and store than large refrigeration machines. Many of these machines have been restored resulting in our having an excellent and very representative collection of these machines. I have visited many such collections around the world and I believe that I can confidently say that we have the finest collection in the world. Albeit not so well or conveniently displayed as in many other countries. This opens up another important aspect of this subject. That is the tourist potential which can provide a very tangible contribution to the financial welfare of the country. On the occasion of the 100th anniversary of the invention of the agricultural tractor at least 4 large rallies were held in this country which attracted crowds of the order of 20000 many of whom were overseas visitors which was quite an achievement.

ENTREPRENEURIAL SKILLS

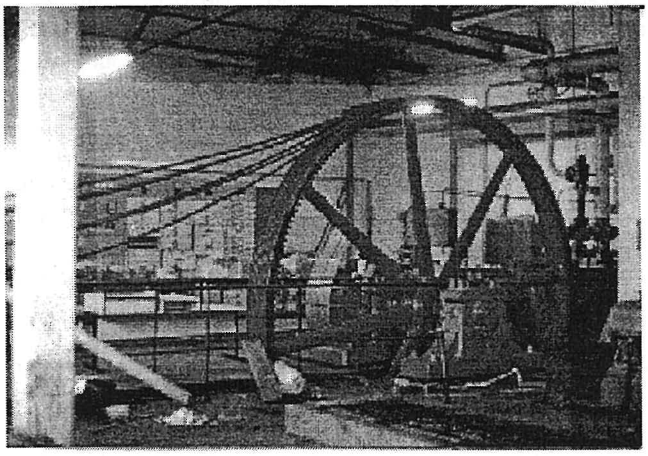
Furthermore these artefacts and their associated history often serve to demonstrate the value and operation of entrepreneurial skills and the value of perseverance. This is particularly so of the history of refrigeration. Harrison was a printer by trade and he observed that when he used ether to clean metallic type it became quite cold. From this observation developed an interest in refrigeration and more especially an appreciation of the great potential that it held for his country's welfare. He and his contemporary Mort in Australia were driven to bankruptcy in their endeavours to help the nation. Many valuable lessons can be brought home from this history, not least of which is to record Government's failure often to properly evaluate enterprises and adequately support and encourage those with potential to advance the national welfare.

COLLECTION STORAGE AND DISPLAY

I believe that the above establishes that there is a valuable national asset in these artefacts and their preservation.

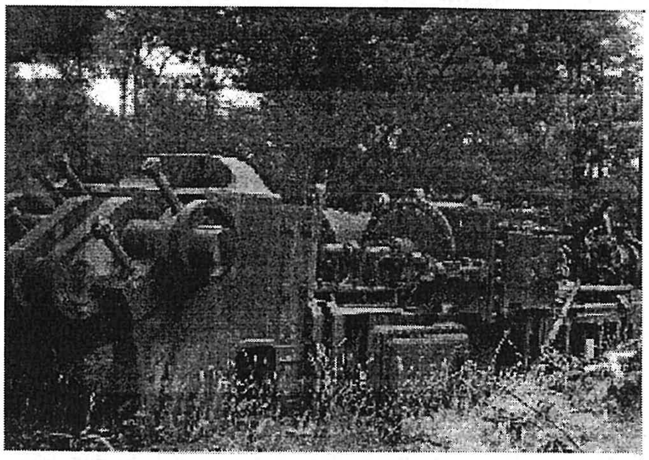
This then raises the consideration of the preparation, collection and storage of these potentially valuable artefacts in a manner that will make the exhibits attractive and accessible. It is also important if their full potential is to be realised that they be displayed to facilitate their use for educational purposes.

Smaller machines and relatively small collections are reasonably easily managed. However if these are to reach their full potential the small collections need to be collected together in convenient locations. Tourists both local and from overseas do not normally have time nor resources for wandering around the country visiting many small and scattered collections. The provision of suitable sites and buildings needs input from local and central government. Some notable collections have been established and well housed in New Zealand. One of these in particular, has been financed I understand by a large bequest. More large bequests would be helpful. A much more difficult problem is presented by larger machines such in particular as early refrigeration machines which are invariably very large and require fairly substantial resources. Illustrations of some such machines are included.



A large machine awaiting housing

Preservation from the ravages of the weather and of vandals is of paramount importance and requires large high stud buildings. The foundations required are often complex and need to be very substantial. All this adds to substantial financial outlays. Smaller and more modern enclosed machines are more easily handled but these are much less valuable particularly for educational purposes. The Lotteries Board and some charitable trusts have been very accommodating and as a consequence a good number of these machines have been preserved by enthusiasts which is most fortunate. An appendix records most of these known collections, our revised national fiscal policies and as a consequence this source of finance threatens to become scarcer. One extremely valuable machine both as a national treasure and as so far as I have been able to date to ascertain an international treasure in so far it is the one remaining machine of its type in the world is rapidly deteriorating in a field in Christchurch.

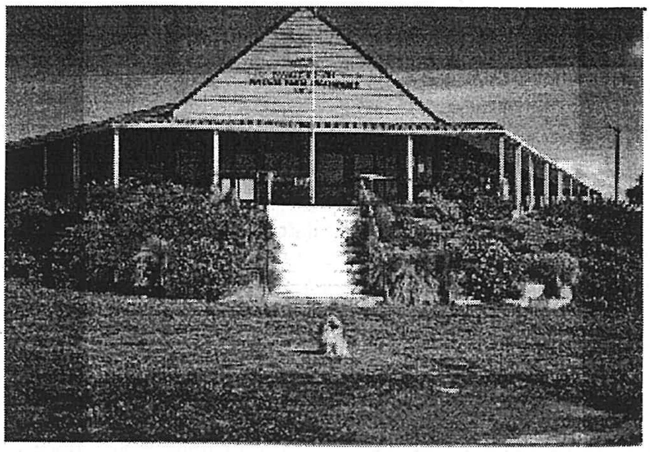


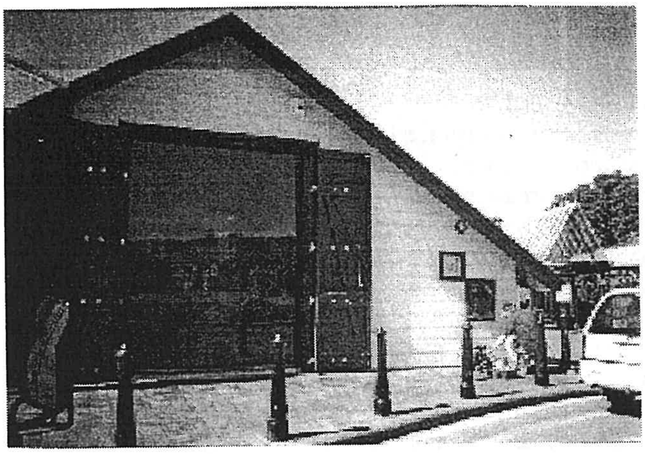
A valuable exhibit awaiting housing and restoration.

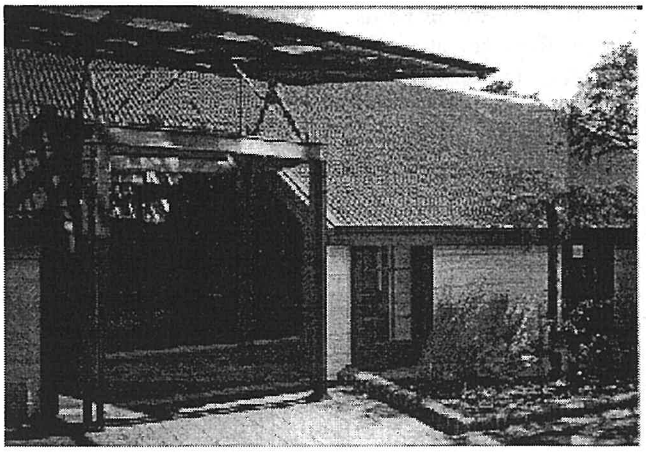
It is a directly steam driven compressor installed and commissioned in 1888 in the fifth freezing works to be built in NZ. It was originally a direct air machine and has subsequently been converted to an ammonia compressor. This machine is deteriorating rapidly and failure to fund its preservation is a national and international disgrace. The organisation which has possession of it at present feel obliged to use all funds that they can obtain to finance projects which have a better potential for earning revenue for the maintenance of existing exhibits.

Displaying this equipment once housing has been provided also needs careful evaluation. Refrigeration machinery in particular though possibly spectacular is rather technical to excite the general public. Thus a museum unless extensive or combined with other displays and in particular more animated exhibits has no hope of being self supporting and able to be kept reasonably continuously open. Nothing is more frustrating than visiting a museum site and finding it closed and there being no opportunity of viewing the exhibits. I wish to make an impassioned plea for viewing windows to be provided so that visitors snatching an odd moment to visit may be able to see a little of the static exhibits.

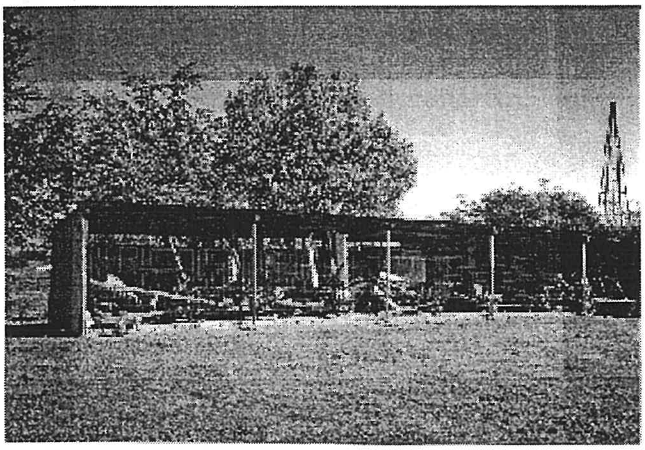
These windows should ideally be combined with internal lighting directed onto the exhibits from above the window. This lighting should ideally be of greater intensity than that immediately outside the window. A coin in the slot meter suitably protected could be provided calibrated to provide a profit for the venture.







An excellent small museum but demonstrating the need for internal lighting.



An excellent museum at Brayshaw Park in Blenheim showing two views of the main building and of a subsidiary building.

ASSOCIATED ACTIVITIES

At present there are no recognised repositories for Historical records relating to historic machinery and engineering achievement. This was highlighted recently in this country when an Engineer of international repute though little known beyond the profession died. He had accumulated substantial and valuable records. His family were anxious to dispose of these and while co-operative, could not wait indefinitely. No organisation or storage facility was available to take these records. In consequence they are now scattered if in fact they still exist. Formerly Government Departments were available with facilities to meet such contingencies but now with privatisation and sedulous intent on profit some provision urgently needs to be substituted. Histories of Engineering enterprises also urgently need attention. A company a few years ago had documented its history almost to the point of publication when it was taken over. Some of this valuable record was accidentally recovered from the local dump. This was an irresponsible action and steps must be taken to curb such.

LEGISLATION

We have had for many years legislation of a sort for the preservation of historical buildings though little if anything in the way of structured financial support. This legislation was recently extensively reviewed and need for financial support established but the state then promptly withdrew a substantial part of the acknowledged inadequate support that had been originally available. Such is good and logical administration?

There is no such legislation for the preservation of historic machinery. The only protection appears to be the Antiquities Act which governs and restricts the export of anything that can be defined as an artefact. This is not primarily concerned with machinery and could only marginally be applicable to such, and in any case can be readily circumvented. If of cast iron take a sledge hammer to it and reduce it to cast iron scrap which can be readily exported and if of steel or timber leave to the elements which will soon dispose of it. This is going on regularly. Legislation needs urgent attention to address this problem. Representation was made at the time of the review of the Historic Places legislation but no action has been taken or considered. Restriction of export or destruction of historic machinery is very desirable but is pointless unless provision is made for funding its preservation.

CONCLUSION

I believe that I have established above that it is very much in the national interest to preserve our Engineering heritage, particularly in respect of machinery. Once destroyed this heritage is lost and so we need nationally to apply ourselves to the problem. Now that the Historic Places legislation has been updated this would appear to be an appropriate time for representation to be made to Government for an urgent review of legislation or lack of it, for the preservation of historic machinery. This must include for the provision of identification of historic machinery of national significance and importance. Some organisation would need to be raised for this function. A register of such machines would need to be established. Some provision should be made for financial assistance to restore and house such machines as are of particular national importance. Local Councils should be required to facilitate the accumulation of scattered exhibits at suitable locations as tourist attractions and for educational purposes. Some Councils have already contributed to such arrangements. Incentives might be devised for companies to establish museums relatives to their past products and very importantly their past histories. The opportunity should be taken to include provision for preservation of historic records also.

Appendix

LARGE REFRIGERATION MACHINES PRESERVED				
MUSEUM	**LOCATION**	**EQUIPMENT**	**HOUSING**	**COMMENT**
Canterbury Steam Preservation Society	McLeans Island Christchurch	Original Haslam air blast machine installed at Islington 1989 since converted to ammonia.	Outdoor, but proposals to house.	At present in pieces and deteriorating. Proposals to reassemble and live steam.
Asburton Railway and Preservation Society	Tinwald Domain near Ashburton	Original Hercules vertical compressor driven by a triple expansion tandem steam engine ex Fairfield, Ashburton.	In enclosed shed. Viewing on open days or by arrangement.	Fully set up and live steamed by temporary connection to one or more traction engines.
Ferrymead Historic Park	Christchurch	Ammonia compressor. Double ball sealed unit.	Open canopy	Static exhibit.
East Coast Museum of Technology	Gisborne	Niven compressor horizontal 14" x 14" direct-driven by electric motor ex Taruhera. Small single-cylinder vertical machine about 5hp. Similar pattern to larger Hercules.	Housed in custom built building and soon to be moved to new complex.	Static exhibit.
Pigeon Valley Steam Museum Society	Wakefield, Nelson	Hercules vertical compressor. 2-cylinder vertical compressor; make not known – ex Picton. Direct driven by two-cylinder vertical steam engine – nicely restored.	Outdoor. Indoors.	Static exhibit. Live steamed regularly.
Tokomaru Steam Museum (Private)	Tokomaru via Palmerston North	Filer & Stowels 1916 compound tandem engine direct driving through common crankshaft. Balls ice maker 16'0" dia. flywheel weighting 13½ tons 355 HP ex Imlay Wanganui.	Enclosed in specially built room with viewing windows.	Live steamed regularly. Can be visited most days.
		Liverpool single-cylinder horizontal compressor direct-coupled to electric motor – ex Longburn	Partly under cover of lean-to.	Temporarily assembled.
		Hercules twin-cylinder vertical crank operated ex Ngauranga.	Indoors storage.	Static. Proposed to be set up with steam engine drive.
		Peter Brotherhood three-cylinder vertical 1929.	Under cover of lean-to.	Electric drive. Static exhibit.
Taranaki Museum of Transport and Technology	Mangorei via New Plymouth	Three-cylinder vertical Sterne.	Not yet provided.	At present in service at Waitara Works. Tentative plans to move to Museum.
Patea Museum.	Patea.	Linde horizontal ammonia. Possibly the original machine. Flat belt driven from an electric motor. Two cylinder vertical Gordon made in Victoria, Australia. Direct driven by electric motor. Two and single cylinder vertical Brotherhood. Direct electric drive.	In ex ANZ Bank building in main street.	Two machines. May be housed outdoors.

Benalla Water Supply

Max.Richards: FIEAust., DipCE, ME, MBS.
Former Engineer Benalla Water Trust

SUMMARY: Development of the Benalla Water Supply commenced in 1882 when the first contracts for provision of water supply were let. All major elements of the original installation remain providing a unique, rare surviving example of a nineteenth century complex. Later additions of new water towers demonstrate changes in water tower design. The complex is also an example of the work of engineers/architects Grainger and D'Ebro. Conservation procedures are explained.

1.INTRODUCTION

Benalla is a small town [pop.14, 000] in Northeast Victoria. Benalla has some fame being the centre of government administration in the time of Ned Kelly, a notorious Australian bushranger. The town is sited on the banks of the Broken River and the original water supply was drawn directly from the river. As the town grew and the demand for water increased, a reliable and secure supply was required. Eventually the river was abandoned as a source of supply and reservoirs constructed with a pipe supply to the town.

By fortunate chance most of the original elements were retained leaving a historical record of water supply development.

The paper describes the original system, subsequent improvements and preservation measures.

2. THE ORIGINAL SYSTEM

Prior to 1882 water was carted from the river. In 1881 agitation commenced for provision of a reticulated water system for the town. The Benalla Water Trust was formed in 1882 and architects and engineers Grainger and D'Ebro were contracted to design and arrange for the installation of reticulated supply to the town.

Grainger and D'Elbro were responsible for many engineering works at that time. It is an interesting side issue that Grainger was the father of the noted composer Percy Grainger.

Contractor Glenross erected a water tank, pumping station and pumps in Riverview Road adjacent to the Broken River. Mains were constructed by Grainger and D'Ebro, and connections by contractor Woolf. Testing took place in March 1883.

An engineer's cottage was erected at the pump station.

3. OVERVIEW OF THE SYSTEM

The original system drew water from the Broken River just upstream of the town. A steam driven pump was used, although a search or available records has failed to determine any details, except that the pump capacity was 16,000 gallons per hour. In 1893 a new plant was installed saving 2.5 cords of wood per week [and saving 100 pounds per year.]. The power sources and pumps were interconnected to allow alternate operation. Apart from the pump house the pumps have been removed. A Mr P.Rebbechi was appointed pump engineer in 1889 and served in this position until 1939. He was followed by his son Mr A.Rebbechi who retired in 1970, providing 81 years of continuous service from the one family. The minute books record that in 1913 after 23 years of service Mr Rebbechi requested an increase of his salary of 6 pound per month.

The second tower was added in 1893 providing additional capacity and head to serve the growing town.

Power was installed in Benalla in 1922 and connected to the state grid in 1924. A new pump was installed in 1929 delivering 136,0000 gallons per hour.

In 1935 a 100,000 gallon [454,600 litre] concrete tower was added providing additional head and capacity. [Total cost 3200 pounds]

The Broken River proved to be an unreliable source of supply in periods of drought. In extreme situations staff were required to pump from water hole to waterhole to maintain some supply. A reservoir was first suggested in 1892, however half a century was to elapse before circumstances forced positive action The Trust purchased land in the Toombullup Ranges on the Upper Ryans Creek and between 1940 and 1945 constructed a 680 megalitre dam to provide a reliable supply. Initially water was transported via the river system until the pipeline system was completed in 1950.

19km of 300 mm CI pipeline was constructed from Loombah Reservoir to a 14 megalitre service basin at

Kelfeera situated 10 kilometres from Benalla. A 375 mm CI pipeline connects the service basin to the water tower.

Supply from a relatively protected catchment considerably improved the quality and quantity of water of water available.

Later additions included [in progressive order]

- 63/64 375 mm CI main Loombah to Kelfeera
- 68/69 low level service basin in Benalla 4.5 megalitre
- 71/73 construction of second reservoir further up Ryan's Creek 1,100 megalitre
- 79/80 second low level service basin 10.3 megalitre
- 92/93 600 mm wrought iron main Kelfeera to Benalla [decommissioning of low level service basins and concrete tower]
- 98/99 filtration plant at Kelfeera Service Basin

3. THE WATER TOWERS

Fig 1 The original 1883 tower with blacksmith shop under

The original water tower is a 6 metre diameter riveted iron tank with bellied base. Twelve iron columns with stylized papyrus capitals support the tank and stand on brick piers with bluestone caps. A facetted brick blacksmith's shop with conical sheet metal roof and radial ties is situated at the base. The blacksmith's shop is fitted with a forge and bellows. The tower was completed in 1883 and is of 40,000-gallon [182,000-litre] capacity. At the meeting of the Water Trust held on the 6th Feb 1883 it was reported that the tank was full. However there had been teething problems as the tank had some leakage and at the first fire up the pump station ran out of wood.

The second tower was erected in 1893 and has a capacity of 40,000 gallons [182,000 litres]. The tower has a riveted steel tank with bellied base and mounted on twelve I-section columns with lateral and cross ties. The tower was opened with a celebration on Monday 22nd May 1893.

Fig 2 The second tower 1893

Following the growth of the town and the limitations of the existing system it became necessary to increase the head and capacity of the tower. In 1935 a new 30 metre high concrete tower was constructed with a capacity of 100,000 gallons [454,000 litres]. The builders were Haundstraup and Co and the total cost was 3200 pounds. The official opening was on the 7th Oct 1935.

In the vicinity of the water towers, a number of the original brick depot buildings remain including the smithy's shop, carpenter's shop and pump house. The pump house is still operational and maintained in case of an emergency. Equipment includes a vintage switchboard, Crompton Parkinson electric motor [45 b.h.p.] and Thompson centrifugal pump.

The pump is maintained for emergency use and was last operated following the record 1993 floods, after floodwaters fractured a supply pipeline.

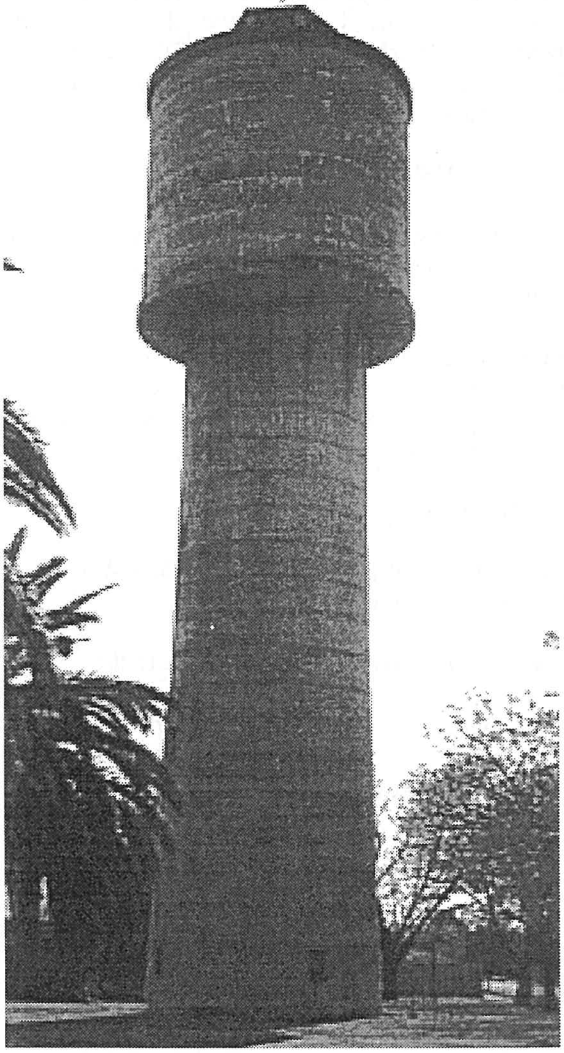


Fig 3 1935 Concrete Tower

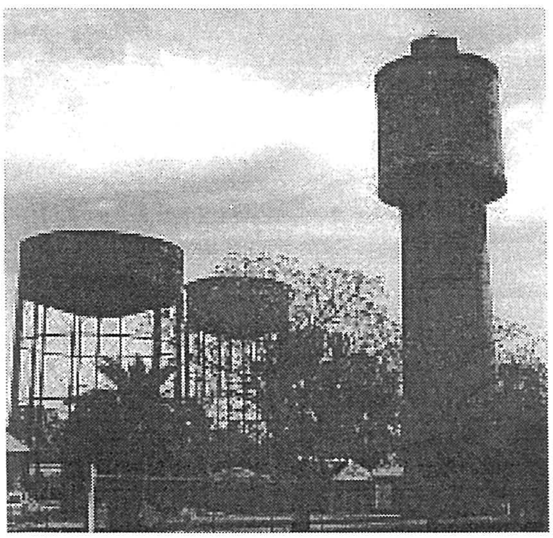


Fig 4 The three towers

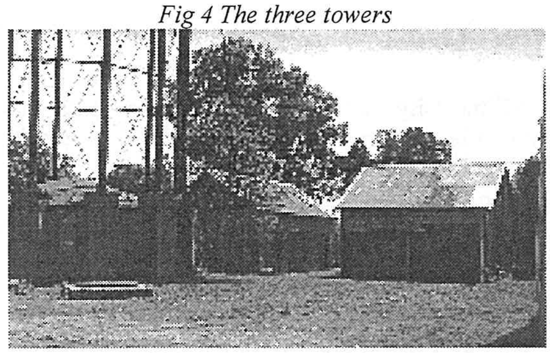


Fig 5 The original complex consisting of blacksmith's shop,carpenter's shop and pumphouse

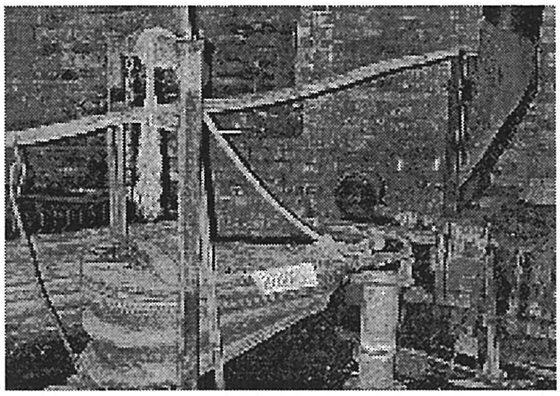


Fig6 Blacksmith's forge

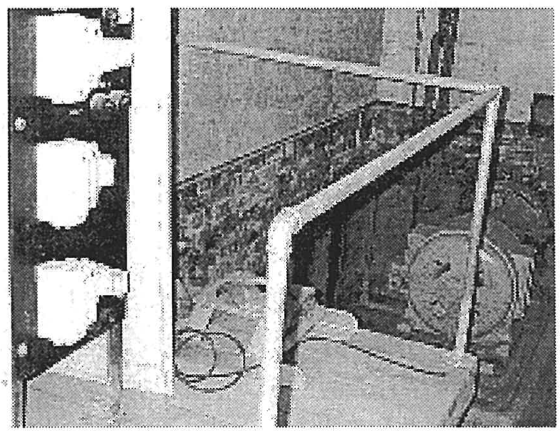


Fig 7 Switchboard, pump and motor

4. CONSERVATION

In 1992 the City of Benalla undertook a conservation study of the City to document significant historic and architecturally important buildings, sites and areas in the city. The Architectural Historian for the study Mr Andrew Ward identified the Benalla Water Supply Depot as an important element of the City's heritage.

The citation for the depot was as follows: ***Significance:*** *The Benalla Water Supply Depot is important at the State level as a rare surviving nineteenth century complex of its type with iron water tower, smithy's shop, carpenter's shop recalling early pipe construction practices, and pump house. It is important for the manner in which it demonstrates changes in water tower design since the early 1880's. The complex is important also at the State level as an example of the work of noted engineers/architects Grainger and D'Ebro, who also designed freezing works, power-generating plants, and water works at Wangaratta [D'Ebro]*

Following the recommendations of the study the complex has now been included in the register of the National Estate [Australian Government Registration] and the Victorian Historic Buildings register. These two registrations recognise the National and State importance of the depot. Planning protection is provided in the Council planning scheme where the complex is listed in the Heritage Overlay. The purpose of this control is to conserve and enhance heritage places of natural and cultural significance.

It is fortunate that the depot remains relatively intact as in the late 1980's proposals were mooted to sell the unused towers. Both the Council and the water authority [Northeast Water] are now aware of the heritage value of the site and any proposals for alteration can receive appropriate consideration.

5. CONCLUSION

This paper describes the Benalla water system and heritage assets. The measures to provide protection have also been outlined.

Engineering heritage assets may have been overlooked in the past but appreciation is now being given to the skills of our predecessors and examples of their work are being preserved for future generations.

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Engineering The Old

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Summary *Old buildings, our architectural and engineering heritage, are subject to many risks. These buildings have value, and the need to upgrade them without diminishing their intrinsic value requires a co-ordinated effort by architects and engineers. Structural upgrading which ensures a building is safe in a seismic event but which destroys much of its heritage fabric is not a satisfactory solution. It is proposed that it is possible to seismically upgrade and at the same time minimise the deleterious effects such strengthening can have on a building. This paper submits that this is achievable without destroying the architectural or heritage value and without generating a number of other building performance-related problems.*

Two recent strengthening projects are examined to show how inappropriate decisions have lead to serious degradation of interiors as a result of seismic strengthening. This experience has shown that while the engineering solution may have addressed the structural problem the solutions chosen generated serious water penetration problems. In any building, very few engineering problems can be regarded as just engineering problems - there is invariably an architectural consideration.

INTRODUCTION

There seems to be general agreement that preserving old buildings is worth doing. There is a value placed on historic structures and places which goes far beyond the rudimentary capacity of commerce to compute their monetary worth, reminding us that the very concept of value is much broader than our political representatives would have us believe. The preservation of historic buildings is driven by two goals - those of life safety and of retaining the building as an artefact.

Historic buildings speak to us of the passage of time, give a sense of where we come from and, for many, a comfortable - and comforting - sense of permanence in a constantly changing world. Also, there is a mute recognition - or at least suspicion - that not all new buildings are all that well designed or well made, and that they exclude and intimidate by their design and detail. It is, in fact, in matters of detail and finish that old buildings are most widely appreciated. This is partly because of that quality of use and age which is so easily discerned in the fabric of an old building - what is often called "patina".

We now build structures which have a greater prospect of surviving the slings and arrows of outrageous nature. We have a far greater variety of building materials and sophisticated decorative materials which have inspired great inventiveness in modern architectural design. The formal variety made possible by technological development is exhilarating and enriching.

We are all beneficiaries and victims of the processes of time. Let us dispose of some illusions: Old buildings in New Zealand were not invariably built by ancient craftsmen in leather aprons who lovingly wrought each detail by hand.

Most buildings were then, as now, the product of industrial technology. In the 19th century, however, technological development and industrial growth evolved remarkably in New Zealand - a country which had been settled by Europeans only five or six decades earlier. The building industry benefited also from the ready availability of relatively cheap labour. We know that our forbears squandered the vast natural wealth of this country, using up a supply of timber which, if it had been well managed, could have supplied the needs of the building industry for generations. All the more reason, perhaps to cherish what has survived.

The difficulties of preserving historic buildings are well recognised. The considerable heritage of timber buildings is always at risk from fire. The smaller - but still substantial - stock of masonry buildings - especially in central areas - is always at risk from a known threat of seismic events. These risks are recognised in statutory instruments such as the Building Act, which places an obligation on building owners to reduce that risk to occupants by strengthening and by introducing fire suppression systems. The beneficial outcomes of either of these processes can be offset by their effect on the very qualities for which the building is valued as an historic place. This is a recurring conundrum which has contributed in the development of many special and innovative technologies.
The reality is that it is pointless to employ measures to protect an historic structure from external threats if the interventions themselves effectively destroy it. Hence, it makes no sense to apply engineering solutions - however dependable or sound - which are inherently destructive of the very features for which a building is valued. It is, therefore, essential to apply

a high level of reflective design to the process. As architects, we are inclined to suggest (arrogantly) that the structural design of heritage buildings is too important to be left to seismic engineers. We also incline to undue optimism about the absolute need in some instances for structural intervention. I am, however, increasingly conscious of the need for professional humility in the face of clear evidence of an enduring risk of earthquake in all parts of New Zealand.

Equally, it is important to understand the effects of any intervention on the overall fabric of a building and to comprehend a building as something akin to a balanced organism, where any change to one part is likely to affect the rest. The risks of ill-considered interventions are considerable and have a bearing on not only the way in which the building performs its intended purpose, but also its ability to carry out the rudimentary functions of keeping its inhabitants dry and warm and its capacity to do all this at modest cost over time.

All this points clearly to the need for a multi-disciplinary approach to the protection of historic buildings. The engineer has a key role in these circumstances to identify the nature of the risk and to quantify this risk in a way which enables an owner to make prudent judgements. In making a judgement, the owner (and also the regulator) has to take account of other factors, including the threat to human safety, cost, potential damage to structure, and the effect on heritage or architectural values. While human life must always be paramount, I am reluctant to accept this as a justification for a course of action which may be ultimately destructive to the building itself, or to its important features. As I have said above, what is the point of destroying these to preserve the building itself. I do not suggest by this that in some way these cultural or social values outweigh human safety, I simply assert that it is not necessary to destroy the one to achieve the other. Good solutions are, inevitably, achieved through accomplished design decisions, inventive problem solving and the application of sound building practice.

EXAMPLES

I wish to develop this discussion by reference to a number of recent examples involving the strengthening of historic or institutional buildings to resist earthquake damage. Two are from the Auckland area where the risk of a major event is least but nonetheless real. The third is from Christchurch, where the risk of earthquake is appreciably greater.

The degree of risk is not, however, a significant factor in developing an effective structural solution. The essential lesson of these examples is the value of a multi-disciplinary approach to such design where heritage buildings are concerned.

Former Auckland Synagogue - Princes Street, Auckland

This building is remarkable for a number of reasons - technological, social and architectural. Built in 1886, it is one of Auckland's oldest surviving concrete buildings, made of unreinforced mass concrete with rendered exterior and solid plaster interior. The interiors are notable for the use of hand painted stencils on ceilings, columns and arches. Prior to adaptation in 1988 to its present use as a bank, the building had been leased from Auckland City as part of a small inner city theatre. It had suffered from very low maintenance and had been subject to chronic gross water entry.

The principal conservation problems were to restore the integrity of the weatherskin, to provide an acceptable level of seismic strength, to make alterations and additions for the intended banking use and to restore the very fine architectural finishes, including a spectacular elliptical staircase. The design solution neatly accommodated all these objectives.

Structural design by Holmes Group was based on the introduction of new sprayed concrete shear walls, in conjunction with diaphragms in the ground and first floors and at roof level. The new elements were carefully detailed to blend with original finishes and, whilst readily identifiable on close inspection, are otherwise imperceptible within the restored interior. In order to include a shear wall in the stair well, the elliptical stair was removed, restored and reduced in width by 150mm to accommodate the shear wall.
The wider importance of this project was that it demonstrated how conservation of an important heritage building, including seismic upgrade and introduction of modern services could be sensitively accomplished as part of a commercially sound development.

Otahuhu College

This South Auckland secondary school is one of several in Auckland which have been upgraded to improve the resistance to earthquake. The building is of concrete frame construction with brick infill panels incorporating a veneer weatherskin. The structural solution was to secure vertical unreinforced elements such as parapets to the structure by bracing through the tile roof covering to the primary structure, and to grout fill the veneer cavity in order to adhere the external single wythe skin back to the inner panels.

The result of this activity was to provide numerous small points of water entry where bolt connections to original structure had been placed without any attention to weathering. Poor attention to detailing and to contract management resulted in a great many failures of basic building features such as gutters, rainwater heads and flashings. The grout filling of the cavity provided an almost perfect water bridge from the external veneer skin to the interior. Consequently, since completion of the work, internal walls have suffered from chronic growth of efflorescent salt crystals and associated paint loss. This is an instance of solving one problem while creating a legacy of chronic water entry problems.

Christchurch Arts Centre - the Great Hall

It is now some years since this building was modified to improve its seismic strength. This was a difficult building based on a large primary space enclosed within high buttressed perimeter walls and featuring a very large stained glass window in the north gable wall. The structural solution is based on post-tensioned cables on both the inner and outer face of the exterior walls. The cables have the advantage of very small bulk, but the distinct disadvantage of being completely intolerant of any architectural feature which obstructs their path.

No consideration appears to have been given in the structural design to the location of these cables in a manner which would have avoided important architectural features in the interior. Consequently, projecting moulded elements in stone and timber were crudely sawn to provide slots for the cables. As the cables were tensioned, the inaccurate alignment of the saw cuts meant that the lateral pressure of the cables under tension broke off adjacent sections of moulding.

CONCLUSION

The thesis of this paper is modest but important - that buildings which are valued for their architectural and social significance, but which are structurally deficient by the standards of modern seismic engineering, require the highest level of reflective design in the development of solutions to strengthen them. This is best achieved through the cooperative efforts of the engineer and the conservation architect.

While there are important issues of aesthetics and architectural form and detail to be considered, the best solution is always going to be one which is readily capable of being implemented with minimum damage to historic building fabric - a practical solution. Currently available technology makes this more than ever possible, but such technology is only part of the solution.
It is of equal importance that all members of the design and construction teams are aware of the significance of the building, and that this awareness permeates the design philosophy, influencing overall strategies and detailed problem solving. Construction methods and contractual arrangements should be those which do not result in collateral damage to the building, whether through lack of awareness of the significance of the building or through lack of concern for the outcome.

The challenge for the engineer and the architect is to introduce new systems to resist earthquake loads in a manner which is at best invisible, and at least unobtrusive, so as to ensure a continuing useful economic life for a building which is valued by the community. The challenge for the project team is to achieve the twin objectives of life safety and meaningful conservation in a way which does not cause irreversible damage to those elements which exemplify that value.

The Hoffman Brick And Tile Company, Melbourne, Australia

R B Sandie, F.I.E. Aust. and B J O'Neill, F.I.E. Aust.

Summary : The Hoffman Brick and Tile Company, Melbourne, Australia, pioneered the use of continuously fired brick kilns in Australia in the 1870's. Part of the works continued in use until 1993. The site is now to be redeveloped and contains the last 19th C brick kilns in Victoria and some old buildings and brick making machinery. Some heritage components are to be preserved as part of the redevelopment. This paper outlines the historical significance of the site and the condition of the remnants, concludes that preservation of some components is important, and discusses some engineering and commercial problems associated with their preservation.

1 INTRODUCTION

The Hoffman Brick and Tile Company is historically important because it pioneered the use of continuously-fired Hoffman brick kilns in Australia and was one of the first users of mechanical brick presses. It helped change the Melbourne brick industry from one of many small scale producers to one of a few highly mechanized large firms.

The company was established in 1870 on a 12 acre (4.9 hectare) site in Brunswick, a Melbourne suburb. It expanded in the land and building boom of the 1880's, when it acquired 36 adjoining acres (14.6 hectares). The original site and much of the second site was sold for land fill and redevelopment during this century but 3 hectares continued in use for brick making with imported clay until 1993. Three large Hoffman kilns, the oldest built in 1884, and a number of early buildings, the most notable being the brick pressing building complete with brick presses, remain relatively intact. The kilns are the only remaining 19th century examples in Victoria and are listed on the Victorian Heritage Register.

The site has now been acquired for residential redevelopment. The O'Neill Group Pty Ltd has been appointed as engineering consultants for the first stage of the project and, as part of the brief, has assessed the condition of the various structures on the site and advised on the work needed to preserve or recycle them.

2 THE HOFFMAN CONTINUOUS FIRING KILN

For most of human history, brick making has been a low technology industry, with bricks being fired in small kilns using a solid fuel, usually wood or coal. Such kilns have poor fuel efficiency and small output but are cheap and simple to construct and are still used in third world countries.

In 1859 Hoffman and Licht patented a continuously fired kiln in Germany, (Searle (1)), which became universally known as the Hoffman kiln. Hoffman kilns had greatly improved fuel economy and output but were much more expensive to build than the conventional small kilns of the time. The operation of Hoffman kilns is described in some detail by Searle (1). An outline follows.

The earliest kilns were circular in plan, with an annular firing space arranged around a central chimney to provide draft for combustion. The firing space was notionally divided into 12 firing chambers, each of which had its own opening in the outer wall to load and unload bricks and its own exhaust flue to connect it to the chimney. Bricks were fired in 4 or 5 of the chambers on one side of the kiln, at temperatures in excess of 900°C, whilst already fired bricks were removed from the other side and replaced with unfired bricks. The fire front burnt continuously around the kiln at about 150mm/hour and completed a circuit in about 12 days.

In 1870 Hoffman patented an improved and larger version of his kiln, elliptical in plan, which incorporated two straight sections joined by semi-circular ends to accommodate up to 24 firing chambers. Most of the kilns constructed on the Brunswick site were of this later improved design. A typical cross section is shown in Figure 1 with further details in Figure 2.

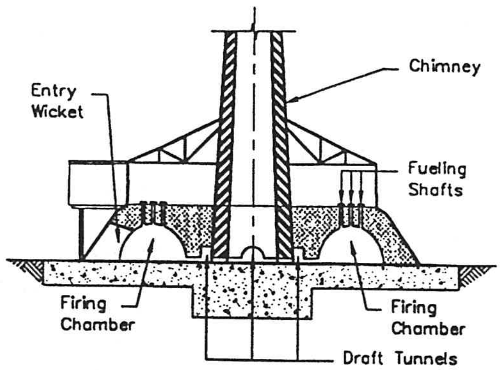

Figure 1 Kiln Cross Section

In operation, a temporary wall was installed between two adjoining final chambers as shown in Figure 2. Outside air was admitted into the kiln through one open wicket, also used to remove fired bricks and replace them with unfired bricks. All other external wicket openings were closed off. The air then flowed around to the chambers being fired, on its way cooling already fired bricks and being heated up itself. After combustion, the hot exhaust gases were directed further around the kiln, using the flue system, controlled by

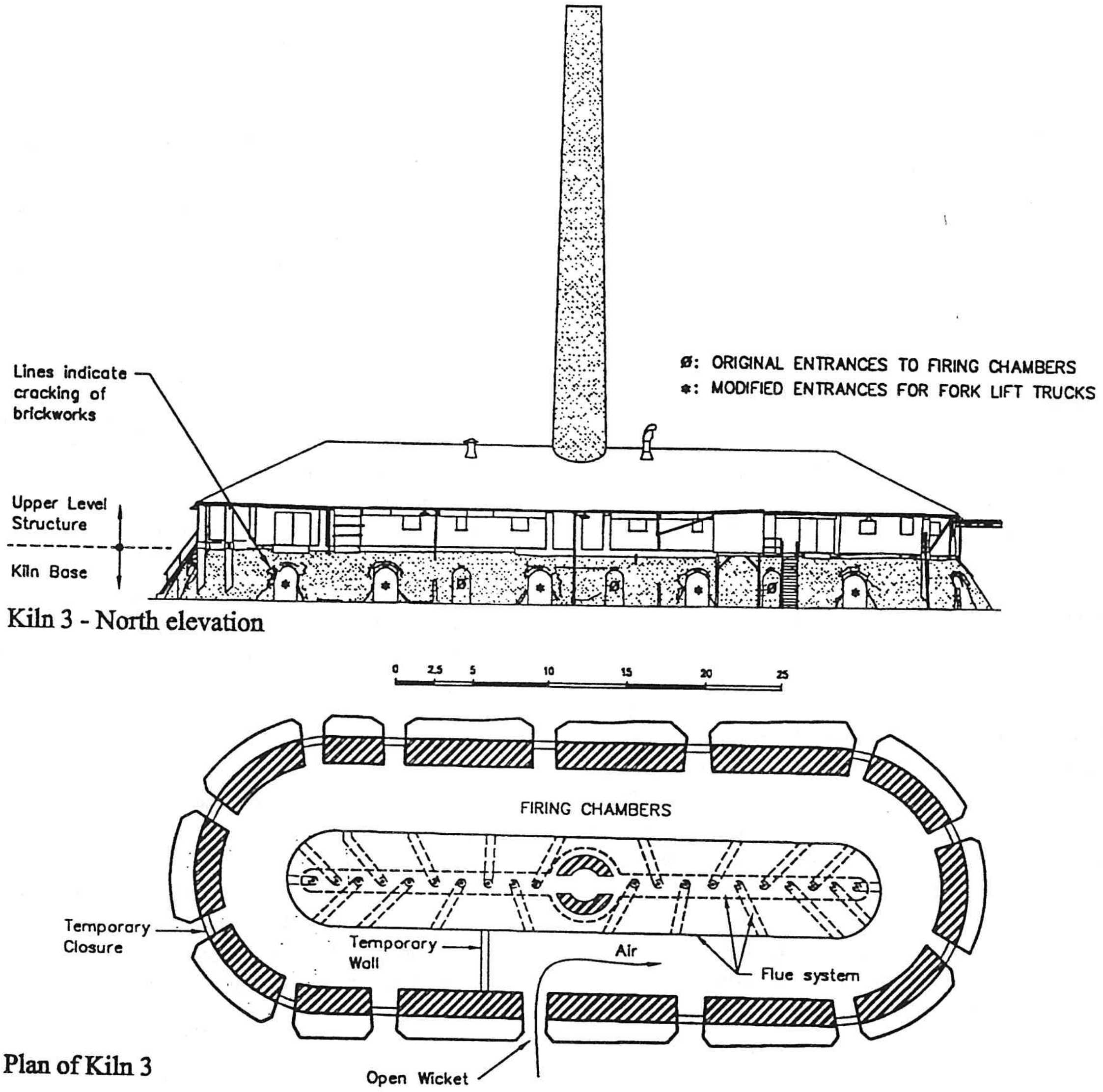

Figure 2 Details of Kiln 3

dampers, to control the flow. The hot gases dried and preheated the unfired bricks, before escaping up the chimney, heavily moisture laden and at temperatures down to about 150 °C. Combustion was maintained by dropping coal down into the firing chambers through small shafts in the top of the arch-roofed firing chambers. These shafts were kept capped except when being used. When the open chamber was full of unfired bricks, the partition and the open wicket were moved along by one chamber and the sequence was repeated, so the cycle was continuous.

In later developments, the rates of advance of the fire front were improved, to be in excess of 300mm per hour and, in this century, some kilns were oil or gas fired.

3 REVIEW OF SITE HISTORY

The history of the Hoffman Brick and Tile Company in its various forms is given in some detail by Stuart (2). An outline is given here to help put the significance of the site into context.

The Hoffman Patent Brick and Tile Company was formed in 1870 by three Melbourne businessmen, Barry, Collier and Owen, who had no apparent prior experience in brick making, although Barry and Collier were builders and engineering contractors and users of bricks. The company acquired a 12 acre (4.9 hectare) site in Brunswick, about 5 kilometers north of Melbourne's central business district. Because of extensive clay deposits, brick making was already an important local industry, with over 40 small scale brick makers in operation.

The new company entered brick making on a considerably larger scale than its neighbours and with a considerably larger capital investment. A two-storey building was erected to house a 25h.p. steam engine to operate a grinding pan and an English "Bradley and Craven" brickpress, probably the first such in Australia. A 12 chamber circular Hoffman kiln was erected, when such kilns were still novel in Britain, from where Australian industry obtained much of its technology.

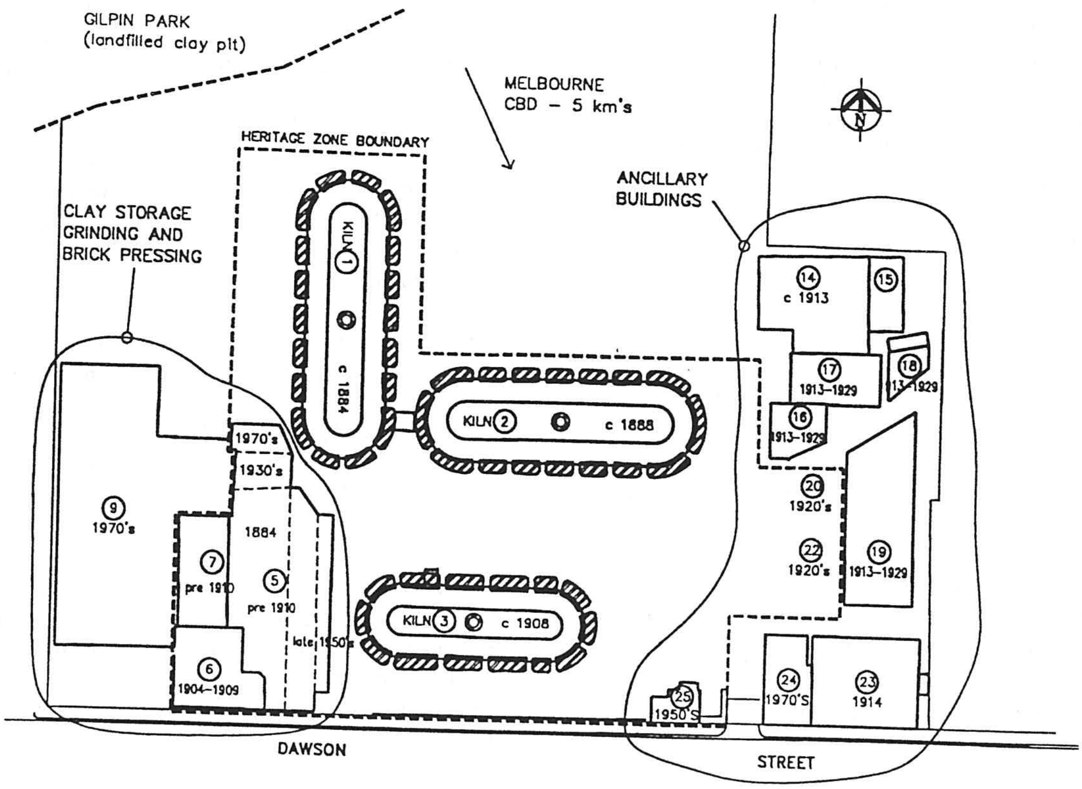

Figure 3 Site Plan

Despite some early production problems, particularly with the brick pressing machinery, by the end of the first year of operation the company was selling about a quarter of a million bricks per fortnight and held about 15% of the Melbourne market. Two large oval Hoffman kilns were erected in 1871 and 1875 and additional brickpresses were installed. By 1878 brick sales were at 30,000 per day.

Demand for bricks was high in Melbourne in the 1880's because of a land and building boom which saw 40,000 houses erected in the decade and the company further expanded. In 1881 Hoffmans floated as a limited liability company and in 1884 restructured as the "Hoffman Patent Steam Brick Company" to better compete with the new Northcote Brick Company. The company purchased 36 adjacent acres (14.6 hectares) in 1884 to form No 2 works, the remnants of which still exist and are shown on the site plan in Figure 1. The firm also expanded into sewerage and sanitary ware.

In 1885 Hoffmans erected an early Foster tunnel kiln on No 2 Works, when such kilns were in their early development phase. The kiln was not a success and was replaced by a Hoffman kiln in 1888.

The depression of the 1890's vastly reduced demand and brick prices plummeted. Late in the decade Hoffmans joined a co-operative of other large manufacturers to fix prices by controlling production.

In the early 1900's Hoffmans commenced manufacture of tessellated roof tiles and moved into pottery production with Bristol and Langley ware. For the first 30 years of the century demand for products fluctuated and no new works were undertaken until 1931, when electricity replaced steam power. In 1932 Hoffmans introduced Melrose decorated pottery, with an emphasis on Australian decorations, which was very successful and boosted sales. The second World War diverted resources and man power away from brick making and Hoffmans declined. No 1 works closed and the site was sold in 1948.

After the war, there was a high demand for bricks but most brick manufacturers had old equipment and a shortage of skilled staff. In the 1950's Hoffmans' major competitors installed new plant and built tunnel kilns whilst Hoffmans stayed with its original plant. In 1958 the clay pits on No. 2 site were sold for landfill and in 1960 Clifton Bricks acquired the company and continued production with clay brought to the site. In the 1960's the kilns were converted to burn oil and in the 1970's the grinding plant was modernized and the kilns converted to use gas. Several kilns remained in use until 1993.

It is ironic that the company, after such a technically innovative start, eventually went out of business because it could not compete with the latest technology, particularly tunnel kilns, with which it had experimented in 1885.

4 SITE AND REMAINING STRUCTURES

The remaining Hoffman Brickwork site at Dawson Street, Brunswick, Victoria is three hectares in area and abuts onto the former clay pits, which have now been filled with landfill, capped and formed into parklands. (Gilpin Park and Clifton Park). The suburb of Brunswick, which is only five kilometers north of the Melbourne Central Business District, has historically been a working class area with a reasonable amount of heavy industry. However in recent times, with the relocation and demise of much of the heavy industry including Hoffman Brickworks, the area has become much sought after for residential renewal. It is close to the city and the University of Melbourne and to several major parklands and has attracted many of the young and the newly affluent as residents.

The buildings and structures remaining on the site have not been used for some years and fall into three groups, as shown in Figure 3.

- The three Hoffman Brick kilns and chimney structures (Kilns No 1, 2 & 3)
- The buildings associated with the storage, grinding, mixing and pressing of the brick making clays and materials (Buildings 5, 6, 7 & 9)
- The ancillary buildings at the south east of the site, commonly of two storey construction, used for offices, pottery making and a variety of related activities. (Buildings 16, 17, 18, 19 & 23)

5 RECENT GEOTECHNICAL INVESTIGATIONS

A geotechnical investigation of the site was undertaken in 1995 to establish foundation conditions for existing structures and for possible new buildings. The underlying materials were found to be Tertiary sediments, predominantly sandy clays and clayey sands with a high plasticity index (up to 45%) and a high shrinkage and swelling potential in the event of soil moisture content changes.

A further complication revealed by the investigation was that, within about 30 metres of the kilns, firing over more than a century had warmed, dried and shrunk the underlying soils to a considerable depth. Bore hole samples from near the kilns were noticeably warm down to 10 metres. The effects of soil shrinkage were obvious in the kiln structures, where the brickwork had deformed and cracked, apparently over many years.

With the cessation of firing in 1993, the soil near the kilns was in the process of slowly wetting up and swelling. Soil heaves well in excess of 100mm were predicted near and under the kilns. This effect decreased away from the kilns and disappeared more than 30 metres away. The wetting process was predicted to be slow and extend over at least 12 years.

Because such substantial movements of the ground have serious implications for the stability of both existing and new structures, a further supplementary geotechnical investigation was carried out in 1998, in an effort to establish how far soil rewetting and consequent soil swelling had progressed.

Soil moisture content is a prime indicator of soil rewetting, so soil moisture content was determined at various depths in a row of bore holes drilled along a line at right angles to kiln 2. Unfortunately, although the results confirmed general trends, they were too variable to permit the rewetting process to be precisely quantified. The variability was attributed to uneven rewetting of the soil due to differences in site drainage conditions along the line of holes, including the effects of paving and of inoperative kiln roof drainage.

The results did indicate that the upper levels of soil outside the kilns had rewetted, down to 6 metres in some locations. Outside the kilns the process is probably about two thirds complete, but further swelling movements of up to 75mm at the kilns can still be expected, reducing to about 15mm at 20m away from the kilns. These heaves should be substantially complete by 2005.

These movements need to be taken into account in repairing existing structures and in designing new structures. For new structures this is normally done by providing foundations strong enough to resist the movements or by erecting flexible structures which can accommodate soil movements without distress.

6. CONDITION OF THE EXISTING STRUCTURES

Prior to the completion of the Conservation Management Plan, The O'Neill Group, Consulting Engineers, undertook a structural appraisal of those buildings and structures which were proposed for retention.

The O'Neill Group also reviewed the work needed to restore the structural integrity of the buildings and commented on the suitability of some buildings for a change of use (eg to office or residential use).

6.1 Kiln Structures and Chimneys

The three kilns are of similar construction to that shown in Figures 1 and 2, with a substantial brick base structure containing the arched firing chambers, an upper level firing floor with a galvanized iron roof where the fuel (coal and later oil and then gas) was introduced and the flue dampers controlled, and a tall central chimney. From a heritage viewpoint it had previously been decided that kilns 2 and 3, including their chimneys, were to be retained and that kiln 1 could be demolished except for the chimney and part of its base structure. As outlined in Section 5, the long term drying out of the moderately reactive clays beneath the kilns has resulted in significant and, to an extent, uneven settlements of the kiln structures, causing widespread cracking of the brickwork. It is interesting to note that, despite the extensive ground movements, the three chimneys have been relatively unaffected.

The kilns to be retained (1 & 2) are in a similar structural state, which can be summarised as follows.

- The base structures are extensively cracked, with replacement brickwork used to repair the more badly affected areas over the years. The unevenness of the brickwork coursing is very apparent. The entrances to the kilns are a combination of the original well-formed brick arches and enlarged entrances modified to accommodate fork-lift trucks. In situ concrete lintels have been used to support the brickwork above the modified openings and there is extensive brickwork cracking in these areas.

Our investigations into the kiln base structures concluded that, despite the settlement, racking, cracking and loose brickwork, overall these base structures are structurally sound. This is not unexpected as massive masonry arch structures of this kind are a very robust structural form and can tolerate considerable cracking and movement without collapsing. However, whilst the kiln base structures are stable, two areas in particular require attention. The first is the brickwork and concrete lintels over the modified entrances and the second is the extensive interior fire-brick lining to the arched firing chambers. Whilst this lining is stable overall, there are areas where the brickwork is loose and, without attention, isolated bricks are likely to fall from the ceiling.

- The upper section of the kiln structures originally consisted of perimeter walls of single leaf brickwork with engaged piers supporting oregon roof trusses. The roof truss system was additionally supported on a central row of columns, which also supported pulley mechanisms which raised and lowered steel dampers for the flue system, used to control the intensity of the firing process and direct hot gases to preheat unfired bricks.

  Due to foundation settlements and firing stresses, much of the upper perimeter wall brickwork has cracked or become unstable over the years and has been replaced with galvanised sheeting. The remaining brick walls to the upper section are badly cracked and damaged to an extent that they are now unsafe. Even if rebuilt in their original form, they would be incapable of satisfying current Australian Code requirements for wind and earthquake loading. The existing timber trusses and purlins can be largely preserved but will need replacement of some elements and additional bracing and propping. Considerable areas of galvanised roofing need to be replaced.

- The three chimneys are of brick, and are in excess of 30metres high. Chimneys 1 and 2 are reinforced by a series of horizontal steel bands over most of their length, presumably installed to resist vertical cracking due to heat expansion. Chimney 3 has bands only at the top. Chimney 2 has a steel flue projecting 4.5 metres above the brickwork presumably added later to improve the draft. The lower few metres of each chimney are surrounded by a flue and by rubble fill placed below the level of the firing floors. During firing the chimneys received hot gases from two large flue systems which run the length of each of the kilns and which are in turn connected to cross flues venting from the main firing chambers. The gases entered each chimney through two arched opening below the level of the firing floor and on opposite sides of the chimney, where the gas flow was controlled by raising or lowering steel damper plates which sealed off the arched openings.

From visual inspection of the outside, the brickwork of all three chimneys is complete, with no missing bricks. At firing floor level, some fine vertical cracks in the outer bricks are present. Differences in mortar colour indicate some repairs to similar cracks in the past. It is likely that thermal expansion during firing was the cause of this cracking.

A photogrammetric survey was used to check chimney vertically and showed leans at the chimney tops of Kiln 1 : 46mm south east, Kiln 2 : 266mm north, and Kiln 3 : 164mm to the north east, with a reported survey accuracy of ±.50mm. Since the original accuracy of construction of the chimneys is not known, the leans cannot be entirely attributed to foundation movements. These leans have been taken into account in checking overall chimney stability but make little difference to the results.

The chimneys were individually checked for structural adequacy, applying the load combination requirements of AS 1170.1 – Australian Loading Code. The following results were obtained:-

- All three chimneys are stable under the action of wind loads, and wind load stresses are relatively low.
- Chimneys 1 and 2 are stable under the action of earthquake loads.
- Parts of Chimney 3 do not satisfy overall stability requirements for earthquake loading by about 6%, but can be regarded as satisfactory due to the conservative requirement for stability in the Code.

6.2 Storage, Grinding and Brick Pressing Buildings (Buildings 5, 6, 7 & 9)

The brick making process commenced at the south-west area of the site, where the brick making clays and other materials were stored, ground into a powder and transported by conveyors to the upper level of the main brick-pressing building (Building 5). At the upper level the ground clay compound was distributed by a north-south horizontal conveyor system into nine large hoppers (which are still in place). Presumably water was added as required, since five water tanks are located along the east wall of the upper level.

From the hoppers clay was discharged into massive brick presses located at ground floor level below each hopper. The nine brick presses are still in position. The "green" pressed bricks were then transported to the kilns for firing.

Building 7 is a relatively modern, steel portal frame building used primarily for clay and material storage. It is of little historical significance and will be removed. Building 9, which is between buildings 7 and 5, previously housed the massive clay grinding machinery. Building 9 is in extremely poor structural condition, probably dangerous, and will also be demolished.

It is the intention to retain Building 6 which was a plant room later used for storage, with high solid brick walls and a galvanised iron roof supported on timber beams and timber trusses. This building is of minor historical significance and is suitable for conversion to a more intense use with the introduction of additional suspended floors.

The most interesting building in this group from an historical and structural perspective is Building 5. The original first floor of this building was constructed to take high loads of the order of 20kPa (the loading imposed by 2 metres depth of water). It consists of 28mm thick tongue and groove pine floor boards supported by 295 x 95m oregon floor joists at varying centres (typically 520mm or less). The joists are in turn supported on large square oregon beams (290 x 290m) with spacings varying between 2500 and 3150m. The main beams are supported by 290 x 290mm oregon columns with capping blocks. Whilst the above description of the first floor structure gives an indication of what the original system may have been throughout, the structure has undergone numerous major modifications over the years. These modifications have included:-

- Cutting columns through to remove sections for the installation of machinery, and then repairing the columns by splicing with steel connecting plates and additional timber.
- Removal of many of the original columns and replacement with a diagonal propping system, parts of which are now missing.
- Lateral displacement of columns to accommodate equipment.
- Removal of the bottom of a column to accommodate machine drive belts, with the column load picked up by horizontal and diagonal beams or by an extra length of column beside the original.

It appears that joints in the main timber beams were originally intended to occur over columns but the removal or shifting of some columns at a later date has resulted in some joints now occurring in the middle of beam spans, spliced by oregon capping blocks which contribute little to the bending stiffness and strength of the beam.

Various attempts appear to have been made to stiffen the floor system and/or to correct excessive beam and floor deflections, including the installation of:-

- Steel splices in the middle of beam spans.
- Diagonal beam props, as previously mentioned.
- Additional timber columns.
- An extended beam over a column cap.
- Additional steel beams and columns.

As a consequence of the many modifications to the floor structure and the big variations in column spacings, the load capacity of the first floor is extremely variable, with certain sections limited to only 1.5kPa for deflection and 2.5kPa for strength, about one tenth of the original strength.

The existing remaining first floor structure is probably an example of the ad hoc methods undertaken by workers to accommodate new machinery and changes in layout and, as such, is historically interesting. It appears that certain beam corbels, additional columns and the like were introduced to stop the impending failure of sections of the structure (or possiblly after failure had occurred).

The roof of building 5 is galvanised iron supported by timber purlins resting either on rafters along the eastern side of the building or on oregon timber trusses over the central section of the building.

The trusses are mostly intact. There are several with missing diagonals and timber vertical members which run alongside vertical steel tension ties which are still in place. Computations indicate that the trusses do not satisfy modern code requirements for wind loading in their present form and condition.

A number of miscellaneous timbers intrude into the roof truss space in between the trusses and the tops of the hoppers, used mainly as braces for the conveyor system. These are not part of the roof structure and, depending on what is to be retained in the upper level, some or all of these would be removed.

7. RESTORATION AND REUSE

7.1 General

The Hoffman brickworks at Brunswick has been recognised as a place of historic, cultural and scientific significance to Victoria and Australia. As a consequence it has been recommended that all future conservation or development of the historic precinct (See Figure 3) should be based on the Australian ICOMOS Charter (The Burra Charter) (Reference 4). Conservation is required to be carried out with preservation given the highest priority followed by restoration and reconstruction as the lowest priority.

Conservation of sites of this kind, however, requires considerable initial capital expenditure in order to restore the buildings, structures and the machinery and further additional annual funding to retain in good condition the restored buildings and structures within the precinct.

In the case of the Brunswick brickworks, whilst some external funding and heritage grants are available, the majority of the funding will need to be provided by the owner/developer as part of the funding for the total development of the site. Because the site is in private ownership, a Conservation Management Plan has been developed aimed at:-

- Conserving and maintaining the building and structures within the historic precinct.

- Finding appropriate uses for the historic buildings to allow access to and recognition of the historic aspects and at the same time generate income to ensure the project is commercially viable.

- Creating a sensitive and integrated residential precinct in the areas immediately outside the historic zone.

The extent and nature of the work involved in the preservation, restoration and rebuilding of the historic structures can be summarised as follows:-

7.1.1 Chimney to Kiln 3

As previously outlined, Kiln 3 is to be demolished with the exception of the chimney and a small amount of the kiln structure at the base of the chimney. Whilst the overall safety of the chimney to Kiln 3 has been checked and is satisfactory, there is a need for a detailed assessment of the condition of the bricks, mortar joints and the presence of cracking in order to specify any restoration work that may be required.

7.1.2 Kilns 2 and 3

Kilns 2 and 3 are in a similar structural condition and will require the following restoration work.

- The base structures containing the firing chambers will require a reasonable extent of exterior brickwork to be reconstructed, particularly at the enlarged wickets, where replacement of some of the concrete lintels will also be required.

- Repairs to the fire brick lining to the arched firing chambers are needed. Whilst these linings are largely intact, it will be necessary to check the entire area for loose brickwork and develop a repair method using grouting or epoxy resin injection to satisfy the safety requirements to allow general access to the kilns.

- Extensive areas of the external walls of the upper sections of the Kilns require replacement. Whilst the original walls were constructed of brickwork, the rebuilding of these walls in this manner is not recommended due to anticipated future movements of the underlying clays. Moreover the rebuilding of these upper walls adopting the original single leaf brickwork with engaged piers would not meet current structural code requirements for stability under wind and/or seismic loading.

- The strengthening and replacement of existing timber members in the oregon roof truss system. Whilst for heritage reasons the timber roof trusses should be retained, new bracing systems will be required in the plane of the bottom chords and roof anchorage will also be needed to satisfy modern code requirements for wind uplift conditions.

- Extensive areas of roof sheeting need replacement in addition to new timber purlins in may areas.

The chimneys of Kilns 2 and 3 also require a detailed assessment of the bricks, mortar joints and the presence of cracking.

7.2 Brick Pressing Building

The Brick Pressing Building (Building 5 in Figure 2) requires extensive restoration work. Despite having remained standing since early this century, its external walls, roof supporting structure and bracing need, in addition to extensive repairs, modification to comply with current wind and earthquake loading requirements. This is partly due to the various alterations made to the structure over many years and partly because of more stringent requirement in modern codes.

The restoration of building 5 will include the following:-

- Major repair and strengthening of the first floor and supporting columns. The floor structure and columns have been extensively altered and modified over the years and, whilst it is the intention to leave many of these modifications to indicate the evolution of the manufacturing process, it is also necessary to ensure the adequacy and safety of the conserved structure for future use.

  The form of the strengthening will depend on how much of the present character of the building is to be retained and how many of the interesting but structurally poor alterations are to be preserved.

- The replacement of the sheeting to the upper walls and roof and improvements to bracing, truss joints and connections between members. It has been recommended that a completely a new roof system be installed, which could be lined and insulated.

  If the original upper structure is to be preserved, the most cost-effective rectification procedure is to dismantle and then rebuild the upper section.

- New walls along much of the west side of Building 5, along the east at ground floor level and on the north. It has been recommended that new walls should be designed around the entire building, in conjunction with the proposed new work on the upper level. The new walls should incorporate adequate bracing for the building.

- Additional measurements to satisfy the design requirements for lateral stability of the building in an east-west direction.

8. CONCLUSIONS

Because of the pioneering role played by the Hoffman Brick and Tile Company in introducing continuously fired brick kilns to Australia in 1870, the 19th C kilns and associated buildings and equipment still remaining on site have significant heritage value and some components are worthy of preservation.

The preservation of such large artifacts and their integration into a redeveloped site presents some difficulties and challenges which, at this point in time, have not all been resolved. These include how to overcome some unique foundation problems, to ensure the ongoing safety of the structures, the extent to which changes can be made without destroying their heritage value and how to balance heritage and commercial requirements, or more plainly, how to pay for it all.

At this stage it appears that a private owner can produce a successful outcome by extensive consultation with all the stake holders and by obtaining sound professional advice.

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Seismic Resistance: Heritage, Architecture and the Post-colonial

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The necessity to incorporate earthquake strengthening in historic structures is a factor affecting many nations as they embrace 'heritage' culture. Strengthening guidelines tend to be globally orientated at a time when local cultural, geographical and geological conditions are being explored. In this paper, politics of preservation and conservation are questioned for their appropriateness to a particular place and building. A design project is offered as a means by which the preservation of a heritage building, in the emerging post-colonial culture of New Zealand, becomes a sign of resistance to internationalisation. It concludes by showing how resistance can reconfigure the history of a land that has been subject to continual imposition and dominance of global/colonial ideas and policies, without critical adaptation by the local.

INTRODUCTION

Post World War 2 building in New Zealand saw an expansion of multi-storey structures, essentially not dissimilar to that in other European/North American cities. Many structures were composed of square columns, thin slabs and glass walls. Some, such as Rostrevor House in Wellington, were constructed through an inventive building method known as lift-slab construction, pioneered in this country by Australian entrepreneurs in the late 1950's. Rostrevor House's other notable characteristic is its references to *Maison Domino*, a building that has become emblematic of the International Style. Le Corbusier's vision sought to generate an architecture geographically and culturally non-specific to its place. Modernist ideals in the form of manifestos and theories, were designed to transcended all social and cultural barriers. They were exported to New Zealand, one of the 'second world' settler cultures that comprised colonies, dependencies, dominions and commonwealths. Said (1) states that after World War 1 roughly eighty-five percent of the world was held this way. It is against this background that modernism was 'comfortably' exported.

However, such architecture in a colonial situation is now being challenged through post-colonial theory and practice. Colonial culture is being shaken by political upheaval, just as local earthquakes are shaking global architecture. However, when architecture is placed in a vulnerable location, one that is about to be shaken, physically by earthquakes, and culturally by political upheaval, seismic strengthening also becomes a sign of resistance.

The design proposal adopts particular tenants of post-colonial discussion as a means of articulating what form this resistance takes. The proposal oscillates between embracing and critiquing the pioneering spirit of New Zealand building, the historical assimilation of Modernist construction and aesthetics and, the institutionalised political perspective of international conservation guidelines.

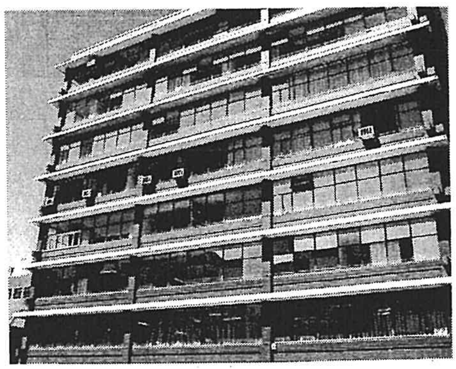

Figure 1 Rostrevor House

CULTURAL BACKGROUND

This paper explores resistance in relation to the white settler attitude epitomised by 'making-do,' an unrefined cultural attitude that accommodates the ordinary and crude, together with a prevalent phenomenon known as 'kiwi ingenuity.' In examining a particular building in this manner, the paper does not attempt to construct, revalue or reiterate an indigenous history, but to recover a Second World settler attitude resulting from a neo-colonial imposition. And since the country has yet to fully sever its ties to the Empire and Britain, this discussion is made knowing that intellectually it is feasible to move beyond colonialism and its ideologies in order to mount a counterattack or critique. Central to this position is an understanding that the West has a "deplorable record of simultaneously denying the existence of any worthwhile history in areas that it has colonised ... and destroying the cultures that embodied that work," Childs and Williams (2).

Post-pioneer colonial settlement brought with it building types shaped by European familiarity, though a material translation from stone to timber was necessary for their production. Of the colonial buildings erected, many have reached an age such that conserving them is necessary for either documenting early settlement patterns, and/or for their cultural significance, particularly when threatened by decay, abandonment, demolition, and most certainly, earthquakes. The way these buildings are preserved effectively re-presents them to the nation. The manner of this re-presentation is a fundamental concern of this discussion. What political statement is made when buildings are preserved and re-presented as our heritage? How might the process of preserving be used to write a new message?

This proposal takes seriously the challenge to avoid another act of simply transporting cultural images from one place to another without their necessary transformation and transgression. New Zealand also has a cultural and political profile that is being shaped primarily by two cultural groups, the white western settler/*pakeha* and the indigenous Maori/*tangata whenua*. Shaw (3) discusses how The Treaty of Watangi signed by the British Crown and the tangata whenua on February 6th 1840 upholds this cultural and political relationship. This treaty confirms New Zealand as an official bi-cultural country.

Consequently, the country's building stock includes culturally imposed edifices that are currently being challenged by the new politics afforded post-colonial countries, as they wrest themselves from the grasp of the 'mother nation,' come to terms with globalisation, and examine their culture as both pre, post and neo-colonial organisms. In their current practice, conservation and preservation simply may become false mimetic signs of inauthentic historic values and influences, an effort to represent a past that never occurred.

One of the concerns when preserving a building in New Zealand, especially in the city of Wellington, is the provision for resistance against earthquake damage. In the 1980s all 'at-risk' buildings were required to be seismically upgraded or torn down. Mayor Michael Fowler used his authority to implement this policy, with the result that it spurred a significant wave of redevelopment in the city and established Wellington as the most progressive earthquake-responsible city in New Zealand. Owners of buildings absorbed either the expense of the refurbishment or that of demolition. Many chose the latter, and hence many structures of possible historic value were lost to the bulldozer because of economic reality - it was far cheaper to demolish and redevelop than to upgrade. The capitalistic imperative was a clear factor. Any strengthening that did occur was often buried within existing surface thickness or added in such a manner that it did not intrude on the visual appearance of the interior or exterior.
This remains the predominant practice today: strengthening is hidden. However, new seismic strengthening guidelines that integrate technical and design criteria for architects and engineers are being developed. Unfortunately there currently exists very little awareness from either building profession regarding the existence or application of international guidelines such as ICOMOS (4) (International Charter for the Conservation and Restoration of Monuments and Sites), and those of the national, possibly more influential governing body, the New Zealand Historic Places Trust. This body is currently changing from a nationally based organisation to a regionally based one. This shift is interesting in light of this paper's discussion on regionalism.

When international guidelines are adopted in earthquake prone countries, their application can become an uncritical act, one that accepts the premise that the value judgements made in one cultural context are relevant and appropriate for another. These international guidelines are meant to be instigated globally despite the tremendous difference amongst current cultures and historical events. When one prepares to renovate a historic structure of modern architecture, these guidelines reveal their own version of colonial importation. Their criteria and guidance clearly privilege architecture of First World countries where civilisation dates back to antiquity. The guidelines seem to assume that historic buildings are made of solid load-bearing walls rather than slender, transparent minimal structure. Further, visual integrity takes precedent over structural integrity.

One difficulty facing an emerging post-colonial, or Second World country concerns the application of guidelines primarily drafted for more ancient building structures within a European, or First World, heritage. When buildings are preserved as clean, respected and beloved architecture they tend to assume a false sense of importance, or at least one alien to their surroundings. This amounts to a double displacement- first that of the original importation of 'mother country' skills and building types to a settlement on the other side of the equator, and secondly, the re-edification of that power by the imposition of preserving those architectural artefacts for historic posterity. How then, do these matters impact on the refurbishment of an existing Modernist building? How does the design engage contemporary cultural and theoretical issues, recent technological innovations in engineering, materials and construction, and still maintain the unspoken professional agreement to respect and propagate contextually sensitive attitudes towards cultural heritage upheld by the Commonwealth?

The project described below renovates a building in an effort to address its vulnerability to earthquakes and to foster its contemporary identity. Both design interventions are figured as strong forms of resistance. The project recalls a colonial heritage and deconstructs that memory while rejecting the formal and aesthetic concerns of the canon of modernism responsible for creating it. The project revalues a local architectural condition of crude, 'make-do,' in a manner that reveals the fragility of the existing structure, and its geological and cultural inappropriateness.

THE PROPOSAL

Rostrevor House (Figure 1) is representative of a number of frame buildings that require seismic upgrading. It distinguishes itself from a number of similar buildings, not by its intrinsic value as a notable piece of city architecture, but by its building construction process and its obvious structural fragility. Despite being built in 1962, it actually qualifies for historic status. It is testimony to the irony that faces all works of modern architecture from that vintage– that their age is not indicative of their value. It does not need earthquake strengthening in order to preserve its beauty, but because it is in danger of falling down. Strengthening is an imperative prompted, not by aesthetics or historical integrity but by a cultural attitude towards building deeply ingrained with economies of material, labour and money, and concern for the preservation of human life.

many instances such innovations were implemented without physical testing research. While lift-slab construction may have perpetuated a crude but innovative version of the International Style in a Second World, it also edited this image by virtue of its rough and ready detailing. In this case, details are blatantly exposed. The inexpensive construction process neglected to imitate the sophisticated detailing of the original. Modernist work of the International Style in Europe and America uses finely tuned detailing to cleanse the space and situation of noise that would obstruct the sculptural work of architecture. Rostrevor House, like many examples of imported Modernism, adopted the economic advantages of the image without understanding the correspondence between refinement and intention. Detailing is simply mechanical fastening or material adjacency resulting from the need for a building to withstand gravity. There is no elaboration after the form work is removed.

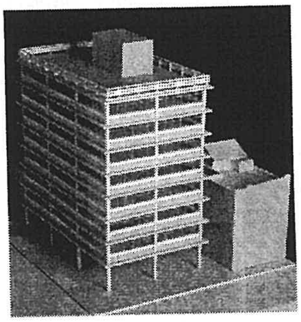

Figure 2 Model of existing building

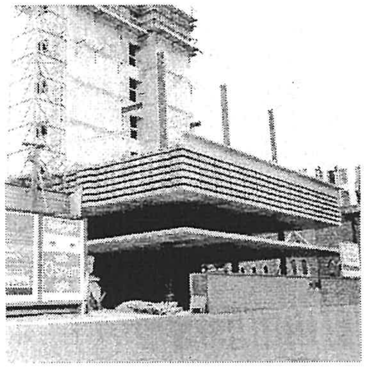

Figure 3 Lift slab construction in-progress
© Joe ten Broeke, 1964

Rostrevor House (Figure 2) is a eight story high rectangular building standing well above its adjacent and even more distant neighbours. Apart from a high ground floor, the elevation is regular, and so is the plan, defined by two structural bays 6.9m wide, and by three 8.1m bays long. Reinforced concrete is the predominant construction material except for the ground and first floor columns consisting of steel box tubes encased in concrete. As a consequence of its lift-slab construction technique, the shallow post-tensioned flat slab floors that were originally cast one on top of another at ground level, are now chocked in place up the columns by steel pins. After jacked to datum and chocked, cast in-situ perimeter upstand beams post-tensioned between columns form the earthquake and wind load moment resisting frames (Figure 3).

The fact that this construction process exemplifies the local enthusiasm for adopting innovative technologies, especially if they reduce building cost, labour and use of materials, is notable to this discussion. It also documents the fact that in

Like many buildings of the same era, Rostrevor House was designed prior to the enlightened yet demanding 1976 seismic requirements contained in *NZS 4203:1976* (5). In the searching light of this Code and its subsequent revisions, the building's fragility is exposed. It is designed for a low load level, lack's structural ductility, and its seismic performance is impaired by strong eccentrically placed 'non-structural' walls. It also has several building configuration defects known to be problematic in damaging earthquakes; a soft storey, short-columns caused by partial height in-fill walls, weak columns and strong beams, and torsional asymmetry. Detailed study of reinforcement detailing would probably reveal other problems expected in a building of this vintage. In the understated language of the New Zealand Building Code, this is an 'earthquake prone' building.

The building's fragility and immediate need for strengthening led to a revisitation of the common ways in which damaged structures are temporarily shored and propped-up. While memories of such propping conjured up tectonically random and chaotic images, reference books depict a very orderly, rational and logical procedure for dealing with structures on the verge of total collapse. It was noted that the rational aspect of the shoring was actually a reflection on the rationality of the original structure (Figure 4). A new version of mirrored geometry was at play, in which timber braces, struts and buttresses envelop, separating the building from the street and public. Using a generous amount of the surrounding land for shoring, props are installed as physical vectors of triangulation. They prevent it from collapsing into an unsheltering material mass, and restate an agreement between building and gravity. The props are a sign of that resistance.

The prominence given to the fully exposed external propping evidences a means by which architecture could be strengthened without being hidden within the building's fabric. As bracing was situated on the exterior of the building, the earthquake strengthening became a dominant and expressive external garb, one announcing the building's fragility, but also promising its stability through the prowess of architectural technology and design (Figure 5). In one sense, the scheme respects the original conceptual intentions of the building: to provide maximum space and view with minimum structure and material. Intentionally, the method by which the strengthening pays homage to this ideal, obfuscates the existing 'pure' exterior form with an amelioration of structural props. The simplicity of the idea and the directness of its inspiration corresponded to building in a straightforward manner. However, their arrangement is not straightforward, and they are deliberately placed asymmetrically in plan and elevation.

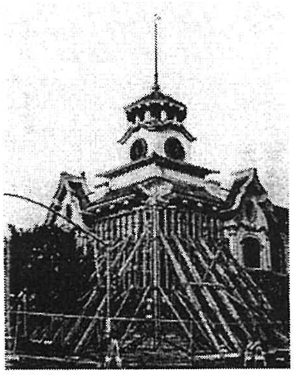

Figure 4 Propping an earthquake damaged building
copyright permission still in progress

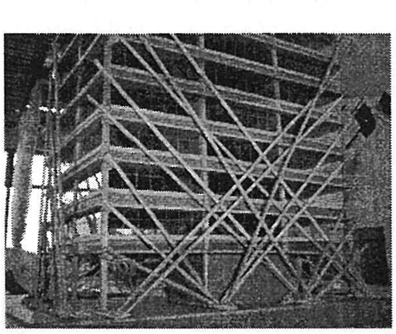

Figure 5 Propping against the face

While the bracing proved to be an effective advertisement of the building's vulnerability, it lodged the team's position about the role of historic refurbishment and renovation in the city. The design was clearly developing in ways that questioned the relevance and sanctity of the Historic Places Trust and ICOMOS Guidelines as active political and cultural agents. Particulars of this building were forcing issues to the forefront. Moreover, the desired random arrangement of the props was tempered in relation to our research on shoring, and the effect the props would have on the streetscape and interior view. Construct-ability and structural considerations had to be undertaken in relation to any theoretical position offered. One form of rationality (born out of the global and abstract notion of universal and regular building systems), became wrapped with another form of rationality deeply indebted to the local craft of pioneers and everyday means of construction. Earthquake strengthening as resistance, acquired an architectural voice of representation outside of engineering problem-solving.

Surprisingly, structural analysis revealed that it was not necessary to completely cloak the building in these odd regulating lines but to prop the building on three sides. The diameter of the props was set at the most slender that structural studies showed sustainable, 200 mm. Such slenderness was made possible by the inclusion of ductile fuses incorporated into the end sections of steel tubes. As a filigree screen, the props provide building resistance. The existing 'historic' body abides beyond the props. Form work, false works and earthquake shoring coincide with 'kiwi ingenuity.' As the design was further developed, three significant details emerged: the shoe (ground level foot-ware), the clamp (upper level head-ware) and the bow tie (mid-level neck-ware).

DE-TALES

The following discussion of the three primary details supports the Frascari (6) mode of construing as the means of imbuing poetic content into construction. If regarded as narrative, these details deter a linear reading or mere image-consumption of cultural heritage. Rather, they translate various culturally charged characteristics attributed to and claimed by New Zealand. They do not shirk the presence of popular culture nor do they avoid the literal use of metaphor commonly residing in Maori and South Pacific culture. They do not hesitate to combine the pioneering settler attitude towards building with the demands of contemporary society for finely crafted artefacts. These details welcome the advances in earthquake technology, and what Thai (7) calls the incoherent contributions resulting from globalisation.

The shoe

At the base of the building anchoring the props are gathered as a number of solid tapered masses, that we described as 'shoes' (Figure 6). They occupy the peripheral zone of the site, taking up a two-metre set-back currently used for car parking. Their arrangement is controlled by the angles and forces in the poles, making each unique. Marble chip surfaces and concrete wedges overlaid with steel plates, suggest a refined version of the rubble commonly used to anchor traditional shoring props. Stainless steel pins are used to visually anchor the wedges, reiterating the shunting of wooden stakes at the ends of temporary scaffolds. The props join the shoe by way of a fuse, a device used in earthquake technology to facilitate structural ductility. To commemorate this technological 'ankle,' the prop is inscribed with a series of ringed markings- a tattooed arm or charm bracelet. This detail epitomises the nature of traditional shoring and relays its structural principles.

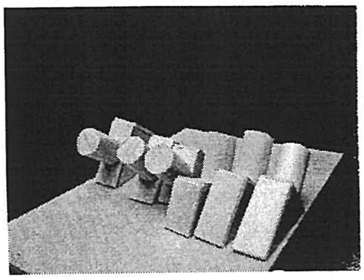

Figure 6 The shoes - concrete wedges shoring props

The clamp

Long, slender steel props stretch from their well-shod heels across the building face, spanning anywhere between one and eight floors. Their surface is marred and scratched to impede glare and reflection, whilst referencing reusable standard scaffolding. In shoring, props are normally positioned perpendicular to a wall, but in this case the props lie normal, positions commiserate to the structural needs of resisting earthquakes. The image of propping has been borrowed and offered back in return, not as a copy but as a critical interpretation, unique to the situation. Each prop terminates at the outside corner of each floor slab where it is clamped and pinned (Figure 7). The scale of these details is larger than life, larger than necessary to perform their structural function. They are of exaggerated proportion in order to be seen from several stories below, but more so, to reinforce the message of the building's fragility.

It was not possible to prop in the manner of shoring, by jamming or notching onto wall-plates. Further, the acuteness of their angles in relation to the boundary line was too great. It was necessary to design a method of fixing that accounted for each pole's unique angle in three-dimensional space. While the clamp and the prop are permanently fixed to ensure their effectiveness as seismic strengthening, their architectural expression emphasises the temporary. These details are far more aesthetically conscious than formwork or shoring on any building construction site. The clamps that latch and the shoes that wedge are reminders of cultural inheritance and revealers of the imminence of earthquake activity.

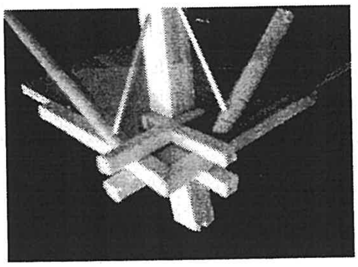

Figure 7 The corner clamp - anchors prop to building

The bow tie

Along their lengths the props are tied back to the building face by a detail we called the 'bow tie.' Designed to prevent buckling, these 'bow ties' stitch the external steel props into the existing concrete frame. This detail grew out of an appreciation of the New Zealand use of native flax or number 8 gauge wire to bind and tie things together. Twisted strands of stainless steel rod and cable are anchored to the existing slab by bolts and eyelets (Figure 8). The cables meet the props via a loose stainless steel sleeve that has anchor points. The technical challenge of this detail proves to be a theoretical challenge as well. These bow ties regulate a fixed position but at the same time allow for movement in the direction along the prop. While the stitching technique has origins to the method of lashing proper neckwear, the detail indicates a revision of resistance.

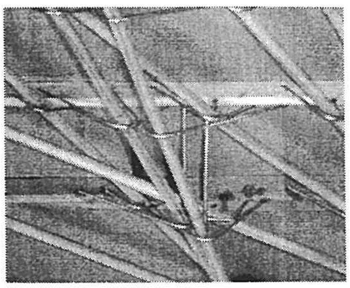

Figure 8 The bow tie - prevents buckling

CONCLUSION

This paper has explored the way global guidelines, for the strengthening and preservation of historic buildings, can be interrogated and used for political means. It has debated the local and global implications of international guidelines and their subsequent interpretation or adaptation to the local. Further, it has questioned the adequacy of historic guidelines to assess a breach in the valuation of architectural history. This proposal registers a turning from that which we have called modern to something that hovers as a hybrid of globalization, technology and regional/site specificity.

Not least of all, this design proposal enunciates the potential that seismic upgrading has towards the re-presentation of architectural ideas and issues. Unlike most strengthening schemes, this design resists the practice of hiding strengthening in order to preserve the visual integrity of a building.

This paper has taken a position of resistance, not against Modernism and the International Style, not against its importation into Commonwealth or Second World countries, and not against traditional definitions of regionalism but towards a revision of how resistance reconfigures that history and re-presents it in a post-colonial situation. The approach taken to the design and its technological development opens a space of struggle. Since the local also inflects unavoidable global practices, regionalism is supported as a composition of unpredictable variants of difference.

The latticed props offer a new means of imaging an aesthetic that has broken with the tradition of modernism.

The crude and the 'make-do' is revalued and re-presented to voice an architectural protestation of an imposed and inappropriate structure. This is a political action that is not measured by decay or armed violence but a passive resistance against continued imposition and dominance of global ideals and policies without their critical transformation by the local. It sees the demarcations of new territories and languages of identification. The props act like writing on the wall: a sign of resistance.

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Early Suspension Bridges in New Zealand

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SUMMARY: The period covered is from 1840-1939. Many suspension bridges were built for foot, horse, and sheep traffic, as well as others for light wheeled vehicles. Economy dictated this form, especially in rural areas, to meet the needs of settlers and gold miners. Fast flowing rivers and also deep gorges required single spans with no mid-stream piers to be washed out by frequent floods. By the late nineteenth century the multiple rope (cable stayed) bridge was in favour. Timber construction predominated last century, followed by stone, steel, and concrete for towers. The epitome of fine design was in the all-steel suspension bridge of the 1930s.

1 INTRODUCTION

England's early suspension bridges originated in 1820 using wrought iron rods and hangers, and in USA the first wire rope bridge dated from 1816. In both countries suspension bridges were regarded as important for very large spans, but were less common for very modest bridges. In New Zealand they were popular as simple footbridges, as well as for light vehicles, especially in rural districts.The obvious advantages were: (a) Suitability for a single span over the many deep gorges and turbulent rivers. (b) Generally they were cheaper than other forms. (c) The difficulties of midstream pier construction and its maintenance were avoided. Prior to World War 2 the live loads were much lighter. Narrow bridges were built for horses and also for stock, usually sheep.

A form of suspension bridge in limited favour in the first two decades of this century was the multiple rope bridge – generally known today as cable stayed. The earliest recorded New Zealand example of a suspension bridge is the 1842 structure over the Waiwakaiho River at New Plymouth. This used anchor chains salvaged from a shipwreck as cables, but inferior local timber caused its early replacement. Today one can see examples of the various types of suspension bridges. The following examples include both demolished and extant structures.

2 MATAURA BRIDGE 1867

This was designed in 1866 by John Turnbull Thomson when Provincial Engineer of Southland. It had a span of 32.67m, and a timber stiffening truss between the rather squat stone towers about 3.6 metres high. The original local timbers were eventually replaced in Australian hardwoods. As with many other early bridges tolls were charged for a period. In 1939 a replacement concrete bowstring arch structure was built on the same site in Mataura township.

3. SKIPPERS CANYON BRIDGE 1868

Sometimes footbridges were built for miners at gold workings. J.T.Thomson designed one, also suitable for horses, over the Upper Shotover River at Skippers in Central Otago.. This bridge did not have towers. Instead the anchors were secured in the schist rock of the canyon walls. The span was 66.8m and the deck width was 1.52m being supported by 12 galvanised iron 114mm cables, An early photograph shows a considerable vertical camber in the structure which would reduce flexing.

4 BRUNNER BRIDGE 1876

Erected over the Grey River 12km north of Greymouth, this bridge was to serve the Brunner Coal Mine with the adjacent coke ovens and brickworks. It collapsed when almost ready for opening because of failure of the cast iron anchor plate at the souh end. This was remedied and the bridge duly opened, but there was a commission of enquiry. The timber towers rested on low stone bases with braced timber posts and planking to retain stone filling. A three metre high timber stiffening truss, and deck over the 91.44m long bridge carried a railway track in the middle of the 2.4m roadway. It was largely rebuilt in 1927 in steel and at some stage was used for road vehicles until the opening of the Stillwater Bridge upstream. The New Zealand Historic Places Trust was given the bridge by the Grey County Council as an integral part of the Brunner Mine Site.

5 KAWARAU GORGE BRIDGE 1880

This fine Central Otago bridge was designed by Harry Pasley Higginson of Dunedin. The towers are schist in ashlar (squared and dressed stone in regular courses). On the northwest end the anchors are embedded in the walls of the cutting. The deck and stiffening truss are of red beech timber with some ironbark for braces and filler blocks. This structure has a 91.44m span with a height of 42.67m above the fast flowing river. It is noteworthy that the design and contract drawings were prepared in only 16 days. Higginson was awarded the Telford Prize by the ICE for his paper on this bridge. In 1963 it was replaced by a steel arch bridge upstream for all traffic, but the suspension bridge has been retained as an historic structure and is used today for bungy jumping. However, the ambience is marred visually by more recent building appendages for the 'circus' participants.

6 DANIEL O'CONNELL BRIDGE 1880

Sited on the Manuherikia River at Ophir in Central Otago this bridge was designed by Leslie Duncan Macgeorge, Engineer to the Vincent County. He used schist (the ubiquitous stone in the region) for the towers with timber deck and stiffening truss. The north anchorage was tied into the solid rock of the approach cutting. The span is 65.53m and width only 3.96 metres. In 1905 the timber work was replaced in steel,.but with new timber deck planking. The large number of Irish gold miners in the area decided on the name Daniel O'Connell, the Irish political leader known as "The Liberator".

Fig. 1 Kawarau Gorge Bridge

7 ALEXANDRA BRIDGE 1882

Spanning the Clutha River this fine bridge was regarded as one of the most beautiful suspension bridges in New Zealand. It had two massive stone towers in the river on stone piers with that on the town side founded on a concrete raft one metre thick and six metres below normal river level. The designer was L.D.Macgeorge being assisted by Robert Hay, a Dunedin consulting engineer. The main span was 79.85m and overall length was 168.29 metres.The contractor was Jeremiah Drummy who was rightly praised for the splendid workmanship in the masonry of the towers. The design of these towers was elaborate with a finish of ashlar in even courses. Curved pediments with ornamental urns graced the tops.The timber deck roadway had a timber stiffening truss suspended on eight 76mm cables, four to each side. With the need for wider and heavier loads this bridge was replaced in the 1950s. Unfortunately the steel arch 'coathanger' bridge is visually too close to the towers which have been retained in isolation in response to popular demand.

8 TEKAPO BRIDGE 1884

This was the most significant and best known of the early multiple rope suspension bridges. The design was by Frederick William Marchant when Engineer to the Mt Cook Road Board, a man of many engineering accomplishments. Spanning the Tekapo River near its outlet to Lake Tekapo there was a stiffening truss and transoms of kauri and ironbark consisting of a central span of 45.72m and two end spans of 22.86m each. Two midstream concrete piers continued as towers tapering from 1.82m dia. at base to 1.06m dia. at the top – the longest being 14.63m overall. These towers, presumably with some steel reinforcing, rest on 24 totara piles on the east side and 16 on the west side. Concrete was laid under water over the cut-off pile tops as a base for the concrete piers/towers.The 28 wrought iron wire ropes of 114mm have gas-barrel sprits to prevent sagging. The central span has understrutting from the piers to the transoms. A greatly admired bridge in its day it was the subject of a paper presented by F.W.Marchant to the ICE in London.

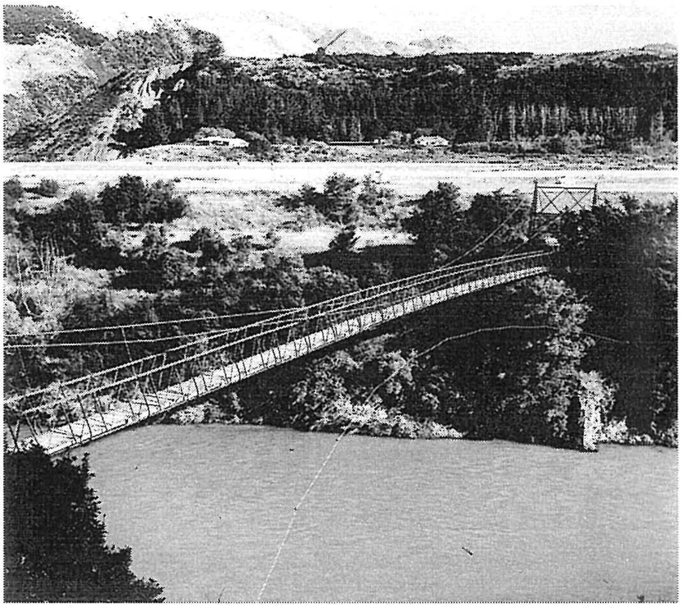

Fig. 2 Glynn Wye Bridge

9 GLYNN WYE BRIDGE 1885

Built over the Hope River in North Canterbury for a runholder, this was a stock bridge for sheep. It was designed and built by J.& A. Anderson of Christchurch while they were contractors for the Waiau Ferry Bridge 25 km downstream at Lochiel. With a span of 75.28m it had wrought iron towers and a stiffening balustrade of iron with timber decking. Sway in the fierce NW gales was reduced by cables underneath as well as on each side. It eventually collapsed through lack of maintenance and a devastating flood.

10 MT ROSS (HARCUS) ROAD BRIDGE 1885

This was built over the Taieri River a few kilometres from Sutton in the Strath Taieri region of Otago. It originally had a timber stiffening truss replaced in 1970 with two 21.8m steel trusses each side for the 43.6m span. The towers are of the widespread schist of Central Otago and support two pairs of woven wire cables for the catenary. The flat plaited form of these, and also their bright red paint finish is unusual.

11 CLIFDEN BRIDGE 1899

This fine bridge over the Waiau River in Western Southland was designed by C.H.Howorth, Engineer to Southland County. The span is 111.5m and it has concrete towers lined in plaster to simulate the limestone of this district. There is a stiffening truss of substantial timber members. After World War 1 it became a memorial bridge with a Roll of Honour on one of the towers commemorating the fallen from this district. When a new bridge was built downstream in 1978 the New Zealand Historic Places Trust accepted the offer of the 1899 structure which today is restricted to foot and cycle traffic. There is a picnic area at the north end provided with help from the local Orawia scout troop.

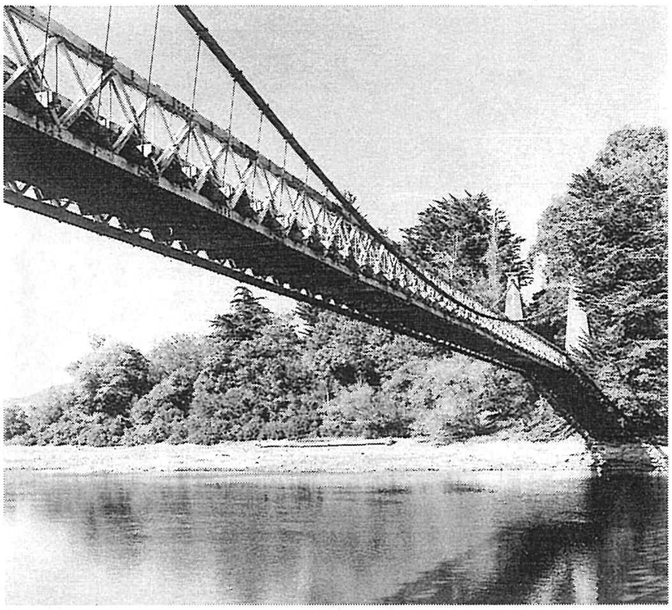

Fig. 3 Clifden Bridge

12 BULLOCK HIDE BRIDGE c. 1900

This bridge, of uncertain date and built to serve a small mining community, is a multiple rope structure over the Wakamarina River. It is sited upstream from Canvastown in Marlborough. Modest in size it is of timber construction with two gantries. The unusual name comes from Bullock Hide Creek, a tributary of the Wakamarina, and the miners' shacks in the nearby settlement which had cowhide chimneys. Still standing but unsafe, it has a wired gate at one end erected by the Department of Conservation to discourage access.

13 SKIPPERS BRIDGE 1901

One of the better known suspension bridges and set in mountainous terrain, this is also the highest, being 91.4m above the Shotover River in the Gorge. It has a span of 96.3 metres. The designer was John Black, Engineer to Lake County. All the earlier suspension bridges of Central Otago had schist masonry towers but here concrete was used for their height of 11.58 metres. The roadway is only 2.2m wide. Today this is another used for bungy jumping.

14 KAIWARRA BRIDGE 1911

Spanning the Hurunui River in North Canterbury this is a private farm bridge built for Walter Macfarlane of Kaiwarra station when subdividing part of his run.. He engaged Arthur Falkner, a consultant engineer in the Wairarapa, to design it having seen his patented designs at a county council conference in Wellington. The bridge with timber towers has a main span of 46.75m and a shore span of 11.65 metres. The stiffening truss is really a series of low queen post trusses with the handrail forming a continuous top chord. To ensure greater stability the main cable has a stay to each tower base passing to its lowest point one metre below the deck to a strut. An auxiliary cable runs from the base of the north tower returning as a straight line to the end post above the abutment. These steel cables are of 44mm diameter.and stabilise the bridge to a remarkable degree. It is no longer used for farm vehicles.

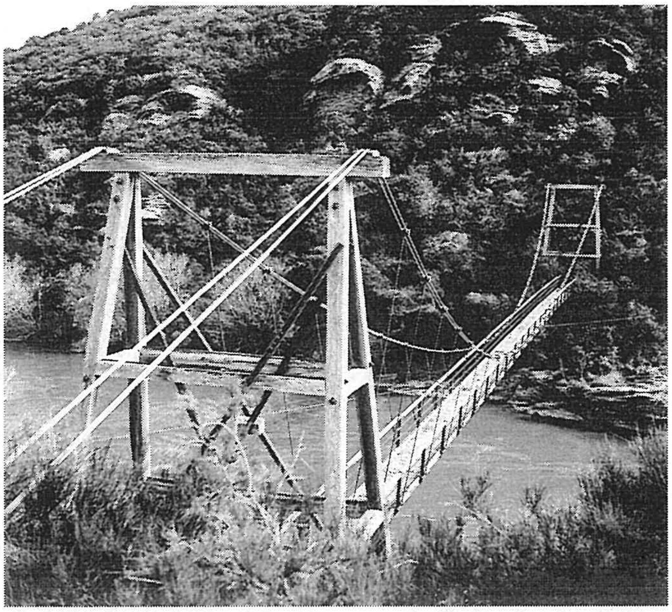

Fig. 4 Horseshoe Bend Bridge

15 HORSESHOE BEND BRIDGE 1913

This is a substantial footbridge erected over the Clutha River about 8km downstream from Millers Flat in Central Otago. The unsatisfactory nature of the manually operated cable and cage for school children, from the small gold mining settlement of Craigs Flat, finally persuaded the Tuapeka County Council to provide a safer means of crossing New Zealand's largest river. A bridge was designed by the County Engineer, John Edie Jnr, whose design received PWD approval to get a government grant towards the cost. Tall timber towers have A frames with two sets of cross ties and also steel diagonal braces. The 50mm thick timber deck is carried on small steel sections and the timber handrail has railway irons as posts with horizontal 75mm steel flats. Considering little or no maintenance has been done over the years it is in remarkably good order. Today it serves a small farm for getting sheep across the river.

16 RANGITANE BRIDGE (OPIKI TOLL) 1917

Crossing the Manawatu River at present day Opiki with its span of 144m it was the longest suspension bridge in New Zealand at the time. The designer and builder was the redoubtable Joseph Dawson, a builder and farmer who specialised in the design and construction of suspension bridges. He generally used concrete towers, in this instance they are 14.6m high to support 16 cables of 34.2mm dia. on each side.The bridge was built for the Tane Hemp Company to carry flax laden horse-drawn wagons on a tramway across the river. When the Tane flaxmill closed in 1921, Hugh Akers a local farmer, bought the bridge naming it Opiki after his farm and charging tolls for public use. A replacement concrete girder bridge in 1969 saw its closure, and to prevent use the deck and stiffening truss was removed to leave the hangers dangling – an impressive but forlorn engineering relic. It has been classified as such by the New Zealand Historic Places Trust.

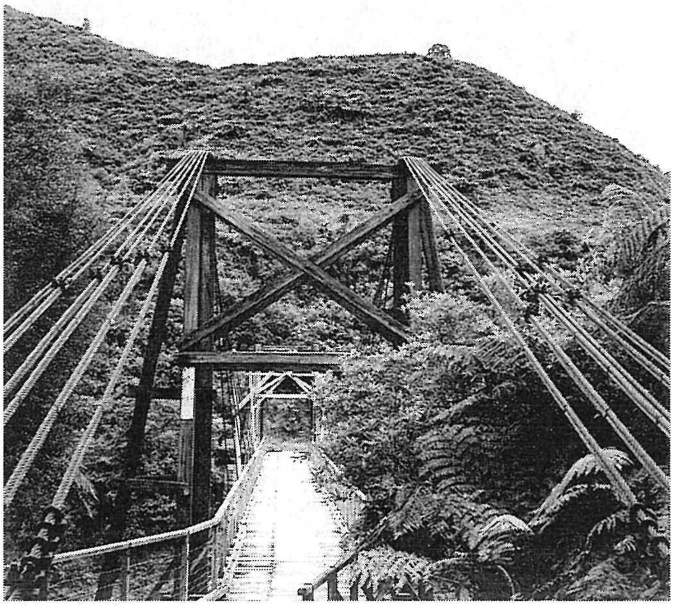

Fig 5 Tauranga Bridge

17 TAURANGA (TRACK) BRIDGE 1922

Spanning the Waioeka River in Eastern Bay of Plenty this is a rare extant example of a multiple rope (cable stayed) suspension bridge. It was built to provide access to farms in a hard, steep bush country block where the government had settled returned servicemen. The scheme failed and the bridge became partly derelict after abandonment of the farms.The Department of Conservation, with the help of Works Civil Construction, has repaired and conserved the bridge making it available for trampers, but not vehicles. It has a span of 57.8m with two gantry-like structures for the cables Timber towers 6.95m high carry the multiple cables. One tower pier is concrete, the other is a timber trestle. Six triple laminated transoms receive a cable for each side. The anchors are by means of a shear block for each set with 60mm dia. steel anchor bars passing to deadmen in the banks. This bridge is noteworthy for its rarity in being the only remaining multiple rope vehicle structure in the country.

18 ARAPUNI POWER STATION BRIDGE 1924

This spectacular footbridge over the Waikato River gives access for the hydro-electric station personnel between the powerhouse and workshops, and the permanent village on the opposite bank.. With a span of 152.4m it has a tall braced steel lattice tower on the sidling road to the powerhouse. As the bridge rises gently towards the village there is no other tower, but instead a cutting at the top of the ignimbrite gorge provides access to it. Above this a massive concrete block anchors the cables. The bridge has single 450mm dia.cables on each side and strong steel mesh protection on balustrades - also for some distance overhead on the powerhouse side. Public use is permitted.

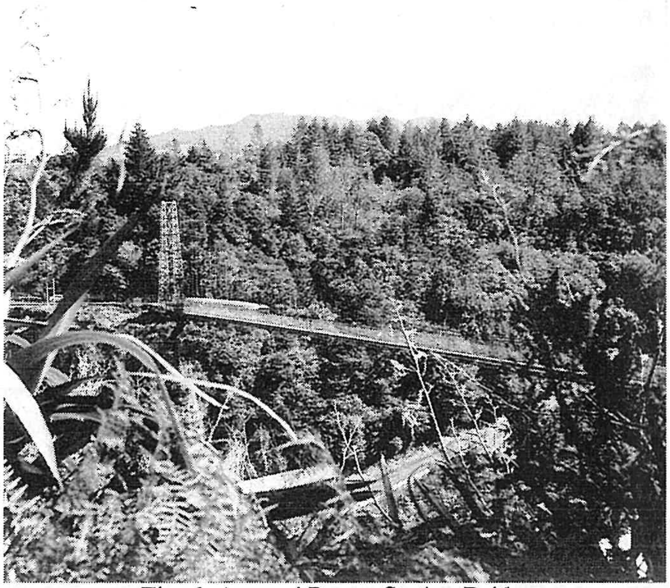

Fig. 6 Arapuni Power Station Bridge

19 SPRINGVALE BRIDGE 1925

In 1971 the Rangitikei County Council offered this bridge over the upper Rangitikei River to the New Zealand Historic Places Trust after a replacement had been built downstream. The Trust accepted and it has been maintained for pedestrian use only.The structure of 61m span has tapered concrete towers 6.7m above deck level and carrying on each side four cables of 140mm circumference made of galvanised plough steel. The timber deck and stiffening truss has 22.2mm dia. steel hanger rods. There is diagonal sway bracing on the underside of the deck and sway cables tie the bridge to the banks both up and down stream in this exposed site on the Ruahine Range.

20 MAKARIKA BRIDGE 1931

Spanning the Mata River south-west of Ruatoria on the East Coast this was the longest vehicular suspension bridge in New Zealand in its day. With a span of 150.87m it had tall steel towers and an ironbark stiffening truss with timber deck. This impressive bridge was built to serve a sheepfarming district and it has been demolished for replacement by a concrete girder structure.

21 HORSE BRIDGE CLEDDAU RIVER 1932

This is sited a few kilometres below the west portal of the Homer Tunnel. The bridge was intended for packhorses to bring supplies to trampers' huts on an alternative track from Milford Sound to Queenstown but this never eventuated. It was left to be virtually forgotten and has recently been repaired by the Department of Conservation. This is an all timber structure having no stiffening truss and a modest span of 36.5m with a width of 1.5 metres over the turbulent Cleddau which flows into Milford Sound.

22 MONYMUSK FARM BRIDGE 1936

Spanning the Leamington River near Cheviot in North Canterbury this modest 25m long bridge was built by Ellis Upritchard to give access to his farm. He constructed small towers of concrete-filled 44 gallon (200 litre) drums. The concrete was placed and tamped by hand and reinforcment consisted of old steel rails from the Parnassus railway track.. The cables are twin pairs of wire ropes, one to each side, salvaged from an abandoned Southland gold dredge, and were hauled across the river by a team of horses pulling on a coil of No 8 fencing wire. The anchors are hand-mixed concrete blocks of 1.52 tonnes in a 4m pit. There are other instances throughout the country where farmers built their own small suspension bridges.

23 HODDER RIVER BRIDGE 1937

The Hodder River is a tributary of the Awatere River in Marlborough about 60km from Seddon. It is bridged by a structure with steel towers and originally had a 3m wide concrete deck. In 1982 the anchorages were strengthened, the hanger rods were replaced in high tensile steel, and the deck replaced with laminated timber. The span is 64m with two end spans both of 5.18 metres. This is an impressive structure, especially when viewed from the riverbed.

24 KARANGARUA BRIDGE 1939

Fig. 7 Karangarua Bridge

This very fine bridge on the West Coast crosses the river of the same name on SH 6 south of Fox Glacier. As with the suspension bridges over the Fox and Cook Rivers to the north it has steel towers, and steel plate girders for stiffening the deck. This is the most impressive of the three, and also the longest with a span of 130 metres. The tall towers have two panels of diagonal bracing and are particularly impressive from the road approaches. However, from all viewpoints this is a superb design, complemented by the majestic backdrop of bush and the snowcapped Southern Alps.

25 CONCLUSION

These few examples show the importance of the suspension bridge in the early development of New Zealand. Although they were often considered to be relatively short lived, when well built and sited some have remained in use for periods up to 120 years. This in spite of floods sometimes rising to 15m above normal river level. High rainfall, searing summer heat, and particularly for suspension bridges, the notorious northwest gales, especially in the South Island all posed threats to their survival. Their popularity shows the pragmatism of early engineers in selecting the most appropriate design and construction for given conditions and financial limitations.

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Fig. 8 Alexandra Bridge

Fig. 9 Tekapo Bridge

Fig.10 Daniel O'Connell Bridge

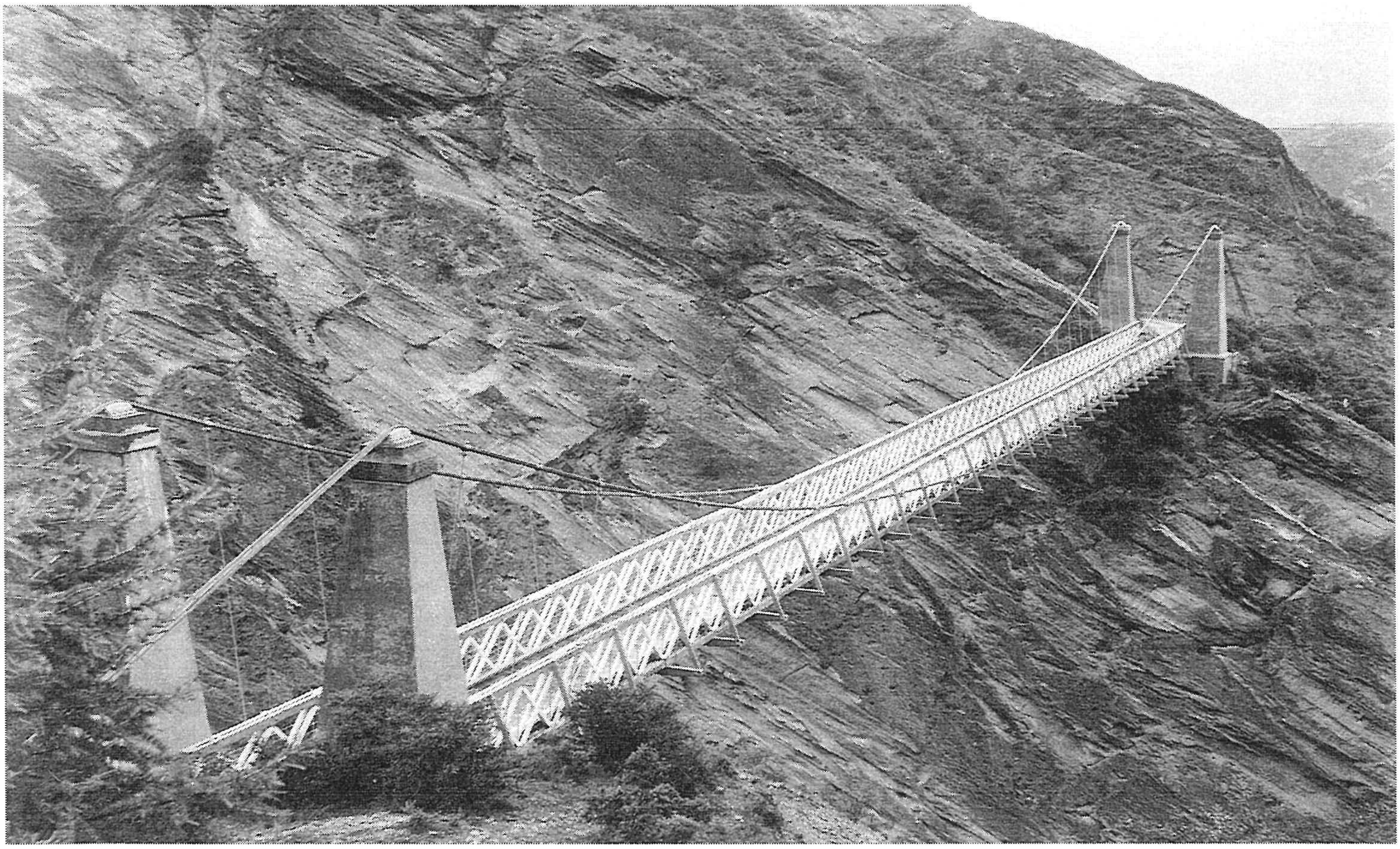

Fig. 11 Skippers Bridge

Early Reinforced Concrete Structures - A Heritage Issue

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Summary: The paper deals with two early reinforced concrete structures in the Geelong area: the Dennys Lascelles wool store and the Barwon sewer aqueduct. It will deal with their concept and construction, and with the pioneers in the design and construction of reinforced concrete in the early 1900s who were involved (Armand Considère and Edward Stone). It will then detail the struggle to save the aqueduct from demolition, it being by then listed on the Victorian Heritage Register. Parallels will be drawn with another heritage building of the same period: The Dennys Lascelles wool store, which had a reinforced concrete hog-back truss roof. The strategisms employed by owners or developers to obtain permission for demolition of heritage-listed places are high-lighted, and countervailing policies are suggested.

1 INTRODUCTION

The early history of the structural use of reinforced concrete (1890s-1930) has by now developed into a heritage issue: a number of structures designed and built in those days were highly imaginative and were witness to optimism and excitement. These were generated by the use of a new building material which had the promise of liberating our built environment, replacing timber flooring with a non-combustible, composite material, strong in both tension and compression, which could be formed on the building site into any desired structural or ornamental shape.

This process is still in train, specially considering the development of prestressed and partially prestressed concrete. As a result, we have inherited a number of outstanding early structures which enable us to trace the development of the use of this material. This paper will sketch the history of two of these structures: the Dennys Lascelles wool store and the Barwon sewer aqueduct. Biographical notes will be given on the engineers behind its development: Armand Considère and Edward G. Stone. The former was the French engineer whose pioneering work in the theory and design of reinforced concrete resulted in the unique concept used in these structures, the latter was the Australian Engineer and builder who put these concepts into practice in Australia

Following the brief history of the construction, use and Heritage listing of these structures, we see that there are two issues which tend to threaten the preservation of Heritage-listed structures: First, the natural degradation with time which requires periodic maintenance, secondly, the pressures generated by "development", "urban renewal", or any other of the catch phrases which originate in the "marketplace" of property speculation. Both these topics will be considered in the following paragraphs.

2. THE ENGINEERS

2.1 Armand-Gabriel Considère

Armand Considère (1841-1914) (1,2) graduated from the École Politechnique in 1865 became an Engineer in the Corps of Roads and Bridges in France, was promoted to District Engineer for Normandy, and after service in the Army Engineers he was appointed Chief Engineer in the Department of Finistère and, finally, promoted to Inspector-General in 1901. Meanwhile, he researched what was at the time the new material: reinforced concrete, and discovered the increase in compressive strength to be obtained by laterally confining the concrete.

In 1902 he offered to give a course of lectures on the subject of reinforced concrete at the École des Ponts et chaussées, specifically in his system of reinforcing compression members (and compression zones in beams) with spirally-wound cages. He stressed at the time that it was specially important to extend the education of senior engineers in the Corps. This offer was accepted by means of voluntary evening classes for serving engineers and for students at the school.

Considère retired from the Corps in 1905 in order to further develop his system of reinforced concrete, which was distinguished by the spiral reinforcement in compression zones and the use of low-slump concrete. He further researched the behaviour of concrete columns and the mechanism of anchoring steel to concrete. He developed the anchor hook for the smooth bars which were in use at the time.

His study of compression and tension zones in beams lead him to develop and test trussed structures, the early bridge at Plougastel being an outstanding example. The Considère system as described in a text in 1913 is remarkably similar to modern common practice, including the use of ligatures and bent-up bars in beams to resist shear, the use of distribution reinforcement in slabs and the special, closely-wound spirals in the heads of piles. The exception is the spiral reinforcement in normal columns, which at present is not normally used. One great advantage of this reinforcement is that it causes the confined concrete to behave in a ductile manner. As this type of behaviour is one of the cornerstones of strength analysis, this is an important feature which is often overlooked. Considère himself seems to have been more impressed with the resulting compressive strength gain than with the resulting ductility.

The Considère system was used in the early 1900s in England and the United States in the construction of industrial buildings.

2.2 Edward Giles Stone

Edward Giles Stone (1873-1947) (3) must be considered one of the important Australian pioneers in concrete design and construction. There is no record of formal training. He served as a cadet under his father, J.J. Stone, also an engineer. He did become a Member of the Institution of Civil Engineers about 1912, and in 1920 a Member of the Institution of Engineers, Australia.

He started his career employed in the Roads and Bridges Department and in the Sewerage Construction Department, both in New South Wales. In 1900 he was engaged by the Sydney Harbor Trust as Chief Designing Officer. He resigned in 1907 to enter private practice as "Consulting Engineer and Structural Architect, specialising in reinforced concrete".

construction. The many initiatives and innovations which emanated from this partnership were undoubtedly Stone's. Its activities encompassed Tasmania, where workshops were constructed in Launceston, and South Australia where it engaged in the construction of the Glenelg breakwater. This latter venture was unsuccessful: work had to be abandoned due to storm damage.

3. THE STRUCTURES

The two structures with which we are concerned are both interpretations by Stone of Considère's work on tension and compression fields in structural concrete. Considère published his research findings in the Annales des Ponts et Chaussées, but a detailed report of the Considère system was also published in English in the textbook "Reinforced Concrete", by Charles F. Marsh and William Dunn in 1906. (4). Research by Alsop shows that the book had found its way to Australia by 1908 and that Stone was almost certainly acquinted with it. Stone was obviously greatly impressed: both the Dennys Lascelles wool store and the Geelong sewerage aqueduct are faithful representations of Considère's work.

3.1 The Dennys Lascelles Wool store

This building (5) was designed as a wool store and showroom for wool auctions. Completed in 1911, the roof consisted of a set of reinforced concrete hog-back trusses, supporting vertical Vierendeel trusses at their panel points. These, in turn, supported precast concrete roof panels, which were sloping from the top chord of one truss to the bottom chord of the next. Complete with the glazing in the Vierendeel trusses this assembly formed a South-light roof, covering an uninterrupted area of 55.5 x 51.9 m, at the time the largest concrete roof in the world.

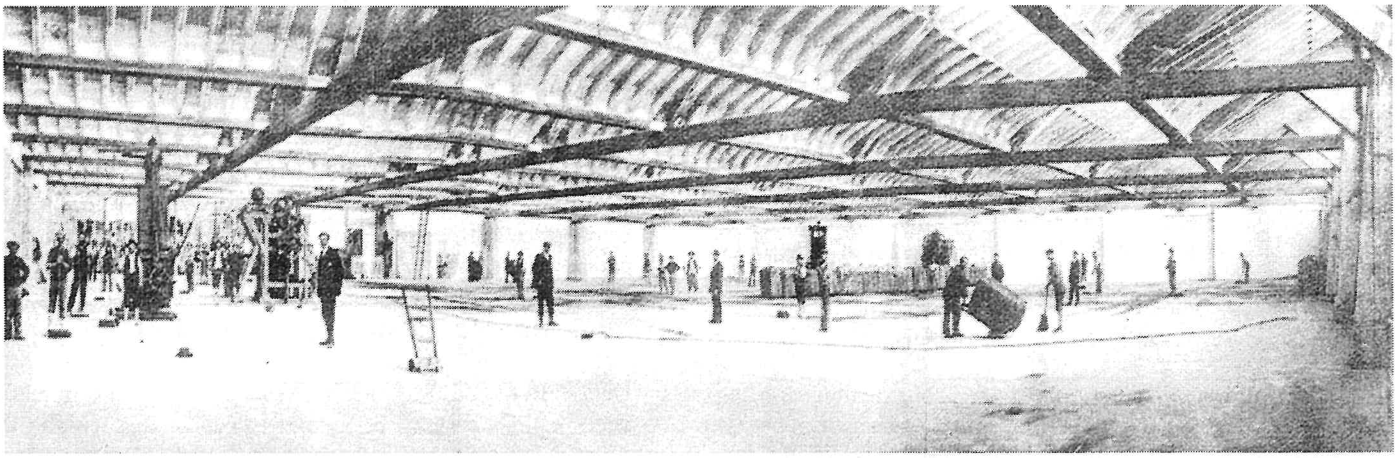

Figure 1 - Show floor of the Dennys Lascelles Wool store in 1911

In 1908 he developed a system for the construction of precast concrete silos, made of curved, recessed panelled plates. He also adapted this system to the construction of houses.

In Geelong, he constructed three silos for the Cheetham Salt Company and, together with Ernest Joshua Siddeley, formed a contracting company specialising in concrete design and construction.

The 51.9 m long hog-back trusses were typical of the Considère philosophy. The compression members had spirally wound cages. The main tension chord consisted of flat steel bars, concreted in after completion of the major roof members to minimise tension cracking.

The great distinction of this arrangement was the uninterrupted floor space with an even, diffuse light from the South-facing windows, partly reflected from the precast roof panels and without shadows from truss or bracing members. This obviously provided ideal conditions as a showroom for the close examination of wool. Some English buyers considered it to be "the finest show floor in the world".

The building was taken out of commission about 1979, and subsequently sold to Myer Shopping Centres Pty. Ltd. in 1983. It was registered in the Victoria Historic Buildings Register in 1984. In June 1986 it was sold to a developer who applied for a Permit to Demolish in December, 1987. This application was denied in April, 1988. After some furious political activity, including personal intervention by the then Premier of Victoria, the building was demolished in 1990, following a damning consulting engineer's report which alluded to the danger that the building would "explode outwards" and so pose a risk for occupants of buildings on the other side of the street in which it was located. This had the effect of the building being declared derelict, causing direct intervention by the Minister for Health, who ordered the building to be demolished. (6).

The demolition contractor, apparently believing the engineer's report found that, contrary to predictions, the building was all but indestructible. He went bankrupt in the process of trying to knock it down. The developer committed suicide in December 1992.

No further development has taken place or is envisaged at present, leaving an unsightly hole used for car parking.

3.2 The Barwon sewer aqueduct

This aqueduct (7), shown in Figure 3, was built in 1913-1916, as a link in the outfall sewer of the City of Geelong to Black Rock on the South coast of Victoria. It straddles the Barwon river flood plain at Breakwater, just South of Geelong, and has a total length of 750 m, in 14 spans. It is by far the longest, and largest, structure built according to the Considére system still in existence.

The aqueduct is the property of Barwon Water, the "corporatised" successor to the Geelong Waterworks and Sewerage Trust. It was commissioned in 1916, and decommissioned in 1992, its function being taken over by a newly constructed pumped siphon located some 20 metres downstream. It was entered in the Historic Buildings Register in 1981, and is thus protected under the Historic Buildings Act, 1981, and its successor, the Heritage Act, 1995.

After considerable public discussion, during which a voluntary, unfunded organisation, the Geelong Aqueduct Committee was formed, Barwon Water lodged with Heritage Victoria an Application for a Permit to Demolish, which it later retracted. In July 1995, Barwon Water commissioned its consulting engineers to report on the structural safety of the aqueduct.

This report was completed in August, 1995, and concluded that the analysis carried out ".....fails to provide any assurance that the structure has any margin of safety under current loading conditions". This conclusion was reached after carrying out a linear elastic analysis, and singling out the first compression verticals of the large cantilever trusses as the critical member.

This member was then analysed using some current design codes. The conclusions continue: "Were this the case (the absence of a safety factor), the structure would be relying on the development of some alternative load path to avoid collapse". As the possible contribution to the overall strength of these alternative load paths was not investigated, the report in fact failed to address its central objective, which is stated as being "to advise on the current safety of .... the

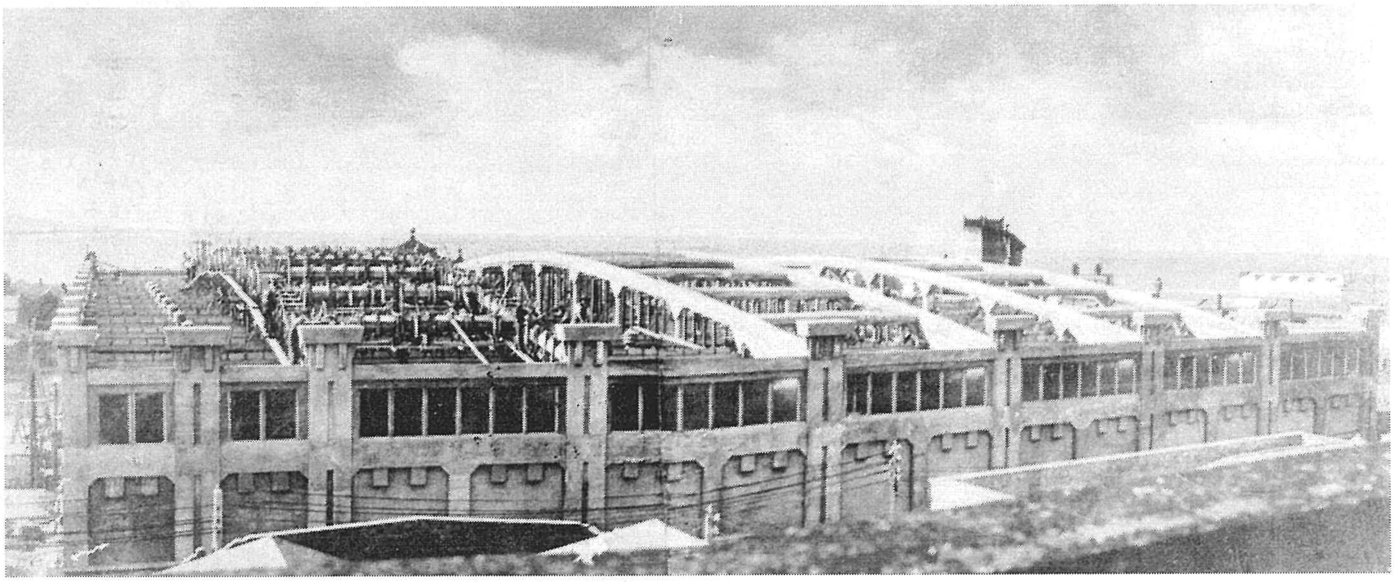

Figure 2 - Roof of Wool store under construction in 1910

aqueduct". The position was later aggravated by a fax message, dated 7 September, 1995, from the consulting engineers to the effect that: "   it is considered prudent for the Board to assume that collapse of the ovoid sewer aqueduct could occur at any time" and that collapse, were it to occur, would happen "with little prior warning".

In November, 1995, the Minister for Planning, the Hon. R.R.C. Maclellan, called a meeting of interested parties, and subsequently commissioned an Independent Panel of Inquiry. During the public hearings of this Inquiry in February, 1996, the two opposing views of Barwon Water (that the aqueduct, being unsafe, should be demolished), and of the Geelong Aqueduct Committee (that it had an adequate safety factor and that it could, and should, be restored) were vigorously debated. The Inquiry found (8) that the aqueduct should not be demolished.

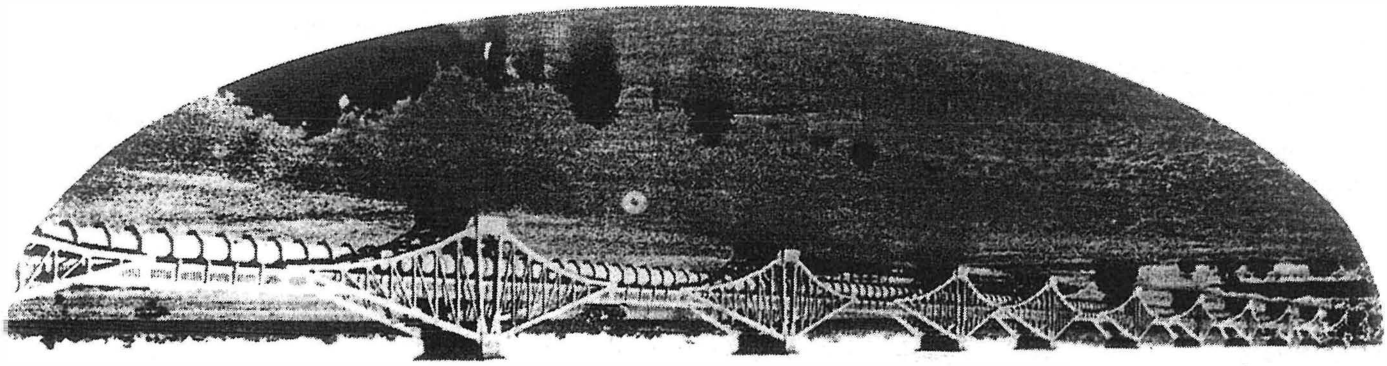

Figure 3 - The Barwon sewerage aqueduct under flood conditions

Subsequently, a detailed collapse load analysis was undertaken at the University of Melbourne, mainly in order to test the veracity of the consulting engineers' report of August, 1995. (9)

Investigation of the strut referred to previously revealed that the consulting engineers had determined the effective buckling length of the vertical compression member making a number of conservative assumptions which resulted in the presence of a hidden safety factor of about 4.6.

In addition, the consultants assumed, erroneously, that corrosion of reinforcement affects tension and compression members to the same extent. This had the effect of further downgrading the computed strength of compression members by a factor of about 1.5, giving a total hidden safety factor on compression members of approximately 7. It is obvious that the conclusions communicated to Barwon Water, and widely advertised by them, could not possibly follow from the investigations conducted.

The collapse load analysis employed an incremental loading technique and applied a corrosion model to account for the degraded state of the structure.

This analysis resulted in indicating a ductile mode of failure. The structure appears capable of sustaining a load of 1.9 x Dead Load. Furthermore, the investigation shows that the critical truss members are the tension chord members at the end of the cantilever, and the end diagonal. These members have comparatively light reinforcement, so that their strength is more sensitive to corrosion. The failure mode was found to be ductile.

Translating the results into Dead Load and Pedestrian Live Load over the area of the foot bridge has the following result:

The overall collapse load for a uniformly distributed load is 953 kN. Using the conventional load factors of 1.25 x DL + 1.5 x LL, and applying an overall capacity reduction factor of 0.8, one arrives at a required ultimate design load capacity of 956 kN. This shows that the structure is capable of safely carrying its own weight, together with a design pedestrian load of 5 kPa on its footbridge. Arguably, the latter load is in excess, by a factor of 3.0, of any pedestrian load which could ever be applied.

The result of the Inquiry referred to above put the aqueduct in limbo: it is very unlikely that it will be demolished, but funding for its restoration, estimated at $500,000 per year for the next eight years does not appear to be forthcoming. The argument advanced by the then Minister for Planning in a private conversation is that the aqueduct should fulfil a useful purpose in order to attract funding, such as being part of a bicycle/pedestrian track. In context, the inference was that this was part of the political reality in this particular case. This point is an interesting debating point for the Conference: "Should heritage structures be required to be 'useful'?"

4. ANALYSIS OF CASE STUDIES

4.1 Similarities

The two case studies show a number of remarkable similarities:

- Both structures were listed on the Victorian Heritage Register.
- Both had outlived the economical usefulness as determined by their original function.
- Both required a considerable financial outlay for their restoration.
- One structure was actually demolished as a direct result of an adverse finding in a consulting engineer's report, the other was seriously threatened with demolition for the same reason. (In the latter case, the presence of a similar report constitutes an ongoing adverse climate which appears to be detrimental to its rehabilitation).
- In both cases, the findings of the engineer's report proved to be wrong.

The common link in the above sequences of events is the appearance, at a critical phase of the debate, of an adverse report on the safety of the structure prepared by a consulting engineer engaged by the party which is advocating its demolition.

4.2 Consequences

The moment the safety of a structure is called into question an overwhelming pressure builds up to have the structure demolished, as any perceived threats to public safety tend to cause, rightly, any public instrumentality to adopt a conservative stance in a defence against the occurrance of injury or death, adverse publicity and/or possible litigation.

The question arising is: "Why were the engineer's reports wrong in fact?". We find that in both the above cases the engineer set out to determine the "factor of safety" of a deteriorated structure, and in both cases did so by performing a structural analysis aimed at determining the compliance, or otherwise, of the structure with a structures code (in this case the Concrete Structures Code issued by Standards Association of Australia). In both cases the engineers found, not surprisingly, that the structure did not meet code requirements. As the code in question was published in 1982 and both structures were built about 1915, this is not surprising. The salient error lies in the assumption by the engineer that the actual factor of safety may be found by a comparison with code requirements.

In engineering terms, "factor of safety" means exactly what it says: it is the factor by which the strength of the structure exceeds the load applied to it. Therefore, what the engineer is required to determine is the collapse load of the structure, a routine entirely different from that of determining its compliance with some code.

The above highlights a grave problem in the professional conduct of engineers. On the one hand engineers should abide by their professional Code of Ethics, which requires them not to engage in work for which they lack expertise, on the other hand, no person knows what he/she does not know. It appears that a great number of engineers are not aware of this difference and therefore are satisfied that they perform the former when, in fact, they perform the latter. This is not surprising: engineers are trained in the latter discipline and would feel uneasy with the former: when determining a collapse load one does not have the advantage of working in accordance with a well-understood, relatively easy-to-follow, set of rules. One has to apply and interpret elementary laws of structural mechanics.

It follows that, unless the analysis is performed by an engineer experienced in this work, or more generally, in the appraisal of heritage structures, this may well lead to grave errors of judgement being made by those executives who have to make decisions in this field. Foremost among these are Directors of Heritage Authorities and their responsible Ministers.

5. APPRAISAL OF HERITAGE STRUCTURES

5.1 The Appraisal Process (10,11,12)

The appraisal of decaying heritage structures is a complex engineering task. The first priority is the completion of a condition survey. This survey may have to be divided into progressively more detailed parts. The planning of the survey and the modifications to these plans as initial steps reveal possible requirements for additional investigations, is of the utmost importance. It must result in the recording of all details which have a bearing on future performance and cost of repairs or renovations.

Its structural competence must now be measured, taking into account the effect of all debilitating details, which were revealed during the condition survey. In all cases an estimate of the collapse load of the structure will need to be made, so that available load factors may be realistically assessed, and areas of weakness, either potential or existing, may be defined.

Ideally, the final report of these investigations will provide the owners of the structure and the Heritage Authority with a number of alternative management plans, costed in some detail, which may be used as a guide to the performance of any remedial work required and to alternatives for future use.

The evaluation of existing structures with a view to determining their likely future structural performance is a specialised task. Yao (13) states:

> "In the current practice, relatively few highly-experienced engineers can successfully perform damage assessment and reliability evaluation of existing structures. Even when these experts are willing, their specialised knowledge cannot be transmitted to

younger engineers in a direct and systematical way without many years of working together."

The truth of this statement has not changed in the intervening years.

Referring back to the case studies, the aqueduct has so far escaped demolition, mainly through the efforts of the Geelong Aqueduct Committee, whose many representations to Heritage Victoria, and to the Independent Panel of Inquiry commissioned by the Minister for Planning convinced the latter that the aqueduct was structurally viable.

If a proper collapse load analysis had been performed at the outset of these deliberations, this would have shown that the aqueduct was not in danger of collapse, and that, therefore, demolition by virtue of its structural inadequacy was not a consideration.

5.2 Conclusions and Recommendations

It will often be the case that the perceived financial interests of the owner run counter to the provisions of the Heritage Act. This is a potential source of conflict, for which resolution mechanisms are available through the Heritage authorities. The outcomes of structural assessments should be a scientific input into the resolution process. They should not be manipulated to distort the output of this process.

The crucial importance of structural assessments in the decision-making process regarding the future of heritage structures cannot be over-estimated. It is, therefore, imperative that their quality is impeccable. In both case studies it has been shown that the structural assessments lacked quality. The effects of this situation were both immediate and far-reaching: the former structure was demolished, while the latter could only be saved from demolition by months of voluntary work, and an expensive inquiry process.

We do not consider that this situation is at all satisfactory, and, in order to eliminate this particular source of conflict, would recommend:

> that the performance of condition surveys and structural evaluations of Heritage structures be considered part of the duties of the relevant Heritage Authority, which is charged with arranging these evaluations by drawing on a panel of professional engineers and/or architects,

> that the members of this panel should be professionals with proven skill and experience in this particular field,

> that these surveys be performed at the time of entry of the structure into the Heritage Register and at such intervals as may be deemed relevant by the Heritage Authority and that the results of these surveys form part of the public record in relation to the structure and kept by the Heritage Authority,

and

> that any structural evaluation carried out in accordance with the above shall be subject to the checking procedures normally required in the field of engineering design.

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Propping up the Past, Concrete Repair Work at the North Head Historic Reserve

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1.1 Introduction

The Department of Conservation manages a number of historic properties throughout New Zealand and a large group of these are made up of the old fortifications once associated with the country's coast defences. Most of these sites contain concrete structures dating from the 1880s up to the time of the disbanding of the coast defence network in the late 1950s. Until recently little or no maintenance had been carried out on these places and over 100 years of exposure to the salt laden air of the coastal environment has caused many of the structures to deteriorate as the reinforcing has rusted and spalling and other deterioration has occurred. This paper describes the different methods used to repair and support these structures and the work done in preparing a manual for the care and repair of historic concrete. A significant amount of this work has involved using the archival record of the construction of the forts to plan repair and maintenance. The majority of the work discussed has occurred at the fortifications at North Head Historic Reserve on Auckland's North Shore. This reserve is rated by the New Zealand Historic Places Trust as the most significant coastal defence site in the country.

1.2 Coast Defences in Auckland

The European coast defences in the Auckland area date from 1841 when Fort Britomart was built next to the new town. Major works did not however begin until 1885 when a series of Russian War scares lead to the construction of a number of coastal forts throughout the country. It was feared at that time that in the event of war between Britain and Russia the ports within New Zealand could become victims of Russian raiders. In Auckland on the south shore of the harbour defences were built at Fort Resolution and Fort Bastion and on the north side at Fort Takapuna, Fort Victoria and at North Head. This construction with much subsequent rebuilding was largely completed by 1900. In 1905 a new 6 inch emplacement was built at North Head at the request of the British government and this was to be the last major work undertaken for 30 years. By the late 1930s the only defences still in operation were the two 6 inch guns at North Head which together with a pair of 12 pounder quick firing guns made up the major defences of the port. (1) By this time however it was apparent that war was imminent. As a result a new 6 inch counter bombardment battery was built on Motutapu Island to cover the approaches to the port (2). Engine rooms and searchlights were upgraded and new equipment was ordered. After the outbreak of World War II more coast defences were built culminating in the large 9.2 inch batteries at Waiheke Island and on Whangaparaoa peninsular (3). By the late 1950s the network of coast defences was abandoned and the coastal artillery units disbanded. At this time a number of the sites became part of the public reserve system around the city. The Department of Conservation was formed in 1987 and took over the management of many of these sites. The Department manages the area of the 6 inch battery at Motutapu Island, the 9.2 inch battery at Waiheke and the large complex of fortifications at North Head Historic Reserve. In the near future the Department will also take over management of the 19th century Fort Takapuna complex in Devonport on Auckland's North Shore.

1.3 Construction Histories

The history of the construction of these fortifications and records of the methods used make up an important component of the planning of maintenance and repair. As is described below these histories vary in detail with the best records dating from the 19th century with less data available from the later periods. This is fortunate in that the earlier structures were built using a much greater range of cements, mortars and methods. The records left by the engineers and works foremen from the 19th century have greatly assisted our work.

1.4 Construction History, 19th Century

In the 1880s the forts had been quickly built with guns hurriedly emplaced in temporary earthworks. After the Russian scares had abated the government realised that to take full advantage of the investment in guns and equipment proper fortifications needed to be constructed. There were in existence at this time a number of planned fortifications drawn up and ready to be built. These had all been designed by Royal Engineer officers and followed standard British models with much brickwork and with guns and magazines at different levels linked by shafts which contained hoists for the movement of ammunition (4). These however were viewed unfavourably by the government of the time as too expensive in both materials and in the need for skilled workmen to build them. As a result of this a complete redesign was ordered and this was carried out by another Royal Engineer, Major Tudor-Boddam, initially as staff officer for the Artillery and Engineering Departments but later promoted to Lieutenant-Colonel and appointed as Defence Engineer. Tudor-Boddam had already been involved in the construction of fortifications in Tasmania and was experienced in concrete construction methods. He designed another complete set of coastal fortifications for New Zealand's ports using concrete construction and planning the forts on a single level. The methods used did not require many skilled workers and were in fact mostly built by prisoners.

The methods he used were broadly these. Prisoners were used to dig out gunpits, tunnels and magazine complexes as open trenches. Drainage was installed and 'lime concrete' floors poured. Civilian carpenters then built formwork for the walls, prisoners mixed and poured the concrete walls, old obsolete railway line was then laid across the roofs, a moving formwork was built by the carpenters and the concrete roofs poured. These were waterproofed with tar and the tunnel roofs backfilled with earth, up to 12 feet of it over the magazines (5). The 'tunnels' therefore seen at Tudor-Boddam's forts are not really tunnels at all but rather buried concrete rooms. This of course has important implications for their future maintenance.

Tudor-Boddam's workload was described by contemporaries as 'almost incredible' (6). When he arrived from Hobart in 1885 he was faced with a massive jumble of earthwork fortifications all of which were sited exactly where he was required to build the new forts. He also had to deal with emplacing the new breech loading 'disappearing guns' ordered by the government. There were no standard emplacements for these and he had to design complete installations from scratch. Tudor-Boddam designed forts for Auckland, Wellington, Christchurch and Dunedin and kept meticulous records many of which have survived. It is Tudor-Boddam's surviving drawings and specifications which have formed the basis of our planning of repairs on his structures.

As well as Tudor-Boddam's well kept records we are also lucky to have the very detailed files of the site supervisor for the 19th century works at North Head, Walter Frankham. Frankham's work has already provided a basis for an earlier paper presented to this organisation (7) and fuller details of his work will be found there. Frankham was the 'Inspector of Defence Works' for the Public Works Department and was stationed at North Head between 1889 and 1893. He has left a very detailed record of his time there in the form of a series of weekly and monthly reports to his bosses in Wellington. This material not only describes how he was building the forts but also contains all his orders for materials. This means we can see what types of concrete he is using, how he waterproofed it, and where he was having problems with materials. For example we can see from Frankham's order books he was using a variety of cements from a number of sources. Between 1889 and 1890 he ordered English and locally produced Wilson's cement as well as hydraulic lime from a number of sources. He also was using shell lime (8). By checking what was ordered against the specification it seems probable that the hydraulic lime was used for floors with the better cements used for walls and roofs. The shell lime and other lime appear to have been used for plaster work and mortar where the hydraulic properties necessary for concrete were not required. It is interesting that one of the first things he records doing is making a series of test blocks of concrete to try out various materials and proportions (9). In all later periods the concrete work while of varying quality has a greater consistency of materials. It is in this early 19th century period that there is this large variation of materials used. Other factors affecting the final state of the concrete are the aggregate used and the methods use to mix it. Frankham's records also list the areas of the volcanic cone at North Head he was quarrying and the type of volcanic material being used as aggregate. Core samples have allowed us to see that in practice almost anything that was available from broken bottles to beach shell was added. Frankham's reports also describe the hand mixing procedures and even where the mixing boards were located on the site. We are lucky therefore to have such detailed records to use in assessing possible repair strategies. We are also lucky that Frankham's workers used the materials they had available so well. One modern assessment of the older parts of the North Head structures states that, 'After studying the construction drawings and specification, we consider that the good design, construction and materials used have resulted in the overall good condition at this age' (10).

1.5 Construction History, Early 1900s

The next phase of construction at North Head came in the early 1900s. North Head, the main coastal fortification in Auckland at this time was still largely reliant on Tudor-Boddam's fortifications. There were however problems with the armament of these almost from the time they were built. The big rifled muzzle loaders first emplaced during the Russian Scare of 1885 were obsolete and had been scrapped in 1904 and used to decorate city parks. The 6 inch and 8 inch disappearing guns while still emplaced and functional had problems. These guns had an ingenious disappearing mechanism which meant the gun, using the power generated by its recoil when fired could 'disappear' below ground where it could be reloaded out of sight of any attacker. This mechanism however had limitations. The guns fired very slowly and they were limited by the geometry of their ingenious carriages. The guns were limited to a maximum elevation of 15° which meant no advantage could be taken of the more powerful propellants which became available. Greater range could only be obtained if the gun could elevate higher. The disadvantages of these guns meant guns on newer mountings were requested by the British government. These were emplaced on the north side of North Head between 1905 and 1908. The two guns were 6 inch MK VIIs and the emplacement was of a standard Imperial design. This emplacement is very well built and still waterproof. In comparison with the cheap solutions of the 1880s and 90s and the emergency works of the Second World War it possibly the easiest to maintain and to date has required very little work. The guns here were still in service at the time the fort was closed in 1959 (10).

1.6 Construction History, 1930s

During the First World War the 6 inch guns and the old disappearing guns remained in service. The nation's main efforts were directed overseas and little work was carried out on the coast defences. This state of affairs continued throughout the 1920s and early 1930s. Economic depression meant that very little was done on defences anywhere in the country. By the mid 1930s however it became apparent that war was possible and the whole of defence policy was reviewed. In the coast defences this lead to the construction of a new 6 inch battery on Motutapu Island and new engine rooms and searchlights at North Head. The battery at Motutapu was again a standard Imperial design and with the exception of blocked drains has caused few maintenance problems. Similarly the engine room and searchlights built at North Head in 1937 are well built to a high standard and with the exception of some minor details have been easy to look after (11).

1.7 Construction History, Second World War

At the start of the Second World War Auckland's coast defences consisted of the new counter bombardment battery at Motutapu and the old 6 inch MK VIIs at North Head. During the war and especially after the entry of Japan further defences were added with new batteries at Castor Bay, Whangaparaoa and Waiheke Island. By this time the old fort at North Head was too close to the port to be of use in defending against the newer cruisers with guns of a greater range. North Head became the main administration centre and regimental HQ for the coastal defence artillery (12). Some small batteries were however built during this time and it is these both at North Head and at the adjacent Fort Takapuna that have needed the greatest amount of work to stabilise and make safe. These are the examination batteries at both forts. The examination anchorage during World War II was directly to the north of both these forts. This was the area where all ships entering port had to wait to be 'examined' to see if they were who they claimed to be and the examination batteries were there to ensure the ships did stop. The guns used in these batteries are a good indication of the lack of suitable guns in the country at the time and the emergency measures that needed to be taken. The 4 inch guns at both batteries had originally been the secondary armament on the First World War battlecruiser HMS New Zealand. After this ship had been scrapped by the Royal Navy in the 1920s the guns came to New Zealand where they had been used as saluting batteries. The urgency of the period after the entry of Japan meant all available guns were pressed into service including these veterans. The emplacements they were put into are also a product of the urgency and shortage of materials in the country at this time. These guns are emplaced in roofed concrete structures called 'Colchester' shelters. These were built partly on the site and partly from prefabricated panels. At the time of their construction there were shortages of materials throughout the country, especially of cement (13). This has meant over time that these structures are amongst the most heavily decayed of the coastal batteries with severe spalling over much of their surface. This is especially bad in the prefabricated parts of the structures. The concrete over the steel is of minimal depth and this has lead to severe spalling as the steel reinforcing has rusted. A number of methods of stabilising these emplacements have been tried and these will be detailed in a later section of this paper.

2. MAINTENANCE AND REPAIR STRATEGIES

After the disbanding of the coast defences in 1959 most of the structures at North Head received little if any maintenance. The 19th century batteries had last been used in the 1920s when the navy had used them to store ammunition while most of the later emplacements were stripped of their armament and left to the elements. Parts of the North Head fort were handed to the local council in the 1960s and at this date much damage was caused by both official and unofficial vandalism. By the time the Department of Conservation took over the reserve in 1987 very little work had been carried out on the concrete defences. At this time most emphasis was being placed on dealing with claims that there were old blocked off tunnels at North Head containing tons of ammunition and possibly old aircraft. The research carried out to disprove these claims has however provided the basis for much of the subsequent repair work at the site. It was partly as a product of this work that the specifications and Frankham's reports were found.

2.1 Initial Assessment

The Department of Conservation after the deaths caused by the platform failure at Cave Creek instituted a series of procedures to assess the safety of all the structures it managed. This also included the large number of historic structures also managed by DoC. The structures at North Head in need of repair had already been identified during the preparation of the Conservation Plan (14). The most urgent work consisted of repairing the roofs in the 19th century South Battery where the railway line used to support the concrete roofs had rusted causing the surrounding concrete to break up and fail. This emplacement contains the 8 inch disappearing gun and is the most visited site on the reserve. The other work planned at this time was the partial demolition of one of the 1941 Colchester shelters at North Battery. This emplacement was in such a poor state that the engineers who had done the initial assessment suggested it was beyond repair. At about this point we realised that we knew very little about the management of historic concrete. Most of the contractors and engineers we talked to were confident they could deal with the later structures but few had any experience of working on large underground 19th century concrete buildings or in repairing what in normal circumstances would be regarded as beyond repair. The Department of Conservation at this stage engaged the firm of conservation architects Salmonds to undertake the management of the project. The final outcome of this process was the preparation of a maintenance and management handbook for historic concrete structures in New Zealand (15).

2.2 The Handbook

The handbook, 'Historic Concrete Structures', was written by Salmond Architects funded by a research grant from the Department of Conservation. Our experience at North head had shown us that while there were good standard practices for working on heritage structures built of brick or timber little was available on concrete. An initial draft of this document is at present available and there is some ongoing funding to monitor methods and materials used to date to assess their efficacy over a longer term. The handbook is divided into three sections dealing with the history of concrete both here and overseas, the types of defects found in structures of this nature and investigation and conservation strategies to remedy these. The handbook also contains a case study using a water tower built at the naval establishment on Motuihe Island in 1941. This sets out in practice the procedures recommended in assessing the work required to repair and stabilise this structure. One of the problems in dealing with historic concrete structures is that inappropriate repair work is relatively easy. There are a number of examples on the structures at North Head where earlier well intentioned repair work using modern materials had caused further damage. There were also examples of reconstruction carried to the point where the original structure was in effect obliterated by the repair. The handbook following usual conservation practice recommends the following procedure. Firstly causes of defects and deterioration need to be established. For this reason the primary focus should be to identify and eliminate the underlying and aggravating causes of deterioration wherever possible. This then needs to be followed by a repair strategy based on the principle of minimum intervention. As is described in the examples below experience is needed to apply these principles.

2.3 Repairs at North Head, an Example

The initial safety assessment had indicated two urgent jobs at North Head, the roofs of the 19th century tunnels at South Battery and the World War II Colchester shelter roofs. These provide a good example of how we have proceeded and some of the problems faced. The first part of the procedure recommended by the handbook is to carry out research on the structures and to review all documentary evidence relating to them. As described above at North Head this has not been a problem as most structures present have good records describing them. The second recommendation is to carry out a field survey to record the structure. In this example this had been carried out as part of the conservation planning process. The next process is to carry out appropriate tests. This was done at North Head as part of the work undertaken by the main contractor, Construction Techniques Ltd (16). Next measured drawings were made of all the affected parts of the structure and finally a full analysis was made of the state of the structures and some possible strategies were planned with the contractor. The 'how to' component of course was the most difficult. We are still trying a number of techniques and it is these that will be monitored in the longer term to assess the relative effectiveness and cost efficiency of the procedure used. The iron rails used to support the roof slabs in the South Battery had rusted severely in places and large pieces of concrete were falling from around these beams. In places while the concrete was obviously failing around the beams it had not fallen. It was decided that the best action was to clear the loose concrete from around the beams, treat the iron and to replaster using appropriate mortars in those areas where the concrete had not already fallen. Where the concrete had already broken away the treated steel was left exposed and no attempt was made to replace it. Initially the loose concrete was removed with a rock breaker although it was found that the old concrete was so soft that it could easily be cut away with a high-powered water blaster. The World War II 4 inch battery roofs however were more difficult and illustrate one of the ongoing problems in managing sites such as North Head. That is financial restraints. As stated above the recommendation was that part of the structure be demolished. This was because one of the roof beams had almost totally failed and was visibly bending. There was a quote from a demolition contractor for $10,000 to remove this part of the roof. At this stage we had the structure reassessed by another engineer with instructions that we would prefer a solution that kept the structure intact. We did not have enough money to carry out a complete repair so instead a simple system of steel props were designed to support the roof which cost less than $1000. This seems to have worked to date. The other problem with these emplacements was that they had been used at North Head differently to the way they had been originally designed. Originally these emplacements were designed to be freestanding. At North Head the same emplacement however had been dug into the hillside and the roofs covered with soil as camouflage. The roofs had been tarred as a waterproofing measure but this had failed allowing the salt laden water to seep through the roof and accumulate on the underside where most of the damage to the steel and thus the concrete had occurred. We still did not have a large enough budget to complete this part of the work. We were helped here by the donation of a large amount of materials and labour by the company Nuralite Ltd. This company sells and installs waterproof roofing membranes and had at the time of this job recently finished installing their product on the roofs at the national museum Te Papa. They offered to waterproof the roofs of both the 4 inch Colchester emplacements. The soil was stripped from the roofs by the Periodic Detention workers who carry out part of their sentence at North Head, the successors to the prisoners who built most of the defences last century. The roofs were prepared and the waterproofing installed and the soil cover replaced. To date this solution appears to have arrested the decay of the underside of the roofs and we have used these areas as a testing ground for other steel treatment products although finally these areas will need further work to ensure their long term protection.

2.4 Subsequent Work, North Head and Elsewhere

In 1999 further work was carried out at North Head. One of the most ruinous of the underground emplacements is the old engine room built in 1886. This building has the largest roof span of any of the 19th century underground structures which use the concrete and railway line construction method. The roof is very decayed and has started to fail significantly. The rails are sagging and falls of the roof concrete are common. The structure is closed to the public. The full repair of this structure is outside current budgets and for this reason other options were examined. Firstly we considered removing the earth cover from the building's roof to lessen the burden the old structure was supporting. Access problems however meant this option was not feasible. Removal of large amounts of soil in this area would also have had the effect of altering the contour of the hill markedly, something we wished to avoid. Instead it was decided to build a timber framework within the building to support the roof until such time as money was available to effect a complete repair. The building remains closed to the public. As stated above the Department of Conservation is to soon take responsibility for another fort at Point Takapuna. Initial preparation for the opening of this site to the public has started. Among the many relics of New Zealand's military history at this site are three Colchester shelters dating from World War II. As is usual with these structures, built in a time of shortages of materials, the shelters are in very poor condition. For safety reasons repairs had to be carried out. The work on these emplacements, which is continuing as I write, has been more complex than we anticipated. We had not previously attempted to repair one of these emplacments but had rather built supports to hold the structure up. As the contractor removed the loose concrete it became apparent that the structures were in much worse condition than was anticipated. Eventually large amounts of the reinforcing was exposed which after treatment was replastered. There were however parts of the prefabricated roof panels that were in such a degraded condition that repair was not possible within the budgetary restraints operation on this job. Patterns were taken from the existing panels and new components were constructed to repair the structure. As there are three of these emplacements at this site and we are only repairing two the other will be allowed to remain in its original condition. The fact that we could not assess the full amount of degraded concrete properly until the contractor started breaking it out meant that a greater part of the structures was removed and replaced than probably fitted the criteria of minimum intervention recommended by the guidelines in the handbook. In future with this type of structure we may used support rather than structural repair as a better option.

3 History From Repair

As stated above obtaining historical data is an important part of planning repair and maintenance strategies. There are however times when the information flows back the other way, when the repair work exposes elements of the history of the site that were previously unknown or incompletely understood. We suspected for example that the World War Two Colchester shelters were built at a time when materials were in short supply, part of the cause of the poor condition these structures were now in. On removing the loose concrete from the examples at Fort Takapuna it became apparent that not only was the concrete even thinner than expected over the reinforcing, less than 5mm in places, but the reinforcing too reflected this shortage of materials. In the roofs of the Fort Takapuna Colchesters reinforcing of varying lengths and thickness had been used. The repair work in general and the modern professional assessment of the 19th century tunnel structures has confirmed the impression that Frankham and his prisoners had built well within the limitations of the technology available. We have also learned some minor footnotes to the history of North Head and its construction as part of the repair process. We knew for example from Frankham's records that a blacksmith had been employed on various parts of the job and had assumed that this was mostly in building the steel gates and repairing tools. As part of the repair work a number of small metal fittings in the tunnels were removed. It became apparent from this that most of the brackets hinges and hooks built into the tunnels had been fabricated from reworked water pipe rather than having been bought in.

4 CONCLUSION

The concrete structures at the fort at North Head are important parts of the country's built heritage. The 19th century concrete work is an example of creative use of materials and techniques to both build cheaply and within the limitations of the labour force available. The original brick fortifications designed by the Royal Engineer officers did not fulfil the requirements of a parsimonious government in a country without the numbers of bricklayers required to easily carry out the projects. The Defence Engineer Tudor-Boddam is to be admired for the innovative techniques he employed and the supervising public servants such as Walter Frankham should be remembered for the skillful way the plans were implemented. It is a tribute to them all that with little or no maintenance the structures they designed and built have stood for over 100 years before needing repair. The process of assessing these structures both in terms of the materials used and the designs themselves has usefully added to our understanding of the processes involved in their construction over 100 years ago. Similarly the work done on the structures built during the period immediately after the entry of Japan into the Second World War reflect the haste and shortage of materials from that time. It was not until we started to think of repair work on these structures that we realised how little we knew about working with historic concrete. The outcome of this has been the preparation of the handbook on maintenance and management of these structures. This is still in a draft form and will be worked up as we gain more experience from the continuing work and from monitoring repairs to date. Copies of the handbook are available from the Auckland Conservancy of the Department of Conservation and comment is welcome. What we have learned is that there is no magic bullet. Every structure needs to be treated individually and at this stage a number of techniques have been tried. In some places defective concrete has been removed, steelwork treated and plastered. On others we have attempted to mitigate the causes of the problem by stopping water flow through the structure while other examples have been supported with steel and timber frameworks. The basis for all this work is however the records kept by the people who designed and built them. In this we are lucky that so much material has survived and it is hoped that this information can be used for future work on structures where information of this nature has not survived.

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Ralph Symonds' Plywood Factory

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Summary: *In 1958 Ralph Symonds Ltd was a company which had a high reputation for the production of timber products, notably structural plywood and glue-laminated beams. Its Chairman, Mr Ralph Symonds, was a creative innovator, who was fired with a belief in the structural potential of his products. The Company obtained a lease on a large industrial site and proceeded to erect several unique buildings thereon, one of which became renowned as the largest of its type in the world. The paper provides a fairly detailed description of the buildings, together with a brief discussion of the circumstances in which they were constructed.*

Introduction

When Ralph Symonds Ltd officially opened its new factory at Homebush on November 16, 1959, the magazine *Architecture and Arts* nearly exhausted its store of superlatives.[1]

The factory was described as "Australia's largest single storey factory", "the largest single storey arch building in the Southern Hemisphere" and the process of construction was "a romance of modern industry". It was pointed out that "Ralph Symonds Ltd are famous throughout the world" for their process of hot bonding plywoods and for "the design and fabrication of laminated timber structural members, arches, beams etc." "The story of the Company lies in the courage of Mr Ralph Symonds" who, it was claimed, was "a pioneer in the field of structural engineering (and who) successfully overcame the resistance of established authorities regarding the use of laminated beams and arches and stressed skin plywood structures".

Strangely, almost all of this journalistic hyperbole is justified. This was a most extraordinary building, and Mr Symonds was an extraordinary man.

The Man

Ralph Symonds commenced producing laminated panels and plywoods in Sydney in 1923, and, having barely survived the depression of the 1930s, became convinced of the potential of plywood as a structural material, rather than as a veneered decorative one. He moved into the design of machines for the manufacture of large sheets, and incorporated these into his factory at Rosebery, where he produced the world's first durable and fire-resistant plywoods. By 1942 he had registered as a proprietary company.

Business expanded greatly during the Second World War. The firm produced a great variety of ordnance for the armed services, ranging from landing barges and folding plywood boats to decoy plywood aircraft that could be parked at airfields to delude the enemy into thinking that Australia was better armed than was in fact the case. Mr Symonds donated the use of his fifty patents to the national war effort for the duration.

In the post-war period, the activities of the organisation expanded greatly, with the firm becoming a public company in 1950, by which time a large factory for the fabrication of laminated structures had been built at St Peters.

Amongst the wide variety of building work that was completed during this period, particular mention should be made of the following:

- The factory constructed for Burge Brothers at Flemington, Victoria, consisting of glue-laminated arches spanning 30 m (1945)[2]
- The roof membrane of the Myer Music Bowl, Melbourne.
- The triumphal arches for the Royal Visit to Sydney, 1954.[3]
- Two plywood domes for Mount Stromlo Observatory.

In all of these projects, Mr Ralph Symonds himself played a pivotal role. Although his formal professional engineering training was limited, he was a gifted innovator and inventor, with an almost obsessive belief in the potential of plywood and his own ability to control and utilize it.

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[1] New Ralph Symonds Ltd Factory Completed, Architecture and Arts, Nov 1959, pp 17-21

[2] Lewis, Miles: Assessment of former Burge Brothers factory, 135-157 Racecourse Road, Flemington for the Australian Heritage Commission, July, 1993

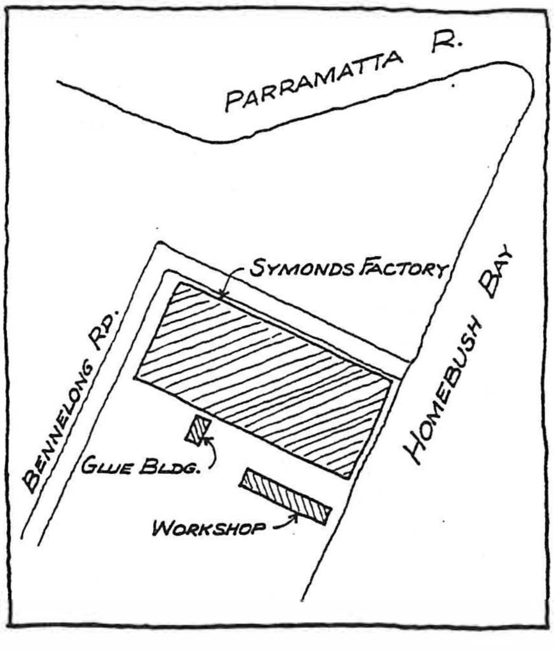
[3] Stanley, M.J., Plywood Cellular Ceramic Arch, Jour. IEAust, v.26,1954. p57

By the end of the 1950s, the company was large and profitable; its assets were valued at two and a half million pounds, and it was returning 38% profit on capital.[4] Planning was in hand for a joint venture to establish a second plywood factory in Scotland. Mr Symonds decided it was time to consolidate his firm's production capabilities under one roof, one *huge* roof, using timber structure on a scale never before attempted in the world.

He succeeded, and the building project was completed in 1960. Tragically, on January 2, 1961, Ralph Symonds was found accidently drowned at Pittwater, a northern suburb. His death was front-page news, and 300 mourners attended his funeral.

The Site

During the 1950s, the Maritime Services Board (which was the public utility responsible at that time for the management of the foreshores of the Port of Sydney) undertook a major work of land reclamation at Homebush Bay, some 12km west of the city. The Bay was dredged and a large area of swampy ground was reclaimed to create industrial sites having access for the docking of shallow-draft vessels.



Ralph Symonds Pty Ltd obtained a lease on a site 216 x 389 m in extent at the northernmost end of the development, with frontages onto two roads.[5] The lease was for a 10 year period with a 50-year option, at a rental of $5,000 p.a. for the first three years. A second lease of an adjoining site was subsequently obtained.

The site was quite remote and totally without services: no power, drainage or sewerage. The first constructions were to remedy these problems: a substation was commenced by mid-1958, and a transmission line was brought out along Bennalong Road. The provision of a sewer connection was a much more difficult task: in September 1958 the Maritime Services Board gave approval for a 150 mm sewer with sewage ejector to be constructed linking the site to the State Brickworks, some 2 km to the south.[6] Symonds claimed that this was one of the largest private sewerage connections in Sydney at the time; it was certainly a difficult one, involving excavations in unstable swamp-land and a 45 m creek crossing.

The Workshop

The first building permit granted to Symonds for the Homebush site was for a "Constructional Building Workshop"[7]. The Specification, dated 1st April 1958 described it as "a workshop from which the main building...is to be fabricated", which would subsequently be used as "an office and administrative building".

The building was a large single-storey shed, about 137 m long and 28 m wide, incorporating wide eave overhangs. It consisted of two-hinged arches of plywood box-beam construction, using laminated softwood chords and plywood webs on either side; they were described by Symonds as "Plywood and laminated timber stressed skin arches", and it is probable that the building inspectors of Auburn Council had never seen anything like them before. The Specification called for the laminates to be 20 mm thick and of "select softwood or other approved timber not subject to attack by borer", and the sides or webs were to be of 12 mm thick "Reswood" waterproof ply treated for fire resistance. The six 20 mm laminates in each chord were to be square butt jointed at their ends, with joints spaced not closer than 600 mm in consecutive layers. The estimated cost of the building was 21,600 pounds.

The drawing that accompanied the B.A. (No 334, dated 26.3.58, by Ralph Symonds Drafting Dept) is a rather primitive document, as were most of the Symonds drawings at this time. The arches are shown as being spaced at 2.1 m centres, and there is a suggestion that they may have been fabricated in two halves and spliced at the centreline. It is probable that they would have been fabricated at Symonds' laminating factory at Holland St, St Peters, but the transporting of half-arches 14 m long and nearly 6 m deep half-way across the city would have been a major difficulty unless additional splices had been provided at the knees of each arch.

The drawing describes the roof cladding as "waterproof plywood roof sheeting", suggesting that the waterproof membrane was to be plywood, rather than metal or asbestos sheet; this is not inconsistent with Ralph Symonds' faith in plywood at this time. (The Glue Building, to be described shortly, was also to be clad in plywood, but metal was in fact used.)

[4] New Ralph Symonds Ltd Factory Completed, Architecture and Arts, Nov 1959, pp 17-21
[5] Letter from Ralph Symonds to Auburn Council, 26 May 1958; Auburn Council Records Office, Microfiche File L8, No 1 Bennalong Rd.
[6] Letter from MSB, 25 September 1958; Auburn Council Records Office, Microfiche File L8, No 1 Bennalong Rd.
[7] Building Application 608/58; Auburn Council Records Office, Microfiche File L1, No 1 Bennalong Rd.

This building no longer exists, which is a pity.[8] It is the first recorded box beam portal frame building constructed by the firm, and may be one of the earliest in the country.

The Factory

The main factory building occupies a huge area. As constructed, the building was more than 350m long and about 160m wide, providing a single covered area about 56,000 square meters in extent.[9] Building approval was gained on May 26, 1958 for a 15-page specification accompanied by six drawings.[10] Drawing No 330, prepared by Ralph Symonds Drafting Department, shows the general arrangement and is dated 11.3.58.[11]

The building was roofed with a modular roofing structure, in which the east-west dimension of each module was 7.62m and the north-south dimension was 52.9m; it is three bays wide, and each bay is roofed with a gable roof, with the ridge aligned east-west,

Rising above the sloping roof planes of these gables are roof monitors, which have vertical glazing on their eastern and western faces. The width of each monitor, and the width of the section of gable roof between monitors, corresponds to the module of the structure along the bay i.e. 7.62 m. All roof surfaces are now clad in corrugated steel sheet, although the Specification called for corrugated asbestos cement.

The structure which creates this roof form is brilliantly simple in its conception. It consists of a three-pinned arch ABCDE, supported at A and E; a steel tie-rod BD between the knees of the arch at B and D provides additional rigidity to the arch. Suspended from the arch are two upper roof-beams, BG and DG, which follow the slope of the main roof of the building; supported above the ends of the arch are two lower roof-beams, FB and HD, also following the slope of the main roof. These arches are spaced along each bay at intervals of 7.62 m, with the central part of the arch rising above the plane of the main roof to form the glazed surfaces of the roof monitors.

Each arched rib consists of 30 laminations of timber (although the Specification nominates only 29 laminates), each lamination being nominally 20mm thick and 150mm wide.[12] Thus the entire arched rib is 150mm wide and approx. 620mm deep. The arch is identified on Drawing 342 as having a straight section 9.6 m long at a pitch of 15° joined to a circular curve of 24.7 m radius. The base of each arched rib sits in a simple steel shoe welded up from 75mm X 6mm steel, which rests on a 25mm round steel rod which constitutes a pin-joint for the arch. At some subsequent time steel plates have been welded on to the upper and lower edges of the shoe so as to provide a measure of rigidity at the base of the arch.

At each knee, approx 6.3 m in plan from the foot of the arch, are a pair of large steel gusset plates, one on each side of the arch rib; these gussets are used to attach the roof-beams to the rib, and to support a large box-beam member which spans between arches at this location. The upper roof-beam is a laminated timber beam 15 laminations deep, with overall dimensions probably about 300 mm deep and 100 mm wide; it follows the slope of the roofplane to the ridge, where it is joined to a matching beam in the other half of the arch. The lower roof-beam is 22 laminations deep, about 450 x 100mm in cross-section; this beam also follows the slope of the main roof down to the valley between bays.

Each upper roof beam was originally suspended from the arch-rib by a series of five steel straps, all perpendicular to the roof-beam . (Supplementary vertical hangers have since been inserted.) The area between the upper roof-beam and the arch rib is glazed in wired semi-obscure glass set into a standard industrial glazing module; many of these glazing panes are cracked.

The structure supporting the 10-m-long lower roof beam is extraordinary. The downpipe beneath the large box gutters was designed as a structural column, supporting the outer ends of the meeting pair of roof beams at the valley. It is a 200mm internal diameter asbestos cement pipe, carrying a light steel bracket at its upper end, and sitting on a conical pedestal on a 900 mm square concrete footing. Beneath the floor slab, and passing through these footings, is a massive stormwater drain, 900 mm in diameter, so that the downpipe discharges directly into the drain, hopefully with no possibility of blockages. The beam is also supported by a 75 mm steel pipe about 3.8 m from its outer end; this pipe slopes outward from its base on the arch footing, and the top of the footing is shaped to accommodate it.

The structural logic behind this arrangement is most unclear. Obviously, it would have been simpler and structurally more efficient to have positioned the steel column vertical, thus providing mid-point support for the beam. Clearly, also, the use of an asbestos downpipe as a structural member in a factory where trucks and large forklifts were to operate was a risky decision. Possibly, the inclined steel post was used to support the beam under normal conditions but also to provide a fail-safe support if the asbestos pipe suffered damage, by allowing the roof beam to cantilever at its end.

The roof purlins are probably one of Symonds' patents; they are of propped beam construction, utilising a timber purlin 125mm X 75mm, which is propped at two points using timber props, 62 mm square, supported on a mild steel strap. The strap is single bolted at each end to the underside of the timber purlin and is dowelled into the end grain of the strutting piece.

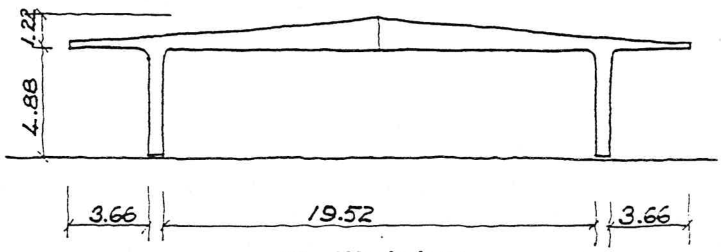
[8] There is a puzzling reference in the Architecture and Arts article (p17) that the administrative block and the glue plant are "later developments scheduled for 1960". This raises the possibility that the Workshop (which was intended to serve later as an administrative block) was not constructed in 1958, despite the approval of the building application. More evidence is required to clarify this uncertainty.

[9] New Ralph Symonds Ltd Factory Completed, Architecture and Arts, Nov 1959, pp 17-21

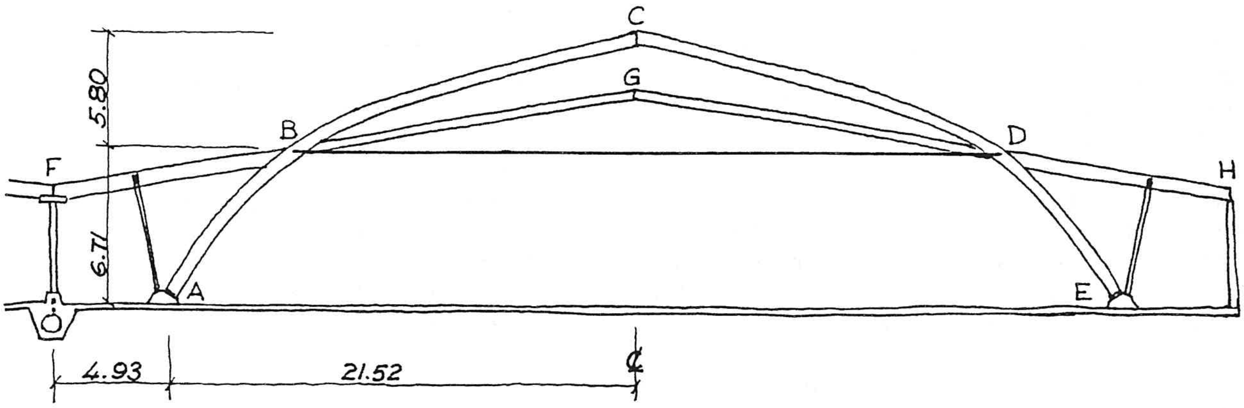
[10] Building Application 990/58; Auburn Council Records Office, Microfiche File L2, No 1 Bennalong Rd.

[11] Auburn Council Records Office, Microfiche File L10, No 1 Bennalong Rd.

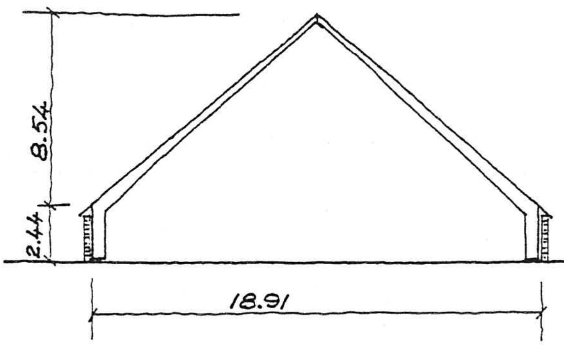
[12] This anomaly occurs several times in Symond's specifications; it might be that the word "laminate" is used for the interface between the laminations.



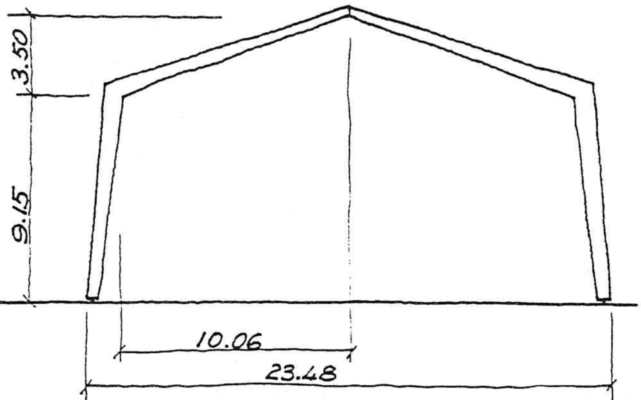
The Workshop



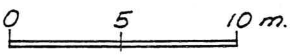
The Factory



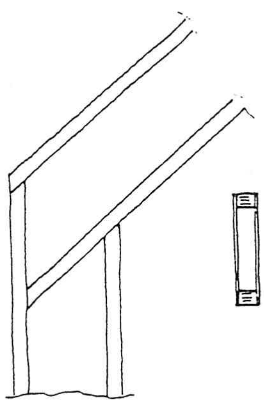
First Glue Building

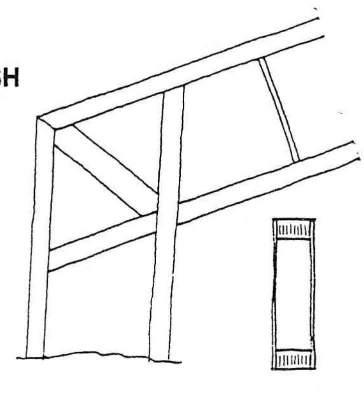


Second Glue Building



RALPH SYMONDS BUILDINGS AT HOMEBUSH





Details

The knees of each arch-rib are tied to each other by a 25mm diameter steel tension rod which runs across the building; this tie member is "lapped and welded where required" without the use of any turnbuckles.

By 1999, it was not easy to identify the original wind bracing system that was used in the building, because of the additional retro-fitted steel-work that is now in place; indeed, the detail of some of this bracing suggests that additions may have been made at several times over the years. However, it would appear that every segment of every panel of roofing was braced in a cross-braced system in the original design. The Specification calls for 50 x 3 mm straps as wind bracing. There is a single cross-bracing system at each eaves section (i.e. between valley and knee), consisting of steel straps and adjustment yokes. In the curved section of roofing, between roof lights, are two sets of cross bracing, each similar to those in the eaves. On the flat runs of roof, between monitors, there is only a single cross brace located in the middle part of each roof run.

The arched ribs, between the knees and the footing, are each braced by a cross brace which runs from the under edge of the box-beam purlin to a point about half-way down the rib. This bracing appears to be fairly old, but its different structural detailing suggests that it may not be part of the original design.

The structural adequacy of the arch ribs was demonstrated by a load test on January 19th, 1959, some six months after the building application was approved[13]. A certificate was issued by consulting engineers P.O.Miller, Milston and Ferris on September 11, 1959, attesting to the "structural soundness" of the building.[14] The official opening, performed by R.J.Heffron, the Premier of N.S.W. was held on November 16, 1959,and represented a triumphant day for Symonds. Amongst the 1,400 guests were the Leader of the Opposition, the Earl and Countess of Dalkeith and many parliamentarians and leaders of industry. The building had cost 1.5 million pounds (five times the original estimate), and had taken only 18 months to completion.[15]

It is apparent that the building has suffered from inadequate lateral stiffness (sideways movement of the arch-ribs, causing them to distort out of their own plane) for some considerable time. This is evidenced firstly by the extent and variability of additional roof bracing that has been inserted over the years, and, secondly, by orally reported accounts of progressive cracking and replacement of the roof cladding and glazing. The major weakness would be in the lack of cross-bracing between the knees of the arch and the footings; the rib in this region is laterally unbraced and unsupported over a length of about 9 m, and it is improbable that the roof bracing of the straight section of roof over the outer roof beams would have been able to compensate for this inherent flexibility.

Moreover, calculations performed in recent years by the engineers responsible for assessing the adequacy of the structure have shown that, if judged by today's standards of loads and allowable stresses, the arch is overstressed by between 40% and 100%.[16] Certainly, distortions of the roof plane are clearly visible when viewing the exterior of the building. The most basic of engineering analyses would show that the shape of the arch chosen by Symonds was inappropriate; in general, it could be said that those parts of the arch which are straight should have been curved and those parts that are curved would have been better straight.

The ribs were laminated using a casein glue, which was the adhesive most commonly used for laminated construction at this time.[17] Caseins were known to be non-waterproof, and subject to fungal attack in damp conditions, but were generally regarded as being suitable for indoor structures. The timber used in the laminations was New Zealand pine, predominantly pinus radiata; these timbers also are recognised for their susceptibility to fungal attack.

There is therefore strong evidence that, by today's standards, the structure is inadequate both in strength and in servicibility.

It is not recorded when remedial structural measures first became necessary, but in 1990 a major structural collapse occurred. The extensive investigations made at that time revealed that there was considerable delamination of the ribs, caused by the fact that the glue line and the timber fibres adjacent to the glue line had suffered fungal attack. Whether this was because of rain penetration caused through claddings damaged by the flexibility of the structure, or whether it resulted from some of the processes carried out within the building, or both, is not certain.

Since that time, deterioration of the structure has progressed. The building has now been divided into three parts by creating two transverse streets through the most badly damaged parts. Most areas now have supplementary support structures in place – trusses and portal frames from structural steel to provide vertical support and lateral stability. For some years much of the floor area has been let as separate tenancies, and, since the closure of Ralph Symonds Pty Ltd in 1998, the building has been prepared for demolition.

The Glue Building

Approval for the original glue building at Homebush was gained on August 1960[18]; the building was described in the BA as having "plywood and laminated timber stressed skin arches and structural members with a plastic surface plywood roof." The cost was estimated at 5,600 pounds.

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[13] Letter from ralph Symonds Pty Ltd to Auburn Council, 12.1.59: Auburn Council Records Office, Microfiche File L7, No 1 Bennalong Rd.

[14] Letter from P.O.Miller, Milston and Ferris, Consulting Structural Engineers, 11.9.59; Auburn Council Records Office, Microfiche File L7, No 1 Bennalong Rd.

[15] Ralph Symonds Magnificent Achievement, The Australian Timber Journal, Dec 1959.

[16] Private communication to author, Hughes Trueman Ludlow, Consulting Structural Engineers

[17] Pearson, R.G., Kloot and Boyd, Timber Engineering Design Handbook, 1958. P158

[18] Building Permit 14482; Auburn Council Records Office, Microfiche File L7, No 1 Bennalong Rd.

The accompanying drawing[19] showed a building 18.91 x 43.61 m in plan, with timber arches spanning 18.91 m spaced at 2.13m centres . The arches were three-pinned, with vertical legs 2.4 m high, and straight, tapering, inclined rafters rising to a height of 10.98 m above floor level. The arches were of box-girder construction: the two chords were glue laminated, nominally 100 x 75 mm, with the laminations perpendicular to the webs, which were of 12 mm plywood. The legs of the arch were not dimensioned, but appear to be about 600 mm deep. In fact, the drawing shows little detail of the proposed method of construction, and suggests that any engineering input was very limited.

The low walls were of cavity brick, but it is unclear how the building was to be roofed; the roof is shown on the Drawing as being of 24 gauge galvanised iron roof sheeting supported on 100 x 50 mm hardwood purlins, yet the elevation also carries the notation "3/4 inch Plastic Skin plywood roofing."

This building was destroyed by fire within two years of being constructed,[20] and a new building application was lodged in November 1962 for "the re-erection of a glue factory", again having "plywood and laminated timber stressed skin arches". The arches were to be constructed at the Homebush Bay Factory and a building permit was issued on January 4, 1963[21].

The drawings for this building (D1662/1 & 3, dated Nov 1962)[22] were prepared by P.O.Miller, Milston and Ferris, a well-known Sydney consulting enginering practice. The three-hinged arches again consist of glue-laminated chords and plywood webs and span 23.48 m, rising to a height of 12.66 m at the ridge. There are fourteen such frames and they were spaced at 3.35 m centres, so that the overall length of the building is about 44 m. Cladding is brick to a height of about three meters, with corrugated steel on 150 x 50 mm timber purlins (at 1.2 m centres) and girts (0.9 m) above.

The chords of the portals are 100 x 188 mm overall, and consist of 10 laminae of softwood, each 20 mm thick, but scarfed joints (slope 1:15) were to be used to join the laminates (although Symonds' own Specification called for butt joints). The sides were of 9 mm thick "Reswood" waterproof ply, treated for fire resistance. The portals were 800 mm deep at the knees, and tapered to 450 mm at the ridge and 500 mm at the base. At the ridge, the half-arches were spliced by a pair of 8 mm thick steel plates, bolted through four 15 mm bolts to each side. At the foot, the arches sat in a fabricated steel shoe, anchored to a concrete footing through a 87 mm diameter steel tube.

The posts in the gable walls, which span up to 12.66 m to the ridge, are also fabricated from plywood box sections. They are composed of laminated chords, 125 x 75 mm with 8 mm thick plywood webs, and are 600 mm deep. They are spaced at about 2.1 m centres.

There are some differences between the building represented on the drawings and that standing at Homebush in 1999. The measured width of the arch members is 235 mm overall, whereas the designed thickness of 188 mm chords plus two 9 mm webs is only 206 mm; it might be that one extra laminate was used during fabrication. (The faces of the members are sheathed in 4.5 mm plywood, so the edges of the laminae cannot be examined.) The plywood webs were nailed to the chords using two rows of flat-headed nails at about 100 mm pitch, although no nailing is specified on the drawing. In the building as constructed, both the intrados and extrados at the knee are curved, but no documentation exists to show how this was achieved or how the bracing at the knee was actually achieved.

When inspected in 1999, the building appeared to be in good structural condition. The portals have suffered incidental damage from impact with vehicles and goods, but there is no obvious evidence of delamination.

Conclusion

There is no doubt that Mr Symonds produced a very significant achievement with these buildings. The box-beam portals of the Workshop and Glue buildings were certainly fairly early Australian examples of this type of construction. Box-beam portal-framed buildings were being promoted by USA timber interests, and several churches were being constructed at locations around the country in the late 1950s, but these were usually of much smaller span than the two Glue Buildings. The main factory building was a breath-takingly daring use of a relatively novel form of construction on an immense scale. Other laminated arches had been built in Australia at this time, and a very similar structural concept had been reported in 1958[23], but the span at Homebush is some 20% larger and the covered area is vast.

Acknowledgments

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[19] Drawing H382; Auburn Council Records Office, Microfiche File L14, No 1 Bennalong Rd.

[20] Letter from Council 20.11.62; Auburn Council Records Office, Microfiche File L6, No 1 Bennalong Rd.

[21] Building Application 945/62; Auburn Council Records Office, Microfiche File L1, No 1 Bennalong Rd.

[22] Drawings D1662/1 & 3; Auburn Council Records Office, Microfiche File L17, No 1 Bennalong Rd.

[23] Pearson, Kloot and Boyd, *op cit*, show a photograph of an unidentified Sydney building; it is possible that this was also constructed by Ralph Symonds, but has not yet been positively identified. Other arched buildings, with spans of about 32 m and probably also by Symonds, have been identified at St Peters in Sydney.

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