OTAGO REGIONAL COUNCIL HEARINGS PANEL

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER Application No's 2010.193-2010.200, 2101.202, 2010.203; RM10.193.01 and 2000.472_V1

Applications by Port Otago Limited to undertake various activities within the Lower Otago Harbour

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STATEMENT OF EVIDENCE BY BRIAN STEWART

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1. INTRODUCTION

1.1 My full name is Brian George Stewart. I reside in Dunedin. I am a trained marine biologist and hold a BSc in Zoology from the University of Canterbury, a Post-Graduate Diploma in Marine Science from the University of Otago and a PhD in Marine Science, also from the University of Otago.

1.2 I am employed as a Senior Environmental Scientist with Ryder Consulting Limited, an environmental consulting business based in Dunedin. Prior to this I have held lecturing positions at the University of Otago and the University of Canterbury.

1.3 I am a qualified SCUBA diver with over thirty five years experience, the past twenty of those as a scientific diver. I also hold a local launch operators certificate.

1.4 During the past 19 years, I have worked on a wide variety of marine and freshwater projects involving macroinvertebrates, fish and algae, sedimentation rates in marine environments, environmental monitoring, and general water and sediment quality throughout the North and South Islands.

1.5 I have been contracted by private companies, regional councils and government departments to provide detailed ecological assessments of inter-tidal and sub-tidal habitats along the Otago coastline, and within Otago Harbour. I have also undertaken estuary habitat mapping for the Otago Regional Council, investigated the effects of sewage and stormwater disposal into the marine environment for the Dunedin City Council and have been contracted to supply numerous resource and ecological surveys for fishing interests in Otago.

1.6 I was, for the four years from 1996 to 1999, the manager of the biological monitoring programme for Meridian Energy in Doubtful and Milford Sounds. The aim of this programme was to determine effects on the fiord ecosystems of any sediments released as a result of the Manapouri Second Tailrace Project by undertaking extensive annual dive surveys at multiple control and impact sites in the fiords.

1.7 I am currently being retained by the EPA as an expert advisor on marine ecological matters pertaining to the Waterview Connection motorway project in Auckland.

1.8 I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Consolidated Practice Note 2006 and I agree to comply with it. I have complied with it in the preparation of this evidence.

2. SCOPE OF EVIDENCE

2.1 I am presenting evidence on behalf of Southern Clams Ltd, Port Chalmers Fisherman's Cooperative, the Paua/Kina Industry Council including Pauamac 5 Ltd, NZ Federation of Commercial Fishermen, Port Otago Fisherman's Cooperative, and the Otago Rock Lobster Industry Association.

2.2 My evidence presents my own interpretation of the technical reports presented in support of Port Otago Ltd's Assessment of Environmental Effects for Project Next Generation. I then compare these with results from my own ecological evaluations of some of the areas likely to be affected by the proposed activities within Otago Harbour and the adjacent areas outside the Harbour. I will follow this with my opinion on the likely ecological effects of the proposed activities and suggest mitigation measures.

3. DESCRIPTION OF OTAGO HARBOUR AND BLUESKIN BAY

3.1 Otago Harbour is a large, semi-enclosed embayment that is an extension of the sea rather than a true estuary. Although the entire harbour is completely inundated at high tide, extensive areas of sand and mud flats are exposed at low tide. Drainage is via numerous channels, including the Victoria Channel and main channel from Port Chalmers to the Heads. The harbour is effectively divided into upper and lower basins by the Portobello Peninsula and what are generally termed the "Halfway Islands".

3.2 It is sheltered from ocean swells and the major source of disturbance comes from winds, especially from the north-east and south-west. As such, it is best described as a generally low energy environment.

3.3 Both the upper and lower harbour basins are modified environments. Their margins are walled for much of their length, they receive stormwater runoff from the greater urban Dunedin area and a sizeable rural catchment and have been the sites of extensive historic and more recent reclamation in a variety of areas.

3.4 In addition, the main channel and Victoria channel have been, and continue to be, dredged to maintain width and depth for navigation (McLean 1985).

3.5 Blueskin Bay is the large embayment to the north of Otago Harbour and, for the purpose of this evidence, includes Waitati Inlet and the coastline and smaller beaches between Taiaroa Head and the Karitane Peninsula (Figure 1).

Figure 1. *Otago Harbour and Blueskin Bay.*

4. ASSESSMENT OF PORT OTAGO LTD'S TECHNICAL REPORTS BASED ON MY OWN RESEARCH CARRIED OUT WITHIN OTAGO HARBOUR

4.1 My professional interest in Otago Harbour stretches back 18 years to my assessment of the environmental effects of blasting during the Beach Street Wharf deepening (Stewart 1993). This interest has continued in more recent years with assessments of the effects of stormwater discharges to the harbour (Stewart and Ryder 2005), annual monitoring of stormwater discharges (e.g. Stewart 2010a), numerous investigations into the environmental effects of road improvements around the perimeter of the harbour (Stewart 2005; 2007a,b; 2010c), assessment of chemical contamination (Stewart and Hickey 2006; Stewart 2008c), and resource surveys for the Ministry of Fisheries and Southern Clams Ltd. (Stewart 2008b; 2010b).

4.2 The resource surveys have involved intensive sampling to categorise the communities associated with clam beds deemed suitable for experimental harvesting (i.e. sanitation areas 1804 and 1805; Figure 2) and surveys of those same areas to determine the biomass and size structure of clams (also called cockles) present.

Figure 2 *Sanitation areas 1804 and 1805 (outlined in yellow) in Otago Harbour.*

4.3 At the time, area 1804 was found to support around 6150 tonnes of clams while area 1805 supported around 7290 tonnes of clams (Stewart 2008b) with a sustainable annual harvestable yield of some 441 tonnes and 255 tonnes respectively.

4.4 Much of the Port Otago Ltd's assessment of effects on the ecology within the lower Otago Harbour Basin is based on the results of the survey carried out by Paavo *et al.* (2008).

4.5 This is, as stated in their report, a comprehensive assessment of the ecology in the lower Otago Harbour Basin. The science and methods used in their investigation are basically sound, with the use of a stratified random sampling design being the correct option.

4.6 The authors state that the lower harbour comprises a mosaic of different, but overlapping communities and, based on their results and interpretation, they suggest that the lower harbour basin may essentially be considered a single system.

4.7 I agree that the taxa found within the lower harbour basin are widespread and there is a high degree of overlap among many of the communities encountered.

4.8 In my opinion, however, and based on my own investigations (Stewart *et al.* 1992, Stewart and Ryder 2005, Stewart 2005, 2007a,b, 2008a,b, 2009, 2010b) the resolution at which sampling was undertaken by Paavo *et al.*

(2008) was insufficient to determine the boundaries of particular communities at the 10s or even 100s of metres scale.

4.9 For example, the sampling regime of Paavo *et al.* (2008) in which 15 or 16 samples were assessed on sanitation area 1804 (Figure 3a) has far less power to detect change than the stratified random sampling regime in which 158 samples were collected for investigation of the clam resource (Figure 3b) (Stewart 2008b).

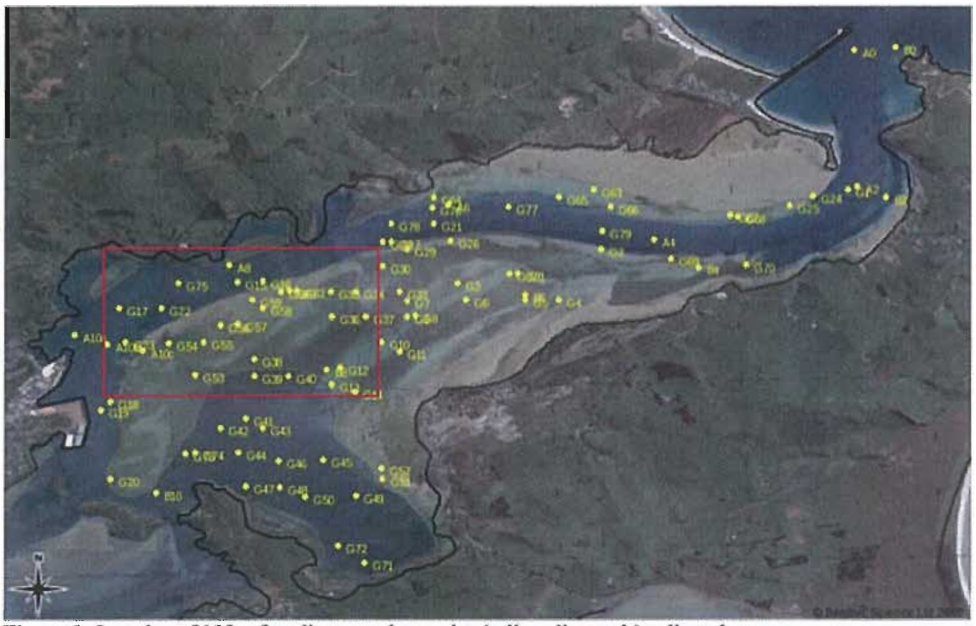


Figure 6. Location of 105 soft-sediment grab samples (yellow diamonds) collected.

Figure 3a *Sampling regime used by Paavo* et al. *(2008). Red rectangle indicates sanitation area 1804.*

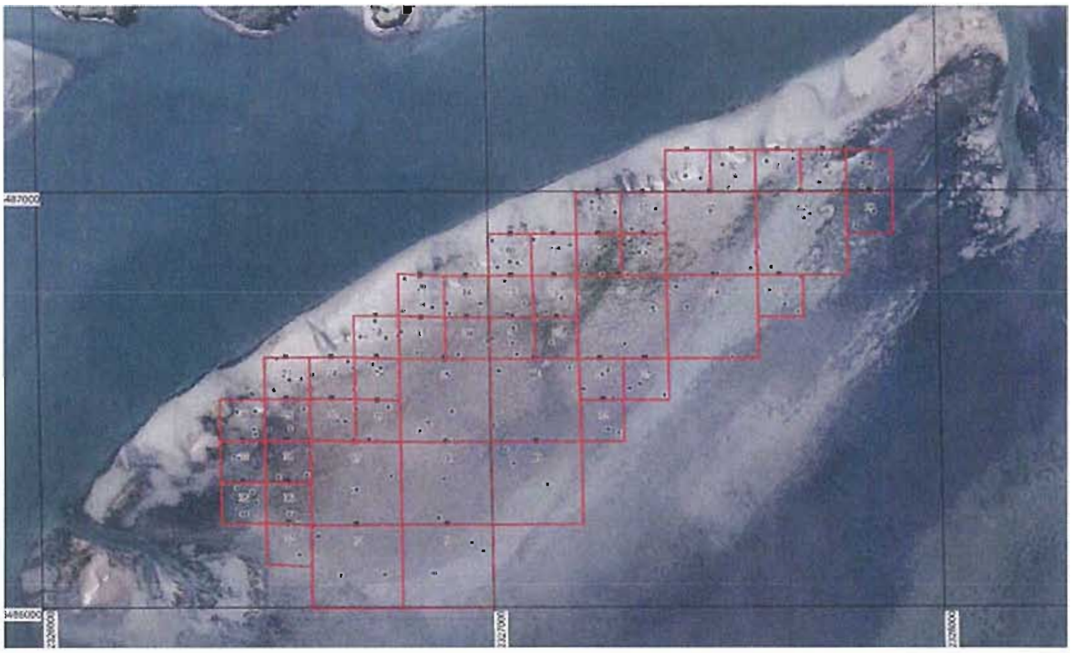


Figure 3b *Sampling regime used by Stewart (2008b) for sanitation area 1804. Each dot represents a sample, with three samples per red square.*

4.20 It should be pointed out at this stage that the areas being referred to are, in fact, not simply intertidal areas of exposed relict shell bed but aggraded shell banks that have an elevation of up to 1m above the surrounding intertidal flat.

4.21 This string of shell islands is unique within Otago Harbour and very rare locally, nationally and internationally (Woodroffe *et al.* 1983).

4.22 While technically not chenier shell plains due to the fact that they do not contact the shore, they are very similar in appearance, character and importance and no recognition of this is made in the Port Otago application.

4.23 A testament to the national and international significance of such landforms is the fact that similar shell banks on the Motu Manawa Marine reserve in the Waitemata Harbour, that are likely to be affected by the proposed Waterview Connection motorway project, are the subject of specific mitigation measures that stipulate they must be removed, stockpiled and reinstated at the conclusion of the project (Beca 2010).

4.24 Figures 4a-d below suggest that at least one of the shell banks is in an area that is likely to be affected by dredging, either directly, or indirectly as a result of settlement and/or wave erosion. I would recommend appropriate avoidance or mitigation measures be implemented for this shell bank.

Figure 4a *Shell bank opposite swinging basin at Port Chalmers showing roosting red billed and black backed gulls.*

Figure 4b *Location of shell bank in relation to swinging basin.*

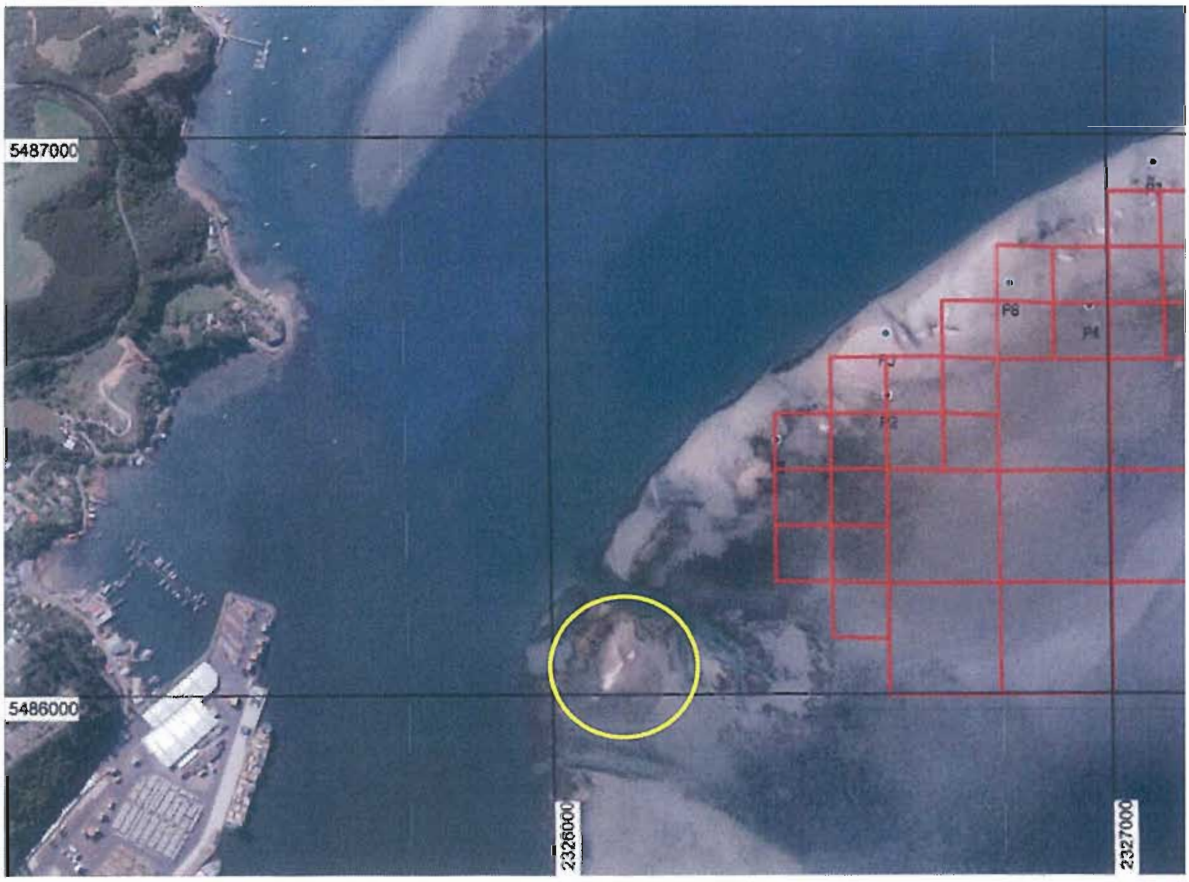


Figure 4c *Location of shell bank (circled) in relation to swinging basin.*

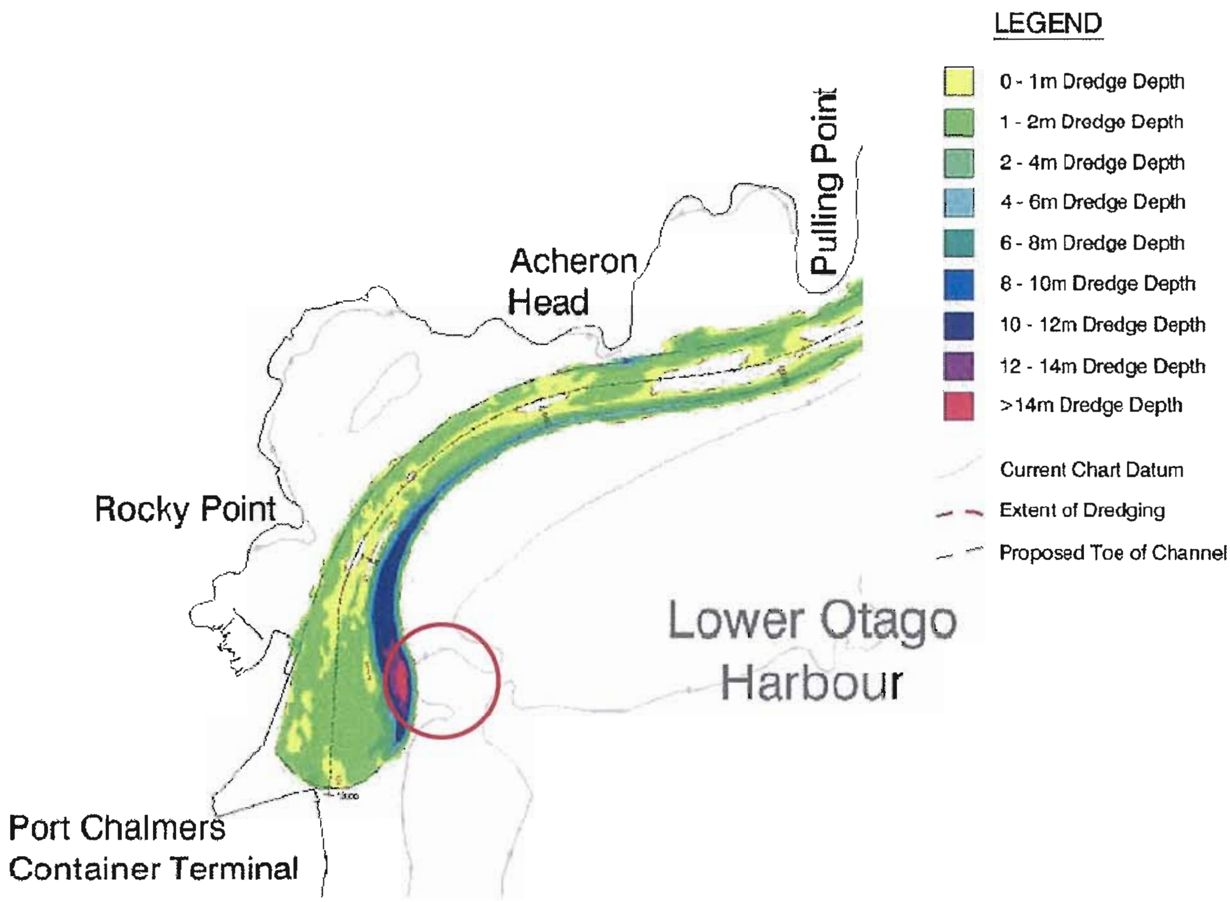


Figure 4d *Area opposite swinging basin to be dredged under the current proposal (Adapted from Pullar and Hughes 2009).*

4.25 Bell *et al.* (2009) have prepared a comprehensive report detailing hydrodynamic properties within the harbour and in Blueskin Bay, modelled using a number of industry standard software programs. They use the results of the modelling coupled with predicted assessments of sediments likely to be dredged and disposed of (OPUS 2008) to predict likely sedimentation rates and final destinations of sediments.

4.26 In this report (p. 134) they suggest that much of the sediment introduced to the water column during dredging activities will eventually be flushed out of the harbour by resuspension and tidal current generated in the main channels.

4.27 However, Single and Benn (2007), in their Executive Summary point out that there is a net inward movement of sediment in the order of 250,000 to 450,000 m^3 per annum which settles mainly in the lower harbour basin, necessitating regular maintenance dredging.

4.28 There is no adequate explanation that I could find of how sediment is expected to be flushed out of the harbour when there is an overall net inflow of sediment.

4.29 As a consequence, I do not agree with the contention that ecological effects on, for example, *Zostera* beds, will be less than minor due to sediment being resuspended and flushed out of the harbour. In my opinion this needs to be examined more closely.

4.30 Bell *et al.* (2009) do concede that there will be settlement of fine sediments in various parts of the harbour (see Table 7.6 in Bell *et al.* 2009) with between 0.2mm and up to 81.7mm of sediment being deposited over the duration of the project, dependent on location and dredging scenario (e.g. Figures 5a-d).

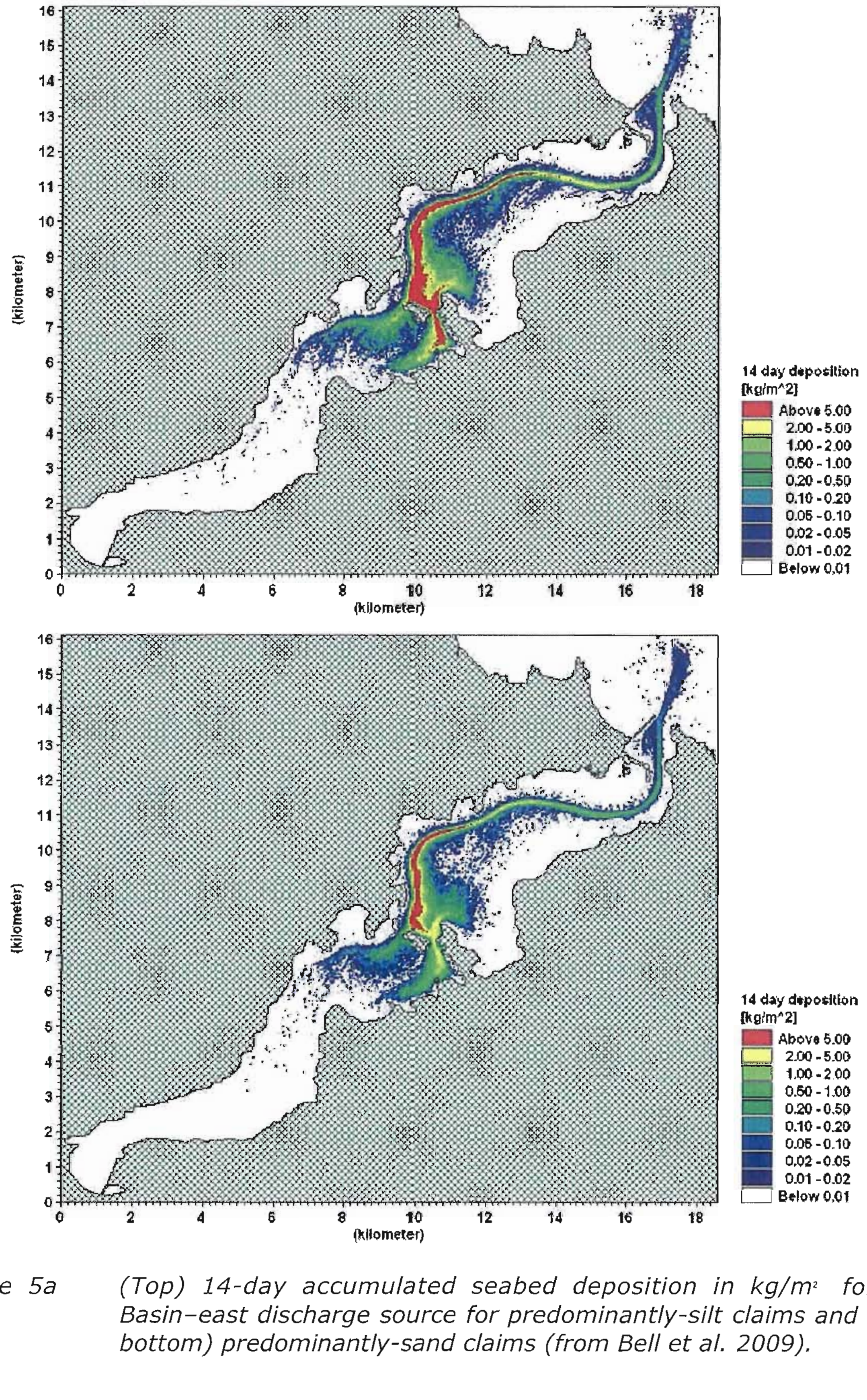


Figure 5a *(Top) 14-day accumulated seabed deposition in kg/m² for a Basin–east discharge source for predominantly-silt claims and (5b bottom) predominantly-sand claims (from Bell et al. 2009).*

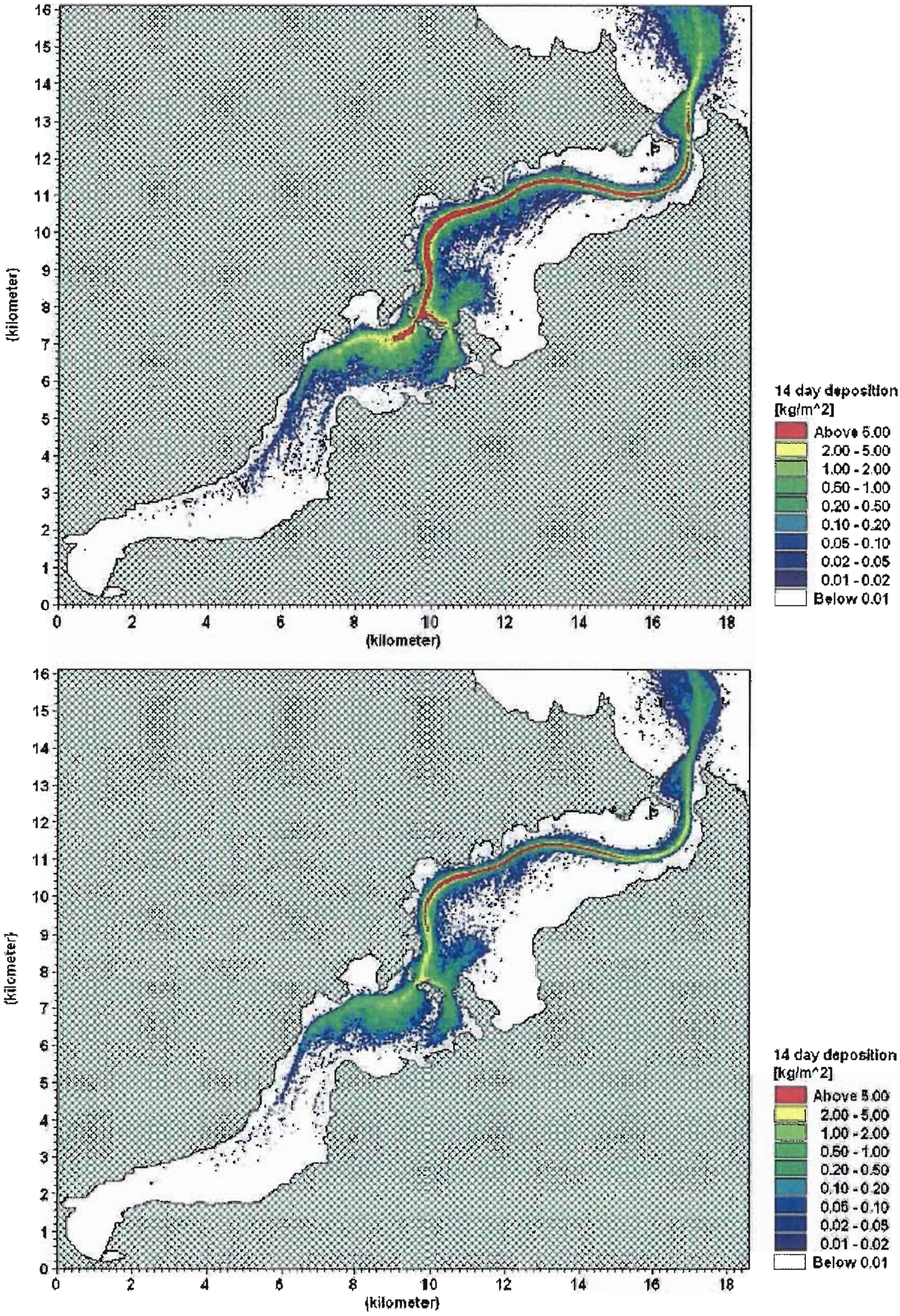


Figure 5c *(Top) 14-day accumulated seabed deposition in kg/m² for a Taylers Bend discharge source for predominantly-silt claims (TOP) and (5d bottom) predominantly-sand claims (from Bell et al. 2009).*

4.31 However, there is a lack of data on ambient suspended sediment concentrations and one assumes that the suggested sedimentation levels are in addition to ambient levels that may be expected under conditions that occur frequently within the harbour, including wind events and rainfall events.

4.32 Trimarchi and Keane (2007), in their evaluation of a similar dredging programme at the Port of Hay Point in Australia, note that weather conditions, particularly as they affect wind and waves (page 48), will affect turbidity by keeping sediments in suspension or remobilising sediments that have settled, particularly in shallow water habitats (Appendix 1).

4.33 The finding that effects of suspended sediments on communities within the lower harbour, especially *Zostera* beds and filter feeding organisms, will be less than minor (James *et al.* 2009) may be true for suspended sediments generated as a result of capital works dredging activities. However, does it remain so if these levels are added to ambient levels?

4.34 Rapid accumulations of fine sediment have been shown to smother benthic communities, including clams (e.g. Norkko *et al.* 1999, Lohrer *et al.* 2004).

4.35 This is amply demonstrated by a land slip on Mt Cargill that occurred in 2007 which deposited of a 0.5mm-10mm layer of clay over a large area of clam bed at the mouth of the Waitati River in Waitati Inlet. The clams in the area were smothered and are only beginning to recover three years later (personal observation).

4.36 In my opinion, there is a need for additional baseline monitoring to establish ambient levels of suspended sediment that appropriately reflect the full range of conditions under which dredging may take place, including wind events, rainfall events and various states of the tide.

4.37 It is gratifying to note that there is provision for such extra monitoring in the draft Environmental Management Plan, although I believe there is a need for 12 months of data gathering, rather then the suggested 6 months, to account for seasonal variations.

4.38 The threshold NTU (turbidity) values suggested in the applicants draft Environmental Management Plan are similar to values used in similar projects overseas. However, I believe that twelve months monitoring, in conjunction with laboratory and/or field experiments on the effects of sedimentation on local flora and fauna in Otago Harbour, are necessary to allow verification that such thresholds were suited to local conditions and would be true indicators of when adverse ecological effects might be expected to occur.

4.39 I note that during the Port of Hay Point dredging programme, the relationship between NTU and suspended solids was found to be 1:2.2 (Trimarchi and Keane 2007), more than double the 1:1 ratio suggested at this hearing in response to questions from the panel.

4.40 The applicant has stated that in order to minimise suspended sediment concentrations generated within the harbour during dredging operations the Trailing Suction Hopper Dredge (TSHD) may be fitted with "green valves" which limit the amount of air entrained in the decant water, thus reducing turbulence (Pullar and Hughes 2009).

4.41 This is a positive step, but could it not also be applied to the smaller dredge, the *New Era*?

4.42 I would also suggest that the implementation of "green pipe" technology, in which a pipe feeds decant water back to the dredge head, should be investigated. Such methods would likely reduce the volume of suspended sediments released into the harbour environment, resulting in much lower levels of deposition than those currently proposed.

4.43 The threshold levels at which various responses are initiated, as outlined in Table 1 of the draft Environmental Management Plan, conform to accepted thresholds set for similar projects overseas. However, I believe it is vitally important that the 12 months of monitoring I have suggested is necessary to establish if such threshold levels are indeed pertinent for communities within the Otago Harbour and within Blueskin Bay.

4.44 Such monitoring should be a condition of the granting of this consent with a suitably qualified and independent person or persons reviewing the monitoring programme and any results.

4.45 A number of submitters have commented on the lack of historical data available that attests to the effects of capital works dredging. To provide some background for the panel I have sought information from a highly respected marine ecologist who has had a long history of association with Otago Harbour.

4.46 With the panels permission, I would like to read a statement made by Associate Professor John Jillett pertaining to his recollections of effects associated with Port Otago Ltd's capital works dredging in the late 1970s (Appendix 2).

5. ASSESSMENT OF PORT OTAGO LTD'S TECHNICAL REPORTS AND EFFECTS OUTSIDE THE HARBOUR

5.1 There are currently three disposal areas, totalling 81ha, utilised by Port Otago Ltd for the disposal of maintenance dredge spoil. These disposal sites are authorised by resource consent 2000.472 and its conditions.

5.2 Project Next Generation proposes a forth disposal site with an area of 314ha (area of circle 2km in diameter) for the disposal of the majority of spoil from the dredging project.

5.3 The cumulative total habitat lost to dredge spoil disposal associated with maintenance and capital dredging operations is therefore 395ha, without any allowance for suspended settlement settling or disposal mound spread.

5.4 Using only the maximum settlement rate suggested in Figure 12.24 from Bell *et al.* (2009) (Figure 6) it seems probable that up to five times that area is likely to be adversely affected by spoil deposition. This is likely true for all deposition sites, an assumption verified by Paavo and Probert (2005) in their investigations of existing spoil disposal sites.

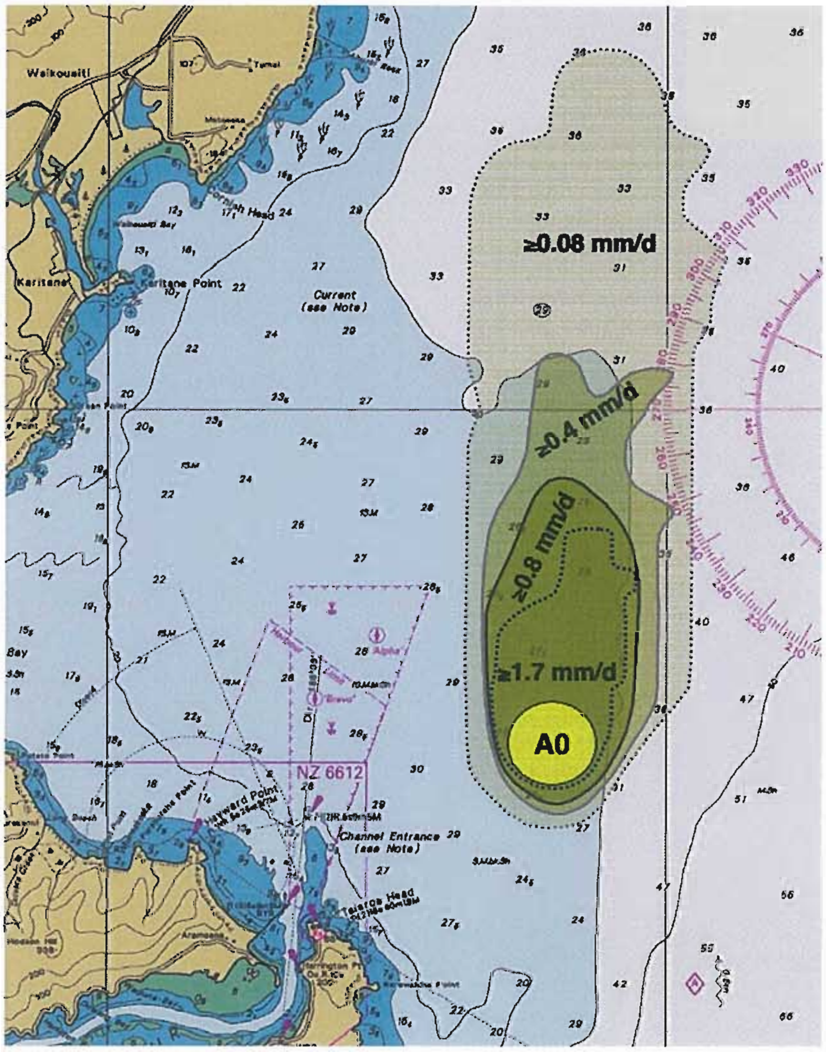


Figure 6 *Likely sedimentation rates resulting from dredge spoil disposal in Blueskin Bay.*

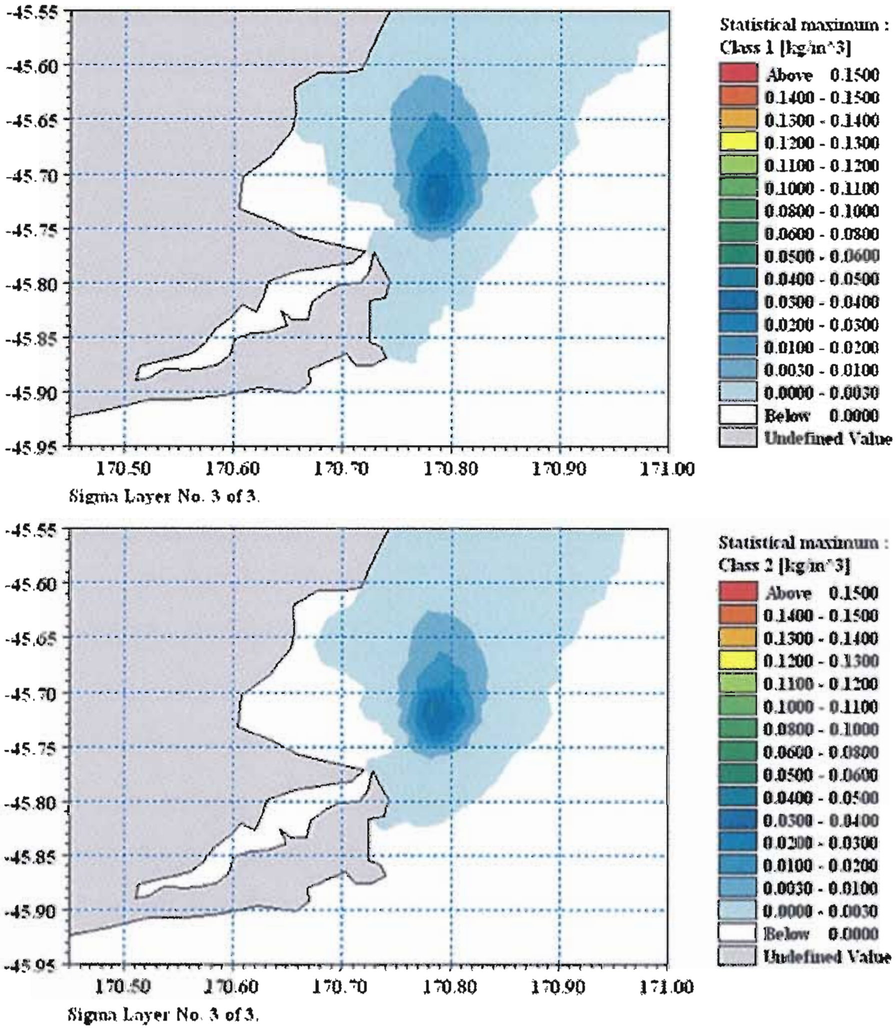
5.5 Thus, conservatively, up to an additional 1884ha of benthic habitat may be affected.

5.6 This amounts to approximately 10 to 15% of the shallow near-shore fishing grounds in Blueskin Bay that will have been cumulatively lost as a result of dredge spoil deposition. I have been advised that these grounds are relied upon by at least three small trawler operators, especially during the winter months, and a crab fishing operation. Foul ground within the area is targeted by commercial paua fishers and cray fishers (Appendix 3).

5.7 James *et al.* (2009) claim that the benthic faunal assemblages will recover over timeframes of months to years, depending on the organisms involved. While this may be true, local fishers advise me that the possible loss of a sizeable percentage of their fishing grounds for 1-3 years will have a significant impact on small operators who rely on these grounds.

5.8 The Port Otago Ltd. AEE suggests that the suspended sediment plume generated from the disposal of spoil will not reach the shore south of Cornish Head. However, modelling by Bell *et al.* (2009) clearly shows that sediment deposited at Site A1 will reach the coast at the north end of

Blueskin Bay under some circumstances, albeit at low concentrations (Figure 7).



Max. SSC composite envelopes for size class 1 (top) and size class 2 (bottom) in the surface layer (L3) over 24 disposal cycles for wind scenario 4 (light NNE wind) at disposal sub-site #1.

Figure 7 Predicted sediment plume from Bell et al. *(2009)*

5.9 Following a peer review of the application by independent peer reviewers, a perceived gap in information meant that further modelling was carried out at Site AO. This appeared to reinforce the contention that currents would carry sediments northward, rather than onshore.

5.10 However, the monitoring was carried out for a relatively short period (47 days in late spring/early summer) and focussed on near bottom currents (approximately 30m depth).

5.11 Given that very fine sediments will remain suspended in the water column for a considerable period of time and that wind and wave action influence surface water such that currents are occasionally directed towards the coast (Bell *et al.* 2009; MetOcean Solutions 2011), there remains a high probability that at least some sediments will reach the shore south of Cornish Head under some wind and wave conditions.

5.12 The area of coast potentially contacted by sediment hosts a number of kelp (*Macrocystis pyrifera*) beds that are important nursery areas for a variety of fish, kina and paua (Fyfe *et al.* 1999, Fyfe 2000) (Figure 8).

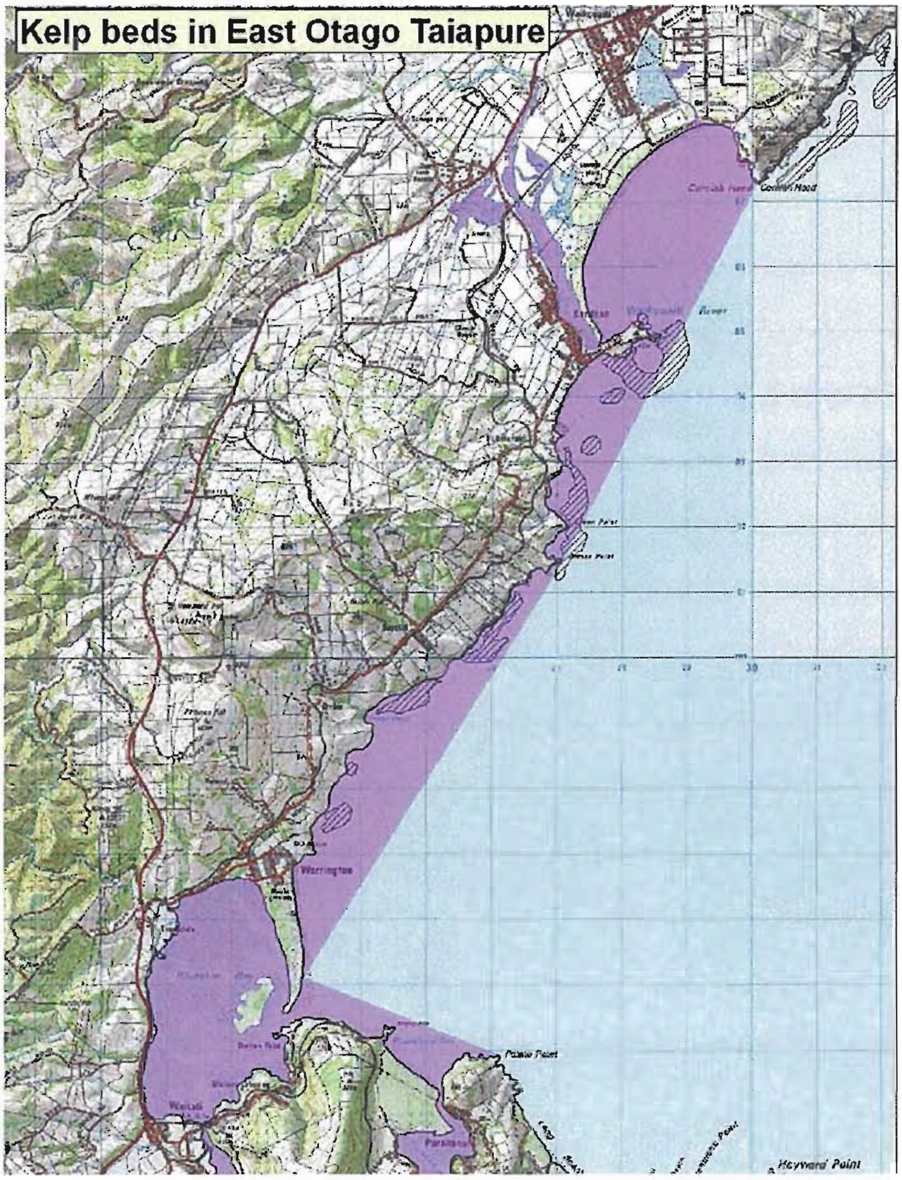


Figure 8 Kelp beds (cross hatched) in Blueskin bay. (from Jim Fyfe, DoC)

5.13 Blueskin Bay is a very turbid environment and any <u>additional</u> sediments in this system could have wide-ranging consequences for productivity in the bay and on the quality of habitats supporting fisheries, with kelp forests being particularly susceptible to sedimentation (Pirker, 2002; Dr Chris Hepburn pers. comm.).

5.14 It has been predicted that deposition of sediments would likely not exceed 0.5mm in a worst case scenario over the dredging programme and that wave action would resuspend sediments. This, however, implies that sediments may persist in the water column, with associated lowering of light penetration and flow on effects for recruitment and growth of algae.

5.15 Additionally, experimental evidence suggests that larval kina (*Evechinus chloroticus*) and paua (*Haliotis iris*), both of which are important to local fishers in the Blueskin Bay area, are extremely susceptible to suspended sediment levels (Phillips and Shima 2006).

5.16 Admittedly, Phillips and Shima (2006) used sediments derived from terrigenous sources in their experiments, but it is my understanding that it is particle size and cohesiveness that play the major role in effects rather than origin.

5.17 There have apparently been little data collected on ambient suspended sediment concentrations in Blueskin Bay in the areas that are likely to be affected by sediment plumes. In my opinion this is a significant shortcoming of the application and does not appropriately accord with the New Zealand Guidelines for Sea Disposal of Waste (1999).

5.18 At the very least I would expect a minimum of 12 months research to be done on ambient suspended sediment concentrations before operations commence. I would also suggest a monitoring programme be put in place to ascertain suspended levels at a minimum of two points in Blueskin Bay during spoil disposal.

5.19 As evidence of the final destination of sediments deposited in Blueskin Bay, the applicant has put forward the example of the spit off Tairoa Head.

5.20 Bell (2011) states that *"at the very long timescales, the offshore submergent spit on which Disposal Site A0 has been placed shows a strikingly consistent North to NNE orientation, which will enhance topographic steering of currents to some degree but it is also indicative of a long term net residual current that has shaped this large sedimentary body."*

5.21 My understanding of this spit, however, is that it is composed of relatively larger particles that are swept along the seafloor by oceanic currents. As such, is not necessarily indicative of what fate may befall much smaller suspended sediment particles during their time at shallower depths within the water column.

6. SUGGESTED CONDITIONS AND MITGATION MEASURES

6.1 I commend the decision by the Applicant to employ adaptive management strategies to manage possible adverse effects. These can be made to work extremely effectively, as shown by the Port of Hay Point dredging project in Queensland (Trimarchi and Keane 2007).

6.2 However, in my opinion the proposed works in their current guise will have significant adverse effects on the biota within Otago Harbour and in Blueskin Bay. Additionally I believe there will be significant adverse effects on the fishing grounds within Blueskin Bay.

6.3 I would request that the application be deferred until sufficient baseline monitoring has been carried out to establish thresholds at which adverse ecological effects, both within the harbour and outside the harbour, may occur. Such monitoring should cover at least 12 months to address any seasonal variations and should be designed by a suitably qualified person or persons.

6.4 However, if the commissioners consider the information provided to date by the Applicant is satisfactory, and consent is granted, I would recommend that green techniques ("green valves", "green pipe") or non overflow loading be applied to all dredging activities wherever possible to minimise the release of sediments within the harbour.

6.5 I believe the proposed 3 year monitoring interval for incremental capital dredging works is too long and should be no more than 1 year for such works with 6 monthly monitoring for major capital works.

6.6 In addition to the turbidity meters located at the sites recommended in the draft Environmental Management Plan, I would recommend that an additional two turbidity meters be located at sites up-harbour, suggested sites being one at the western end of Sanitation area 1805 and one in Macandrew Bay.

6.7 A minimum of two extra turbidity meters in Blueskin Bay, in addition to the one proposed at the disposal site in the draft Environmental Management Plan, should also be deployed.

6.8 The sites of the additional meters would be finally determined in consultation with affected stakeholders.

6.9 The draft Environmental Management Plan suggests annual meetings to review monitoring results during incremental work. I would suggest that this is insufficient with possible adverse effects likely occurring within the space of weeks or months.

6.10 I would also suggest that the objective in the draft Environmental Management Plan stating that the Manawhenua Consultative Group is to be consulted on the design of monitoring programmes should be included in the objectives of the Project Consultative Group, so that the full range of stakeholders has input into the design of any monitoring programmes.

6.11 Finally, I would like to recommend that a suitably qualified, independent, person or persons be appointed to review any proposed monitoring programme and to review any results from such monitoring programmes throughout the project.

BRIAN GEORGE STEWART

14 April 2011

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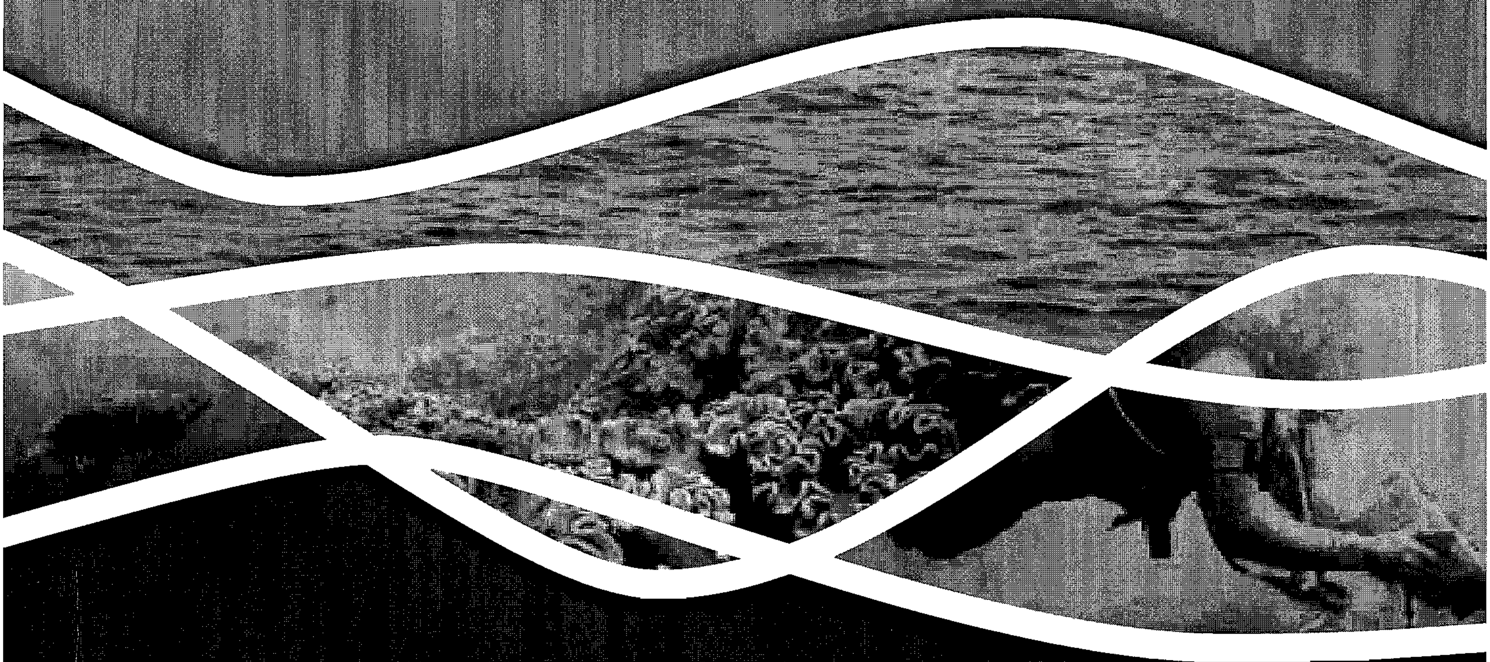
APPENDIX 1

PORT OF HAY POINT APRON AREAS AND DEPARTURE PATH CAPITAL DREDGING PROJECT: ENVIRONMENTAL REVIEW. ECOPORTS MONOGRAPH SERIES NO. 24.

Port of Hay Point Apron Areas and Departure Path Capital Dredging Project

Environmental Review



Ports Corporation of Queensland

GHD

Authors:
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EcoPorts Monograph Series No. 24

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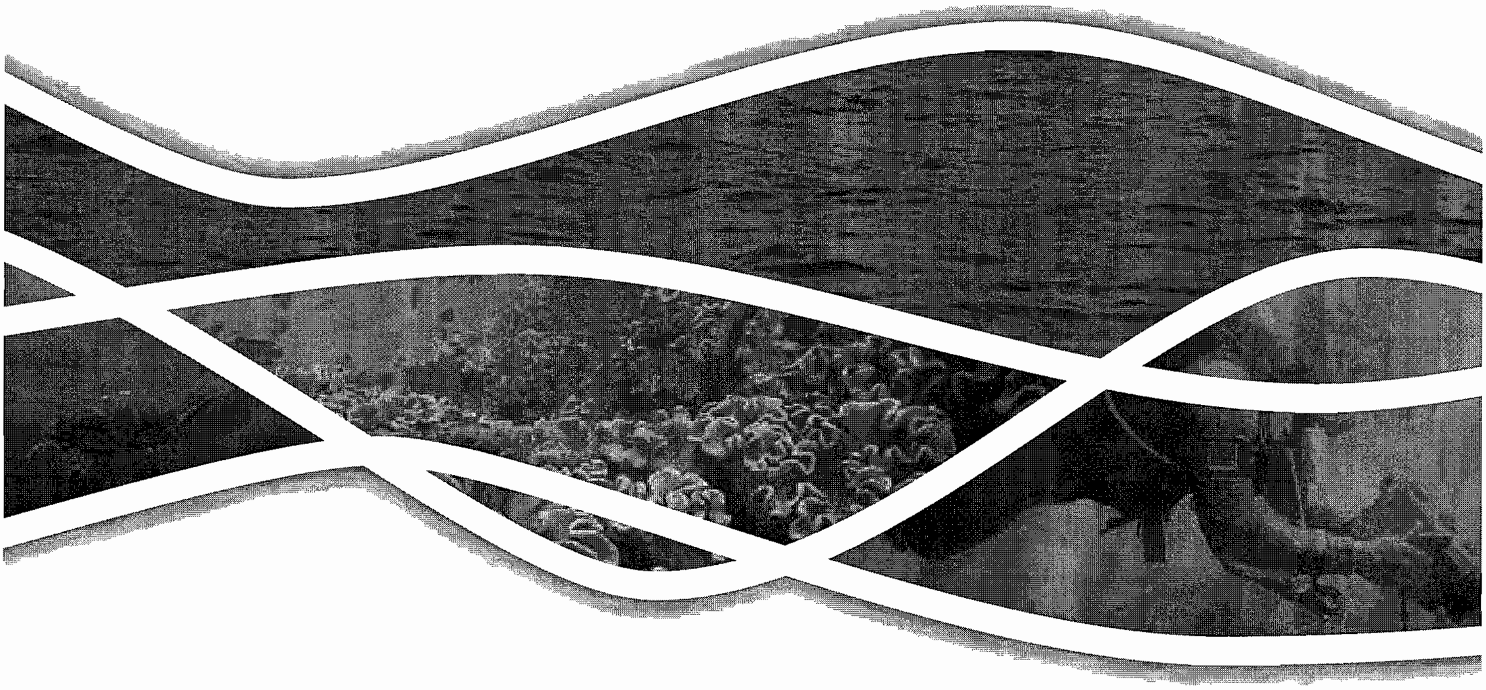
Environmental Review



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Executive Summary

Ports Corporation of Queensland (PCQ) completed major capital dredging works at the Port of Hay Point, Queensland in October 2006. Initial capital dredging totalled almost 9,000,000 million cubic metres of seabed material. Implementation of the project followed the completion of a detailed Environment Impact Statement (EIS) and Environmental Management Plan (EMP).

The project is located within the Great Barrier Reef World Heritage Areas and partially within the Great Barrier Reef Marine Park. A number of sensitive environmental habitats, including fringing coral reefs are located in close proximity to the Port at Round Top Island and Victor Islet.

The development of the EIS and EMP was undertaken in close partnership with approval agencies to ensure all environmental issues were addressed within the context of the project and sensitive environment in which it was to be undertaken, but also having due regard to the practicalities of undertaking the works. An important outcome of the approvals process was that the project EMP (GHD 2006a) identified engineering, technical and economic constraints which had been identified at the commencement of the EIS process and considered throughout the assessment.

The EMP outlined mitigation strategies to protect flora, fauna, water quality, cultural heritage and the social environment, and detailed integrated and innovative monitoring programs to be undertaken to assess potential environmental impacts and investigate long-term effects (GHD 2006a). The EMP formed the basis for approvals and management of the project.

The monitoring program was designed to enable gradual reduction in monitoring intensity, if environmental impacts were demonstrated to be below predicted levels. This maintained the focus on environmental outcomes rather than proceeding with excessive monitoring.

The EMP included detailed water quality and coral condition monitoring programs as well as a validation program for hydrodynamic modelling.

Water quality monitoring was primarily undertaken through the use of remotely accessed telemetry based water quality loggers. The TSS trigger value for the project was 100 mg/L for a period of at least six continuous hours. An assessment of all TSS data recorded pre-dredging, during dredging and post-dredging identified a total of 31 water quality trigger exceedences at Victor Islet and none at Round Top Island.

All exceedences at Victor Islet were recorded during dredging and post-dredging. Six exceedence events were recorded during the dredging period, with a maximum duration of 20.6 hours and a total of 21 exceedences were recorded during the post-dredging period (38.2 hour maximum duration).

Coral condition monitoring undertaken showed evidence that sediment deposition associated with the migration of the dredge plume occurred at both Round Top Island and Victor Islet. This deposition resulted in damage to some corals between three and six months after the start of dredging, with a maximum of about 4% (Round Top Island) and 6.5% (Victor Islet) of corals showing some patches of mortality.

Whilst it was considered that the measurement of coral bleaching does not provide a significant indicator for dredge impact, it assists with the 'big picture' consideration of coral health and demonstrates what is occurring regionally. Therefore bleaching should be investigated pre and post-dredging. However it is uncertain what mucous production information (from *Porites*) indicates about coral health, so it may be worth reviewing whether this parameter should be measured in the future.

The post dredge survey conducted six months following completion of dredging repeated the April 2006 baseline survey. The nominal but not significant reduction in hard coral cover at Round Top Island and Victor Islet since the 2006 baseline survey was 1% and 3% respectively, similar to the reduction recorded at the Slade Islet reference location (1%) and much less than the significant 20% reduction at the Keswick Island reference location. The EIS indicated that a reasonable conservative expectation for coral mortality due to the impacts of the dredge plume might be 16% live coral cover at Round Top Island, with mortality at Victor Islet being unspecified. Dredging activities do not appear to have influenced overall percentage coral cover at the impact locations during the dredging program by more than a fraction of 1%.

The validation of the hydrodynamic indicated that the model generally performed well when comparing the predicted TSS (above background) concentrations against measured TSS concentrations. For Round Top Island, there was good agreement between predicted and measured TSS over the whole simulation period. For Victor Islet, the predicted TSS concentrations compare well against the measured values for low TSS concentrations but less well against the higher TSS concentrations. Shallow depth, wind-driven resuspension and poor representation of actual background concentrations at Victor Islet are factors as to why the model does not 'capture' the high TSS concentrations.

Management of the dredging program was overseen by a Management Reference Group (MRG) comprising representatives of each of the approval agencies for the project. Community representatives who had been involved in the development of the EIS and EMP were also kept informed through the Technical Advisory and Consultative Committee.

A lessons learned workshop was undertaken after the completion of dredging to review project outcomes. The workshop was attended by MRG members as well as coral, seagrass, hydrodynamic modelling and water quality specialists involved throughout the project.

The workshop reviewed all aspects of the project from approval processes through to implementation and environmental outcomes. From the three key regulators providing conditions of approval for the project, the implementation of the EMP was generally seen as a positive outcome of the integrated approval. It was noted that this project was a one-off and did not result in any significant environmental impact.

Overall, the project was able to be successfully undertaken and achieved the environmental goals set in the EIS and EMP with no significant environmental impact occurring. The outcomes of the monitoring program reinforcing the link between the investigations and findings of the EIS and the effectiveness of the monitoring programs set by the EMP and implemented during works.

1 Introduction

1.1 Project Description

The Port of Hay Point is located approximately 40 kilometres south of Mackay in Queensland and is one of eight commercial ports operated by Ports Corporation of Queensland (PCQ). As one of the world's largest coal export ports, it is critical to ensure the port continues to operate efficiently and cater for existing and future demands. The port however, is also partly located within the Great Barrier Reef Marine Park (GBRMP) and wholly in the World Heritage Area and therefore must be managed appropriately, with due regard to strategies necessary to protect the marine environment and preserve the World Heritage values of the region.

The Port of Hay Point is a significant contributor to the local, State and national economy. In the financial year 2005/2006, close to 82 million tonne of coal was exported from the port via 929 ship visits (PCQ 2006). Current predictions forecast tonnage to grow to over 125 million tonne per annum in the next five years. In order to achieve greater efficiencies and accommodate projected tonnage growth, PCQ undertook capital dredging at the port in 2006. The capital works required the dredging of seabed material in the order of 9 million cubic metres. The general location and extent of capital works is shown in Figure 1.

The dredging works included:

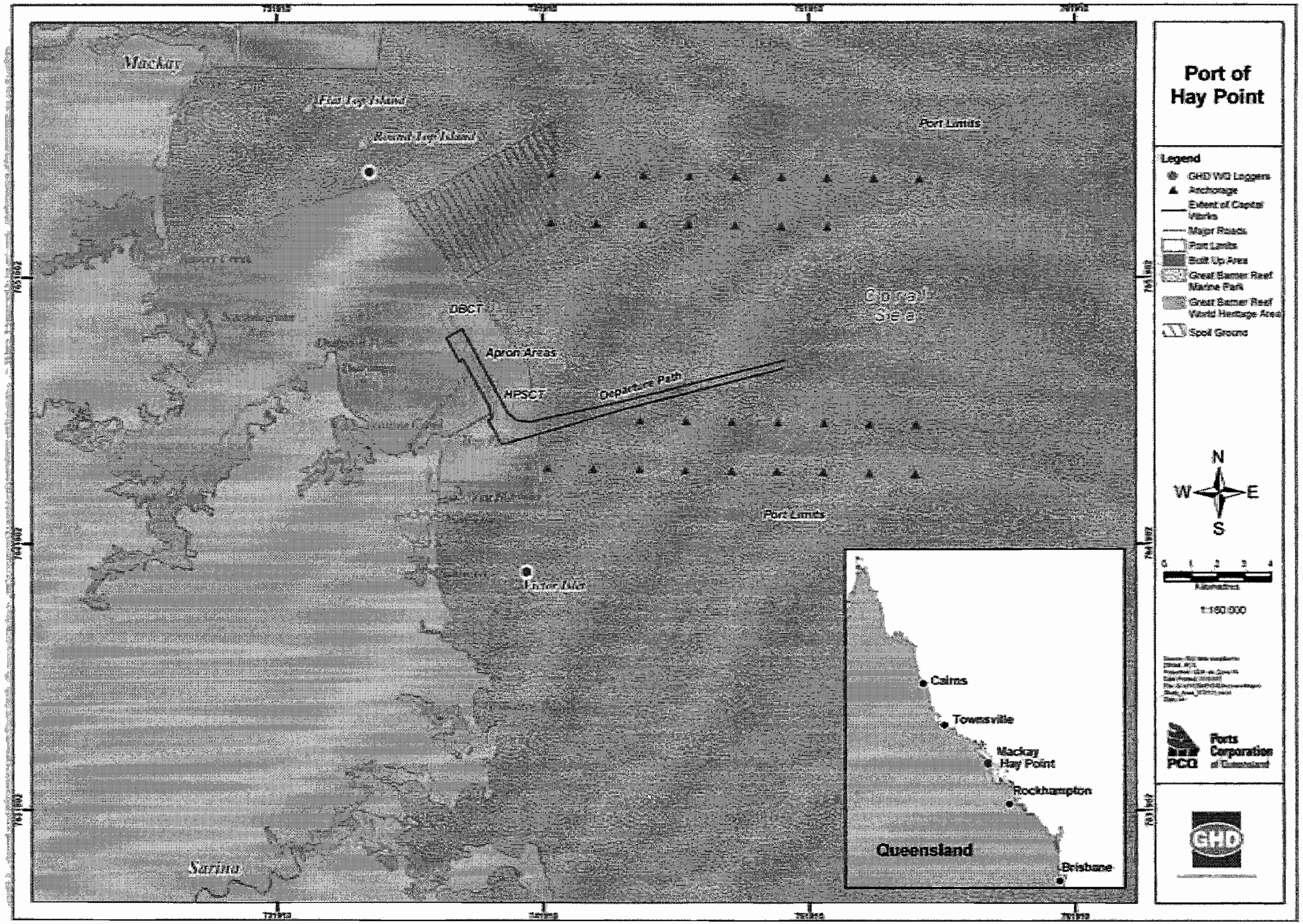
- A ship manoeuvring apron area approximately 500 metres wide adjacent to the existing berths.
- A departure path from apron to sea approximately 9,500 metres long. The first 500 metres is 500 metres wide, after which it tapers to a width of 300 metres for the next 3,000 metres. The remainder of departure path is 300 metres wide.
- Installation of four beacons to mark the departure path for shipping.

1.2 Project Implementation

Dredging commenced on 9 May 2006 using the world's biggest trailer hopper suction dredger, the *WD Fairway*, and ceased on 17 October 2006. Approximately 8.6 million cubic metres of capital material was removed and placed in a dredge material relocation area of approximately 1,840 hectares in the GBRMP (Figure 1). This was the largest dredging project to occur in the southern hemisphere in 2006. Overall, there was a 1.4 metre increase in the declared port depth to RL – 14.5 metres LAT (Lowest Astronomical Tide). Further minor capital dredging is anticipated in the future to reach a declared depth of -14.9 metres LAT. Maintenance dredging of the departure path and apron areas will also be required in the future (Trimarchi 2007).

The construction of the apron area and departure path will now allow most ships to load to maximum draft, thus increasing the efficiency of the port. It is estimated that an additional 1.7 million tonnes of coal will be exported per year worth approximately $100 million per annum and earlier sailing times will result in an equivalent of up to $60 million of infrastructure investment. Dead freight, that is, the lost opportunity of transporting product due to short loading, will be reduced, saving up to $55 million per year. The capital dredging project, therefore, was of national and State economic significance (Trimarchi 2007).

Figure 1 Project location and extent of dredging works (GHD 2005a)



2 Environmental Impact Statement

2.1 EIA Process

Based on an Initial Advice Statement prepared by PCQ, the capital dredging project was declared a 'significant project' by the Queensland Coordinator-General, whereby an Environmental Impact Assessment (EIA) was required in accordance with State legislation. Furthermore, the Commonwealth Department of the Environment and Water Resources (DEW), (formerly the Department of the Environment and Heritage) one month later, declared the project a 'controlled action' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). An Environmental Impact Statement (EIS) was developed in accordance with publicly reviewed Terms of Reference (TOR) and comment invited from the community and regulatory agencies on the document in August 2005 (Trimarchi 2007).

A Supplementary EIS was developed in September 2005 following the EIS public review period, after which the Coordinator-General concluded that the EIS documentation met impact assessment requirements and allowed for an informed evaluation of the potential environmental impacts. The Coordinator-General imposed a number of conditions on the project, including compliance with a comprehensive Environmental Management Plan (EMP) and the implementation of research and monitoring programs to determine the impacts of the dredging (Trimarchi 2007).

2.2 Approval Process

2.2.1 Overview

Current environmental assessment processes for major projects introduce a range of complex approval requirements which must be managed to achieve project outcomes. Some recent projects have demonstrated the range of difficulties to be addressed where a project triggers multiple approval requirements from Commonwealth, State and local government agencies. The complexities arise in not only meeting the potentially competing interests of various agencies, but also navigating the logistical issues associated with varying timeframes for approvals. The Port of Hay Point Capital Dredging Project is one project which required the development of a number of innovative solutions to meet the demanding requirements of regulatory agencies and achieve the project outcomes sought by the proponent.

Often in approval processes, adversarial relationships can develop between the proponent and regulatory agencies. This approach is counterproductive to all parties concerned. The approach implemented for the Hay Point EIA was to work in a collaborative manner with all stakeholders from the commencement of the project. Collaboration is not limited to working closely to develop reporting approaches and methodologies for technical studies, but also includes working to the benefit of each party and understanding the limitations in which each party operates. This involves 'give and take' and the willingness of all parties to negotiate for favourable outcomes for all.

2.2.2 Approach to Approvals

Defining Complex Approvals

The Port of Hay Point Capital Dredging Project required approvals by the Australian Government and Queensland State Government. As previously discussed, the proposal was determined to be a 'controlled action' under the EPBC Act on 7 October 2004, and the controlling provisions for the proposal were Sections 12 and 15A (World Heritage), Sections 18 and 18A (Listed threatened species and communities), Sections 20 and 20A (Listed migratory species) and Sections 23 and 24A (Marine environment). On 16 September 2004, the project was also declared a 'significant project' pursuant to Section 26 of the Queensland *State Development and Public Works Organisation Act 1971* (SDPWOA).

On 12 October 2004, a delegate of the Commonwealth Minister for the Environment and Heritage determined that the Bilateral Agreement between the Australian Government and Queensland (*An Agreement between the*

Australian Government and the State of Queensland under Section 45 of the Australian Government Environment Protection and Biodiversity Conservation Act 1999 Relating to Environmental Assessment) was applicable, with the level of assessment for the proposal being set at EIS under Part 4 of the SDPWOA.

As the Port of Hay Point is located within the GBR World Heritage Area and partially within the GBRMP, the Great Barrier Reef Marine Park Authority (GBRMPA) and DEW subsequently received applications for permits under the Commonwealth *Great Barrier Reef Marine Park Act 1975* (GBRMP Act) and the *Environment Protection (Sea Dumping) Act 1981* (Sea Dumping Act) respectively, for related parts of the proposal. These agencies referred the actions to the Commonwealth Minister for the Environment and Heritage under Section 161 of the EPBC Act for advice. In the case of the EPBC Act Section 161 referrals, the scope of the environmental impact assessment must address all relevant aspects of the environment. The delegate of the Minister subsequently determined that the referred actions under the GBRMP Act and the Sea Dumping Act should also be reviewed by accredited assessment, namely by EIS under Part 4 of the SDPWOA.

The assessment was required to be conducted in accordance with Schedule 1 of the Bilateral Agreement. Amongst other things, Schedule 1 includes a requirement for the assessment to contain enough information about the action and its relevant impacts to allow the Commonwealth Minister for the Environment and Heritage to make an informed decision about whether or not to approve the action under the EPBC Act. This requirement also includes the need for enough information about the direct and indirect impacts of the action.

In summary the project required the following approvals:

- Controlled action under the EPBC Act;
- Disposal of marine sediment at sea under the Sea Dumping Act;
- Undertaking works in the GBRMP under the GBRMP Act;
- Significant project under the SDPWOA;
- Development Approval under the Queensland *Integrated Planning Act 1997*;
- Undertaking works in a marine park under the Queensland *Marine Parks Act 1981*;
- Operation of a port under the Queensland *Environmental Protection Act 1994* (EP Act);
- Damage to marine plants under the Queensland *Fisheries Act 1994*; and
- Works within a coastal protection area under the Queensland *Coastal Protection and Management Act 1995* (CPM Act).

By using the Bilateral Agreement between the Australian Government and Queensland and the accredited process for the SDPWOA and GBRMPA Act, it was possible to use a single assessment (EIS) to inform multiple approval agencies of the proposed works and associated environmental impact.

Developing Relationships with Approval Agencies

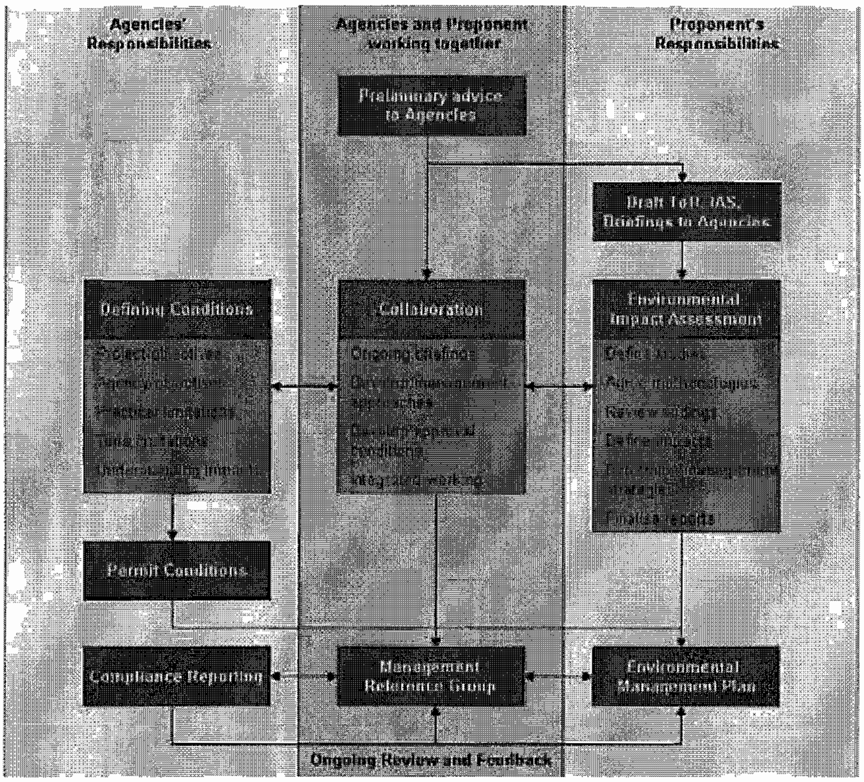
The number of approvals required in itself presented a level of complexity which was only exacerbated by the number of agencies involved in granting the approvals. In order to minimise the potential delays and conflicts of interests which could arise due to the number of agencies involved, it was determined that a proactive process of working with the agencies was necessary to ensure project outcomes. This not only achieved the objectives of the project, but ensured that the requirements of each agency were met and minimised the approval processing times. In total, two Commonwealth and three State government agencies needed to grant approvals for the project to be undertaken.

The approach shown in Figure 2 commenced prior to the lodgement of the EPBC Act referral documentation or any applications for approvals. An initial briefing to each relevant agency was undertaken to firstly establish the project and seek input on the best approach to deliver the project. This initial briefing was the first in a number of ongoing briefings throughout the project. The key goal of the briefing sessions was to ensure a continued line of communication and information exchange, with the project team seeking feedback and input from agency representatives.

Reporting on critical aspects of the project was undertaken in an iterative process with the goal of achieving agency 'buy-in' on technical and scientific approaches. This approach was critical to the development and acceptance of several key studies being undertaken to support the EIS. Of particular contention was the hydrodynamic model and the approach to determining potential impacts on benthic communities located proximate to the works. This was an important component of the EIS phase as the modelling assisted in identifying the potential extent of the dredge plume and its associated impact on the environment.

Difficulties that can arise in complex projects are often related to limited resources and technical knowledge within assessment agencies. By involving the agencies early on and providing them with details of methodologies and assumptions to be utilised in the study, a better understanding of the technical issues was obtained. This reduced the risk of rework to test differing approaches and allowed agencies to provide input throughout the process. For example when the collection of scientific data on previously un-investigated sensitive habitats was undertaken in full consultation with lead agencies such as GBRMPA, methodologies and data analysis were reviewed and approved by all parties. This joint approach consequently led to general acceptance of the results obtained during the study, instead of agencies questioning their validity. PCQ applied for and obtained permits for the project from the GBRMPA, DEW, the Environmental Protection Agency (EPA) and the Department of Primary Industries and Fisheries (DPIF). Project approval as also gained from the Coordinator-General.

Figure 2 Approach to delivering integrated approvals and conditions



Source: Keane (2007)

2.3 Approval Conditions

2.3.1 Developing Conditions

As previously discussed, the collaborative approach of working with the regulatory agencies was the first step in obtaining approval of the EIS. The initial development of conditions began with the assessment of potential impacts based on EIS outcomes and consideration of the engineering, technical and economic limitations under which the project would be implemented.

The scale of the project presented a number of practical challenges which influenced the development of approval conditions. For example, dredging was predicted to take up to six months of constant operation. The analysis of habitat tolerances showed that the best way to minimise impact was to minimise the period of dredging. Therefore, operational limitations on the dredge, such as working in non-overflow mode or stopping the dredge to reduce turbidity, would prolong the period of dredging two fold and three fold, respectively, resulting in a significantly longer period of operation and prolonging the period of impact, with little reduction of turbidity concentrations at the sensitive receivers. This was demonstrated through additional modelling undertaken at the request of agencies. From this, the first clear management measure was identified, that is, to undertake the works in the quickest possible timeframe in overflow mode, with the dredge not directed to stop at all throughout the campaign. The following describes the development of approval conditions for two examples that is, hydrodynamic modelling and the definition of sensitive habitats.

2.3.2 Hydrodynamic Modelling of Water Quality Impacts

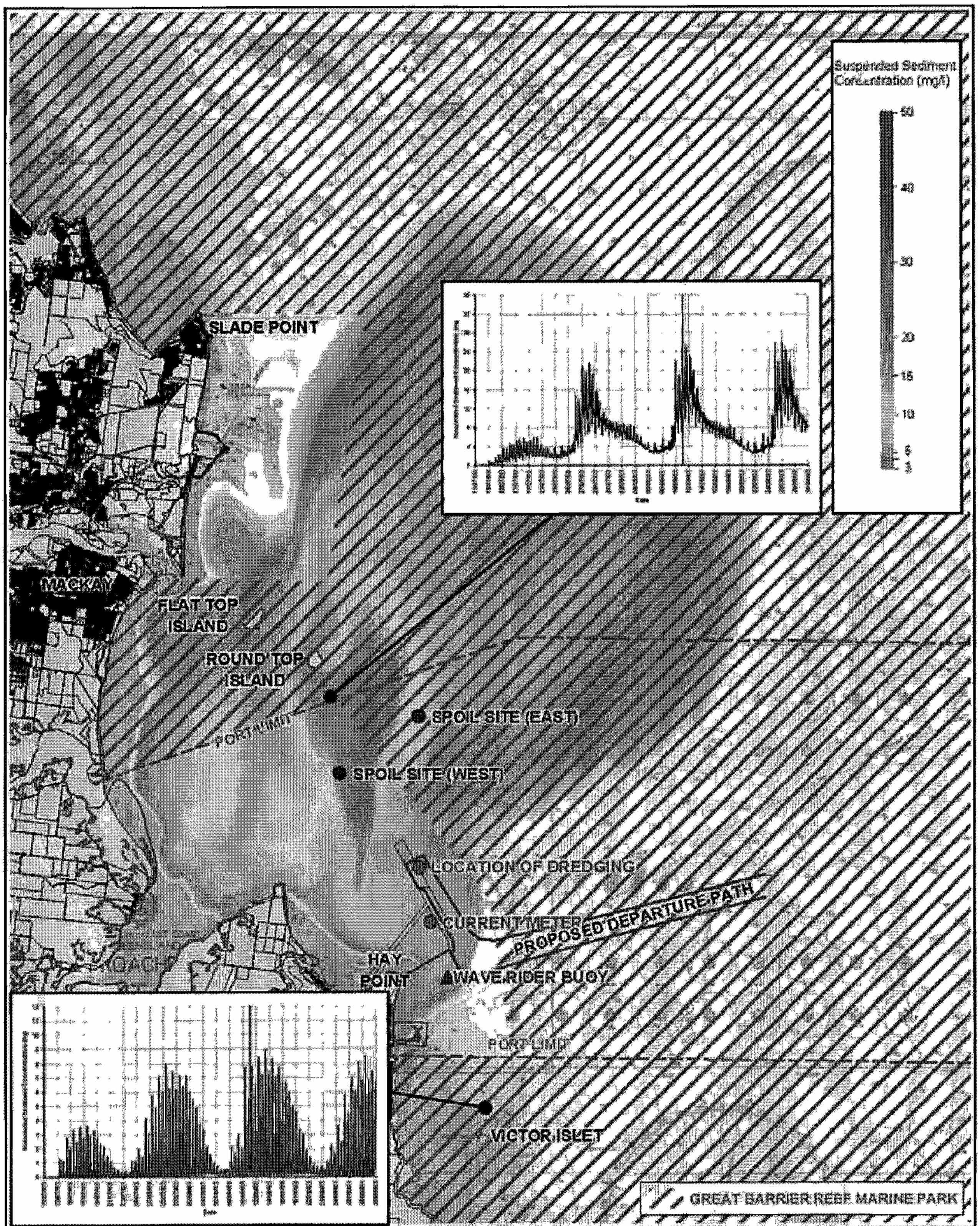
Dredging increases water turbidity and relocation of dredged material to an offshore site can spread the plume over a greater area (Clark 2001). The approach to developing the hydrodynamic model for the project was to predict the spatial extent of impact from turbid plumes as well as the concentrations of suspended sediments that would be experienced by biota through the reduction in available photosynthetic light and through physical smothering of deposited dredge sediments. This approach enabled the project team to predict turbidity related impacts and develop management and mitigation strategies prior to the commencement of the project and occurrence of impacts. The focus was on the dredging process to enable a responsive approach to management. As part of the predictive monitoring approach, mitigation measures based on tolerance values were developed for sensitive habitats and then used to develop management responses.

The key was developing a model which accurately represented natural tidal conditions and hence sediment movement within the study areas. Prior to completing modelling scenarios, the model assumptions were also presented to agencies to ensure acceptance of the outcomes (Fryar *et al.* 2005). The model provided a means to assess the following:

- Prediction of the currents and hence how a sediment plume may behave;
- Prediction of sediment deposition during dredging and disposal; and
- The potential for sediment resuspension.

The results of the hydrodynamic model were then used to assess, amongst other things, the sedimentation and turbidity as a result of dredging activities and consequently potential impacts on marine flora, fauna and biological processes within the study area. Figure 3 shows the predicted extent and level of concentrations of suspended sediment expected at Round Top Island following 31 days of constant dredging.

Figure 3 Predicted extent of plume for highest concentrations at Round Top Island (GHD 2005b)



GHD MANAGEMENT ENGINEERING ENVIRONMENT

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North

METRES

Source information: PCQ and Chart AUS 249, Australia East Coast Approaches to Hay Point to Mackay

Port of Hay Point Capital Dredging

Sediment Plume After 31 Days of Dredging Worst Condition for Round Top Island Dredging at Apron & Dumping at Spoil Site (East & West) During Spring Tide Cycle

PCQ Ports Corporation of Queensland

2.3.3 Defining and Understanding Sensitive Habitats

The Hay Point area is a harsh environment for corals and other reef organisms. Spring tides range from 6 to 7 metres and currents are strong in shallow waters, resuspending fine silt. Three fringing reef communities were identified at Flat Top and Round Top Islands to the north of the port and Victor Islet to the south (Figure 1). The three islands are fully exposed to the predominant SE winds.

Detailed benthic surveys of each island community were undertaken following consultation with GBRMPA to agree appropriate methodologies. Results showed a number of features of the marine communities that suggested the water conditions were typically highly turbid. Furthermore, there was a presence of a number of coral species common on fringing reefs south of the GBRMP region and on Lord Howe Island, but normally rare on the GBRMP. These corals are more common in cooler climates and often occur in higher turbidity environments.

A comparison of coral cover on the three Hay Point island reefs with other fringing reefs in the GBR region was undertaken to assist in establishing their regional value. Hard coral cover on these reefs was generally lower, hence it was determined they were not regionally significant and the loss of coral cover due to the project would not have an adverse impact on the regional values of the habitat.

This information provided an important input to the risk assessment for the project undertaken by the GBRMPA, which later led to the definition of approval conditions relating to acceptable limits of mortality within the coral communities (PCQ 2007). Figure 4 is an example of a reef community present at Round Top Island.

Figure 4 Acropora species at Round Top Island (GHD 2006c)

Previous dredging approvals for the Port of Hay Point had been subject to conditions which included arbitrary turbidity values which would trigger the requirement to either amend the dredging practice or cease operation. This condition was not scientifically based and was onerous in terms of the monitoring required to ensure trigger values were not exceeded and the costs incurred if works had to be modified or ceased. Through detailed survey of the sensitive habitats which were being sought to be protected, the sole implementation of arbitrary trigger values was proven to be ineffectual as a determinant of potential impact.

In negotiating approval conditions for Hay Point, the EIA sought to recognise that water quality values should be an 'early warning' and management mechanism for monitoring sensitive habitats. It was clear that the use of water quality trigger values as a compliance trigger does not work on its own as it does not measure the impact on biota. Rather water quality is better utilised as a management measure to trigger monitoring of sensitive habitat to determine actual impact on biota.

Solely applying a water quality trigger level for suspended solids in sensitive areas, which required dredging practices to be modified, was also shown to be ineffectual. Management measures such as stopping the operation of the dredge were modelled with the results demonstrating that depending on tidal conditions, the suspended sediment may stay in the water column for an extended period of time even if dredging had ceased. It was concluded that the most practical measure to minimise potential long term impacts was to minimise the duration of dredging, that is, once dredging commenced, it should be completed as quickly as possible to minimise the period of stress on sensitive habitats and allow natural recovery. These aspects were important elements in defining conditions for water quality monitoring.

The EIS placed the focus of monitoring on the habitat being protected, rather than the water quality. However, the focus of a number of agencies remained on the implementation of water quality trigger values, as this was the traditional approach to managing dredging projects. This ultimately led to performance criteria being included in the EMP which adopted the predicted maximum turbidity values, based on modelled outcomes for Round Top Island and Victor Islet, as water quality indicators.

On 6 July 2006, after dredging had commenced, the MRG determined that a trigger level of 100 mg/L (based on a 6 hour rolling mean) be adopted for the remainder of the dredging campaign, whereby exceedences triggered further investigation by the group into the dredging activities and potential impact on coral. This trigger was adopted after trigger levels identified in the EIS were determined to be unrealistic.

2.3.4 Integrated Approval Conditions

Key risks to the successful delivery of the dredging project related to the achievement of timely approvals which comprised implementable conditions. These risks are generally common to most major projects.

Prior to commencement of dredging, a suitable dredging contractor needed to be identified. Given the size of the Hay Point project, this required the engagement of one of the world's largest dredges to be sourced from overseas. To secure a suitable contractor, major project approvals were required to be finalised in early 2006 to allow dredging to commence by 1 May 2006. With these constraints as the key drivers for the project, it was quickly recognised that a standard approach to the project would fail to achieve the tight timelines and. Developing and implementing innovative solutions to delivering approvals was at the forefront from the commencement of the project .

The approach to achieve the desired outcomes for the project was to work closely with approval agencies. Working collaboratively with regulatory agencies through the development of the EIS resulted in:

- Consistent, simplified permits without overly prescriptive or unworkable conditions;
- Permits tied into a single EMP document for managing the project;
- Approvals that clearly reflected the stakeholder's environmental objectives; and
- Integration of approvals within a clearly implementable framework.

The collaborative approach was also effective in ensuring that recommendations and measures identified in the EIS were effectively transferred into the development approval. Where this approach does not occur, EIS recommendations are generally not reflected in approval conditions (Tinker *et al.* 2005).

2.3.5 Environmental Management Plan

Monitoring forms an important part of project management to ensure that impacts are as predicted, that unintentional harm to the marine environment is being avoided and to provide reassurance to other users of the port and sea (CEFAS 2003). An important outcome of the approvals process was that the project EMP (GHD 2006a) identified engineering, technical and economic constraints which had been identified at the commencement of the EIS process and considered throughout the assessment. The EMP outlined mitigation strategies to protect flora, fauna, water quality, cultural heritage and the social environment, and detailed integrated and innovative monitoring programs to be undertaken to assess potential environmental impacts and investigate long-term effects (GHD 2006a). These programs included:

- Coral condition monitoring of fringing reef communities at Round Top Island and Victor Islet.
- Water quality monitoring program involving telemetry based water quality loggers and vessel based turbidity monitoring.
- Deepwater seagrass and algae community distribution at Hay Point.
- Survey of areas proposed for dredging and the proposed material relocation site for targeted introduced marine pests.
- Hydrodynamic model validation program

The primary focus of the monitoring program was:

- To identify environmental impacts associated with dredging activities through quantitative assessment of water quality and sensitive marine communities.
- To develop a set of trigger values so that management could respond in a timely and effective manner

3 Project Implementation

3.1 Management Reference Group (MRG)

A Management Reference Group (MRG) was established to monitor and review the outcomes of the monitoring programs and determine appropriate action in the event of an exceedence. The group comprised regulatory agencies (GBRMPA, DEW, DPIF, EPA, QPWS), PCQ and their environmental consultants (Trimarchi 2007).

The objectives of the group, based on the National Ocean Disposal Guidelines for Dredged Material (NODGDM) (EA 2002), were to:

- provide continuity of direction and effort in protecting the local environment;
- aid communication between PCQ and regulatory agencies, and provide a forum where points of view can be discussed and conflicts resolved;
- review ongoing monitoring and management of dredging and dumping activities in accordance with the permitting arrangements; and
- make recommendations and give directions to PCQ as necessary with regard to environmental monitoring and management during the campaign, in particular, action required in the event of greater than predicted impacts.

The MRG met on a monthly basis, as a minimum, to review the project's progress and the results of the monitoring programs. Each MRG member was provided with access to a specific project website (GHD's "ClientNet"), where all monitoring data and reporting information was posted as soon as it became available. This allowed the MRG members to access up-to-date project information at all times (Trimarchi 2007). Changes in the level of reporting required throughout the project were a result of MRG intervention.

3.2 Water Quality Monitoring

3.2.1 Approach

The closest principal sensitive habitats of the study area were two fringing coral reef communities located at Round Top Island and Victor Islet, to the north and south of the port respectively. These reef communities were recognised to be at potential risk from dredging due to the migration of the dredge plume. Sediment plumes increase turbidity within the water column, thus causing light attenuation (reduced light penetration). Through their association with zooxanthellae, corals rely on photosynthetic processes. Corals are thus sensitive to the migration of sediment plumes, especially in deeper water where they may already be near their limit of tolerance to low light conditions.

Both dredging and relocation of marine sediment can affect the water column (CEFAS 2003). Water quality monitoring for the capital dredging project was undertaken using two techniques to monitor the effects of dredging activities. Firstly, remotely operated telemetry based monitoring of the works was carried out for the first month prior to dredging, the full period of works and five months following dredging. The second component involved an intensive vessel-based monitoring program, which was conducted for a period of six weeks at the beginning of dredging. This vessel-based monitoring provided the necessary data to assist in the validation and refinement of the hydrodynamic model of plume dispersion and sedimentation, while quantifying the contribution of plume migration to water quality in the vicinity of the telemetry-based loggers.

3.2.2 Telemetry Based Monitoring

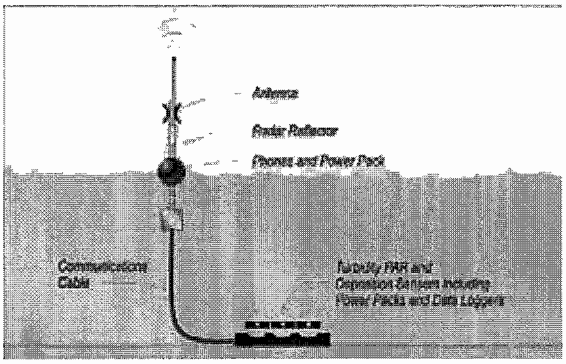
The water quality program established for the capital dredging campaign provided management with a unique coverage of key water quality parameters (TSS, PAR and deposition) through the application of telemetry based data acquisition (see Figure 5). The adoption of remote telemetry services allowed the collation of significant quantities of data from impact and reference sites established prior to the dredging campaign.

As part of the EIS background data was obtained from the impact sites of Victor Islet and Round Top Island prior to the commencement of dredging, spanning a period of approximately six months. This program resulted in a substantial dataset from both Round Top Island and Victor Islet (approximately 25,000 background sets of data).

During the dredging, approximately 100,000 data points were recorded for each of the following parameters: TSS, PAR and sediment deposition. In total, 300,000 individual readings were captured at between 10 and 20 minute intervals from the two impact locations (Round Top Island and Victor Islet) and two reference locations (Slade Islet and Keswick Island).

Data from each telemetry site was downloaded remotely daily from Monday to Friday each week using a mobile phone fitted with a data cable. Raw data was obtained using Microsoft Hyperterminal communications and each logger had a unique mobile phone. Once downloaded, the raw data was copied directly into an Excel spreadsheet. The time and date for the recordings was then added. The loggers and phones were interchanged during periodic maintenance and re-charging. As each instrument had different calibrations, care was taken to incorporate the logger numbers with each set of downloaded data. This ensured that the correct instrument calibrations were applied when reporting raw data as TSS (mg/L).

Figure 5 Schematic of telemetry communications and water quality sensors (GHD 2006a)



3.2.3 Vessel Based Monitoring

Examination of the formation, migration and dispersion of sediment plumes was undertaken as a vessel-based program for six weeks at the commencement of dredging (10 May and 23 June 2006). A four week vessel based program was initially planned, but due to adverse weather conditions the program was extended to six weeks to ensure the recorded dataset was statistically rigorous. Vessel-based monitoring was conducted during daylight hours, over ebb and flood tides and spring and neap tidal phases. Monitoring stations were located within the plume at set distances from the dredging operation so that data delineated the direction, dispersion and migration of the plume to the vicinity of the coral reef communities at Round Top Island and Victor Islet.

Monitoring was undertaken at the following distances from the dredge.

- 250 metres from the dredge;
- 500 metres from the dredge;
- 1,000 metres from the dredge;
- 2,000 metres from the dredge;
- 4,000 metres from the dredge; and
- 6,000 metres from the dredge or immediately south of Round Top Island (ebbing tide) or north of Victor Islet (flooding tide), depending on the distance from the dredge to the sensitive habitat.

Additional monitoring was also undertaken at the following locations:

- At the telemetry based loggers and at two other sites on the reef slope; and
- South of Victor Islet on the flooding tide and north of Round Top Island on the ebbing tide.

On the ebbing tide, sites were located between the dredge and Round Top Island and on the flooding tide, monitoring sites were located between the dredge and Victor Islet.

On a flooding tide, monitoring commenced at Round Top Island and headed towards Victor Islet and on an ebbing tide, monitoring commenced at Victor Islet and headed towards Round Top Island. In this way, each site was monitored twice each day during daylight hours.

Water quality of the dredge plume was measured with a hand held YeoKal 611 Water Quality Analyser which measured turbidity, dissolved oxygen, pH, temperature and conductivity. Measurements were recorded *in situ* by lowering the logger by a cable down through the water column to pre-determined depths where measurements were recorded from the surface using the logger feature. Data was collected at the surface, middle and bottom of the water column with 10 replicate measurements taken at each depth. In all instances, the environment was not disturbed by deployment. Data was downloaded to a computer each day to prevent data loss. Turbidity data gathered during this program was utilised to validate the hydrodynamic model established for this project. This data also provided evidence as to the role of the plume in validating water quality measured by telemetry-based loggers located at fixed locations adjacent to coral communities.

3.3 Coral Habitat Monitoring

3.3.1 Overview

Babcock and Davies (1991) state that sedimentation can affect reef-building communities. It was identified that the communities at Hay Point would experience sedimentation from dredging and material relocation, as well as reduced light. As sediment plumes migrate, particles fall out of suspension, causing a depositional footprint that may extend beyond the boundary of the dredge area and material relocation site. Corals and other organisms deal with moderate rates of sediment deposition as a normal phenomenon in shallow coastal waters, however, when rates of sediment deposition are inordinately elevated, these organisms may become smothered.

The project EMP (GHD 2006a) included a coral condition monitoring program, which examined the physicochemical and biological processes that best defined the interaction between dredging, water quality and coral reef condition. In doing so, the program detected acute and chronic impacts and shifts in community structure of the fringing corals reefs during dredging, and thus guided the implementation of timely and well-directed management responses. The coral condition monitoring program examined:

- Diversity and abundance of benthic communities and fish;
- Percentage of coral bleaching;
- Percentage of coral mortality;
- Percentage of mucus production in *Porites* colonies;
- Rates of sediment deposition on corals (measured in mm); and
- Rates of sediment deposition (dredged derived) on substratum (measured in mm).

3.3.2 Locations

Fringing reefs were surveyed around two small near-shore island impact sites. Victor Islet was 6.5 kilometres to the south, while Round Top Island was about 12 kilometres to the north (Figure 1). Surveys were also conducted at two reference locations: Slade Islet and Keswick Island approximately 21 kilometres north and 37 kilometres north-east of the port, respectively.

3.3.3 Monitoring Frequency

The program comprised a baseline survey of coral condition, diversity and abundance at the o impact and reference locations prior to the start of dredging (19-27 April 2006). This survey was followed by fortnightly monitoring of coral condition at impact locations for three consecutive surveys and concluded with a fourth fortnightly full survey of impact and control locations. The frequency of subsequent monitoring was evaluated after this time by the MRG. Two post-dredging surveys were also completed after the cessation of dredging work on 17 October 2006. Table 1 provides a summary of the frequency and extent of each survey.

Table 1 Monitoring program survey components carried out during the different surveys

Survey date	Base line	May 20	Jun 1	Jun 21	Jul 1	Jul 29	Aug 16	Sep 21	Oct 15	Nov 25	April 2007
Impact (I) or reference (R) sites surveyed	I+R	I	I	I	I+R	I	I	I+R	I	I+R	I+R
Benthic line intercepts	X				X			X		X	X
Bleached intercepts	X	X	X		X			X		X	X
Porites mucus	X	X	X	X	X	X	X	X	X	X	X
Sediment on corals	X	X	X	X	X	X	X	X	X	X	X
Substratum sediment				X	X	X	X	X	X	X	X
Damaged coral counts		X	X	X	X	X	X	X	X	X	X
Fish counts	X				X			X		X	X

X indicates that component was carried out during that particular survey. Shading represents surveys undertaken during dredging

3.3.4 Benthic Line Intercept Surveys

Abundance surveys of the marine communities surrounding the four islands were undertaken at six sites around each island respectively. Four 20 metre, randomly positioned, line intercept transects were identified within a narrow depth stratum along 50 metres of reef. The cover of major benthic reef organisms was then recorded at each site. The depth range for the surveys at each site depended on the depth of the reef and the stratum where corals were most abundant (Table 2).

The transects were permanently marked with 12 millimetre reinforcing rod stakes driven into the seabed bottom at 5 metre intervals. The survey tapes were stretched tightly between the stakes close to the substratum and all benthic organisms directly below the tape were measured.

Table 2 Depth ranges of survey transects at the different sites

Site	Round Top	Victor	Slade	Keswick
1	-2.5 to -4.5	-2.0 to -3.5	-3.0 to -4.0	-0.5 to -2.5
2	-1.5 to -2.5	-1.0 to -2.0	-1.0 to -2.5	-2.0 to -4.0
3	-4.0 to -6.0	-2.0 to -3.0	-1.5 to -3.0	-4.0 to -6.0
4	-4.5 to -6.5	-2.0 to -3.0	-2.0 to -2.5	-1.5 to -3.5
5	-5.0 to -7.0	-2.0 to -3.0	-0.5 to -1.5	-1.5 to -3.5
6	-4.5 to -6.5	-0.5 to -2.0	-3.5 to -4.5	-2.0 to -4.0

Depths refer to metres below (-) Lowest Astronomical Tide.

Intercept lengths for all colonies of a species or benthic group along each transect were totalled and converted to a percentage cover measurement. The following organisms or groups of organisms were recorded: algae, sponges, hard corals identified to species level (or to growth form if more appropriate) and soft corals. These techniques have been used in many other surveys of fringing and offshore reefs in the GBR region (Mapstone *et al.* 1989; Ayling and Ayling 1995; 2002). Line intercept surveys were undertaken during the baseline and at all full surveys during dredging. Sedimentation on corals and seabed was measured by divers using a ruler (mm)

3.3.5 Power and Cost Effectiveness of the Design

An important aspect of the design phase of the monitoring program was to ensure that the survey design was both statistically valid and provided some rigour. The power of monitoring designs has previously been investigated for a number of similar fringing reef monitoring programs within the GBR (Mapstone *et al.* 1989).

A dominant feature of the permanent transect based methodology adopted for the Hay Point coral monitoring was that it was able to detect changes between means from 5-20% with at least 90% power (Mapstone *et al.* 1989).

This design also provided cost effectiveness which was an important consideration of the project. It enabled a minimum number of sites to be surveyed that would provide statistical power and rigour the program.

3.4 Seagrass Monitoring

In general, seagrass habitats in the tropics are influenced by frequent disturbance and are spatially and temporarily variable (Waycott *et al.* 2004). Little is known about the dynamics of deepwater seagrass and algae communities found in the Port of Hay Point or the role they play in primary and fisheries production (DPIF 2005 in GHD 2006a).

Potential impacts on marine plants from dredging include direct removal, burial at the material relocation site, loss due to the turbid dredge plume, reduced light and sedimentation (Clark 2001; Erftmeijer and Lewis 2006).

At the direction of the Coordinator-General, PCQ were required to implement a monitoring program investigating the potential impact of the project on deepwater seagrass and algae in the port (Trimarchi 2007). This research project aimed to fill some gaps in the existing knowledge on how these deepwater habitats change naturally through time, their role in fisheries productivity and their resilience and capacity for recovery from disturbance associated with dredging (DPIF 2005 in GHD 2006a).

The marine plant monitoring program was developed and carried out by DPIF and comprised two pre-dredge surveys (December 2005 and March 2006), monthly surveys throughout dredging (May to October 2006) and six post-dredging surveys (November to December 2006, March, June, August and November 2007). Two impact and two control sites were sampled during each survey, with nine x 100 metre transects per site (three replicate areas within each site, containing three x 100 metre transects). Sampling was undertaken through replicate video transects developed by DPIF for analysis of deepwater seagrass and benthic communities (Rasheed *et al.* 2004; 2001; Coles *et al.* 2000). Data recorded at each site included seagrass species and composition, seagrass biomass and algae.

Beam trawling for fish and invertebrates in seagrass meadows was also undertaken in conjunction with seagrass sampling during the pre-dredge surveys, then every three months throughout dredging and post-dredge surveys.

Seagrass that had previously been identified in the port in July 2004 was no longer present during the pre-dredge baseline survey undertaken in March 2005. No seagrass was identified during the monthly surveys conducted during dredging and the density of macro algae decreased (from 5 % cover during baseline) as dredging progressed. Seagrass was identified in the November 2006 post-dredge survey at the inshore control site near Victor Islet. This seagrass however, was not present during the January 2007 survey but returned by the time of the July 2007 survey (Rasheed pers.com 2007).

3.5 Introduced Marine Pests

Marine pests can be introduced via ballast water and hull encrustations and can consequently have a negative effect on the environment (Zann 2000).

To minimise the risk of introducing marine pest species, the *WD Fairway* was slipped in Shanghai and cleaned prior to sailing to Australia to undertake the Hay Point Capital Dredging Project. The Bureau Veritas (International Register for Classification of Ships) Marine Branch provided an attestation on 27 March 2006, that on completion of the maintenance, a visual inspection was undertaken and no evidence was found of marine growth on the underwater side of the ship. Furthermore, the *WD Fairway* complied with all the Commonwealth requirements for ballast water management to minimise the risk of introducing marine pest species (Trimarchi 2007).

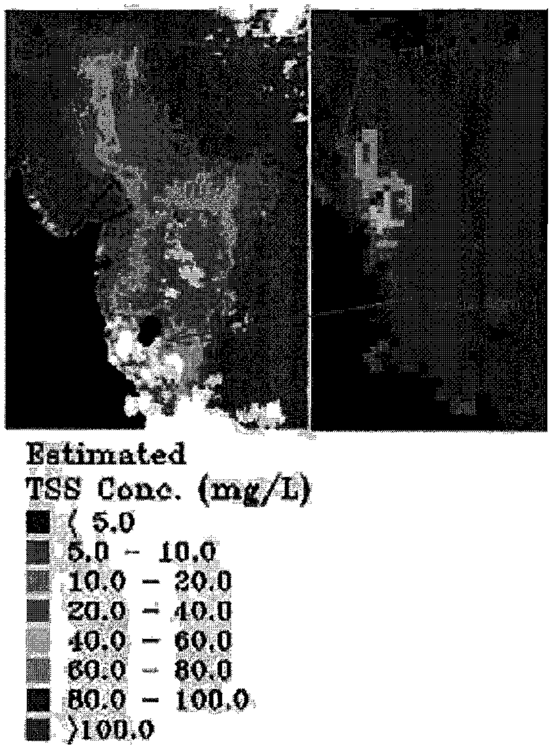
As directed by the Coordinator-General, PCQ was required to implement a strategy to further reduce the risk of the introduction and spread of marine pest species. As detailed in GHD (2006a), DPIF developed and undertook an introduced marine pests monitoring program for targeted marine pests of concern, involving a survey of soft sediment habitats in areas to be dredged and at the material relocation site. The aim of the program was to provide reliable data on the presence, prevalence and distribution of any targeted marine pests of concern that may be present prior to the commencement of any works, as well as after dredging. The survey was designed to comprehensively cover a range of sites that were representative of the entire area proposed for dredging and material relocation (Stafford 2006). Sampling was undertaken using benthic sleds and grabs, and the targeted species were based on published knowledge of what pests may occur and typical species density (DPIF 2006 in GHD 2006a).

No introduced marine taxa were found to be present in any of the samples collected during the March 2006 survey and the risk that dredging activities would collect exotic taxa and transfer them to the material relocation site was low (Stafford 2006). Preliminary results from the post-dredge survey undertaken in April 2007 did not reveal any introduced marine pests (Rasheed pers.com 2007).

3.6 Remote Sensing

As part of a pilot project and in addition to the comprehensive water quality monitoring program implemented throughout the dredging campaign, the spatial distribution of total suspended solids (TSS) was monitored by Geoscience Australia using satellite remote sensing (Wang *et al.* 2006) at the recommendation of GBRMPA personnel. TSS maps were generated from Landsat and MODIS imagery for specific time periods. The use of satellite technology in combination with field monitoring was useful in aiding communication and management as it provided the 'big picture impact' of the plume (Wang *et al.* 2006). Figure 6 shows an example of a TSS map generated from Landsat 5 and MODIS imagery.

Figure 6 Estimated TSS map generated from Landsat 5 (left) and MODIS (right)



Source: Wang *et al.* 2006

4 Consultation

4.1 Introduction

The consultation process for the project aimed to facilitate the active participation of stakeholders and the community in the project, whereby their ideas, views, issues, concerns and interests were taken into account, and the participants were kept informed about how their input influenced the project.

In order to identify the communications and interactions for the project, a stakeholder consultation plan was developed during the EIS phase. The plan identified key stakeholders and detailed the media protocol, risk and issues management plan, consultation action plan, consultation materials and progress reporting.

Stakeholders identified included:

- Commonwealth agencies including DEW, GBRMPA and CSIRO.
- State Government Departments including, EPA, DPIF, Maritime Safety Queensland (MSQ) (Regional Harbour Master), Queensland Parks and Wildlife Service (QPWS) and the Office of the Coordinator-General.
- Sarina Shire Council (elected representatives and officers).
- Environment/conservation groups (Mackay Conservation Group, Mackay Turtle Watch).
- Social/community/recreational fishing groups (Sunfish (Mackay), Queensland Seafood Industry Association).
- Traditional Owners (Yuibera, Wiri # 2).
- Tourism industry and professional associations (Mackay Whitsunday Regional Economic Development Corporation).
- Marine industry and professional associations.
- Industry, including the coal terminal lessees (BMA, DBCT, BBI).
- Media.
- General community (Community Reference Group representatives).

The aim of the consultation process was to raise awareness and understanding about the project, provide information to key stakeholders and other members of the community on the project, seek stakeholder and community participation, input and feedback and incorporate such feedback into the project.

4.2 Technical Advisory Consultative Committee (TACC)

In addition to the establishment of the MRG who had a management and regulatory role in the project, a Technical Advisory Consultative Committee (TACC) was established which enabled PCQ to consult with community representatives and other stakeholders (Trimarchi 2007). Membership was drawn from relevant Commonwealth, State and local Government and non-Government organisations with expertise, responsibilities or interest in the dredging of the port. The objectives of the TACC, in accordance with the NODGDM (EA 2002), were to:

- provide continuity of direction and effort in protecting the local environment;
- aid communication between stakeholders and provide a forum where points of view can be discussed and conflicts resolved;
- assist in the establishment, as appropriate, of longer term permitting arrangements;
- review ongoing management of dredging and dumping activities in accordance with the Guidelines and permitting arrangements; and
- make recommendations to PCQ and DEW as necessary or appropriate.

The group was initially formed during the EIS. After approvals were obtained, the primary regulator representatives from the TACC formed the MRG to collectively manage and monitor the project. The TACC was kept as a consultative committee with other stakeholders. PCQ held TACC meetings at Hay Point throughout the development of the EIS and the dredging itself.

TACC members were provided with the opportunity to undertake aerial surveillance of the works in order to obtain a better understanding of the dredging occurring in their local area. This proved to be a very useful mechanism for engaging the local community and stakeholders (Trimarchi 2007).

One of the strengths of the TACC was receiving feedback on what was being discussed about the project in the local community. Response from the TACC on the dredging project was positive, in particular with regards to PCQ's community consultation and monitoring efforts.

4.3 Community Liaison

Traditional Owners of the Hay Point area were identified early in the project (Yuibera and Wiri # 2) and consulted throughout the EIS process. No major cultural heritage issues were identified in the EIS however, a Cultural Heritage Management Plan (CHMP) was developed and signed off between the parties in order to protect the interests of the Traditional Owners throughout the project. Traditional Owners were provided with monthly progress reports which included details of dredging, monitoring and management activities. One Elder undertook a visit on the *WD Fairway* to obtain a better understanding of the project and dredging operations (Trimarchi 2007).

Project newsletters were made available on the PCQ and GHD websites and distributed to the stakeholders in the Mackay and Sarina regions in order to inform local residents about the project. The newsletters were also distributed through the local paper, letter box drops, targeted mail outs and via fishing organisations, and fishing and tackle shops. Furthermore, project staff manned an information stall at the 2006 Sarina and Mackay Exhibition shows to answer any questions the community had about the project. PCQ received positive feedback on the extensive and effective consultation undertaken throughout the project (Trimarchi 2007).

5 Environmental Review

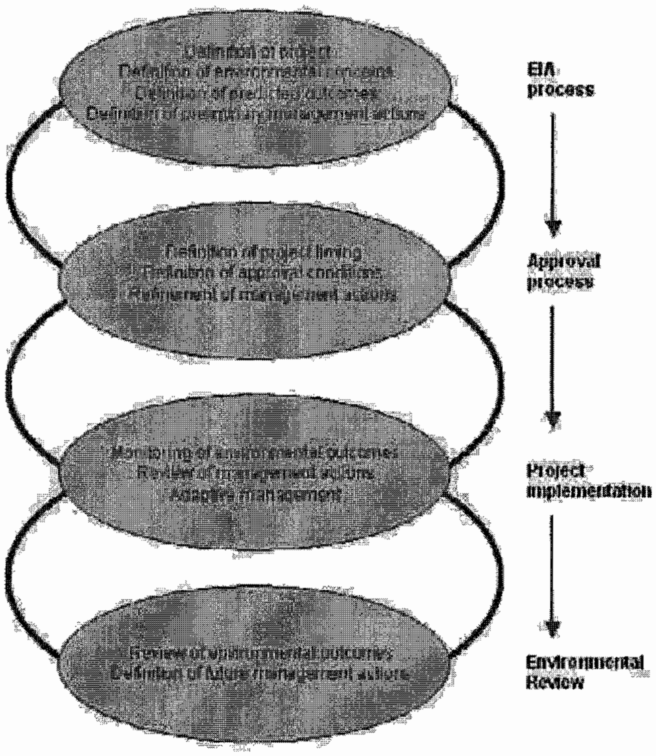
5.1 Overview

Environmental review is a process of examining the outcomes of a project to evaluate the accuracy of predictions made during the environmental assessment process. Also referred to as environmental follow-up, the process is becoming increasingly implemented as a component of best-practice management and as a regulatory requirement (Marshall *et al.* 2005).

Whilst environmental review was not a regulatory requirement of the Hay Point Project, the project EMP included elements of review. The implementation of the EMP included undertaking a number of studies which would provide an assessment not only of compliance with the approval conditions, but effectively review the predictions of impact included in the EIS. This provides a critical feedback loop and enables learning to occur from experience. The role of the MRG, in continued review and adoption of management actions, also acted as an environmental review throughout the implementation of the project. Further, review of the EIS has since been conducted, through development of this Monograph, to provide a more detailed assessment of the outcomes of the EIS and also provide learnings for future projects.

As shown in Figure 7 environmental review effectively closes the loop on the environmental assessment process, ensuring that it is not the predicted outcomes that are relied upon, but the actual outcomes of the project are evaluated which can then provide effective mechanisms for future assessment and management of environmental impacts. Further, it is the real outcomes of a project that are relevant for protecting the environment (Marshall *et al.* 2005).

Figure 7 Environment review and learning



Source: Keane forthcoming

5.2 Water Quality Outcomes

5.2.1 Overview

Cognetti and Maltagliati (2005) state port environments in general are subject to unpredictable conditions due to various factors such as wide variations in physio-chemical parameters, including water turbidity. Water quality parameters for the dredging project were analysed against factors such as wind speed, wave height, tide, dredge location and volume to determine whether these factors had a significant influence on water quality, particularly at the impact sites. By determining factors that have a significant impact upon water quality, management actions can be refined in future to minimise deleterious effects on marine biota.

5.2.2 Turbidity (NTU) and TSS (mg/L) Correlations

Water quality outputs from the model were in mg/L however, the telemetry loggers recorded turbidity in NTU. In order to enable comparison of the two it was necessary to determine a correlation factor.

An objective of the vessel-based water quality program was to verify the accuracy of the turbidity readings being recorded by the telemetry loggers. The telemetry loggers were equipped to record turbidity (NTU) which was then converted to mg/L once the data had been downloaded. To ensure telemetry logger turbidity (NTU) readings were being accurately converted to TSS (mg/L), a range of water samples were collected during the vessel-based monitoring program for laboratory for analysis of TSS. At each sample site, a set of turbidity readings were recorded for comparison to the laboratory results.

Regression analysis of the laboratory results identified a significant correlation between TSS and turbidity (Figure 8). TSS in mg/L could therefore be calculated using the relationship formulae:

TSS = 0.9942 + 0.4768*NTU

Or in simple terms 1:2.2

Given that the regression analysis of NTU and TSS samples collected from the boat resulted in a very low coefficient r^2 value of 0.28 it was identified that further logger calibration was required.

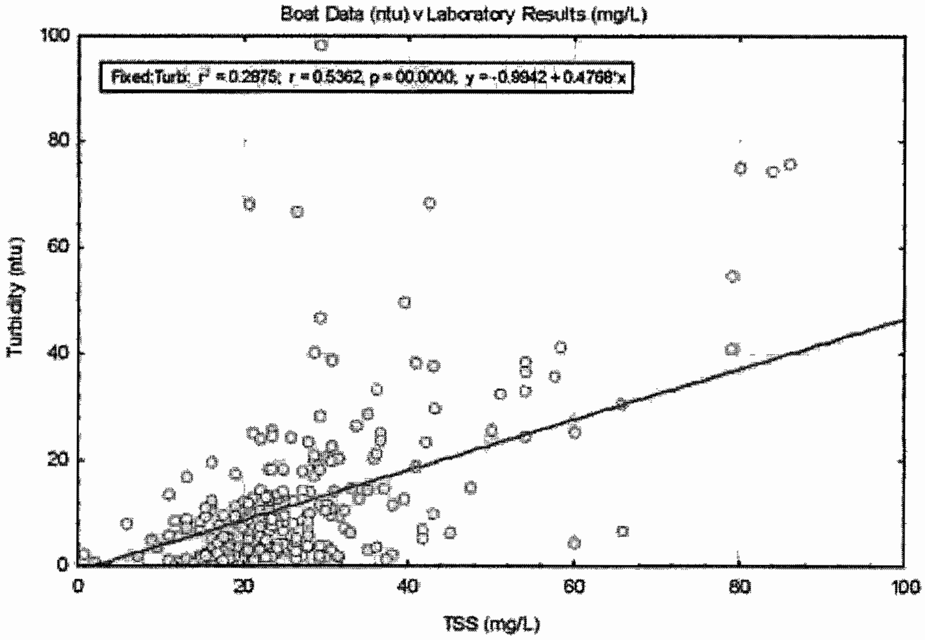
Regression analysis of logger TSS data and boat turbidity and TSS data resulted in a r^2 coefficient of 0.7 respectively. On completion of this assessment, a factor of 2.2 was applied to the turbidity (NTU) data for conversion to TSS (mg/L) for each telemetry logger. This assisted in ensuring that all loggers were calibrated accurately for the duration of monitoring.

5.2.3 Interaction Between TSS and Light Levels

The interaction between TSS and light was investigated to determine whether there was a significant relationship between these variables. Linear regression analysis of the effect of TSS on light levels (day time readings only) during the first eight weeks of dredging indicates that TSS has a significant negative impact on light readings at Victor Islet ($F=144.94$, $p<0.0001$) and Round Top Island ($F=59.58$, $p<0.0001$).

This information confirms that if turbidity increased there was a corresponding significant decrease in light levels caused directly by the suspension of sediments, whether directly from the plume or mobilisation of previously deposited sediments due to weather effects.

Figure 8 Regression analysis between hand-held turbidity meter (NTU) and laboratory results (mg/L)



5.2.4 Wind and Sea State Influences

Physical processes of sediment mobilisation and remobilisation maintain strong linkages with wind speed and sea conditions. Wind categories used to determine sea states have been formulated using Beaufort wind scale and Pierson-Moskowitz Sea Spectrum. Breakdown of the wind speeds and sea-states applied to the Port of Hay Point are shown in Table 3.

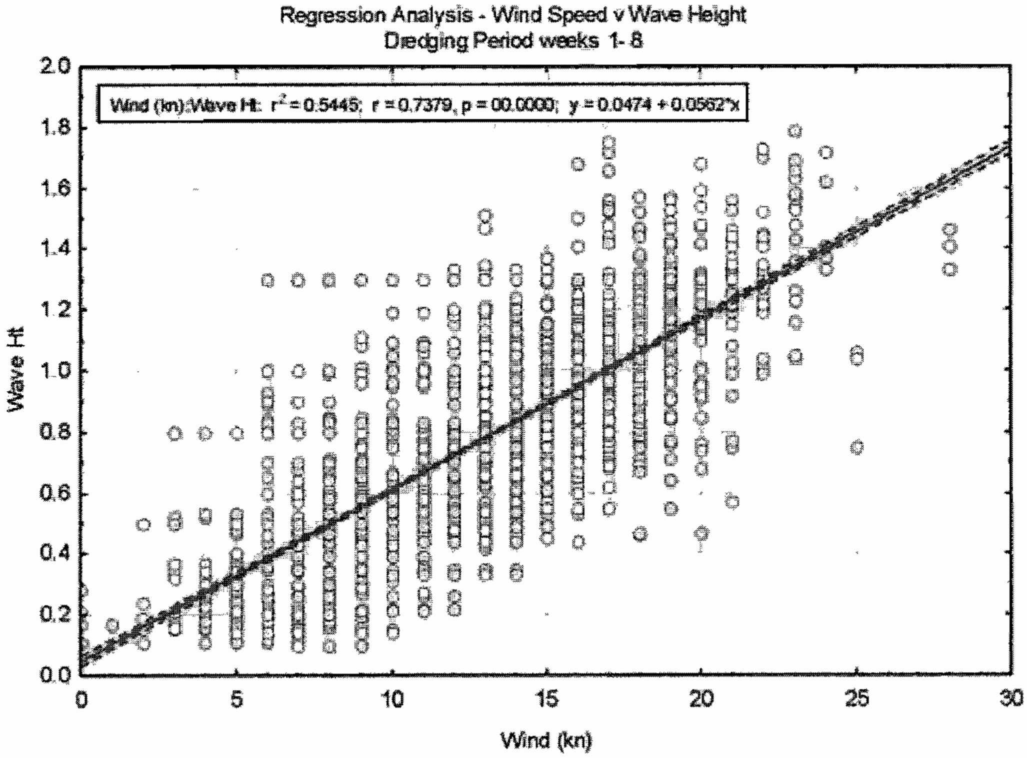
Table 3 Mean wind speeds (knots) used to determine sea-state and categorise weather conditions

State	Wind (knots)	Sea State
Calm	0 – 8	0 – 1
Slight	9 – 17	2 – 3
Moderate	18 – 20	4
Rough	21 – 25	5
Very Rough	25+	6 – 9

Modelling indicates that weather conditions such as wind speed, and corresponding sea state, can have an influence on plume dynamics in shallow water environments. Similarly, weather conditions will affect turbidity by keeping sediments in suspension or remobilising sediments that have settled, particularly in shallow water habitats. Increasing wind speeds cause increased sea-states and in combination, these features influenced observed turbidity levels. Data captured during the Hay Point campaign was analysed to demonstrate this relationship in shallow water environments as experienced at the fringing reef habitats of Round Top Island and Victor Islet. Linear regression analysis of wind speed (knots) against wave height (m) indicates that wind speed is indeed a significant determinant of sea state conditions within the study area (r^2=0.5445; p<0.0001). Figure 9 illustrates the relationship, with increasing wind speed causing deterioration in sea-state from calm to rough conditions.

While this relationship explains a significant proportion of the shared variability, it is important to note additional factors such as logger depth, spring/neap and ebb/flood tides, wind direction and site orientation, all influenced the observed results. Despite these factors, results clearly demonstrate the significance of wind and sea state interactions.

Figure 9 Plot of regression analysis between wave height (m) and wind speed (knots)



Note:
Solid line represents relationship between the variables with 95% confidence limits (dotted lines).

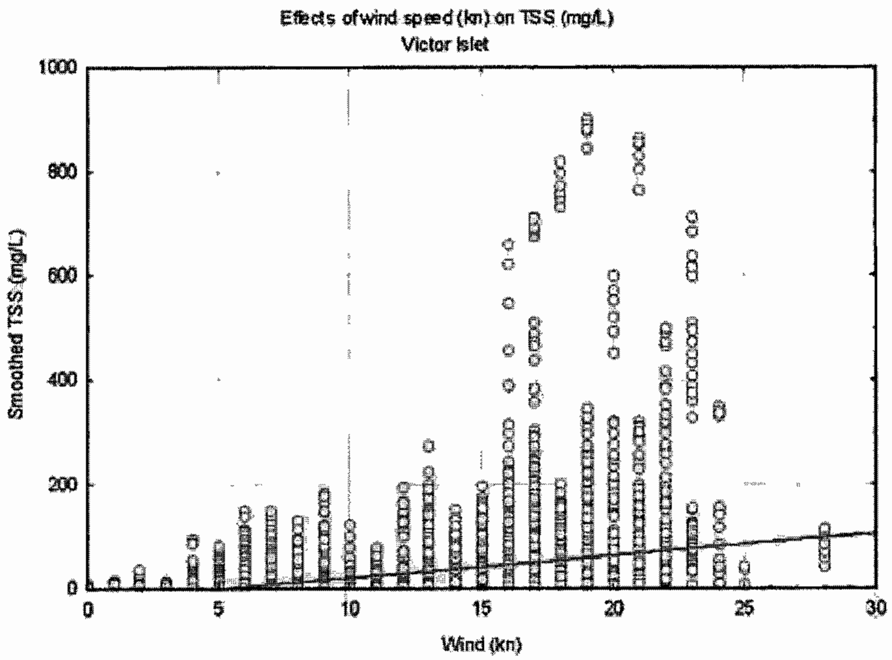
Effects of Wind on Water Quality

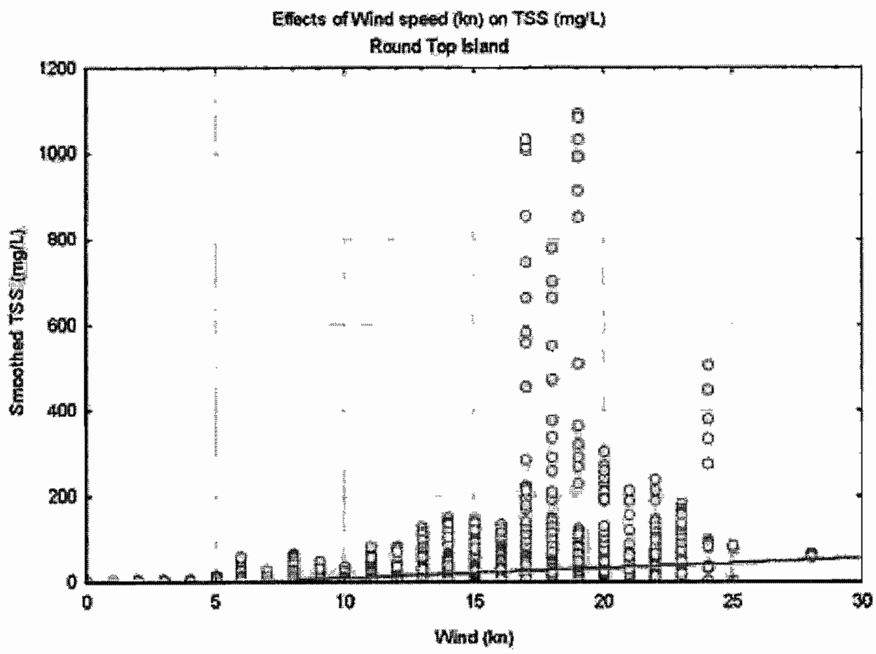
Wind speed data was recorded from the Bureau of Meteorology (BOM) weather beacon every 30 minutes. This data (in knots) was matched to TSS data recorded at the impact sites of Victor Islet and Round Top Island during weeks 1 – 8 of dredging. Linear regression analysis indicated that wind speed (knots) had a significant effect on TSS (mg/L) at Victor Islet ($F=1242.2$, $p<0.0001$) and Round Top Island ($F=784.97$, $p<0.0001$) (Figure 10). This confirms that wind speed is a significant determinant of TSS at both impact locations. Examination of the data indicates that there is a substantial increase in TSS when wind speed reaches 16 knots at Victor Islet and 17 knots at Round Top Island.

Wave Height on Water Quality

Wave height data (metres) was recorded from the EPA wave rider buoy at Hay Point every 30 minutes. This data was matched to TSS data recorded at the impact locations of Victor Islet and Round Top Island during weeks 1 – 8 of the dredging. Linear regression analysis indicated that wave height (metres) had a significant effect on TSS (mg/L) at Victor Islet ($F=2267.7$, $p<0.0001$) and Round Top Island ($F=652.97$, $p<0.0001$).

Figure 10 Effects of wind speed (knots) on TSS (mg/L) for impacts sites Victor Islet and Round Top Island





5.2.5 Tidal Effects on Water Quality

Spring and neap tidal phases exhibit distinctly different physical forces due to changed hydrodynamic conditions. Flux in tidal phase is considered important to understanding processes of mobilisation, remobilisation and deposition of fine sediments, both inside and outside the dredge footprint. To understand the differences in water quality between spring and neap tidal phases, summary statistics were calculated for both impact and reference site locations (Table 4). A calibration coefficient factor of 2.2 was used to convert turbidity to TSS (see section 5.2.2) and a 6 hour rolling mean was applied to the TSS data to reduce the impact of any anomalous data on the statistics.

Victor Islet experienced significantly higher TSS levels during neap and spring tidal phases when compared with all other sites ($p<0.0001$). Regression analysis indicates that during the dredging period, TSS at Round Top Island and Victor Islet was significantly higher during spring tidal phases compared with neap phases ($p<0.0001$). Total suspended solids concentrations at Round Top Island were not significantly different to the Slade Islet reference site during neap tides, but remained significantly higher during spring tides ($p<0.0001$). This result suggests that the transportation of dredge-derived plumes was more pronounced at Round Top Island during spring tides. It is likely that the higher TSS concentrations observed from Victor Islet can be attributed to a location-specific interaction between dredging activity and tidal phase.

Table 4 Summary of differences between tidal phases, pre-dredge and dredging conditions

Site	Neap		Spring	
	Mean TSS (mg/L)	**sd**	**Mean TSS (mg/L)**	**sd**
Pre dredging				
Victor Islet	5.96	1.66	18.34	28.84
Round Top Island	1.27	2.27	2.67	3.37
Dredging				
Keswick Island	4.44	6.87	5.74	10.43
Slade Islet	11.29	12.76	22.46	29.6
Victor Islet	16.28	18.99	54.61	92.41
Round Top Island	11.14	15.37	29.86	71.77

Note:
sd = Standard Deviation

5.2.6 Compliance Assessment

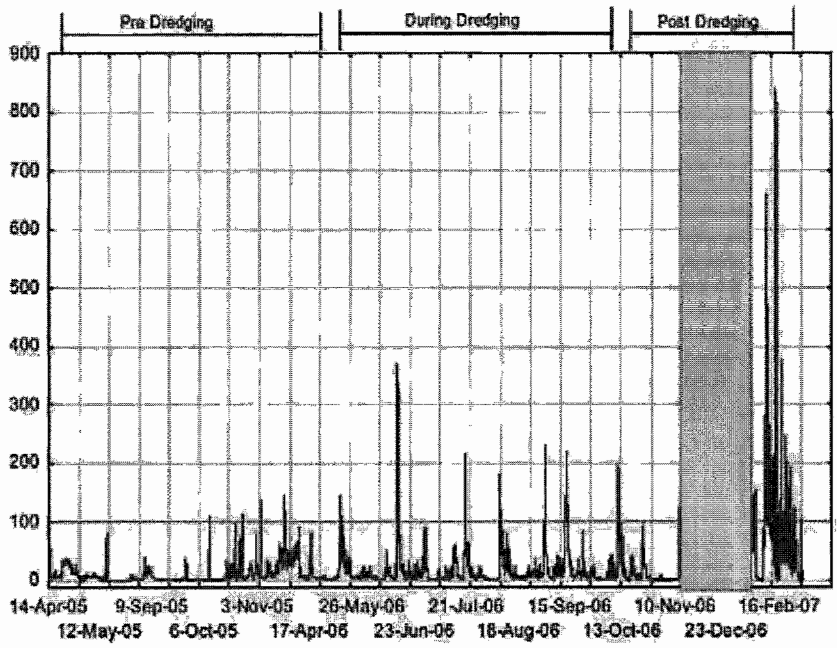
The TSS trigger value for the project was 100 mg/L for a period of at least six continuous hours. This trigger was determined by the MRG after initial triggers identified in the EIS were found to be unrealistic. This was an example of the MRG implementing adaptive management which enabled flexibility and the consideration of real time data to refine the water quality trigger. An assessment of all TSS data recorded pre-dredging, during dredging and post-dredging identified a total of 31 water quality trigger exceedences for Victor Islet (Figure 11) and none for Round Top Island (Figure 12).

All exceedences at Victor Islet were recorded during dredging and post-dredging. Six exceedence events were recorded during the dredging period, with a maximum duration of 20.6 hours over the 100 mg/L trigger level recorded on 11 October 2006, just before dredging ceased (17 October 2006). A total of 21 exceedences were recorded during the post-dredging period at Victor Islet. A maximum duration of 38.2 hours over the 100 mg/L trigger was recorded on 14 November 2006.

The non-compliance data has identified distinct differences in water quality between pre, during and post-dredging events at Round Top Island and Victor Islet. While it is not possible to conclude that dredging has caused any change to the number of TSS exceedence events at Round Top Island which recorded no events, it is clear that dredging did have some impact on the exceedence events at Victor Islet. This can be summarised by comparing the number of events between pre, during and post-dredging periods, which were four events, six events and 21 events, respectively.

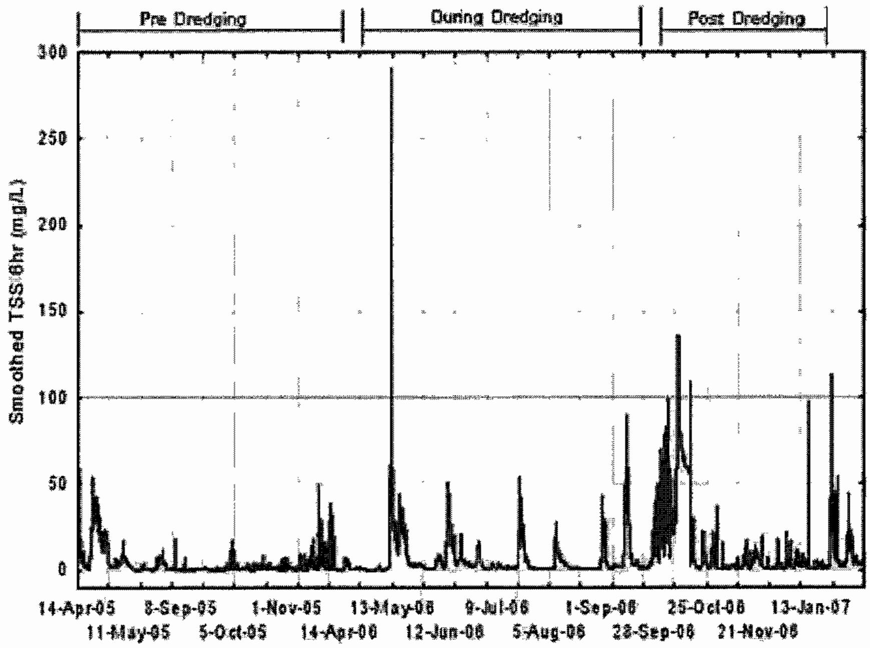
It is, however, surprising that there is a substantial increase in the number of non compliant events recorded post-dredging compared with during dredging. This is likely due to the localised hydrodynamic regime at Victor Islet causing the deposition and accumulation of fine dredged sediments and weather conditions observed during the post-dredging period. This, along with other observed differences in water quality both spatially and temporally at both logger sites, is discussed in more detail in section 5.2.7.

Figure 11 TSS concentrations (mg/L) recorded pre, during and post-dredging events at Victor Islet



Note:
*Graph represents all data and shows all 100 mg/L events including those events that exceeded 6 hours.
Red gridline represents 100 mg/L concentration.
Shaded area represents data removed from analysis due to issues with the function of the logger at the time.

Figure 12 TSS concentrations (mg/L) recorded pre, during and post-dredging events at Round Top Island



Note:
*Graph represents all data and shows all 100 mg/L events including those events that exceeded 6 hours.
Red gridline represents 100 mg/L concentration.

5.2.7 Analysis of Non-Compliance

Round Top Island

TSS data recorded at Round Top (Figure 13) shows differences in the duration of turbidity events ranging from >1 mg/L to >200 mg/L recorded during pre, during and post-dredging events. A one hour rolling mean was applied to all data provided in this section.

Results demonstrate a distinct increase in event durations for TSS concentrations >1 to >10 mg/L during dredging, with the mean duration ranging from 0.5 to 4 times that of the pre-dredging period for Round Top Island. Post-dredging mean duration events generally displayed a slight decrease in TSS range compared with the dredging period. The most substantial increase in mean duration during and after dredging was for TSS events >1 to >3 mg/L.

For TSS concentration events >20 mg/L, similar results were displayed for all three conditions although slight increases in mean duration were observed for events >80 mg/L and 200 mg/L respectively, during dredging. Mean durations for turbidity events >100 mg/L (compliance) level were substantially lower than TSS events >1 and >20 mg/L, displaying a mean of approximately 1 hour in duration for each dredge event (pre, during and post) (Figure 13).

The maximum duration recorded for each period is presented in Figure 14. Results indicate that the maximum duration for TSS concentration events greater than 10 mg/L to 80 mg/L increased during dredging. The biggest increase is observed for TSS events >30 mg/L, which increased from 33 hours during the pre-dredging period, to 264 hours during dredging.

Victor Islet

The mean duration of TSS concentrations from >1 to >3 mg/L increased substantially during dredging compared with the pre-dredging period (see Figure 15). Mean duration for TSS events >1 mg/L varied significantly from 17 hours during the pre-dredging period, to 145 hours during dredging ($p<0.05$). Mean duration for TSS concentrations >5, >10 and >20 mg/L remained similar for pre and during dredging periods. The mean duration for TSS events >40 to >200 mg/L was slightly higher for dredging periods, but still generally lower than the lower mean TSS durations. Most noticeably, post-dredging TSS concentrations >3 to >60 mg/L exceeded both pre and during dredging conditions substantially. Generally, post-dredging mean durations were more than two times greater than those recorded pre and during dredging.

A similar pattern was observed for TSS maximum duration periods. The maximum duration recorded for each dredging condition is shown in Figure 16. Post-dredging maximum durations exceeded maximum durations for most TSS concentration groups. Pre-dredging maximum durations for lower TSS groups (> 1 to > 10 mg/L) exceeded maximum durations during dredging. This pattern, however, is reversed for TSS groups >20 mg/L. For such events, maximum duration periods before and during dredging are approximately the same. For maximum TSS events of >30 to >50 mg/L, dredging concentrations are approximately two times greater than pre-dredging. TSS events between >60 and >100 mg/L during dredging are approximately 4 to 9 times higher than those that occurred pre-dredging.

Figure 13 Mean duration of TSS events recorded at Round Top Island before, during and post-dredging

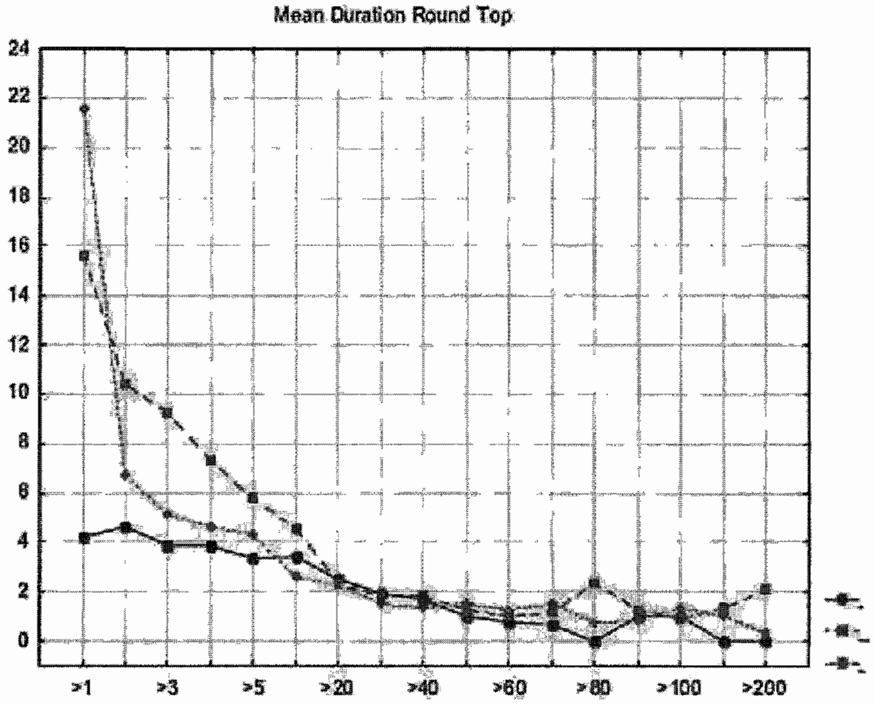


Figure 14 Maximum duration of TSS events recorded at Round Top Island before, during and post-dredging

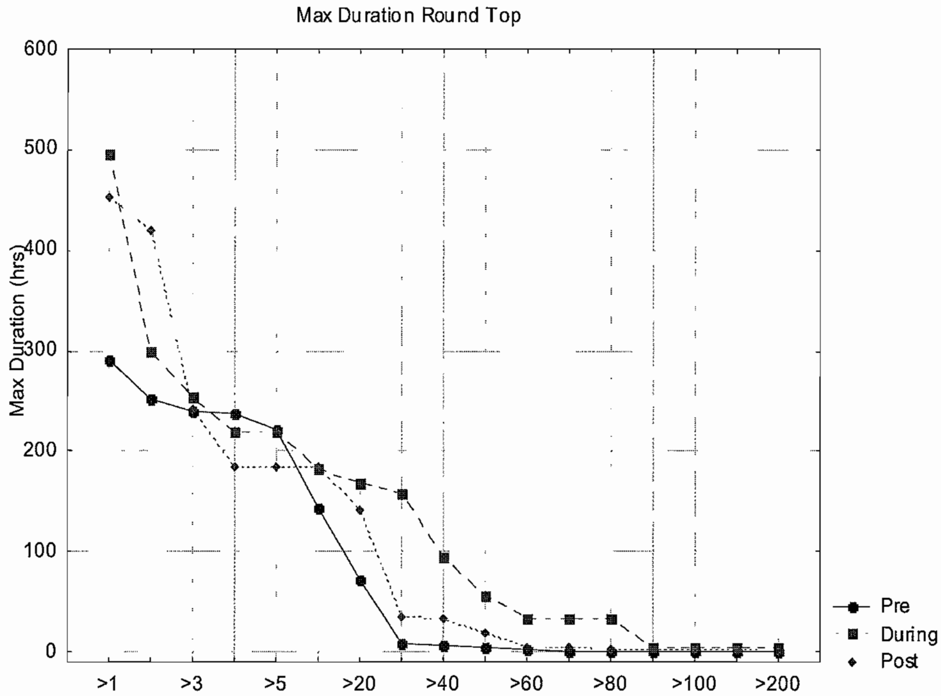


Figure 15 Mean duration of TSS events recorded at Victor Islet Island before, during and post-dredging

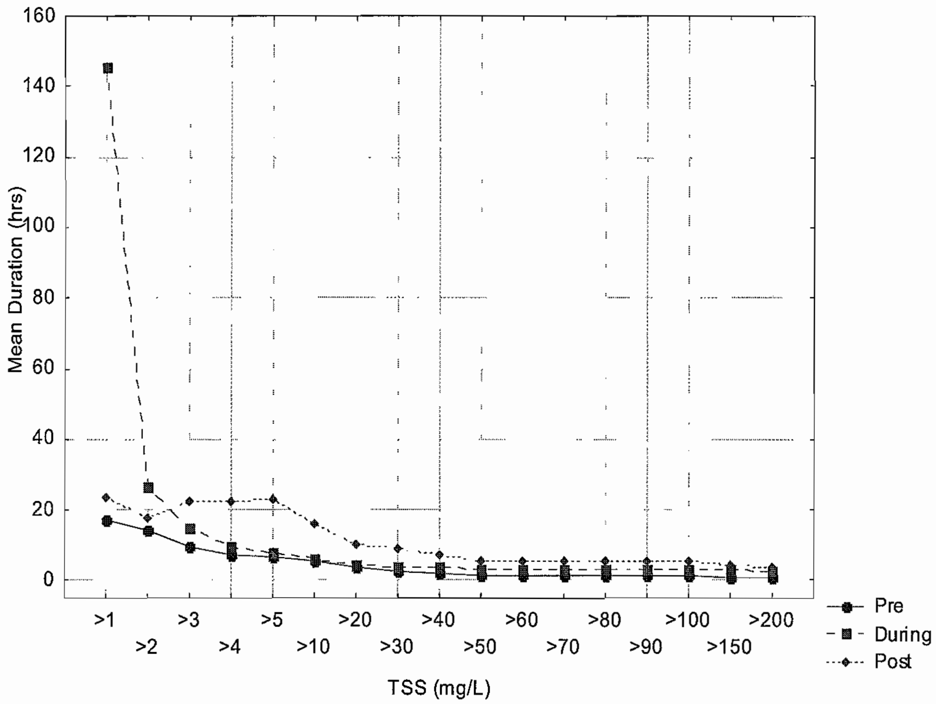
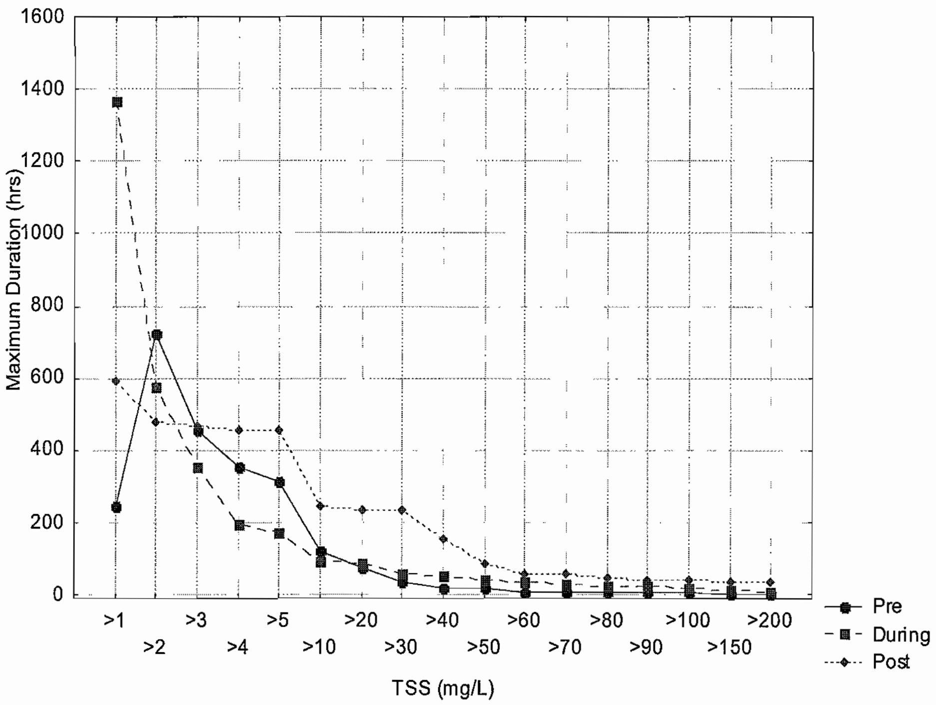


Figure 16 Maximum duration of TSS events recorded at Victor Islet Island before, during and post-dredging



5.2.8 Summary Outcomes

As would be expected, capital dredging at the Port of Hay Point reduced the water quality at monitoring sites located at Victor Islet and Round Top Island during dredging and potentially for a period following the dredging. Mean TSS concentrations were significantly increased at both impact monitoring sites.

The water quality at Victor Islet and Round Top Island during this monitoring period substantially differed between logger sites. Victor Islet displayed substantially higher TSS concentrations that extend for longer periods of time compared with Round Top Island.

The reasons for these differences are likely to be twofold. Firstly the bathymetry of waters around Victor Islet and Round Top Island contributed to the scale of each turbidity event (duration and TSS concentration). The shallow bathymetric nature of Victor Islet (average 3-6 m AHD) allows sediments to become more exposed to wave action and wind generated surface currents. In contrast, Round Top Island has a deeper bathymetric character (6-10 m AHD) and sediments are therefore less affected by wave action and become mobilised less often. Secondly the hydrodynamic conditions of the northwest facing shoreline of Victor Islet (where the logger was located) favour fine sediment deposition. Coral monitoring at sites located in this area have previously identified increased fine sediment deposition on corals and substrate compared with all other Victor Islet and Round Top Island sites. The presence of fine sediments caused TSS concentrations to increase through resuspension from slight increases in wave and tidal action. Sediments located adjacent to Round Top Island for example had a much higher particle size and hence required more energy to become suspended.

5.3 Coral Condition Outcomes

5.3.1 Overview

Coral condition surveys were conducted on two occasions since completion of dredging, that is, the immediate post-dredging survey (November 2006) and the six monthly post-dredging survey (April 2007) (GHD 2007). The two surveys provided the opportunity to analyse overall impact and recovery of coral. Overall impact on coral condition due to dredging was been assessed through comparison of the pre-dredging (April 2006) and immediate post-dredging survey (November 2007). Recovery since the completion of dredging was assessed through comparison of the immediate post-dredging survey (November 2006) and the six monthly post-dredging survey (April 2007).

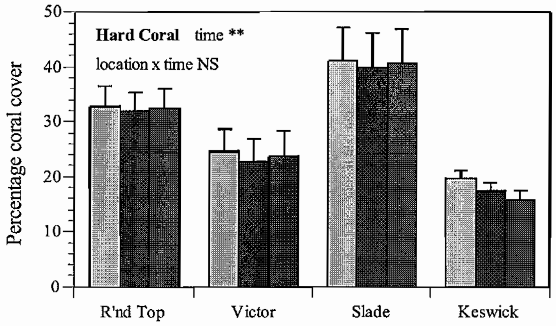
The approved EIS (GHD 2005a) completed for the Port of Hay Point dredging program indicated that a reasonable expectation for coral mortality due to the impacts of the dredge plume might be 16% live coral cover at Round Top Island, with mortality at Victor Islet unspecified. This formed the basis for an approved mortality rate of 20% to be included in the EMP as a performance indicator.

The impact of dredging activities does not appear to have influenced the overall percentage of coral cover at the impact locations during the dredging program by more than 1% (GHD 2007). This represents a significantly lower level of impact than conservatively estimated through the EIS and that which was approved in the EMP.

5.3.2 Benthic Cover Changes During Dredging

Overall coral cover at the end of the dredging program was significantly lower at both the impact and the reference locations (Figure 17) with a 5% mean reduction in cover. This was due to decreases in siderasterid and *Turbinaria* cover in all locations due to presumed disease (Table 5). Some colonies of these groups showed progressive circular patches of mortality with a discoloured edge as is typically seen in coral disease. There was also a significant decrease in poritid cover on Keswick Island but not at the other three locations due to partial mortality of some *Goniopora* colonies. There was no change in the cover of *Montipora* spp. which was the major group affected by sediment damage at Victor Islet and Round Top Island during the dredging program (see Figure 18d). This damage caused such a slight reduction in coral cover (estimated to be <1%) that it was not detectable.

Figure 17Percentage change in hard coral cover at impact (Round Top, Victor) and control (Slade, Keswick) sites



Graphs show grand mean percentage cover from the baseline April 2006 (yellow), November 2006 (blue) and April 2007 (red) surveys for hard coral for each island from four 20 m line intersect transects at six sites. Error bars are standard errors. R'nd Top = Round Top Island. Source: GHD (2007)

Table 5 Fringing reefs benthic changes between baseline and immediate post-dredging surveys: anova results

Family/Group	Loc (L)	Site (S)	Time (T)	LxT	SxT
Total hard corals	NS	***	**	NS	NS
Acropora spp.	NS	***	NS	NS	NS
Montipora spp.	NS	***	NS	NS	NS
Pocilloporidae	*	**	NS	NS	NS
Siderasteridae	*	***	**	NS	NS
Turbinaria spp.	**	***	**	NS	NS
Faviidae	NS	**	NS	NS	NS
Poritidae	NS	***	**	*	NS
Total soft corals	NS	***	NS	*	*

NS = not significant; * = 0.05>p>0.01, ** = 0.01>p>0.001; *** = p<0.001.

5.3.3 Benthic Cover Changes During Recovery

There were no significant changes in overall coral cover during the first six months post dredging recovery period (Figure 17, 6) but there was a significant increase in the cover of fast growing *Montipora* corals (Figure 18d). There was a further significant decrease is siderasterid cover at three of the four locations most likely resulting from disease.

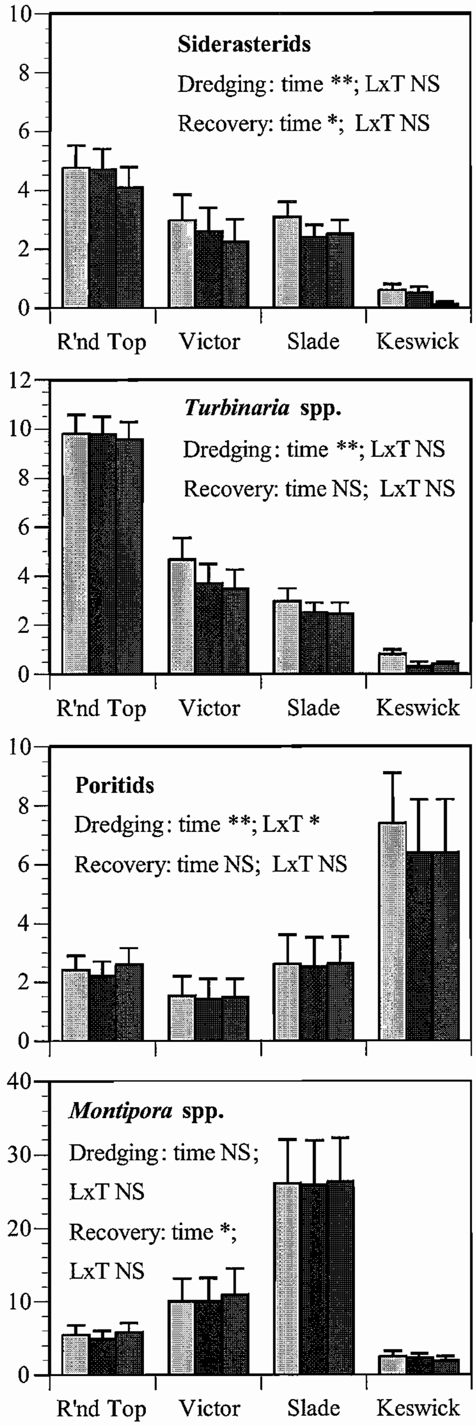
Table 6 Fringing reefs benthic changes between immediate post-dredging and six month post-dredging surveys: anova results

Family/Group	Loc (L)	Site (S)	Time (T)	LxT	SxT
Total hard corals	NS	***	NS	NS	NS
Acropora spp.	NS	***	NS	NS	NS
Montipora spp.	NS	***	*	NS	NS
Pocilloporidae	*	**	NS	NS	*
Siderasteridae	*	***	*	NS	NS
Turbinaria spp.	**	***	NS	NS	NS
Faviidae	NS	**	NS	NS	NS
Poritidae	NS	***	NS	NS	*
Total soft corals	NS	***	*	NS	*

NS = not significant; * = 0.05>p>0.01, ** = 0.01>p>0.001; *** = p<0.001

Source: GHD (2007)

Figure 18Changes in percentage cover of major benthic groups



Graphs show grand mean percentage cover from the baseline April 2006 (yellow), November 2006 (blue) and April 2007 (red) surveys for hard coral for each island from four 20 m line intersect transects at six sites. Error bars are standard errors. R'nd Top = Round Top Island. Source: GHD (2007)

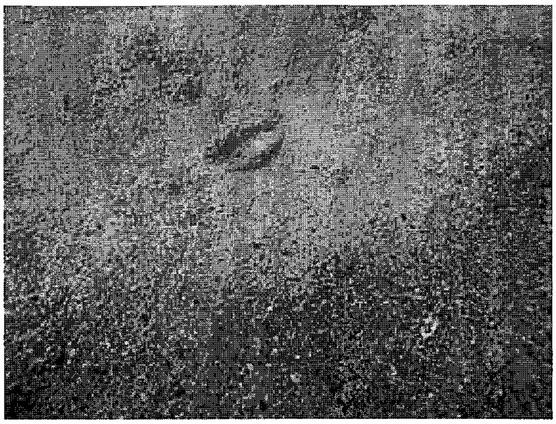
5.3.4 Partial Bleaching

Any stress that may have been caused by exposure to the dredge plume did not result in the bleaching of any corals at the impact sites.

5.3.5 Sedimentation

The dredge plume has affected sediment levels at both impact locations during the past 12 months of monitoring. Fine dredge plume sediment had settled on the substratum at the Round Top Island and Victor Islet locations within a month of the start of dredging, especially at the sheltered northern sites (Figure 19). There was similar fine sediment on the surface of the substratum at the two reference locations during the baseline (April 2006) survey especially at the more sheltered Keswick Island sites. The sediment in these locations was equally fine and resuspended very easily with diver activity, but did not have same high plasticity associated the dredge plume sediment identified at impact locations.

Figure 19 Dredge plume sediment on the sand substratum at Victor site 5



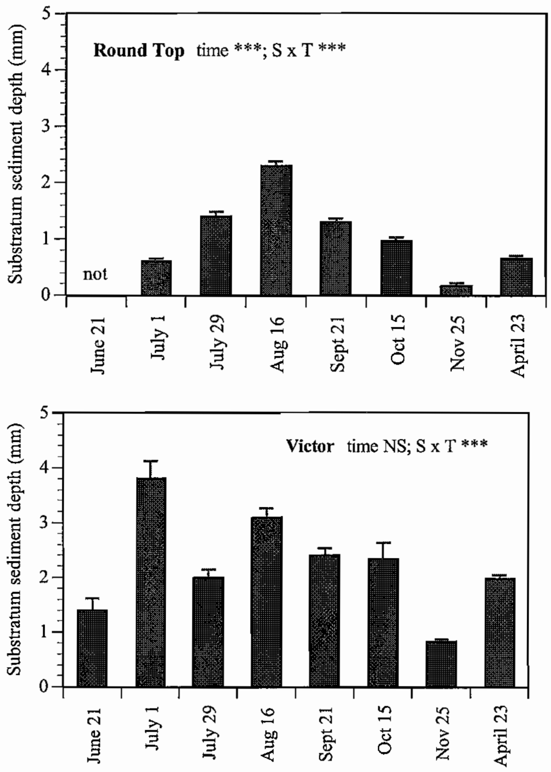
There was a greater depth of sediment on the substratum at Victor Islet and Keswick Island at the time of the latest survey (April 2007), compared to Round Top Island and Slade Islet and these differences were significant ($F=6.68$; $p=0.003$). Site differences were very significant ($F=12.94$; $p<0.001$).

The amount of dredge sediment on the seabed and on the corals fluctuated over the time of this study (see Figure 20), especially on Round Top

Island, probably as a result of changes in sea state. Rough weather caused sediment resuspension and both the number of colonies of with sediment deposition and the sediment depth on these colonies was lower during and immediately after strong wind episodes. Sediment cover increased after prolonged calm weather, as fine sediment settled to the bottom and underwater visibility improved.

At Victor Islet approximately 30% of corals had some sediment load, with a mean maximum depth of around 1 millimetre. By the time of the six monthly post-dredging survey (April 2007), fine sediment had significantly reduced on the protected northern sites, but were much higher than normal at the more exposed sites (GHD 2007).

Figure 20 Changes in substratum sediment depth in the impact locations



Graphs show grand mean sediment depth on the substratum from 20 points selected haphazardly along each transect (total of 480 for each location). Error bars are standard errors. The significance of the time change and site x time interaction is indicated on each graph. Source: GHD (2007).

The April 2007 survey was carried out after a week of calm weather. Underwater visibility was very good and it appeared that the high levels of substratum sediment reflected a combination of settled sediment that was suspended during rough weather and dispersal of the fine sediment normally found at the protected northern sites. It appears that fine sediment had been dispersed and incorporated into the existing sediment very rapidly after input of new sediment from dredging into the system had stopped.

It took a month or two for the dredge sediment to cause any coral mortality, after which small patches of dead tissue were identified on many of the affected corals (Figure 21 and Figure 22). A maximum of ~ 4% (Round Top Island) and 6.5% (Victor Islet) of corals showed some patches of sediment related mortality. This partial mortality represented around 10% of the colony surface and had not caused any whole-colony mortality within the study area.

Figure 21 Sediment accumulation on a Victor Islet *Montipora* colony

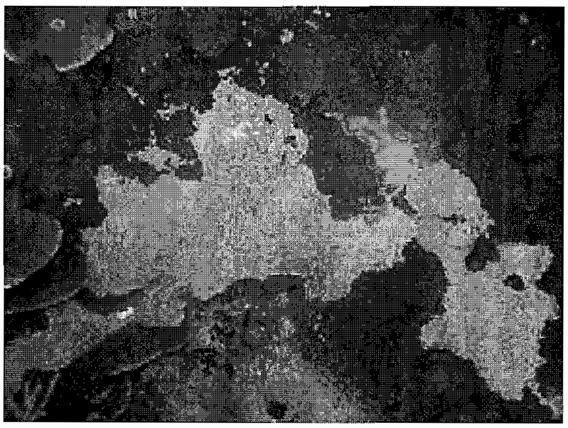
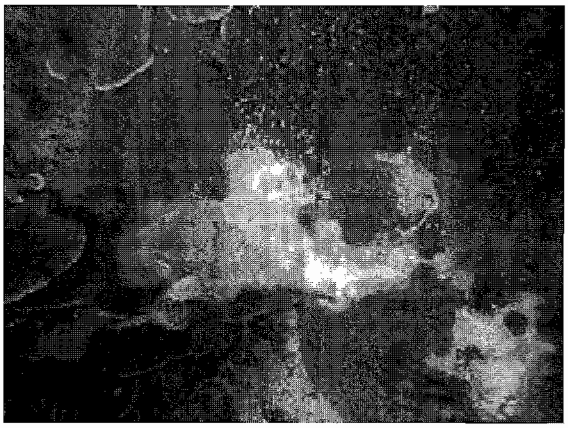


Figure 22 *Montipora* colony partial mortality from sediment smothering



By the time of the November 2006 and April 2007 surveys, many of the sediment damaged corals had lost their sediment cover and most were starting to regrow into the damaged patches (Figure 23). Many of the white, supposed dead patches on *Turbinaria* and *Porites* colonies appeared healthy again at this time (GHD 2007).

Figure 23 Recovery from sediment damage of an Explanate *Montipora* colony on Victor Islet

GHD (2007) advise that although the quantity of dredge sediment on the seabed around Victor Islet had decreased and dispersed more widely, the depth of this sediment was still up to 10 millimetres thick in some places at the time of the April 2007 survey. The underwater visibility at Victor Islet had improved since the completion of dredging and was similar in April 2007 to that encountered during the baseline (April 2006) and EIS (May 2005) surveys.

5.3.6 Mortality, Damage and Disease

GHD (2007) state that over 96% of corals were still healthy at both impact locations (Figure 25 and Figure 24) at the time of the last survey (April 2007). The number of presumed diseased colonies was similar at all locations and had not changed significantly over the course of the study at any of the locations (Table 7). While it is possible that the increased turbidity from the dredge plume caused some disease at the impact locations, the presence of similar densities of diseased corals at reference locations and the consistent level of disease throughout the study, suggests that disease at the impact sites did not increase as a result of the dredging.

Figure 24 Over 96% of corals on Victor Islet were still healthy

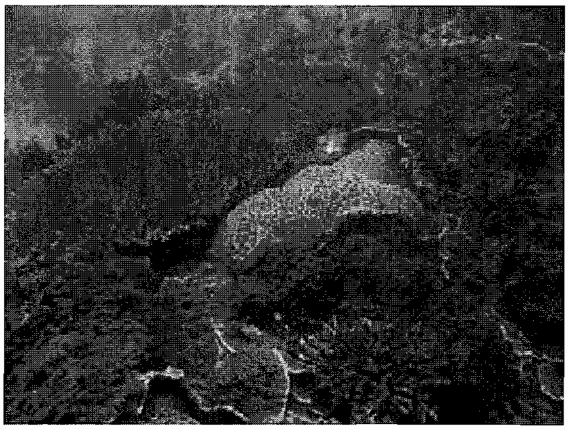
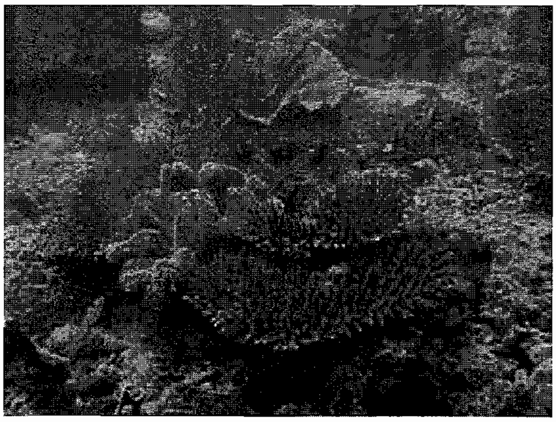


Figure 25 Over 96% of corals on Round Top Island were still healthy



The number of sediment damaged colonies at Round Top Island ($p<0.001$) and Victor Islet ($0.01>p>0.001$) increased significantly throughout the study (see Table 7 for Anova results). During the dredging, most of these damaged corals were at sites 1 and 2 at Round Top Island and sites 5 and 6 on Victor Islet, which were on the protected north face of the islands. The overall number of corals affected was relatively low and only patches of the colonies had died, so there was no significant decrease in coral cover of the most affected coral groups (see Table 5 and 6) (GHD 2007).

Table 7 Sediment damaged coral colony changes: Anova results

Analysis:	Site	Time	S x T
Round Top diseased corals (9 surveys)	*	ns	**
Victor diseased corals (10 surveys)	***	ns	***
Round Top sediment damage (9 surveys)	***	***	***
Victor sediment damage (10 surveys)	***	**	***

ns = not significant; * = $0.05>p>0.01$, ** = $0.01>p>0.001$; *** = $p<0.001$; na = not applicable

Source: GHD (2007)

Since the cessation of dredging, sediment levels on corals decreased and many of the damaged corals have either recovered or are in the process of recovery. Although up to 17% of corals were partially affected at some stage by sediment deposition at the worst affected impact location sites, this did not cause a significant or measurable reduction in coral cover and does not appear to have had any long term effect on the benthic community (GHD 2007).

By combining the estimates of the area of colony mortality with the number of damaged corals and percentage cover, an approximate measure of the overall reduction in coral cover caused by sediment mortality was calculated. Reductions in coral cover were only a fraction of a percent (Table 8), one to two orders of magnitude less than could be detected using the line intersect transects (GHD 2007).

Table 8 Extent of mortality on sediment damaged coral colonies

Location	R'Top	Victor	Slade	K'wick
Mean % of area of sediment damaged colonies dead	5.5	3.3	1.5	6.5
Estimated decrease in % cover caused by sediment mortality	0.04	0.05	<0.01	<0.01

Source: GHD (2007)

5.3.7 Massive *Porites* Mucus Production

The amount of mucus production in *Porites* corals had not changed at Round Top Island since the baseline survey (April 2006) and is unlikely to have been affected by the impact of the dredge plume. During the late July 2006 survey, the *Porites* colonies at Victor Islet sites 5 and 6 did not show the high level of mucus cover they had shown since the baseline (April 2006). It was thought that this may have been a negative change and that corals at these sites had stopped producing mucus to keep their surface clean, due to continuing high rates of sediment deposition. However, although the dredge plume was still being resuspended around Victor Islet during the October 2006 survey and visibility at most sites was low, the production of mucus at these sites during October 2006 had increased again and was close to the level recorded during the baseline (April 2006). In spite of continuing poor visibility at Victor Islet, there was no mucus on any *Porites* colonies during the November 2006 survey.

Although Slade Islet water conditions were similar to those at Round Top Island and often had visibility similar to that at Victor Islet, no *Porites* colonies at this location had been observed to produce mucus during any of the surveys. The orientation of Slade Islet allows waves from the predominant southeast winds to travel down both sides of the island so there are no protected sites. It is possible that water movement removed the mucus from the *Porites* colonies at this location as soon as it formed. Similarly, the movement of water may have also removed sediment from the colonies, so corals did not have to produce mucus to clean themselves.

It is clear that measures of mucus production by *Porites* corals do not assist our understanding of sediment impact on these fringing reef communities. The process is not understood well enough to enable an assessment of the importance of changes in mucus cover. This parameter was not measured in the April 2007 survey.

5.3.8 Fish Density Changes

The application of non-destructive fish counts as part of this program relied on reasonable water clarity and visibility, given that visual counts were required. The reduced visibility encountered at certain times and locations during the fish surveys reduced the reliability of results. In a survey of fish on fringing reefs in turbid conditions in Shoalwater Bay (south of the Mackay region), Ayling and Ayling (1999) suggest that survey results were worse affected when the visibility dropped below 4 metres. The fish counts at the Hay Point fringing reefs that can be accepted as reasonably reliable therefore, are the baseline (April 2006), post-dredge (November 2006) and six monthly (April 2007) surveys. These surveys suggest that fish densities have not changed as a result of the dredging (GHD 2007). Fish populations on fringing reefs often have to deal with periods of very low visibility during prolonged rough weather episodes and most of the species present are able to deal with these conditions. During the November 2006 survey, many recruits of pomacentrids and labrids were present, suggesting that normal processes were still occurring.

5.3.9 Summary Outcomes

There is strong evidence to suggest that sediment deposition associated with the migration of the dredge plume occurred at both Round Top Island and Victor Islet. Sediment deposition appeared to have been greatest at Victor Islet sites 5 and 6.

The density of sediment damaged corals increased significantly at both Round Top Island and Victor Islet between three and six months after the start of dredging, with a maximum of about 4% (Round Top Island) and 6.5% (Victor Islet) of corals showing some patches of mortality that was related to sediment accumulation on the colony surface. This partial mortality generally represented around 10% of the colony surface and had not caused any whole-colony mortality within the study area.

It appears that the accumulation of fine sediment within and around the leeward side of Victor Islet reduced rapidly since the completion of dredging and dispersed more widely around the island. However, there was still significantly more sediment damaged corals at Victor Islet than at any of the other locations, six months after the completion of dredging.

The April 2007 survey repeated the detailed survey of percentage cover of benthic biota that was first recorded during the April 2006 baseline. The nominal but not significant reduction in hard coral cover on Round Top Island and Victor Islet since the 2006 baseline survey has been 1% and 3% respectively, similar to the reduction recorded at the Slade Islet reference location (1%) and much less than the significant 20% reduction at the Keswick Island reference location. All these reductions appear to have primarily been the result of disease processes in the coral communities rather than an effect of the dredging.

The approved EIS completed for the Port of Hay Point dredging program indicated that a reasonable conservative expectation for coral mortality due to the impacts of the dredge plume might be 16% live coral cover at Round Top Island, with mortality at Victor Islet being unspecified. Dredging activities do not appear to have influenced overall percentage coral cover at the impact locations during the dredging program by more than a fraction of 1%.

5.4 Hydrodynamic Model Validation

5.4.1 Overview

A hydrodynamic model was developed as part of the project EIS, with the outcomes of this model reported in the Port of Hay Point Hydrodynamic and Water Quality Modelling Report (GHD 2006b). The following section is largely based upon this document..

Preliminary model validation was conducted in November 2005 with data obtained from maintenance works undertaken in the port. This exercise showed that the model predictions for Round Top Island were very conservative, providing an underestimation of turbidity. At Victor Islet, the validation identified that elevated suspended sediment would occur during the spring tidal phase, however, this was likely to be from naturally high ambient turbidity.

As a condition of approval and element of the EMP, PCQ was required to conduct a validation of the model once capital dredging commenced. The purpose of the model validation process was to evaluate the output of the model against actual conditions and to provide recommendations that would assist in the development and implementation of these types of models in the future. The validation exercise utilised data gathered during the capital dredging campaign and reconfirmed that the estimation of the model parameters is an important process. It also highlighted the stochastic nature of the marine environment and the effects that this has on model input and results.

5.4.2 Scope of Study

The model was validated over a four week portion of the dredging campaign. Descriptions of the cases modelled were:

- hydrodynamic modelling of the coast of Hay Point for a four week period with pre-dredge bathymetry; and
- modelling of the sediment plume generated by the combined effects of dredging at a static location within the apron area and the material relocation site for the same four week period.

During the validation process, it was decided to represent simulated dredge movements.

5.4.3 Model Development

One of the key challenges of developing the model was accounting for the effects of wind on suspended sediment concentrations:

- Wind is a known driver of suspended sediment concentrations. It is therefore an important parameter in many water quality models, particularly in shallow waters.
- Wind is a highly stochastic variable with strong spatial and temporal components and consequently it is difficult to account for all scenarios prior to dredging because of the variability and unpredictability of wind.
- Incorporating the effects of high wind in a model is a challenge because high winds are typically transient.
- The dredging area is relatively deep compared with the areas of interest (Round Top Island and Victor Islet). Consequently, the shallower water around the areas of interest (reefs) are more likely to be affected by wind causing greater remobilisation of deposited sediment.

The assumptions used in the preliminary model were based on the best available information at the time. Several of these assumptions were able to be improved as data and knowledge were updated. This included undertaking tests of water samples collected during dredging to determine settling velocity.

There remains a degree of variability in the amount of suspended sediment that is generated at the point of dredging. Better quantification of this parameter would enhance the realism of the model, however, this was not able to be quantified during this validation program.

Another issue was how best to account for the probable effects of wind and wave action on the plume and also on background TSS concentrations. Sensitivity tests on the preliminary model indicated that the inclusion of strong winds in the model produced results that were unrealistic. Ultimately, the settling velocity was decreased to provide a broad proxy of the effects of wind and wave on the plume. However, the ability of the model (or any other software) to account for strong wind and wave action requires further investigation.

5.4.4 Estimating Background TSS Concentration

The background TSS concentration for the simulation period was estimated by averaging the TSS concentrations measured at the two control sites. Conditions were different at each control site, with respect to:

- their comparative distances from Round Top Island and Victor Islet (Keswick Island is located further away);
- the different water depths at which the loggers are located (water depth at Slade Islet is 3 to 4 metres shallower); and
- the differences in TSS recorded at each site (Slade Islet is higher).

Six-hour averaging was used in order to minimise the impact of transient and intermittent concentrations on the composite time-series.

Overall, the background TSS time-series estimated and reasonably captured the general trend of the concentrations measured at the two control sites, including the high turbidity period recorded between 13 and 16 June 2006.

5.4.5 Comparison of Predicted and Recorded Turbidity

The effect of adjusting the model output to allow for the estimated effects of background conditions for Round Top Island and Victor Islet is marked, particularly for the period of 13 to 16 June 2006 where elevated TSS concentrations were recorded at all four sites. During this high turbidity period, the effects of adding a background TSS concentration to the predicted time-series were:

- increases the peak TSS concentration from about 25 mg/L to almost 60 mg/L at Round Top Island; and
- increases the peak TSS concentration from about 18 mg/L to over 50 mg/L at Victor Islet.

Figure 26 and Figure 27 show the predicted and measured TSS concentrations at Round Top Island and Victor Islet respectively.

Figure 26 Predicted + composite background TSS vs measured TSS at Round Top Island

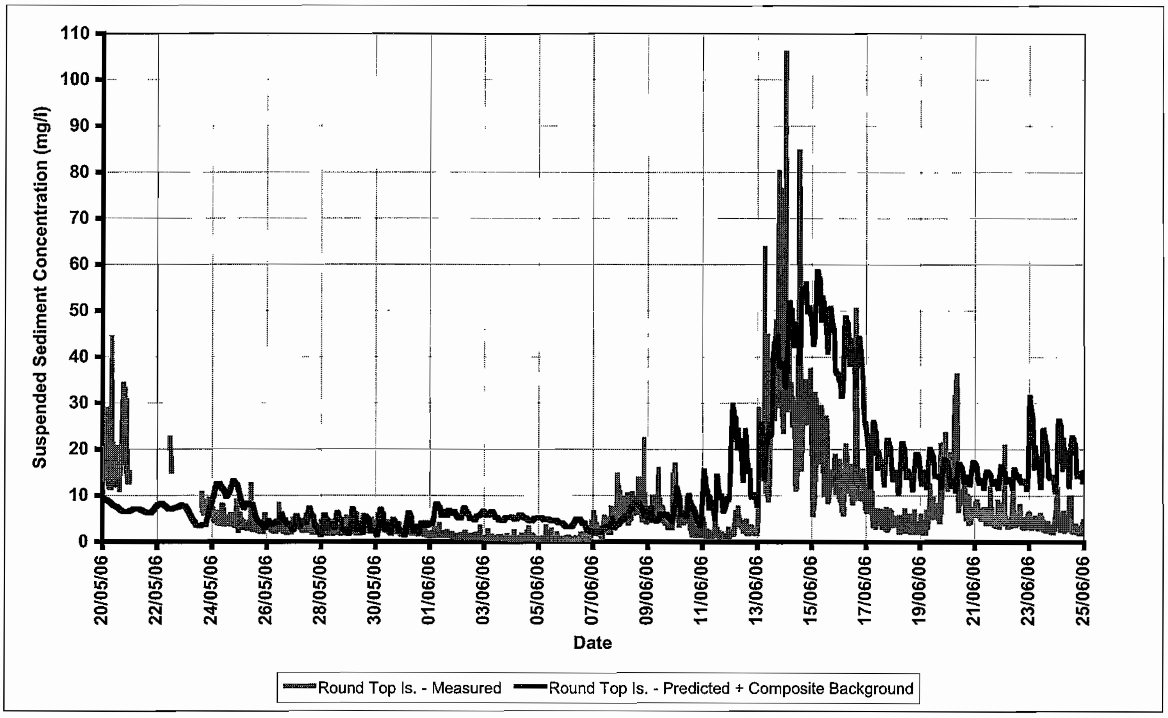


Figure 27 Predicted + composite background TSS vs measured TSS at Victor Islet

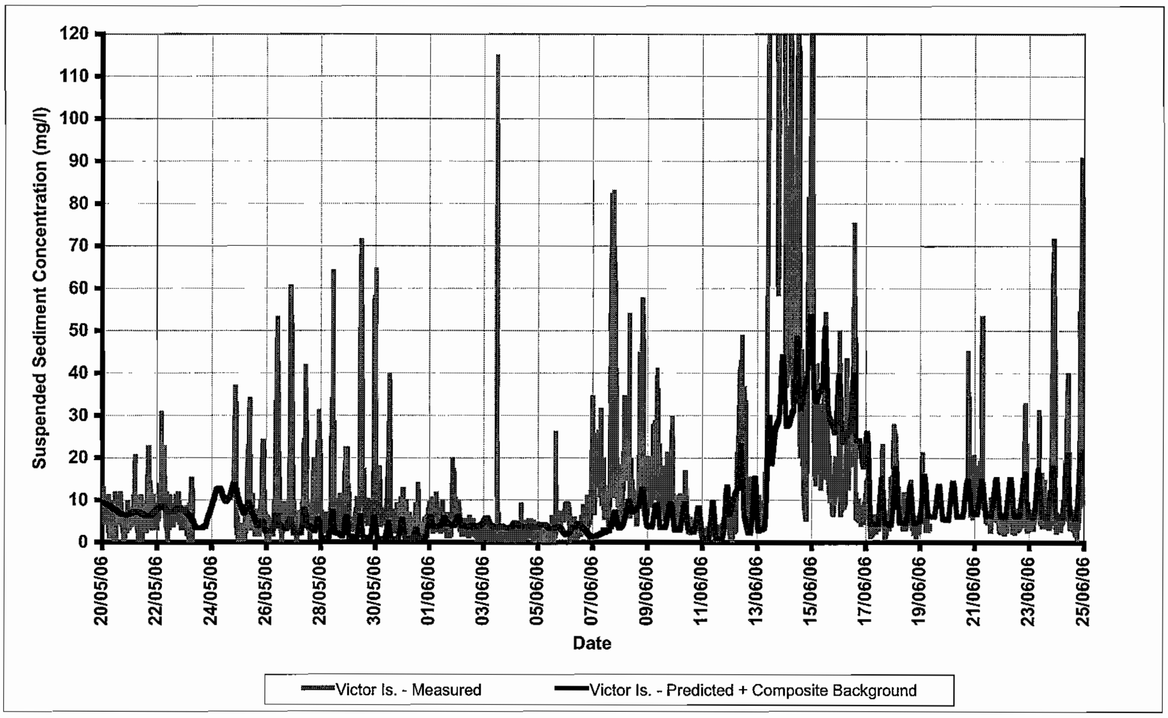


Figure 26 shows that the predicted TSS concentrations in the vicinity of Round Top Island compare well with the measured TSS concentrations following adjustment for background levels. In comparison, Figure 27 shows that the predicted TSS concentrations in the vicinity of Victor Islet compare less well with measurements. The issues to be considered when determining why this might occur are:

- the water depth at Victor Islet (5 to 6 metres), is shallower than at Round Top Island (8 to 10 metres). This means that the wind and wave generated resuspension is likely to be higher at Victor Islet; and
- the background TSS conditions may be more representative of Round Top Island than Victor Islet owing to the closer proximity of the reference site Slade Islet, to Round Top Island.

Overall, the inclusion of a background TSS concentration appears to improve the general relationship between predicted and measured values although they are still lower than the peak TSS values measured at the impact sites. However, this disparity may be in part due to the semi-subjective nature of calculating the background TSS concentrations and the differences in water depth at the control sites.

5.4.6 Summary Outcomes

Generally, the model performed well when comparing the predicted TSS (above background) concentrations against measured TSS concentrations. For Round Top Island, there was good agreement between predicted and measured TSS over the whole simulation period. For Victor Islet, the predicted TSS concentrations compare well against the measured values for low TSS concentrations but less well against the higher TSS concentrations. Shallow depth, wind-driven resuspension and poor representation of actual background concentrations at Victor Islet are factors as to why the model does not 'capture' the high TSS concentrations.

The predicted TSS (above background) concentrations were characterised by overall higher concentrations to the north (Round Top Island) than the south (Victor Islet) through the updated modelling and shows similar values at both locations:

- the peak TSS concentration predicted in the vicinity of Round Top Island decreased from 32 mg/L (preliminary model) to 25 mg/L; and
- the peak TSS concentration predicted in the vicinity of Victor Islet increased from 11 mg/L (preliminary model) to 18 mg/L.

Actual conditions during the dredging campaign were characterised by a larger portion of the dredging occurring further to the south than originally modelled, and the occurrence of strong winds and wave action.

The effect of background concentrations is estimated to increase the peak TSS concentration predicted at Round Top Island to approximately 60 mg/L and 50 mg/L at Victor Islet. Based on time averaged values, the predicted mean was within 7 mg/L of the measured mean at both sites.

The near-shore control site of Slade Islet was initially selected to provide the background suspended sediment concentrations for Round Top Island and Victor Islet. However, the water quality monitoring data for Slade Islet indicated that high wind conditions were driving the resuspension of sediment in these shallow waters to levels higher than what was recorded at Round Top Island during dredging.

To reduce the effects of wind-driven resuspension in the shallower waters of Slade Islet, the background concentrations were estimated by averaging the suspended sediment concentrations measured at Slade Islet and the off-shore control site, Keswick Island.

The preliminary modelling assumption of a dredge size (hopper capacity) of 18,000 cubic metres working at the apron area was used to calculate a mass loading rate (5,530 grams per second). However, this predicted dredge size was somewhat smaller than the actual dredge size (35,000 cubic metres). To account for the higher TSS generated by a larger dredge, the mass loading rate was increased to 8,295 grams per second.

The assumption that the dredge cycle consisted of 4.75 hours of dredging, 1.25 hours travel time with 15 minutes for discharging was similar to the recorded cycle for the simulation period. However, for increased accuracy, the actual dredge cycle periods obtained from the dredge logs were incorporated in the model.

The sensitivity analysis showed that the model output was sensitive to changes in settling velocity. Decreasing the settling velocity from 0.00006 metres per second to 0.00003 metres per second as a proxy for the impact of wind and waves, increased the average TSS concentrations at Round Top Island by 4.5 % and at Victor Islet by 18 %.

The result of increasing the dredge load, changing the dredge location, increasing mass loading rate and settling time was an increase in TSS concentrations at Victor Islet and a decrease at Round Top Island compared to the preliminary model.

At the end of the simulation period (one month), the model predicted a low rate of deposition at Round Top Island and Victor Islet. However, this should be considered in the context of the duration of the simulation (one month) compared with the actual dredging period (over five months) and also the potential impact of variable deposition and resuspension at all sites.

5.5 Summary

Overall the model performed well when comparing the predicted TSS (above background) concentrations against measured TSS concentrations. For Round Top Island, there was good agreement between predicted and measured TSS over the whole simulation period. The peak TSS concentration predicted in the vicinity of Round Top Island had decreased from 28 mg/L (preliminary model) to 25 mg/L (GHD 2006b). For Victor Islet, the predicted TSS concentrations compare well against the measured values for low TSS concentrations but less well against the higher TSS concentrations. The peak TSS concentration predicted in the vicinity of Victor Islet has increased from 11 mg/L (preliminary model) to 18 mg/L (GHD 2006b).

6 Lessons Learned

6.1 Overview

Following completion of dredging works in 2006, a "Lessons Learned" workshop was conducted to review the outcomes of the project. The workshop ran over a two day period and was hosted by PCQ. It was attended by MRG members as well as coral, seagrass, hydrodynamic modelling and water quality specialists that had been involved throughout the project. The following discussion in this section is largely based upon the outcomes of this workshop (PCQ 2007).

The objectives of the workshop were identified as:

- Review of the monitoring and management of the Hay Point Capital Dredging Project at a high level.
- Document the environmental management success of the project as well as the lessons learned by each stakeholder, that is, what could be improved next time.
- Identify which aspects of monitoring and management could have a broader application as a 'best practice' standard for future major dredging projects.

The primary discussions of the workshop focused on coral, water quality, marine plants and introduced marine pests. There was also discussion on the benefits of remote sensing for monitoring of plumes and turbidity, and the benefits and constraints of hydrodynamic modelling.

6.1.1 Approval Agency Perspective

From the three key regulators providing conditions of approval for the project, the implementation of the EMP was generally seen as a positive outcome of the integrated approval. However the important aspects of setting conditions with regard to engineering, technical and economic constraints were reviewed and continued to present a difficult element of consideration for the agencies.

From the GBRMPA perspective, it was noted that the initial assessment needed to look at the importance of biota/systems on a local and regional scale to gain perspective. Therefore, the best way to look at managing the project was to determine the value of the corals at Round Top Island and Victor Islet locally and regionally, and consider the impact if they were lost. "The GBRMPA assessment took a lot of time looking at the worst case scenario, which was total loss of the coral reef systems and the effect this would have on the region". Ultimately the agency was confident that there would be low levels of coral morality (which there was), but it was acknowledged that there was a chance (albeit small) that there may be a greater impact than what was predicted".

GBRMPA reiterated that adaptive management is best practice, whereby decisions are made throughout the project. In particular, with the Hay Point project, a number of impact management strategies were explored, but few could be demonstrated to have a significant effect in limiting turbidity. The focus, therefore, was on coral condition and if the dredging was having an impact.

Linking the development permit to environmental impact limits defined subsequent to issue of the permit and specified in a project EMP presented some concerns for the Queensland EPA, particularly in terms of confidence in enforcement of performance indicators as opposed to limits defined in conditions of approval. This was particularly apparent in relation to the performance indicator of 20 % coral mortality and resultant management measures to be implemented should mortality occur. Reliance on GBRMPA to define acceptable limits of impact to coral communities, and the need to issue a development permit to allow contractual negotiations to proceed, strongly influenced the approach taken by the EPA in conditioning the permit. The EPA accepted that if performance criteria specified in the EMP were not met, then this would result in specified corrective action being undertaken. However, it was concluded that, from the EPA's perspective, agreed limits to environmental impact are better defined by conditions of a development permit rather than in an EMP in order to give greater certainty to both the regulator and port authority at the time of issue of the permit.

The DEW identified that key points for proponents and regulators to learn from the project with regards to predictive modelling were that the model is a guide of potential impacts, rather than an absolute indication of what will occur from a project. Furthermore, it is important that 'worst case' scenarios are modelled to provide an indication of the greatest impacts that could occur.

6.1.2 Proponent Perspective

PCQ sought to achieve an integrated approach to the conditioning of the project from the outset. This approach provided obvious benefits to the proponent during the implementation phase. Particularly in regard to simplifying the management of the project with a single integrated management document, that is, the EMP. This, combined with consistency amongst regulators in their approach to conditions and management responses throughout the project, meant that the objectives of all parties could be achieved.

Even though the conditions were contained within the EMP rather than explicitly outlined in permits, the effectiveness of their implementation was demonstrated through the project outcomes. Rather than limiting agency authority to intervene should a non-conformance occur, it provided an opportunity to conduct real-time monitoring and evaluation of impacts by all stakeholders.

It was noted that if conditions in permits are not practical or are overly stringent, then there is a risk a project may be stopped, when in fact there is no environmental harm occurring. This results in increased costs and an extended dredging program, which has a greater environmental impact in the longer term. The outcomes of the Port of Hay Point project demonstrated that a focus on monitoring sensitive habitats and then using an adaptive management approach is an effective mechanism for achieving environmental objectives. The controls were established, and the environmental management of the project offered a different model to the traditional one, enabling more options to explore management strategies.

6.2 Workshop Outcomes

6.2.1 Overview

From the lessons learned workshop, it was generally determined that the monitoring undertaken for the project was environmental best practice and the first of its kind in Australia with regards to the ability to access water quality data remotely on a daily basis, the focus of impact monitoring on coral, the use of the MRG to review and manage the environmental aspects of the project and the internet-based environmental reporting system. The benefits of the management mechanisms and community consultation were identified. Several recommendations for improving hydrodynamic modelling, baseline studies and setting water quality triggers, and environmental approval conditions were identified. These are detailed in the following sections and are recommended to be incorporated into future capital dredging campaigns.

6.2.2 Management and Advisory Groups

Management Reference Group (MRG)

Overall, the MRG worked well and has set a good benchmark for the future management of dredging projects. It resulted in good communication between the regulatory stakeholders and allowed an open forum to discuss technical issues, and make decisions and recommendations for the project. Membership was appropriate, however, in future, it may be useful to have a dredging contractor's representative present to provide technical input on dredging issues.

There was variance in some member's expectations of the group, which could be improved in future by having a more defined Terms of Reference or a formalised tiered response process.

Throughout the project, it was at times difficult to differentiate between dredge related impacts and natural conditions at the time. However, the MRG reaction in terms of corrective action was commensurate with impacts being observed.

The MRG were provided with technical reports on water and coral monitoring but providing lengthy, very detailed reports quickly was difficult at times. Therefore, it is important that prior to a dredging project commencing, the MRG agree on the scale of reporting required for decision-making, that is, summary reports after monitoring and data analysis with more detailed reporting undertaken later.

Technical Advisory Consultative Committee (TACC)

It was useful to have the TACC in order to communicate and consult with other stakeholders, however, the group was not a technical advisory committee and had no decision making or management role, therefore, in future, the name of the community group should be changed to "Consultative Committee" or the like. The frequency of meetings, that is before and after dredging and approximately every two months throughout the campaign, was deemed to be appropriate.

It was recommended that future meetings of the Consultative Committee continue to be undertaken on site, with MRG meetings following, however, presentations to the Committee should be less technical than those to the MRG.

6.2.3 Coral Monitoring Program

The coral monitoring program was set up as a tiered management response, that is, if a water quality trigger was exceeded, then coral health would be examined. It was acknowledged by PCQ that there can be a delay between a high turbidity event and a coral condition response, however, partial mortality indicators will generally pick up any potential problems. Monitoring frequency was also subject to appropriate weather conditions with monitoring generally limited to weather conditions of less than 10 knot winds, during neap tides and good visibility.

The focus on triggers is a rolling process based on frequency, intensity and duration and future projects should move away from 'one' trigger. Once data is obtained and correlated with a reactive program, the MRG can review the trigger as the project progresses and apply adaptive management throughout.

The coral monitoring program highlighted the importance of examining the hydrodynamics of the monitoring sites, that is, do sites favour sediment deposition and are the proposed sites easily accessible. The program also highlighted the difficulties in identifying appropriate reference sites. The overall cost benefit of monitoring programs also has to be kept in mind during the program design. Frequency of surveys adds significantly to costs and therefore frequency should be considered based on optimising outcomes.

The workshop reviewed the detail and frequency of surveys, and the parameters surveyed. The Hay Point coral monitoring program had over 80 % power and the ability to discriminate what was happening at the various sites, so the level of monitoring was appropriate to provide enough information for management and a higher density/high statistical program was not required in this case.

The frequency of surveys was initially set to provide fortnightly rapid surveys and monthly detailed surveys. As proposed in the monitoring program, following the initial period of fortnightly surveys, the MRG were satisfied that no significant impacts were occurring from dredging and the frequency of surveys was reduced to monthly. Surveys were undertaken often enough to allow for weather delays or other issues and yet still pick up any changes in coral condition.

The review of factors measured during the survey found that the initial methodological change of using a 20 metre x 2 metre transect rather than a narrower transect, was a good method to determine the number of colonies with disease or damage, and it could be done in water with low visibility.

Additional changes to the coral monitoring methods recommended during the workshop were:

- Estimation of the surface area of sediment on corals.
- Application of a rating system to provide a better estimate of coral mortality (scale 1 to 10).
- Continued measurement of sediment deposition, but the preferred method to be further investigated.
- Measurement of recruits or reproductive effort in corals to be considered, although it was recognised that this is difficult and time consuming.

Whilst it was considered that the measurement of coral bleaching does not provide a significant indicator for dredge impact, it assists with the 'big picture' consideration of coral health and demonstrates what is occurring regionally. Therefore bleaching should be investigated pre and post-dredging. However it is uncertain what mucous production information (from *Porites*) indicates about coral health, so it may be worth reviewing whether this parameter should be measured in the future.

One of the most significant outcomes of the Hay Point coral monitoring program was the demonstration of the severe water quality conditions and levels of sedimentation in which coral communities can survive.

6.2.4 Water Quality

The water quality monitoring program provided valuable data on changes in water quality resulting from the migration of the dredge plume. The initial period of reporting on a daily basis was of value, but this frequency was reduced to weekly once the MRG were confident in the condition of coral and its response to the elevated TSS conditions. The use of telemetry based loggers was invaluable in this regard as they allowed 24/7 recording and access to data.

Some initial issues with the calibration and treatment of data highlighted the importance of having field survey data to enable accurate calibration between loggers measuring TSS in mg/L and loggers measuring TSS in NTU. The programmed field survey was important to enable this calibration even though some delays were caused by weather. The need to resolve calibration and data smoothing were identified as issues that should be resolved as early as possible in a project.

Determining the relationship between NTU and turbidity was not simple therefore it is critical to calibrate the instruments and not use assumptions from previous projects. In order to get the best correlation, it is important to look at water quality over a range of conditions, from calm to very rough. Inter-calibration exercises should be undertaken during the baseline study to provide greater certainty.

The value of the water quality monitoring program for the Hay Point project was that it highlighted that an exceedence of a water quality trigger alone should not be used to stop or move the dredge but rather be used as an "early warning" indicator to examine coral condition and determine what the measurements actually mean to the coral.

The workshop also highlighted the importance of evaluating the duration of natural elevations in TSS which can be identified from the background data and control site data. This was important to identify the differing chronic and acute impacts to coral communities. It is important to correlate sea state and wind with water quality, as background conditions on a windy day are very different to those experienced during low wind and wave periods. These comments have been addressed in some of the post-dredging analysis of water quality data included in this report.

6.2.5 Marine Plants and IMP

The marine plant monitoring program demonstrated that not all marine plants are the same. There would be very different results if the marine plants were denser intertidal meadows that are typically less variable, instead of deepwater meadows. Given that no marine plants were present in the port prior to and throughout dredging, it would have been beneficial to survey areas outside the port limits but time and weather did not allow it.

Baseline information is very useful in the development of a marine plant monitoring program. It also assists in planning a dredging campaign, particularly with determining the material location site. The design of the marine plant monitoring program for the Hay Point project was partially based on the modelling, in particular for identifying reference sites outside the influence of the plume. In this case, the effect of the plume was greater than what modelling anticipated, hence reference sites were partially affected by the plume. The selection of reference sites therefore, should be a multi-disciplinary approach, based on as much information as possible and not just modelling. Habitat information, such as the locations of benthic communities such as seagrass, algae and corals should also be incorporated into modelling if possible.

In future assessments for a capital dredging projects, regulatory authorities should consider the value of different types of marine plants, particularly if marine plants recruit in an area after dredging has stopped, which means the loss was only temporary. Furthermore, the value of the marine plants to turtles and dugong, not just fisheries, should be identified. Finally, it should not be assumed that because a marine plant is not present, that the area is not potential habitat.

6.2.6 Remote Sensing

Remote sensing made it possible to track plumes spatially and identify actual events occurring on the coast, such as algae blooms. The calibration of the imagery was good, with scatter plots showing the r^2 = 0.9 which is a very good correlation.

There are some technical issues associated with remote sensing, such as data storage and processing times, and the fact that sometimes, forecast data is not available in time for atmospheric correction. The satellite measures reflection on the surface of the water and as water loggers for the Hay Point project were located on the seabed, there may have been some disconnect.

Remote sensing may be useful for community consultation as it produces images which are a good method of demonstrating what is occurring with the plume. It has been identified that it is possible to overlay wind imagery (Quickstat) on data and provide information on the behaviour of the plume during various wind events. This could be useful in demonstrating to stakeholders the behaviour of the plume. There is a danger however, of images not being interpreted correctly.

Remote sensing will not replace other forms of monitoring such as water quality monitoring. Furthermore, it does not have a predictive capability to demonstrate what impact the dredging may have, so it will also not replace hydrodynamic modelling. Remote sensing images should not be compared to hydrodynamic models as they may not be based on the same set of conditions.

The technology was useful from a remote access point of view, but use of the technology for future dredging projects will depend on monitoring budget availability and time restrictions. If used for future capital dredging campaigns, it would be useful to input vessel based water quality data to assist with correlation analysis and digital bathymetry data to model the contribution from bottom reflection.

6.2.7 Hydrodynamic Modelling

Hydrodynamic modelling is complex and at times not well understood, however, it is a predictive tool critical to the EIS process. Modelling requires data for input, and assumptions to be made and consequently there may be some uncertainties (Turner *et al.* 2005). Increasing stakeholder understanding of these uncertainties is critical if the model is to be interpreted correctly.

It can be difficult to find a good site to obtain background data as there are many influencing factors, such as sediment type, depth, exposure to wind and waves etc. When there is the benefit of good baseline information, modelling can work very well, but if it is not available then a sensitivity analysis can be undertaken at the start of the project to provide a greater understanding.

The movement of sediment in the marine environment is dependant on wind, waves and the tidal phase (spring/neap). The key lesson learned with respect to hydrodynamic modelling associated with the Hay Point project is that all dredging modelling should incorporate the effects of wind and waves. The model undertaken was quite accurate for low/moderate wind and wave conditions. It represented the tidal forces and absence of high wind and waves well, but in shallower areas, such as reef communities, it is important to model both wind and waves.

The weather conditions during a dredging project cannot be predicted in advance, but a range of situations can be modelled. Furthermore, all possible weather conditions or dredging scenarios will never be able to be modelled, so it is important to look at the major issues of concern and represent these in the model, in particular, the worst case scenario. If additional time and funding is available, an extra model run could be undertaken for calm weather conditions as well as high wave conditions.

Settling velocity should be obtained before modelling starts if possible, through surface seabed samples or geotechnical core samples and it should be accepted that the size of the dredge will not be known until approximately six months before dredging starts, so this model input will almost always be assumed.

It was determined that in future, EIS Terms of Reference need to specify what parameters should be modelled, that is, wind, waves, sediment, tides etc., so that these can be incorporated into the modelling program. Regulators should consider performance criteria for a model and look at what the model will be used for. If it is to be used to determine the spatial extent of the plume, then one set of performance criteria would be required. If the model will be used to set trigger values, then more precision is needed and another set of performance criteria needs to be established.

6.2.8 Baseline Studies and Setting Triggers

With all projects, there is a limit on reference sites to what is available in the area. There is, however, still a scientific basis for including such reference sites, for example, it allows the investigation of large scale events, such as coral bleaching. For large scale dredging projects, more extensive baseline studies should be undertaken if the project schedule and budget allow, in order to have a large baseline dataset that covers a suite of natural variability. This provides a better background turbidity value and determines how sedimentation in the system works. Where practical, this requirement should however, be identified at the Terms of Reference stage in order to allow the proponent the time to undertake the required baseline studies.

Relationships between weather and water quality should be established early on in the project, as should the effects of water quality on key biota. Developing threshold tolerance curves in the EIS to assist in determining the likely impacts of reduced light and higher turbidity on coral is recommended.

PCQ (2007) identifies that one of the key issues associated with the management of the project was the determination of appropriate water quality triggers to be used as an 'early warning' and consequently prompt the examination of coral health if exceeded. It is recommended that water quality investigation triggers be developed from baseline data available and they are agreed before a dredging project commences.

Once dredging and associated monitoring commences, water quality investigation triggers can be adjusted up or down based on frequency, intensity and duration of turbidity events, and the response of biota to such conditions. Management of dredging projects should move away from one specific trigger and instead use rolling triggers to identify potential issues and investigate the impact on biota.

Water quality triggers are only an estimate and attempt to establish an understanding of what is occurring in the marine system. Exceedence of a trigger does not necessarily mean that there is an associated impact on biota. During capital dredging projects, the relationship between water quality and coral health should be the focus rather than just compliance with the water quality trigger. It is recommended that an adaptive management trigger be used for future dredging campaigns and the focus of monitoring be on the direct impact of biota.

6.2.9 Environmental Approval Conditions

During the lessons learned workshop, regulators identified the importance of imposing 'reasonable' conditions for dredging projects without being excessive, however, 'reasonable' can be hard to define. A regulator can set 'limits' in a permit or allow a proponent to propose specific limits in an EMP which the regulator can either accept or reject. Having very tight restrictions in permits is not of value if they are not proven to have an improved environmental effect or are not a practical option for management. The project may risk being stopped when in fact no environmental harm is occurring. This would result in increased costs and an extended dredging program which can have a greater environmental impact in the long term. By looking at the importance of biota or habitats on the local and regional scale, regulators can gain perspective and consider the overall environmental impact if these were impacted due to dredging activities.

The approval conditions for the Hay Point project were primarily tied into the development of an EMP that addressed how the project would be monitored and managed from an environmental perspective. From a proponent's perspective, this is best practice as it allows for practical, adaptive management, whereby decisions are made throughout the project. It is important, however, that the proponent explores specific management strategies prior to the development of the EMP, to determine what strategies will actually result in improved environmental outcomes.

The management method undertaken for the Hay Point dredging project did not give regulators the type of conditions they were used to imposing, but regulatory representatives were actively involved in the monitoring and management throughout via the EMP and MRG.

From a best practice point of view, it is important to obtain the permits in a reasonable timeframe and allow extra time to work out the exact details (that is management strategies) in an EMP prior to the dredging campaign commencing.

A key outcome of the project was that through the adaptive management process inherent in the project approvals, monitoring requirements, and hence project costs, were able to be reduced. The monitoring program was designed to enable gradual reduction in monitoring intensity, if environmental impacts were demonstrated to be below predicted levels. This maintained the focus on environmental outcomes rather than proceeding with excessive monitoring.

7 Conclusions

Capital dredging at the Port of Hay Point undertaken in 2006 was highly successful and resulted in minimal environmental impact, which was well within the predictions of the EIS. It demonstrated that through a collaborative approach to EIA, approval conditioning and implementation, common objectives can be achieved for all stakeholders.

The approach to the EIA process delivered an integrated approval which was practical and easily implemented. Importantly this approach also focused on management strategies which were responsive to actual changes in habitat, rather than previously used practices of imposing arbitrary water quality trigger values that do not have a direct correlation to impact on habitat. The innovative monitoring and management undertaken for the project is considered to be best practice and approaches were designed to contribute to the overall knowledge of habitats likely to be impacted through similar projects.

Monitoring programs and actions outlined in the EMP were demonstrated to be effective mechanisms for the monitoring, reporting and management of the dredging program. Outcomes of monitoring programs have provided a wealth of knowledge unparalleled by similar project undertaken within Australia.

The monitoring program was designed to enable gradual reduction in monitoring intensity, if environmental impacts were demonstrated to be below predicted levels. This maintained the focus on environmental outcomes rather than proceeding with excessive monitoring.

The assessment and management process, which included, collaboration with stakeholders, management via the MRG, real-time water quality monitoring, and the focus on coral condition, provided a high level of confidence in the management of the project. This enabled regulators to be confident that the desired environments outcomes for the project would be achieved.

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APPENDIX 2

STATEMENT BY ASSOCIATE PROFESSOR JOHN JILLETT

Statement On The Historic Ecological Effects Of Capital Dredging In Otago Harbour, 1977

My name is John Jillett, former director of the Portobello Marine Laboratory (1974 – 1993). I was a member of academic staff of the Marine Laboratory, Department of Zoology and later Department of Marine Science at the University of Otago for over 30 years, from 1966 until my retirement in1997. I have continued to maintain my interest in marine ecology, following on from my own research and the supervision of many Otago postgraduate students through my career.

I have been asked to outline my recollections of environmental effects resulting from capital dredging undertaken for the development of Port Chalmers as a container port in about 1977. There is no doubt in my mind that this dredging work had by far the greatest deleterious impact on the ecological health of the Otago Harbour in my whole 45-year experience at Otago University.

Capital dredging operations, especially the cutting of the new turning basin, necessitated the disturbance of fine sediments and resulted in the suspension over a prolonged period of large quantities of fine silts and clays in the water column. These fine suspended sediments became widely distributed throughout the harbour by tidal currents. During these operations the display tanks in the public aquarium at Portobello generally became so cloudy it was not possible to see the back walls. Settlement of suspended sediments necessitated a greatly increased onerous workload to keep the tanks clean. As a result he seawater supply to the laboratory and aquarium has since been routinely cleaned by sand filtration, the filters having been installed in the mid-1980s.

Two research projects in particular, being undertaken at the Portobello Marine Laboratory, bridged the 1977 capital dredging work and resulted in direct and indirect observations of its ecological effects. One was a postdoctoral study of grazing interactions and competition between intertidal grazing molluscs and algae on open coast and harbour rocky shores. The second study concerned growth, reproduction and feeding of Bluff oysters suspended from a raft in harbour waters off the marine laboratory.

In the study of intertidal grazer interactions, the spread of a continuous mantle of fine silt and clay over intertidal rock surfaces completely sabotaged the objectives of the study and many of the grazing molluscs originally present died, apparently through starvation. Their normal food is derived from microscopic films of algae that were smothered by the sediment mantle.

In the oyster study several seawater parameters were being monitored, these included suspended sediments, phytoplankton standing crops and nutrients in harbour waters. The monitoring programme was extended to measure the quantities of suspended sediments on a more frequent basis. The approximate values for suspended sediments in harbour waters during the 1977 dredging operations were as follows:

	Normal Values	Values During Dredging
Calm conditions	4 – 8 $g.m^{-3}$	18 – 25 $g.m^{-3}$
Storm Conditions	18 – 25 $g.m^{-3}$	200 –350 g.m-3

In other words the previous storm conditions came to apply during fine weather and there was something like a 10-fold increase in the quantity of suspended sediment during stormy weather.

The effects of dredging included the smothering of benthic organisms, the loss of condition through starvation of filter feeders such as sponges, ascidians and bivalves. During this period the only significant population of pipi (*Paphies australis*) within the harbour disappeared. Macroalgae also suffered through being cloaked with sediment that reduced the amount of light available for photosynthesis.

These effects were long-lasting and it took 10 to 12 years, that is until the mid-1980s, before harbour ecology improved to the pre-dredging state. Since then the general ecological health of the harbour has further improved to a better condition than at any previous time in my experience.

There is no doubt in my mind that "incremental" dredging, undertaken progressively over a prolonged period, is much more environmentally sympathetic than intense capital dredging with a short time frame.

Note: The original data gathered on suspended sediment disappeared from the marine laboratory files many years ago and subsequent efforts to locate them have failed. Therefore I have not been able to be exactly precise about the quantities and timing.

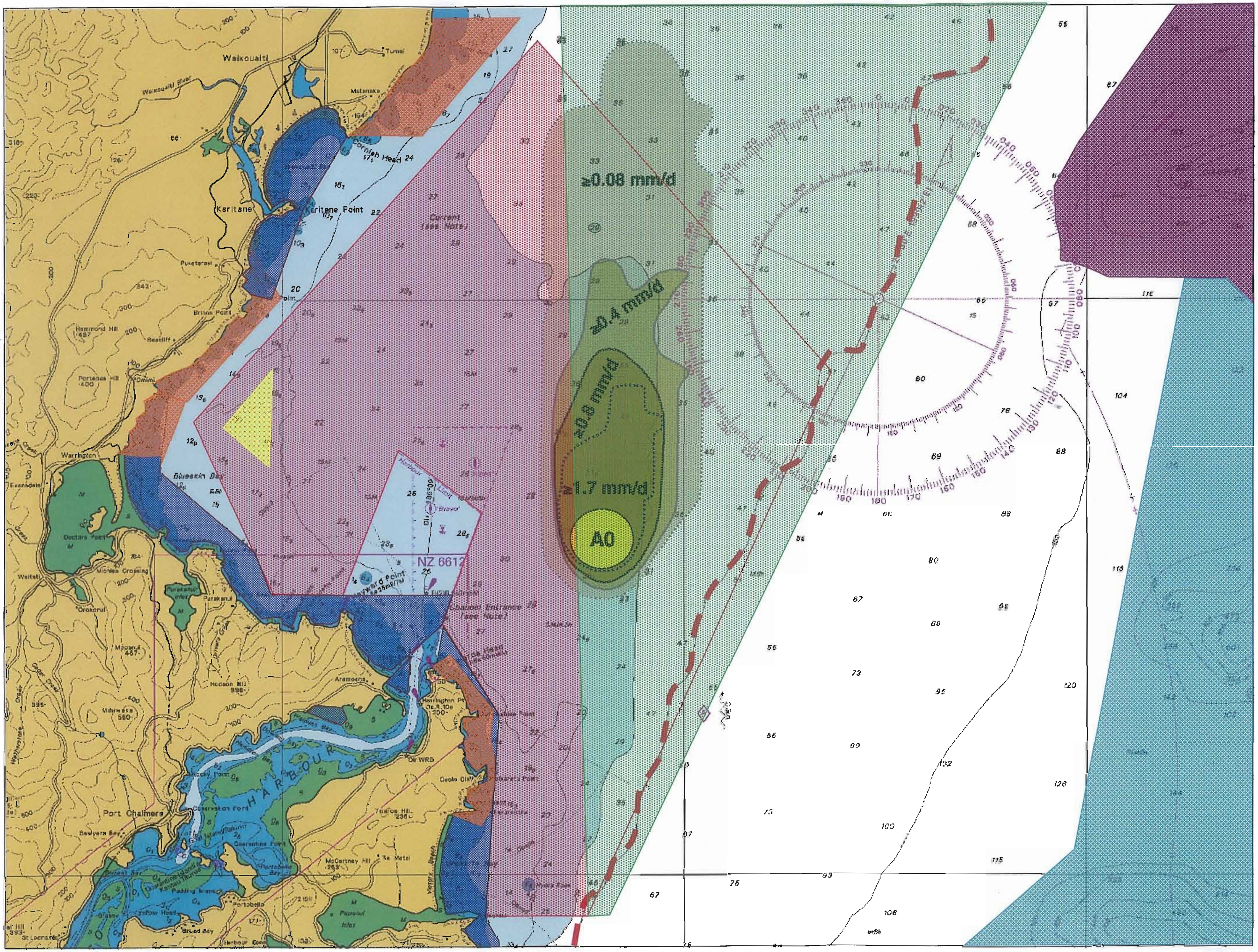
John Jillett ONZM MSc PhD

51 Every Street
Dunedin 9013

7 April, 2011

APPENDIX 3

DELINEATION OF FISHING GROUNDS WITHIN BLUESKIN BAY AND SURROUNDS


≥0.08 mm/d
≥0.4 mm/d
≥0.8 mm/d
≥1.7 mm/d
A0
NZ 6612
Waikouaiti
Karitane
Karitane Point
Cornish Head
Warrington
Blueskin Bay
Port Chalmers
HARBOUR

KEY:

Small inshore vessel trawl ground

Larger vessels working flatfish and elephant fish with some gurnard and red cod

Approximate outer limit of flatfish grounds

Paddle crab grounds

Crayfish and Paua

Naturally created "bog hole" due to gyre

Set netting

Queen scallop grounds