



Measured environmental impacts of dredging operations

S.J. Priestley

Beca Carter Hollings & Ferner Limited, Auckland, New Zealand

Abstract

Recent dredging operations in the port of Auckland, New Zealand were preceded by detailed environmental impact assessments. One operation was completed in 1992 for the removal of 270,000m³ of marine mud from the commercial port basins using a trailer suction dredger. Another operation was completed in 1993 for the removal of 10,000m³ of marine mud from a small enclosed boat harbour using a clam shell dredger. As part of the approval process, a compliance water quality monitoring programme for turbidity and suspended solids released by the dredger was conducted during both dredging operations. This included intense monitoring during a full tidal cycle and weekly up current and down current monitoring. The results of both compliance monitoring programmes concluded that the environmental impact of the dredging operations was minimal.

1 Introduction

The introduction of the Resource Management Act in 1991 required that a resource consent was necessary for any dredging operation which disturbed the seabed sediments. As part of an application for a resource consent a full environmental impact assessment is required. The essential parts of the impact assessment include a description of the project, a description of the existing environment, an assessment of the environmental effects of the project on the natural environment, an evaluation of alternatives and the introduction of any mitigative measures which would reduce any adverse effect on the natural environment. Finally, the impact assessment should make recommendations on compliance monitoring. Such a programme is to ensure that the project has not exceeded the effects described within the assessment and the results can be used as a management tool to control or limit the extent of the project.

Two case studies of dredging operations are addressed in this paper.



2 Background

The first case study relates to the dredging operations carried out in the port of Auckland, New Zealand which is at the seaward end of the Waitemata Harbour. It has a mean tidal range of 2.5m and a corresponding mean water surface area of about 83 km². All port basins within the port of Auckland are protected but are adjacent to the main tidal channel. Typically tidal velocities in the main tidal channel are between 0.5 and 0.6m/s while secondary eddy velocities within the basins are less than 0.1 m/s.

Water quality in the Waitemata harbour is generally good with a mean suspended solids concentration of 12 g/m³ (n = 246, standard deviation = 6 g/m³). During significant rainfall events and moderate wave conditions the suspended solids can rise and have been measured in the order of 50 to 100 g/m³.

The annual deposition of sediment in the port basins has been estimated from hydrographic surveys at about 35,000 to 40,000 m³. The overall sedimentation rate is about 100mm per year. The deposited material is an unconsolidated marine mud which comprises 20% sand, 40% silt and 40% clay. Notified depths within the main commercial basins which require maintenance dredging vary between 10 to 12.3 metres below Chart Datum.

The second case study is for a small boat harbour in the port of Onehunga. This port is located at the extreme upper end of the Manukau Harbour which has a mean tidal range of 2.8m and an average surface area of 245 km². It's extensive mud flat areas give rise to relatively poor water quality with total suspended solids being between 30 to 100 g/m³ on a fine day to 50 to 250 g/m³ on wet and windy days.

The majority of the dredging carried out at the port of Onehunga is in the main tidal channel which has tidal velocities between 0.7 and 0.9 m/s. The material in this location varies between muddy sand to marine mud. Annual deposition of material at this berth is about 10,000 m³/year which corresponds to a sedimentation depth of about 1 m/year. The notified depth at this berth is 5.5m below Chart Datum.

3 Case Studies

3.1 1992 Dredging: WH Resolution with no overflow

In 1992 Westham of Australia were awarded the dredging contract for the removal of 270,000m³ of unconsolidated marine mud from the port basins at the port of Auckland. The nominated dredger was the WH Resolution which was an ocean going trailing suction dredger. It has a hopper capacity of 4,000m³ and a dredging rate of 3,000m³ (insitu) per hour. The normal mode of operation was to dredge in the basins for 15 minutes, steam to the disposal site which was 35 km away, dispose of the material and return to the



dredging site. This had a total cycle time of about 4 hours. A condition of resource consent approval was that no overflowing was permitted during the dredging operation. The project took about 2½ months to complete.

During the dredging operation, monitoring was undertaken either weekly or on an intensive basis. For the weekly sampling, samples were collected at an up drift control, ie. area A on a flood tide or area C on an ebb tide - see Figure 1. Other samples were taken around the harbour at potentially affected areas. An intensive sampling monitoring programme was conducted at distances 200m, 1000m and 3000m down drift of the dredger. Continuous turbidity readings were taken across a harbour transect and the worse turbidity of the surface or subsurface samples was tested for suspended solids. All the suspended sampling results have been lumped together and are shown graphically in Figure 1. As an overall conclusion based on a standard z-test, there was no discernable difference between the updrift and downdrift readings from either the weekly or the intensive sampling.

3.2 1992 Dredging - WH Resolution with hopper overflow

During the same 1992 dredging campaign there was an approved experiment whereby the dredger's hopper was permitted to overflow for about 6 hours while it was filled with dredgings from a separate cutter suction dredger. The dredging rate was about 200 m³ (insitu) per hour. The purpose of this experiment was to assess the increase in hopper payload by allowing the overflow and to monitor the effects of the overflow operation. The sampling for turbidity and suspended solids was the same as the intensive monitoring programme as discussed in Section 3.1. All the suspended solids results are shown graphically on Figure 2. Again there is no discernable difference between updrift and downdrift readings.

3.3 1992 & 1993 Dredging at Port of Onehunga with the Tasman Bay

The annual maintenance contract was awarded to a local contractor using the dredger - Tasman Bay. This is a specifically designed grab dredger with a dredging rate of 80m³ (insitu) per hour and a hopper capacity of 160m³. Annual dredging has been carried out on two occasions at the Port of Onehunga with corresponding compliance monitoring. In 1992 samples were collected on a two weekly basis but were extended in 1993 to monthly sampling. The sample locations are shown in Figure 3 and the sample design is based on collecting surface and subsurface samples at updrift and downdrift locations depending on the state of the tide.

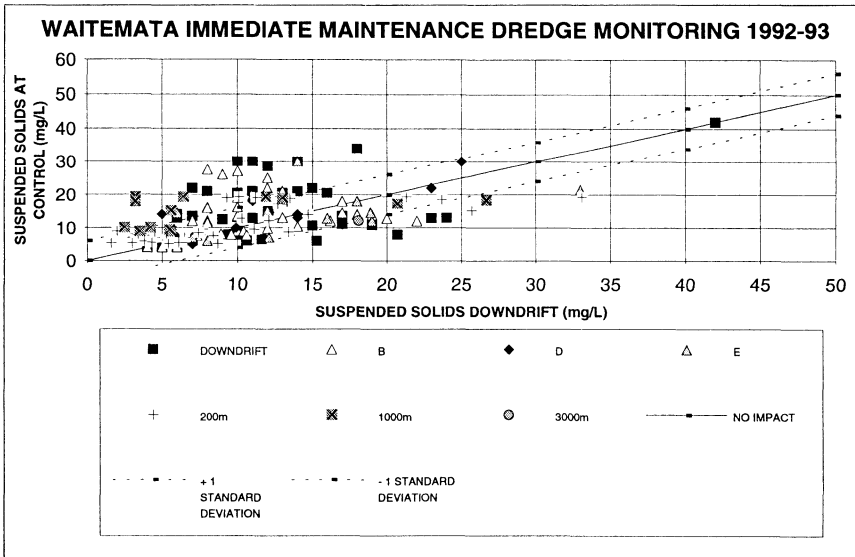
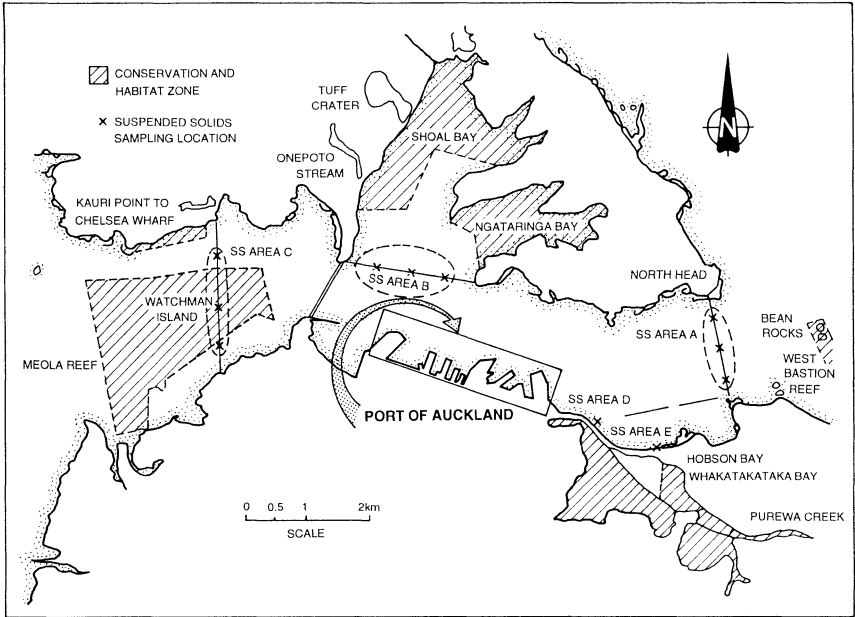
Results from these two sampling programmes are shown graphically on Figure 3. There is no discernable difference between updrift and downdrift readings.

4 Physical Processes

Sediment suspension caused by suction dredging includes:

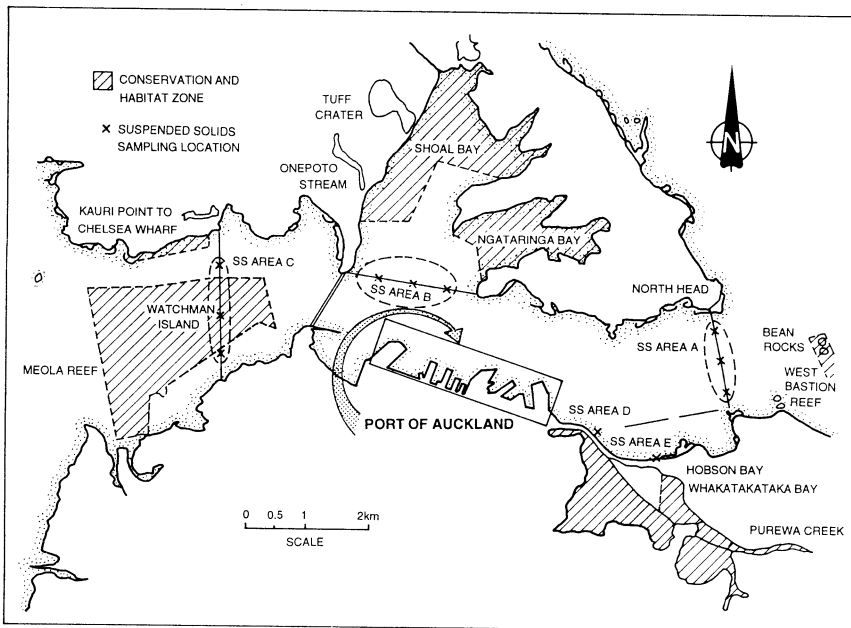


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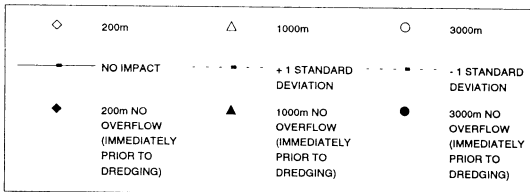
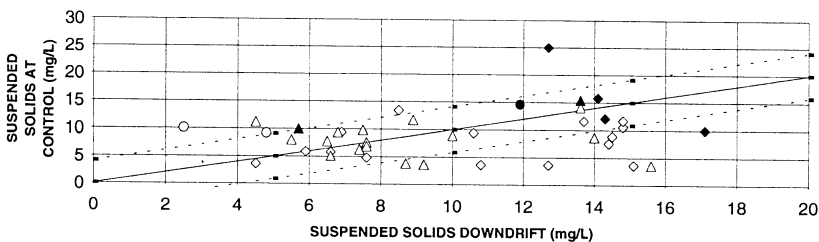


SUMMARY OF DATA							
CONTROL	DOWNDRIFT	B	D	E	200m	1000m	3000m
X = 12.46	X = 12.06	X = 11.12	X = 12.15	X = 13.39	X = 9.82	X = 9.14	X = 7.61
S = 6.02	S = 5.17	S = 4.4	S = 6.38	S = 7.88	S = 7.12	S = 6.72	S = 6.87
N = 54	N = 42	N = 42	N = 13	N = 13	N = 38	N = 24	N = 12

Figure 1 - Port of Auckland Dredging



WAITEMATA DREDGE OVERFLOW MONITORING 1992

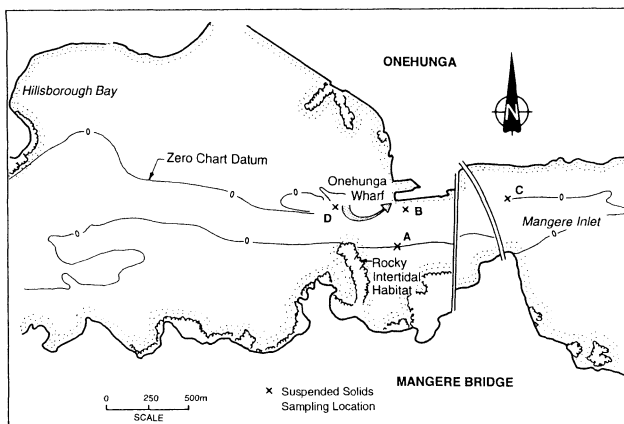


SUMMARY OF DATA			
CONTROL	200m	1000m	3000m
X = 8.94	X = 11.56	X = 8.85	X = 6.4
S = 4.12	S = 3.78	S = 3.26	S = 4.9
N = 13	N = 19	N = 18	N = 3

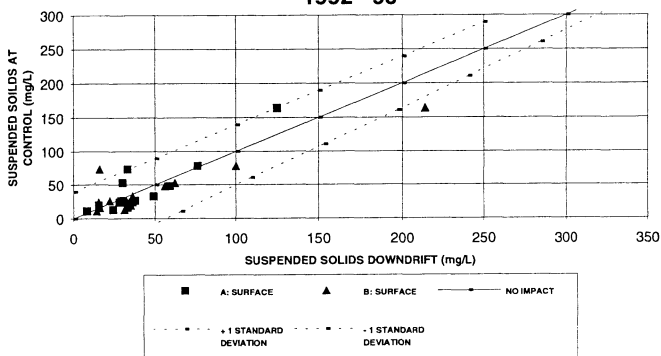
Figure 2 - Port of Auckland Dredging (with Overflows)



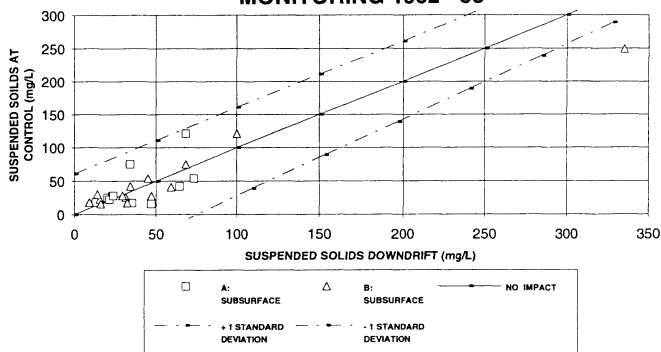
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ONEHUNGA IMMEDIATE MAINTENANCE DREDGE SURFACE MONITORING 1992 - 93



ONEHUNGA IMMEDIATE MAINTENANCE DREDGE SUBSURFACE MONITORING 1992 - 93



SUMMARY OF DATA

CONTROL SURFACE	CONTROL SUBSURFACE	A SURFACE	A SUBSURFACE	B SURFACE	B SUBSURFACE
X = 42.2	X = 52.67	X = 40.71	X = 36.93	X = 46.24	X = 56.68
S = 39.49	S = 60.97	S = 28.63	S = 20.96	S = 51.9	S = 80.79
N = 15	N = 15	N = 15	N = 12	N = 15	N = 15

Figure 3 - Port of Onehunga Dredging

- disturbance of the seabed from the drag head or cutting head
- overflows from the hopper
- propeller wash and manoeuvring.

Sediment suspension caused by mechanical dredging includes:

- disturbance of the seabed as the bucket or grab enters and digs into the seabed sediments
- spillage and wash off of sediment as the bucket is lifted from the seabed to the water surface
- spillage from the bucket as it swings over to the receiving hopper
- overflows from the hopper
- propeller wash and manoeuvring

The work of Nakai¹ indicated that large grab dredgers working with fine materials may release up to 85 kg of sediment per m³ of insitu dredged material. Similarly, for trailing suction dredgers he indicated that the resuspension rate would be 25 kg/m³.

Bruun² comments that the settling of suspended solids in an overflow operation is not covered by Stoke's law but by gravity or density currents. He gives an example of measurements taken 100m behind a hopper which recorded the bulk of the overflow being returned to the seabed. Only a small part that has been diluted around the edges of the stream of the overflow remained in suspension. Kuo³ *et al* determined release rates of between 0.11% to 0.18% of the dredging rate (on a mass basis) from field calibration of sediment plume models from two sites where samples were taken in the sediment plume away from the dredging area. This approximately corresponds to between 0.7 and 5 kg released per m³ of dredged material. These rates are significantly less than the potential resuspension rates given by Nakai¹.

The principle physical processes associated with the impacts of the dredging operation include density currents, sedimentation and lateral dilution. In the original environmental impact assessment associated with the dredging operations described in Section 3, the deposition of material due to the density currents was underestimated. This resulted in an area of anticipated environmental effects being significantly larger than the compliance monitoring recorded.

The plume induced by the density current is similar to the disposal descent plume as described in USACE⁴. This model allows the bulk of the material to move rapidly to the seabed as a density plume with some resuspension due to impact and entrainment around the edges of the plume. Truitt⁵ suggests that between 95 to 99% of the sediment falls rapidly to the seabed as a density plume for disposal operations. It may well be that a similar percentage of material falls to the seabed during a normal dredging operation.



5 Conclusions

From compliance monitoring results of two separate dredging operations it is concluded that effects of dredging are very localised and almost limited to the immediate surrounding area of the dredger.

The resource consent or approval process resulted in a number of conditions that were imposed on the dredging operation, e.g. no overflow and compliance monitoring, which encouraged the dredge master to undertake the works in the most environmentally sensitive manner.

For projects next to very sensitive ecological areas, special precautions would still be required but for general maintenance dredging operations the adverse effect on nearby ecosystems will generally be minor. Natural ecosystems in a port area would have adapted to the relatively high rates of deposition of sediment as well as any regular dredging operation, and the frequent berthing of vessels.

An interesting observation was also made during the investigations, before the 1992 dredging at the port of Auckland, that the turbidity and suspended solids caused by the normal ship vessel movement when the port had minimal under keel clearance was worse than suspended solids recorded during the dredging operation.

6 Acknowledgments

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7 References

1. Nakai, O. Turbidity generated by dredging projects in management of bottom sediment containing toxic substances, *Proceedings of the Third US-Japan Experts Meeting, EPA-600/3-78-084*, 1978.
2. Bruun, P. *Port Engineering* Volume II Fourth Edition, Gulf Publishing Company, Houston, 1990
3. Kuo, A.Y & Hayes, D.F. Model of turbidity plume induced by bucket dredge. *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol 117 (N°6), 1991.
4. US Army Corp of Engineers, *User's guide for models of dredged material disposal in open water*, Technical Report HL:1987, Mississippi, 1987.
5. Truitt, C.L. Dredged material behaviour during open water disposal *Journal of Coastal Research*, Vol 4(2), pp489-496, 1988.