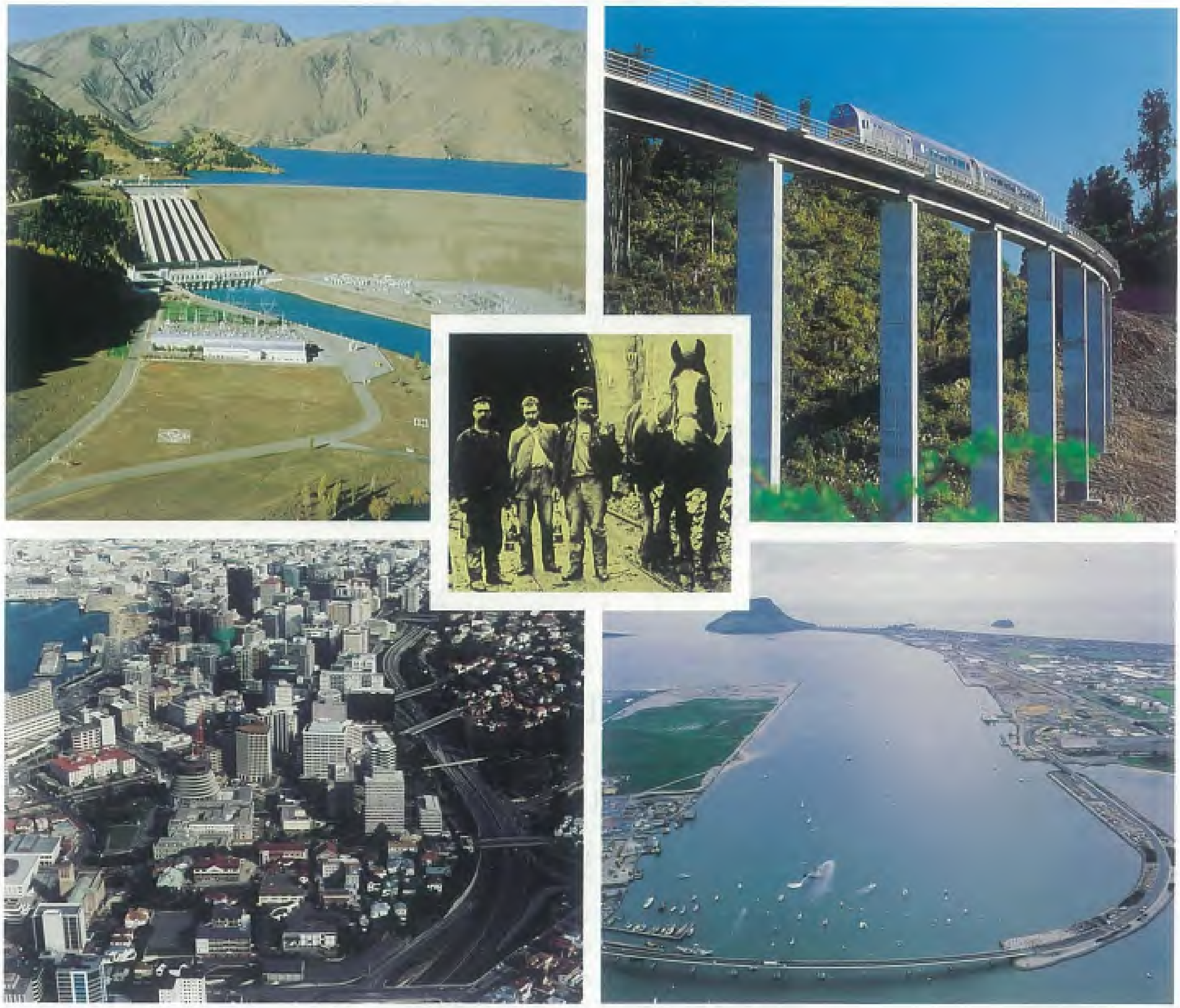
ENGINEERING TO

IPENZ

1990

New Zealand 1990
OFFICIAL PROJECT



THE INSTITUTION OF PROFESSIONAL ENGINEERS NEW ZEALAND

ACKNOWLEDGEMENTS

The text of Engineering to 1990 was compiled for IPENZ by F.N. Stace, foundation editor of *New Zealand Engineering* (1946-1980) from information supplied by the nominees of the engineering works commemorated.

Organisations who have given approvals and financial support for the projects are listed on page 4.

Thanks are also due to Trevern and Anna Dawes whose photographs from their book 'Kiwi Curiosities (published by Pacific Publishers and later by Penguin Books Ltd) are reproduced on pages 15, 51 and 53.

The cover photograph of the Wellington Motorway is by Woolf Ltd.

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THE INSTITUTION OF PROFESSIONAL ENGINEERS NEW ZEALAND

LEARNING·SERVICE·ACHIEVEMENT

ENGINEERING TO 1990

The Institution of Professional Engineers New Zealand is actively involved in our country's 1990 sesquicentennial celebrations.

We are proud of the enormous contribution engineers have achieved in New Zealand's development. It is there for all to see — in our roads, railways, bridges and buildings; in our systems for electricity, gas, water and telecommunications; in the production of steel and aluminium, and in agriculture and forestry. The application of engineering has enhanced the lives of all New Zealanders.

During 1990, the Institution has placed commemorative plaques on 68 selected sites throughout the North and South Islands. This publication describes those sites and their importance to New Zealand's engineering heritage.

B J BUTCHER
PRESIDENT

IPENZ

The Institution of Professional Engineers New Zealand is a society of professional engineers joined together for the advancement of the science and profession of engineering.

It was originally incorporated in 1914 as the New Zealand Society of Civil Engineers, became The New Zealand Institution of Engineers in 1937, and took its present name in 1982. Its membership embraces professional engineers from all disciplines, particularly civil, mechanical, electrical and chemical.

The Institution sets the qualifying standards for professional engineering in New Zealand. It represents in the widest sense the New Zealand engineer to the New Zealand public and, through its membership of the World Federation of Engineering Organisations, to overseas countries.

New Zealand 1990 OFFICIAL PROJECT

On this map the places at which the IPENZ "Engineering to 1990" sites can be found are indicated in heavy type.

ENGINEERING TO 1990

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ENGINEERING TO 1990

IPENZ gratefully acknowledges the approvals given by all owners of the Engineering to 1990 projects and the financial support given by the following organisations.

New Zealand Lottery Grants Board through the New Zealand 1990 Commission
Transit New Zealand
Works Civil Construction
Works Consulting Services
NZ Railways Corporation
Trans Power NZ Ltd
Electricorp Production
Department of Conservation
Downer & Company Ltd
Fletcher Development & Construction Ltd
Fletcher Civil Engineering Ltd
Wilkins & Davies Ltd
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Worley Consultants Ltd
NZ Steel Ltd
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Auckland Regional Council
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Protech Engineering Ltd
Kelly Tarlton's Underwater World Ltd
Bruce Wallace & Partners Ltd
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Carter Holt Harvey Timber Ltd
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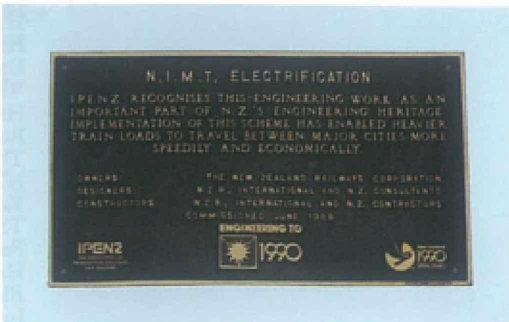
Bechtel International Inc



Cement Works in Northland

Mahurangi

These engineering remains (2 km south of Warkworth) are an important part of New Zealand's engineering heritage. Opened in 1876 to produce hydraulic lime, the plant was developed in 1884 to become the first Portland cement works in the Southern Hemisphere. The works were closed in 1928.

In 1883 Nathaniel Wilson of Warkworth began experimenting with local materials to produce Portland cement. With the assistance of J A Pond, government analyst in Auckland, full-scale production began under the name John Wilson and Company. This local production of Portland cement was the first both in New Zealand and in the Southern Hemisphere, and introduced an important building construction product to the colony at a time when the same product was far from being in general use elsewhere in the world.

Wilson expanded his works to increase production by utilising the latest in overseas technology. In the mid-1890s he sent his son to the United States, following which visit rotary kilns and ball and tube grinding mills were installed, providing for high capacity output to the growing colony. Production grew from 1520 tonnes in 1897 to 7620 tonnes by 1902, and with a major extension to the works in 1903 annual production rose to 20 230 tonnes.

The availability of Portland cement in tonnage quantities from the beginnning of this century enabled rapid development of durable port facilities, particularly in Auckland.

The Mahurangi remains are also notable in that the 1903 extensions used unreinforced concrete walls of about 225 mm thickness and 12 m height which are still standing though much of the structure is derelict.

Original owners, builders and operators: John and Nathaniel Wilson

(1878 John Wilson and Company)

(1903 John Wilson and Company Ltd.)

Portland

Located near an unusually consistent reserve of high-grade raw material this plant is the largest and most modern in New Zealand. The original plant opened in 1913 and the 'Dry' process commenced in 1983.

Nathaniel Wilson and his brother John, later followed by a third brother, were largely responsible for promoting the construction of the Portland cement works, 8 km south of Whangarei. Fullers Engineering Co. of the United States was responsible for the design of the Portland works and also provided 11 grinding mills. The Wilkes Barre Co. (also of United States) provided kilns, driers and coolers.

The reconstruction in 1980 was designed by Gatx-Fuller, the same company that did the original plant, and local contractors Whangarei Engineering Co Ltd (WECO) and Wilkins and Davies were responsible for the construction work.

With the latest improvements the Portland plant is a very sophisticated engineering project and its conversion to the dry process makes it for its size, one of the most efficient plants in the world.

Companies involved:

New Zealand Portland Cement Company Ltd

Dominion Portland Cement Company Ltd

Wilson's (NZ) Portland Cement Company Ltd

Present owners: Fletcher Challenge.

Grafton Bridge

At the time of its construction (1907 - 1910) in the city of Auckland, Grafton Bridge had the longest arch span in the world (97.5 m) and for many years the largest in the Southern Hemisphere.

Its architectural style utilised false piers to create the visual impression of strength associated with traditional masonry construction, while the slim ferro - concrete load - bearing members provided the true structural support.

The structure demonstrated at an early date the potential of reinforced concrete for major engineering works. It has become a striking monument to early bridge engineering design and as such is a work of national significance. The bridge has been given an 'A' classification by the NZ Historic Places Trust.

Owner: Auckland City Council

Engineering supervision: W E Bush, City Engineer

Contractor's design engineer: R. F. Moore

Contractor: Ferro-Concrete Company of Australasia Ltd.

Auckland Ferry Building

Opened in 1912, after a 2½ year construction period and a cost of about $136,000 the Ferry Building was strengthened and refurbished in 1988, for about $8 million. It is a fine example of a restored historical building.

Original owner: the Auckland Harbour Board

Original architect: Alexander Wiseman

Original builder: W Philcox & Sons

Current owner: Ports of Auckland

Restoration: Challenge Properties Ltd

Architects: Henson & Morrison Ltd

Engineers: Smith Leuchars Ltd

Builders: Fletcher Development & Construction Ltd

New Zealand Yacht KZ 1

Launched in March 1988 the yacht KZ 1 competed in the 1988 America's Cup Challenge at San Diego and is the first craft of its size comprising a fibreglass hull of shell form construction.

The fibreglass is specially formulated with carbon inclusion for lightweight yet tough construction.

Owners KZ1: Michael Fay and David Richwhite

Designers: Bruce Farr Associates

Engineers: Rikan Engineering

Advanced engineering services: High Modulus

Contractors: Marten Marine McMullen & Wing.

Western Springs Pumping Station

For 33 years the beam engine and pump pictured below supplied the city of Auckland with water, and the plant then served as a backup for a further 46 years.

The pumphouse shown above was opened in 1877. The pumping machinery is the finest in New Zealand that is still in demonstrable working order. The pumps are housed in a mid-Victorian brick structure with internal beams and columns of cast iron.

The pumps drew water from the artesian source at Western Springs and supplied the growing city of Auckland from 1877 to 1936 when the first of the Waitakere water supply schemes was commissioned.

The pump machinery is now activated by an electric motor four times daily for visitors. The pump gallery is also the site of a display of the Auckland Regional Council's water supply system.

The pumphouse is the focal point of Auckland's Museum of Transport and Technology (MOTAT) which opened in October 1964. Both the pumphouse and the steamhouse have a 'B' classification from the NZ Historic Places Trust.

Owner: The Museum of Transport and Technology
Engineer: William Errington
Manufacturer: John Keys & Sons, Scotland.

Vacreator Cream Pasteurising Plant

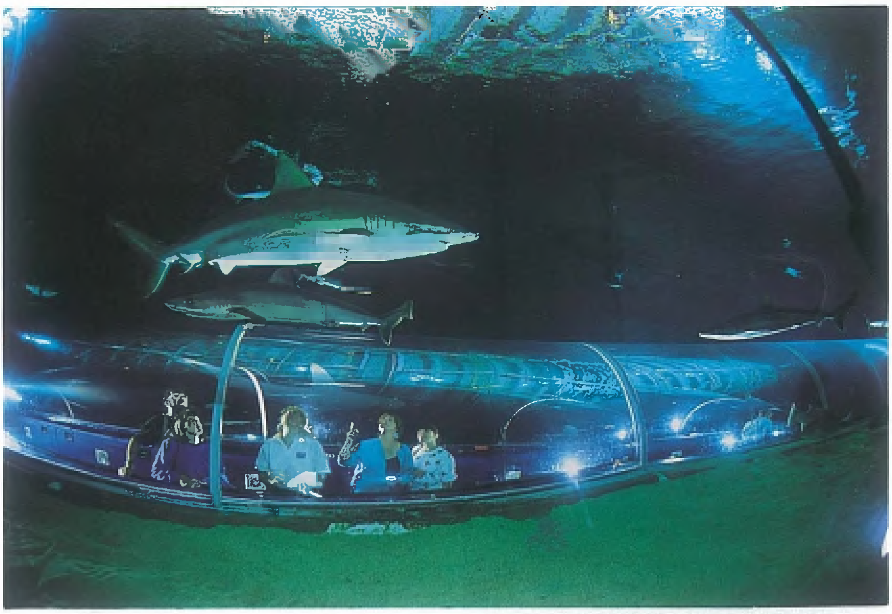
The vacreator process mixes steam with cream to both pasteurise and deodorise the cream. Invented in New Zealand in 1923 by Lamont Murray this process is now used throughout the world and is a vital factor in New Zealand's butter export trade.

Pasteurisation is necessary to kill micro organisms while deodorisation removes feed taints from the cream. Vacreation deodorises the cream so that butter kept frozen for two years still has an acceptable flavour. This feature was most significant in developing the butter trade with the United Kingdom prior to World War II.

The vacreator is in use in all butter factories in New Zealand and it is proposed to have a vacreator museum at MOTAT. Vacreators have been sold in Australia and South Africa, and made under licence in the United States of America.

Development: Murray Deodorisers; NZ Dairy Research Institute, and Protech Engineering Ltd.
Manufacturer: Protech Engineering Ltd.

Kelly Tarlton's Underwater World



This is a fine example of entrepreneurial engineering, and the unique technology developed in New Zealand to build an acrylic tunnel for undersea viewing is now sought internationally. Innovatively created inside disused sewage holding tanks, Kelly Tarlton's Underwater World is Auckland's major tourist attraction.

The aquarium is designed to recreate the world the diver sees on a typical Hauraki Gulf volcanic reef. Spectators move through this world inside a clear acrylic-covered tube set in a trench in the base of the aquarium. They travel on a conveyor belt, stepping on and off to watch colourful fish life around and above them.

Kelly Tarlton, who died in 1985 aged 47, not long after welcoming the 100 000th visitor to the aquarium, was a world renowned diver with an impressive list of achievements in the underwater sphere.

His Underwater World was created inside existing disused sewage holding tanks located under Auckland's harbourside Tamaki Drive. By the innovative use of 70mm thick acrylic panels bent to a tunnel shape, visitors can move through the base of the aquarium on a conveyor. The mechanical services and water-filtering equipment were all designed and built to meet the particular requirements of the project.

Until the opening of Kelly Tarlton's in 1985, conventional aquaria used acrylic panels in flat sheets in viewing galleries. The construction techniques developed to construct the acrylic tunnels were unique and have since been successfully used internationally.

The project showed that New Zealand engineers are not afraid to try something new. After research into new materials and methods (e.g. acrylics and silicones, waterproofing and fish care) they evolved techniques to overcome the problems encountered e.g. bending of acrylic sheets into arches, forming horizontal bends using 'lobster-backs', and used a baggage conveyor for the transport system.

The subsequent companies formed by Kelly Tarlton's associate, consulting engineer, Ian Mellsop, have played major roles as specialist consultants in five 'underwater world' complexes in Australia and Asia with four more in the initial planning stages in Australia, Hong Kong, Hawaii and Europe.

Owner: The Helicopter Line
Concept: Kelly Tarlton
Architectural - Structural - Mechanical Design: Bruce Wallace Properties Ltd
Construction: Kelly Tarlton and Precast Construction Ltd

Carter Holt Harvey Pavilion

Opened in 1984 this is an outstanding example of timber engineering; the main roof is supported by 44 m long beams formed from glued laminated timber and plywood, the largest span timber beams in the Southern Hemisphere.

The pavilion, at the New Zealand Expo Centre, Auckland, was required to accommodate easily exhibits such as full-size houses, yachts and also to be used for public sporting and cultural activities.

A central span of 44 m was accomplished with a plywood box beam measuring 2.4 m deep by 0.45 m wide with the top and bottom chords in continuous glulaminated radiata timber.

Owner: NZ Expo Centre
Designers: P Simperingham and P Hill
Contractor: Fletcher Development & Construction

Manukau Sewage Purification Works

Commissioned in 1960, with major expansions between 1975 and 1980, this is New Zealand's largest sewage treatment plant and its oxidation ponds are the largest in the world.

The treatment plant, which currently handles an average daily flow of 320 000 m^3 has been instrumental in dramatically improving and subsequently maintaining the water quality in parts of Auckland's Waitemata and Manukau harbours.

The plant occupies some 600 hectares and serves more than 600 000 people plus most of Auckland's industry.

The decision to construct oxidation ponds as a secondary treatment of sewage was influenced by the sunny climate, which is necessary for the efficient working of the ponds, the suitability of available mudflats and the large fluctuations in the organic load. Covering in excess of 525 hectares, the ponds have subsequently proved to be an inexpensive and efficient component of the secondary treatment.

Few cities anywhere are confronted with the high proportion of trade wastes in the total sewage flow which Auckland experiences. Animal wastes particularly, together with the discharge from industries such as tanning, brewing, wool scouring and timber processing, complicate treatment processes.

Owner: Auckland Regional Council

Design: Auckland Metropolitan Drainage Board and Brown & Caldwell U.S.A.

Lower Nihotupu Dam

This dam by Huia Road in the Waitakere Range (6.5km from Titirangi), was built between 1945 and 1948. It was New Zealand's first major roll-fill dam to utilise the science of soil mechanics.

The dam is 24.7 m high above its foundation and has a crest length of 381m and a volume of 359 100 m^3. The lake storage area is 4 810 000 m^3. Its successful construction established the science of soil mechanics in New Zealand and this was shortly followed by the inclusion of engineering geology as a major subject at the School of Engineering, Auckland.

Original owner: Auckland City Council

Present owner: Auckland Regional Council

Designers: C W Firth and A.C.C. Design Staff

Contractors: Downer & Co Ltd, Wellington, jointly with W A Stevenson & Sons Ltd, Auckland.

Auckland Motorway System

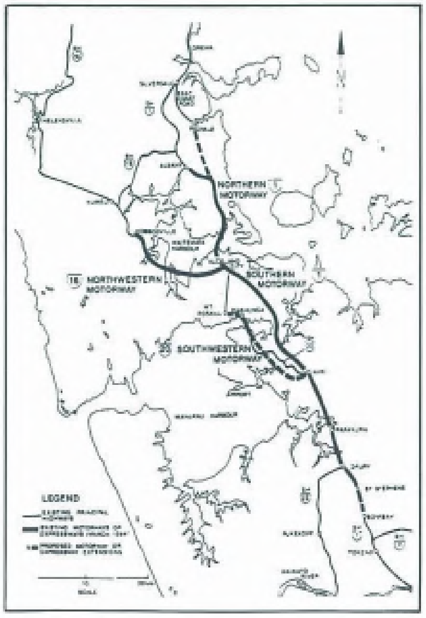
Innovative design and construction combine successfully to thread about 90 km of motorway and 100 major structures through greater Auckland. The motorway includes the Auckland Harbour Bridge, New Zealand's largest engineering structure.

Among the major structures within the central city area are the Symonds Street Bridge and the Newmarket Viaduct. The Symonds Street Bridge was the first major bridge in New Zealand to use the system of off-site segmentalised span construction followed by epoxy jointing and prestressing to make the finished structure on site.

Symonds Street is a main traffic artery leading into Auckland City. A bridge had to be built to take Symonds Street traffic over the motorway. However the alignment had to be identical and no major detours could be made. A major excavation was needed for the motorway at this point.

The bridge was built in two sections maintaining traffic flows through half the carriageway at a time, but this did not allow excavation to take place. Therefore construction of the bridge piers and foudation piling was carried out from road level prior to limited excavation taking place. The continuous prestressed box girder was then precast in segmented single spans off site. The individual segments each weighing some 20 tonnes were then brought to site, placed in position, epoxy glued together, prestressed into single spans, and then further connected together into a three-span continuous structure through a second stage of prestressing. The structure was completed with handrails, etc, and carried traffic before the major excavation took place underneath it to take the motorway alignment.

The carriage of the motorway over Newmarket called for a major elevated structure with long spans, S-shaped geometry and varying superelevation.



MOTORWAYS

Location	Length
Northern Motorway, Onewa Road to Albany	12.4 km*
Auckland Harbour Bridge & Approaches, Onewa Road to Cook Street	4.2 km
Central City Interchanges, Grafton & Newton Motorway connections	8.4 km
Northwestern Motorway, Newton Road to Hobsonville Road	17.3 km
Southwestern Motorway, Queenstown Road to Coronation Road	4.4 km*
Southern Motorway, Symonds Street to St Stephens	42.0 km
TOTAL LENGTH:	88.7 km

(* Includes sections to expressway standard)

STRUCTURES

Motorway	Number of Bridges	Length
Northern Motorway	11	515.5 m
Harbour Bridge & Approaches	4	1908.4 m[1]
Central City Interchange	14	2172.5 m
Northwestern Motorway	14	1246.2 m
Southwestern Motorway	2	691.0 m[2]
Southern Motorway	48	3281.4 m[3]
TOTALS:	93	9.815 km

NOTES:

1. Includes Auckland Harbour Bridge, 1020 m.
2. Includes Mangere Bridge, 644 m.
3. Includes Newmarket Viaduct, 689 m.
4. Adjacent twin structures considered as single bridge.
5. Pedestrian structures and drainage culverts omitted.

The resulting structure is complex to build even by today's standards, and in the early 1970s it was breaking new ground in New Zealand.

This structure was the first prestressed continuous box-girder bridge in New Zealand and the first such structure constructed without falsework using the cantilever construction techniques. It was also the first use of a Freyssinet type concrete hinge at the base of the columns.

The pioneer continuous box girder design and cantilever construction techniques contributed significantly to the knowledge and understanding of temperature and creep effects in complex prestressed structures.

A major retaining wall was a key element in the planning and construction of the Newton Gully Interchange. The wall, together with the Karangahape Road Underpass, makes possible the passage of the motorway at two levels under Karangahape Road. Construction of this wall significantly reduced land and property compensation costs by limiting the area required for the interchange. Both the design and construction technique were unusual at the time. (1969 - 1971).

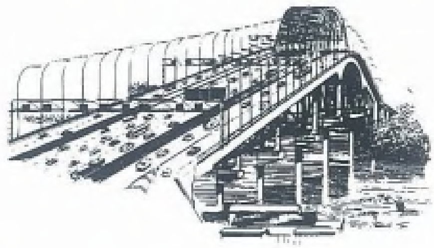
Controlling Authority: Transit New Zealand

Main Motorway Design: Ministry of Works

Construction: Various NZ contractors

Staged completion: 1953 to 1990

Auckland Harbour Bridge



As originally constructed, between 1955 and 1959, the Auckland Harbour Bridge was New Zealand's largest bridge and the one with the largest span. It still is. 'Clip-on' extensions, doubling the traffic lanes from four to eight, were added between 1968 and 1969.

These extensions, prefabricated in Japan, and then built on the original bridge foundations, were of orthotropic box structure and, when designed in the mid 1960s, were at the forefront of technology. Much of the detailing incorporated into the structures has been shown by subsequent research to be less than optimum in terms of fatigue performance.

Fatigue cracks discovered in 1985 required the removal and replacement of some 2000 splice joints in the stiffening troughs immediately below the bridge road surface. Special techniques needed to be developed, first to enable pieces of the bridge to be safely removed while the bridge was still under dead load, and replaced without causing welding distortions, and secondly, the techniques had to permit economic production rates because repairs could be undertaken outside peak hours only and the bridge could not be opened to traffic with incomplete repairs.

Semi-automatic welding machines, using fluxed covered wires were utilised and extensive procedure trials were undertaken to develop techniques which met the demanding technical and time requirements for the work. The techniques employed are "state of the art" and have been received with great interest in welding circles worldwide.

The 'management' of fatigue effects is now an integral part of the maintenance of the extensions (clip-ons) to the Auckland Harbour Bridge. Detailed analysis following discovery of the trough splice cracks in 1985 has led to predictions of the fatigue life of the identified 'at risk' details throughout the bridge. A detailed inspection manual defines the locations, inspection intervals and techniques to be used as part of an ongoing programme.

Formal quality assurance principles were applied to the two major welding repairs undertaken on the bridge between 1986 and 1989. Building on the experience gained in these two exercises, the consultants have now implemented quality assurance procedures for the bridge maintenance painting contract.

Owner: Auckland Harbour Bridge Authority; National Roads Board from 1 April 1984

Consultant: Works Consultancy Services (formerly Ministry of Works and Development)

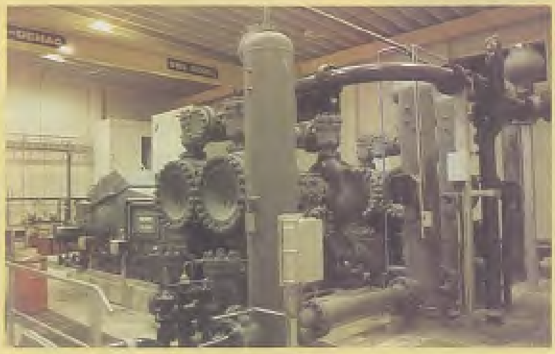
Designer: Freeman Fox & Partners

Original bridge contractors: Dorman Long/Cleveland Bridge Co;

Extension contractors: Ishikawaima Heavy Industries.

SLURRY TECHNOLOGY

INNOVATIVE PROJECTS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1 New Zealand Steel Ltd Iron Sands Pipeline Positive Displacement Pumping units

2 Nerang River Entrance, Gold Coast, Queensland. Fixed Automatic Sands Bypass System (World First)

3 156km Ok Tedi Copper Concentrate Slurry Pipeline, Papua New Guinea

Slurry Systems Pty Limited is the designer of the New Zealand Steel Ironsands Slurry Pipeline. The Company has a proven "hands on" record in the forefront of slurry technology and technology innovation.

Slurry Systems provides the following services

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- Slurry Testing
- Definitive Design
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- Start-up and Commissioning
- Operation

Slurry Systems Pty Limited
P.O. Box 424
Northbridge NSW Australia 2063
Telephone: (02) 958 0811
Facsimile: (02) 958 0064

SlurrySystems

Steel from Ironsand

The production of steel from titanomagnetite sand is a world first, and this plant at Glenbrook, South Auckland, is the only one of its type. It was designed to use a process largely developed by New Zealand engineers to produce steel from indigenous ironsand and sub-bituminous coal — the biggest single-site development in New Zealand.

The original works, designed to produce 150 000 tonnes/year of steel billets, was commissioned in 1970 but was subject to extensive modifications, additional plant and other improvements which were not completed until 1978. The construction period for the original works was from 1967 to 1969.

The Stage 1 expansion from 150 000 tonnes/year to 750 000 tonnes/year commenced in late 1985.

The following features were all optimised in the original 150 000 tonnes/year plant:

1. The utilisation of the multiple hearth furnaces to pre-heat the ironsand concentrate and de-volatilise the coal.
2. The hot pan conveyors which transport this material to the kiln.
3. The reduction kiln process.

Although the major plant items have been used elsewhere in the world (for different purposes) the configuration of the plant and the method of operation are unique.

The plant design also includes significant innovations to improve productivity and reduce operating costs including a 34 MW capacity co-generation plant.

Owner: New Zealand Steel Ltd
Designers: W S Atkins & Partners
Contractors: Dillingham - Stevenson

Stage 1 Expansion (iron and steel making only)

Project managers/engineers: Davey McKee (Stockton) Ltd

Major plant contractors: G E C Materials Handling Ltd, Lurgi GmbH (kiln) Elkem A/S (melters), Flakt - Aust. (waste gas treatment), Davey McKee (KOBM).

Slurry Pipeline

Opened in 1986, this was the world's first polyurethane-lined high pressure underground pipeline transporting abrasive granular materials by positive displacement pumps. The project extended the then known bounds of slurry pumping technology.

The expansion of steel making at Glenbrook to 750 000 tonnes/year involved a five-fold increase in primary ironsand concentrate usage from 250 000 tonnes/year to over 1 500 000 tonnes/year. This made it impractical to use the existing road transport over the 18 km between the Maioro mine site and the works at Glenbrook.

Prefeasibility studies were carried out using different transportation methods including aerial ropeways, conveyors, pneumatic capsules, railway and a slurry pipeline. During this process, the slurry pumping alternative, in which New Zealand Steel had detailed experience at Taharoa, was ruled out! A detailed world-wide search confirmed that the parameters of particle size, density and abrasiveness of the slurry concentrate grains, together with the volume to be transported and the distance, exceeded by far those of any other slurry pumping system.

Rail was chosen as the most economic alternative and negotiations continued with the New Zealand Railways and an environmental impact report was prepared. Pressure from the farmers along the proposed rail route caused the company to reconsider the slurry pipeline option resulting in conceptual tenders being called for a turnkey contract.

A unique feature of the project was the formation of a study group comprising the client and the successful tenderer to decide the most appropriate parameters and then the optimum system. The resulting scheme included:

1. A welded joint polyurethane-lined pipe, the first in the world.
2. A guaranteed 25 year life for the pipeline.
3. An extremely low energy consumption - 7.82 kW/tonne of concentrate for the 18 km journey.
4. A system which created a world slurry pumping record.

Owner: New Zealand Steel Ltd

Design, quality assurance, inspection and commissioning: Slurry Systems Pty Ltd.

Construction and project management: McConnell Dowell Construction Ltd.

A & G Price Ltd

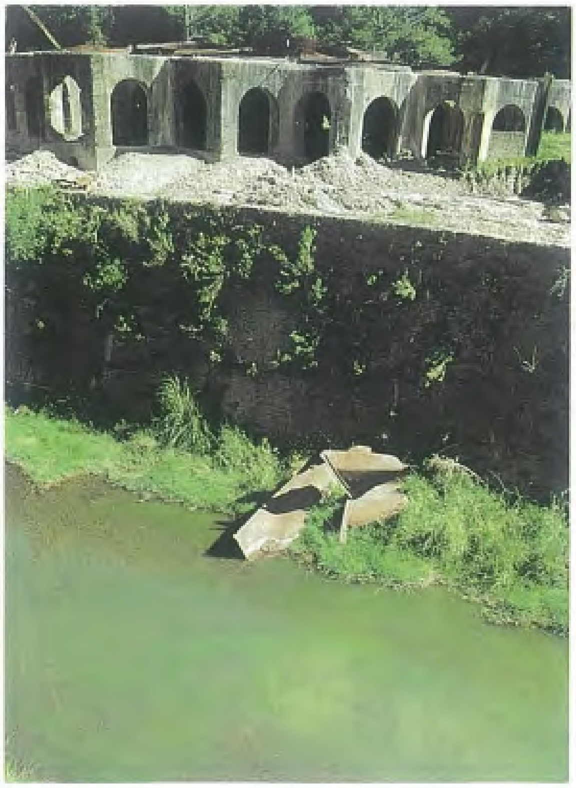
Products as diverse as flax dressing machines, logging winches, pelton wheels, locomotives and steamships, all of which have helped to develop New Zealand, have been manufactured in these engineering works established at Thames in 1871.

Founded in Onehunga in 1868, A & G Price is one of our longest established engineering firms. Throughout 122 years they have made a major contribution to New Zealand's progress by the design and construction of over 100 steam locomotives, road graders, rock crushers, boilers and marine engines, mining and sawmilling and forestry equipment.

At their Onehunga and Thames works, the Price brothers, Alfred and George, were able to design and construct much of the manufactured equipment, needed to service the colony and the nation. In particular the Thames and Waihi goldfields were very well served and A & G Price are still serving the latest gold development.

Owner: Cable Price Downer Ltd
Founders: Alfred and George Price

Gold Mining at Waihi



Waihi fostered the development of the cyanide process formerly used worldwide to extract gold from low grade ores.

The Martha Mine at Waihi was the site of the greatest gold strike in New Zealand. Under the control of the London-based Waihi Company, and with the use of cyanide technology, the mine produced 224 000 grams of gold and 1 680 000 000 grams of silver in a 66 year period ending in 1952. Nearly 160 km of tunnel were excavated under Martha Hill and all the quartz was crushed, pulverised and treated with cyanide in extensive workings at nearby Waikino.

Today only a handful of mementos survive. The concrete cyanide tanks erected in 1895 still stand on Union Hill and have received an 'A' classification from the NZ Historic Places Trust.

The pumphouse on Martha Hill once housed steam engines and machinery which removed water from shafts almost 650 m deep; at Waikino the remains of the high complex are akin to ancient Roman ruins.

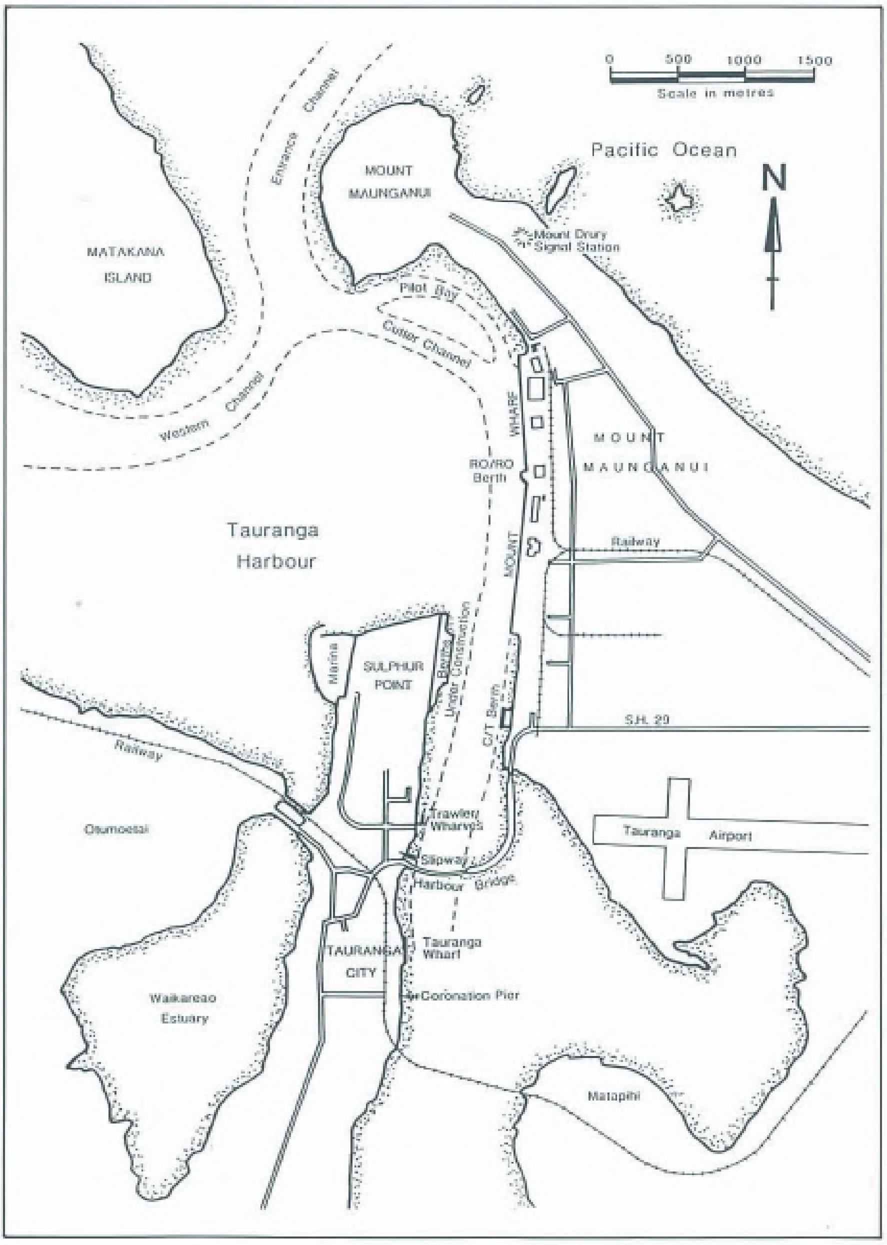
Port of Tauranga Development

The Port of Tauranga, located in the Bay of Plenty on the North Island's East Coast, is a natural harbour and the only deep water port between Auckland and Wellington providing a safe berthage in all weather.

Here the combined skills of harbour and bridge engineers have converted a once shallow coastal port into New Zealand's largest export centre.

In 1958 the Tauranga Harbour Board commissioned a study of the harbour by the Wallingford Hydraulics Research Station, England. Results of this physical model study led to a dredging programme to deepen the entrance, from the cutter channel and deepen the Maunganui Roads alongside the Mount Maunganui wharves. Some dredge spoil was taken out to sea and dumped but a large quantity of the dredge material was pumped ashore to reclaim both behind the new wharves at Mount Maunganui and some 80 ha of land at Sulphur Point.

In 1983, the Bay of Plenty Harbour Board commissioned a mathematical computer model of the harbour. This was undertaken by a team of scientists from the Ministry of Works & Development, the Danish Hydraulics Institute, Waikato University and Dr K Black. The model was established on the Waikato University computer using historical records and freshly collected data. It has been used to study the effects of projects such as the Harbour Bridge, Sulphur Point wharf development and further dredging, on the tidal flows and sediment transfer in the harbour and entrance.



In 1984, a Ship Manoeuvring Simulation study was conducted at the Maritime Research Institute in the Netherlands (MARIN) to help determine the capability of the port to handle safely larger or different types of ships. The study used port pilots on a computer simulator under a variety of conditions such as wind, tide, tug power and channel widths.

Meanwhile to keep pace with progress and demand, an almost continuous berth-building programme was undertaken, accompanied by channel and harbour deepening, reclamation works, construction of port facilities, and the acquisition of floating and shore plant. In particular:

+ Between 1961 and 1978 port draught was increased from 7.31 m to 10.7 m to handle the 68% increase in shipping (269% increase in net register tonnage).
+ The main wharf was lengthened from the original 372 m to 1843 m (Since lengthened to 2055 m).
+ Large transit storage sheds were built.
+ A 600 tonne slipway and jetty were constructed.
+ A linkspan and a $2 million Forest Industry Terminal was established to serve the direct roll-on/roll-off service to Australian and South Pacific island ports.
+ A heavy lift multi-purpose gantry crane was installed at a cost of $3.9 million, and became operational in September 1979.
+ A bulk Cement/Tanker berth was constructed and became operational in June 1980.
+ The original berths were progressively deepened.

A continuous concrete quay-type wharf structure currently 2055 m long now provides a nominal 11 berths plus a separate specialised 80 m concrete dolphin type berth for tankers, cement and woodchips located to the south of the main quay. These modern concrete structures include some of the strongest wharf structures in New Zealand.

The new Tauranga Harbour Bridge is an integral part of the total port complex.

This 480 m bridge, over the Stella Passage, joining the two sides of the harbour

development, was constructed ashore and then cantilevered into place. It was completed, at a cost of about $25 million, two months ahead of schedule and was opened in March 1988. It is estimated that toll charges will clear all debt by 1997 or 1998.

Owner: Port of Tauranga Ltd
Designers: Ministry of Works 1953-1968,
Tauranga Harbour Board 1968-1970
Bay of Plenty Harbour Board 1970-1988
Port of Tauranga Ltd. 1988-1990
Major constructors: Ministry of Works; Bay of Plenty Harbour Board

Harbour Bridge

Design: Murray-North Ltd
Construction: Fletcher Construction Co Ltd
Project managers: Beca Carter Hollings & Ferner Ltd

Arapuni Power Station

Commissioned in 1929, Arapuni was the first Government-built station on the Waikato River, 55 km upstream from Hamilton and 16 km from Putaruru. Arapuni was the pioneer development of the Waikato Valley hydro-electric power programme carried out between 1929 and 1966, and of the seven stations built on the Waikato during that period only Maraetai exceeds Arapuni in capacity.

In 1923, worldwide tenders were called for the building of Arapuni and access to the site from Putaruru was commenced. A contract was placed with the British firm of Armstrong Whitworth in September 1924.

The diversion tunnel was completed in July 1926, and the site dewatered soon after. Good progress was made with the head works, but at the powerhouse site there was disagreement between the contractor and the Public Works Department over the suitability of the foundations. The impasse was broken by the Public Works Department taking over the works in December 1927.

The works progressed in the face of extensive difficulties, not the least of which was severe flooding. However the first 15 MW unit was put into service in June 1929 and by June 1930, three generators were in service, with work well advanced towards the fourth.

In that month a crack developed between the end of the spillway and the adjoining structure. There was a small but definite movement of the whole country above the powerhouse — a movement which partly reverted when the spillway water level was drawn down to empty the headrace. The station was then shut down and not put back into service until April 1932.

Two Swedish experts, Professor Hornell and Mr Werner, supported by New Zealand geological experts were engaged and various remedial measures were recommended and carried out, including an impervious lining to the headrace.

A powerhouse extension, doubling its original size, was built in the 1934-37 period, and two more machines installed by February 1938. The final two machines were delayed by wartime disruptions, but were eventually commissioned by October 1946. This brought the station to a total capacity of 162 MW, by far the largest then in New Zealand.

The dam built across the Arapuni Gorge to divert the river is 64 m high from its foundations to the roadway running along its crest, and raises the water 42.7 m above its old level. The water then flows about 1.2 km in an open headrace, and then through penstocks to the powerhouse at the base of the gorge. The powerhouse is a reinforced concrete structure 136 m long, 22.8 m wide, and 22 m from tailrace water level to roof.

Eight steel-lined penstocks each 3.6 m diameter feed the water from the forebay to the turbines. The eight vertical Francis type turbines have a total capacity of 164 MW. From the main busbars at the outdoor station, power at 110 kV is supplied to the North Island system.

After half a century of service, the headrace lining showed signs of deterioration and had to be replaced. As this involved a complete station shutdown it afforded an ideal opportunity to upgrade and refurbish the whole operation. This $50 million operation took place in two stages:

Stage 1 involved the construction of a diversion channel incorporating four radial control gates to enable the full Waikato flow to be diverted away from the Arapuni headrace and intake structure.

Stage 2 involved the replacement of the headrace lining, channel widening and the raising of the existing intake platform and spillweir. The tailrace was deepened and a radial gate installed to control the tailrace water-level. The new structure resulted in increased flood storage capacity of Arapuni Lake, helping flood control of the Waikato River.

At the same time the powerhouse was refurbished, a new control room was built, and new plant and equipment installed.

Arapuni returned to service in 1990, and is expected to provide at least another 50 years of reliable generation.

Owner: Electricity Corporation of New Zealand Ltd.

Original design: Public Works Department

Original construction: Begun by Sir W G Armstrong Whitworth & Co Ltd, completed by Public Works Department

Refurbishment 1990:

Design: Works

Refurbishment contractor: Fletcher Civil Engineering Ltd.

Wairakei Geothermal Power Development

The Wairakei station, the world's second geothermal power station, and the first to utilise flash steam from geothermal water as an energy source to generate electricity, was first commissioned in 1958 and was completed in 1963.

Wairakei lies on an active volcanic zone about 250 km long and 50 km wide, except at both ends where it narrows to 15 km. The power station is built beside the Waikato River 10 km north of Taupo, and uses the steam from wells drilled in the nearby Waiora Valley. Over 50 wells are at present in production, with an average depth of over 610 m, the deepest being some 1500 m.

The scheme is based on the tapping of a vast underground water system that has been heated by very hot, perhaps molten, rocks. Steam is produced by drilling to release the great pressure on the very hot water, causing it to boil. The boiling water-steam mixture is brought to the surface and separated, with the 'dry' steam being piped to the power station's turbines, and the hot water discharged into silencers where a drop in atmospheric pressure causes some of it to flash into the large clouds of steam which produce the spectacular displays seen in the steam fields.

The station consists of two powerhouses, now with installed capacities of 67.2 MW and 90 MW respectively. With an annual energy output into the national system of 1100 GWh Wairakei produces about 5% of the North Island's electricity needs.

The success of this station is a tribute to the scientists and engineers (from D.S.I.R., M.W.D. and N.Z.E.D.) who conceived, designed, built and operated it.

Owner: Electricity Corporation of New Zealand Ltd
Design: Ministry of Works
Construction: Ministry of Works

Ohaaki Power Station

Developed in harmony with Maori tribal values, the Ohaaki power station is an integral part of the Wairakei system. Ohaaki uses tower cooling instead of river water and conserves the borefield by condensate reinjection. Located on the Broadlands geothermal field, about 25 km north of Wairakei, and opened in 1989, Ohaaki added 108 MW generating capacity to the national grid and contributes annually about 750 GWh to the country's energy resources - approximately 3% of total requirements.

The geothermal fluid is fed to five separation plants where the steam and water are separated. To avoid any contamination of the Waikato River, this hot separated geothermal water is reinjected back into the ground at 150°C to avoid a silica build-up in the pipelines and plant. The steam is piped to the power station and passes through the turbines to generate electricity.

The steam then passes to the condensor where circulating water is sprayed through the steam to cool it. The resultant warm water is then passed through a natural draught cooling tower, a concrete structure which is a first for New Zealand. Incorporating 'state of the art' design, its thin shell and special foundations are designed to resist wind and earthquakes. It is 105 m high, 70 m diameter at the base, and 40 m at the throat.

The tower will remove 420 MW of heat from the 20 000 tonnes per hour of circulating water as it falls through an induced flow of air. The evaporation of a small fraction of water provides the necessary cooling of the circulating water. In this way the circulating water system continuously gains condensed steam, which is balanced by evaporating losses from the cooling tower and by discharge of condensate which is reinjected into the ground.

Reinjection has not been carried out previously in New Zealand on such a large commercial scale. The non-condensable gases, mainly carbon dioxide, are extracted from the condensor by gas exhausters and are dispersed from the cooling tower. A system continuously monitors the concentration of hydrogen sulphide in the area surrounding the plant to ensure that there is no build-up of gas.

Owner: Electricity Corporation of New Zealand Ltd
Designer: Works Corp/Design Power, Rankine & Hill Ltd
Construction: Power Build, Wilkins & Davies Ltd.

State Highway 1
Wairakei to Taupo

This four-lane section opened in 1972, is one of the first parts of State Highway 1, to be specially designed and constructed to maintain sympathy with the natural environment.

In 1968 D A Thom presented to the Auckland Branch of the NZ Institution of Engineers (now IPENZ) a paper entitled 'Roads in the Landscape', and in 1970 the then Prime Minister (the Rt Hon Sir Keith Holyoake) told an environmental conference that it was a sign of New Zealand's progress that no longer did we regard a road simply as a road, but we realised that not only must a road be functionally efficient but it must also be pleasing to the eye and in tune with its environment.

That environmental conference made several recommendations to the then National Roads Board on the landscaping and beautification of all public roads.

The same year (1970) a revision of Thom's original paper published in *'New Zealand Engineering'* set down an environmental code for the implementation of the conference recommendations and placed on record some relevant aspects of road design and planning incorporating also recommendations from a British 'Countryside' conference, and a U.S. White House conference on national beauty.

Because the impact of roading on the environment is immense, the roading engineer is a key figure and his positive contribution can add greatly to the potential of New Zealand's scenic attractions.

This section of State Highway 1 is a prime example of this policy.

Controlling authority: Transit New Zealand

Design: Ministry of Works and Development

Contractors: Taylor & Culley Ltd

North Island Main Trunk Railway

Made possible by pioneering engineering amid the challenges of a frontier land, and lately enhanced by modern technology, the North Island Main Trunk Railway is New Zealand's most significant land route.

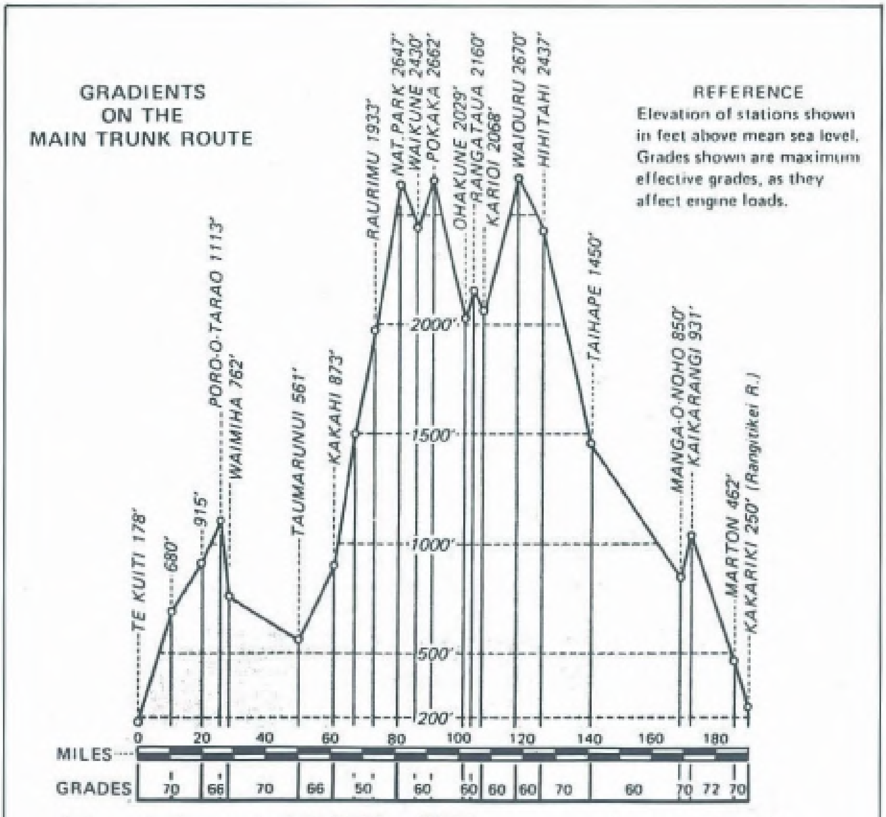
From 15 April 1885 when Maniopoto paramount chief, Wahanui turned the first sod of the Main Trunk railway project near Te Awamutu, and Premier Robert Stout wheeled this away, it took 23 years to complete the line. Another Premier, Sir Joseph Ward, drove the last spike on 6 November 1908 (see overleaf). A through train service began three days later.

Most of the construction work had to be carried out by hand. Oxen, horses and small steam locomotives assisted with the bulk movement of materials. It was only in the last two years that one of New Zealand's first steam shovels was brought in to help dig the cuttings. That was the start of a mechanical age in earthworks for this country.

The line traversed some extremely challenging terrain which posed many problems for the engineers locating the route. The diagram shows the grades between Te Kuiti and Marton and gives an indication of the problems encountered.

The location of the Raurimu spiral about 1898 by R. W. Holmes was the key to a workable climb from Taumarunui to the National Park summit. At that time detailed location of the final line was still a field engineer's decision. The required 132 m rise over a distance of 2 km in a direct line was achieved by the use of the famed 'Spiral' loop and horseshoe curves using the topography very skilfully to minimise cut, fill and tunnelling.

The bridgeworks, designed by the Public Works Department and built by the Public Works Department and engineering firms such as Andersons Ltd of Christchurch, were to the best standards of the day and were surprisingly modern. The Mangaweka Viaduct (now demolished) a portion of which is shown on page 24 was typical of many of the major structures on the North Island Main Trunk. Most of these viaducts had

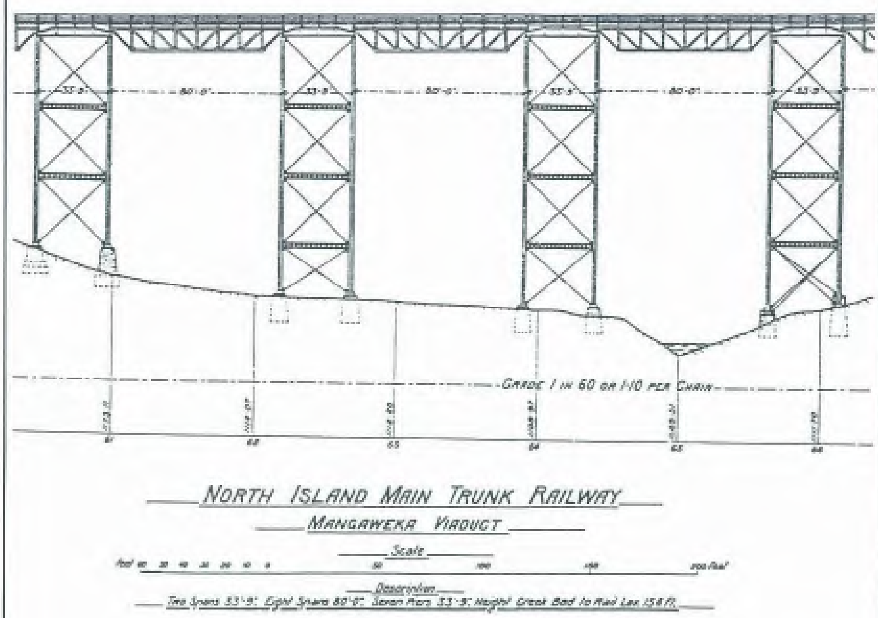


Acknowledgement: A L R Merrifield **(From - Troup)**

their steelwork fabricated in the pioneering settlements such as Mangaonoho and Makatote. (There is still an Ironworks Road at Mangaonoho, although the sites of both workshops are less obvious).

Andersons' workshop at Makatote was extremely well equipped for its time. It had electric overhead travelling cranes and the cableway used to erect the viaducts was electrically controlled as well. The design loading for bridges and viaducts was an engine of 84 tons, although the 94 ton 'X' Class were used from the opening of the line. Following detailed strengthening these structures have carried the 145 ton 'K' and 'Ka' locomotives, while those retained on the now electrified route carry the 106 tonne '30' Class electrics of even higher axle loading than the steamers.

Owner: NZ Railways Corporation
Design: Public Works Department
Resident engineer (south): F W Furkert
Resident engineer (north): J B Louch



From: AJHR 1903, Appendix D-1

Hapuawhenua Viaduct

The Hapuawhenua viaduct epitomises the three aims of engineering: function, economy and (above all) grace.

Completed in 1987, this 414 m long viaduct is the major structure on the 10 km Ohakune to Horopito deviation.

The Hapuawhenua viaduct was built not only to improve alignment but also to eliminate concern over the remaining fatigue life of the old curved viaduct. Constructed from a combination of reinforced and prestressed concrete, this slender structure is a 'state of the art' design, which takes advantage of the development of engineering knowledge of the behaviour of structures under extreme conditons, and especially those of a major earthquake.

As a result of improved knowledge the amount of material used in construction has been minimised while the safety of trains has been enhanced.

Owner: New Zealand Railways Corporation
Design: Beca Carter Hollings & Ferner Ltd
Contractor: Fletcher Construction Co Ltd

Synfuel Gas - to - Gasoline Plant

This is the world's first commercial production plant for converting natural gas to synthetic fuel. Opened at Motunui in 1986, it is also the world's largest methanol production facility.

The Synfuel plant takes natural gas from both the offshore Maui and onshore Kapuni gas fields and converts the combined gas feed first to methanol and then to synthetic gasoline via the Mobil Methanol-to-Gasoline (MTG) process.

The plant produces a premium unleaded gasoline blendstock suitable for use directly in the transport fuels market. The total annual production from the plant is equivalent to about one third of the New Zealand gasoline market. When combined with the production of condensates associated with the offtake of Maui and Kapuni gas, plus the use of CNG and LPG as a fuel, this has enabled New Zealand to achieve almost 50% self sufficiency in petroleum products, a significant shift from the situation in the early 1980s when the country was 85% dependent on foreign oil.

The Synfuel plant thus plays an essential part in supplying the New Zealand petroleum market, contributing directly to reducing New Zealand's vulnerability to uncertainly in supplies of imported crude oil. Operation of the plant represents the successful conclusion of a major engineering task and the demonstration of a first-of-a-kind application of zeolite catalyst technology. Other highlights of the project include:

+ The application of engineering design methods to reduce the environmental impact of noise.
+ The first application of seismic design in accordance with recommended criteria laid down for petrochemical plant.

+ Continuous dewatering of a saturated sub-strata sand layer to reduce the likelihood of site liquefaction under a severe earthquake.
+ Modular construction techniques requiring specialist shipping and transportation methods, including New Zealand's largest ever movement by road transport.
+ Non-conventional operating regimes within the methanol plant involving complex computer plant simulations and specialist process engineering expertise.

Construction and ongoing operation of the Synfuel plant has provided an international, national and regional focus to New Zealand engineering with much interest focused on the capability of New Zealand's engineering resources as a result of the project being completed within budget and on schedule.

Owner: NZ Synthetic Fuel Corporation

Designers: Davey McKee Corp, Foster Wheeler Energy Corp, Works Corp

Constructor: Bechtel Petroleum Inc & New Zealand subcontractors.

New Plymouth Power Station Chimney

When completed in 1972 this 198 m chimney, an integral part of the New Plymouth Power Station, was the tallest structure in New Zealand. It contains 16 400 tonnes of concrete, 1200 tonnes of reinforcing steel and almost one million bricks.

The main structure of the chimney is a 90 ft diameter reinforced concrete windshield which contains five 11 ft diameter flues made of bricks, laid at the rate of 10 000 per day, supported by steel platforms at regular intervals throughout the height of the chimney.

Slipforming of the windshield commenced in February 1971 and with one interruption was completed as a continuous pour at an average rate of 5 inches/hour. The work was carried out as a design/build contract.

Owner: Electricity Corporation of New Zealand Ltd

Designer: Karrena Feuarungasbau GmbH - Germany

Project manager: Ministry of Works and Development

Principal contractor: Downer & Co Ltd

Kiwi Co-operative Dairies Ltd

This factory, at Whareroa, 3 km south of Hawera, is the world's largest single-site processor of dairy products.

Operations began on the site in August 1973. Capacity more than doubled in 1984 with the merger of Kiwi and Taranaki co-op. dairy companies, and Kiwi Dairies now processes 15% of New Zealand's milk production. Owned by 1500 dairy farmer shareholders, Kiwi Dairies can process 4.5 million litres of milk daily into milk powders, butters, cheeses and casein protein powders.

Unique features of the complex, apart from its size, include:

+ Rapid milk reception system.
+ Centralised milk reception and standardising.
+ Integrated energy system.
+ Allen-Bradley PLC network (large system).
+ Layout of site from milk reception to product load-out including services with flexibility for future expansion.

Other New Zealand dairy companies have had to follow the Kiwi lead into large centralised, highly efficient milk-processing sites to remain competitive, and many of the features of the Kiwi plant and layout have been copied.

Kiwi is the major employer and a major economic factor in South Taranaki through the contribution dairying makes to the region. Kiwi earns $300 million a year in overseas exports. Duing 1990 it hoped to pay out $250 million to supplying dairy farmers, plus $20 million in salaries and to service suppliers. The company has budgeted $6 million a year over the next five years for continuing capital expenditure.

Architects: Laurenson, Robinson and Boon

Plant design: National Dairy Association NZ Ltd

Building construction: Arthur Brown Construction Co Ltd

Ohakea Hangars 2 & 3

Designed in 1937 and built during 1938 and 1939, these air base hangars have huge two-hinged arches which signified growing confidence in reinforced concrete design. The reinforced concrete roofing is supported by the arches, spanning 67 m and 19.8 m high.

The design was adopted for several other defence bases, such as Whenuapai in New Zealand and Karachi and Hyderabad overseas.

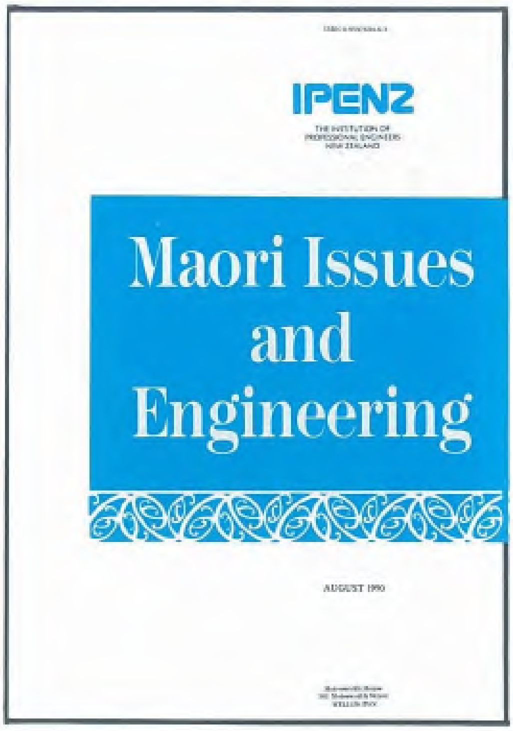
The Ohakea hangars have recently been strengthened and cladded with a steel roofing, and they still have much life left in them.

Owner: Ministry of Defence

Chief design engineer P.W.D: C. W. O. Turner

Construction: Public Works Department

Maori Issues and Engineering



This booklet was published as part of the Institution's 1990 project, to bring to the attention of all engineers the Maori cultural values that particularly relate to engineering works. It contains material from two sessions at the Institution's 1990 annual conference.

One of these sessions was devoted entirely to Maori issues and water, and that is reported in detail in the booklet; the other, the session on continuing education, is represented by the paper on Maori issues and engineering that was included in it.

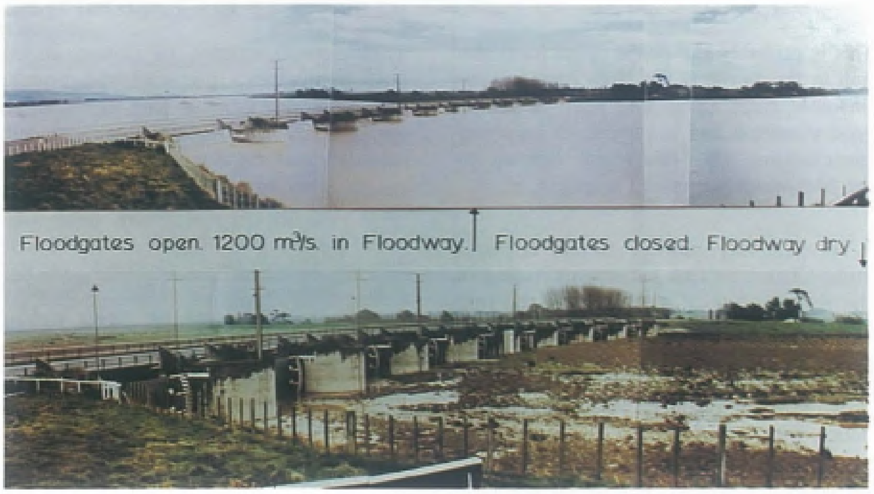
In his introduction to the booklet, the President said that he believed that through its publication, the 1990 project, which mainly celebrated the past, would have an element that reached into the future, for the continuing benefit of the people of New Zealand.

Copies of the booklet have been sent to all Institution members.

Further copies are available from Institution headquarters, P.O. Box 12241 Wellington at $3.00 each, including GST.

Moutoa Sluice Gates — Manawatu River Control

These gates, (5 km from Shannon on the road to Foxton) which can divert more flood water than any similar structure in New Zealand, form part of the country's first major river control scheme.



The Lower Manawatu River Control Scheme gives flood protection to 300 km^2 of valuable rural land, and to large parts of Palmerston North and Feilding, which could otherwise be flooded by the Manawatu River and its tributaries. The scheme includes 100 km of stopbanking on the Manawatu between the sea and the gorge, and another 120 km of stopbanking on the tributaries.

The function of the sluice-gates, completed in 1962, is to divert floodwater from the Manawatu River down a floodway 10 km long that bypasses 30km of river channel which is very winding and has too flat a gradient to carry the necessary discharge. About a third of the land protected by the scheme is dependent on the gates.

During the design event (a 100-year flood), these gates can divert 3000 m^3 second which is 70% of the design flow. They have been operated at an average frequency of once in 18 months to two years for periods of up to 60 hours.

The gates were subject to intensive model testing to optimise hydraulic performance and to check for possible problems with seepage, piping and uplift.

Features of construction included well-pointing on a large scale to permit the 210 m by 37 m structure to be built in dry conditions. The groundwater level was lowered 5 m, down to 2.5 m below mean sea level.

The road bridge running along the top of the structure included one of the early uses of precast post-tensioned beams.

Owner: Manawatu-Wanganui Regional Council

Engineers: Newton-King O'Dea

Contractors: Wilkins & Davies Construction Ltd

State Highway 1 Mangaweka to Utiku Deviation

Here where the road blends back into the landscape, modern engineering skills have removed the last major impediment (and irritation) to the long distance road user.

All motorists (and their passengers) will remember near the middle of any central North Island journey, the 10km of narrow winding road, slip prone too.

Constructed through steep mud and sandstone formations and with major earthworks, the Mangaweka to Utiku deviation (staged construction 1972-1980) changed one of State Highway 1's most hazardous sections into a modern highway. Travel times for the road traveller have been greatly reduced also.

Environmental aspects were an integral part of the design.

Controlling authority: Transit New Zealand

Design: Ministry of Works and Development

Contractors: Stage 1 Taylor & Culley Ltd

Stages 2 & 3: Kaipara Excavators

Toetoe Bridge - Easton Steel/H Bullock

Mokopeka Hydro-electric Station

This is probably the oldest operational station in the world: it has been running continuously since 1892! The plant is still in good condition and is capable of supplying space-heating and emergency lighting to the Mokopeka homestead nearby.

Hawkes Bay pioneer farmer/engineer John Chambers first became interested in the new science of electricity in the mid 1870s, within five years of Thomas Edison's invention of the incandescent lamp. During the 1880s Chambers studied practical electrical engineering by correspondence with an American university and on the completion of his course set about the task of building his own generating plant and electrical appliances. He designed his power plant based on a 14 hp Victor turbine by Frederick Well, London, and a second-hand 8kW - 110V d.c. dynamo originally installed in the Midland Railway Co Ltd's St Pancras Station, London in 1886.

While he awaited the delivery of the plant, Chambers built a dam across the Maraetotara stream, constructed a 600 ft headrace canal, excavated a tailrace tunnel and turbine enclosure and erected a power house to contain the electricity generating plant and associated control equipment.

Designing and installing the plant was only part of the project. Chambers also erected poles, insulators and overhead lines to the homestead, workshop and shearing shed, and installed the internal wiring within these buildings.

In September 1892 the plant was completed and the turbine operated for the first time.

By the turn of the century, Chambers used electric motors to power all his farm appliances - his workshop grinder, drill press and lathe as well as his shearing shed and woolshed. He subsequently invented and developed small independent shearing hand-pieces that were driven by electric motors and flexible leads.

Early in the present century the demand for electricity overtaxed the original dynamo. In 1926 Chambers imported and installed a larger turbine and dynamo and converted the original dynamo into a motor to drive the water pump. The new turbine gave Mokopeka the luxury of an automatic governor which regulated the water supply to provide a near constant voltage output, thus alleviating some of the previous control difficulties. No other New Zealand generating plant was so advanced at that stage.

Electricity remained unavailable to most Hawkes Bay people until the 1920s, and some of Chambers' neighbours did not receive electricity until the 1940s, 50 years after he had gained its benefits.

In 1965, after severe drought periods, the Maraetotara stream could no longer provide sufficient water to meet, by then, the considerable demands for power at Mokopeka. It was at this point that the Chambers family decided to take supply from the Power Board after more than 75 years of supplying their own electricity. However, the hydro plant was retained to provide heating to the homestead and still does this today.

Owners: The Chambers family
Designer and constructor: John Chambers Jnr

Mohaka Viaduct

With a deck 95 m above the river this is the highest rail viaduct in Australasia.

Construction began in 1930 but with foundations completed and structural steel on site the rail line was abandoned in 1931. When work resumed in 1936 with construction engineer D. O. Haskell as project engineer, the viaduct was completed in remarkable time and was opened in July 1937.

At the time of its construction the viaduct was the fourth highest in the world and its completion was the final link in the Napier - Wairoa rail line which had commenced at Napier in 1912.

The Mohaka Viaduct is a fine example of the skilled engineering construction work involved in the development of the New Zealand Railway system through difficult country.

Owner: Railways Corporation of New Zealand
Design: Public Works Department
Construction: Public Works Department

North Island Main Trunk Electrification

Implementation of long deferred main line electrification schemes has enabled a 50% increase in train load and has cut the transit time by 1.5 hours.

By far the most significant and far reaching improvements to New Zealand's railway network since the completion of the North Island Main Trunk in 1908 are the track upgrading and 25 kV a.c. electrification of its mountainous central section between Palmerston North and Te Rapa, north of Hamilton.

Begun in 1984, the four-year project, involving 411 km of track cost about $260 million. Included were major civil engineering works — the elimination and lowering of tunnels, the easing of curves and gradients, the strengthening and replacement of bridges.

Typical of these works is the spectacular Mangaweka Deviation. This deviation avoids the unstable ground on the right bank of the Rangitikei River by two crossings of that river and one of the Kawhatau River. The bridges are all major structures designed by Beca Carter Hollings & Ferner Ltd. The South Rangitikei bridge, built by Codelfa Construction Ltd, is 315 m long and is 76 m above river level. This tall structure includes damped stepping pier bases for earthquake resistance.

The 9 km Hapuawhenua Deviation called for the elimination of a 208 m tunnel and the replacement of three aging viaducts that would be unable to cope with the increased axle loadings and higher freight tonnages.

Another significant factor was to ensure that the large civil engineering works — tunnel daylighting and by-passing, and major track re-alignments and deviations — did not permanently damage and scar the surrounding environment. An Auckland consultancy, Kingston Reynolds Thom & Allardice was retained to undertake environmental studies of the route and prepare assessments, the final version of which formed part of the design brief for each of the civil works.

Another consultancy, Tonkin & Taylor, was engaged to conduct land stability assessments — a particularly important aspect in planning the Ohakune to Te Kuiti section of the route.

Ten thousand prestressed concrete poles with over 2100 km of wire were erected for the traction overhead powered from the national grid through special substations. In addition, completely new signalling and communications systems incorporating the latest in technology were installed throughout the section.

The project also called for the purchase from Britain of 22 class 30 electric locomotives, each weighing 108 tonnes, and having a continuous power rating of 3000 kW, making them the most powerful ever to operate in New Zealand.

Electrification enables the Railways to operate longer, heavier freight trains, faster between Palmerston North and Hamilton, ensuring the most economic use of energy and assisting the Railways Corporation achieve commercial viability in the future.

Owner: The New Zealand Railways Corporation

Design: New Zealand Railways, international and New Zealand consultants

Construction: New Zealand Railways, international and New Zealand contractors

Lower Wairarapa Valley Development

This is one of the largest flood control and land reclamation projects in New Zealand. It involved the reorganisation of a major river system in an intricate manner and the primary contract attracted world-wide attention. The floodgate at Kumenga on the Raumahanga River required special foundation design owing to its location on recent marine deposits.

One unique feature was the large amount of land which was reclaimed for agricultural and pastoral use. Special provisions for the enhancement of wildlife were made in the latter stage of the construction period.

The project, commenced in 1964 and substantially completed in 1984, has made a tremendous improvement to the wellbeing of the region by means of flood prevention for a substantial area of land, the reclamation of a large area, the provision of cross-valley access and many other benefits. The increase in agricultural production has been significant.

Owner: Wairarapa Catchment Board

Principal designer: Wairarapa Catchment Board

Major contractors: Costain Blankvoort (UK) Dredging Co Ltd (river widening and stopbanking) Downer & Co Ltd (floodgate barrage)

Hutt Estuary Bridge

This was the first major prestressed concrete bridge constructed in New Zealand. Opened in 1954 its unique features were:

+ The adoption of a post-tensioned prestressed system with no precedent in New Zealand.

+ The adoption of precast concrete beams spanning 105 feet with a weight of 40 tons each and the associated solutions adopted for casting, storage, handling and final erection in the completed structure (80 beams in all).

+ The use of high-strength concrete demanded by the prestressed concrete solution and the associated quality controls involved in mixing, placing and curing (uncommon for its time).

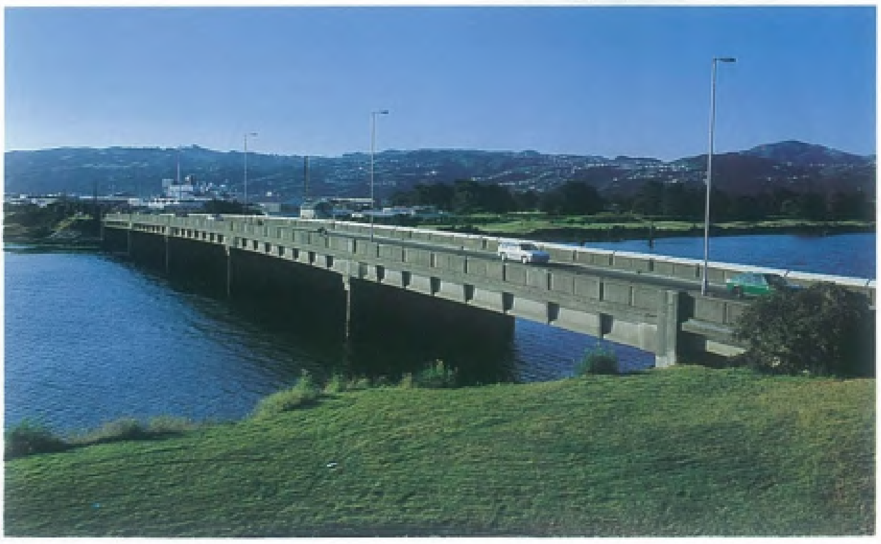
+ The temporary engineering works and ingenuity involved in handling beams to storage and subsequently into the permanent structure.

+ The development and implementation of quality controls associated with the prestressing operations.

+ The problems of design and construction of the four pier foundations in the river bed consequent upon the artesian water-bearing strata of the Hutt Valley artesian system. Each of the four pier foundations necessitated significantly different design and construction techniques.

+ The confidence of the combined local bodies, the technical advisory committee and the consulting engineer, in a design for which there was no New Zealand precedent for what was at the time, and even by today's standards, a major and locally significant river crossing.

Owner: Lower Hutt City Council
Consulting engineer: W G Morrison
Contractor: Wilkins & Davies (Construction) Ltd



K Class Locomotive (Ka 945)

More powerful than standard gauge counterparts, the K series locomotives, designed and built in New Zealand, served the main lines from 1930 to 1960.

Under the direction of the N.Z.R. Chief Mechanical Engineer (P. R. Angus), the design team was required to produce a locomotive 50% more powerful than prevailing mainline mixed-traffic locomotives, working within limits far more stringent than almost any other railway had coped with at that time. As well, the design had to be such as to enable it to be produced in local railway workshops. The resulting engines were the mainstay of the Main Trunk rail services for more than three decades and attracted considerable attention from overseas.

Building these large modern locomotives represented the highest achievement of mechanical engineering in New Zealand up to that time. The locomotives themselves enabled the New Zealand Railways to cope with increasing traffic, which reached a peak during World War II.

The main design parameters were: Tractive effort, around 30 000 lb; axle load not to be above 14 tons; maximum height, 11 ft 6 in; and maximum width, 8 ft 6 in.

The resulting engine weighed 136 tons, had a tractive effort of 32 730 lb at 85% of the boiler pressure and an axle load right on the 14 ton limit. The machine was more powerful than most locomotives running on standard gauge in Britain, where a much larger loading gauge (clearances above and beside the line) prevailed. This achievement of a 'quart in a pint pot' attracted considerable attention overseas.

The first K, No 900, is preserved at Auckland's Museum of Transport and Technology. The first Ka to enter service (945) is preserved at Steam Incorporated's museum at Paekakariki near Wellington and a Kb is preserved at the Ferrymead Railway, Christchurch.

Present owner: Steam Incorporated - Paekakariki
Design engineer: R. J. Gard - New Zealand Railways
Built: New Zealand Railway Workshops, Woburn 1939

State Highway 1 - Wellington Motorway

This section of State Highway 1 in Wellington City embodies innovative techniques in design and construction to give an environmentally sensitive development.

The motorway extends 8 km from the bottom of Ngauranga Gorge to Willis Street. It contains 15 bridge structures and one tunnel. The project is unique in that tight constraints on geometric layout resulting from the varying topography, the proximity of the hillside and the narrowness of available corridors, were all overcome in a short length of motorway.

Bolton Street and Aurora Terrace bridges were the first in the world to be protected from earthquake forces by the use of lead extrusion dampers. The Ngauranga bridges were the first incrementally launched prestressed concrete box-girder bridges in Australasia.

The Wellington Motorway forms an important part of the State Highway system. It was built in a geologically complex terrain to cope with high traffic volumes in an already built-up section of inner Wellington. The effort expended in ensuring that the system blended with the environment was rewarded by the conferring of the IPENZ Environmental Award in 1972.

The complete length was opened to traffic between the Thorndon overbridge and including the Terrace Tunnel in 1978. Construction took a total of 18 years, and consisted of several contracts.

The Wellington Motorway forms a boundary between the residential and commercial sections of the northern end of the city, and lies at the foot of steep hillsides on part of which is prime housing. The project was particularly significant in that it required the intrusion of a motorway system within the already built-up section of inner Wellington. A large effort was put into ensuring that the system blended with the environment.

Because of the varying topography and its constraints, about one third of motorway is carried on bridge structure.

The Terrace Tunnel design endeavoured to keep disruption to the existing steep surrounding land form to a minimum, as this land contains not only housing but also bush. Consequently, retaining walls up to 15 m high were designed for the approaches to the tunnel portals.

The Terrace Tunnel is understood to be the largest cross-section road tunnel in New Zealand, being 42 ft wide from wall to wall and 26 ft high. More than 2000 tonnes of structural steel arches were needed to support the section of city that lay on top of it, as the tunnel passed through the bad ground of the major Wellington fault.

The project is unique in that an unusual number of engineering problems had to be overcome in a very short length of motorway. These included the tight constraints on geometrics, not only in respect of the longitudinal profile of the motorway, but also in order to ensure adequate length for merging and exiting at open road speeds. The varying topography, proximity of hillside and narrowness of available corridor dictated heavy reliance on both bridge structures and the Terrace Tunnel to enable the high speed traffic environment to be successfully accomplished.

Controlling authority: Transit New Zealand

Principal designer: Ministry of Works and Development

Construction: Various New Zealand contractors

Total Energy Centre — Wellington Hospital

This "Total Energy Centre" was in 1981 the first to service a hospital in New Zealand and when designed was the largest in the Southern Hemisphere.

Total energy is an all-embracing term which describes a scheme in which maximum benefit is taken from the energy available in the fuel used for the system. In the case of Wellington Hospital the principal fuel used is natural gas, supplemented with diesel fuel oil, which is also used as a standby fuel.

On site the fuel is used to propel a prime mover which generates electricity. Heat is recovered from the engine-jacket cooling-water circuits and used to preheat the low-temperature hot-water circuits within the complex. High-grade heat is recovered from the engine exhausts and is used as a source of heat for a high-temperature hot-water distribution system.

The feasibility of the concept and selection of equipment could be assessed only after exhaustive evaluation of the energy demands likely to be encountered on the final redevelopment site of the Wellington Hospital. The energy demands were assessed from a detailed computer analysis which evaluated the effect of the local climatic conditions on each building proposed for the site.

After the viability of the scheme was established, approval for design to proceed was given with tenders being called in December 1975 for the prime movers and associated heat-recovery equipment. This equipment was to satisfy the assessed energy demand of 8.3 MW daily electrical peak, while refrigeration demand was 10.12 MW and peak winter heating demand 12.31 MW. This latter heat demand includes steam, high-temperature hot water for heating and process loads.

Since this particular energy complex is serving a hospital, a high importance factor applied to maintaining services support for the medical functions which were likely to be tested to capacity following some major disaster.

Owner: Wellington Area Health Board
Consulting engineers: Kerslake & Partners, and Edwards Clendon & Partners
Contractors: Fletcher Development Construction Ltd and Hawker Siddeley Engineering Pty Ltd

Department of Health Building, Wellington

This building, opened in 1982 as the William Clayton Building, is the first in the world to utilise the principle of "base isolation" to provide earthquake resistance, with superstructure supported on special bearings.

The building is thus unusually able to resist major earthquakes without damage, though moving horizontally in a controlled way relative to the ground. This motion greatly reduces the level of acceleration felt within the building, and hence the prospect of damage and personal injury.

The whole superstructure, including the basement, is supported on 80 lead-rubber bearings. During earthquake the building is capable of 150 mm of movement in any horizontal direction. Special separations are provided at all points of interface of the building with surrounds to ensure freedom to move during earthquake shaking.

Owner: Government Property Services Ltd
Design: Ministry of Works and Development
Contractor: James Wallace Pty. Ltd

Wellington Railway Station

Once New Zealand's largest public building, the Wellington Railway Station was also the first major New Zealand structure to incorporate a significant measure of earthquake resistance.

When opened in 1937, this was the largest building in New Zealand. It covers 0.6 hectares and the original floor area was 2 ha, comprising 250 rooms and 1.2 km of corridors. Two storeys were added to the northern end of Featherstone Street wing during World War II.

The station was built to accommodate 675 head office and district staff and also to replace Wellington's two former stations, Lambton and Thorndon.

It was built on reclaimed land and was designed in accordance with studies of seismic effects on contemporary buildings in Japan. The steel frame is encased in reinforced concrete and supported on groups of reinforced concrete piles. Bricks used for the outer cladding are of a special design with slots to accommodate vertical rods reinforcing the brickwork and binding it to the structural members. The building required 1.75 million bricks, plus 1500 tonnes of decorative stone (granite and marble).

The station was among the first modern seismic-resistant structures in New Zealand to be built on this scale. It was also a large structure for recently reclaimed land.

Wellington Railway Station has worn well. It still copes with daily passenger loads with very little alteration having proved necessary. In its first year, 7600 passengers made 15 200 trips on 140 trains daily. Today, 22 000 passengers make 44 000 trips on 3900 trains. (These figures exclude long distance services).

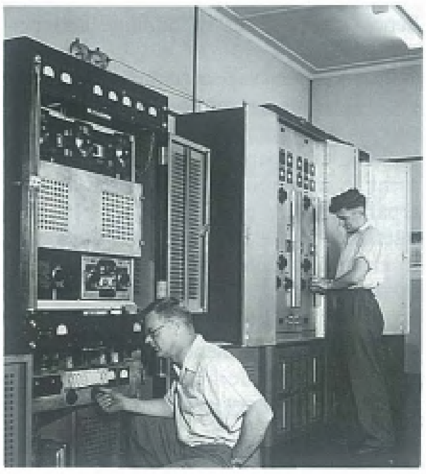
As well as an impressive functional record, the building is a dignified and largely undated structure, the architecture of which is impressive. It is listed by the NZ Historic Places Trust.

Owner: New Zealand Railways Corporation

Design: Peter Holgate & Chief Engineer N.Z.R.

Construction: Fletcher Construction Co Ltd

Telecom Museum and Archives



Established in 1939, the museum has grown into a unique assemblage of New Zealand telecommunications literature and artifacts dating back to the 1860s. It maintains collections relating to the development of telegraph, telephone and radio telecommunications in New Zealand.

The Telegraph collections contain some hardware from the first commercial telegraph system (Christchurch-Lyttelton, 1862) and a good selection of all types of equipment to the present. No attempt is made to collect a system of each kind but rather sufficient items to show the chronological development and changes of technique which have occurred.

The Telephone collections contain the first telephones made in New Zealand by William Furby in 1877, and also four examples of the first commercial telephones used in New Zealand — the 1881 model "Bell-Blakes". A representative collection of telephones to the present is maintained together with many more obscure "specials". Collections of exchange equipment, the manual and the various forms of automatic, are also maintained.

Radio equipment forms a large part of the collections. Spark wireless is well represented as are more recent local products by manufacturers such as Collier and Beale. The collection contains six RCA AR88-D receivers bearing the company serial numbers 1 to 6. What is reputedly the oldest valve-operated radio receiver in New Zealand, a De Forrest 1B, c. 1916, is also in this collection.

The collections, containing some 2000 artifacts, are extensive and diverse. All local manufacturers are represented. Machine printing systems are well covered as are telephone dials and relays. The relay collection, designed to show the great diversity of types and styles, would rate among the best. The submarine cable collection, with its associated paraphernalia, is possibly a world best.

This museum, when compared with others of its type, is considered to be the fourth best in the world; after Sweden, Germany and Holland.

The Archive consists of a technical library, an extensive photograph collection and much historical documentation dating back to 1860. The technical library includes books probably unique to the Southern Hemisphere. The historical documents collection contains much very old handwritten material.

Owner: Telecom Corporation of N.Z. Ltd

Operator: Telecom Wellington Ltd

Trans Power - HVDC Link

Haywards Substation

Benmore Power Station
(DC switchyard on right
of picture in background)

Trans Power New Zealand Ltd owns and operates the national electricity grid, transmitting electricity throughout New Zealand.

The High Voltage Direct Current (HVDC) link transmits direct current electricity between Benmore in the South Island and Haywards in the North Island.

When constructed in the early 1960's to provide bulk electricity more efficiently and economically to markets in the North Island, it attracted world attention for being the largest and most innovative project of its kind. At 609.2 kilometres, it is still one of the longest HVDC links in the world.

Work to increase its capacity from 600MW to 1200MW is due to be completed in 1992 enabling Trans Power to transmit greater quantities of electrical energy between the two islands.

H.V.D.C. Link, Benmore to Haywards

When it was commissioned in 1965, this transmission link was the world's longest, with the highest power rating and the largest submarine cables. Many technically complex parameters were extended by its innovative engineering achievements.

It was a very significant step towards integrating the high voltage alternating current electrical power network in the North and South Islands into one integrated power system. This has allowed good management of the differing water storage patterns of the two islands and enabled cheap South Island power to be exported to the North Island. It also aided the integration of all New Zealand energy resources. The project was not achieved without considerable difficulty but has proved to be of enormous value to New Zealand.

The Benmore to Haywards high voltage direct current link is one of the first H.V.D.C. links still in operation and still one of the larger such links in the world.

It was one of the most ambitious heavy electronic projects undertaken in New Zealand and the world at the time of its inception and it contained many new aspects of power transmission. For example: First use of solid/magnetic controls for H.V.D.C. transmission; first use of third generation mercury arc valves for transmission.

After 25 years of successful operation the link is now being extended.

Although many took part in the design, construction and management of the project the initial vision and driving force must be credited to M. G. (Bill) Latta, chief engineer of the State Hydro-Electric Department, whose pioneer paper in 1950 showed that the end of economic North Island hydro-electric development was in sight and that the solution was to cross Cook Strait with submarine power cables and link with untapped power in the South Island.

Owner: Trans Power NZ Ltd

Design: N.Z. Electricity Department, ASEA Electric, British Insulated Callender's Cables

Picton Terminal — Cook Strait Rail Ferry

The terminal, which handles three million tonnes of freight and 750 000 passengers annually, is an integral component of the New Zealand railway system. A major port and a railways industrial facility are combined with an essential tourism function in a setting of natural beauty.

There were severe site constraints and the need to maintain the existing service without interruption during the construction of No 2 berth and erection of the overpass over highway and rail yards, the conversion of No 1 berth including lengthening the longarm and replacing the linkspan and gangways, and the subsequent conversion of No 2 berth for larger vessels. Dominant factors therefore were urgency, economy, the limitations of the port itself and the desirability of high standards of public amenity.

Technical features included:

+ The design of berth structures including fendering.

+ The piled foundations designed for low cost construction over water and economic variation of depth.

+ The stream diversion culvert under road and railways yards which remained in service

+ The fender dolphins for exceptionally high loading and easy repair.

+ The stern buffers for exceptional impact loading, rail linkspan seatings on the vessels, offset from the axis of girders, a unique linkage to allow for heeling of vessels under loading and unloading of trains.

+ The road linkspan seatings on the vessels for exceptional displacements in three modes.

Total reliability of operation over 17 years has been achieved.

Owner: Port Marlborough New Zealand Ltd

Consultant engineers: Ian Macallan & Co

Principal contractors: T. H. Barnes, Cresswell Electrical, Downer & Co, Fissenden Bros, C.W.F. Hamilton, Kidson Construction, Thompson & Devanny, Wilkins & Davies.

Maitai Water Supply Scheme

To provide an essential commodity, this scheme, opened in 1987, has paid particular attention to both safety and the environment.

The dam and water supply provide Nelson City and surroundings with an assured high quality water supply to meet its needs into the 21st century. Because of its proximity to the city it also provides a degree of flood mitigation and a recreational resource, while for the same reason its design has been particularly conservative including an analysis of the effect of a dam break due to unforeseen circumstnaces. The project is of national interest in its setting of high standards of safety and technical design for urban water supply.

The dam break analysis, by Dr Alec Sutherland of Canterbury University School of Engineering, represented the state of the art in this specialist field.

The environmental evaluation and debate, and the resulting provisions for environmental enhancement and safeguards are unsurpassed in New Zealand for this type of project. It highlights the level of planning and public involvement needed to develop properly an environmentally sensitive project, and the need to budget for associated time and costs.

The intake facilities of the dam are of special design, and a key part of technical measures to avoid water treatment.

The project has also been noteworthy as a leading example to the engineering profession through its attention to safety aspects and use of detailed peer review of design and construction throughout the project. It is also noteworthy for the unusual solution to meeting the requirement of a judgement on the appeal against the water rights whereby the quantity of water abstracted by the intake on the adjacent tributary is replaced below the intake by water released from the dam in certain low flow conditions.

The project's contribution to the region has been fundamentally beneficial in ensuring a reliable water supply to Nelson City and the surrounding area.

Owner: Nelson City Council
Designers: Tonkin & Taylor Ltd, Worseldine & Wells
Constructors: Wilkins & Davies Ltd, O. F. Howey Ltd

Denniston Self-acting Incline

Locals called it the eighth wonder of the world.

Built for the Westport Colliery Company, and opened in 1879, the Denniston Incline involved a daring use of railway wagons. Between 1879 and 1967 they carried over 13 million tonnes of coal down from the Rochfort Plateau to Waimangaroa for the ships at Westport, a fall of 518 m in a track distance of 1670 m!

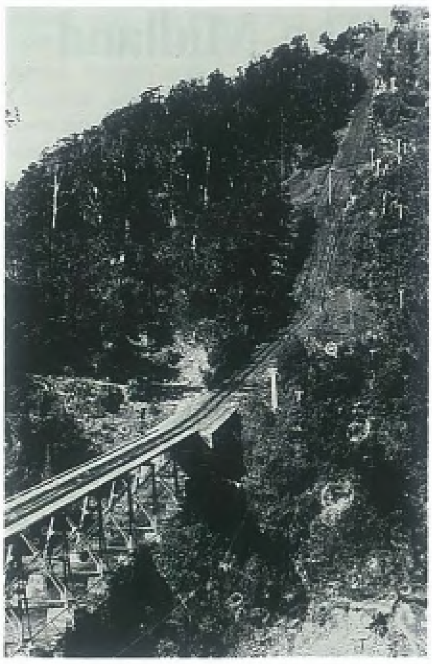
The location of the coal measures on the Mt Rochfort Plateau, especially their height above sea level, presented a big problem when it came to getting the coal down the face of the escarpment.

Work commenced on the incline itself in late 1878, and at the end of the year tenders were being called for construction of the bridge over Conn's Creek near the foot of the incline. This bridge was constructed with two laminated arches with a span of 115 feet. These arched ribs were built up of ironbark laid in nine thicknesses measuring 17 in x 10 in with heavy paint between them. The crown of the arch was 30 ft above the creek with the roadway a further 12 ft higher thus making the decking 42 ft above the water level. The 40 lb rails were laid on 7 ft sleepers, and the width of the bridge in the clear was 10 ft.

Across the bridge a timber viaduct alongside the spur carried the rails onwards and upwards towards Denniston on grades as steep as 1 in 1.25 (80%)! At the Middle Brake, where trucks were exchanged between the Upper and Lower Inclines, the grade flattened out to 1 in 120 (0.83%), but once across Brown's (or McDonald's) Bridge and up the upper incline it was as steep as 1 in 1.69 (59%) for a short distance.

From the bins and screens at Denniston to the foot of the incline at Conn's Creek, the fall was 1700 ft in a track distance of 83 chains. The upper incline was 33 ch long with a vertical fall of 830 ft, and the lower grades associated with such a drop necessitated a form of control capable of handling wagons weighing at least 12 tons fully loaded.

The braking system adopted resembled a direct-acting horizontal winding engine, but the action was directly opposite. Water was used to check the action of pistons, instead of steam to give them motion. The water was drawn off at each stroke and replaced by a fresh supply, as



the severe pressure would raise it to boiling point! There was also a very effective strap brake around the raised centre of the drum that could be used in emergency or when bringing a load to a stop. It could be wound up tight by the brakeman for this purpose.

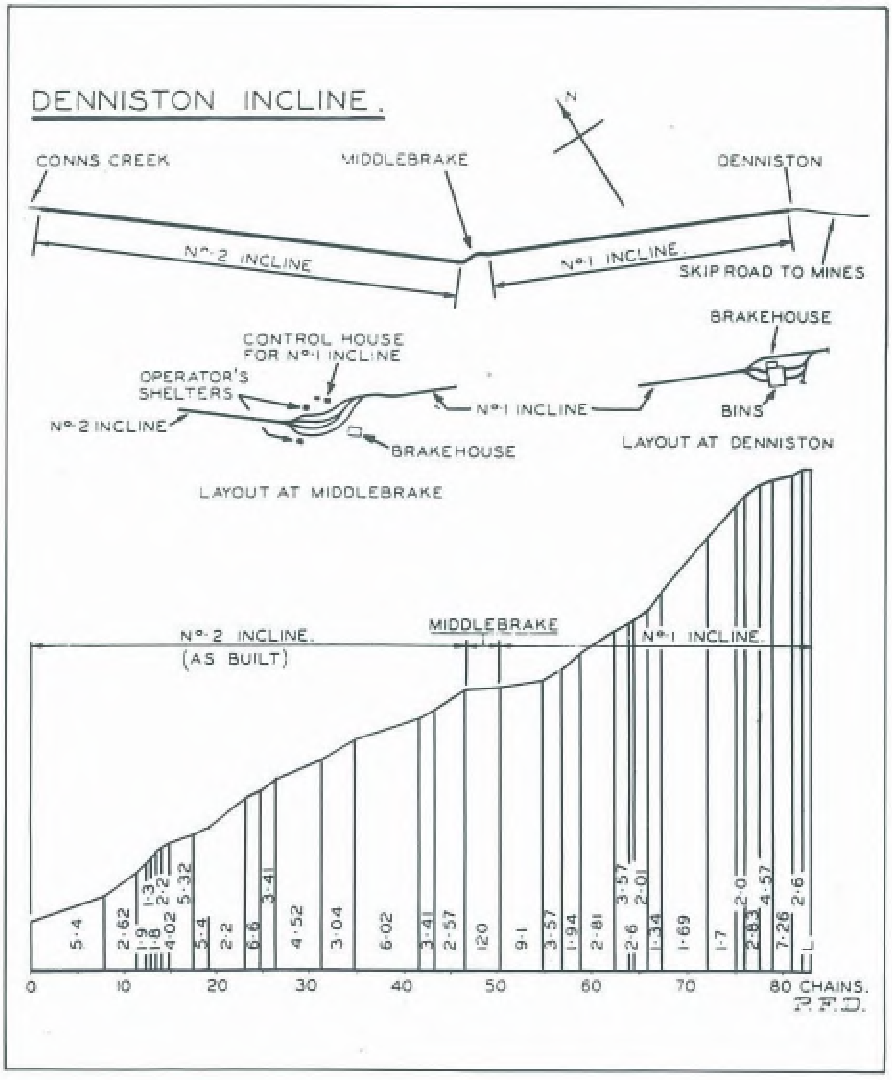
The actual system for working the incline was that of a counter-balance, whereby the descending full wagon pulled the empty one up. Four-inch diameter steel wire rope was used, and the rails were laid so that the wagon ascending on the right or "company" side of the line was wound around its side of the drum while the rope on the other or "donkey" side unwound and let the descending wagon down the incline. For the next load the procedure was reversed.

The building of the screens and bins at Denniston was the next step, as was the construction of the 2 ft gauge horse tramway to the coal face at the Banbury Mine. This 28-chain double-track had a grade of 1 in 120 in favour of loaded skips.

By the end of 1882 the ouput of the Banbury Mine was 24 198 tons for the year, and it continued to increase each year. There was talk of working the incline at night in order to cope with the enlarged output and increasing orders, but this was not possible until Mr R B Denniston's patent indicator was fitted to the brake drums. This piece of equipment could be fitted to the end of the brake drum shaft and connected to the indicator by bevelled gears. These gears in turn worked a vane that moved up or down the indicator board, thus informing the brakeman where the truck, which was often out of sight, was located on the incline. Greater safety was ensured by this device and, with a lantern hung on each wagon, night work was possible.

Initially ordinary N.Z.R. wagons or trucks were used to carry coal from the Denniston bins to Conn's Creek and the shipping at Westport, but later some of these were fitted with fixed hoppers to make it easier to unload the coal. Eventually the "O" class fixed hopper wagon came into use, followed in 1897 by the first "Q" class removable hopper. "L" class highside four-wheel wagons were also used.

Concept: R. B. Denniston (surveyor - colliery manager)
Engineers: H. W. & R. A. Young (Young Bros.)
Contractors: Day & Blair
Owner: Department of Conservation



The Otira Gorge Road S.H. 73

Through the terrible winter of 1865 men toiled to cut a coach road from Christchurch through the Otira Gorge and over Arthurs Pass to the West Coast goldfields.

The Arthurs Pass extends 13.4 km from the township of Arthurs Pass to the township of Otira. The Pass contains 11 bridge structures, totalling 406.6 m.

Tight constraints are placed on the geometric layout as a result of mountainous topography, geological instability, adverse weather conditions and the limitations of the corridors available.

Road gradients range from 1 in 30 to 1 in 8. Five 360° bends through the zig zag section facilitate ascent and descent over the Pass. The summit of the Pass is at 922 m above sea level with Arthurs Pass township at 762 m and Otira township at 427 m.

The construction through the Pass in atrocious weather conditions was completed in 10 months and the original coach road was opened in March 1866.

Some realisation of the terrible conditions in which those early road builders worked can be gained from recent data on the climate in the Arthurs Pass. An average annual rainfall of 4000 to 7000 mm/year is recorded; snowfalls during winter are frequent. The minimum temperatures range between -1 and -2°C (measured at 3 p.m., so much lower temperatures would be expected in the morning). The road was built by labourers with picks, shovels, wheelbarrows and two -horse drays.

Many lives were lost during the road construction, often owing to drowning in the frequently flooded rivers - six drownings in one week are recorded.

The Arthurs Pass is now a section of State Highway 73 which is an important communication link between Canterbury and Westland.

Controlling authority: Transit New Zealand

Original authority: The Canterbury Provincial Council

Engineers: Edward Dobson, George Thornton, Walter & Edwin Blake

Contractors: J. Smith & E. G. Wright

The Midland Railway

The best route was up the Waimakariri Gorge and under the main divide. To provide it pioneer engineers and engineering firms faced and overcame problems which even today are formidable.

This coast-to-coast railway (Christchurch to Greymouth) opened in 1923 after 36 years of demanding construction. It includes five major bridges, five viaducts and 17 tunnels.

Railway development in the South Island in the 1870s was concentrated on a main line linking the established centres of Christchurch, Timaru, Dunedin and Invercargill and light, easily constructed branch lines serving the arable plains. These later included a branch to Springfield which was reached by January 1880.

In 1882 the East and West Coast Railway League was formed and in 1884 a Royal Commission, although fully aware of the construction difficulties of the Waimakariri Valley-Arthurs Pass route, as compared with the somewhat easier but longer Hurunui Valley-Harpers Pass route, chose the more direct route.

However, New Zealand was in depression and the Government was in no position to make further investment in railways, so the East and West Coast and Nelson Railway Act enabled the railway to be built and operated by private enterprise and a deputation of Arthur Dudley Dobson, Alan Scott and C.Y. Fell visited London to interest financiers in promoting a company.

In July 1885 the deputation accepted an offer from a committee which was to become the New Zealand Midland Railway Company. The company contracted with the Government to build 235 miles (376 km) of railway between Christchurch and Nelson via Brunnerton within 10 years but with insufficient capital and a London management remote from the realities of railway construction in New Zealand it had little chance of success.

The company commenced construction from Brunner, the Nelson line heading up the Grey Valley towards Reefton while the Christchurch line diverged from it at Stillwater. It was not until 1890 that work commenced at the Canterbury end: the contract for the 5.5 miles from Springfield to Pattersons Creek being let to J. & A. Anderson Ltd of Christchurch. The work was to include steel viaducts over the Kowai River and Pattersons Creek.

Inevitably the company ran out of

money and all construction ceased in 1895. On the Springfield section only the Kowai bridges and 4.5 miles of track to Otarama was usable as a railway. The foundations for Pattersons Creek viaduct were in place but the steel superstructure still had to be manufactured and erected.

The Crown seized the company's assets and completed works, on the grounds that the contract had expired with the works incomplete. Legal argument and court actions between the parties ensued and it was not until 1898 that the Public Works Department took over and resumed the works.

The major obstacle to the route now lay immediately ahead: the forcing of the Waimakariri and Broken River gorges, some 8.5 miles (13 km) of the route surveyed by C. Napier Bell in 1883 and described to the Royal Commission by District Engineer W. N. Blair as "very rough, the mountain slope rises from the riverbed while the river runs in a fearful gorge all the way".

The section would include 16 tunnels and four major viaducts not including the Kowai already constructed. The viaducts were built under Treasury contracts by both New Zealand and British bridging firms. The most spectacular of these, the Staircase Viaduct carries the rails 240 feet above the bed of the stream.

It was slow laborious work with men, horses, picks, shovels and very little machinery. It was not until 1906 that trains were running to a temporary terminus at Broken River — in time for the Christchurch Exhibition and at last enabling the journey, by rail and coach, from Greymouth to Christchurch to be completed in one day. Progress slowed after that although the country to be traversed became much easier. Cass was not reached until 1910 and Arthurs Pass township in 1914 — the Westland section meantime having advanced to Otira — to meet the other major obstacle.

Midland Railway Company registered: 1886

Company assets taken over by the Government: 1894

Canterbury West Coast Section completed: 1923

Partially complete Nelson Section abandoned: 1955

Owner: New Zealand Railways Corporation

The Otira Tunnel

Driven through wet shale and rotten rock this 8529 m tunnel was opened in 1923 and was then the longest in the British Empire and made the first use of electric locomotives in New Zealand. It completed the Christchurch to Greymouth rail link.

The Midland Company had intended to cross Arthurs Pass by using the Abt rack rail system on a grade of 1 in 15 rising some 600 feet (180 m) from Bealey Flat station (the present Arthurs Pass township) to Arthurs Pass station at the summit of the pass itself — then descending 1500 vertical feet again mostly at 1 in 15 above the Otira Gorge on the slopes of Mount Rolleston to regain the Rolleston riverbed (a tributary of the Otira) a short distance away from the present western Otira tunnel portal — some 6.5 miles of rack railway involving two engine reversals. A number of short tunnels were required in the Otira Gorge to avoid broken and unstable country.

This was not a practical solution for a trunk railway intended to carry heavy traffic. Each rack rail engine could haul about as much as its own weight on such a grade at a speed of little more than walking pace whether travelling up or down grade. Thus a very limited tonnage of freight could have been taken over the line each day.

Finally a tunnel 5 miles 25 chains (8.55 km) was decided upon with a steady gradient of 1 in 33 descending from the east portal at Arthurs Pass towards the west.

Tenders for the tunnel were called in 1907. Five years were to be allowed for its completion, in fact it took 15. The contract was awarded to John McLean & Sons, the most capable and experienced contractors in New Zealand at that time, for the sum of £599,794. As events were to prove the final cost of the tunnel would be over twice that.

Labour troubles bedevilled the job — union leaders of the day, Bob Semple, Paddy Webb and Tim Armstrong — promoted strikes and persuaded union members to work elsewhere than at Otira. This contributed to a chronic shortage of suitable labour which in its turn brought poor productivity, a rise in accidents, excessive drunkeness and the like.

McLean and Sons, who had been highly thought of both as responsible contractors and as good employers, petitioned Parliament to be released from their obligations from which they were freed towards the end of 1912. The company went out of business soon after, financially destroyed by the Otira Tunnel contract.

The Public Works Department had to step in and take over. World War 1 intervened and although work continued it was not pushed to any great extent. Eventually on July 20, 1918 the tunnel was holed through and the surveyors' centre lines produced from each end were found to vary in line and level by only 0.75 inch (19 mm) for line and 1.25 inch (29 mm) for level. Excellent accuracy before the days of lasers. But much remained to be done — the headings had to be enlarged to full tunnel profile and the concrete lining set in place — so it was not until September 1921 that the tunnel was complete — as a tunnel only but not as a working railway.

When first projected the Otira Tunnel was to have been traversed by steam locomotives, railway electrification being still in its experimental stages. During the tunnel construction electric railway traction showed itself to be a practical and economic proposition particularly in long tunnels with their inherent problems of smoke and furnace gases leading to undesirable and often dangerous situations. Tenders were called in 1920 for a steam generating plant at Otira, six electric locomotives and 8.5 miles (14 km) of electrified line. The successful tender was English Electric of London.

The Midland railway was then finally opened for through traffic in August 1923 after almost 40 years in the building. The railway company formed to build it had come and gone. The largest New Zealand contracting company had been destroyed — but the railway was complete.

Design: Public Work Department

Contractors: J. McLean & Sons 1908 - 1912, New Zealand Government 1912-1923.

Owner: New Zealand Railways Corporation

The Original Laboratory of the School of Engineering

The School was founded by Canterbury College (now the University of Canterbury) itself founded in 1873 as a constituent college of the University of New Zealand. In 1887, despite some local misgivings, the Board of Governors resolved to set up a School of Engineering.

New Zealand's first, the fledgling school, then one of only a few in the British Empire, was placed under the nominal supervision of the professor of mathematics, C.H.H. Cook M.A. (Cantab) under whom two part-time lecturers were appointed to give the tuition. Civil classes came under Edward Dobson, Canterbury's first Provincial Engineer and by then, in his seventies, the province's grand old man of engineering. The other appointee, for mechanical engineering, was the burly and forceful manager of the Addington Railway Workshops, Robert Julian Scott.

Fired by a commitment to engineering education, the immensely ambitious Scott at 28 gave up a most promising railway career to become the School's full-time Lecturer in Charge — a title which later became Professor in Charge and ultimately Director. Initially he declined a commensurate salary increase to ensure the building of an Engineering Laboratory.

Its design by the province's leading architect, Benjamin Mountfort, was accepted without significant modification. On the ground floor this provided for a "Testing Room" while above were a "Drawing and Lecture Room" and a "Model Room". A "Boiler Room" and a 'Store and Dark Room" were also on the ground floor; above were lavatories and a "Lecturer's Room". Although the uses have changed, this section survives with minimal alteration.

In 1890 the chairman of the Board declared that the new engineering additions "will provide all the accommodation required" and by 1891 the building was complete. The cost was £2740. Unfortunately for the expectant Lecturer in Charge, equipment was not provided! It was not until 1894 that a reluctant Board faced that need and Scott was enabled to purchase his first major item, an experimental steam plant "made by Messrs J & H McLaren of Leeds to comply with the conditions set by Professor Scott." The unique and highly flexible experimental engine is on display at the Canterbury Steam Preservation Society's MacLeans Island Museum.

An electrical laboratory was added in 1901 and was followed by a hydraulics laboratory in 1913. The last major additions to the school; new mechanical and electrical laboratories, were virtually complete when ill health forced Scott to retire in 1922. By then through Scott's energy, enthusiasm and vision a small liberal arts college had fostered an engineering school highly regarded throughout the British Empire.

In 1960 the School headed the move to a new campus at Ilam, now the home of the University of Canterbury.

In all 1335 graduates passed through the School between the year of its foundation and the transfer to Ilam. By modern standards the number is not great; these days over 200 engineers graduate from Ilam every year. Their influence, however, was substantial and helped to win the world-wide recognition accorded New Zealand's professional engineers.

Owner - Originally Canterbury College, now Christchurch Arts Centre.

Fort Jervois

Dominated by four disappearing guns Fort Jervois preserves military technology from an age when 5 - mile ranges were considered sufficient to fend off the world.

Built on Ripapa Island for the defence of Lyttelton Harbour, Fort Jervois formed part of a British plan for the protection of Australia, New Zealand and the Pacific naval forces. Similar works were constructed at North Head, Auckland, Point Gordon, Wellington and Taiaroa Head, Dunedin, but none of these is as complete or as comprehensive.

The following extract is from a Defence report to the General Assembly in the 1890s.

"The fort occupies the whole of the Island, following its irregular outline. Four breach-loading guns are arranged in a quadrilateral plan and severally connected by passages from pit to pit successively, which start from either end of a wide gallery or bastion trace closing gorge, and loopholed to sweep parade in rear.

"From the centre of the gorge gallery is a central passage to the centre of the passage between No 3 and 4, 8 inch guns on the front of the quadrilateral. On either side of this passage are bombproof casemates (towards the rear end) and magazines (in centre of quadrilateral) with ammunition passages between No 2 and 3 and 4 and 5 guns respectively.

"The whole is covered with 10 ft of earth, escarped to the sea with high wall and forming solid rampant mass which is profiled at the rear over the gorge gallery into musketry parapet (20 yards), sweeping top, with QF gun emplaced at right end. From either end of the gorge loopholed wall, musketry parapets enclose a low level terreplein (of rest of island) (total trace including loopholes about 230 yd) with escarp walls to the sea and No 6 QF gun on the left flank.

"Entrance from the jetty is by an arched gallery with drawbridge lower end and loopholed gates upper end. Bombproof accommodation in gorge gallery and casemates for 50 men in war. Corrugated iron barracks (in open) on parade for 60 men in war".

Concept: W.F.D. Jervois G.C.M.G., Governor

Design: Lt. Col. Boddam, Engineer for Defences

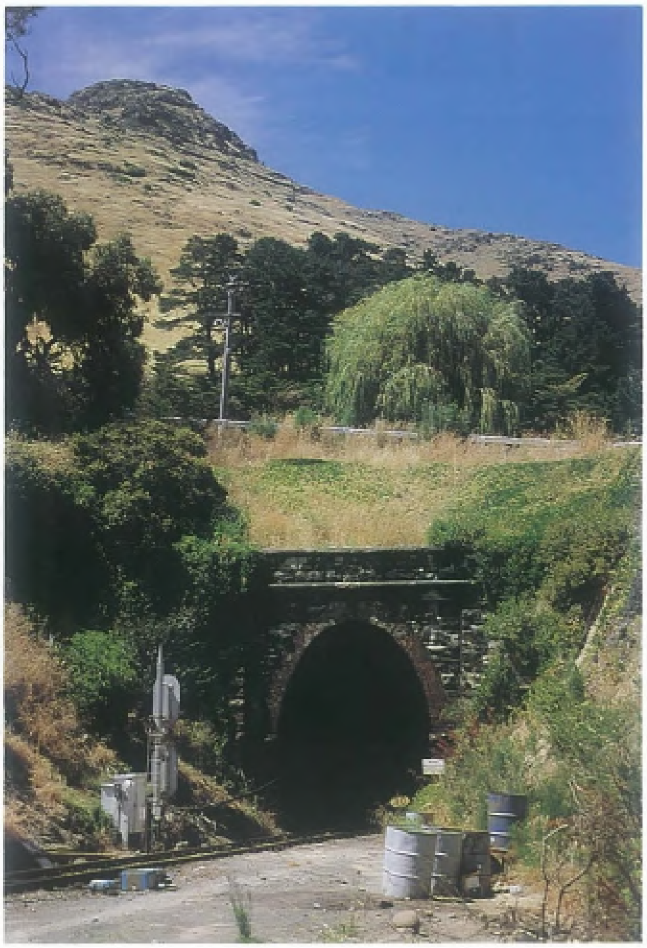
Gun Maker: Sir W G Armstrong & Co

Construction: Permanent Artillery, contract labour, relief workers and prison labour

Commenced 1885 - Basic fort completed 1895

Owner: Department of Conservation

Moorhouse Railway Tunnel



A huge provincial undertaking, the tunnel linking the port of Lyttleton and the town of Christchurch was the first ever driven through the flank of an extinct volcano.

In 1850, when the first four ships arrived at Lyttleton, there were only two ways of reaching the township of Christchurch; by scrambling up the foot trail over the hill, or by taking a boat over the Sumner bar and up the Avon river.

In 1853 the Canterbury Provincial Council considered possible rail routes and how to finance them. Finance was the bugbear and the scheme was shelved until 1858 when the Superintendent of the Province, W.G. Moorhouse, exhorted his council to "consider and determine the best method of securing safe and expeditious transit of our marketable productions to the place of export".

A Provincial Commission consulted Robert Stephenson, eminent son of the famous George. Stephenson, with his health declining, passed the matter to his cousin George Robert Stephenson, who favoured the direct line, 6.25 miles, (10 km) long with a tunnel 1.6 miles (2.6 km) in length. He recommended the firm of Smith & Knight of London as contractors to complete the work within five years from late 1859.

It is claimed that the tunnel was the first to pass through the wall of a volcano. This the London contractor thought was too difficult and so abandoned the contract. True or not the boring attracted much geological interest and Julius von Haast, the noted geologist, was greatly involved in exploration, interpretation and advice to the engineers. Moorhouse, anxious to press on, had Edward Dobson, the Provincial Engineer (who was responsible for the whole undertaking from 1854 onwards) open up the access cuttings at each end of the tunnel and commence tunnelling on a day work basis in anticipation of a further contract being let.

The new contractor was Holmes and Co. of Melbourne who undertook in 1861 to carry out the contract for £240,000 of which the tunnel itself complete with stone portals was to cost £195,000. The contract price did not include locomotives, rolling stock and station buildings. The works were to be completed in five years.

Boring went on from both portals and in 1867 a breach was made from the Lyttelton heading into the Heathcote one. Rails were laid through the tunnel and by mid November the first locomotive went through. Passenger services began in December but the tunnel was then not complete. After the last train passed through each evening, work gangs, for another three years, occupied the tunnel till morning, completing the drainage and widening works.

The railway had been operating between Christchurch and a temporary terminus at the Ferrymead wharf since December 1863, the locomotives and rolling stock having been brought in parts over the Sumner bar and assembled in the open. The broad gauge of 5ft 3in between the rails was decided on by expediency. The Melbourne to Essendon Railway, built to that Victorian gauge, had an unused locomotive which was not required because traffic had failed to develop as the company expected. Holmes & Co. required an engine for ballasting duties and the purchase of this engine, built by Slaughter Gruning & Co. of Bristol apparently determined the matter. The province had originally stipulated a 5ft-6in gauge as used in India.

The Canterbury Railways' broad gauge lines extended to Rakaia in the south and Amberley in the north before the gauge was changed to the standard 3ft-6in by December 1877. Narrow gauge trains had been using the Moorhouse tunnel from April 1876.

Since the gauge conversion, the tunnel itself has been altered very little, although heavier rails, improved signalling, electrification and more recently dieselisation have come progressively.

Electrification was investigated by the British firm of Merz and McLellan in 1925 and the following year the tender of English Electric for the overhead contact system and six 1200 horsepower electric locomotives, was accepted. The electrified service was opened in 1928; with 24 passenger trains and 12 freight trains each way each week day.

When the Tunnel Road was opened there was no longer a need for an intensive rail passenger service and much of the port freight also went by road. The electric locomotives and substations were phased out in 1970 and replaced with diesels.

Original owner: Canterbury Provincial Council

Present owner: N.Z. Railways Corporation

Engineer: Edward Dobson

Geologist: Julius von Haast

Contractor: Holmes & Co. Melbourne.

Lake Coleridge Power Station

The Lake Coleridge power scheme, which lies on the Rakaia River about 100 km west of Christchurch, was the first major state-owned entry into electric power supply.

Construction began in 1911 following the 1910 Aid to Waterpower Act which gave the Government authority to borrow money for hydro-electric development. The station with its first three 1500 kW generators (of six planned) was opened on 15 November 1914 by Prime Minister Bill Massey and a regular supply was given to Christchurch in March 1915.

The construction of the powerhouse was a remarkable feat for that time, in that it had to be built on loose shingle of the Rakaia River and this led to many troubles which the New Zealand engineers had to master the hard way. This experience, however, produced benefits for subsequent stations such as Waitaki and Highbank, and contributed to world knowledge on how to construct big hydro plants on loose shingle.

Also of significance was the construction of two 66kV transmission lines to Christchurch - the highest voltage, and at 100 km, the longest length in New Zealand to that time. This work was started in 1913, and completed in November 1914.

The progressive development of the scheme owing to post-World War I demand led to further generators, a second intake, surge chamber, tunnel and pipelines and the final commissioning in 1930 with total output increased to 34,500 kW.

To meet the potential of the scheme, it was necesasry to obtain further water which came first from the Harper River, later from a diversion of water from the Acheron Stream and finally from the Wilberforce River.

Through the sales promotion of Lake Coleridge power, most of the boroughs and counties near Christchurch were induced to become electricity supply authorities. The making of numerous contracts with relatively small-scale consumers or groups became unwieldy and led to the Government passing the Electric Power Boards Act 1918 which was later consolidated as the 1925 Act, setting the ground work for the orderly distribution of electric power in New Zealand.

Owner: Electricity Corporation of New Zealand Ltd

Designers: Public Works Department, Electrical Branch

Constructors: Powerhouse building — Taylor Bros & Moorhead, Christchurch

Intake, tunnel, surge chamber, etc — Public Works Department, Electrical Branch

Penstocks — Dunedin Engineering & Steel Company

Turbines, generators and allied transformers, switchgear — Public Works Department, Electrical Branch

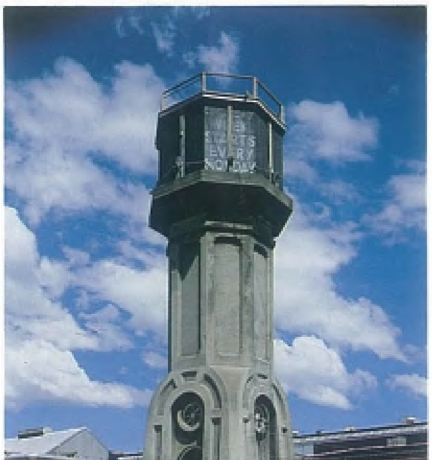
Manufacturers of power plant: Turbines — Escher Wyss & Cie, Zurich

Generators — Bruce Peebles & Co Ltd, Edinburgh

Addington Water Tower

This Christchurch water tower was one of the world's first structures in reinforced concrete.

Built in 1883 to provide a pressure water supply for the Addington Railway Workshops, the tower still performs this task, although deterioration of the top iron tank has greatly reduced its capacity. However the concrete tower itself is in good condition and the concrete is sound.



Construction of the tower was supervised by the designer's brother, a foreman in the government service, and it is reported that prison labour was used.

In 1964 a reinforced concrete ring beam was cast around the top as part of an earthquake strengthening programme.

The tower was an innovative and daring structure built at a time when reinforced concrete was still very novel. The tower foundation consisted of clay upon quicksand, and nine inches (230 mm) of settlement took place by the time it was completed.

The design concept for earthquake loading was an interesting early idea. The design was such that the centre of gravity was very low even with the tank full of water so that an earthquake would have to be very severe to capsize it.

Owner: New Zealand Railways Corporation.

Designer: Peter Ellis (N.Z.R.)

Builder: J A Ellis (Government foreman)

Rangitata to Rakaia Diversion Race

The first major river diversion in New Zealand (opened 1945) supplies our largest irrigation scheme as well as providing hydro power in winter.

The concept was bold from the outset — a major diversion of a major river along the foothills above the Canterbury Plains for 42 miles (67 km) passing under major rivers on the way to discharge to the Rakaia River at Highbank using the power drop to produce 25.2 MW of electricity. The prime purpose was to irrigate the farmlands of Ashburton County, raising the production, five or six fold, and enabling maximum diversification of farming, be it cropping, meat and wool production, dairying, fruit production, whatever. Although the irrigation was slow to get underway — taking some 20 years to reach full capacity, it has been a thorough success completely transforming the district.

The race is carried along the sidling of hills for many miles and unstable hillsides were encountered just south of the Ashburton River crossing. A 2.68 km inverted syphon was substituted requiring twin pipes of such a diameter that the Minister of Public Works (the Hon R. Semple) drove a car through them! The pipes were made on site near Mayfield and were believed to be the second largest spun reinforced concrete pipes made in the world up to that time.

Design: Public Works Department (T.G.G. Beck irrigation engineer)

Construction: P.W.D. and contractors.

Rakaia River Bridge S.H. 1

This crossing is the country's longest.

The present concrete bridge is a replacement for a timber bridge begun in 1869 and modified for road-rail traffic in 1873.

The Rakaia road bridge is typical, yet a notable example, as well as the longest, of many standard simply supported reinforced concrete bridges with standard spans, standard parapets and standard appearance.

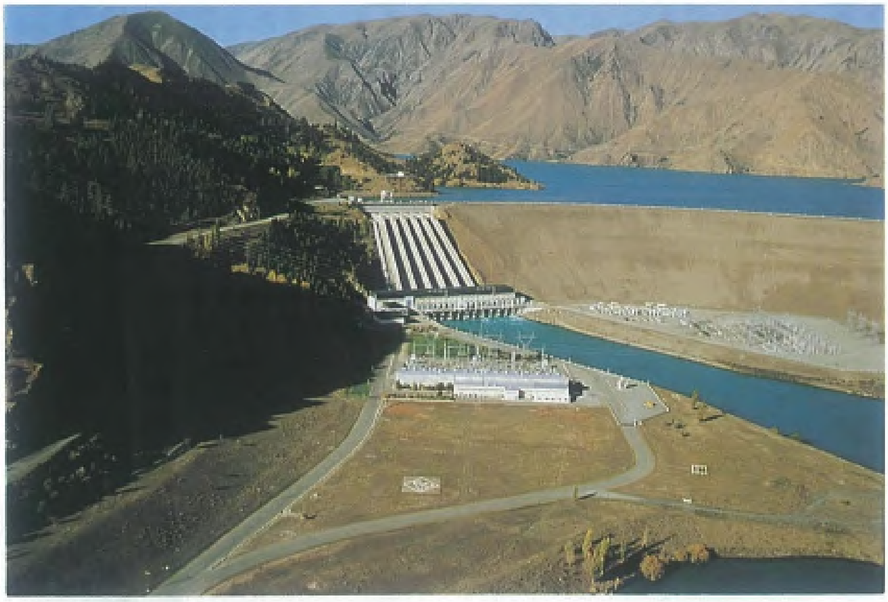
Completed in 1939 it superseded a frightening crossing of a combined road-rail common deck. The new bridge was 1.1 miles (1.8 km) of 40 feet (12.2 m) spans.

Controlling Authority: Transit New Zealand

Engineers: Public Works Department

Contractor: Rope Construction Company

H.V.D.C. Link Benmore to Haywards



The Benmore power station at Otematata in the South Island is the power source for the high voltage direct current link to the North Island and the Benmore converter station is the South Island terminal of that link.

Construction on the Benmore project began in 1958 and the power station was opened in 1965 to co-incide with the completion of the H.V.D.C. link.

Benmore dam is the largest earth dam in New Zealand and, at 118 m to crest, our highest. At the time of its construction the dam was very large in world terms (11.7 million cubic metres).

Impounded behind it is New Zealand's largest man-made lake which provides various recreation facilities.

In front of the dam the massive prestressed concrete penstocks are a unique feature.

The power station contributes about 2200 GWh per year to either the South or the North Island; if for the latter by means of the converter station with its seismic designed rectifier units and the H.V.D.C. link which now provides for reversal of power flow.

Both the converter station and H.V.D.C. link were state of the transmission art in 1965 and are now being expanded, again using state of the art techniques.

Power station owner: Electricity Corporation of N.Z. Ltd

Designer: Civil - Ministry of Works, Electrical - N.Z. Electricity Department

Contractors for main equipment: Turbines - Dominion Engineering, Canada. Generators - Canadian General Electric. Transformers - Canadian General Electric & ASEA, Sweden. H.V.D.C. Link - see page 38.

Hamilton Jet Marine Propulsion Unit

First built at his Irishmans Creek workshop for boating on Canterbury's shingle rivers in the 1950s, Sir William (C.W.F.) Hamilton's development of the water jet propulsion unit was innovative in both design and manufacture and the Hamilton Jet is acknowledged as a world leader in its field.

The waterjet unit had been an on again/off again project of the late Bill Hamilton in a search for a craft that would give him access to the remote corners of his sheep station at Irishmans Creek in the Mackenzie country.

The first jet boat ran successfully upriver in 1953 and since then, the Hamilton Jet has enjoyed a high profile, both in New Zealand and overseas.

From its early beginnings, the product and its market have altered from river boats to high speed commercial craft. However the ability of the firm of C.W.F. Hamilton to adapt, plus their philosophy of continuous improvement, have maintained their market dominance.

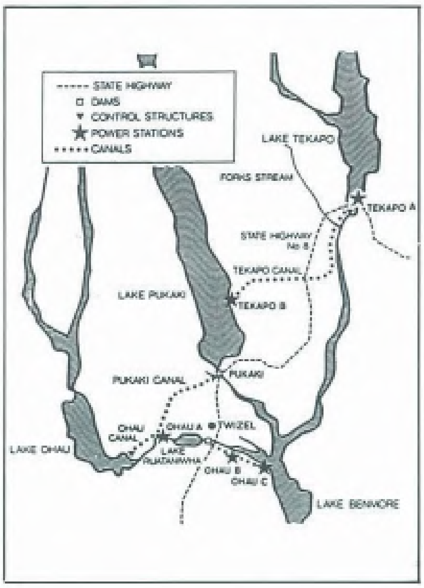
The Hamilton 400 Series waterjet unit, developed from 1978 and commissioned in 1981, was the first, designed and built using CAD/CAM technology, for craft 15 to 30 m long with diesel engines to 1500 hp. Jet efficiencies were improved to be comparable wth conventional propellers up to 25 knots and more efficient at boat speeds higher than that.

Today, there are more than 2 500 000 hp of jets in operation worldwide with the installation rate increasing all the time.

Upper Waitaki Power Development

Here the canal system linking lakes and hydro-electric power stations required the most extensive earthmoving project ever undertaken in New Zealand.

There are over 50 km of canals with a flow rating from 120 cumecs up to 525 cumecs. The scheme also includes the unique feature of a large earth dam on the top of a hill.



The scheme utilises the combined water storage of Lakes Tekapo, Pukaki, and Ohau by dams and canals and successive stations of Tekapo B and Ohau A, B and C. These were commissioned in 1977, 1979, 1980 and 1983/5, and added 848 MW to the South Island system.

The whole project is a fully integrated system of hydro-electric power development, and generates 4000 GWh per year, a significant proportion of New Zealand's energy requirements.

The Ohau and Tekapo B stations and their canals, dams and control gates are controlled by ultra-high-frequency radio links from the Twizel area control station.

Owner: Electricity Corporation of N.Z. Ltd
Design: Ministry of Works
Construction: Ministry of Works, NZ Electricity Dept.,
NZ sub-contractors.

Waianakarua Bridge – S.H. 1

Built from local stone in 1874 this fine bridge with its 18 metre span skewed arches is one of the oldest on the State Highway network; 28km south of Oamaru. It was designed by the Otago Provincial Council's Chief Commissioner of Surveys and Works, John Turnbull Thomson, civil engineer.

The bridge is particularly interesting in that it has skewed arches - ie arches that are oblique to the axis of the bridge. Note, too, the vermiculated voussoirs, tapered stones forming an arch, which define in a very positive manner the soffits of the arch.

The bridge is classified by the New Zealand Historic Places Trust as a monument of national importance.

Controlling Authority: Transit New Zealand.

Hillside Railway Workshops

The five government workshops — Addington, Hillside, Otahuhu, Wanganui, and Woburn were early industrial complexes. Hillside in Dunedin, opened in 1881, with major upgrading and expansion during 1926-29, to manufacture wagons and locomotives.

Between 1897 and 1967, Hillside manufactured a total of 190 locomotives, including 90 4-6-4 tank engines (Classes Wg, Ww and Wab) between 1910 and 1927, and 35 4-8-2 Ja express engines between 1946 and 1956. During World War II Hillside manufactured 3 inch mortars, as well as machined components for other weapons systems.

Prior to the 1950s, Hillside was the largest industrial complex in the southern half of the South Island, employing a maximum of nearly 1200 people in 1946.

Since 1966, Hillside has manufactured nearly 1600 wagons, including 1200 bogie container wagons between 1971 and 1988. More recent contracts include large car carrier wagons and hopper wagons for fertiliser, utilising both steel and aluminium alloys.

In 1989 the workshops were renamed Transtec Hillside Engineering, a division of Transport Engineering Equipment Liaison (TEEL) Business Group of the N.Z. Railways Corporation.

Transtec Hillside is now the largest structural engineering enterprise in New Zealand, and incorporates the largest metal foundry. It concentrates on iron and steel castings, steel and aluminium machining and fabrication, wagon assembly, and shot/sand blasting and painting, together with the physical testing of metals and castings.

Ross Creek Waterworks

The water impounded by New Zealand's oldest surviving large dam, provided Dunedin in 1867, with the country's first major urban water supply.

The dam is New Zealand's oldest surviving large dam, impounding 220 000 cubic metres (50 million gallons) and there are 4400 metres of pipeline, most of it through the "main street" of Dunedin.

The dam is an earth dam with a puddled clay core straddling a fairly steep valley. There are stream bypassing channels on both sides. Abstraction is via a fine masonry tower, still in use.

The treatment plant has had chlorination (1950s), microstraining (1971) and fluoridation (1967). In 1990 clarification has been added using magnetite as the primary coagulant — the first in New Zealand and only fourth in the world.

Thus the site now has the unique contrast of the oldest hydraulic structures and the newest treatment process in New Zealand.

Owner: Dunedin City Council
Built for: Dunedin Waterworks Company
Engineer: Ralph Donkin
Contractor: David Proudfoot & Co.

The Development of Gold Dredges

Gold winning by bucket dredge is a New Zealand development which began in Otago.

By means of dredges, which were first used for winning gold in New Zealand, wash-dirt was obtained from the beds of large rivers. The earliest "spoon-dredges" were employed in 1863 and for a time they won a considerable amount of gold with very simple appliances. Five years later the bucket type of dredge was introduced, and this, in various forms, has been used ever since. Important changes however, have been the introduction of steam dredges about 1882, and electric dredges in 1890, and the accidental but very profitable discovery at the very end of the century, that often there were rich gold-bearing deposits concealed beneath a hard layer which was apparently the bottom of the river bed.

The first successful gold dredge was commissioned through the vision and perseverance of Sew Hoy (Sew Hoy Big Beach Mining Co) and was built by Kincaid & McQueen, Dunedin.

Both the first electric dredge and also the first one to be electrically-operated from a 3-phase alternating current supply were built and operated in New Zealand.

The former of these, "The Sandhills Dredge" — was designed and put into operation in 1889-90 by R.C. Jones who later became one of the founders of the firm Turnbull & Jones. This dredge operated on the Upper Shotover River, Central Otago, power being supplied at 1300 volts to operate the plant on what proved to be the first electrically operated gold dredge in the world. The dredge was a complete success, the electrical equipment performing its work faithfully.

This success was followed several years later by another pioneer — "The Fourteen Mile Beach Dredge" — which was the first electrically-operated dredge in the world driven by a three-phase alternating current supply.

By 1900 there were 187 dredges at work among the gravels of the Clutha. It is said to have been the greatest assembly of gold dredges the world has ever seen. In the boom period of dredging, about that time, efficient dredges secured as much as 1000 ounces of gold in one week's working.

Only a few years ago the *Kanieri,* the last of the 150 gold dredges that worked the West Coast, was still operating on the Taramakau River. Gravel scooped up by a chain of buckets was washed over sluice boxes and gold tables and the waste or tailings deposited at the rear of the dredge, something that environmentalists would not tolerate today.

Patearoa, 17 km south of Ranfurly, had its goldrush in the early 1860s. One of the few relics from those days is a dredge which was operated from a barge on the nearby Taieri River in 1896. It was abandoned and became partly submerged in the river, but was salvaged and restored in 1978 for display in the town.

The dredge buckets in Cromwell Town Centre, Cromwell represent the development of bucket dredging from the "Shine No 1" in 1900, to one of the world's largest, the "Austral Malay" in 1940.

N.Z. Express Co Building

Originally built for the N.Z. Express Co Ltd in Dunedin and opened in 1908, this is an early multi-storey building which incorporates precast concrete, structural steel and a reinforced concrete raft foundation.

The *Evening Star* of 21 September, 1908 said "this class of construction has so far not yet been generally adopted in the colonies" and "the full plans and specifications were submitted to two competent engineers for report as it is admitted the whole system is an engineering one."

This building is one of the very early reinforced concrete multi-storey buildings in New Zealand. It has many features which were very advanced for its time and predated by many years their general adoption elsewhere in New Zealand.

These features include: The use of reinforced concrete for the structural frame; precast concrete floor slabs; proof testing the design by loading full-sized models of parts of the structure to destruction; a reinforced concrete raft foundation; and a central heating system using hot water distribution and radiators from a single boiler.

The raft foundation was probably a first for New Zealand, as the ground was very recently reclaimed from the Otago Harbour.

The many innovations in its design and construction undoubtedly are the reason for the building's long life, as they gave considerable flexibility to the internal spaces which allowed the very diverse needs of the multitude of firms and companies who have occupied it over 82 years.

Architect and engineer: A. E. Luttrell
Master builder and engineer: C. Fleming McDonald
Owner: Southern Properties Ltd

Kawarau Gorge Suspension Bridge

For over 80 years this bridge on a remote and difficult site was a vital transport link for Central Otago.

Built between 1878 and 1880 this magnificent bridge was a link in the Central Otago/Queenstown road, crossing the rugged Kawarau River gorge. It continued in use until 1963.

One aspect of the bridge quite incredible to modern engineers is best described by its engineer as follows:

"It may be for local reasons that the work was laid out, and the designs and specifications were made, within 16 days from the date the Author received his instructions. The designs did not suffer from this hurry, as was proved by the fact that the only departure from the contract plans was necessitated by the sudden dip of the rock upon the south side of the river, the consequence of which was that vertical anchor-shafts had to be adopted in lieu of tunnels upon the north side". Such speed with design and specifications was an extraordinary ahievement.

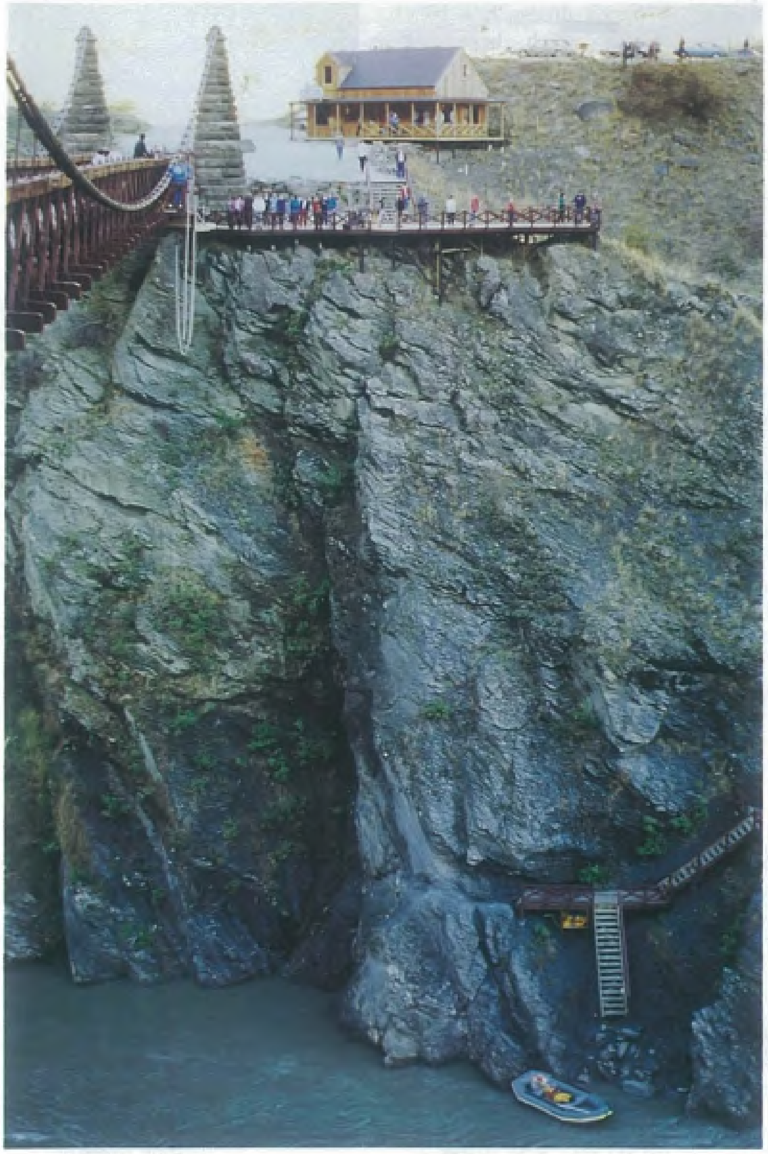
The cables were manufactured in England, and the keys at the stiffening truss chord joints were Australian hardwood, but all the rest of the materials including the wrought- and cast-iron work was done in New Zealand.

The cables were drawn together at the centre by 6 feet (1.8 m) forming horizontal as well as vertical curves. This was the general American practice and gave great lateral stability to the platform.

The bridge continued in service until the new bridge constructed a hundred or so metres upstream was completed in 1963.

The suspension bridge is now in a reserve and is classified as an historic structure of the highest national importance.

Built for: Lake County Council
Owner: Department of Conservation
Engineer: Harry Pasley Higginson
Bridge builder: J McCormick



T.S.S. Earnslaw

The largest steamship built in New Zealand, T.S.S. *Earnslaw* is now one of the world's last coal-fired passenger steamers. The ship is unique in that the hull was constructed in Dunedin, dismantled, transported to Kingston and fitted out for use on Lake Wakatipu.

The hull and machinery, including the boilers and engines, were designed and built in New Zealand.

When launched in 1912 the *Earnslaw* was an extension of the New Zealand Railways network from its terminus at Kingston. The development of the Wakatipu Basin owes much to the steamer for the role that it played in the servicing of Queenstown, Glenorchy, Kinloch and several major sheep stations on the shores of Lake Wakatipu.

With present day road and air services the role of the ship is now that of a unique relic of early history, still servicing the remote sheep stations on the western shore of the lake, but better known as a tourist and entertainment attraction for which it has an international reputation.

Built for: New Zealand Railways
Designer: Hugh McRae – Dunedin
Builders: J McGregor & Co – Dunedin.

Percy Burn Viaduct

One of the biggest timber viaducts ever built in New Zealand, the Percy Burn viaduct in the Waitutu State Forest, 20 km west of Tuatapere, Southland, is 125 metres long by 35 metres high. It is made of Australian hardwood, and was opened in 1923.

From 1918 Port Craig in Southland had been the site of two Marlborough Timber Company mills. When built, one of these mills was the largest and most modern mill in New Zealand, capable of producing seven to eight million feet of timber per year.

In 1928 both mills were forced to close because of falling timber prices. A skeleton staff was left to keep the equipment in working order, but after the depression, when timber prices still had not recovered enough, the mills were dismantled and moved elsewhere.

While the mills operated, the Maori land and some State forest between Port Craig and Wairaurahiri River was logged, the logs being transported by tram. The company put up four large viaducts to carry the tram rails over deep streams. The largest of these was the Percy Burn.

The viaducts are good examples of engineering in the early 20th century and, recently redecked for safety, remain as important relics of sawmilling in Southland.

They now serve trampers in the Waitutu Forest.

Owner: Department of Conservation
Original owner: The Marlborough Timber Coy Ltd
Designer: Unknown
Contractor: Rope Construction Co

Homer Tunnel – S.H. 94

In 1935 five men with shovels and wheelbarrows began to pierce this 1240 m tunnel into the Cleddau Valley and the magnificent country beyond.

Shovels, picks and wheelbarrows were the bulldozers of the day; isolation and deprivation the constant companions of the men employed on the work. With an average rainfall of 250 inches (6350 mm), heavy snowfall and avalanche danger, conditions were severe for both tunnellers and road gangs. Accommodation was in canvas tents that seldom saw the sun for six months of the year. Pay was on a contract basis which meant that, with the continuous rainfall, wages were often reduced to a mere pittance, sometimes as little as £1 6s ($2.60) per month.

The tunnel section is 24 ft x 18 ft, the length 4118 ft and on a down gradient of 1 in 10 from the eastern portal; the western portal being inaccessible until the tunnel was pierced.

The rock could be described as of a granite type and therefore quite stable. Although full-face tunnelling could have been used on a more level grade, a 14 ft x 9 ft heading was put through to ease the problems of seepage water discharge, and of ventilation, then enlarged in one operation to the required size by a system of ring drilling.

The Upper Hollyford and Cleddau Valleys are typical of nature's glacial

handiwork, with a floor approximately 800 m wide, walls almost vertical for 800 m, and then lying back approximately 30°, vast areas of snowfields, up to 2500 m elevation with an annual snow precipitation of approximately 5000 mm. As a source for avalanches, this could be equal to anything in the world.

Two types of avalanches, the wet and the dry, occur. The wet avalanche occurs when snowfields become unstable and slide off the mountains. The wet type provides plenty of noise and takes an appreciable time to cascade down the mountain. It is regular and can be predicted.

Dry avalanches have a different cause. They occur when it is snowing on the tops, are noiseless, until suddenly a terrific air blast occurs, and a snow cloud of the atomic bomb type emerges. The blast from this is powerful enough to shear off 50 cm diameter beech trees without uprooting them, throw 40 kg 10 cm water pipe 200 m and blow over a 4-tonne tractor. Ordinary temporary structures are as straw and in one case a 100 m mass of reinforced concrete avalanche protection, the basic design of which was based on continental design for avalanche areas, was demolished.

In one specific dry avalanche, it was estimated that 250 000 tonnes of snow and ice, glissaded off the snowfield, and fell, as a blanket 450 m. When it landed, the entrapped compressed air burst out releasing energy calculated at 450 MW.

So the road took its toll. In July 1936 a tunneller was killed and several men injured when an avalanche struck the tunnel entrance. A reinforced shelter built out from the tunnel mouth proved to be no certain protection, for the following year, the engineer in charge and the tunnel superintendent, both at work near the tunnel entrance, were killed by avalanche blast.

Nevertheless, work continued and 'hole-through' was achieved in February 1940. World War II held up the work and in 1945 the massive reinforced concrete approach was destroyed by another avalanche. The damage is still evident.

In 1953 a private contract was let for the tunnel completion and in the summer of 1954 the first private car drove through. Now there are over a quarter of a million vehicles each year.

Design and roadworks: Public Works Department

Tunnel construction: P.W.D. and Downer & Co Ltd

Bluff All-weather Package Loaders

The first such facility in the world, these loaders were designed and built by New Zealanders to permit the all-weather loading of frozen meat.

In the port of Bluff a specialised all-weather loading berth was established where frozen meat from railway wagons or road transport could be unloaded on to conveyors inside a wharf shed. The five loaders were commissioned in 1963 and four of the original loaders are still in use.

In 1952 when considering a development scheme for the port, the Southland Harbour Board saw the need for speeding up the loading of frozen meat, particularly during the peak of the killing season. In 1953 a Donald portable elevator was purchased and adapted for the loading of carcass and packaged meat.

It was put into operation and was used more or less continuously for the loading of vessels for a period of 2½ years. Despite problems setting up, and keeping meat up to the loader, it proved itself to be mechanically satisfactory. Although the loader had its limitations and could not be fully weatherproofed, it did prove that the mechanical handling of suitable unit cargoes could increase the loading rate, so in conjunction with the working of the Donald loader, the Harbour Board investigated how a system of mechanical loading of frozen meat could best be adopted.

The design of a suitable system was undertaken by an overseas firm, the builder of the original Donald elevator, and several proposals were prepared but not accepted. Subsequently, the Board's engineer (D.E.S. Mason), assisted by the design engineer (H. Bulters), prepared a scheme which seemed acceptable. William Cable Ltd were then asked to prepare a complete design prior to calling for tenders. They suggested several changes before the final proposal was developed.

The loading equipment consists of a Transfer Shed 159 m x 32.5 m with five lines of rail track and five horizontal belt conveyors with roof hatches through which the loading bights of the five travelling ship loaders can be lowered to take the carcasses off the belt conveyor. The ship loader is of the chain apron type with a continuous apron so that carcasses or packages are carried from

the belt conveyors through the roof hatches, gantries and luffing booms into the ship's hold. The conveyors and loaders are weatherproofed so that an 'all weather' loading system may be obtained.

The operator in the cabin controls all loader movements. The hatchman, who is stationed in the hold near and above the discharge end has a control box fitted with an emergency stop button and a 2-way telephone and is able to have the loader started on request, by telephone to the operator in the cabin, at whatever speed is desired, and can either have the machine stopped or do so himself by pressing the emergency stop button. The watersider stationed at the transfer point in the shed is in constant communication with the hatchman in the ship, and the operator, and he also has an emergency stop button.

The operator directly controls all movement of the loaders along the berth, the luffing of the boom, or other movements of the loader pocket lines, as well as varying speeds and resetting of the electrical relays after an emergency stop.

The five loaders were designed to carry whole lamb and mutton carcasses up to 27kg in weight each at a maximum capacity of 2100 carcasses per hour per machine, from five lines of rail tracks in the quayside transfer shed, into five ships' holds at one time.

Cartons of offal up to 40 kg weight each, and other packs of suitable shape, length not exceeding 1370 mm and girth between 760 mm and 1350 mm of near circular or square shape, can be carried in alternate conveyor pockets at a maximum rate of 1050 packages per hour.

The travelling ship loaders are capable of loading into the holds of any of the standard refrigerated ships coming to New Zealand as well as any other ships of similar characteristics and dimensions.

Between the shed and the ship's deck the carcasses travel in a weatherproofed structure. Between the loader head and ship a temporary hatch covering was designed to cover all sizes and types of standard ship's hatch and is fitted with a series of hatch boards and covers which permit it to be either partially left open during working operations, or completely covered during wet weather. The adjustable trunk portion into which the head of the loader boom fits is designed in 'concertina' form and allows for minor variations in ship level throughout loading and tidal rise and fall without being unduly affected by heavy wind.

The loaders are designed to operate in winds of at least 72 k/h and when stowed to be stable up to 170 k/h. Storm anchors are fitted to prevent movement along the wharf.

Design: Southland Harbour Board & William Cable Ltd
Construction: William Cable Ltd
Present owner: South Port New Zealand Ltd

Invercargill Water Tower

This tower, which combines utility with profuse adornment, was built in 1889 to support the city's first high-pressure water supply tank.

Invercargill's water tower has been described as an architectural treasure and a prime example of Victorian architecture. For the engineering profession the Invercargill water tower demonstrates their ability to provide a utilitarian structure which is aesthetically pleasing.

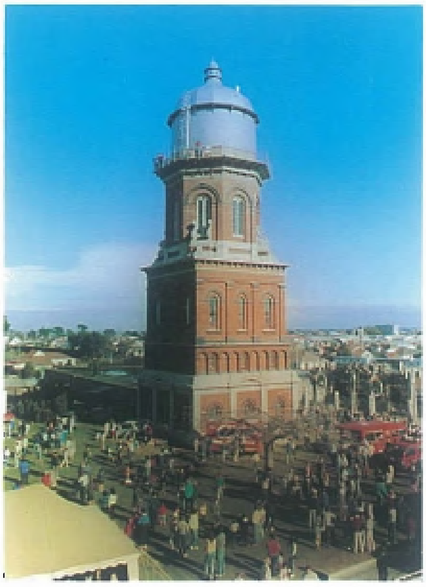
High land or hills are not in abundance in Invercargill, the highest point within the Invercargill Borough in the 1880s was designated as reserve land with consequent protection against development. To complement reserve status, Invercargill's tower was built in brick with a tank covered by a distinctive cupola, unlike many structures of this type which were constructed of concrete or steel with purely function and not form in mind.

Built originally as the primary means to pressurise the city's water reticulation system, the tower is still a working part of that system but now in a 'back up' role. Pumps now pressurise the reticulation by direct pumping into the mains. However, should the power supply be disrupted and the pumping cease, pressure is provided by the tower. This can occur frequently in winter months as power to the pump station is on interruptible 'ripple supply'.

Over the years some deterioration in the tower's appearance has occurred, particularly the removal of the cupola in 1934 and more recently the eroding of brick and plaster work. To preserve the structure against further deterioration and to commemorate its centenary, the original water tower project was 'revisited' last year and work done to restore the structure to its former glory.

The restoration project received sponsorship from varied sources and attracted much interest from the community. The building is recognised by the New Zealand Historic Places Trust who have awarded it a "B" classification.

Design: William Sharp — consulting engineer



Builders: Matthew & Hugh Mair
Restoration: 1989
Design and supervision: Invercargill City Engineer's Department
Main contractor: Fletcher Development
Owner: Invercargill District Council

Advertising and Production Control: Dylit Media Ltd, Auckland
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