Port Otago Ltd

Next Generation – Channel Development

Short History of Otago Harbour Development and Dredging

FINAL

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Port Otago Ltd

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Short History of Otago Harbour Development and Dredging

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1.0 HISTORICAL BACKGROUND

1.1 Geomorphology of Otago Harbour

Otago Harbour as we know it today was formed by a progression of geomorphological processes that can be summarised as follows:

Several million years ago the land form of this area was dominated by a series of ridges, roughly parallel to the present coast line and formed by the uplifting and folding of the earth's crust.

The land eventually subsided and a system of drowned valleys was formed, part of which provided the two bodies of sheltered water we now know as the Upper and Lower sections of Otago Harbour.

The two drowned valleys lay between the hills on the western side and an island on the eastern side. The island eventually became the Otago Peninsula through the processes I will describe shortly.

The drowned valley which became the Lower Harbour (i.e. from Port Chalmers to the sea) was open to the sea at its northern end.

The valley which formed the Upper Harbour was open to the south through the area now occupied by St Clair, St Kilda, Tainui and South Dunedin. The heads of the two valleys were separated by a ridge running roughly east-west, the remnants of which are the Port Chalmers and Portobello Peninsulas, Goat Island and Quarantine Island.

1.2 Sedimentary Processes

These land forms, once submerged, were then exposed to the coastal processes of erosion and sedimentation.

The natural sediment transport processes, driven by prevailing winds from the southerly quarter resulted in the deposition of sand in the southern opening, between the mainland and the island, thus forming the St Kilda, St Clair isthmus. The island then became what is now the Otago Peninsula.

The same littoral processes were active where the northern valley opened to the sea. Here, the deposition of sand partly closed off the opening to the valley with the formation of the Aramoana Spit. An opening, now the entrance to the harbour, was maintained in a state of dynamic equilibrium by tidal flows now determined by the combined tidal capacity of the Upper and Lower Harbours.

The combined effects of the littoral (inshore coastal) processes and the tidal regime within the harbour created a shallow inlet with extensive areas of sand banks exposed at low tide and a pattern of channels, shallow in the Upper Harbour, slightly deeper in the Lower Harbour. These conditions presented some difficulties when the harbour was first used for whaling and then commercial purposes and they have continued to be dominant factors in the engineering development and navigational operations in the harbour.

Put simply, the two processes have worked thus:

- The littoral system delivers a copious supply of sand in a stream which crosses the harbour entrance. Various estimates have been made of the volume of sand transported by this stream, that of Kirk (1980), being based on a more scientific evaluation is probably the most reliable. Kirk estimated the volume to be in the range 450,000 to 500,000.
- The flood (ingoing) tide picks up some of this sediment and redistributes it within the area over which the harbour's tidal system has influence.

The principal effects of these processes are:

- Due to frictional and hydraulic losses within the harbour, the energy of the ebb (outgoing) tide is less than that of the flood tide. As a result, ebb tides transport less sand than the flood tides so there is a nett retention of the sediment brought into the harbour by flood tides.
- The velocity of the ebb tide current is reduced as the flow expands on exit from the harbour mouth. This results in deposition of sand in the formation of an 'ebb tide bar' across the entrance.

The same processes which formed the outer bar also created a bar in the area known as Harington Bend. Here, the flood tide stream, having passed through the narrow or 'throat' section of the entrance was able to expand in the wider channel with a consequent drop in the current velocity and deposition of some of the suspended sediment.

1.3 Harbour History

The first recorded commercial use of the harbour was by European sealers and whalers in the 1820's.

At this time, the harbour was recognised as a shallow tidal inlet, providing a sheltered haven but presenting mariners with a series of difficult conditions and many navigational hazards.

For example, there was the outer bar off the entrance, NW of Taiaroa Head, two channels and the inner bar at Harington Point and two channels at Deborah Bay.

What is probably the first chart of the harbour, drawn in 1824 and titled Port Oxley, shows an anchorage in what is now known as Harington Bend. The chart extends only a short distance beyond the bend and is shown in Figure 1 over.

Much of the harbour was occupied by sand banks, exposed at low tide. The Upper Harbour in particular was shallow with two shallow channels, one along the eastern (peninsula) side and the other along the western (Ravensbourne) side.

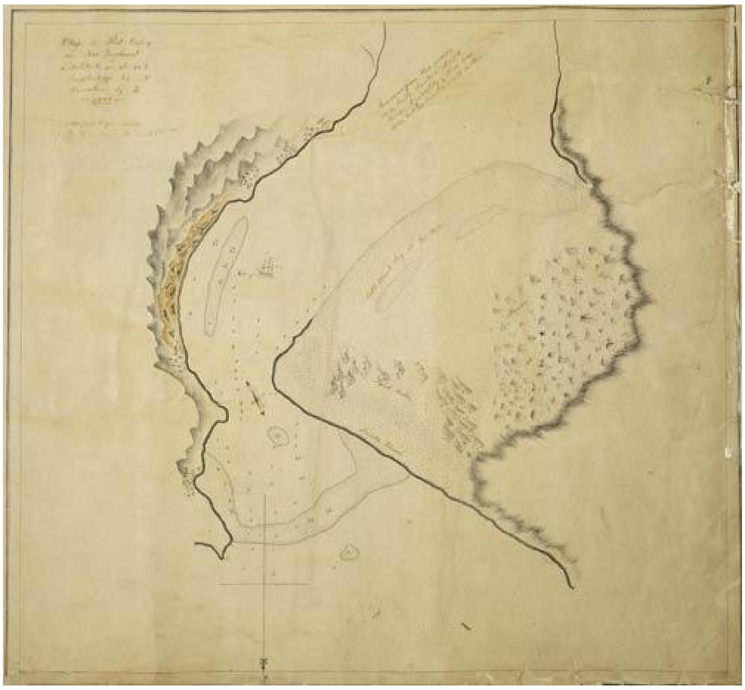


Figure 1 “Port Oxley” drawing by James Herd dated 1826

(Source: www.teara.govt.nz/NewZealanders/NewZealandPeoples/EuropeanDiscoveryOfNewZealand/9)

It was not until 1844 that a survey of the harbour commenced and which was completed in 1846. A further survey was made by Captain Stokes on *HMS Acheron* in 1850 and was the first comprehensive survey of the harbour, see Figure 2.

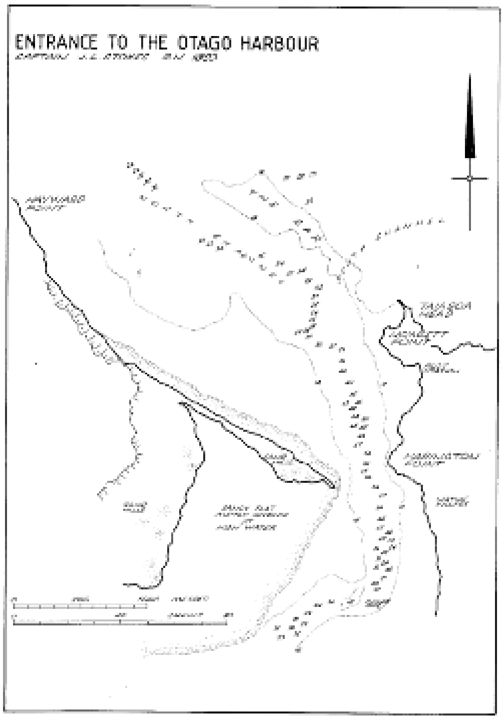


Figure 2 Tracing of Harbour Entrance chart from Stokes 1850

The results of these surveys are significant in providing reliable information on the true state of the harbour relative to the navigation needs at the time but, more importantly in the present context, in providing a basis from which to establish the extent of the works that have been undertaken to create the present harbour and what has remained unchanged.

The first survey showed depths of less than 4 metres on the outer bar.

Captain Stokes' survey showed that ships with draft over 21 feet (6.4m) could not get further into the harbour than Harington Point. Vessels drawing 21 feet or less could, with care, get to Port Chalmers and to within 6½ miles (10.4 km) of Dunedin. Ships drawing 6.5 feet (2m) might get alongside the jetties at Dunedin.

The depth of water in the western channel in the region of Maia and Ravensbourne was little more than a half metre. The harbour at this time clearly had serious limitations and there was already a demand for deepening the entrance, the inner bar and the channel to Dunedin to meet the requirements of the increasing size and numbers of ships trading to the new colony.

Captain Stokes' survey was done just two years after the arrival of the *John Wickliffe* and *Philip Laing* and larger ships were then being used to bring immigrants to Otago, export trade was developing and by 1858, the first direct shipment of wool to London was made.

2.0 DEVELOPMENT OF THE HARBOUR

2.1 The First Harbour Works

The first administration of the harbour as a commercial port was under the jurisdiction of the Provincial Council who recognised the need to deepen the entrance, to create an adequate channel from Port Chalmers to Dunedin and to 'dredge out a dock or port in front of Dunedin'.

The Council, in 1859 embarked on a development programme which was estimated to take 30 years to complete.

It is significant that priority was given to dredging ahead of the construction of wharves, there being a general acceptance that cargo and passengers could be transported in small boats from ships anchored offshore, to very basic jetties.

The Provincial Council had the first dredger for the port built in 1868, this was the original *New Era*. A second bucket dredger, the *Vulcan* (Figure 3), was built in 1877 by which time the administration of the port had passed to the Otago Harbour Board which was constituted in 1874.

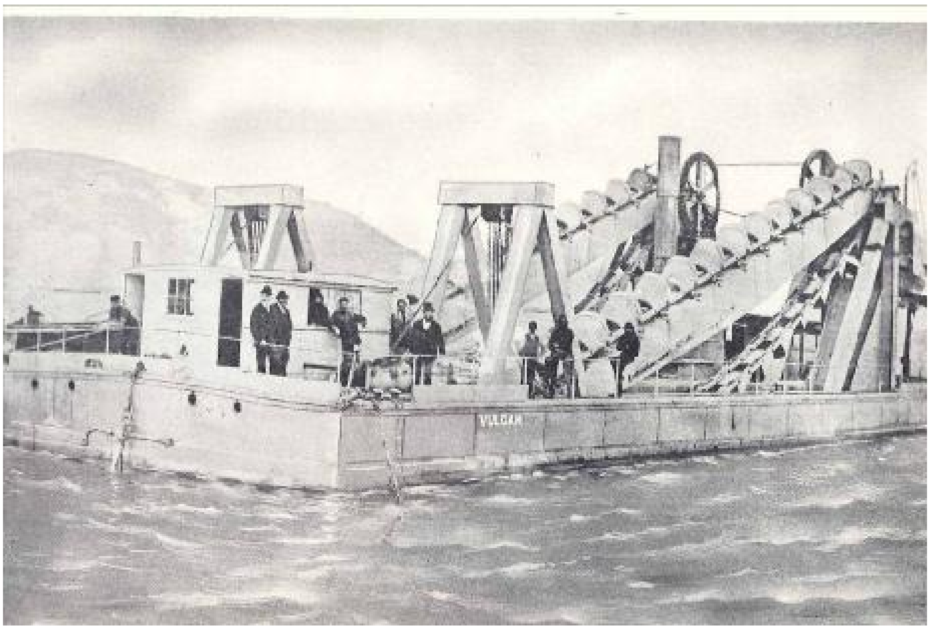


Figure 3 The bucket dredge *Vulcan* circa. 1877

The early efforts of the first two dredgers were concentrated in improving the berths and access to the Dunedin basin.

A third bucket dredger, the *222* was built in Scotland and delivered to the Harbour Board in 1882, see Figure 4. This was a hopper dredger and was acquired for its capability, albeit somewhat limited, to dredge the bar at the entrance. This dredger did major development work at the entrance, Harington Bend and Deborah Bay.

Figure 4 The bucket-dredge *222*

Concurrent with dredging, the Harbour Board undertook major works to construct training walls within the Upper Harbour and at the entrance for the purpose of directing the flow of water into defined channels that would be maintained, or even deepened, by natural scour.

The largest of these works was the mole, started in 1884. Located on the north western side of the entrance, it confines the ebb tide flow of the harbour, and the resulting jet (nozzle) effect has substantially altered the bar-forming mechanism to the extent that the entrance channel can be maintained at adequate depth for shipping purposes by regular but manageable dredging.

Returning now to the matter of development dredging, the early records of the Harbour Board provide dramatic evidence of the magnitude of the dredging operations undertaken by the Board, noting that this work was performed by its own equipment.

Significant works were undertaken to deepen the outer bar; the inner bar was completely removed by a combination of dredging and natural scour and the channel alignment at Harington Bend and Deborah Bay was improved. The Port Chalmers basin was also dredged but the most impressive project was the dredging of Victoria Channel to provide a more direct route between Port Chalmers and Dunedin.

Based on detailed surveys in 1875, it was estimated that to provide a channel 18 feet (5.5m) deep at low tide, with a bottom width of 300 feet (91m), a volume of 4.1 million cubic yards (3.15M m^3) would have to be excavated.

To this was added a further 3.2 million cubic yards (2.45M m^3) to dredge the Dunedin basin and berths making a total of 7.3 million cubic yards (5.6M m^3). This work was completed and the channel has since been dredged to a minimum depth of 24 feet (7.3m) and the berths to 28 feet (8.5m).

It is interesting to note that in 1915, J Blair Mason estimated the volume to be excavated to deepen Victoria Channel to 25 feet (7.6m) at low tide, with the bottom width remaining at 300 feet (91m) as 3.06M m^3 to which would be added 11.7M m^3 for the basin and berths to total 14.76M m^3.

2.2 Further Development

With Otago being well established as a major export port, the Harbour Board continued to develop the port to meet the needs of the larger ships that were being brought into the trade.

The major part of this development was in dredging. The need for increased capacity for both development and maintenance was evident so in 1929, the Board took delivery of a new bucket hopper dredger *Otakou*, designed and built in Scotland to meet the specific requirements of Otago Harbour, see Figure 5. At the time, this was the largest bucket dredger in the Southern Hemisphere and equal to the largest in Europe.

While development of the channels and basin proceeded without any undue difficulties, the demands for deeper water in the channel through the bar at the harbour entrance were more difficult to meet.

A full explanation of the sediment transport regime on the bar is not justified here but it is relevant to record that in order to accelerate the effects of scour induced by the mole, in 1936 the bucket dredger was fitted with trailing suction dredging equipment so that it could work in the swell conditions which prevail at this location.

As development continued, so did maintenance dredging and the board's plant which after 1929, consisted of one large bucket dredger and a stationary suction dredger were in constant use until the major demands of the developments commenced in the early 1970's exceeded their capabilities.

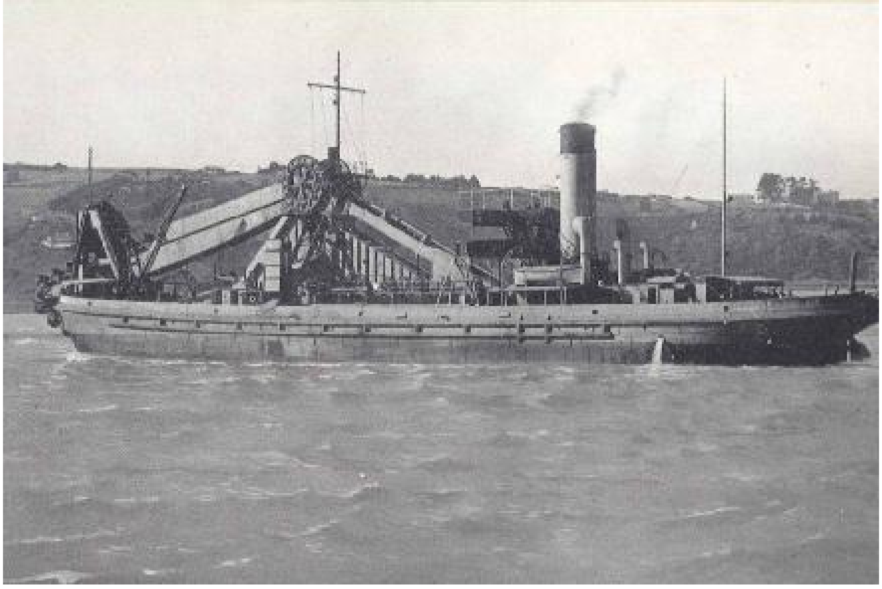


Figure 5 The bucket-dredge *Otakou* in Otago Harbour 1929

2.3 Dredging of Rock

Up to this point, all dredging covered by this historical review has been in sand, silt or clay materials, deposited in the harbour by the natural coastal processes described earlier or by the erosion of the harbour shores and surrounding catchments.

There have been three major projects, and one of lesser extent, to remove rock from the bed of the harbour. In the 1930's a rock spur which extended into the channel from Goat Island was blasted off. This was followed by a major project which ran over the period 1950 to 1955 when the channel between the islands was widened by 100 feet by cutting a bench on the Goat Island side to a depth of 30 feet at low tide. Excavated rock was used to top up the groynes at the Kaik and Harington Bend.

The second project was in 1966-67 when rock was removed from the east side of the Port Chalmers basin to provide the bed for the caissons for Beach Street Wharf and to deepen part of what was to become the berths at Beach Street. Blasting was required to fracture the rock in the berth and once excavated was dumped at sea off Heyward Point. Rock from the caisson trench was used to backfill behind the caissons.

The Beach Street berth was also deepened in the mid-1990's to provide additional depth. This was once again carried out by blasting the rock, excavation by the grab dredge *Vulcan* and disposal of the rock material in the Heyward Point and spit disposal grounds.

The channel depth at both Rocky Point and Acheron Head has been successfully deepened on an incremental basis without blasting over the period 1990 to 2000. The incremental increase in depth is due to the nature of the material and the equipment available. Once exposed to the elements, the rock weathers to a state where the grab dredge *Vulcan* can excavate the surface layer. Once the harder underlying material is exposed this is left until it then follows the same weathering process.

2.4 Summary

The descriptions above show that at the time that Europeans first used the Otago Harbour, it was barely suited to the navigational needs of the small ships then used by whalers, sealers and traders.

The harbour provided a sheltered haven with very restricted access to any area where berths could be provided. Without adequate margins for safe navigation and with no suitable berths, the port would not have survived.

The development of the channels, turning basins and berthage areas has been achieved by extensive and continuous dredging and is clearly illustrated by Figure 6 which shows typical cross sections plotted from soundings of the harbour between 1949 and 2006.

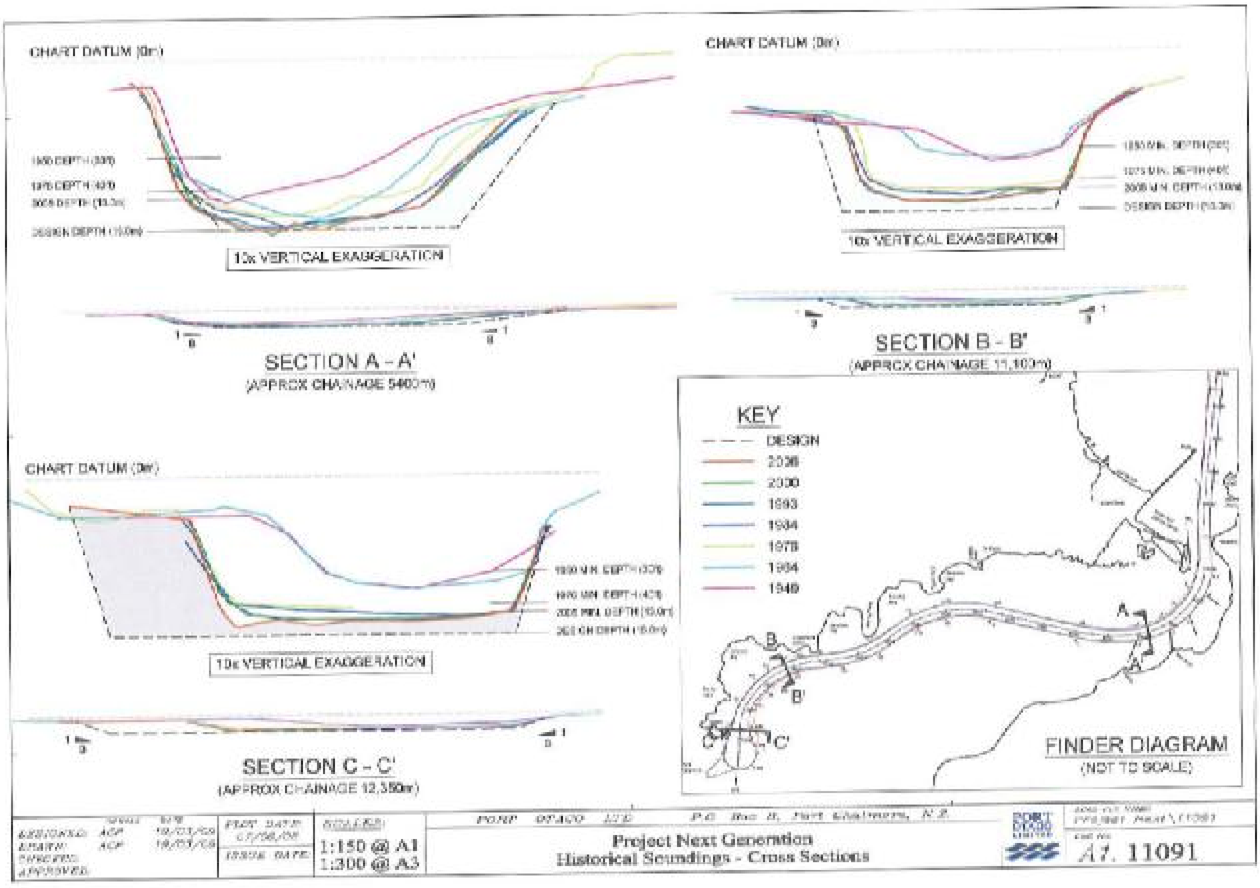


Figure 6 Cross Sections of Channel from 1949 to 2006

It is noteworthy that since 1868, the port has, at any particular time, owned at least one dredger, see Appendix A, and up until the advent of the very large container ships, has been able to undertake development and maintenance dredging with its own plant.

The natural processes described above, which caused the deposition of sedimentary materials in the original drowned valley, still exist today and have been modified to only a relatively minor extent by works such as the mole and the lesser training walls.

This means that any future development of channels and more particularly those nearer the harbour entrance, will be subject to siltation and will therefore have to be dredged periodically to maintain the depth and alignment required for safe navigation.

Dredging has been and will remain an important part of Port Otago's operations.

3.0 THE CONTAINER ERA

As referred to above, the development of the channels, turning basins and berths to meet the requirements of increasing ship dimensions was achieved by using the Harbour Board's own plant, that is, until the advent of large container ships.

With the increasing use of containers, there was less overseas shipping through Dunedin and there was no demand for further development of Victoria Channel and the Dunedin basin.

The present requirements for shipping to Dunedin and Ravensbourne can be met by maintenance dredging of the existing channel and with the demise of coastal shipping, improvements to Victoria Channel would be difficult to justify at the present time.

In the context of this review, no further consideration need be given to developments in the Upper Harbour but the descriptions given above will serve to illustrate the major significance of dredging in the development of the Upper Harbour. The wharves at Dunedin and Ravensbourne are still used for commercial shipping, and more specifically for bulk petroleum and bulk materials for the manufacture of fertiliser.

As the result of progressive development of the Lower Harbour channel and the turning basin, by 1969 Port Chalmers could handle ships up to 230m length, 10m draft and 35,000 tonne displacement.

At this time the Harbour Board prepared a case for the development of the port to the standards required for an international container terminal.

In 1970 the Board publicised its plans to develop the channel, turning basin and berths to enable container ships to operate at any state of the tide up to the following limiting dimensions:

Length:	250m
Beam:	31m
Draft:	9.5m
Displacement:	50,000 tonne

In 1971, the depth in the entrance channel was increased to a minimum of 13.7m at low tide. This work was beyond the capacity of the Board's own plant so the Australia-based trailing suction dredger *Geopotes V* was chartered for this purpose. At the same time, the Board adopted the policy to develop the Lower Harbour Channel for drafts of 11.6m at high tide and 10.1m at low tide.

The depth to be dredged was beyond the capability of the Board's equipment and the volume of material was well beyond the capacity of any other plant in New Zealand to complete the work in time for commencement of scheduled container services to

Japan and Europe, so in 1975 a contract was awarded to Sydney-based WestHam Dredging Pty Ltd to dredge to the following parameters:

- The Lower Harbour Channel (Port Chalmers to the entrance channel) – minimum depth 12.2m at low tide over a bottom width of 183m.
- Port Chalmers Turning Basin, 503m diameter with minimum depth 12.2m at low tide.
- George Street Wharf Berth 13.7m at low tide.

These parameters were set to allow ships with drafts up to 11m to operate at any state of the tide.

The dredging contract was commenced by the trailing suction dredger *Endeavour* in December 1975. *Endeavour* was later replaced by the twin-pipe trailing suction dredger *Resolution* when the larger vessel had completed a major project in Newcastle, NSW. The contract was completed early in 1977 the total volume dredged being 3.9M m^3. This enabled Port Chalmers to offer 24 hour operation to the largest container ships trading to New Zealand at that time.

By the time the development dredging was completed, the 48 year old bucket dredger *Otakou* had been withdrawn from service and laid up for disposal.

The Timaru Harbour Board's trailing suction dredger *WH Orbell* was chartered as required for maintenance of the Lower Harbour Channel until the board acquired the new trailing suction dredger *New Era* in 1985.

This dredger was designed to handle the wide range of materials encountered within the harbour and has the ability to operate in the swell conditions usually present at the harbour entrance and approach channel.

4.0 THE 1975-77 DREDGING PROJECT

The authority for the Otago Harbour Board to develop Port Chalmers as a container port emanated from:

(i) The decision of the NZ Ports Authority on 4 December 1974.
(ii) The reserved decision on the confirmation of this in the partial decision of the Minister of Transport.
(iii) The final decision of the Minister of Transport on 16 June 1975 confirming the development of Port Chalmers.

The development was approved by Order in Council, and the NZ Ports Authority and Local Authorities Loans Board approved expenditure for dredging, reclamation, paving and equipping the terminal.

The implementation of these works pre-dated the Resource Management Act but an environmental impact report was completed by the Board in 1975.

The EIR covered the reclamation and the associated works including the dredging which, as well as contributing to the development of the channel and turning basin, provided the 450,000M m^3 of sand fill for the reclamation necessary for the container yard.

An EIR was not required for the major channel development dredging but the relevance of issues raised in the EIR for the reclamation and associated works justifies reference to it in the present review.

The EIR was reviewed by the:

- Conservation for the Environment
- Nature Observation Council
- Wildlife Service, Department of Internal Affairs
- NZ Historic Places Trust
- NZ Railways
- Ministry of Agriculture and Fisheries
- Ministry of Transport
- Department of Health
- Ministry of Works and Development
- Port Chalmers Borough Council
- Department of Scientific and Industrial Research
- NZ Institute of Architects
- The Committee of Concern
- Dunedin City Council
- Otago Catchment Board

No adverse comments or objections against the proposed development were received.

The two sections of the EIR that relate to dredging are reproduced as Appendix B of this review. These are Section 9 of the report and Appendix 6.

Referring firstly to Section 9 of the EIR, the predictions made regarding the effects of the dredging have proven to be sound and no adverse effects have been recorded.

In respect of Appendix 6, the Report from the Portobello Marine Laboratory, University of Otago, identified a number of effects that dredging could have on harbour ecology. The relevant conclusion reached in that report is:

> *"The associated dredging operation will have a number of direct and indirect effects upon marine life, but none of these are considered to be permanently detrimental. Possible long-term consequences, resulting from a slightly modified hydrology, are difficult to predict but are considered to warrant the most attention."*

The University report makes brief reference to the effect of dredging in increasing turbidity. The report recognised the natural occurrence of turbidity due to wind-wave effects in the shallow waters of the harbour and the tolerance of species which have evolved in such habitat. It also acknowledged the probable temporary nature of the effects.

There were no problems with turbidity during the dredging for the Stage Two reclamation but during the 1975-77 channel dredging project, there were occasions when the dredge encountered clay materials, that resulted in very fine suspended sediment being carried into the area where the marine laboratory has its water intakes for the sea-water supply to aquarium tanks, many of which held species which were not tolerant to fine suspended material.

It was necessary for the laboratory to provide additional sea water storage to ensure a supply of clean water when the conditions in the harbour were not suitable. The additional storage also served the function of a settling tank to lessen the material in suspension. The Harbour Board contributed to the cost of the additional storage.

Apart from this problem, which was satisfactorily resolved, no other causes for concern were raised during the dredging operations.

Material dredged during the channel development was predominately fine sand. There were small isolated areas where the bed contained a smaller proportion of medium sand. The sands contained a proportion of shells, more particularly in the areas between the entrance and the Cross Channel and adjacent to the Turning Basin.

Silts were encountered in a number of places in the general areas of Taylor Bend, Pulling Point, Hamilton Bend and on the outer side of the Turning Basin.

The silty areas were minor in extent and although they may have indicated the presence of clay, only small patches were found close to Pulling Point.

At no stage during the channel development was it necessary to use dredging techniques or equipment other than those initially set up to handle sand nor was it necessary to amend the channel configuration to avoid materials which may have made dredging difficult.

Over the period from 1961 to 1987 when the author had overall responsibility for maintenance and development dredging in Otago Harbour and since that time, through his continued participation in recreational fishing, he has seen no significant changes to the marine habitat. The harbour continues to produce a wide range of fish species.

Although some of the spoil dredged during channel development was disposed of in reclamation, by far, the majority was dumped at sea.

Similarly there have been no reports of adverse effects attributable to this disposal.

No undue difficulties were experienced during the contract dredging. The contractor's equipment was well suited to the materials of the harbour bed. The larger, twin suction dredger in particular achieved very high output in the sand and had sufficient power to handle the clay materials.

The channels and turning basin side slopes were formed by "box cutting". In this process, the bottom of the channel or basin is dredged to its intended final depth to a line which is midway up the expected final batter, as determined from the natural bottom slope, pre-dredging. The dredged face is then allowed to slump to its natural batter.

In practice, this process is somewhat imprecise, the side cut may slump immediately or it may hang-up and slump some time after dredging is finished. It is also common for slumped material to over-run and spread beyond the design toe-line.

There is also the possibility of changes in tidal flow transporting sediments into the new cut and these processes can be exacerbated by gravitational flow of sediment.

In all of these cases, it is necessary for the dredger to return to the cut and tidy up the results of these processes until they stabilise naturally.

In the 1977 project, the cut on the outside of Harington Bend took some time to stabilise and it was necessary for the dredger to return twice after the initial cut was made.

The need to return to "tidy-up" was expected but the extent of this phase of the work at Harington Bend was not expected.

Dredging to maintain the channel to the design width and depth at the toe lines has continued since the completion of the major development programme and is evidenced by the volumes of maintenance dredging recorded annually. The accumulation of sand along the toe line in this area is a combination of slope stabilisation and deposition by the natural sediment transport processes. These volumes are trending downwards as shown in Figure 7. This trend indicates that the channel sides which were box cut during the 1977 contract are now reaching their natural slope. This is confirmed by the conclusions reached by Lusseau, 1999.

Based on the experience with box-cutting at Harington Bend, it is probable that future development will require that the channel side slopes be dredged to profile in this area.

With the exception of the tidy-up, the 1977 dredging contract ran very smoothly and the work was completed to the specified requirements. It is noted that all spoil dredged in this contract was dumped at sea.

5.0 RECENT DREDGING WORKS – POST 1985

5.1 Maintenance Dredging

With the commissioning of the trailer suction dredge *New Era* in 1985, Figure 8, the OHB gained the ability to undertake all dredging maintenance works without any reliance on external contractors. Detailed figures of dredging and disposal during this period are shown in Figure 7. At a high level this analysis shows a reducing volume of dredging over this period.

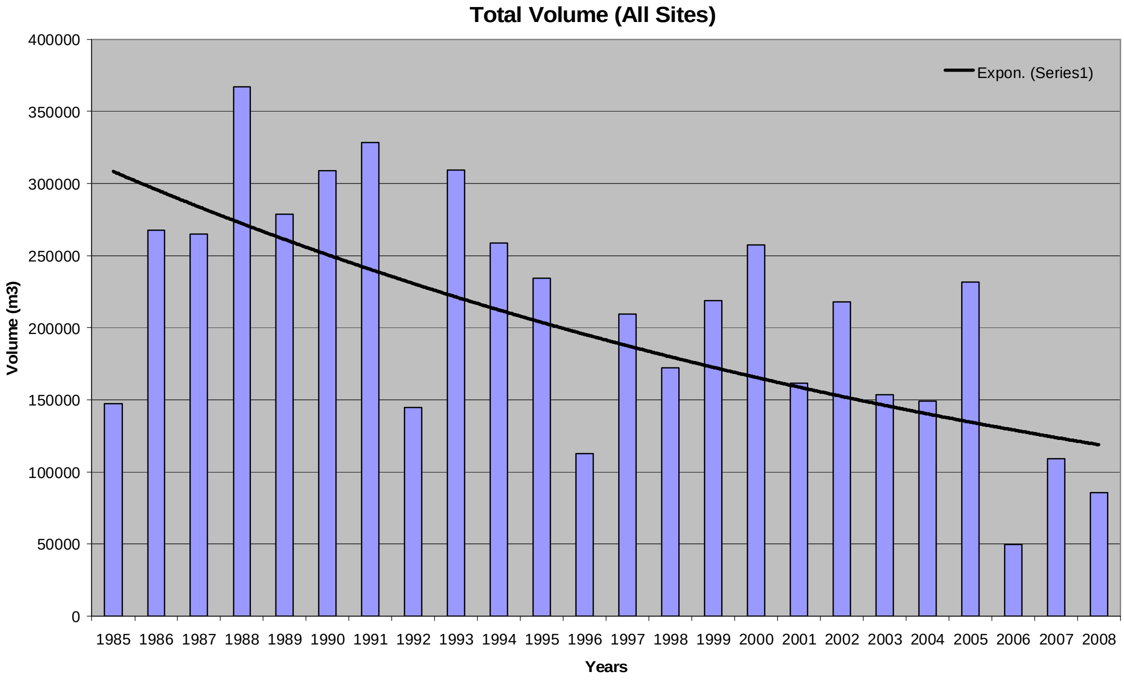


Figure 7 Total Dredging Volume Disposed from Otago Harbour since arrival of New Era in 1985

Figure 8 Dredge *New Era* passing Spit Wharf fully loaded

5.2 Widening of Upper Harbour Channel Opposite Sawyers Bay

In the period (October 1996 to July 1997) alignment improvements were made by widening a section of the eastern side of the Upper Harbour Channel opposite Sawyers Bay. The reason for this was to improve the safety of navigation for larger vessels, particularly fuel tankers.

After an initial test dredge at the site with the grab dredge *Vulcan* during May 1995, it was determined that due to the material having a reasonably high clayey silt fraction, that both *New Era* and *Vulcan* would be required to complete this project. However, the *New Era* continued and was able to complete the dredging without the need to remobilise the *Vulcan*.

As this was regarded as an incremental improvement to the channel, all material was deposited at the approved disposal sites.

5.3 Lower Harbour Incremental Improvement to 13.0m.

Over the period from July 2003 to June 2005 the suction dredge *New Era* made incremental improvement to increase the depth of the lower harbour channel to a minimum depth of 12.8m (previously 12.2m). From July 2005, until June 2008, a further 0.2m increase in the minimum depth to 13.0m was made.

This additional 0.8m of depth allowed the largest container vessels visiting the port, the 4100 TEU or Albatross class of vessels, additional tidal window to safely sail when at or near their maximum draft of 12.6m. As much of the harbour areas were deeper than 13.0m, dredging was only required in distinct areas to achieve this increase in depth.

As the incremental increase in depth was being undertaken concurrently with the maintenance dredging activities, it is difficult to accurately determine the volume. Whilst in the initial years of 2003 to 2005 this work proceeded to plan and budgeted volumes, the following three years between 2006 and 2008 were all less productive with the dredge being hired out to other ports and being laid up for long periods at Otago. An estimate of 100 - 120,000m^3 is a realistic total volume of material dredged as incremental improvements carried out concurrently with maintenance over these latter years was much reduced.

The material removed was undisturbed harbour bottom consisting of predominantly sand, but with some silt and clay materials encountered.

5.4 Widening of the PC swinging basin.

The Port Chalmers Swinging Basin when originally developed in 1976-1977 was not dredged to its full design diameter. A section in the middle of the basin was left approximately 60 metres short of the design turning area. With vessels getting bigger, the desire to incrementally improve the safe navigability of channel included the depth improvement detailed above, but also included the widening of the basin turning area during the period from June 2000 to October 2003.

This dredging proved challenging with a trailing suction dredge as the volume was contained in a short length of channel against a steep bank (1 in 3). The New Era plugged away at this by carrying out a box cut along the toe of the bank until the bank collapsed. This process was not very productive dredging however significant improvement was achieved with a total of 220,000m^3 being dredged between the above dates.

5.5 Summary

In all of the above works, Port Otago has utilised the excess capacity of its existing equipment to incrementally improve the channel. Undertaking the work in this manner has achieved the improvements progressively over a period of time with no records or feedback received in relation to any adverse effects from this work.

6.0 DREDGED VOLUMES

6.1 Summary of Volume of Material Dredged from Otago Harbour

The following table summarises dredged volumes.

For Period	Derived From	Volume m^3
1875 – 1885	Historical Reports	1,150,000
1885 – 1899	No reliable records. Estimate based on previous output of dredges.	1,606,500
1899 – 1909	From dredging records confirmed by D Lusseau, University of Otago, 1999.	3,464,488
1910 – 1913	Estimate based on performance of dredgers.	1,210,000
1914 – 1933	From D Lusseau 1999.	4,904,375
1934 – 1975	From D Lusseau 1999	10,240,244
1976 – 1977	Capital dredge, From D Lusseau 1999	3,902,620
1978 – 1998	From D Lusseau 1999	5,789,471
1999 – 2007	From POL records	1,834,600
	TOTAL	**34,102,298**

6.2 Disposal of Dredged Spoil

Early records were not specific in regard to disposal but it is known that the dredging plant used up until the arrival of the dredger *222* in 1882 did not have hoppers for transporting spoil so barges were used. We know also that all early dredgings were used for reclamation at the head of the harbour in the area of the developing Dunedin town and in Lake Logan and Pelichet Bay. Some spoil was also dumped in the Kaik-Harington Bend areas.

The records from 1914 onwards are sufficiently reliable for us to deduce that in the period 1875 to 1914, approximately 7.4M m^3 of spoil was put into reclamations.

The following table shows the location used for disposal of dredged spoil.

		Cu.m
Disposal to Reclamations		16.15M
Dumped within the Harbour		0.45M
Dumped outside of Harbour		
§ Off the Heads	0.29M	
§ At sea (not specific)	5.90M	
§ Off Heyward Point	7.31M	
§ Off Spit	4.00M	17.50M
	TOTAL	**34.10M m^3**

7.0 DREDGING EQUIPMENT

With increasing attention being given to minimising the environmental effects of dredging, a commentary on the equipment used in the harbour development is justified.

Apart from the small amount of maintenance dredging done with grabbing equipment and the chartering of the Timaru trailing suction dredger for short periods to do maintenance between 1978 and 1984, all dredging prior to the major contracts in 1975-77 was done by bucket dredgers.

By their very nature, bucket dredgers create significant disturbance of the sea-bed and they cause high levels of turbidity or suspended sediment as the results of material being disturbed on the sea-bed, by being washed from the buckets during their passage to the surface and from spillage (overflow) from the buckets as they move from water level and discharge their contents over the top tumbler.

To supplement this disturbance, all the bucket dredgers used in the development of Otago Harbour required heavy anchors and mooring cables, all of which were at some stage either embedded or in contact with the harbour bottom.

In addition to their in-water effects every one of the bucket dredgers was coal-fired and would have produced typical emissions from this source. Even the last of the bucket dredgers (*Otakou*) used coal for a period when the price of heavy fuel oil increased.

The dredgers used by the contactors, the Timaru Harbour Board's dredger and the Otago Harbour Board's replacement for *Otakou* are all diesel powered trailing suction dredgers.

These dredgers cause less disturbance to the seabed, and with the dredged spoil being contained with the suction pipe, there is no loss between the drag head and the discharge to the hopper. There is therefore significantly less turbidity than is created by a bucket dredger.

The diesel powered dredgers also produce less in the way of emissions to the air and there are no anchors or moorings involved in their operation.

A pictorial history of dredges owned by the Otago Harbour Board is included in Appendix A.

8.0 RECLAMATION

When dredging first commenced, spoil disposal was solely in reclamation. There were three good reasons for this:

1. the dredging equipment was not suitable for disposal at sea.

2. it was convenient to transport the spoil a short distance and dump it in reclamations.
3. reclamation of the foreshore in front of the town removed the unsightly mud flats and provided land area for the growing town of Dunedin.

The first reclamations were in the area behind the present wharves, and at Lake Logan/Pelichet Bay (now Logan Park). When these areas were completed, reclamation extended into the Southern Endowment which was principally developed for the disposal of dredging rather than to meet any demand for industrial land. However, the creation of this land was a very beneficial adjunct to the harbour development.

From the very beginning of reclamation works, right through to the completion of the Southern Endowment in the late 1960's and subsequently, when reclamations were required for the roll-on ferry terminal at Dunedin and for the container terminal at Port Chalmers, concerns were raised over the effect that reclamation would have in reducing the tidal compartment of the harbour and the consequent inability of the tidal scour to maintain the entrance channel.

The earliest engineers' reports recognised the possibility of this happening and applied very basic techniques to manage the risk.

It is noteworthy that none of the dire consequences for the harbour entrance as forecast by the opponents of reclamation came about. In fact, the opposite occurred and prior to the entrance being dredged in 1977, the depth was being increased, albeit by a modest amount, by natural scour.

In the late 1950's the Otago Harbour Board constructed a hydraulic model of the harbour. From this it was possible to make a quantitative assessment of the effects of reclamations and other works.

Also at this time, research had established the scientific relationships between the physical components of a tidal inlet and its performance in respect of sedimentary processes. These principles could then be applied to any assessment of the effect of harbour works.

It was also established that dredging and other works within the harbour had improved the hydraulic characteristics and the tidal range had increased as the result of less frictional resistance to tidal flow enabling the water to enter and exist from the harbour more readily.

The means for scientific assessment of the effects of harbour works have been refined and sophisticated computational modelling tools are now available for the examination of these effects.

While no reclamation is involved in the present works programme, the effects of the enlarged channel and turning basin can be assessed with a high level of precision.

9.0 CONCLUSIONS

The summary of the history of dredging and a perusal of the schedules showing the volumes of material dredged from Otago Harbour, very clearly illustrate the magnitude of the work required to develop the channels, turning basins and berths to create the ports at Dunedin and Port Chalmers.

The schedule showing the volumes of material dredged to maintain the channels, basin and berths also illustrates the magnitude of natural sedimentation processes that filled the drowned valleys initially and which continue to supply and deposit sediments in the harbour.

Significant conclusions to be drawn from these historical facts are:

- Dredging of the harbour commenced in 1868 and has been carried out continuously for 140 years.
- During this time, the volume of material removed is of the order of 34.1M m^3.
- Approximately 51% of this volume (17.5M cu.m) has been disposed of at sea.
- Most of the dredging has been done by equipment owned by the Harbour Board (and its successor Port Otago Ltd) and the volume dredged averaged about 200,000M m^3 per year.
- There have been two development projects undertaken by chartered dredgers which respectively totalled 50,000M m^3 and 3.9M m^3. These were completed over periods of a few weeks and a little over 1 year.
- Over the entire period of 140 years of dredging, with one exception, there are no reports of any detrimental effect on the environment, on the harbour ecology, on navigation or on recreation or commercial activities in the harbour. The exception is the turbidity which was experienced for a brief period during the major works in 1976.
- Casual observation will confirm that marine plants are widespread and healthy, water quality is good and birdlife is plentiful.
- The harbour provides excellent opportunities for fishing with the following species available to line fishers, by netting or for children fossicking in rock pools:

Baracoutta	Cockabullies	Leather Jackets
Flounder	Moki	Yellow-eyed Mullet
Blue Cod	Seven-gilled Sharks	Red Cod
Wrasse	Crayfish	Salmon
Rigg	Octopus	

There are also large colonies of crabs; cockles are prolific and there are scallops, paua and tuatua.

Seals are common at the harbour entrance and occasionally venture as far as Dunedin.

If dredging has had any effect on the ecology, it is not evident. It is to be expected that those areas where regular maintenance is required, will be recently deposited mobile sand and unlikely to provide ideal habitat but generally there appears to be abundant weed beds in and adjacent to the channels.

Areas where the bed materials which have been exposed by development dredging, are visible such as on the side batters of the channel and turning basin are indistinguishable from areas which have not been disturbed by dredging.

Similarly the offshore disposal of nearly 34.1M m^3 of spoil has not produced any effects which are shown to be detrimental to the environment. More particularly, the dumping of the more than 7M m^3 off Hayward Point has not produced any evident adverse effects.

The engineered dumping of sand off the south spit beach for beach nourishment has been of benefit to the spit.

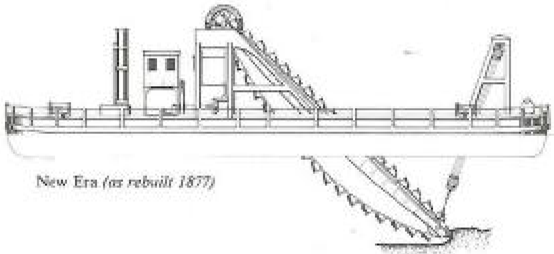
Overall, there is no evidence to support any view other than that which emphasises the benefits that have accrued from dredging operations which, from the beginning of the harbour's history have been engineered to optimise those benefits in the face of very severe financial constraints in the first half century, hard economic times and competing demands through the next 50 years and the increasing need for environmental protection over the last 48 years.

Appendix A

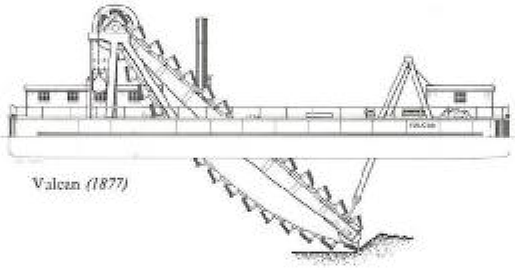
Otago Harbour Board

Dredge Fleet 1877 to 1985

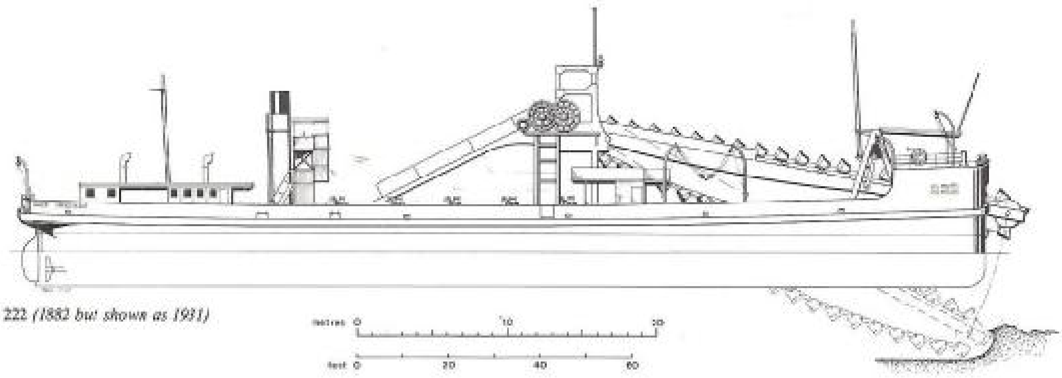
DREDGE FLEET 1877-1985



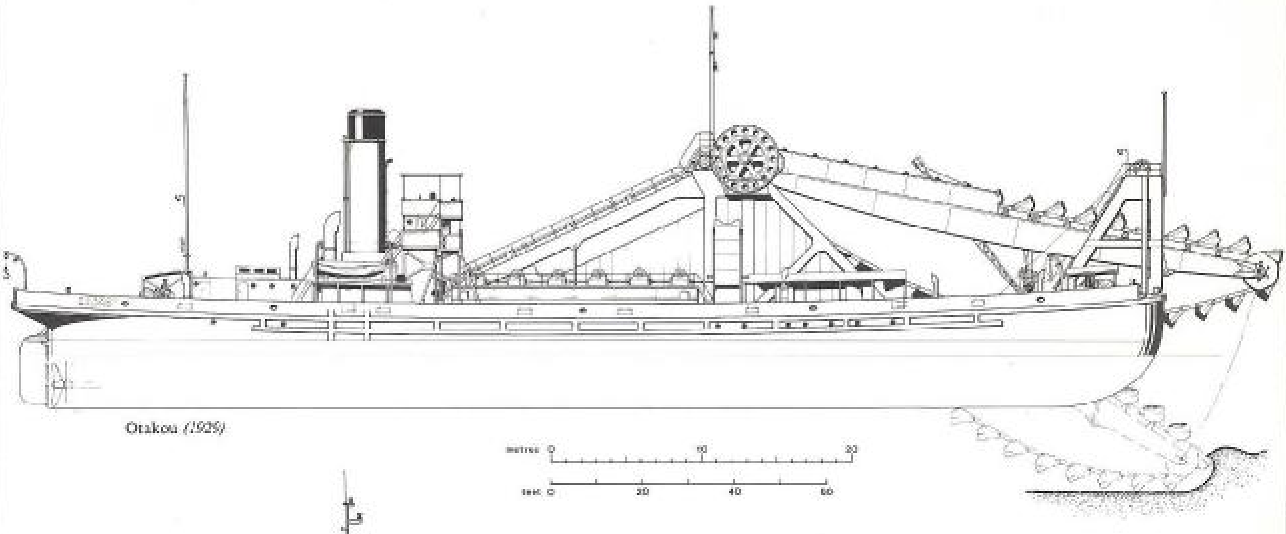
New Era *(as rebuilt 1877)*



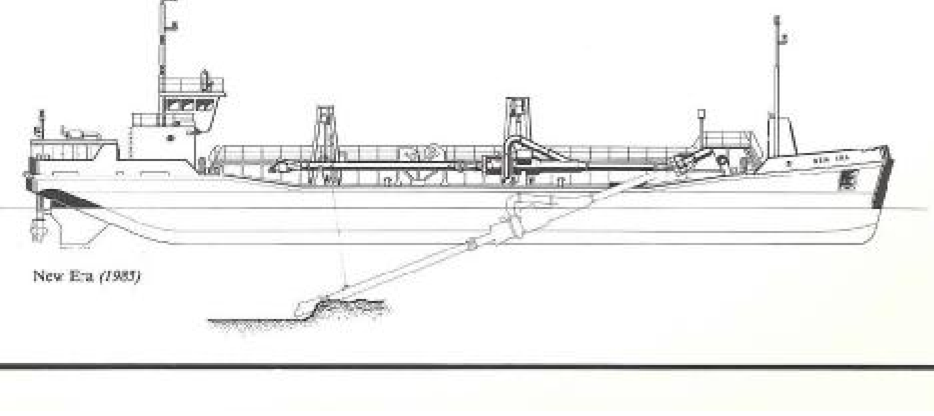
Valcan *(1877)*



222 *(1882 but shown as 1931)*



Otakou *(1929)*



New Era *(1985)*

Appendix B

Extract from Environmental Impact Report for Port Chalmers Container Terminal Development Otago Harbour Board 1975

B Hydraulic effects of proposal

B1 General

The boundaries of the proposed reclamation have been positioned to meet the physical conditions of the site while still causing the least interference to the hydraulic regime of the area.

The Board is aware that any dredging and reclamation works will affect the hydraulics of the harbour and investigations have been made for the present proposal in two fields.

(a) The effect on ship handling
(b) The effect on the existing channel and sand bank formulations in the harbour.

In each of these fields, it is necessary to note the separate effects of the dredging and the reclamation.

B2 Limits of Reclamation

The alignment of the face of the reclamation on which the second container berth will eventually be built was finally decided after consideration of several alternative shapes. It is obvious that the most practical arrangement would result from extending the present berth seawards for 304m on the same line. This would also simplify the crane structures which would not need to negotiate a curve between the two berths and it would allow the reclamation of a greater area behind the berth. This arrangement would, however, extend the reclamation into the natural channel and cause a major deflection of tidal flows which would in turn produce undesirable eddies and almost certainly result in erosion of the sand banks on the north-eastern side of the channel.

A great quantity of dredging would also be necessary to extend the turning basin, and for reasons of economy and the desire to change the tidal flow as little as possible, the line of the second berth has been drawn at 23º to the first berth and this is parallel to the existing channel.

B3 Model Studies

The Board has a fixed bed hydraulic model of Otago Harbour to which the proposed reclamation had been added. Test runs show no measurable change in tidal flow patterns and only an insignificant increase in velocities.

At the time of writing this report, the bed of the model is being reshaped to include the proposed turning basin and approach channel extensions. When this is completed, test runs will be made to determine the actual tidal velocities, but is confidently expected that the increased cross section of the channel will result in a reduction of velocities to offset the slight increase mentioned above. Ship handling conditions should therefore show an overall improvement. As the model is of the fixed bed type, it is not possible to show any effects of tidal scour. However, it is possible to detect areas where scour may be induced through increased velocities. We do not expect such conditions to be produced, but should they occur the shape of the turning basin will be modified to reduce adverse effects.

B4 Effects of Tidal Compartment

Tests carried out on the hydraulic model have confirmed observations from the prototype which show that the adverse effects resulting from the reduction of tidal compartment through reclamation have in total been more than offset by the improvements in the channel hydraulics as the result of dredging. The widening and deepening, especially at Harington and Deborah Bay bends will ensure that the same principles apply to the present proposal.

B5 Conclusion

The proposed reclamation will have no detrimental effects on the hydraulics of the harbour and when considered with the associated dredging works, there will be an overall improvement in ship handling conditions.

Appendix C

Report from Portobello Marine Laboratory of the University of Otago (Included in the 1975 Environmental Impact Report)

REPORT TO THE OTAGO HARBOUR BOARD ON THE MARINE ENVIRONMENTAL IMPLICATIONS OF THE PROPOSED RECLAMATION FOR CONTAINER TERMINAL DEVELOPMENT AT PORT CHALMERS:

PHASE TWO

P.K. Probert

Portobello Marine Laboratory

The effect on the marine environment of the proposed reclamation for container and cargo assembly at Port Chalmers, Phase Two, is seen to involve four main areas for consideration:

1. The sea-bed community that will be lost through reclamation, and the significance of this loss to the harbour ecosystem.
2. Possible direct and indirect effects to marine life of the dredging that is required to provide seabed material for reclamation.
3. New substrata, in particular seawalls, that will become available for colonisation.
4. Possible long-term effects resulting from altered patterns of water movement and sediment deposition.

1. Loss of Habitat

The bottom deposits and larger animals and plants of the area of seabed included in the reclamation proposed were sampled by dredge and trawl on 18 July 1975 from the research vessel ‘Munida’. An anchor dredge sample was taken at each of the stations A-H (Fig 1). The contents of the dredge were washed on a 2.5mm mesh to extract the resident organisms and coarse debris. The mean volume of the 8 samples was 24.4 litres. The animals and plants living on the surface of the seabed were sampled by a 56cm wide Agassiz trawl towed across the study area (Station J in Fig 1).

A soft, muddy sediment, khaki to black in colour, was recovered at each of the dredging positions. Dead shell, particularly of Zeacolpus symmetricus and Maoricolpus roseus, was common as a coarse constituent of the sediment from the outer station A, C and D, while sediment from the inner station H contained an admixture of coal and clinker fragments. The sediment retrieved at station F was noticeably anaerobic.

The general sedimentary uniformity was reflected by the associated fauna whereby all samples could be considered representative of the same community. The dredge samples were dominated numerically by polychaete worms. The tubicolous species Paraboccardia syrtis was especially abundant. The more conspicuous members of the fauna that were taken in the dredge and trawl are listed in Table 1.

Polychaetes	Molluscs
Aglaophamus macroura	Chione stutchburyi
Armandia maculata	Maoricolpus soseus
Capitellidae	Solemya parkinsoni
Euchone sp	Crustacea
Glycera mmericana	Amphipoda – unidentified
Glycera lamellipodia	Hemiplax hirtipes
Glycinde sp	Nectocarcinus antarcticus
Lanice conchillega	Palaemon affinis
Maldanidae	Echinoderms
Owenia fusiformis	Ophiomyxa brevirima
Paraboccardia syrtis	Trochodota dendyi
Pectinaria australis	Fish
Phyllamphicteis foliate	Forsterygion varium
Platynereis australis	Stignatophora longirostris
Prionospio aucklandica	Syngnathus blainvillianus
Scolopos sp	Trachelochismus pinnulatus
? Scolelepis sp	

Table 1 – Species collected from station A-J

The trawl sample revealed that a large quantity of unattached weed had accumulated in the study area, particularly Ulva. This observation, together with the recovery of fine sediments, indicates that the area under consideration is not subject to strong water movements.

Rainer (1969) has made a detailed survey of the fauna of deposit substrata in Otago Harbour and has distinguished four major Harbour communities, each of which may be described by its associated sediment type. Although the area proposed for reclamation does not include a sampling position worked by Rainer, the species assemblage in Table 1 shows strong affinities with his Mud Community and Fine Sand Community, both of which are well represented in Otago Harbour. Of the 68 Harbour samples examined by Rainer, 16 were assigned to the Mud Community, and 24 to the Fine Sand Community.

The area proposed for reclamation is already subject to artificial disturbance, particularly through maintenance dredging carried out approximately every 3-4 years. A periodic disruption of this nature inhibits the development of a mature, diverse bottom fauna community and favours one with a prevalence of the more opportunist species – those that are usually encountered in a wider variety of habitats. This appears to be the case with the assemblage detailed in Table 1, which includes a preponderance of well know, widely distributed species.

2. Dredging

An integral part of Phase Two reclamation is the dredging of approximately 350,000m^3 of sea-bed material over a period of 8-9 months in order to excavate the turning-basin and provide spoil for reclamation.

The study by Rainer (1969) indicates some of the changes in the distribution of sea-bed communities that may be expected to result from this dredging activity. A short transect of three stations, comprising 23 individual samples, was worked from the shipping-channel off Carey's Bay east to the adjacent sandbank. The 7 samples from the deepest station (ranging in depth from 10.2 to 12.1m) were all assigned to a Stable Shell-sand Community, characteristic species of which are listed in Table 2.

Polychaetes	Crustacea
Prionospio sp	Asterope grisea
Armandia maculate	Nebalia longicornis
Travisia olens	Parawaldeckia sp
Molluscs	Parawaldeckia thomsoni
Eatoniella kerguelensis	Phoxocephalus regium
Nucula nitidula	
Mysella unidentata	
Neolepton unidentatum	
Paphirus largillierti	
Tawera spissa	
Scintillona zelandica	

Table 2: Species widely distributed within the Stable Shell-sand Community

A further 7 samples (3.0 to 5.3m depth) were collected at an intermediate station from the eastern side of the channel, and here an Unstable Sand Community was recognised (Table 3).

Polychaetes	Arthropods
Travisia olens	Macrochiridotea uncinata
Molluscs	Achelia sp
Amphidesma forsterianum	

Table 3: Species widely distributed within the Unstable Sand Community

Nine samples (+0.1 to -0.1m depth) were taken from the easternmost station (on the sandbank) and here a third distinct community was evident. Characteristics species of this Fine Sand Community are given in Table 4.

Polychaetes	Molluscs
Aglaophamus macroura	Macomona Liliana
Prionospio aucklandica	Crustacea
Travisia olens	Haustorius sp
Capitella capitata	Pontophilus australis
Heteromastus filiformis	
Macroclymenella stewartensis	

Table 4: Species widely distributed within the Fine Sand community

Ralph and Yaldwyn (1956) also noted the different faunas of the shipping channel and adjacent shoals.

Excavation of the turning basin will involve a radical disruption of seabed community associated with the deposits of this area. Upon completion of the turning basin, however, colonisation of the recently disturbed area can be expected to take place with the gradual development in the appropriate areas, of the communities described by Rainer: a Stable Shell-sand Community around the edge of the newly dredged area, giving way once again to the Fine Sand Community of the sandbank.

Subsequent maintenance dredging carried out in this area will be a continuing artificial influence on these communities and will tend to depress species richness. Tow diver-retrieved, seabed samples taken by Rainer from the shipping channel of Acheron head contained low numbers of species and individuals. The bottom was observed to be "shelly with paralled ridges probably due to dredging". A significant reduction in faunal density following dredging was reported by Leathem et al (1973) in Delaware Bay.

Dredging is normally accompanied by an increased suspended matter load in the water, which may affect marine life in a variety of ways.

Light penetration into water is impaired by suspended solids and a reduction of the sublet zone of the water column usually means a decreased in primary productivity in the marine environment. The minutes, floating, photosynthesising organisms, which are the basis of marine food chains, require light energy in order to manufacture food materials. Flemer (1970) noted short-term depression of productivity arising from a reduction in light penetration through spoil disposal, but the effect was temporary for a given location. Similarly, in Otago Harbour, increased turbidity might result in location impairment of primary productivity but owing to strong water movements the overall impact of suspended solids on productivity is not likely to be significant during the 8-9 month dredging period.

Increased water opacity may also interfere with the feeding of those fish that hunt mainly by sight, and may also effect feeding and gill ventilation mechanisms of bottom-dwelling animals by physical irritation and choking. Again, it is probable that these effects will only be experience locally and temporarily.

An important factor in increased turbidity impact is the existing condition in the area. Otago Harbour is for the most part a shallow body of water in which fine deposit substrata predominate. Wind-wave induced re-suspension of dine, bottom sediment is a natural character of the Harbour and a high background turbidity may commonly be present. The types of animals living in soft deposits are normally those that have evolved to occupy niches where a high suspended matter load in commonly experienced at the sediment-water interface.

The more rapid sedimentation of coarser-grained particles disturbed by dredging may result in some local smothering of seabed habitat. In comparison, however, to the direct community disruption wrought by dredging, and in view of the animal sediment relations of soft substrata mentioned above, this factor on its own is not considered to present a major source of stress.

The gross disturbance of sediment by dredging is normally accompanied by a marked lowering in the level of dissolved oxygen owing to the release of previously unavailable organise material (Sherk, 1971: Salia et al, (1972). In a study of the effects of hydraulic dredging and overboard spoil disposal (191,000m^3) on bottom fauna, Leathem et al (1973) noted a marked fall in dissolved oxygen saturation from 94% to 52%, following the dredging operation. Approximately two months after dredging the oxygen values returned to pre-dredging levels, indicating "that potential damage to the benthos was probably negligible". In the case of Otago Harbour, a reduction of this magnitude in the dissolved oxygen saturation could have serious implications during the summer months, but the flushing characteristics of the Harbour, and the routing of spoil to reclamation, are likely to alleviate this potential problem.

The release of sediment entrapped organics through dredging may counteract the possible turbidity induced depression of local productivity mentioned earlier.

3. New Substrata

Through the proposed reclamation, new area of seawall would become available for colonisation by marine organisms. Thus replace other surfaces lots in the reclaimed area.

The outer surface of the new seawall would consist of randomly tipped rock, resulting in a fairly open surface. This new substratum would gradually become colonised by attached and crevice-dwelling organisms for the most part. The rocky shore community at Portobello described by Batham (1956), and will represented in Otago Harbour, indicates some of the community elements likely to become associated with a new seawall.

4. Long-term Effects

The reclamation and associated dredging under Phase Two will inevitably have some long term effects upon patterns of sediment deposition through altered water flow behaviours within the Harbour. Some gradual changes in bottom topography and the related animal and plant communities might, therefore, be expected to take place.

The hydraulic effects of the proposal are discussed elsewhere in this report. A further appreciation of these findings in relation to the harbour ecosystem would be desirable, especially if Phase Two is considered to be a stage of a more extensive development. In the Otago Harbour Board booklet 'Containers at Otago', a possible extension of Phase Two is considered which would involve reclamation of Carey's Bay (Phase Three), with provision for subsequent development north-eastwards. Under such circumstances, the interim and eventual repercussions of altered hydrology on marine life of the Harbour deserve clarification.

A hydrological change that may relate to reclamation already carried out at Port Chalmers has been observed by staff at the Portobello Marine Laboratory. Following reclamation in the Observation Point to Battery Point region, increased siltation, together with the greater accumulation of unattached weed has occurred in the bay to the north of the Laboratory, while set-netting, which was formerly carried out in the deeper part of the bay is now no longer feasible owing to an increased current spread in this area. Although the reclamation proposal under consideration here may not affect the hydrology at Portobello, similar types of changes may be experienced elsewhere in the Harbour.

Conclusions

It is difficult to accurately assess the impact of the proposed Phase Two reclamation and dredging on the marine environment, mainly owing to the complex interaction of actors which relate to ecological systems. It would appear, however, that the ecological 'health' of the Harbour would not suffer significantly through the loss of the area proposed for reclamation. Nor does this proposal appear to threaten an area which has a particular biological interest. The associated dredging operation will have a number of direct and indirect effects upon marine life, but none of these are considered to be permanently detrimental. Possible long-term consequences, resulting from a slightly modified hydrology, are difficult to predict but are considered to warrant the most attention.

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