BEST PRACTICE ENVIRONMENTAL MANAGEMENT

GUIDELINES FOR DREDGING

EPA VICTORIA

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GUIDELINES FOR DREDGING

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FOREWORD

Dredging is necessary to create and maintain shipping and boating channels so that we can continue to engage in international trade and to enjoy safe fishing and recreational boating. However, dredging has the potential for significant environmental impact. These guidelines identify such impacts and suggest measures that may be taken to minimise them. They have been developed in consultation with organisations that undertake dredging, dredging contractors and conservation interests.

In many cases impacts are minimal, but any impacts can cause considerable public concern. For example, discharge of black anaerobic sand onto sandy beaches looks and smells unpleasant, but the environmental impacts are minimal, and a typical sand colour returns after a few days exposure to air. Where the impacts of dredging are poorly known these are identified in the guidelines and addressed through monitoring or targeted research where this is considered more appropriate.

A new mandatory process for consideration of dredging proposals is outlined. This represents a new step towards better control of the impacts of dredging that started when EPA developed the Trial Dredge Protocol in 1992. It involves a cooperative approach between Environment Protection Authority and the Department of Natural Resources and Environment, and the issuing of a *Coastal Management Act* 1995 consent for dredging works. Further advances in dredging technology and in our understanding of the major impacts will, in time, lead to further improvements to these guidelines.

Finally, I thank members of the Dredge Protocol Management Committee for their contribution to the development of these guidelines. The technical appendices were written by Greg Parry, Sue Bextream (appendix 6), Gus Fabris (MAFRI, appendix 3) and Andrew Longmore (MAFRI, appendix 4).

BRIAN ROBINSON

CHAIRMAN

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1. INTRODUCTION

These guidelines have been developed to advise agencies of environmental requirements for dredging in Victorian waters. They apply to both dredging and disposal of sediments within Victorian jurisdiction. It is noted that disposal of sediments off the open coast (rare in Victoria) also requires a Commonwealth permit, though sand bypassing and beach renourishment are normally exempt.

These guidelines are based on many years of experience using the "Trial Dredge Protocol" and on an independent review of its effectiveness. They also take into account the ANZECC guidelines for disposal of sediments in waters under Commonwealth jurisdiction. When justified by new knowledge or understanding, the Guidelines will be revised accordingly.

In Victoria, maintenance dredging removes approximately 1.2 million m^3 of sediment annually from shipping and boating channels (table 1). Capital dredging projects occur when there is a need for new or deeper channels. In recent years, major capital dredging works have included deepening the Geelong Channel (five million m^3 1997), creation of a new berth at Webb Dock (450,000 m^3 1997) and dredging turning basins and berth pockets in Western Port (1.5 million m^3 1967–73).

On an international scale the amount of dredging in Victoria is small. In the USA, more than 230 million m^3 are dredged annually from waterways and a similar volume is dredged in Europe, with 40 million m^3 being dredged annually from waterways in the Netherlands alone (Donze 1990). The proportion of contaminated sediment in Europe and the USA is also significantly greater than in Victoria as a result of much larger manufacturing industries having discharged contaminants. For example, polychlorinated biphenyls (PCBs) are major contaminants in several US rivers near the site of manufacture. PCBs are persistent toxicants in Victorian sediments, but, as they were never manufactured locally, quantities are seldom of concern and they are far below those of contaminated US rivers.

In Victoria most dredged sediment is clean sand (table 1). Large quantities of sand are dredged annually to bypass harbours at Lakes Entrance, Portland and Queenscliff and in sections of shipping channels where sand waves cause shoaling. Parts of a three nautical mile (n mile) and a 5 n mile section of South Channel in Port Phillip Bay and parts of a 1 n mile sector in Western Port shipping channel are dredged periodically. There are also many smaller dredging projects undertaken to remove sand accumulated behind man-made coastal structures or from the mouths of creeks and rivers to maintain navigational channels.

The largest volume of fine sediments is dredged from shipping channels, including parts of the Yarra River, in the Port of Melbourne. This is deposited in a spoil ground 15 km south of Melbourne. Small quantities of fine sediments are also dredged from shallow channels in Western Port as required. Typically, fine muddy sediments cause greater environmental problems as they are more likely to be contaminated and they cause more persistent turbidity than does sand.

Maintenance dredging often involves the removal of sediments recently deposited from estuaries. This dredging can be minimised by improved catchment management. Erosion controls in the catchment reduce the sediment load in rivers and reduce the need for dredging downstream. Similarly, controls on discharges of toxic chemicals into streams reduces sediment contamination within the estuary and avoids the need for expensive procedures to reduce the impact of contaminated sediment when dredging. In Victoria, improved environmental regulation since the 1970s has reduced the input of many contaminants. However, as a result of historical inputs and non-point source contamination, lead from petrol and zinc from galvanised surfaces are still evident, and these are difficult to control. Since the 1970s, discharges of heavy metals have declined and use of many persistent organics has ceased. Levels of cadmium in Corio Bay (Phillips *et al.* 1992) and mercury in flathead in Port Phillip Bay (Fabris *et al.* 1992) have decreased markedly since the 1970s, and the use of polychlorinated biphenyls (PCBs) and DDT, ceased during the 1970s (Phillips *et al.* 1992).

Table 1: Average sediment volumes (m^3) dredged per annum to maintain channels in Victorian coastal regions

Location	Volume (m^3)
Western Victoria	**172,000**
Portland fixed bypass	110,000
Port Fairy	32,000
Apollo Bay	30,000
Port Phillip Bay	**530,000**
Queenscliff	90,000
South Channel	150,000
Port of Melbourne	200,000
Yarra (N of City Link bridge)	15,000
Small-boat harbours/creeks	75,000
Western Port	**~15,000**
Shipping channels	10,000*
Small-boat harbours/creeks	<5,000
Eastern Victoria	**510,000**
Corner Inlet	70,000
Lakes Entrance (main entrance)	300,000
Gippsland Lakes, internal channels	70,000
Gippsland Lakes, others	70,000
Total	**1,227,000**

* Based on 30,000 m^3 dredged in sand wave field in 1995, but not dredged since.

1.1 Objectives and Scope

Water-based recreation (including boating and fishing), navigation and shipping, and maintenance of natural ecosystems are all protected beneficial uses in Victorian coastal waters (EPA 1988). Dredging is required to create and maintain channels for shipping and boating, adequate channel depth being necessary to guarantee important trade links, and to allow safe access for fishing and other commercial and recreational boating. However, the removal and disposal of sediments inevitably has some environmental impact. Best practice involves minimising these impacts at and near the dredging and disposal sites. Both the cost and effectiveness of measures to reduce impacts need to be considered. For example, costly measures to minimise small impacts due to limited turbidity or sedimentation, adjacent to greatly modified dredge sites or spoil grounds, are often not justified.

Many in the community are concerned that our estuaries and seas are protected. While mostly appreciating the need for safe navigation, these concerned individuals and organisations need an assurance that dredging is being undertaken in a way that minimises environmental impacts. These guidelines describe those issues that should be addressed in order to minimise the environmental impact of dredging, and suggest measures to minimise impacts. Dredging technology and the effects of dredging on the environment are also described, to better focus concerns on the more significant environmental issues. Most dredging in Victoria is undertaken by a small number of agencies, most of which have had input into the development of these guidelines.

1.2 Best Practice Environmental Management (BPEM)

The BPEM publication series provides guidelines and codes of practice for industry sectors or activities. They outline what is needed to achieve optimum environmental outcomes, consistent with the industry's economic viability.

BPEM may encompass site selection, process design, technology choice, key operating parameters and procedures, contingency arrangements, and monitoring and auditing aspects.

State environment protection policies provide ambient environmental quality objectives and general approaches to achieving them. With limited exceptions, these do not specify precisely how the objectives and strategic approaches will be achieved. BPEM guidelines provide more specific actions to achieve policy objectives.

BPEM publications outline key objectives relevant to the industry or activity and suggest measures to achieve these objectives. However, operators should feel free to consider alternatives and to apply the best site-specific solution equivalent to, or better than, the suggested measure. In this way, innovation is not stifled and flexibility is provided, while those seeking greater direction or certainty can apply the suggested measures.

The underlying philosophy of BPEM guidelines is to provide a forward-looking approach rather than simply reflect what is presently the norm. Where problems or issues occur within the industry, a direction or solution will be included.

A comprehensive environmental management system is an integral part of Best Practice Environmental Management. For large dredging projects, the principles outlined by the International Organisation of Standardisation in the ISO 14000 series, provide an ideal basis for such a management system.

Finally, a BPEM guideline is not of itself mandatory but the potential exists to call up such a document in approvals, licences or permits. Regulatory authorities generally expect that forward-looking proponents and businesses will be committed to continuous improvement through a total quality management approach and will voluntarily adopt BPEM guidelines.

1.3 Using these Guidelines

The permits required and the current legislative framework are considered in section 2. Section 3 describes those issues that are most directly relevant to dredging proponents, as they must be considered in developing an environmentally satisfactory dredging proposal. Section 4 describes the environmental management of dredging, including a list of the usual elements of an Environmental Improvement Plan (EIP) to deal with environmental contingencies during dredging. A glossary is included in section 5.

An application form for dredging is included in appendix 1. Dredging technology and the effects of dredging on the environment are described in appendix 2 to better focus the concerns on the most significant environmental issues for particular dredging projects. The technical requirements for testing for chemical contaminants in sediments to be dredged are described in appendix 3, the estimated release of nutrients during dredging is described in appendix 4, the maximum sustained turbidity to maintain seagrass is estimated in appendix 5, spawning periods for fish are described in appendix 6, a checklist for land disposal is described in appendix 7, and the format for submission of electronic data is specified in appendix 8.

1.4 How to Apply for Dredging Permits

Coastal Management Act *1995 Consents and Planning Permits*

Where the site to be dredged is within the Victorian coastal area, including estuaries to the extent of tidal influence, a *Coastal Management Act* 1995 (CMA) consent must be obtained. An application for consent should address all issues described in sections 3 and 4 of this document and summarised on the application form in appendix 1. Applications should be sent to the regional office of the Department of Natural Resources and Environment (NRE). NRE will forward the application to EPA for its consideration before a decision is taken on issuing a consent. This process is outlined in figure 1.

Where new (capital) dredging is proposed within an area covered by a planning scheme, the planning scheme application is also regarded as the application for *Coastal Management Act* 1995 consent, provided that this application is referred to NRE. For major works the Minister for Planning may require an Environmental Effects Statement (EES). The same information described in these guidelines should then be included in the EES. Thus in summary:

- Check with local council whether the area is subject to a planning scheme. If so, apply for planning permission and ensure this is referred to NRE.
- If planning permission is not required, apply to NRE for consent under the CMA.
- If an EES is required, prepare documentation in addition to the above process.

The application should address all issues on the form in appendix 1 and be sent to the responsible authority, usually the local council. The responsible authority will refer the application to NRE which will consider the application both as a referral authority under the *Planning and Environment Act* 1987 and as an application for consent under section 40 CMA. The application will be considered by EPA before a decision is taken.

Proponents should also consider whether the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 could apply (see Section 2.2).

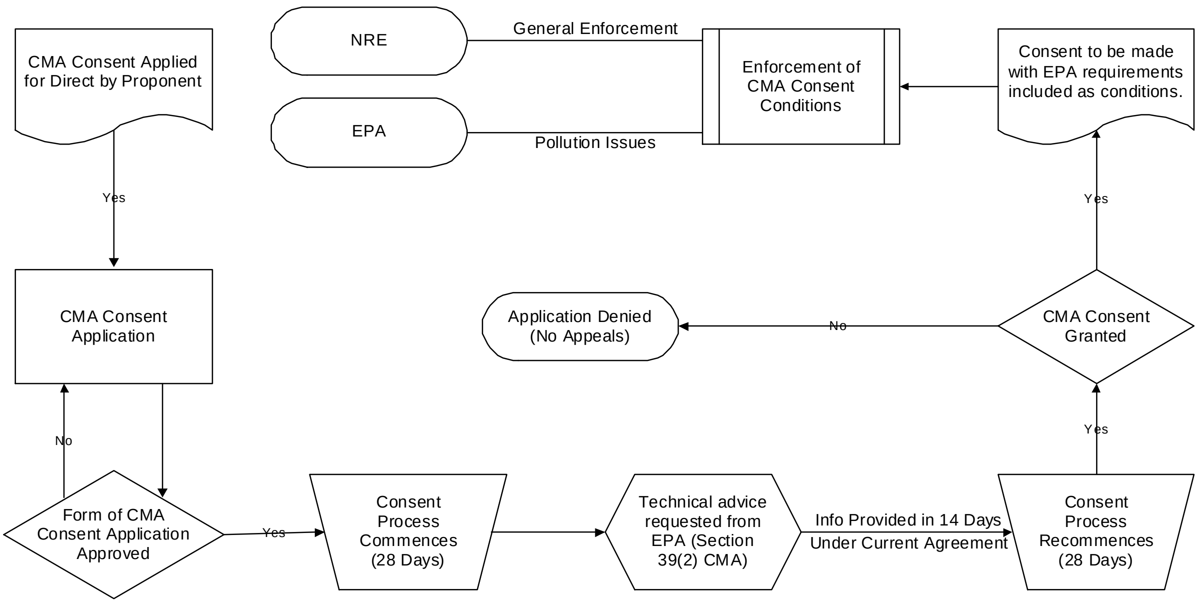


Figure 1: Dredging approvals process for all maintenance dredging and capital dredging in areas not subject to a planning scheme or EES.

Permission from Port Manager

Dredging within port waters requires the permission of the local port manager, to ensure that the dredging design, safety and operational issues are satisfactory. In smaller estuaries, dredging is usually undertaken on behalf of the local port manager; where this is not the case, proponents must obtain the permission of the local port manager as the first step.

Parks Victoria is the port manager for dredging undertaken in the Yarra River (upstream of the Charles Grimes Bridge), Port Phillip Bay and Western Port. Gippsland Ports is the port manager for Gippsland Lakes. For dredging in the major ports of Hastings, Geelong, Melbourne and Portland and in shipping channels, permission must be obtained from the Victorian Channels Authority.

Public consultation

It is essential that proponents discuss their dredging proposal with all parties likely to be affected, as early as possible in the planning stages.

Where dredging requires a planning permit under the *Planning and Environment Act* 1987, the responsible authority (usually the municipal council) may require the proponent to give notice of the planning permit application to any people who may be affected by the dredging. The form of notice may be by direct written notification, a sign on or near the site and/or a notice in local or regional newspaper(s).

In considering applications for consent under the *Coastal Management Act* 1995, NRE will require the proponent to demonstrate that the appropriate notice and/or consultation with people most likely to be affected has been undertaken prior to NRE considering whether or not to provide *Coastal Management Act* 1995 consent for the dredging.

It is important for proponents to recognise the need to consult with people most likely to be affected, whether or not they have been asked to give formal notice and/or consult with these people by the responsible planning authority or NRE. Effective public consultation takes time, so proponents should ensure that in planning dredging works that a minimum of four weeks is allocated for consultation, and possibly longer if notice and/or consultation is required by a responsible planning authority and/or NRE.

Timelines

Applications for planning permits and CMA s.40 consent for dredging must normally be submitted at least six weeks before the proposed dredging; a longer period may be required where significant public consultation is required.

2. LEGISLATIVE FRAMEWORK

2.1 History of Controls on Dredging

During the early 1990s, EPA, with considerable input from port authorities, Melbourne Water and the public, developed the Trial Dredge Protocol (EPA 1992) in order to set environmental standards for dredging in Victoria. Since 1992 the Dredge Protocol Management Committee (DPMC) has considered most dredging proposals in Victoria. Its role has been to assess whether dredging proposals conformed to the requirements of the Trial Dredge Protocol (TDP). The DPMC included representatives from EPA, Department of Natural Resources and Environment, Department of Infrastructure, Victorian Channels Authority and Parks Victoria.

The operation of the TDP was reviewed in 1994–95 (EPA 1995a). This review recommended the development of these best practice guidelines and that the voluntary TDP should be replaced by mandatory controls. The review recommended controlling dredging through the *Planning and Environment Act* 1987, with the EPA acting as a referral agency. While this approach was endorsed in the Coastal Strategy released in 1997 through the extension of planning schemes over coastal waters, it has been adopted only partially. A planning permit may be required for new (capital) dredging where a planning scheme extends, or is extended, over the area to be dredged. However, mandatory control of maintenance dredging will be through section 37 of the *Coastal Management Act* 1995. Since 1997, maintenance dredging has required consent under this Act so it provides the most efficient administrative mechanism for mandatory control of maintenance dredging.

The Trial Dredge Protocol (TDP) supported the development of dredging strategies to reduce the need for endorsement of individual applications for repetitive maintenance dredging. These strategies addressed the range of environmental issues considered in the TDP. Once endorsed by the Dredge Protocol Management Committee, dredging work that conformed to the dredging strategy required no further endorsement. The review of the TDP (EPA 1995a) recommended that these strategies should be employed for a period of five to ten years.

These guidelines place increased emphasis on the need for long term planning, but new administrative arrangements make the term ‘dredging strategy’ unnecessary. All dredging proposals must now address the long term need for spoil disposal and consents will only be issued where such planning is adequate. Proponents who demonstrate adequate forward planning may be issued with a *Coastal Management Act* 1995 consent for maintenance dredging for up to 10 years.

2.2 Legislation that Affects Dredging Proposals

Environmental Issues

The *Coastal Management Act* 1995 requires that in Victorian coastal regions, including estuaries to the extent of tidal influence, the Minister for Conservation and Land Management must provide written consent for any use or development on the coast, including dredging and spoil disposal. However, where a planning permit is required through the *Planning and Environment Act* 1987 and the Department of Natural Resources and Environment is a referral authority, the planning permit application is considered to also be the application for *Coastal Management Act* 1995 consent.

Dredging proposals involving large economic, social and environmental impacts (eg deepening shipping channels) should be referred to the Minister for Planning under the *Environment Effects Act* 1978 for his decision on the need for an Environment Effects Statement (EES).

On the open coast, dumping of dredged material, other than beach renourishment, must satisfy the requirements of the Commonwealth *Environment Protection (Sea Dumping) Act* 1981 administered by the Environment Protection Group of Environment Australia. All current dredging operations outside the bays in Victoria are beach renourishment and therefore do not require approval from the Commonwealth.

Water-quality criteria and environmental objectives for various coastal regions are specified in State environment protection policies (SEPPs). The *State Environment Protection Policy (Waters of Victoria) Schedule F6 Waters of Port Phillip Bay* (EPA 1997) requires that dredging and spoil disposal should be conducted so that:

1. They are in accordance with the most current code of best practice approved by the Authority.
2. Local exceedances are confined to the smallest practicable area and over the shortest practicable time in the vicinity of the dredging and disposal operations.
3. Resuspension and/or dispersal of sediments or accumulated contaminants will not be detrimental to the long term protection of beneficial uses.
4. Dredge spoil is disposed to land in preference to water wherever practicable and environmentally safe as determined by the Authority.
5. Protection agencies must ensure that any permit issued or approval given in relation to a planning scheme for dredging or desilting operations contains requirements that are consistent with point one above.
6. Protection agencies must ensure that works for beach maintenance and beach renourishment are consistent with the long term protection of beneficial uses, particularly the maintenance of natural aquatic ecosystems.

The *Environment Protection Act* 1970 specifies substantial penalties for pollution. Penalties can apply to individuals, companies and/or company directors. Where there is concern that dredging or spoil disposal may cause pollution, EPA may issue a Pollution Abatement Notice (PAN) under section 31A or a Minor Works Pollution Abatement Notice under section 31B of the *Environment Protection Act* 1970. A PAN takes effect 30 days after it is served, while a minor works PAN is effective immediately and may be served if urgent action is required, but only if the cost of compliance will not exceed $50,000. A Notice may also be issued under Section 62A of the *Environment Protection Act 1970* where cleanup of contaminated sediment or other material is required.

The Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (the EPBC Act) is administered by Environment Australia. It establishes an environmental assessment and approval system that is separate from and additional to State systems. The EPBC Act establishes matters of national environmental significance (that is, World Heritage properties, Wetlands of international importance (Ramsar wetlands), listed threatened species and communities, listed migratory species, nuclear actions, and Commonwealth marine areas). Under the EPBC Act, a person must not take an action that has, will have or is likely to have a significant impact on a matter of national environmental significance, except where certain processes have been followed and/or certain approvals obtained. Penalties for unlawfully taking such an action include a fine of up to $5.5 million or up to seven years imprisonment.

The EPBC Act requires proponents of actions to which the EPBC Act may apply to seek a determination from the Commonwealth Environment Minister as to whether or not their proposed action is a 'controlled action'. Proponents must then, if the Act applies, seek approval for the controlled action directly from the Commonwealth Environment Minister. The State Government is not able to advise proponents on whether or not any particular proposal is affected by the EPBC Act; this advice can only come from the Commonwealth Environment Minister.

For more information see the web sites referenced Victorian Government (2001) and Environment Australia (2001).

Planning, Design, Construction and Maintenance of Channels for Safe and Efficient Port Operations

The *Marine Act* 1988 enables the Minister for Roads and Ports to designate an agency as a local authority for particular state waters. Parks Victoria was designated the local authority for Port Phillip Bay and Western Port in 1997 with the following powers relevant to dredging: to manage a safe, efficient and effective port, to provide and maintain navigational channels, to plan, design, construct and maintain and to authorise and control the construction, use and maintenance of dredging.

The *Port Services Act* 1995 gives the Victorian Channels Authority wide powers to undertake dredging, 'subject to obtaining any permit, consent or authority required under any other Act.'

Melbourne and Metropolitan Board of Works Act 1958 section 273 gives the board powers with respect to any waterways such that the board may '…dredge and improve the beds banks and channels thereof.' Parks Victoria now administers this part of this Act.

3. ENVIRONMENTAL CONTROLS

The environmental impact of dredging should be minimised by considering the range of issues described in this section. For any particular proposal, only those issues that are relevant to it need to be addressed. However, issues also need to be considered as part of a well-integrated plan. A consent will only be issued if adequate long term planning is evident and an adequate Environmental Improvement Plan (EIP) exists as described in section 4 of this document.

3.1 Minimise the Need for Dredging and Spoil Disposal

As all dredging causes an environmental impact at the dredged site and the disposal site, the proposed amount of dredging must be justified. As dredging is also costly, dredging proponents usually have a strong economic incentive to minimise dredging.

Where proposed new dredging works will require ongoing maintenance dredging, a satisfactory means of disposal of spoil from maintenance dredging must be determined before the works are approved. Similarly, where there is a need for ongoing spoil disposal from maintenance dredging of established channels, proponents must indicate the amount and frequency of future dredging and how spoil can be disposed without progressively increasing the area impacted near the dredging site.

Erosion in catchments is a major source of sediments that must eventually be dredged from streams or coastal areas. EPA recognises that controls on inputs from catchments are largely outside the control of dredging proponents, but all options to reduce inputs should be explored. For example, partial funding of the establishment and maintenance of sediment traps on streams that reduce the need for dredging downstream, including port areas, may be investigated. If traps prevent input of contaminated sediments, they may result in both environmental benefits and cost savings to the dredging proponent. Dialogue between catchment management authorities and those engaged in river and port dredging may facilitate actions that reduce the need for dredging.

Any increase in the depth and width of channels should be justified. Shipping channels are currently maintained at depths of 12.3 m to Geelong, 13.1 m to Melbourne, 14.3 m at Western Port, five m to Port Welshpool, and 6.5 m to Barrys Beach. No dredging is required outside Portland Harbour where the natural depth is 13.5 m; Portland Harbour is dredged to accommodate vessels drawing 12 m (inbound) and 12.6 m (outbound). These depths are based largely on the depth requirements of current vessels, although the 14 m depth of the rocky entrance to Port Phillip Bay currently limits the draft of vessels entering the Bay. The amount of dredging and the volume of spoil also depends on the width and profile of channels. In the case of shipping channels, these are determined by international standards (for example PIANC 1997).

When shipping channels are deepened, large economic, social and environmental impacts result, so such proposals should be referred to the Minister for Planning under the *Environment Effects Act* 1978, for a decision on the need for an EES.

The depths and widths of channels maintained for small vessels must also be justified in terms of the needs of the local boating community. Throughout Victoria, the depths to which channels are maintained for small boats are typically 2-3 m, and should be justified when channel depths exceed 2.5 m. Commercial fishing vessels and large yachts may require channels deeper than 3 m and 4 m respectively.

Where there is evidence that realignment of a channel would reduce the need for maintenance dredging, this option should be fully investigated. Similarly, and consistent with vessel safety, movements of deep-draught ships should be coordinated with periods of high tide, so that large vessels can be accommodated without the need for dredging deeper channels. This is already standard practice in most ports.

Double handling of spoil, where spoil is discharged at a temporary spoil site before it is removed and placed at its final disposal site, should be avoided, as this method typically doubles the seabed area impacted by spoil. Where a temporary disposal site can be confidently confined to an area of low environmental value or to an area that will soon be dredged anyway, use of such a temporary disposal site may be acceptable. Double handling of spoil is also acceptable where there is no practical alternative, for example, where a land disposal site is beyond pumping distance of a dredger and sediments must be dried before transport to their final destination.

In the urban lower reaches of the Yarra River, dredge spoil has periodically been discharged to the fast-flowing central section of the river. This practice results in these sediments being dredged again sometime later from shipping channels in the port area and should be avoided. Where feasible, sediments from the urban lower reaches of the Yarra should be disposed to land. Experimental studies (Alexander 1986) have shown that increased sand load on upland streams may reduce fish populations and benthic food organisms, and cause major habitat alterations. Large estuarine systems, which are exposed to multiple, cumulative impacts, have been less adequately studied, making carefully designed (eg BACI) studies of impacts desirable, although not always practical (Niemi *et al.* 1990; Sparks *et al.* 1990). Where this method of disposal is adopted, the fate of dredged sediments should be confirmed by subsequent monitoring. The effects of this sediment on benthic communities should be established as part of a river-monitoring program that assesses particular impacts and enables evaluation of catchment improvements and other management measures.

Where areas of land are to be excavated, dredging should be land-based and spoil should be disposed on land. Only in special circumstances would disposal to sea be considered. Similarly, where artificial basins and canals are to be connected to a waterway, as much excavation as possible must be carried out in a dry environment and beds and banks should be fully stabilised before being connected to the sea.

Where a dredging project will generate sand, coordination of the project with beach renourishment should be considered so that the amount of dredging across the two projects is minimised.

Minimising Dredging
Objective *To minimise need for dredging and spoil disposal.* **Suggested measures** • Support actions that minimise erosion in catchments. • Justify depth and width of channels. • Re-align channels where this will reduce future dredging. • Use tides to assist entry of deep-draught vessels. • Avoid temporary spoil sites. • Avoid discharging dredge spoil into rivers. • Maximise excavations in the dry and dispose of sediments to land. • Coordinate dredging proposals, particularly with beach renourishment. • Establish spoil disposal arrangements for maintenance dredging for new and ongoing dredging that minimise long term impacts.

3.2 Minimise Physical Effects of Spoil Disposal

The total area covered by spoil should be minimised. The selection of appropriate dredging and disposal methods is critical to achieving this objective (see section 3.5).

The volume of spoil to be placed on a spoil ground should be estimated, including an allowance for overdredging and bulking. For large dredging proposals (greater than 100,000 m^3 of sediment), the footprint of the spoil should be estimated by taking into account the dredging and disposal methods to be used and the extent of fluidisation of sediments that may occur.

Beneficial Use of Spoil

Whenever possible, dredge spoil should be treated as a resource. At an early stage in the planning of each dredging project, any beneficial uses that may be appropriate for the spoil should be identified. To date, beneficial uses that have been found for spoil in Victoria include land reclamation for port development, beach renourishment, raising the level of residential land, island creation and creation of breeding habitat for little terns. Uses that have been found for spoil in the USA include wetland restoration, parks, agriculture, horticulture and forestry (USEPA 1992a). In general, coarse-grained sediments are suitable for a wide range of beneficial uses, but fine-grained dredge material may only be suitable for recreational sites or for lightweight structures that require only weak foundations.

The feasibility of particular beneficial uses also depends on the contamination status of the spoil and various logistical factors (USEPA 1992a). Contaminated spoil is not suitable for many beneficial uses. Logistical factors that need to be considered include distance between the dredging project and the proposed beneficial use, site accessibility, dredging equipment required *versus* equipment required to transport material to site, size of project *versus* size of disposal site or beneficial use, and the compatibility of timing between the needs of the beneficial use and the need for dredging. Where disposal is to land, there must be a site near the dredge site suitable for sediment dewatering where the high salt content of the sediment and leachate will not cause other environmental problems.

Beach Renourishment

Beach renourishment provides a means of erosion control and a means of restoring beaches damaged by human interference. Commonly, beach renourishment is required as part of a sand bypass system necessary to maintain natural coastal processes. Creation of new sandy beaches should not threaten significant biological communities in the area which have values different from those of sandy beaches. For example, while loss of small areas of seagrass during beach renourishment may be acceptable, extensive naturally occurring seagrass beds should not be impacted by beach renourishment. Beach renourishment is a beneficial use of spoil that should be considered whenever a dredging project will generate sandy spoil. As noted in the previous section, beach renourishment should, where possible, be coordinated with other dredging projects so that the amount of dredging across the two projects is minimised.

Maintenance of Natural Coastal Processes

Where dredging is required to remove sand accumulated behind a breakwater or similar man-made structure, or to maintain a navigable river entrance, the preferred disposal option is usually that which will cause minimal impact on coastal processes. Dredging that enables sand to bypass man-made obstructions and duplicates the effect expected from natural sediment transport processes will be preferred, provided that sediments are not contaminated.

New Spoil Grounds

New spoil grounds require a *Coastal Management Act* 1995 section 37 consent. Before new areas are designated as spoil grounds, the proponent should: assess the proposed location, assess marine communities at the disposal site, document any items of historic interest (for example, shipwrecks), and assess beneficial uses of the area. This will usually involve consultation with environment and fisheries organisations, local fishers, divers and other relevant organisations. If existing information is inadequate, surveys of marine biota at the disposal site and appropriate control sites may be required to ensure that the designated area has no identifiable critical resources, or to provide a baseline against which changes can be measured. Sampling in the latter case will need to be quantitative and should be replicated at all appropriate spatial scales and, where necessary, stratified by depth.

Sediment Characterisation

In all but the smallest dredging projects, the physical characteristics of the sediment to be dredged should be established. The particle size, specific gravity and organic content of the sediment to be dredged must be determined and if data are not available for sediments on the spoil ground, the parameters for these sediments must be measured as well. The number of samples required is discussed in appendix 3 and summarised in table 2.

Comparisons of the physical characteristics of sediments between the dredge and spoil sites indicate the likely stability of spoil. (Grain size of sediments also indicates the likelihood of contamination, as coarse sediments are rarely contaminated; see section 3.3).

Table 2: Typical number sediment cores to be sampled for dredging proposals removing different volumes of material (summarised from appendix 3)

Volume of material to be dredged (m^3)	No of cores required at dredging site[a]	No. of cores required at disposal site[b]
up to 25,000	3	3
25,000 – 100,000	4– 6	3
100,000 – 500,000	6–10	6
500,000 – 2,000,000	10–20	6
for each 1,000,000 above 2,000,000	additional 10	

a In certain circumstances, samples may be composited as this allows the analysis of sediments from more sites for the same cost. Where the site history indicates that contamination at depth is unlikely, measurements of contaminants will only be required in surface sediments.

b Not required when these data are already available. Only surface samples are needed to assess grain size and background contamination. If the disposal site is new, samples may be collected within the disposal area, otherwise samples must be collected from reference sites adjacent to the spoil ground but beyond the influence of any sediments disposed previously.

Assess Spoil Ground Stability

It is preferable that spoil is disposed in areas with similar sediment characteristics because similar biological communities are likely to re-establish and spoil is likely to be stable. The stability of spoil grounds should be established by comparison of grain sizes of sediments to be dredged with those at the spoil ground and, for larger proposals, by modelling.

Dispersive spoil grounds, such as sandy channels with fast currents, are suitable only for the deposition of sandy sediments with similar grain size to the spoil ground. Sediments finer than those native to such spoil grounds will disperse more readily and may contribute to ongoing turbidity far from the disposal site.

Where large amounts of sediment are placed in a spoil ground, and previous studies have been inadequate to confirm their stability, their fate should be confirmed by subsequent monitoring (see section 3.8).

Physical Effects of Spoil

Objective

To minimise physical effects of spoil.

Suggested measures

- Minimise area covered by spoil (select methods carefully; see section 3.5).
- Estimate volume of spoil, and size of footprint where large volumes of spoil are disposed to marine spoil grounds.

- Use spoil as a resource where possible.
- Maintain natural coastal processes.
- Assess ecological significance of proposed new disposal sites.
- Characterise sediments to be dredged and at the spoil ground.
- Assess stability of spoil ground for the sediments concerned.

3.3 Minimise Effects of Contaminated Sediments

Contamination of dredged sediments is the result of inputs to catchments and to the port areas themselves. Port managers should identify issues that should be addressed by catchment managers to reduce inputs of contaminants in catchments that impact on port areas. Contaminated stormwater from hard-stand areas in ports should be treated before discharge. Port of Townsville has reduced berth contamination by introducing a user pays approach. Berth areas are surveyed annually and berth users are charged for any additional costs associated with clean-up of their berth area.

Port (and other marine) managers also need to be aware of their responsibilities to minimise the risk of introducing exotic species through ballast water and hull fouling. Actions to minimise such risks (including the spread of organisms through dredging) should be supported. Some species have life stages which lie dormant in sediments, causing risks in subsequent dredging.

Assess Chemical Contamination

The contamination status of the site to be dredged must be established prior to dredging. The history of uses that may contribute to contamination of sediments in the area must be documented and previous analyses of contamination or dredging at the site summarised. Where the site history indicates contamination is unlikely or where sand is being dredged, or a very small amount of dredging is involved, measurements of contaminant concentrations may not be required. Where an unforeseeable emergency requires urgent dredging, it may be appropriate to require collection of samples for analysis after dredging occurs. However, typically, the concentration of a range of organic and heavy metal contaminants on the site to be dredged must be measured before dredging commences. The choice of contaminants to be measured will be based on the site history and the volume of material to be dredged.

Proponents must ensure that the suite of contaminants analysed and the intensity of sampling adequately characterise the area to be dredged. A guide to sampling intensity is given in table 2, but as the mobilisation costs of field sampling are high, proponents should take at least twice the number of samples they plan to analyse. Should further analyses then be required they can be done quickly and without further field sampling. If high levels of contamination are suspected, the sampling intensities in table 2 are likely to be inadequate where: sediments must be disposed on land – the sampling requirements for land disposal then become appropriate; or where the site contains a mixture of contaminated and clean sediments and the proponent wishes to dispose of the two fractions separately.

All contaminant testing should follow the technical guidelines set out in appendix 3, including the use of specified detection limits.

Aquatic Disposal

The sediment quality guidelines for aquatic disposal are based on measured toxic effects and are based primarily on the interim ANZECC ocean disposal guidelines (ANZECC 1998).

Levels of contamination in sediment should be compared with both the low and high screening levels specified in the interim ANZECC ocean disposal guidelines and the background levels in the area (table 12). A low screening level is the concentration of a contaminant where toxic effects occur rarely (10 per cent of studies), while at the maximum screening level, toxic effects are common (occur in 50 per cent of studies). Note that guidelines for sea disposal are based on measured toxicity of contaminants to aquatic organisms.

The interim ANZECC ocean disposal guidelines classify sediments into one of three categories. Where the geometric means of all contaminants are below the low screening level sediments are considered clean and suitable for disposal at sea. Where the background level of a contaminant is naturally high (for example, background nickel level in Port Phillip Bay exceeds the low screening level; see table 12), the contaminant is unlikely to be in a toxic form. Spoil is considered clean if it contains less than twice the background level.

The disposal site for some clean sediments, in which heavy metal levels are more than twice background levels, should be carefully considered to prevent the unnecessary spread of contaminants. Where practical alternatives exist, unconfined dumping of this spoil will not be permitted. Where it is impractical to dispose of this slightly contaminated spoil except on a spoil ground, preference will be given to disposal on nearby areas that are similarly contaminated or on spoil grounds already contaminated above background levels. This situation could occur with cadmium, copper and lead contamination in Port Phillip Bay (table 12). Note that in comparing differences in heavy metal levels between sites, allowance must be made for any differences due to variation in grain size between sediments.

Where contaminant levels exceed the low screening level (or twice the background level for those sediments with high background values) but are below the maximum screening level, sediment is considered moderately contaminated. Its suitability for disposal at sea then needs to be established by further testing.

If analyses indicate trace metals exceeding the low screening level, further metal analyses should be conducted using dilute acid extraction. Further tests may also include measurement of acid volatile sulphide content of sediments.

Once suitable sediment toxicity tests are developed for local species, toxicity tests are likely to be required for all sediments classified as moderately or highly contaminated. There are no tests yet approved for this purpose in Australia, but tests are currently being developed. Until suitable tests are developed the acceptability of mildly contaminated spoil for unconfined sea disposal will be determined based on the practicality and likely cost of the alternatives, and the likelihood of significant toxicity based on the number of contaminants and the extent to which the low screening level is exceeded by each.

Where the high screening level is exceeded, the sediment is considered highly contaminated and disposal at sea is unlikely to be acceptable unless extensive testing indicates it is not toxic, either directly or through bio-accumulation. Alternatively, rather than undertake extensive chemical and biological testing, proponents dealing with contaminated sediment may elect to consider land or other disposal options as described in section 3.5.

Despite the approach proposed above, which largely reflects the approach of the USEPA, the frequency of dredging of contaminated sediments in Victoria is low, and may not be high enough to financially support the technical expertise necessary to develop and maintain accurate sediment toxicity tests. The need for routine sediment toxicity tests in Victoria needs to be confirmed, by assessing ecological impacts of contaminants at sites in Victoria known to be contaminated. This may be best undertaken with a one-off synoptic survey of the impact of contaminated sediments on benthic communities. This survey could, for example, use the sediment triad (for example, Chapman *et al.* 1997), in which the toxicity, benthic fauna and chemistry of contaminated sediments are all measured. This approach would enable assessment of whether there is a need for widespread application of toxicity tests and/or whether improvements to the management of contaminated spoil are required. If the sediment triad approach was adopted, sediment toxicity tests would be developed and these could be applied when necessary (see section 3.8).

Land Disposal

The reuse, storage or disposal of dredging spoil on land must not result in adverse environmental impact. Waste producers, transporters, and receivers have a range of obligations under provisions of the *Environment Protection Act* 1970 and its subordinate legislation, including a duty of care to ensure that management of waste does not cause any adverse impact to human health or the environment.

If land based management of dredging spoil is proposed, reference should be made to *Classification of Wastes* (EPA Publication 448) for guidance on the classification of wastes and their associated management requirements. Generally, the classification and management of dewatered dredging spoil should follow the requirements outlined in EPA Publication 448.

Where land based management of dredging spoil is proposed, the dredging spoil must be dewatered so that it is 'spadeable', that is, dry enough to be moved with a spade.

In some cases, dredging spoil may be contaminated with metals or other contaminants such that it is classified as a prescribed industrial waste. The classification criteria and management requirements for prescribed industrial wastes are also outlined in the *Environment Protection (Prescribed Waste) Regulations* 1998 and the

Industrial Waste Management Policy (Prescribed Industrial Waste).

Acid Sulfate Soil

'Acid Sulfate Soils' are soils, sediment or rock that contain elevated levels of metal sulfides (principally pyrite – FeS_2). Exposure of metal sulfides to oxygen – for example by drainage and excavation of these materials – can generate sulfuric acid. This may result in acidification of soil, sediment, rock, surface water and groundwater. Runoff and leachate from acid sulfate soils can adversely impact aquatic communities, agricultural practices and engineering works. Acidic leachate can release aluminium, iron and other metals from soil and sediment, potentially impacting on the beneficial uses of the environment, which are established in State Environment Protection Policies (SEPPs).

Site occupiers have a duty of care not to cause adverse impact to the environment due to disturbance or transport of acid sulfate soil. Waste acid sulfate soil must be managed in accordance with the requirements of the *Industrial Waste Management Policy (Waste Acid Sulfate Soils)*. The policy sets out the management regime required for disposal and reuse of waste acid sulfate soil, and specifies the responsibilities of those involved. The policy requires that sites receiving waste acid sulfate soil must have an EPA approved Environment Management Plan (EMP) for this purpose. Dredge spoil disposed to an approved spoil ground is exempt from this requirement.

For subaqueous disposal of dredging spoil, the Policy requires that best practice environmental management methods are used during dredging and disposal in order to minimise adverse impacts.

In some cases, waste acid sulfate soil may be contaminated with metals or other wastes such that it can also be identified as contaminated soil (low level) or contaminated soil under the *Environment Protection (Prescribed Waste) Regulations* 1998. In these cases, the contaminated waste acid sulfate soil requires management in accordance with the regulations in addition to management in accordance with the policy. The classification criteria and management requirements for soil wastes is provided by EPA (1995b).

EPA (1998) also provides guidance for the identification, assessment and management requirements for acid sulfate soil.

Biological Contamination by Exotic Species

Testing for exotic organisms will be required if the dredged site and spoil ground are far enough apart that exotic species could occur on the dredged site but do not occur on the spoil ground. In practice, economic constraints on transport of spoil suggest that this problem will arise very rarely, as the spoil is usually dumped close enough to the dredged site that there are many other means of transferring exotic species between these sites.

Trailing suction hopper dredges (TSHDs) can move rapidly between different areas of the world. In doing so, they may translocate exotic species between different geographic regions. The risks from this source of exotic species do not appear to have been assessed separately from that of other international shipping, although the amount of unwanted sediment transported by TSHDs is likely to be much greater than contained in most ballast. Consequently, there is a risk of introducing a suite of exotic species different from those carried in other ballast. The seriousness of this issue should not be underestimated: the introduction of a single pest species could cause a much more serious and longer-lasting impact than dredging itself.

A risk assessment of the likelihood of introductions from TSHDs should be undertaken well before the dredge leaves its previous dredging location. This assessment should consider the climatic similarity of the location of the previous dredging project compared to Victoria. For example, dredges that have operated most recently in tropical waters will not contain species likely to establish in Victoria. Where there is a risk of exotic species from the last operation surviving in Victorian waters, special precautions should be taken to minimise the risk of introductions. The last few dredge loads in the previous location should be deep abiotic sediments from greater than 50 cm and preferably deeper. Surface sediments must be avoided. Hoppers should be cleaned as thoroughly as possible at the completion of the last dredging. Overseas vessels should be cleaned while outside of coastal temperate Australian waters. All vessels entering an Australian port from overseas must obtain a quarantine ship clearance from Australian Quarantine and Inspection Service (AQIS).

Hoppers of vessels considered a risk should be inspected before dredging commences, and, for overseas vessels, preferably before they depart for Australian waters. If exotic species are found during inspection of the hopper within Australia, considerable costs will result from delays to the dredging while they are removed. Consequently, it is important that the need for precautions is made clear at the tender stage.

Effects of Contaminated Sediments

Objective

To minimise effects of contaminated sediments.

Suggested measures

- Support policies that reduce discharge of toxicants in catchments and exotic species in coastal waters.
- Assess contamination of sediment to be dredged.
  - Document history of site where contamination is suspected.
  - Develop sediment-sampling plan to adequately characterise sediments.
  - Measure levels of contaminants of concern at site.
  - Compare contaminant levels with guideline values.
  - Assess risk of translocation of exotic species in spoil.
- Assess risk of new introductions of exotic species by dredges, particularly TSHDs.

3.4 Minimise Effects on Water Quality

The two main effects of dredging on water quality are toxic effects due to release of contaminants and effects on turbidity that may impact light-requiring species (eg seagrass). Control of turbidity is usually also the most practical means of limiting the release of contaminants, as most contaminants are adsorbed on particles rather than dissolved. The effects of both of these potential impacts may also be reduced by dredging at a time of year that minimises the effects on important biological values.

Release of Contaminants

In a typical disposal operation most contaminants remain associated with the dredged material as it settles to the bottom and limited water-column impact is caused during descent.

The criteria for assessing water-quality impacts of disposal follows USEPA (1991,1994) guidelines. Water-quality criteria, defined in the relevant State environment protection policy, should not be exceeded after allowing for mixing that will occur within four hours of dumping.

Elutriate tests measure the release of contaminants after a 1:4 mixture of sediment and seawater has been shaken under standard conditions (see appendix 3).

Elutriate tests may be required to demonstrate that water-quality criteria will not be exceeded in the four-hour period following discharge. The need for such tests should be discussed with EPA, as historical data from dredging in similar sediments may be adequate to demonstrate that water-quality criteria will not be exceeded.

Similarly, if modelling can demonstrate that water-quality criteria will not be exceeded even under the assumption that all contaminants are released, elutriate tests will not be required.

Release of Nutrients

Dredging will release nutrients contained within pore water from dredged sediments. The levels of these nutrients are not significant for any but large dredging projects, and even these release small amounts of nutrients compared to other inputs such as Werribee Treatment Complex (appendix 4). Where dredging must occur during seasons in which algal blooms are likely, levels of nutrients released into the water column should be monitored (see section 3.8). Dredging operations particularly those in Port Phillip Bay should assess the release of nutrients to ensure dredging operations comply with the *State Environment Protection Policy (Waters of Victoria) Schedule F6 Waters of Port Phillip Bay*, in particular the Nutrient Reduction Plan (Clause 12).

Note spoil may also change the ability of sediments to remove nitrogen by reducing the effectiveness of denitrification processes.

Control of Turbidity

The most effective means of minimising turbidity is often selection of the most appropriate work method (see section 3.5).

As most TSHDs now have overflow at keel-level, the use of a TSHD without keel level overflow in Victoria would need to be thoroughly justified. Overflow of very fine sediments from TSHDs (for example, Yarra River) is unacceptable, but is encouraged where sandy sediments are involved, such as in South Channel. In the latter case, not only are dredging costs reduced, but the duration of dredging impacts is minimised by the faster completion of the works. Turbulence from propellers and movement of hulls may also contribute to turbidity from TSHDs and cutter suction dredges (CSDs) where under-keel clearance is limited. In shallow water, workboats may also contribute significantly to turbidity.

Silt curtains should be used where fine sediments will elevate natural levels of turbidity for an extended period. As few background turbidity values are available for Victorian waterways, the need for silt curtains must be assessed on a project-by-project basis. Until better background data on natural turbidity are available silt curtains will be required where the material being dredged is principally fine sediments, and currents and wave action do not preclude their deployment.

Better data on natural background turbidity and on impacts of sediment inputs unrelated to dredging (for example 70,000 m^3 of sediment are estimated to be discharged annually from drains into Western Port, Sargeant 1977) will enable a more objective rationale for the use of silt screens.

Diffuser heads on outlet pipes may be used to minimise turbidity. A specially designed 'cooking pot' was used to control surface turbidity during dredging of Geelong Channel (Wessels 1997). This novel device surrounded the discharge pipe of a cutter suction dredge with a cylindrical plastic screen 10 m in diameter that extended 4 m below the surface. Slurry was discharged into the middle of the cylinder via a diffuser head which directed sediment towards the walls of the cylinder. Density flow then caused the dense, turbulent, sediment-laden water to flow directly to the seabed. Subject to limitations determined by patents applied for on the cooking pot the use of this device is encouraged for submarine discharge of fine sediments.

In specifying limits to turbidity allowable to protect seagrass during the many months of dredging the Geelong Channel during 1997, turbidity was not allowed to exceed five NTU over seagrass beds. These controls were designed (see appendix 5) to ensure that the theoretical depth limit of seagrass declined no more than 0.5 m as a result of reduced light penetration. Where water clarity is similar to that near Geelong and seagrass grows to a maximum depth of approximately 3 m, similar controls will be required. Where water clarity is greater and seagrass grows to a greater depth, more stringent turbidity criteria may be applied for sustained turbidity over seagrass habitats.

Timing of Dredging

If possible, dredging should occur when the environment is least vulnerable. However, species only become seriously threatened by dredging when a particular life-history phase is highly aggregated in an area to be dredged. As most species are widely distributed, and dredging impacts are usually confined to a small area, few species are threatened by dredging.

Where environmental risks are similar in all seasons or unknown, the timing of dredging may be determined by other considerations. Dredging of boat channels immediately before the peak period of use is often appropriate, as this maximises boating safety without increasing the amount of dredging.

Dredging in particular seasons may reduce the risk of causing algal blooms, as well as impacts on aquaculture operations, seagrass and fish communities. Impacts on other biota may also be minimised by careful timing of dredging, but few studies have been undertaken.

Bulthuis (1983) showed that seagrass is more vulnerable to light deprivation in summer than in winter. However, no other seasonal effects for impacts of dredging on the environment have been proven. Indeed, as ecological links are often complex, dredging could, for example, improve larval survival when conducted while fish were breeding, if turbidity reduced the risk of predation on fish larvae. As the possible consequences can be serious, a cautious approach is taken here. Where fish breeding, algal blooms or mussel spat (juvenile) collection are confined to specific habitats and seasons, these should be avoided where possible. If they cannot be avoided, monitoring of possible impacts should occur, where practical, so that in time the causal links between dredging and these potential impacts are established. (Monitoring the area of algal blooms is often practical, but following survival of larval fish near and distant from dredging is currently impractical.) Should further information become available to demonstrate that dredging has seasonally different impacts on biota other than fish, algae and seagrass, these may act as further constraints on the timing of dredging.

Toxic and Noxious Phytoplankton

Where algal blooms occur in predictable seasons, dredging should avoid those seasons. If possible, dredging in Hobsons Bay should avoid the period from December to mid April when *Alexandrium catenella* blooms are most likely. In all regions of Port Phillip Bay, *Rhizosolenia chunii* blooms are likely between late July and late September. Where possible, dredging during this period should be avoided, especially near mussel farms. If dredging must occur during a period in which blooms are likely, phytoplankton sampling should be sufficient to ensure that if a bloom occurs it can be determined whether it commenced near the dredging or elsewhere. This monitoring will, in time, demonstrate whether dredging facilitates blooms; the acceptable dredging seasons should then be re-evaluated (see section 3.8).

Mussel and Fish Farming

Fish and mussel farmers should always be consulted prior to dredging near their farms. Where possible, dredging should be designed to keep sediment from aquaculture facilities. Increased sedimentation is likely to affect mussels of all sizes, but, in Port Phillip Bay, impacts on farms may be greater between May and October while mussel spat (juvenile) collection ropes are deployed. Large amounts of dredging near spat collection areas should be avoided as mud build-up on ropes prevents spat settlement. The above period also includes the period between late July and late September when blooms of *Rhizosolenia* are most likely (see above and appendix 7.2.1). Blooms of this species may cause mussels to be unmarketable. Consequently, where possible, dredging near mussel farms should be avoided during this period.

Seagrass Vulnerability

Nearly complete shading of the seagrass *Heterozostera tasmanica* causes 100 per cent mortality in four months during winter and in two months during summer (Bulthuis 1983). As seagrass appears to have more reserves in winter, or these reserves last longer at winter temperatures, dredging in areas where turbidity could impact seagrass communities should occur in winter, where possible.

Effects on Vulnerable Fish Species

Dredging is most likely to affect fish when a vulnerable life-history stage of a species is confined largely to the area being dredged. The timing of the main life-history stages of fish in Victoria are documented in appendix 6 and summarised in table 3. This summary illustrates that few species of fish are sufficiently aggregated that dredging would have a disproportionate impact at a specific site or time.

Snapper, the most popular recreational species, appear to breed on reefs between St Kilda and Ricketts Point between November and March. Consequently, where possible, dredging should not occur in this area during this period.

Three small species of estuarine fish (Australian grayling, broad-finned galaxias and spotted galaxias) have been classified as either ‘potentially threatened’ or ‘vulnerable’ (appendix 6), but only the grayling has been listed under the *Flora and Fauna Guarantee Act*. As juvenile grayling occur in estuaries between April and November, it may be beneficial to avoid dredging in estuarine waters during this period. Unfortunately, there is no information available on the habitat requirements of these species. Further research is required before it can be established where juvenile grayling are located within the estuary in different months and hence how dredging should be timed within the estuary to minimise impacts (appendix 6).

Minimise Effects on Water Quality

Objective

To minimise effects on water quality.

Suggested measures

- Undertake elutriate tests where there is inadequate data to demonstrate that water-quality criteria will not be exceeded.
- Select appropriate dredging method.
- Install silt screens where practical and sediments are fine.
- Dredging should be timed to occur when impacts are minimised.

3.5 Optimise Dredging and Disposal Methods

The dredging and disposal methods selected often have a very large effect on the environmental outcome of a dredging proposal. Methods chosen affect: the physical effects of spoil (spoil fluidity, spoil ground stability; area impacted by spoil); the effects of sediment contamination (confinement of contaminated spoil, material handling problems with contaminated spoil); and water quality (turbidity, contaminant release).

The type of dredge chosen for the work should be justified for each project, particularly those involving fine or contaminated sediments. The work method chosen is often the key decision as far as the cost and the environmental outcomes of a dredging project are concerned; it should therefore be taken with some care.

In large dredging projects, there is often greater flexibility in choice of method, as dredges must normally be brought from interstate or overseas. In addition to any other environmental standards, the proponent’s preferred dredging method(s) and disposal method(s) should be discussed with EPA and the proponent's dredging consultant. Following discussion, methods that are considered unsuitable should be detailed in the tender documents as well as an indicative preferred method. Bids from tenderers wishing to use alternative methods would need to demonstrate that their methods will not create significantly greater environmental impact than the preferred work method. The successful tender should be chosen on the basis of both cost and the environmental acceptability of the methods chosen.

Justify Disposal Site Chosen

There are often cases where there is no use for dredge material and there is no alternative to disposal. The proponent must then justify the disposal site chosen. The most appropriate disposal site depends on both environmental impacts and costs. The degree of contamination is a major factor in site selection, as is the impact on the disposal site and the likely cumulative impacts of its continued use. The three broad alternatives are:

- disposal at sea
- disposal in shoreline enclosures
- disposal to land.

Shoreline enclosures are considered as a means of dewatering sediment prior to land disposal, but shoreline enclosures for the permanent containment of contaminated sediment (for example Slufter Dam, appendix 2) are not considered further, as the known quantities of contaminated spoil in Victoria do not currently justify the expense of such structures.

Table 3: Months in which the eggs (E), larvae (L), juveniles (J), and adults (A) of marine and estuarine fish in Victoria may be vulnerable to dredging impacts. Months in which a life-history phase of a species is sufficiently aggregated that its vulnerability to dredging should be considered when determining the timing of dredging are shown in bold (see appendix 6 for details)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seagrass habitats												
King George whiting	J							J	J	J	J	J
Silver trevally						J	J	J				
Southern sea garfish	J									E	E	J
Southern calamari									**E**	**E**		
Australian salmon (western)								J	J	J		
Australian salmon (eastern)	E	E	E								E	E
Elephant shark	E	E	E	E	E	E	E	E	E	E	E	

Yank flathead										E	E	E
Yellow-eyed mullet*	E										E	E
Reef habitats												
Red mullet												
Rock flathead											E	E
Blacklip abalone												E
Gummy shark	J										J	J
Snapper	**E**	**E**	**E**								**E**	**E**
Angel shark												
Common gurnard perch												
Mulloway	E?	E?							E?	E?	E?	E?

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Soft-sediment habitats												
Greenback flounder						E	E	E	E	E		
Long-snouted flounder				E	E	E	E	E	E	E		
Sand flathead									E	E		
Scallop								E	E	E		
Estuarine habitats												
Australian grayling				E	E	**J**	**J**	**J**	**J**	**J**		
Black bream										E	E	E
Broad-finned galaxias					L?	L?	L?		J	J	J	
Common galaxias						A	A?	A		J	J	
Long-finned eel	A+J	A+J	J	J	J							A
Pouched lamprey							J	J	A+J	A+J	A	
Sea mullet			E?	E?	E?/J	E?/J	E?/J	E?/J	E?/J	J	J	
Short-finned eel	A	A			J	J	J					A
Short-headed lamprey								J	A+J	A	A	
Southern anchovy	E	E	E							E	E	E
Spotted galaxias	J				L?	L?				J	J	J
Tasmanian mudfish							L?	L?	L?+J	J	J	
Tupong	J	J	J	A	A	A+J	A+J	A+J	J	J	J	

Disposal at Sea

Internationally most unwanted clean dredged material is disposed at sea, either to declared spoil grounds, into seabed depressions, underwater bunds or to form islands (Bray *et al.* 1997). There has been minimal use of seabed depressions, underwater bunds or islands in Victoria.

Unconfined Disposal

Uncontaminated spoil is traditionally disposed to declared spoil grounds and there seems no reason that this practice should not continue, subject to appropriate environmental management identified in this document.

Confined Disposal

Confined disposal is appropriate for containment of fluidised clays, where it is impractical to use a dredging method that does not cause fluidisation, or for containment of contaminated spoil. Spoil may be disposed of in natural seabed depressions, or specially dredged pits, or between underwater bunds. Disposal in bunded areas or depressions is similar, but construction of bunds is more expensive and is not practical in very deep or very shallow water. Special disposal methods and care are required to ensure that spoil remains within the confined area intended (Bray *et al.* 1997).

At sites where there is an ongoing need for disposal of low-level contaminated spoil, long term planning should be undertaken in order to create a confined disposal site (Palermo *et al.* 1998). At a disposal site in central Long Island, a series of small mounds was made over several years and the depression created was then filled with 500,000 m^3 of contaminated sediment. The spread of contaminated spoil was thereby greatly reduced and the spoil could be capped using a much smaller volume of material (Fredette 1994).

Capping of Contaminated Material

Capping is a cost-effective method of isolating contaminated sediments from the marine environment. Capping may be used with unconfined disposal where contaminated spoil is merely covered by clean sediment, or with confined disposal in which the cap may cover the spoil within a depression or between bunds. The capping needs to be deeper than the depth disturbed by animal burrows (30 to 50 cm) and special care must be taken during construction of the cap to ensure that the capping material does not mix with the contaminated material below. Capping of silts and clays is technically difficult, so careful planning and appropriate work methods must be selected.

Successful capping projects are summarised in Bray *et al.* (1997) and site requirements, design and construction methods are described in a series of US Army Corps of Engineers publications (Truitt *et al.* 1989; Palermo 1991a, 1991b, 1992; Palermo *et al.* 1998). While simple in concept they need to be well-designed to be effective, and monitored to ensure that they continue to effectively contain contaminants.

Land Disposal

Onshore disposal is preferable where spoil is seriously contaminated, and when fine sediments are likely to impact sensitive marine environments such as seagrass habitats.

When chemical contaminants exceed the low screening level, and toxicity or other tests indicate that levels are of concern, an assessment of the costs and benefits of a range of disposal options, including land disposal may be required. When chemical contaminants exceed the maximum screening level, proponents will be required to assess the costs and benefits of a range of disposal options, including land disposal.

In seagrass habitats, onshore disposal using a cutter suction dredge is usually the preferred option when there is an area of suitable land nearby.

For land disposal to be practical when using a cutter suction dredge, a dewatering site must be available and meet the following requirements.

1. Occur within approximately 1 km of the dredging, or within 3 km if the additional expense of a booster station is justified.
2. Have little value in its existing state.
3. Be large enough for containment bunds suitable for dewatering to be constructed.

4. Be able to be secured so that quicksand-like properties of fines present no safety risks.
5. Be acceptable to remain in a degraded state for up to 12 months if an extended period for drying is required.
6. Be sited so that it is practical for seawater to be discharged back into the sea or an estuary rather than into a freshwater stream, where impacts would be unacceptable.
7. Be able to be drained so that evaporative water loss from the bunded area is minimised so that excessive salt is not retained in the sediment.
8. Be accessible to trucks if it is planned to empty the site prior to the next dredging of the site.
9. Be acceptable to the informed public (considerable consultation with those parties that may be affected is necessary).

The turbidity of water discharged from land disposal sites should not exceed 50 NTU and should routinely be less than 25 NTU. It should be controlled by increasing the length of travel of water, to maximise settlement of solids within the discharge area, and, when necessary, by use of silt screens. The turbidity of the discharge should be monitored (see section 3.8).

See summary checklist of land disposal issues in appendix 7.

Optimise Dredging and Disposal Methods
Objective *To optimise dredging technology.* **Suggested measures** • Small dredging projects – justify choice of dredging method. • Large dredging projects – proponents and independent consultants to determine unsuitable methods, with comments from EPA, before going to tender. • Justify disposal site chosen. • When contaminants exceed low guideline values, seek advice on need to assess feasibility of all disposal options. • When contaminants exceed maximum guideline values, assess feasibility of all disposal options. • Assess feasibility of land disposal when fine sediments would otherwise threaten sensitive marine habitats (such as seagrass).

3.6 Control of Noise

In Victoria, dredging does not appear to have caused significant noise problems, as most dredging occurs well away from residential areas. Where dredging or beach renourishment does occur near residential areas, special precautions may be required to avoid excessive noise. Dredging equipment operating in the Melbourne metropolitan area must comply with the *SEPP (Control of Noise from Commerce, Industry and Trade) No. N-1*, and in country Victoria, compliance with the *Interim Guidelines for the Control of Noise in Country Victoria* is required. Typical noise levels that are likely to be required outside adjacent residences are summarised in table 4.

Because of the high potential for noise to affect residential amenity, management should give high priority to liaising with the local community so that it can be aware of, and resolve, noise issues. The disturbing effects of noise depend on the level of the noise and its character, such as tones, intermittency, etc. Higher-frequency tones are more disturbing than lower-frequency tones. Lower-frequency tones are not easily controlled and can penetrate buildings, such as houses. Noise can cause physical and psychological stress in both employees and neighbours of the plant. Noise may also disturb animals, but the extent of disturbance is difficult to estimate. Birds, except for owls, have a hearing response similar to humans', so the limits required to protect humans will usually be adequate to protect at least birds (Carr *et al*. 1995).

Sound levels are measured in units of decibels, dB(A). The 'A' weighting of a measured sound level approximates how the human ear perceives sound. If a sound is intensified by 10 dB(A), it seems to the ears that the sound has doubled in loudness.

Noise Sources from Dredging and Beach Renourishment Equipment

Major noise sources may be:

- engine noise
- generators
- opening and closing gates
- radios
- reverse warning devices.

Noise Mitigation Measures

Noise abatement can often be achieved by relatively simple measures, such as:

- fit efficient muffling devices to all engines
- locate noisy equipment away from potential sources of conflict or behind sound barriers
- use enclosed generators
- position access and exit points away from sources of conflict
- use optical alarms in preference to audible alarms.

Limit operations to between 7 am and 6 pm Monday to Friday and to between 7 am and 1 pm Saturday if other noise mitigation measures are inadequate.

Where noise abatement requires more detailed analysis and control, an acoustic specialist should be consulted.

Noise
Objective *To ensure that no noise nuisance results from the dredging or beach renourishment.* **Suggested measures** • Liaise with the local community to identify noise issues. • Select quiet equipment. • Alter or enclose equipment to reduce noise at the source. • Use sound-absorbing materials to prevent the spread of noise by isolating the source. • Limit times of operation.

3.7 Control of Odour

Odour from anaerobic sediments containing hydrogen sulphide from dredging is rarely more than a temporary problem. Typically, during beach renourishment and when dredging channels at the entrance to rivers, discharged sand is initially anaerobic. When first discharged it is grey in colour and may smell, but the smell is lost and the colour of the sand changes to yellow within a few days of its exposure to air. Before discharging grey sediment, proponents should ensure that residents in the immediate vicinity are aware of the proposed dredging and assured that any smell will be lost and sand will become yellow with a few days exposure to air. This should be done by notices placed in the letterboxes of nearby residents, and with sandwich boards placed near the discharge point and at the most public vantage point.

However, if a contaminated site is to be dredged, the history of the site should be reviewed to assess the risk of odour prior to dredging and spoil disposal.

Odour
Objective
To ensure that small odour problems do not alarm nearby residents.
Suggested measures
• Inform residents of temporary nature of any odours and of grey sediment.
• Assess odour risk if contaminated.

Table 4: Examples of typical noise limits for various types of land use, based on (1) Interim Guidelines for Control of Noise in Country Victoria, and (2) SEPP No. N-1

Land Use	Noise Limits, dB(A)		
	Monday–Friday 07:00–18:00 hours Saturday 07:00–13:00 (excludes public holidays)	**All nights 22:00–07:00 hours**	**All other times**
Quiet rural areas (1)	45	32	37
Mainly residential (2)	50–54	39–43	44–48
Residential, commercial and industrial (2)	54–59	39–43	44–48
Commercial and industrial (2)	56–59	47–52	48–52
Industrial (2)	63–68	52–56	57–61

3.8 Establish Appropriate Monitoring Programs

Monitoring is required at two different timescales for different purposes. Operational monitoring during dredging projects is required to ensure that turbidity, for example, does not become excessive so that an immediate operational change to dredging methods, and so forth, is required. This monitoring forms part of the Environmental Improvement Plan and is discussed in section 4. Longer-term monitoring is also required to improve future dredging by better assessment of impacts, where they may be significant but their duration or extent are poorly documented, and to confirm predictions in larger projects.

In developing forward-looking monitoring plans the following issues need to be considered.

1. Assessment of impacts can usually be undertaken much more efficiently by thoroughly monitoring particular proposals rather than inadequately monitoring each proposal.
2. Some impacts are better assessed by targeted research than by routine monitoring.
3. Monitoring programs should be integrated with regional monitoring programs where possible.

For example, in port areas, monitoring to assess dredging impacts should be one component of a port monitoring program addressing a range of port-related impacts (dredging, contamination, exotic species). This in turn should be integrated with monitoring for regional areas, such as Port Phillip Bay. Integration enables greater efficiency, through the use of similar data, to address different issues and provides a better basis for comparing different impacts, thereby focusing attention on the more serious impacts.

As the costs of monitoring small and large dredging projects are similar, monitoring is done predominantly on large projects. Even here, monitoring should address specific objectives, either contributing to ongoing improvement of dredging methods or providing reassurance to the public through accurate information on measurable impacts.

Where adequate information already exists on the extent, duration or cause of dredging impacts, further monitoring should not be required.

Assess Biological Impacts on the Seabed

The duration of effects of spoil on benthic communities and demersal fish communities should be monitored where large-scale dredging occurs. The primary purpose of this monitoring is to better estimate the rate and extent of recovery of the benthic communities and their dependent fish communities. Such studies may also enable a better evaluation of the role of disturbed areas such as spoil grounds in facilitating the establishment of exotic species. Consequently, the need for further studies (and particularly their sampling intensity) depends on the results of previous relevant monitoring studies. A small number of well-monitored impacts provides greater insight than a large number of studies that are inadequate. In practice, the effects of sediments and of contamination may be difficult to distinguish and studies to assess ecological effects of contaminants (discussed in the next section) may overlap with those to assess rates of recovery from sediment deposition.

Assess Biological Effects of Contaminated Sediments on Spoil Grounds

The health of biological communities on large spoil grounds that receive significant quantities of contaminated sediment (for example, Port of

Melbourne spoil ground) should be monitored. The frequency of monitoring should not be determined until the extent of impacts from historical deposits of contaminated sediments is known.

Assessment of sediment toxicity through an analysis of past impacts is likely to be a more reliable and cost-effective means of assessing sediment toxicity than (short term) laboratory tests and may reduce the need for these tests (see also section 3.3).

Improved spoil ground management involving separate disposal regions for mildly contaminated and uncontaminated sediments, together with monitoring of sediment contamination and biological communities, would greatly improve the sensitivity of this approach. Records should be maintained of the source and contamination status of spoil dumped in different areas of the spoil ground. The capacity to cap contaminated sediments on the spoil ground, if they create toxic effects in the field (determined through monitoring), may also reduce the need for routine laboratory sediment toxicity testing.

In conjunction with assessment of impacts of contaminants on spoil grounds, it will usually be wise to identify the source of contaminated sediments. This may enable the most contaminated sediments to be disposed of elsewhere. Once the sources of contaminated sediments are identified, the need for further biological assessments should be reviewed and the level of monitoring altered appropriately.

Assess Spoil-Ground Stability

The fate of sediments deposited on a spoil ground should be confirmed where this is uncertain (see sections 3.1 and 3.2). Methods could include detailed hydrographic surveys of historical changes to depth on and (particularly) near the spoil ground, tracer studies, placement of turbidity meters on and near the spoil ground, placement of measuring stakes within the spoil dump, and observations of revegetation of spoil grounds. Where spoil is not expected to remain on the spoil ground, sequential aerial photographs and/or monitoring at sites where environmental changes due to changes in sediment transport processes are anticipated, may also be appropriate.

Monitor Release of Contaminants

Where extensive dredging of contaminated sediment occurs, and elutriate tests suggest that significant quantities of contaminants may be released, monitoring of contaminants in water and accumulated in biota near the dredging site may be required. In common with other monitoring, a small number of well-monitored studies are better than a multitude of poorly monitored studies.

Monitor Nutrients and Algal Blooms

Algae should be monitored when dredging must be undertaken at a location and during a period where algal blooms are likely. This is to establish whether dredging does indeed increase the risk of algal blooms. For small dredging proposals, algae should be monitored near and sufficiently distant from the dredging that it can be determined whether the bloom was initiated near to or distant from the dredging. To reduce costs, water samples may be collected and algae preserved with fixative and only analysed if a bloom occurs during the dredging. For large dredging projects, nutrient levels (N, P and silicate), as well as algae should be monitored where *Rhizosolenia* spp. blooms are of concern.

Monitor Turbidity and Seagrass Health

The area of the visible turbid plume should be described for all dredging operations so that the area impacted by the plume is determined. For small projects with many coastal reference points, a sketch indicating the size of the visible plume is adequate. For large projects, aerial photos may be required and/or turbidity measurements required within the plume. Turbidity measurements will normally be required where a silt screen has been installed and when spoil is discharged to land into a bund. For very large projects, where sediment plumes may impact on resources sensitive to turbidity (eg seagrass), changes in turbidity over these resources should be predicted using numerical models, and the results of the models subsequently verified by field measurements.

Monitoring of turbidity should be intensive enough in the early phase of a dredging project to quickly identify any problems, but the monitoring should be scaled back if no problems arise.

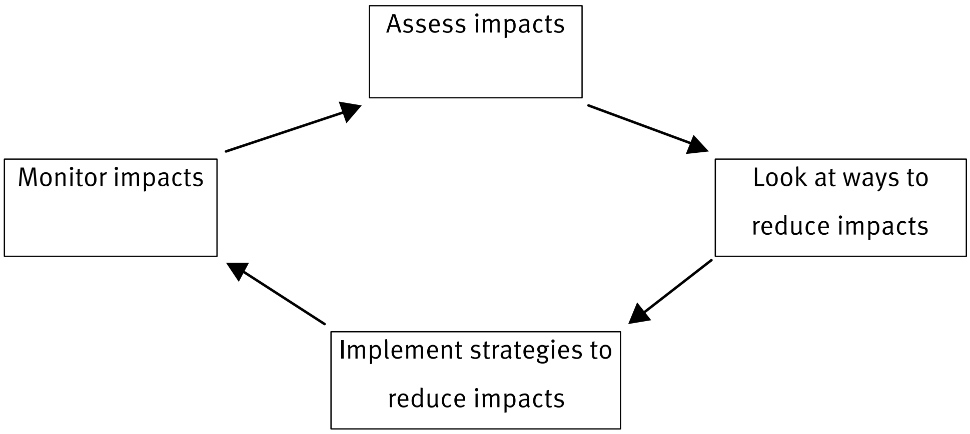
Where dredging will significantly elevate turbidity levels for more than 15 days in summer or 30 days in winter, seagrass communities may be at risk. Careful investigation of the light requirements of seagrass, and detailed monitoring of selected dredging projects in seagrass habitats, is required to determine if these seagrass communities are indeed at risk from dredging. Limited monitoring of many small dredging projects in seagrass habitats will not greatly assist in better defining tolerance of seagrass to elevated turbidity. Instead, more detailed investigation into the effect of dredging on seagrass on a small number of projects is required. As greater knowledge of seagrass tolerance to dredging-related turbidity may enable a relaxation of turbidity criteria to protect seagrass, proponents dredging in areas of seagrass should consider funding such studies.

Monitoring
Objective *Increase knowledge of dredging impacts, to reduce future impacts and provide reassurance to the public.* **Suggested measure** • Agencies undertaking substantial amounts of ongoing maintenance dredging should develop a dredging monitoring program that is appropriately integrated with regional monitoring programs.

4. ENVIRONMENTAL MANAGEMENT

Environmental management is the process by which all of the issues identified in section 3 are appropriately considered and implemented.

Quality environmental management implies continual improvement by a process involving review of impacts, reduction of impacts through improved processes, and monitoring of subsequent impacts. The process can be simply summarised.



To ensure that environmental impacts are minimised, all impacts need to be adequately assessed. Where impacts are substantial, means of reducing impacts must be investigated.

Where impacts are already as small as current technology permits, and appear minimal, monitoring programs will not be required. For example, where clean sand is dredged to bypass a river or a man-made structure, long term impacts are usually adequately minimised by ensuring that sediment is disposed of in the direction of the natural sediment transport.

Where impacts are uncertain, they should, where feasible, be reduced, or at least monitored so that impacts are eventually quantified. Where there is uncertainty, where a compromise must be struck between costs and impacts or between different impacts (for example, land versus marine impacts), discussion between affected groups should be initiated as early as practical in the planning of the project.

In Victoria, the most significant impacts of dredging appear to be: (a) cumulative impacts in seagrass habitats, (b) the possible effects of remobilisation of spoil and (c) the effect of contaminated sediment on benthic communities. In the first case, land disposal using bunds for dewatering of spoil should be considered, where a suitable site exists near the dredge site. Where remobilisation may be a problem, monitoring and research programs should be developed to determine the fate of spoil. Small quantities of highly contaminated dredge spoil should be disposed of in a landfill licensed for disposal of such wastes. Where it is impractical to dispose of large quantities of mildly contaminated spoil to land, the effects of this spoil on marine benthos should be determined and the feasibility of capping contaminated sediments with clean sediments investigated.

Historically, where dredging and spoil disposal have occurred there is usually a continuing need for both. Consequently, consents will usually be issued for 10 years. But a *Coastal Management Act* 1995 consent will only be issued if adequate long term planning is evident and an adequate EIP exists. The EIP is designed to minimise impacts during the operational phase should impacts prove larger than anticipated; the EIP also should identify those aspects of the dredging that can be modified after dredging commences.

4.1 Environmental Improvement Plans

An Environmental Improvement Plan (EIP) is a document developed by the proponent and/or contractor detailing how dredging operations will be conducted to minimise environmental impacts.

The EIP should cover all relevant environmental issues discussed in section 3. Contingency plans should also be developed to ensure prompt control of adverse environmental impacts caused by unintended events.

The EIP should consider addressing the operational management of issues such as turbidity, noise, odour, water quality and contaminated sediments. The EIP should also address the collection and storage of sewage and garbage on board all vessels as well as contingencies for oil spills.

Issues that should be addressed in an Environmental Improvement Plan are detailed below.

Minimise Effects on Water Quality

- increase monitoring for turbidity (this will identify but not minimise turbidity);
- incorporate or reorientate silt screen;
- reduce overflow of barges or bunds;
- increase travel path of fluid within bunds to increase sedimentation;
- decrease rate of dredging;
- select appropriate dredge for material being dredged
- relocate dredge to an alternative location.
- Use silt screens where practical and sediments are fine.
- When necessary, monitor water quality including turbidity, as well as seagrass and other sensitive species.

Minimise Effects of Contaminated Sediments

- Monitor water quality near dredging operations removing highly contaminated sediments.
- Dredge contaminated sediments first and dispose to land or place on spoil grounds first and cover with clean sediments.
- Use silt screens to contain contaminated sediment

Sensitive Biological Communities

- Map location of sensitive communities.
- Detail measures to protect sensitive communities when dredging.

Land Disposal

- Site bunded area to minimise impacts.

- Control water quality of discharge.
- Monitor discharge to ensure excessive sediment is not discharged.
- Minimise potential salt impacts on soils.

Prevent Noise Nuisance in Residential Areas

- Liaise with the local community to identify areas and times sensitive to noise.
- Alter or enclose equipment to reduce noise at the source.
- Use sound-absorbing materials to prevent the spread of noise by isolating the source.
- Monitor noise levels.

Ensure that Small Odour Problems do not Alarm Nearby Residents

- Inform residents of temporary nature of any odours and grey sediment.
- Cease dredging on very hot days (greater than 35°C) or times of high public use.
- Inform public of works using on-site signs.

APPENDIX 1: APPLICATION FORM FOR SECTION 40 (COASTAL MANAGEMENT ACT 1995) CONSENT FOR A DREDGING PROPOSAL

Project no.

Office use only

1 Contact information

Name of applicant ____ Date ______________

Contact address ____

____

Telephone ________________ Mobile ___________________ Fax __________________

E-mail ____

2 Background information

Location of proposed dredging ____

(Melway ref, map, etc.)

What is the land status?

(eg unreserved Crown land) ____

Who is the land manager? ____

Is the application being made by the land manager? Yes/No

If no, please attach the land manager's written support

Does this proposal require a planning permit under the local planning scheme? Yes/No

(Check with your local Council's planning office)

If yes, have you made an application for a planning permit Yes/No

Have you sought permission from the relevant port manager? Yes/Not applicable

(If yes, attach a copy of the port manager's written consent)

3 Description of dredging project

Volume of sediment to be dredged during next dredging _______________ m^3

Estimated cost of dredging and disposal works $ _____________________

Estimated volume and frequency of future dredging ___________ m^3 per _______________ years

Mean particle size of spoil ____________ Mean particle size spoil ground _______________

(Attach sediment grain-size analysis, specific gravity measurements)

Description of proposed dredging and disposal methods. Attach map showing area(s) and depths to be dredged and disposal site(s).

4 Adequacy of long term planning to minimise impacts

Future dredging and spoil disposal needs.

(For maintenance dredging, provide estimated dredged volumes in each year that dredging occurred previously and the disposal site used on each occasion. Maps showing spoil-disposal sites should be provided. For new dredging the volume and frequency of future maintenance dredging should be estimated and the disposal site indicated.)

Can the method of dredging and the disposal site proposed be used indefinitely so that it will not result in incremental damage _______?

If no, what other dredging and disposal options have been considered? Justify why these were not selected.

Desired duration of consent. ______________

(CMA consents for dredging will be issued for up to 10 years where long term planning is adequate, but such proposals must be advertised to facilitate public comment. Note also that where long term planning is inadequate, consent may not be granted.)

5 Public consultation

(Provide the names of those groups and individuals with whom this proposal has been discussed and indicate whether the proposal has been advertised near the dredging site or in a newspaper, and whether further advertising is proposed.)

6 Need and justification for dredging (see section 3.1)

(Note whether dredging is needed to maintain access to planned or existing infrastructure, and if it forms part of a management plan or coastal action plan.)

7 Measures taken to minimise physical effects of spoil (see section 3.2)

8 Contamination levels of sediment (see section 3.3)

(Attach results of laboratory analyses.)

Identify all contaminants that exceed the low screening level, twice background or elutriate tests that exceed water-quality criteria.

9 Measures taken to minimise effects on water quality (see section 3.4)

10 Justification for dredging and disposal methods (see section 3.5)

11 Environment improvement plan – consideration of turbidity, noise and odour (see sections 3.6, 3.7 and 4.2)

Where possible, responses to exceedances of criteria should be indicated.

12 Monitoring studies proposed (see section 3.8)

Except for monitoring that forms part of the EIP, monitoring will usually only be required for large dredging proposals.

APPENDIX 2: DREDGING OPERATIONS AND IMPACTS

Dredging Technology and its Appropriate Use

The main types of dredges used throughout the world are cutter suction dredges (CSD), trailing suction hopper dredges (TSHD) and grab dredges. CSDs are used principally for removing hard sediments in capital dredging projects, while TSHDs are used mostly for maintenance dredging of soft sediments in shipping channels. Grab dredges have much lower rates of production than suction dredges and are used principally in confined areas such as alongside wharfs.

Cutter Suction Dredger

CSDs are typically mounted on a barge and consist of a rotating cutter head with an adjacent suction pipe that collects a slurry of cuttings and water which it pumps through a discharge pipeline to its destination. In Victoria, several small CSDs are used to maintain boating access to small rivers in Port Phillip Bay and elsewhere, and large CSDs are used occasionally for capital dredging projects.

The action of the suction near the cutter means that most of the sediment removed by the cutter is captured. A variable proportion of sediment may be missed and fall to the seafloor below the cutter. These losses are usually small and consist primarily of solid sediment. As the economics of dredging is greatly affected by losses near the cutter and by overdredging, their minimisation is a primary concern for the dredging contractor. As high dredge efficiency and low turbidity at the cutter head are closely linked, it is uncommon for turbidity near the cutter head to cause environmental concern. Where very low turbidity is required near the cutter head or where contaminated sediments are dredged, the cutter head may be replaced with other intake systems (for example, sweep head suction head, see Seurynck and deVos 1997).

The site of discharge is the source of most environmental concern with CSDs. Typically, runoff water is controlled by the use of bunds and sluice boxes to enable settlement of solids and to improve water quality before it is discharged. Where sand is pumped, the resulting turbidity is typically confined to a small area near the discharge; spoil remains at the site of discharge. Where silts and clays are pumped, turbidity and spoil stability are more problematic. Clays, if pumped significant distances, may fluidise and therefore should not be pumped long distances into unbunded areas, either on land or on the seafloor. Dredging of the Geelong Channel during 1997 involved pumping of fine clay sediments over distances of greater than 1 km and created very fluid spoil that had a very low angle of repose and covered much larger areas than desirable.

Trailing Suction Hopper Dredger

A TSHD consists of a self-propelled ship with a large hopper. The vessel is equipped with one or two suction pipes which end with a draghead. The dragheads are lowered to the seabed and a slurry of sediment and water is pumped through them into the hopper. Dredged material settles in the hopper and the water drains off through a controllable hopper overflow system. Settlement of material in the hopper is dependent upon grain size, therefore, loading times can vary markedly for different sediments. The dredger usually deposits the contents of the hopper on a spoil ground through doors or valves in the bottom of the hopper. Split hulled vessels are common for smaller dredgers of this type. Most modern TSHDs are also fitted with pump ashore equipment and are able to discharge the hopper load through a floating pipeline connected to the bow of the dredger. TSHDs have been used to maintain shipping channels in Port Phillip Bay and Western Port. The April Hamer is a purpose-built side-casting dredger, designed to operate in shallow water and maintain access to Bass Strait at Lakes Entrance. This dredger is not built with a hopper but discharges the dredged material directly abeam by use of a swivelling boom.

During dredging, TSHDs create turbid plumes as a result of the intake bypass, overflow and turbulence caused largely by the ship's propeller. The bypass system is designed to prevent water being discharged into the hopper at the commencement and conclusion of dredging. A sensor in the dredge line switches the discharge over the side of the vessel when the sediment concentration falls below a threshold value. Overflow occurs once the hopper is full and is used to increase the sediment load. Overflow creates a turbid plume on the surface particularly when fine sediments are dredged. Technical information to support the need for restrictions on overflow is limited (Palermo and Randall 1990).

Overflow is of greatest environmental concern where fine sediments are dredged as they create the largest plume. Consequently, overflow of fine sediments is not usually permitted by environmental agencies. When fine sediments are dredged (for example, Yarra River shipping channels), there is also no economic advantage to overflowing these sediments as there is negligible settlement in the hopper, so the sediment concentration in the intake and the overflow are similar. When sand is dredged (for example, South Channel), increasing overflow results in appreciable economic benefits as settlement in the hopper means there is a large differential between the sediment load in the intake and any overflow. Also, the hopper load is increased.

Restrictions on the overflow of fine sediments are justified on both environmental and economic grounds. But restrictions on overflow to minimise turbidity must, on occasions, be balanced against a longer period of turbidity if hopper loads are reduced. Modern TSHDs discharge overflow at keel level, rather than above water level, to reduce turbidity and dispersal of fine sediments.

Measurements in Chesapeake Bay indicate that 12 per cent of the load transported in a TSHD was redistributed, but the resulting sedimentation caused minimal impact (see 'Direct effects' in appendix 2). Turbidity also increases when sediment is dumped. Studies of spoil dumped from TSHDs dumping sediments similar to those dredged from the Yarra, indicate that all but one to four per cent of the sediment remains on the site where it is dumped; the remainder settles at a greater distance over the next 24 hours (Truitt 1988).

Grab Dredgers

A grab dredger consists of a crane mounted on a pontoon. The grab normally discharges into independent hopper barges. Grab dredges may cause minimal disturbance and dilution of clays compared to hydraulic methods used by CSDs and TSHDs, but may cause high turbidity in loose silts where a significant fraction of the load may be washed out as the grab is hauled through the water. Grabs are also better able to handle boulders, debris, ropes, chains, and so forth, than are dredges which rely on pumps. They are also well-suited to dredging in confined places such as alongside wharfs, and their depth of operation is limited only by their cable length. Their main disadvantage is that they have slow rates of production.

Agitation Dredging

Agitation dredging involves disturbing seabed or riverbed materials by forcing them into suspension, after which they are moved by natural water flow to be redeposited elsewhere. Suspension of materials may be achieved with water jets, or by raking or pumping. This method may be suitable for fine sediments in channels, but before such methods are adopted it is important to establish the likely pattern of deposition and be satisfied that it will be acceptable.

Injection Dredging

This is a variation on the agitation method. A fixed array of water jet nozzles are lowered to penetrate the seabed from a self-propelled vessel. Pressure injection of water into the near-surface seabed deposits reduces the *in situ* density of the material to the point where it behaves like a liquid and is induced to flow. If the seabed slopes then large masses of sediment may be induced to flow at high rates. Unlike agitation dredging, the object is not to raise the individual sediment grains into the water column, although this can be achieved, intentionally or otherwise, using the same equipment.

There is evidence that consolidation of certain materials that have been subject to water injection may be hindered, but this process is not fully understood (Bray *et al.*1997).

Backhoe Dredger

The backhoe dredger has most of the advantages and disadvantages of the grab dredger, but can operate more quickly. Unlike a grab dredge, its maximum depth of dredging is limited by the length of its dredging arm.

Sweep Bar

A sweep bar consists of a large steel bar which is dragged across the seabed to level it. The bar is suspended horizontally from a barge and towed by a tug. It is usually used within port areas where grab dredges have been operating to achieve a minimum depth throughout berth areas without unnecessary dredging, but may also be used to remove high points following dredging by TSHDs or other dredges.

Stationary Slurry Pumps

Near the entrance to Portland harbour there is a stationary pump that uses water jets to fluidise sand before the resulting slurry is pumped approximately three km beyond the harbour entrance. The design of this pump/dredge has been patented.

Special-Purpose Dredges

There are many specialised dredges that are not readily available in Australia. Descriptions are provided by Bray *et al.* (1997).

Dredge Selection

Since dredging and spoil disposal are usually site-specific, the ideal dredge varies between dredging projects (Raymond 1984). Dredge selection depends on availability and cost, physical characteristics of sediment, amount to be dredged, depth, distance to disposal site, depth of disposal site, physical environment at dredging and disposal sites, contamination level of sediments, dredging site and method of disposal. The production rate relative to levels of turbidity generated, project duration, background levels of suspended sediment and contamination levels should all be considered when evaluating dredges (Raymond 1984). In evaluating dredges, it is also important that all phases of the dredging operation (excavation, transportation and disposal) are considered as an integrated system.

Typically, CSDs have the least effect on turbidity at the dredging site and TSHDs produce similarly low turbidity when used without overflow. Grab dredges and TSHDs, when used with overflow, produce significantly higher turbidity throughout the water column near the dredging site than do CSDs, and in clay may create surface turbidities two to three times those of CSDs (Raymond 1984).

However, at the disposal site, the reverse may be true. Grab dredges do not disturb the structure of clay sediments as much as CSDs or TSHDs do, which may fluidise sediments by mixing them with water. Fluidisation of clays by CSDs and TSHDs may cause spoil to cover an excessive area, and fluidised spoil may take some time to consolidate thus providing a source of ongoing turbidity until consolidation has occurred. Consequently, suction dredges may be preferred if the vicinity of the dredge site is particularly sensitive, while a grab dredge may be favoured if the vicinity of the spoil site is sensitive.

While sand may be pumped out of TSHDs with few environmental problems, pumping out sediments with a high clay content is not desirable, as fluidisation of clays is increased as the fines are twice mixed with water. This process is undesirable, and while it may be acceptable if sediments can be effectively contained within bunds on the seafloor, bottom dumping of fine sediments is preferable.

Table 5: Guidance on selection of appropriate dredges for maintenance dredging (from Bray et al. 1997)

Site conditions	Standard trailer	Small trailer	Cutter suction	Grab	Backhoe
Bed material					
Loose silt	1	1	1	2	2
Cohesive silt	1	2	1	1	2
Fine sand	1	1	1	2	2
Medium sand	1	1	1	2	2
Coarse sand	1	2	1	2	1
Sea conditions					
Impounded water	3	2	1	1	2
Sheltered water	1	1	1	1	1
Exposed water	1	2	3	3	3
Disposal to					
shore	2	2	1	N	2
tide	1	1	1	N	N
sea	1	1	N	1	1
Quantities (m^3)					
<100,000	2	1	1	1	1
<250,000	1	2	1	1	2
<500,000	1	2	1	3	2
>500,000	1	2	1	3	3
Heavy traffic	1	1	3	2	1
Confined working	N	3	2	2	1

1=suitable, 2=acceptable, 3=marginal, N=not usually suitable

Table 6: Guidance on selection of appropriate dredges for capital dredging (from Bray et al. 1997)

Site conditions	Standard trailer	Small trailer	Cutter suction	Grab	Backhoe
Bed material					
Loose silt	1	1	1	2	2
Cohesive silt	1	1	1	1	2
Fine sand	1	1	1	2	2
Medium sand	1	1	1	2	2
Coarse sand	1	1	1	1	2
Gravel	1	2	1	1	1
Soft clay	1	2	3	1	2
Medium clay	2	3	3	2	1
Stiff clay	3	N	3	3	1
Boulders	N	N	3	3	1
Very weak rock	3	N	1	3	1
Weak rock	N	N	1	N	1
Moderately weak rock	N	N	2	N	2
Pretreated rock	2	N	3	3	1
Sea conditions					
Impounded water	N	3	1	1	1
Sheltered water	1	2	1	2	1
Exposed water	1	1	3	3	2
Disposal to:					
shore	1	2	1	N	N
tide	1	1	2	N	N
sea	1	1	3	1	1
Quantities (m^3)					
<100,000	2	1	1	1	1
<250,000	1	2	1	2	1
<500,000	1	3	1	3	2

>500,000	1	3	1	3	3
Heavy traffic	1	1	2	2	2
Confined working	3	3	3	1	1

1=suitable, 2=acceptable, 3=marginal, N=not usually suitable

Similarly, dredging of contaminated sediments with a CSD may create a major materials-handling problem at the discharge point due to the large amount of water entrained with the sediment.

A summary of the conditions suitable for use of dredges of different types for maintenance and capital dredging are summarised in tables 6a and 6b.

Impacts of Dredging and Spoil Disposal

The main environmental effects of dredging are usually those at the site of the dredging and where the spoil is deposited. While these direct impacts are often the most significant, indirect effects are often the main focus of environmental concern. The most significant indirect environmental impacts occur where fine sediments are dredged, causing turbidity which may result in an extended reduction in light levels in a habitat with light-dependent species, or where the sediment contains toxic materials that are released by dredging.

The particle size of sediments at the dredge site and the disposal site are of critical importance in understanding their likely impact. Sandy sediments typically pose few dredging problems. Sand settles quickly (fall velocity of sand is ~10 $mm.s^{-1}$ compared to mud ~0.3 $mm.s^{-1}$), and it is unlikely to move from the disposal site unless subject to extremely high wave energy or currents. Sand particles also have limited surface area compared to muds, so they rarely contain significant quantities of contaminants. In addition, sandy sediments usually occur naturally in areas of high wave energy (close to or on the beach), so animals that inhabit these sediments are probably better able to recolonise abiotic sediments as large scale natural movement of sediments are common in such habitats during storms.

Direct Effects

Where sediments and their associated biota are removed, dredging causes impacts at the site of dredging, Inevitably, there are also impacts where spoil is discharged, and often in the process of transferring spoil between the dredge and spoil sites. A layer of spoil greater than 10 cm deep is usually deep enough to bury and kill most of the fauna. As the thickness of spoil is usually much greater than this, few organisms survive beneath freshly deposited spoil (Maurer *et al.* 1982). Impacts are greatest where spoil and substrate differ in particle size. Where dredging causes a change in physical conditions in channels or spoil grounds through a change in depth or change in sediment type, biological communities may never return to their pre-impacted state.

Unfortunately, there are few adequately controlled studies of the recovery of biological communities in dredged channels or on spoil grounds. Minimal recolonisation of a small dredged channel in New York occurred within 11 months (Kaplan *et al.* 1975) while full recovery of a dredged channel in Florida had not occurred in 10 years (Taylor and Saloman 1968, cited in Kaplan *et al.* 1975). In Chesapeake Bay, recolonisation of spoil grounds occurs 'within months to a year and a half, depending on the type of communities' (Nichols *et al.* 1990), while full recovery of macrobenthic community at 60 m depth off Canada took more than two years (Harvey *et al.* 1998). Qualitative studies on two spoil grounds, upon which 2.6 to 3.8 million m^3 of spoil were deposited in Florida showed significant recovery of macrofauna and fish over eight to 16 months, but complete recovery was expected to take several years and was not monitored (Amson 1988). Comparisons of benthic communities on dredged and undredged regions of Botany Bay suggest that where dredging exposed different sediments, a different benthic community re-established and stabilised in two to four years (SPCC 1979). In estuaries subject to frequent natural disturbances such as floods, spoil grounds may be similar to adjacent control sites within five months (Flemer *et al.* 1997). Qualitative studies of spoil grounds in Western Port (Watson 1974) indicated considerable recolonisation occurred in one to two years but full recovery was not expected for four to five years.

Indirect Effects

Turbidity and Sedimentation

Turbidity represents a complex composite of several variables that collectively influence the transparency of water. Frequently, it is poorly correlated with measurements of suspended solids (for example Truitt 1988). High levels of turbidity and sedimentation in the vicinity of either the dredge site or the spoil dump site may affect adjacent plant and animal communities. High sediment loads may clog animal gills and high rates of sedimentation may cover macroscopic plants and animals, but in general these impacts do not appear to be large. High turbidity reduces photosynthesis and will reduce plant growth and, in extreme cases, will cause mortality. Prolonged high turbidity will cause plant mortality particularly in the case of seagrass. Seagrass requires higher light levels than most macroscopic algae, and they often occur in fine sediments which cause more persistent turbidity when dredged.

The effect of high sediment loads on benthic animals near areas of spoil generally appears to be small. In Chesapeake Bay, detailed studies of turbidity and associated sedimentation caused by a large trailing suction hopper dredge (7,000 m^3 capacity) working in fine sediments (soft plastic silty clay, less than 20 per cent sand) with extensive overflow indicated 12 per cent of the total material removed was redistributed by turbulence near the draghead and from overflow (Nichols *et al.* 1990). In the overflow discharged 5 m below surface sediment concentration was 169,000 mg/L, but this reduced to 120–840 mg/L 300m behind the vessel (measured at 7 m depth) and reached background levels 5.2 km behind the dredge. With time, the plume width increased from ~140 m after seven minutes to greater than 1,100 m after 63 minutes; resulting in a plume 5.7 km^2 in area. During several months of dredging, sedimentation adjacent to the channel formed a layer up to 20 cm thick, but thickness decreased to 10–11 cm at 200m, 5–8 cm at 400 m and 3–7 cm at 640m from the channel. Benthic communities adjacent to these channels showed no evidence that their distribution patterns could be related to the thickness of the layer of dredged material or the distance from the channel. The minimal impact of sedimentation on benthos was attributed to the uncontaminated nature of the sediments, the similarity of channel sediments and those adjacent to the channel, that sedimentation occurred over several months and that the community was largely comprised of short-lived mobile fauna (Nichols *et al.* 1990).

Other estimates of the plume area of TSHDs are comparable to those found in Chesapeake Bay. In fine sediments in Geelong Channel during 1997, the areas of plumes from a 9,000 m^3-capacity TSHD with keel level discharge, were measured daily near the dredge and over the spoil ground. Both areas were estimated by plotting the 10 NTU turbidity contour around the area where the TSHD operated, as well as over the spoil ground, but the period between the dredging and spoil disposal and the measurement of turbidity varied. The plume area around the dredge was 3,200 m^2 (median) 19,000 m^2 (mean), 440,000 m^2 or 0.44 km^2 (maximum). The plume over the spoil ground measured 970 m^2 (median), 690,000 m^2 (mean), 40 km^2 (maximum). Studies conducted with a 7,000 m^3 capacity TSHD in sandy sediments (790 µm) in Hong Kong (Demas 1995) indicated the plume was 100–300 m wide and approximately 700 m long. After 10 minutes, the suspended solids never exceeded 70 mg/L, decayed to less than 40 mg/L in 20 minutes and within an hour were at background levels.

In Port Phillip Bay, measurements of impacts of scallop dredges on benthic infauna also suggest that soft sediment communities can withstand high rates of sedimentation. Behind scallop dredges, many animals were physically removed from the sediment, the turbidity was two to three orders of magnitude greater than occurs during storms (Black and Parry 1994) and sedimentation rates were greater than 13cm/three days (Parry, unpublished data). But mortality rates were still only ~20–30 per cent for most infauna (Currie and Parry 1996). Most of the mortality is likely to have been due to burial by the grader-like action of scallop dredges rather than high rates of sedimentation.

Rice 1984 (cited in Amson 1988) found the 10-day survival and growth rates of sponges and corals were unaffected by suspended sediment loads of up to 199 mg/L. Other studies (summarised by Engler *et al.* 1991) have shown lethal concentrations of suspended sediment to be an order of magnitude or greater than observed in the field during dredging operations. Most animals have apparently evolved means of dealing with moderate rates of sedimentation during storms, and are able to withstand higher than natural rates of sedimentation caused by dredging.

Impacts of turbidity on plants are of great concern when light is reduced for an extended period. A month of higher turbidity than normal was enough to cause significant seagrass loss in Chesapeake Bay (Moore *et al.* 1997). Seagrasses appear particularly vulnerable to increases in turbidity as they require a much higher percentage of incident light than required by most other groups of marine plants (Dennison *et al.* 1993). However, when seagrasses are subject to low light levels, their epiphytes typically die first. This appears to be due to the high light requirements of ephemeral epiphytic algae and the greater capacity of seagrasses to store energy reserves in their rhizomes (Masini *et al.* 1990). In Victoria, the subtidal seagrass *Heterozostera tasmanica* is probably the species most vulnerable to a decrease in water clarity. Nearly complete shading of *H. tasmanica* caused 100 per cent mortality within two months during summer and within four months during winter (Bulthuis 1983). As light probably limits the depth at which *H. tasmanica* occurs, any reduction in light due to dredging is likely to cause greater mortality in deep populations.

Lengthy periods of moderately elevated turbidity may cause accumulation of muddy pseudofaeces on mussels which may reduce their marketability and weaken their attachment to mussel ropes. Increased suspended sediment concentrations may affect trophic interactions in plankton (Cuker 1993) and change the feeding behaviour of fish (Barrett *et al.* 1992). Fish may also avoid highly turbid rivers on their upstream migrations (Rowe and Dean 1998). Laboratory studies on six species of juvenile fish that migrate through New Zealand estuaries indicate that all could feed at a wide range of turbidities from 0–640 NTU. Whitebait (*Galaxias maculatus*) was the most tolerant: its feeding rate was not reduced until turbidity exceeded 320 NTU, while the banded kokopu (*G. fasciatus*) was the most sensitive; its feeding rate declined above 20 NTU – close to the turbidity avoided by this species in flume tank tests (Rowe and Dean 1998). Ecological changes caused by turbidity are only likely to be significant when turbidity is elevated over a large area for an extended period. The significance of changes should be judged against natural background changes in turbidity, but only limited data on turbidity in marine and estuarine waters in Victoria are available.

Turbidity is a conspicuous result of dredging and in fine anaerobic sediments a temporary black oil-like scum may result. After reviewing studies assessing impacts of turbidity, Engler *et al.* (1991) concluded that in many situations the main effect of dredging-related turbidity is its aesthetic impact.

Effects on Phytoplankton

As phytoplankton populations require less light than seagrass, and are more ephemeral than macroalgae, impacts of turbidity on phytoplankton would not normally be measurable. Given the usual scale of dredging and the rapid dilution and mixing in the water column, impacts on phytoplankton would usually be expected to be smaller than the effects of natural phenomena, such as storms, which impact far larger areas.

Dredging may encourage blooms of toxic algal species such as *Alexandrium catenella* and *A. tamarense*, which cause paralytic shellfish poisoning (PSP), a disease potentially fatal in humans. PSP is caused by eating shellfish that have consumed toxic algae. Dredging may also encourage the noxious diatom *Rhizosolenia cf chunii*, which can have a devastating effect on the economics of mussel farming as it causes mussels to become too bitter to market. Despite these possibilities, there is no unequivocal evidence that dredging increases the risk or duration of algal blooms. Nutrient release or disturbance of *Alexandrium* cysts by dredging could both increase the risk of algal blooms, but turbidity caused by dredging reduces light so may lessen the risk of blooms.

Alexandrium catenella blooms have only been recorded in Hobsons Bay during summer (December to mid-April), and cysts are known to be abundant near the Yarra mouth but to decrease in abundance towards the Westgate Bridge (Arnott *et al.* 1994). Cysts collected near the Westgate Bridge were successfully germinated, but those taken near Holden Dock and further upriver could not be germinated. Cysts are abundant in Hobsons Bay but appear rare on and near the Port of Melbourne spoil ground (Arnott *et al.* 1994). Where toxic algal cysts are present on the dredge site, the spoil should ideally be placed in an environment where the cysts will not survive to act as a new source of blooms.

In July 1993, a single bloom of *Alexandrium tamarense* was recorded in Port Phillip Bay; this resulted in a two-week closure of the harvesting of farmed-mussels (Arnott, personal communication). *Rhizosolenia cf chunii* blooms may occur throughout Port Phillip Bay and usually occur between late July and late September (Parry *et al.* 1987, Arnott, personal communication). It is not known whether this species has cysts, so the mechanism by which dredging may affect blooms is unclear.

Release of Contaminants

Where sediments contain contaminants these may be released by dredging. Most contaminants of concern are of two broad types: organic compounds and heavy metals. Many organic compounds, while man-made, are degraded by bacteria, and only those which are both toxic and slow to degrade are of major concern. Such compounds include polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, polychlorinated biphenyls (PCBs) and petroleum hydrocarbons. Heavy metals cannot be degraded, but most organisms have biochemical processes for detoxifying them, presumably because significant levels of heavy metals occur naturally in sediments from normal geological weathering processes. The natural occurrence of heavy metals also complicates the assessment of the toxicity of heavy metals to benthic organisms. Heavy metals are not always bio-available, as they occur in the mineral matrix, as insoluble sulphides or in chelated forms, which are unlikely to cause ecological problems.

Internationally, sediment quality guidelines have been derived either from databases of contaminant concentrations that cause toxic effects, or by using a multiplier of background levels for judging the acceptability of spoil. The first approach has strong scientific support, as the chosen levels are based on levels observed to cause biological effects and is largely adopted in these guidelines. Guidelines derived from the second approach are more difficult to justify as the multiplier used is arbitrary. However, where background levels are low in relation to known toxic concentrations, it is still important that contaminated sediment is not dispersed unnecessarily widely. This cautious approach is justified as the long term effects of contaminated sediments are uncertain because toxicity-based criteria do not account for bio-accumulation, and because there have been few actual measurements made of toxicity in Australian marine organisms.

There are several means of reducing the environmental impact of contaminated spoil. Spoil may be treated to remove contaminants, it may be disposed of in special enclosed facilities on land, it may be disposed of in containment facilities by burial in the seabed or by covering it on the seabed, and finally, it may be mixed with less contaminated material and disposed of to a spoil ground. These alternatives are listed in order of decreasing cost. Additionally, the last alternative is the least environmentally satisfactory means of dealing with contaminants.

Disposal of contaminated dredge material (CDM) is a significant international problem. While contaminated sediments constitute only a small percentage of the total volume dredged in the USA and Europe, they represent a disproportionate share of the total cost of dredging projects. In the USA, the traditional approach to dealing with CDM has been to construct containment areas on land (Truitt *et al.* 1989). In Holland where large volumes of contaminated sediment are dredged from ports subject to inputs from rivers draining the Ruhr and other industrial areas, a number of large onland facilities have been constructed. The Slufter Dam is the largest of these. It encloses an area of 260 hectares and has a storage capacity of 150 million m^3 of CDM. The Slufter accommodates most of the 10 million m^3 of moderately contaminated sediment dredged annually in Rotterdam. Very heavily contaminated sediment is disposed to the nearby Papegaaiebek disposal facility, which has a capacity of 1.5 million m^3 and is lined with high-density polyethylene plastic (Bray *et al.* 1997).

The cost of treating contaminated spoil is high but decreasing (PIANC 1996). Contaminated spoil typically contains a mixture of contaminants and variation in the strength of bonds between contaminants and sediments means that treatment of CDM is difficult and very project-specific. Most techniques are still in the experimental phase. Successful treatment is likely to require good preliminary research and pilot studies before the appropriate treatment is determined (PIANC 1996).

Land disposal is usually less expensive than treatment, but five to 10 times more expensive than conventional disposal to an open water spoil ground (Truitt *et al.* 1989). More recently, less expensive means of containing CDM have been developed by covering CDM on the seafloor beneath a capping of clean material.

APPENDIX 3: TECHNICAL GUIDELINES FOR ASSESSMENT OF CHEMICAL CONTAMINATION OF DREDGED SEDIMENTS

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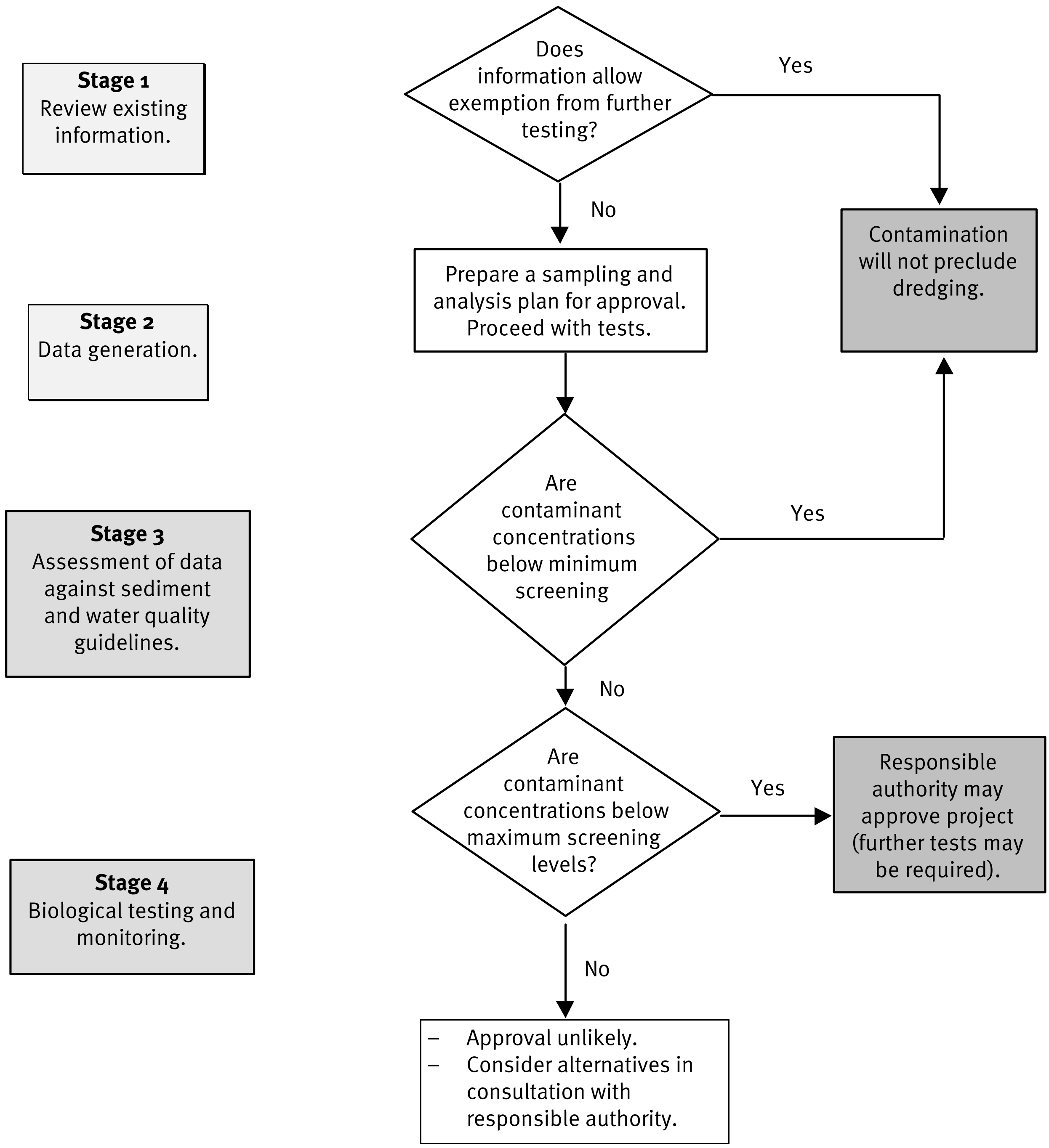
TECHNICAL GUIDELINES FOR ASSESSMENT OF CHEMICAL CONTAMINATION OF DREDGED SEDIMENTS (APPENDIX 3).

Outline of Approach

The technical procedures used to obtain the required data for assessing the contaminant status of dredging proposals are divided into four sequential stages, outlined in figure 2.

Figure 2: Flowchart for assessment of contamination status of sediments to be dredged



Stage 1 – Review of Existing Information and Preliminary Documentation of Sediment Contamination

The collection and review of existing data on the sediments to be dredged allows an initial assessment of whether additional data is required. The quality of existing data should be assessed. If a substantial body of recent environmental data exists, fewer samples may be required, the levels of fewer contaminants may need to be measured, or the project may be exempt from further contaminant testing.

Depending on the scale of the project and the advice from the responsible authority, the following information may need to be collected and interpreted.

- Review data from previous studies, including those in scientific literature, environment and planning studies, unpublished consultants' reports, and dredging investigations that may be archived in relevant government departments.
- Compile a synopsis of dredging-site history, including:
  - knowledge of past contamination and distribution and concentration of contaminants
  - assessment of homogeneity of sediments. Reduced sampling effort may be justified where sediments are well mixed by frequent dredging (every one to two years), high currents, wave action or shipping traffic.
- Identification of the contaminants of concern by reference to the site history and the contaminants listed in tables 11 and 12.
- For large dredging proposals in areas of contaminated sediment a review of existing information on the pre-disposal levels of contaminants in biota, particularly those eaten by humans, may be required. If existing information is inadequate, surveys of the marine biota at the disposal site and appropriate control sites may be required. Biota may be collected directly or suitable indicator species may be deployed at disposal and control sites (Phillips and Rainbow 1995).

Unless the Stage 1 investigation shows that sufficient information is available to make a decision about disposal, additional information will need to be obtained following the procedures detailed in Stage 2.

Stage 2 – Data Generation

Sampling and Analysis Plan

A sampling and analysis plan should be prepared and, where necessary, discussed with EPA prior to commencement of fieldwork. The level of detail included in the plan should match the scale of the dredging and the expected level of contamination. The plan builds on the information obtained from Stage 1 and should include the following key elements.

- An outline of the dredging proposal, including the area(s) to be dredged, the depth(s) of dredging, the type(s) of sediment involved and the final amount of material (in cubic metres) that will require disposal.

- Map(s) showing the dredge and disposal area(s) and the proposed sampling locations, including the proposed length of cores and the depth intervals to be sub-sampled from cores.
- The contaminants to be measured and the sampling sites selected will depend on the previous history of the area, consideration of environmental factors (for example, currents) that may have affected the distribution of contaminants and advice from EPA.

Sampling

The quality of the final results can be no better than the quality of the sampling program. Samples should be representative of vertical and horizontal variation and variability in the properties of materials to be dredged, using the correct methods and precautions to avoid contamination. Without due care, analytical data will be rendered invalid (ANZECC 1992a).

Number of Samples or Cores Required

The appropriate number of sampling sites depends on the variability of sediments and their pollutant content. Sediments from areas with a uniform geomorphology and distant from point sources of pollution require fewer samples than near-shore sediments with complex geomorphology and close to point sources of pollution. The number of samples required typically increases with the volume of material to be dredged. EPA's basic guidelines are summarised in table 7 (EPA 1992; USEPA 1991; ANZECC 1996). If initial tests indicate that contamination may be a concern, further samples may be required.

It is recommended that proponents collect at least twice as many samples as they plan to analyse initially. These additional samples need not be analysed unless the results indicate that contaminant concentrations are of concern. Taking additional samples during the first collection trip adds little to the overall cost, whereas an additional field collection can add significantly to costs.

A stratified random sampling-procedure is recommended and should be used unless circumstances favour some other design (USEPA 1991; ANZECC 1998). The following general scheme is one that could be used, but technical advice on the scheme that best suits particular circumstances should be sought.

- The area to be dredged may be divided into segments that are representative of that area. The size of segments depends on a number of factors, such as the expected distribution of contaminants. Contamination may, for example, be greater in fine-grained sediments that accumulate in turning basins or inside channel bends and may change with depth. If sub-surface strata are clearly defined and known to predate industrialisation, minimal sampling of these may be appropriate. The sampling design will be affected by the depth of cut of the dredge, sampling limitations and the results of pilot studies for large dredging projects (Baudo 1990).

- Sampling locations should be randomly distributed within each segment.

Segments that are thought to contain contaminants at concentrations exceeding the allowable concentrations listed in table 12, may need to be sampled more intensively than uncontaminated segments. The results should then be reported as volume-weighted geometric means.

Table 7: Typical number of sediment cores to be sampled for dredging proposals removing different volumes of material

Volume of material to be dredged (m^3)	No. of cores required at dredging site[a]	No. of cores required at disposal site[b]
up to 25,000	3	3
25,000 – 100,000	4–6	3
100,000 – 500,000	6–10	6
500,000 – 2,000,000	10–20	6
for each 1,000,000 above 2,000,000	additional 10	

a In certain circumstances, samples may be composited. This allows the analysis of sediments from more sites for the same cost.

b Not required when the disposal site is well characterised. Only surface samples are needed to assess grain size and background contamination. If the disposal site is new, samples may be collected within the disposal area, otherwise samples must be collected from reference sites adjacent to the spoil ground but beyond the influence of any sediments previously disposed.

For large dredging projects, a pilot survey may be needed to define the number of segments and samples per segment. Such a pilot survey may involve the collection of five to 10 per cent of the cores that would be taken in a full-scale study.

Sediment samples must be taken so that they are as representative as possible of the sediment that will be removed by the proposed dredging. For example, if a sediment consists of several strata, a sample should be taken from each major stratum. Otherwise, if the dredging method removes sediment in a 0.3 m layer for each pass, samples should be collected in 0.3 m layers. The top 30 cm of a core (or the depth of dredging if less than 30 cm) should be homogenised before chemical analysis. A second sample should be taken from the 30–60 cm interval, and below 60 cm cores should be homogenised for analysis in 1 m lengths or greater if it has been demonstrated that the chemical composition is comparatively uniform. Homogenising can be done by any method that ensures that the sample is not contaminated.

Projects having low environmental concern will require fewer samples than similar-sized works of higher concern. The level of concern is considered by the responsible authority on a case-by-case basis.

Sampling Techniques for Sediments (Chemical and Physical)

Whatever sampling method is used, the proponent or consultant must ensure that the integrity of the samples is not compromised by contamination during the course of sampling and that the sample is representative of the depth profile being tested.

For all coring methods, core liners should be at least 50 mm internal diameter in order to provide sufficient sample for analysis and replication. In some instances, replicate cores may need to be taken in order to provide enough material for all tests.

Core liners should be of polycarbonate, appropriately cleaned to avoid contamination of the sample. Grab samplers should be made of stainless steel and free from grease or corrosion. All sampling devices must be washed clean between each sample. Subsamples of sediment must not be taken from the portion of sediment in contact with the sampler.

Grab sampling using a van Veen or Smith-McIntyre type grab is appropriate where it can be demonstrated that sediments are well-mixed over the depth range to be dredged. Surface samples can also be collected by divers using SCUBA, grabs or appropriate scoops made of stainless steel, polytetrafluoroethylene or any other non-contaminating material.

Piston coring (Davis and Doyle 1969), either with a trigger mechanism or drill string, is suitable where the dredging depth is less than 3 m and sediments are fine. The corer can only be used in calm weather to avoid up and down movement during its descent into the sediment. The operator must ensure that the core enters the sediment vertically.

Hand-coring by SCUBA diver is suitable where the dredging depth is less than 1–1.5 m and the sediments are fine and unconsolidated. Hand-coring overcomes many of the limitations of mechanical coring techniques, but it is generally limited to water depths of less than 20 m. Hand coring should not be used where the sediments are likely to be so contaminated that skin contact needs to be avoided. Hand-coring can be used at the proposed disposal site(s).

Vibracoring can be used for sediments in the range 3–6 m or more, but the operator must ensure that vibration is minimised in fine or unconsolidated sediments, otherwise the upper layers can be greatly disturbed (ANZECC 1998). Vibracoring is an appropriate method for sampling hard clays where other coring techniques may not be successful. Vibracoring of fine unconsolidated sediments is not recommended because of the risk of disturbing and mixing the sample (Hakanson 1992).

Free-fall corers cause compaction of the vertical structure of sediments and are not recommended except where samples are not to be sectioned prior to analysis (for example, sediments are well mixed to the required depth). Loss of surface fines can also be a serious problem when coring fine silts and muds because the impact of the corer with the bottom can push this material out of the way. The operators must ensure that the corer enters the sediment vertically.

Drilling can be employed for sampling cores deeper than 6 m.

Sampling Techniques for Water (Chemical)
Water for elutriation testing should be collected with either a non-contaminating peristaltic or magnetically coupled impeller pump, or with a discrete collection bottle. If a pump is used, the system should be flushed with 10 times the tubing volume of water prior to collecting a sample. The discrete collection bottle should ideally be of the close–open–close type so that only the target water sample comes into contact with the sample. Seals should be coated with polytetrafluoroethylene (PTFE).

It is imperative to limit potential sample contamination from vessels and other apparatus used in sampling to ensure that all components within several metres of the sampling system will be non-contaminating. Operators are referred to the sampling techniques described in USEPA (1995) for details.

Seawater for elutriation tests can be collected from any site that provides uncontaminated seawater.

Sample Handling
Sample handling techniques must ensure that changes that occur as a result of chemical, physical or biological action in the composition of the samples are minimised. It is desirable that sampling is carried out by operators who are accredited for sampling by National Association of Testing Authorities (NATA) to ensure that standard operating procedures and appropriate quality control and quality assurance practices are maintained.

To minimise the generation of spurious data, appropriate procedures to limit sample contamination should be followed at all times. This includes ensuring that samples to be analysed for metals do not come into contact with metals and that samples to be analysed for organic compounds do not come into contact with inappropriate plastics. All sample containers should be appropriately cleaned (acid rinsed for metals, solvent washed for organics). Samples should completely fill the storage container, leaving no air spaces unless the samples are to be frozen, in which case just enough air space should be left to allow for expansion of the sample. The container labels should be waterproof and securely attached to the container. A summary of the collection methods, container type, preservation technique and holding time for each type of analysis is given in table 8.

Table 8: Sample collection methods, storage conditions and holding times for the various analyses (from USEPA 1991, ANZECC 1998)

Test	Collection method	Container	Preservation technique	Maximum holding time
Physical				
Particle size	Grab/corer	Polyethylene bag[a]	Refrigerate @ 4°C	6 months
Chemical				
Metals	Grab/corer	Polyethylene bag[a]	Freeze with dry ice and store frozen @ -20°C	Hg – 30 days; others 6 months
Organics: Polychlorinated biphenyls Total petroleum hydrocarbons Pesticides	Grab/corer	Air tight precleaned and solvent rinsed glass jar with PTFE lined lid.	Freeze with dry ice and store frozen in the dark @ -20°C	30 days[b]
Nutrients	Grab/corer	Polyethylene bag[a]	Freeze with dry ice and store frozen in the dark @ -20°C	30 days
Total organic carbon	Grab/corer	Heat-treated glass vial with PTFE-lined lid	Freeze with dry ice and store frozen in the dark @ -20°C	10 days[b]
Elutriation testing	Grab/corer	Air-tight precleaned and solvent-rinsed glass jar with PTFE-lined lid	Completely fill and refrigerate in the dark @ 4°C	30 days[b]
Water (for elutriation tests)	Discrete sampler or pump	Acid-washed glass	Completely fill and refrigerate in the dark @ 4°C	30 days[b]
Tributyltin	Grab/corer	Polyethylene bag[a]	Freeze with dry ice and store frozen @ -20°C	30 days[b]
Biological				
Toxic and nuisance algae	Grab for cysts/water sampler or plankton net for algae	Cyst samples in polyethylene bags/ plankton sample in plastic bottle	Cyst samples refrigerate at 4°C in the dark/ plankton samples at <20°C	Cyst samples indefinite/ plankton samples less than 6 hr

a=or other appropriate material that has been pre-cleaned.

b=arbitrary time based on the likely time between sampling and analysis.

Quantity of Sample Required for Analysis

The amount of material required for analysis depends on the determinations required and the analytical procedures adopted by different laboratories. Recommended minimum quantities are shown in table 9. It is probable that analyses can be undertaken with smaller amounts than indicated in table 9, but as the cost of sampling is comparatively high it is prudent to collect more material than is likely to be needed.

Sample Documentation

A complete record of field procedures, including any circumstances that could affect the final results, should be documented and maintained. Relevant information that should be recorded includes:

- time and date of collection;
- name of person who took the sample;
- exact location of site and depth of water;
- depth of core into the sediment;
- sampling method;
- visual inspection of sediment core; and
- environmental conditions (weather, tides, currents).

Table 9: Recommended quantities of sediment or water required for various analyses (USEPA 1991; ANZECC 1998)

Analytical variables	Quantity required per test
Organic compounds	250 g
Inorganic substances	100 g
Miscellaneous analyses	100 g
Grain size	200 g
Total organic carbon	50 g
Moisture content	50 g
Elutriation testing sediment	1,000 g
Elutriation testing water	5,000 ml*
Toxic/nuisance alga	
Cyst samples	100 g
Plankton samples	1,000 ml

* includes additional water for rinsing containers

Physical Analyses and Classification of Sediments

The following analyses are required on all samples:

- grain size; and
- total solids.

and, where contaminants are measured, the following must also be measured:

- total organic carbon and iron.

Settling times of sediment may also be required at the discretion of the responsible authority.

Grain size analysis can be done by wet sieving of the coarse fraction, followed by pipette or hydrometer analysis of the fines (Lewis 1984). Alternatively, the settling tube method can be used (Gibbs 1972). The associated Udden-Wentworth size classes and quantitative measures for particle size gradations are listed in table 10. The general classes of gravel, sand and mud are useful for providing a qualitative textural description of the samples (Lewis 1984).

Size classification data should be presented in a graphical or tabular format that allows assessment of textural compatibility of sediment from the dredge and disposal sites as well the settling properties of the material.

Table 10: Classification of grain size of sediments based on the Udden-Wentworth grain size scale (Lewis 1984)

General classification	Wentworth size class	Particle size range (μm)
Gravel	Granule	>2,000
Sand	Very coarse sand	1,000 –2,000
	Coarse sand	500 –1,000
	Medium sand	250 – 500
	Fine sand	125 – 250
	Very fine sand	63 – 125
Mud	Coarse silt	32 – 63
	Medium silt	16 – 32
	Fine silt	8 – 16
	Very fine silt	4 – 8
	Clay	<4

Total solids is the mass of organic and inorganic material remaining after removing the water by drying. Samples may be oven dried at 105° ± 2°C or freeze-dried to constant weight. It is used for converting chemical analytical data from wet weight to dry weight basis.

The total organic carbon (TOC) concentration is a measure of the total amount of oxidisable organic material in the sediment. The analytical method for TOC should be based on methods that use high-temperature combustion which converts the organic carbon to carbon dioxide. Inorganic carbon present as carbonates and bicarbonates must be removed prior to the determination.

Iron determinations can be made at the same time as those of other metals using the same analytical method(s). Sediments containing higher iron levels usually contain higher natural levels of other metals, as many naturally occurring heavy metals are deposited with iron oxides/hydroxides. Consequently, iron concentrations can often be used to help interpret the results of other contaminants.

Settling time can be measured during the grain-size analysis if the settling tube or pipette methods are used. Results may be used to predict regions that may be impacted by turbidity plumes during dredging and disposal operations (ANZECC 1998). However, during disposal, much of the sediment falls as a result of a density difference with seawater; settling time measurements are only directly relevant to well-dispersed sediments. Additional physical characterisation of the material may be required depending on the outcome of the preliminary investigation (Stage 1) or at the discretion of the responsible authority.

Chemical Analyses of Sediment

The chemical and biological contaminants that are most commonly measured are listed in tables 10 and 11. The contaminants that are to be determined depend on the outcome of the preliminary investigation (Stage 1). Typically, measurements of only a few of the contaminants in tables 10 and 11 will be required. However, the responsible authority may require additional contaminants to be measured if it is suspected that these are present. Laboratory methods, including quality assurance and quality control procedures, must be appropriate for the low concentrations expected in marine sediments and elutriated samples. Analyses should be performed on whole sediment after removal of gravel-sized (greater than 2 mm) material by sieving. This sieving may not be required for samples that consist primarily of sands and muds. Results are to be reported for whole sediment on a dry weight basis. Samples should be homogeneous before subsamples are taken for analysis.

Metals and Other Inorganic Substances

Most of the available toxicity data on impacts of metals on benthic biota is based on values obtained from hot concentrated acid extraction methods (Long *et al.* 1995). It is current international practice to use hot concentrated acid extraction procedures to determine the concentrations of metals and metalloids in sediments for environmental assessments (ANZECC 1998). Various strong acid-leaching methods are available (for example, USEPA 1986 – method 3050A; Agemian and Chau 1976; Kimbrough and Wakakuwa 1989). These yield comparable results for sediment trace metals, except for chromium (Zwolsman *et al.* 1996). Additional methods are described in other scientific publications, but if these methods are used they must be validated (Juniper 1995).

Organics

Detailed procedures for the analyses of contaminants in solids are given in *Test Methods for Evaluating Solid Wastes* (USEPA 1986) and *Reference Methods for Marine Pollution Studies* (UNEP/IOC/IAEA 1992). Appropriate analytical methods are also described in other scientific publications, but if these methods are used they must be validated (Juniper 1995). Analyses must be performed on wet samples, since drying will result in loss of volatile contaminants (UNEP/IOC/IAEA 1992). The procedure for extracting the organic compounds must take into account the fact that the samples are wet (eg use of water-miscible solvents).

Elutriation Testing

The elutriate test is carried out to determine the concentrations of organic and inorganic contaminants that could be released into the water column from sediments during their disposal, and their possible release into pore water within the sediments. If a total analysis of the sediment material demonstrates that individual contaminants are below the minimum screening level (table 12), then an elutriation test is not required. If the minimum screening level is exceeded, the need for elutriate tests should be discussed with EPA (see section 3.4). Should an elutriation test be required, the elutriate should be analysed for iron as well as those contaminants selected by EPA.

Elutriation Test Procedure

The elutriation procedure is based on USEPA standard elutriation test (USEPA 1991), modified as described below.

All laboratory equipment must be thoroughly cleaned by washing with detergent, rinsed with copious quantities of tap water, soaked overnight with 10 per cent hydrochloric acid, rinsed with copious quantities of tap water again, then thoroughly rinsed with either distilled or de-ionised water before use.

Clean seawater (salinity = 33–35 and dissolved oxygen ~5 ml l^{-1}), free of contaminants (contaminant concentrations should be below the detection limits listed in table 11), should be used for the test. The elutriation test should use water with a similar salinity to that at the disposal site but free of contaminants. The water must be collected using clean sampling techniques (USEPA 1995).

Preservatives should not be added to sediment samples or the water before the test is carried out. Sediment samples may be frozen and water to be used for the elutriation test may be refrigerated (4°C) in the dark. Elutriate tests must be undertaken within 14 days of sample collection; elutriate solutions must be analysed within 14 days of preparation.

Wet sediment to be tested should be mixed with unfiltered seawater/fresh water of the correct salinity at a sediment-to-water ratio of 1:4 on a volume basis at a temperature of 20°±2°C. Volumetric displacement may be used to measure the volume of sediment. Vessels used for the elutriation test should be made from borosilicate glass or polytetrafluoroethylene (PTFE). Plastic bottles, other than PTFE must not be used.

The sediment/water mixture is to be continuously mixed by turning the vessels end over end at a rate of 30±2 revolutions per minute for a period of 30 minutes. Mechanical agitation, using apparatus similar to that described in USEPA (1992b) method 1311, can be used for mixing. After the 30-minute mixing period, the mixture is allowed to settle for one hour.

After the one-hour settling period, the supernatant liquid is siphoned off and filtered through a 1 µm nominal pore size borosilicate glass fibre filter. Glass fibre filters must be precleaned by washing with dichloromethane, air drying, then washing with 1M hydrochloric acid followed by a distilled-water rinse. Filtration may be performed with either pressure or vacuum filtration systems that can accommodate filters with a minimum diameter of 47 mm. Filtration devices must be made of borosilicate glass or PTFE. Several filters may be required, depending on the content of fine, clay sized, particles in the sediment and the amount of elutriate solution required for the various analyses. Prefilters must not be used. At all times care should be taken to avoid contamination of the sample during the filtration step.

The elutriate solutions should be prepared for analysis and analysed as soon as possible, but within no more than 14 days following extraction. Elutriate samples must be preserved for all analytes as required by the appropriate analytical methods

Chemical Analyses of Elutriate Samples

Detailed procedures for the determination of inorganic variables in waters are described in *Test Methods for Evaluating Solid Waste* SW-846 (USEPA 1986), *Standard Methods for the Analysis of Water and Waste Water* (APHA 1995) and other appropriate standard methods. Additional methods are described in scientific publications. Most of the standard methods require modifications to achieve the necessary detection limits for seawater and these need to be validated (Juniper 1995).

At least 1 L of elutriate should be used for the determination of organic compounds.

The raw seawater used for the elutriate tests does not need to be analysed.

Laboratory Capabilities

Laboratories performing chemical analyses should have demonstrated expertise and experience in performing chemical analyses on marine samples. Analytical methods for marine samples must account for the effects of the high water content of sediments and the high salt content of the elutriate solutions. Direct application to these samples of methods developed for dry soils and freshwater are not valid.

Usually, laboratories will hold current accreditation and registration by NATA, or approved equivalents, for the specific operations and tests to be determined. When possible, analytical tests should have NATA endorsement and incorporate quality assurance and quality control programs in accordance with the guidelines outlined in this document. Where the responsible authority has reason to suspect the accuracy of chemical analyses, they may require replicate samples to be analysed by another laboratory.

Detection Limits

The ideal detection limits required for sediments and elutriate solutions are listed in table 11. The detection limits for organics in the elutriate solutions have been set at T/2, where T is the appropriate ANZECC (1992b) or EPA water-quality guideline value (table 12), because of analytical limitations. For inorganics, the detection limits have been set at T/10. Less rigorous detection limits for elutriate solutions may be allowed by the responsible authority if it can be shown that the detection limits listed in table 11 cannot be achieved because, for example, of deficiencies in sample volume.

Table 11: Desirable detection for contaminants in sediment and elutriate samples, based on ANZECC (1992b)

Indicator	Desirable detection limit in sediment (µg g^{-1} dry weight basis)	Desirable detection limit in elutriate solution (µg l^{-1})
Sediment characteristics		
Total solids % as kg dry sediment per kg wet sediment	0.1%	
Particle size	Textural classification as described in table 11	
Settling times in seawater	Settlement time after 50% and 90% of material has settles from suspension in seawater	
Total organic carbon	0.1%	
Iron	50	
Organic substances		
Organochlorine insecticides	0.001 (each compound)	
aldrin		0.005
chlordane		0.002
dde		0.007
ddt		0.0005
dieldrin		0.001
endosulfan		0.005
endrin		0.0015
heptachlor		0.005
lindane		0.0015
hexachlorobenzene		0.0035
Organophosphate insecticides	0.005 (each compound)	
chlorpyrifos		0.0005
demeton		0.05
guthion (azinphos-methyl)		0.005
malathion		0.05
Parathion		0.004
Triazine herbicides including: atrazine, hexazinone, metribuzin, prometryn, simazine	0.005 (each compound)	
Chlorinated Phenols	0.05 (for each compound)	
monochlorophenol		3.5
2,4-dichlorophenol		0.1
trichlorophenol (total)		9
2,4,5-trichlorophenol		8
tetrachlorophenol		0.5
pentachlorophenol		0.1

Table 11 Continued Indicator	Desirable detection limit in sediment (μg g⁻¹ dry weight basis)	Desirable detection limit in elutriate solution (μg l⁻¹)
Polyaromatic hydrocarbons		
polychlorinated biphenyls (pcb)	0.005	0.002
polychlorinated dibenzo-p-dioxins	0.00002	
Polycyclic aromatic hydrocarbons (PAH): naphthalene, acenaphthylene, acenaphthene, fluorene, phenenthrene, anthracene, fluoranthene, pyrene, benz[a]anthracene, chrysene, benz[b]fluoranthene, benz[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, dibenz[ah]anthracene, indeno[1,2,3-cd]pyrene	0.01 (each compound)	0.15 (each compound)
Petroleum hydrocarbons		
total petroleum hydrocarbons (sediments)	10	1
soluble aromatic hydrocarbons (elutriates)		
Organometallic		
Tributyl tin (as tin)	0.0003	0.0003
Inorganic compounds		
Metals		
arsenic (As)	0.5	0.5
cadmium (Cd)	0.1	0.2
copper (Cu)	0.5	0.5
chromium (Cr)	0.5	0.5
mercury (Hg)	0.01	0.01
nickel (Ni)	0.5	1.5
lead (Pb)	1	0.5
selenium (Se)	0.01	7
silver (Ag)	0.1	0.1
zinc (Zn)	0.5	2.0
Non-metals		
cyanide (Cn)	0.01	0.5
ammonia (undissociated)	0.1	0.8
sulphide	0.1	0.02
fluoride		150

Table 11 Continued Indicator	Desirable detection limit in sediment ($\mu g\ g^{-1}$ dry weight basis)	Desirable detection limit in elutriate solution ($\mu g\ l^{-1}$)
Other		
pH	0.1 units	0.1
pE	0.1 units	0.1 ml l^{-1}
dissolved oxygen	0.1 ml l^{-1}	12 Becquerels l^{-1}
radionuclides*	1 Becquerels g^{-1}	

* Where there is the possibility of contamination of the sediment or water with radionuclides then the responsible authority may require appropriate investigations to be undertaken. Naturally occurring K^{40} is the major contributor to the total radioactivity of sediments. K is mainly in clay minerals and the highest values are about 1 Bq $^{g-}$1 dry weight. Where there is a contribution by thorium in heavy minerals, such as is found in commercially exploited beach sands, the activity can be higher; and these should be subject to control when they occur. Seawater of salinity 35 contains K^{40} at 12 Bq l^{-1} – this is the major contributor to the radiation. The limits for total radioactivity in seawater cannot be below this (J.D. Smith 1997, pers comm 1997).

Quality Assurance and Quality Control

Results for quality control samples should ideally be reported for each batch of 10 to 20 samples. ANZECC (1998) emphasises that quality assurance practices should include the following procedures for the analyses of all water and sediment samples.

- Incorporation of one laboratory blank. Results for blanks should be at or close to the detection limit of the method used. The statement of analytical results should note whether results were corrected for the blank values.
- One container blank in cases where volatile compounds are required.
- For metals, one standard reference material (for example, BCSS-1 for sediment; USEPA quality control samples for elutriates). The values obtained should be within the certified range, where results lie outside this range analyses should be qualified as either high or low.
- For organics, one sample spiked with variables being determined (or surrogate spike for organochlorine compounds). Recoveries should be between 60 and 125 per cent.
- One triplicate sample to determine the precision of analysis. Three uniquely labelled samples should be collected in the field and their standard deviation and co-efficient of variation documented.
- One sample should be analysed from a previous batch (if more than one batch is involved) to determine the variation between batches.

The responsible authority may approve an alternative quality assurance strategy, particularly where fewer than 10 samples are to be analysed.

Stage 3 – Assessment Against Sediment and Water Quality Guidelines

Sediments

The assessment of the contamination status of dredged sediments is made on the basis of whether the concentrations of contaminants comply with the appropriate sediment and elutriate guideline concentrations. Figure 2 provides a summary of the sequential decision-making process and is based on the following scheme.

- If the geometric mean concentrations of all contaminants in the sediment to be dredged are less than the minimum screening level, or twice the background where this applies, the sediment is considered clean. The allowable concentrations based on levels found to cause toxic effects (ANZECC 1998), and values that are twice the background concentration of uncontaminated sediments in Port Phillip Bay are listed in table 12.
- If the geometric mean concentration of one or more of the contaminants in the sediment to be dredged lies between the allowable concentration and the maximum screening level listed in table 12, sediment is classified as moderately contaminated. Until suitable toxicity tests are developed for local species, the acceptability of moderately contaminated spoil for unconfined sea disposal will be determined based on the practicality and likely cost of the alternatives, as well as the likelihood of significant toxicity based on the number of contaminants and the extent to which the low screening level is exceeded by each. Once suitable toxicity tests are developed for local species, direct measurement of sediment toxicity will be required; decisions regarding the suitability of such sediments for unconfined disposal will be based on the results of sediment toxicity tests.
- If the geometric mean concentration of one or more contaminants in the sediment to be dredged lies above the maximum concentrations listed in table 12, the responsible authority may not approve the proposal. The proponent should investigate the cost and feasibility of all possible alternatives to unconfined sea disposal. The proponent may also negotiate with the responsible authority regarding additional tests which could be performed to assist with an assessment decision. Such tests may include ecotoxicity and bio-accumulation studies outlined in Stage 4.

Once suitable sediment toxicity tests are developed for local species, toxicity tests are likely to be required for all sediments classified as moderately or highly contaminated. There are no tests yet approved for this purpose in Australia, but they are currently being developed.

Where the high screening level is exceeded, the sediment is considered highly contaminated and disposal at sea is unlikely to be acceptable unless extensive testing indicates it is not toxic, either directly or through bio-accumulation. Alternatively, rather than undertake extensive chemical and biological testing, proponents dealing with contaminated sediment may elect to consider land or other disposal options as described in section 3.5.

Water Quality

Elutriate tests will be required when there is inadequate information to demonstrate that relevant water-quality criteria will not be exceeded after allowing for mixing that occurs within four hours of dumping (see section 3.4).

Stage 4—Biological Testing and Monitoring

Ecotoxicology and Bio-Accumulation

There may be circumstances where toxicity and bio-accumulation tests are needed to assess a dredging proposal. At the discretion of the responsible authority, tests may be required for any of the following:

- Toxicity of elutriate to biota, involving water-column bio-assays (elutriation test) in order to determine the potential toxicity/impact of dissolved and suspended contaminants on organisms in the water column. The test organisms should be representative of sensitive water-column organisms occurring at the disposal site(s).
- Toxicity of dredge spoil to infauna (bottom-dwelling organisms), to determine the potential toxicity of the dredged materials to benthic organisms at the disposal site(s). The test organisms should ideally represent sensitive infaunal organisms occurring at the disposal site.
- Bio-availability and bio-accumulation of contaminants such as heavy metals and organics that are present in many marine systems, either from natural weathering processes (for example, metals) or from anthropogenic inputs (for example, metals, organochlorine insecticides). These substances may bio-accumulate in the tissues of animals, either by respiration, ingestion or sorption, to levels which threaten the health of organisms or their consumers.

Table 12: Minimum and maximum screening levels for contaminants for sediments (ANZECC 1998, ANZECC - ARMCANZ, 2001) and twice background levels for selected contaminants in Port Phillip Bay. Water-quality guidelines for elutriate solutions are also shown. Consult the responsible authority for contaminants not listed

Indicator	**Minimum screening level** **μg g^{-1} dry weight**	**Maximum screening level** **μg g^{-1} dry weight**	**Twice background level (2 x central Port Phillip Bay sediments)** [a] **μg g^{-1} dry weight**	**Water-quality guideline** [b] **μg L^{-1}**
Organic substances*				
Organochlorine insecticides				
aldrin			0.002	
chlordane	0.0005	0.006		0.03 (freshwater)
DDE	0.0022	0.027	0.002	
DDD	0.002	0.02		
DDT			0.004	0.006 (freshwater)
total DDT	0.0016	0.046	0.006	
dieldrin	0.00002	0.008	0.002	
endrin	0.00002	0.008		0.004
heptachlor			0.002	0.01 (freshwater)
lindane	0.0032	0.001		0.05
hexachlorobenzene				
Organophosphorus insecticides				
chlorpyrifos			0.04 (each compound)	2 x 10^{-8}
guthion (azinphos-methyl)				0.01 (freshwater)
malathion				0.002 (freshwater)
parathion				0.0007 (freshwater)
Triazine herbicides including: atrazine, hexazinine, metribuzin, promethryn, simazine			0.2 (each compound)	0.2 (freshwater)
Chlorinated phenols				
monochlorophenol				160 (freshwater)
trichlorophenols			0.006 (each compound)	3 (freshwater)
tetrachlorophenols			0.002 (each compound)	10 (freshwater)
pentachlorophenols			0.006 (each compound)	11
PCBs & Dioxins				
polychlorinated biphenyls (PCB) – total	0.023	0.18		
polychlorinated dibenzo-p-dioxins			0.000356	

Table 12 continued Indicator	Minimum screening level $\mu g\ g^{-1}$ dry weight	Maximum screening level $\mu g\ g^{-1}$ dry weight	Twice background level (2 x central Port Phillip Bay sediments) [a] $\mu g\ g^{-1}$ dry weight	Water-quality guideline [b] $\mu g\ L^{-1}$
Polycyclic aromatic hydrocarbons (PAH):				
naphthalene	0.16	2.1	0.02	50
acenaphthalene	0.044	0.64	0.02	
acenaphthene	0.016	0.5	0.01	
fluorene	0.019	0.54	0.01	
phenanthrene	0.240	1.5	0.03	
anthracene	0.085	1.1	0.02	
2-methylnaphthalene	0.070	0.37	0.02	
low molecular weight PAHs	0.552	3.16		
fluoranthene	0.600	5.1	0.07	
pyrene	0.665	2.6	0.07	
benzo[a]anthracene	0.261	1.6	0.04	
chrysene	0.384	2.8	0.05	
benzo[a]pyrene	0.430	1.6	0.05	
dibenz[a,h]anthracene	0.063	0.260	0.06	
high Molecular weight PAHs	1.7	9.6		
indeno[1,2,3-cd]pyrene			0.06	
benzo[ghi]perylene			0.06	
benz[b]fluoranthene			0.07	
benz[k]fluoranthene			0.06	
Total PAHs	4.00	45.0	0.4	
Petroleum hydrocarbon				
total petroleum hydrocarbons (TPH)			29	
soluble aromatic hydrocarbons				3 (freshwater)
Miscellaneous organics				
Tributyl tin (as tin)	0.005	0.07		0.0004
Inorganic substances				
Metals				
arsenic (As)	20	70	20	
cadmium (Cd)	1..5	10	0.30	0.70
copper (Cu)	65	270	13	0.30
chromium (Cr)	80	370	79	0.14
mercury (Hg)	0.15	1.0	0.12	0.10
nickel (Ni)	21	52	46	14
lead (Pb)	50	220	24	2.2
selenium (Se)			0.50	
silver (Ag)	1	3.7	128	0.8
zinc (Zn)	200	410		7
Non-metals				
cyanide (Cn)				2
ammonia (NH4)				490

Table 12 continued Indicator	Minimum screening level µg g^{-1} dry weight	Maximum screening level µg g^{-1} dry weight	Twice background level (2 x central Port Phillip Bay sediments) [a] µg g^{-1} dry weight	Water-quality guideline [b] µg L^{-1}
Other				
radionuclides[c]	2 Becquerel g-1	2 Becquerel g-1		

* Screening levels for all organic contaminants are normalised to 1% organic carbon. If the sediment content is markedly different from 1%, the guideline value should be adjusted. More organic carbon in sediment reduces the toxicity of organic contaminants.

a Background levels were compiled from Bremner et al. (1990), Maunsell (1993), EPA (1995c), EPA (1995d), Fabris et al. (1994), Maunsell (1995). For organic compounds, such as organochlorine, organophosphate insecticides and herbicides, the values listed are twice the detection limits quoted in EPA (1995d).

b Values are from the NWQMS (ANZECC - ARMCANZ; 2001).

c Where there is the possibility of contamination of the sediment with radionuclides, the responsible authority may require further investigations to be undertaken. Naturally occurring K40 is the major contributor to the total radioactivity of sediments. The K is mainly in clay minerals and the highest values are about 1 Bq.g-1 dry weight. Where there is a contribution by thorium in heavy minerals, such as is found in commercially exploited beach sands, the activity can be higher; these should be subject to control when they occur (J.D. Smith 1997, Chemistry Department, University of Melbourne, pers comm).

APPENDIX 4: ESTIMATED NUTRIENT RELEASE BY DREDGING

Dredging releases water held within the sediment, and this pore water typically contains higher levels of nutrients than in the water column above. The ecological influence of these additional nutrients depends on background concentrations in the water column as well as on the amount of nutrient released during dredging. This in turn depends on the rate of dredging, depth of dredging, the proportion of pore water released at the disposal site and the rate of dilution of the released pore water. The amount of nutrient in the sediments depends on the porosity of the sediments and the concentration of nutrients in the pore water. The model below estimates nutrient release by dredging. The numerical example is a near worst-case scenario based on dredging with a large dredge, similar to that used to deepen the Geelong Channel in 1997. Nutrient release with smaller dredges, and so forth, can be estimated directly from the model.

Model

Mass of nutrient released/day = pore water concentration (μmol.L^{-1}) $\times$ volume dredged/day (L) $\times$ porosity $\times$ proportion of pore water released $\times$ formula weight...............................Equation (1)

Representative nutrient concentrations in pore water for different regions of Port Phillip Bay are summarised in table 13.

Table 13: Nutrient concentrations in pore water (μmol.L^{-1}) from different regions of Port Phillip Bay, representative values from Nicholson et al. 1996

Nutrient	Corio Bay	Werribee and Geelong Arm	Central Port Phillip Bay	Hobsons Bay	Eastern Sandy Port Phillip Bay
NH_4-N	50	50	20	200	30
NO_2+NO_3-N	2	1	1	1	1
PO_4-P	25	25	10	50	10
SiO_4-Si	100	100	100	300	100

Release rates of nutrients/day (table 14) were estimated using the model in Equation (1), the nutrient concentrations in table 1, and the following assumptions:

Volume dredged/day	10,000 m^3
Depth dredged	1 m
Proportion of pore water released at site	0.50
Porosity	0.8

Table 14: Estimated release rates of nutrients (kg/day), using data from table 1, equation 1, and the assumptions on the previous page

Nutrient	Corio Bay	Werribee and Geelong Arm	Central Port Phillip Bay	Hobsons Bay	Eastern Sandy Port Phillip Bay
NH_4-N	2.8	2.8	1.1	11.2	1.7
NO_2+NO_3-N	0.1	0.1	0.1	0.1	0.1
PO_4-P	3.1	3.1	1.2	6.2	1.2
SiO_4-Si	11.2	11.2	11.2	33.6	11.2

The above values may be compared to nutrients in Port Phillip Bay–Werribee Treatment Plant and the Yarra River. Release rates from these sources are summarised in table 15. The increase in concentration of nutrients in the water column following disposal of dredge spoil depends upon the rate of dilution, which depends on a range of oceanographic factors such as currents, mixing, waves, etc. Approximate estimates of increased nutrient concentrations in the water column following dredging for different areas of Port Phillip Bay are summarised in table 16, using the release rates summarised in table 14. Estimates are near worst-case scenarios, and are estimated below by assuming that spoil is disposed in an area 500 m × 200 m and in a depth of 15 m, so that pore water released from the spoil is well mixed throughout the water column.

The model assumes:

depth of water over disposal site	15 m
area of disposal site	500 m × 200 m
dilution volume	1,500,000 m^3

concentration increase/day = Nutrient release rate/volume of receiving water × formula weight……………………………………………Equation (2)

Increased nutrient levels described in table 16 may be compared to background levels of these nutrients, which are summarised in table 17.

Table 15: Typical release rates (kg/day) of nutrients from major sources in Port Phillip Bay, Longmore et al. 1996

Nutrient	Western Treatment Plant, summer	Western Treatment Plant, winter	Yarra River
NH_4-N	1,500	11,300	430
NO_2+NO_3-N	400	600	1,500
PO_4-P	1,000	2,800	923
SiO_4-Si	2,900	3,700	10,684

Table 16: Increase in concentration (μg L^{-1} d^{-1} of the element) in the water column for different regions of Port Phillip Bay, using Equation 2 and the assumptions on the previous page

Nutrient	Corio Bay	Werribee and Geelong Arm	Central Port Phillip Bay	Hobsons Bay	Eastern Sandy Port Phillip Bay
NH_4	1.8	1.8	0.7	7.4	1.1
NO_2+NO_3	0.14	0.00	0.00	0.00	0.00
PO_4	2.2	2.2	0.9	4.0	0.9
SiO_4	7.5	7.5	7.5	22	7.5

Table 17: Range of mean concentrations (μg L^{-1} d^{-1} of the element) for nutrients in different regions of Port Phillip Bay, Longmore et al. 1996. ND = not determined.

Nutrient	Corio Bay	Werribee and Geelong Arm	Central Port Phillip Bay	Hobsons Bay	Eastern Sandy Port Phillip Bay
NH_4	ND	8.4-28.5	6.7-7.1	15.1	5.9-7.7
NO_2+NO_3	ND	2.4-10.9	0.4-1.8	17.9	1.1-6.2
PO_4	ND	86-99	55-62	82	36-74
SiO_4	ND	118-133	143-146	275	81-196

APPENDIX 5: ESTIMATED MAXIMUM SUSTAINED TURBIDITY TO MAINTAIN SEAGRASS HEALTH

Seagrass is dependent upon sufficient light being available for its survival. While seagrass stores reserves in its rhizomes to enable it to withstand periods of low light, if these reserves are used up the seagrass will die; recovery of seagrass beds may be extremely slow. The subtidal seagrass *Heterozostera tasmanica* is the species most likely to be impacted by increases in turbidity, except in the Gippsland Lakes, where the seagrass *Zostera* spp. is the dominant subtidal seagrass.

To predict the effect of turbidity on seagrass, both the light requirement of seagrass and the relationship between turbidity and light transmission must be established. Only approximate estimates of both these relationships are available currently.

Light requirement of seagrass

The light requirement of seagrass may be established experimentally or from measurements of the light intensities at the maximum depth to which seagrass is found, although the latter approach assumes that light limits the depth distribution of seagrass. Experimental studies suggest that *Heterozostera tasmanica* survives at light levels estimated to be between five and 13 per cent of surface radiation (Bulthuis 1983).

By definition:

Attenuation coefficient × depth = ln (I_o/I_d), where I = intensity of PAR at the surface (I_o) and at depth d (I_d)…………………Equation (1)

Serving as a case study, background measurements of the attenuation of photosynthetically active radiation (PAR) from three studies in seagrass habitats in the Geelong Arm are summarised in table 18. Measurements have been made at a 10 m site near Clifton Springs (A. Longmore, MAFRI, unpublished data), at 21 sites throughout the Geelong Arm (VCA 1997) and at nearshore sites at Clifton Springs, Avalon and Point Henry (Black *et al.* 1994).

If seagrass requires a mean value of 10 per cent of surface radiation, the attenuation coefficient of 0.3 means this light level (10 per cent) reaches 3.3 m (see Equation 1), which is approximately the depth to which *Heterozostera* is found in the Geelong Arm. Alternatively, if seagrass requires only five per cent of surface radiation, then if seagrass occurs to a depth of 3.3 m the mean attenuation co-efficient in the Geelong Arm must be 0.39. The latter scenario appears less likely, as most seagrass species require more than 10 per cent light for survival; typically, they require nearly 20 per cent for survival (Dennison *et al.* 1993). The measured values of mean light attenuation in the Geelong Arm are all less than 0.39.

Table 18: Background measurements of attenuation coefficient for PAR in Geelong Arm

Attenuation coefficient	No. of sites	Frequency of measurements	Duration of measurements	Source
0.30 (median) 0.4 (80th percentile)	1	2 weekly	Aug 1990–Jul 1996	A. Longmore, MAFRI, unpublished data
~0.3 (mean)	3	Continuous	Jan 1994–Apr 1994	Black *et al.* 1994
0.35 $\pm$ 0.05 (mean)	21	~2 weekly	Feb 1996–Dec 1996	VCA (1997)

Relationship Between Turbidity and PAR

The relationship between attenuation coefficient for PAR and turbidity was established by C. Gibbs (EPA, unpublished data) by measuring both parameters over a wide range of turbidities in the plume of three ships passing along the Geelong shipping channel during early 1996. The resulting curve, based on those values where turbidity did not change significantly with depth, was used to calculate the relationship between light attenuation and turbidity.

Attenuation co-efficient = 0.276 +0.028 × turbidity (NTU)…………………. Equation (2)

The relationship between turbidity and attenuation coefficient was also estimated by measurements obtained during dredging of the Geelong Channel in 1997 (table 3.1, VCA 1998).

Attenuation coefficient = 0.263 + 0.055 × turbidity (NTU)………………..Equation (3)

Equations (2) and (3) give similar predictions of light attenuation at low turbidities but they diverge considerably at high values of turbidity. If the mean background attenuation coefficient is 0.30, then these equations imply that the mean background turbidity is 0.9 NTU (Equation 1) or 0.7 NTU (Equation 2).

The only measurements of background turbidity in the Geelong Arm were obtained between February 1996 and December 1996. Measurements were taken at 21 sites at approximately two weekly intervals and continuous measurements were obtained at seven sites throughout this period (VCA 1997). The mean turbidity at the seven continuously monitored stations was 0.47 NTU, and at the other 21 stations, 0.55 NTU; the mean turbidity at different sites varied between 0.2 and 0.9 NTU. The frequency distribution of turbidity at the seven continuously monitored sites is shown in table 19.

Table 19: Frequency distribution of turbidity at 7 sites monitored continuously (15 min intervals) between February 1996 and December 1996

	NTU			
Site	0–1	1–2	2–5	>5*
Avalon pile	87.7	2.9	3.8	5.6
Inner spoil ground	95.1	2.1	1.1	1.8
Moolap pile	82.1	13.5	2.2	2.2
Outer spoil ground	84.7	7.6	4.2	3.6
Point Richards pile	63.2	20.2	7.6	9.0
Sweeney Bay pile	80.2	11.9	3.9	4.1
West Point Wilson pile	91.5	4.3	2.2	2.0

Development of Criteria to Protect Seagrass

If an environmentally acceptable decrease in light over seagrass beds reduces the maximum depth at which seagrass survives by 0.5 m from 3.3 m–2.8 m, this corresponds to an attenuation coefficient of 0.36, or an increase in mean attenuation coefficient of 0.06. This corresponds to an increase in mean turbidity of 2.14 (based on Equation 2), or 1.09 (based on Equation 3).

Therefore, the following turbidity criteria can be developed for the Geelong Arm.

	Turbidity (NTU)
Background (mean)	0.5–0.9
Acceptable increment in mean (seagrass requires 10% ambient light)	1.1–2.1
Acceptable mean turbidity over seagrass	1.6–3.0
Suggested trigger turbidity to change dredging operations	5

Development of criteria to protect seagrass must acknowledge that seagrass tolerates periods of naturally high turbidity and can withstand some increase in the frequency of turbid events. Turbidity from dredging is unlikely to be continuous at any particular site due particularly to changes in wind and tidal conditions but also due to changes in dredge location and dredging rate.

During the dredging at Geelong in 1997, similar data to those above were converted into the following operational criteria. Two lines were established, one, the action line, approximately followed the edge of seagrass beds (approx the 3.3 m contour), and the other, the warning line, followed 200 m on the seaward side of this line. If turbidity exceeded five NTU on the warning line EPA was contacted. If the turbidity exceeded five NTU on the action line as a result of dredging activity (based on dredging location, wind direction and plume position), dredging ceased at that location. Note the value of five NTU assumes that the distribution of turbidity through time remains similar to that prior to dredging and makes some allowance for natural exceedances of values of five NTU. This criterion was effective at protecting seagrass, but dredging-induced turbidity exceeded five NTU over seagrass beds only rarely. Such a criterion is unlikely to be effective if five NTU was exceeded frequently. Clearly, more accurate data is required on the light requirements of seagrass, natural background values of turbidity and the effect of sediment on light penetration and turbidity. Unfortunately, the last two relationships appear to vary significantly with the sediment type, so relationships must be established under a range of circumstances.

The large variation in sediment particle size in natural sediment suspensions causes suspended solids to be poorly correlated with turbidity and light attenuation (for example, VCA 1997 1998). But there is a tight linear relationship between turbidity and suspended solids in simulated dredged sediment. C. Gibbs (EPA, unpublished data) mixed different amounts of sediment from sediment cores in Corio Bay with seawater, then allowed them to stand for 15 minutes before turbidity and suspended solids were measured. The following relationship was established.

Suspended solids (mg/L) = $1.2 \times$ turbidity (NTU).................................. Equation (4)

This site-specific relationship was used to provide engineering criteria based on suspended solids.

APPENDIX 6: IMPLICATIONS OF FISH LIFE HISTORIES FOR DREDGING PRACTICES IN PORT PHILLIP BAY

Introduction

Most species of fish are widely dispersed during all their life-history stages and hence are never exceptionally vulnerable to site-specific impacts. But where there is a concentration of eggs, larvae, breeding adults or juveniles in particular locations, these areas should not be impacted during critical periods.

This report summarises the breeding times and preferred breeding locations and habitats of all fish of commercial, recreational and conservation significance in coastal Victoria and particularly in Port Phillip Bay. The seasons in which dredging may have greater impacts at a particular location are identified, to the extent that current information allows.

The four main habitat types in Port Phillip Bay are seagrass, reef, soft sediments and estuaries. The fish species that occur in each habitat are summarised in table 20 and their biology is described below. The months in which each species may be particularly vulnerable to site-specific impacts are summarised in table 21.

Several species are more vulnerable during particular seasons, as most of a life-history stage (eggs, larvae, juveniles or adults) are concentrated in a restricted habitat type or a specific geographic region. Few fish populations are likely to be seriously impacted by dredging, but impacts on three species should be avoided where possible. Snapper is a very important recreational species. Its spawning grounds may be vulnerable to extensive dredging during the period between November and March. The Australian grayling and the Tasmanian mudfish are both considered vulnerable and are listed on the *Flora and Fauna Guarantee*, but the Tasmanian mudfish occurs in very few Victorian estuaries. There have been periods when both the broad-finned galaxias and the spotted galaxias have been considered potentially threatened (Koehn 1990), but they are not listed on the *Flora and Fauna Guarantee*. The estuarine habitat requirements of all these migratory species needs further investigation. The salinity preferences, food and other habitat requirements of these galaxias are unknown, as is their tolerance of disturbance by dredging. There is wide variation in the tolerance of turbidity by juvenile fish that migrate through estuaries, but most species have a wide tolerance (Rowe and Dean 1998).

Species Mostly Found in Seagrass Habitats

King George whiting (Sillaginodes punctatus) Late-stage larvae, approximately 20 mm in length, enter Port Phillip Bay at an age of 100 to 170 days between September and November (Jenkins *et al.* 1996). The only known spawning area is the nearshore coastal waters of South Australia, a distance of approximately 800 km from Port Phillip Bay (Jenkins and May 1994). Currents may transport larvae from South Australia to Victorian bays.

Within Port Phillip Bay, sparse seagrass in the Portarlington area may be of disproportionate importance as King George Whiting larvae settle out principally in this area then move into the Geelong Arm within a few months in search of food in the sandy patches between seagrasses (PPBFMPBP

1996). Studies in Western Port indicated juveniles depend upon seagrass flats and their associated macrofauna throughout the first three years of life. Postlarvae (greater than 20 mm) are found in dense seagrass from August to September through to December to January when they move onto bare mudflats adjacent to seagrass to feed on ghost shrimp (Parry *et al.* 1990; Klumpp and Nichols 1983; Robertson 1977).

Silver trevally (Usacaranx georgianus) This species is abundant in coastal and estuarine waters, usually in schools (Hutchins and Swainston 1986). Juveniles usually inhabit estuaries and bays, while adults are pelagic over deeper areas of the continental shelf (Parry *et al.* 1990; Edgar *et al.* 1982). They are a summer spawning species which release eggs in both estuarine and offshore waters. Juveniles move into inshore and estuarine areas at approximately three months of age (four cm length) and begin to move offshore when they reach approximately 20 cm length (PPBFMPBP 1996). The juveniles occur preferentially in beds of macrophytes (Parry *et al.* 1990), while older fish have been caught in coastal waters as deep as 110 m (Winstanley 1981).

Table 20: Habitats for marine and estuarine fish of commercial, recreational and conservation importance in Victorian coastal waters

Species	Habitat			
	Seagrass	Reef	Soft sediment	Estuary
King George whiting	+			
Silver trevally	+			
Southern sea garfish	+			
Southern calamari	+	+		
Australian salmon	+		+	
Elephant shark	+		+	
Yank flathead	+		+	
Yellow-eye mullet	+		+	
Red mullet	+	+	+	
Rock flathead	+	+	+	
Gummy shark		+		
Snapper		+		
Angel shark		+	+	
Common gurnard perch		+	+	
Mulloway		+	+	+
Greenback flounder			+	

Long-snouted flounder			+	

Table 20 Continued

Species	Habitat			
	Seagrass	Reef	Soft sediment	Estuary
Sand flathead			+	
Australian grayling				+
Black bream				+
Broad-finned galaxias				+
Common galaxias				+
Long-finned eel				+
Pouched lamprey				+
Sea mullet				+
Short-finned eel				+
Short-headed lamprey				+
Southern anchovy				+
Spotted galaxias				+
Tasmanian mudfish				+
Tupong				+

Table 21. Months in which the eggs (E), larvae (L), juveniles (J) and adults (A) of marine and estuarine fish in Victoria may be vulnerable to dredging impacts. Bold type indicates life-history phases which are more vulnerable as they may be confined to a small area or period.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seagrass habitats												
King George whiting	J							J	J	J	J	J
Silver trevally						J	J	J				
Southern sea garfish	J									E	E	J
Southern calamari									**E**	**E**		
Australian salmon (western)								J	J	J		
Australian salmon (eastern)	E	E	E								E	E
Elephant shark	E	E	E	E	E	E	E	E	E	E	E	
Yank flathead										E	E	E
Yellow-eyed mullet*	E										E	E
Reef habitats												
Red mullet												
Rock flathead											E	E
Blacklip abalone												E
Gummy shark	J										J	J
Snapper	**E**	**E**	**E**								**E**	**E**
Angel Shark												
Common gurnard perch												
Mulloway	E?	E?							E?	E?	E?	E?
Soft-sediment habitats												
Greenback flounder						E	E	E	E	E		
Long-snouted flounder				E	E	E	E	E	E	E		
Sand flathead									E	E		
Scallop								E	E	E		

Table 21 Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estuarine habitats												
Australian grayling				E	E	**J**	**J**	**J**	**J**	**J**		
Black bream										E	E	E
Broad-finned galaxias					L?	L?	L?		**J**	**J**	**J**	
Common galaxias						A	A?	A		J	J	
Long-finned eel	A+J	A+J	J	J	J							A
Pouched lamprey							J	J	A+J	A+J	A	
Sea mullet			E?	E?	E?/J	E?/J	E?/J	E?/J	E?/J	J	J	
Short-finned eel	A	A			J	J	J					A
Short-headed lamprey								J	A+J	A	A	
Southern anchovy	E	E	E							E	E	E
Spotted galaxias	J				L?	L?				**J**	**J**	J
Tasmanian mudfish							L?	L?	L?+J	J	J	
Tupong	J	J	J	A	A	A+J	A+J	A+J	J	J	J	

*Spawning location is unknown. If inshore in localised sites eggs are potentially vulnerable to dredging impacts, but if offshore eggs are not at risk.

Southern sea garfish (Hyporhamphus melanochir) This is the most abundant species of garfish found in Victorian waters. It may spawn in either marine or estuarine environments between October and March, with the most intense activity during October and November (PPBFMPBP 1996; Ling 1958). The eggs, which are large and clear, have adhesive filaments for attachment to aquatic vegetation at the bottom of shallow, sheltered bays, hence, seagrass beds are an essential habitat (Collette 1974). Juveniles are found in estuaries, but they rarely move more than 3 to 4 km from the estuary mouth (Parry *et al.* 1990).

Species Mostly Found in Seagrass and on Reef Habitats

Southern calamari (Sepioteuthis australis) Southern calamari inhabit vegetated and reef areas of Port Phillip Bay throughout the year. Although principally a demersal species, they have often been observed at the surface. During late winter and spring, large numbers of calamari aggregate in the Port Phillip Heads region to spawn and attach their egg masses to algae on reefs and to seagrass. A fixed substrate and a food supply for the larvae are the two most important factors determining the site of spawning (Hall and MacDonald 1986; Parry *et al.* 1990). The highest catches of calamari are taken during September and October, this being the peak spawning period (Nicholson 1992).

Species Mostly Found in Seagrass and on Soft Sediment Habitats

Australian salmon, western subspecies (Arripis trutta esper) The western subspecies is the predominant form in the Port Phillip Bay region. Mature individuals reproduce in the coastal waters off south-western Australia between February and May (Robertson 1982). Recruitment within Port Phillip Bay appears to proceed from late August through to October. Robertson (1982) found the earliest captures of 0+ aged individuals in Western Port to have a mean length of approximately 6 cm. At this size, juveniles are unlikely to be susceptible to dredging impacts.

Australian salmon, eastern subspecies (Arripis trutta marginata) Individuals of this subspecies between the ages of 0+ and 3+ have been found to inhabit Port Phillip Bay areas, although they contribute significantly lower numbers to the Bay's salmon population than does the western subspecies. They are thought to breed in coastal waters off Gippsland and southern NSW, and spawn between November and April (Stanley 1978).

Elephant shark (Callohynchus milii) Also referred to as Elephant fish. A common demersal inhabitant found over sand or mud, in shallows and deeper waters down to at least 120 m. More common in offshore waters. Females enter shallow bays in summer to deposit eggs in muddy channels and seagrass areas. Eggs are encapsulated in chitinous cases, which are flat and elongate with an oval-shaped chamber (Gomon *et al.* 1994). Young hatch after about eight months and move out to deeper water (Kuiter 1996).

Yank flathead (Platycephalus speculator) Yank flathead is widely distributed in Port Phillip Bay (Parry *et al.* 1995) but is less abundant than sand flathead and makes only a small contribution to commercial landings of flathead (Parry *et al.* 1990). Spawning occurs between October and December in the Bay (Brown 1977); eggs are probably planktonic. They are an inshore coastal species known to occur on sandy bottoms and in seagrass beds, particularly in shallow protected bays at depths to approximately 30 m (Hutchins and Swainston 1986; Gomon *et al.* 1994; Brown and Davies 1991).

Yellow-eyed mullet (Aldrichetta forsteri) Early juveniles are extremely abundant in Port Phillip Bay, however, larvae are rare or absent (Jenkins 1986). Spawning occurs during late spring and early summer (Parry *et al.* 1990; Hall and MacDonald 1986) and migration into nursery areas usually occurs at a late larval or early juvenile stage (Jenkins 1986). The location of spawning grounds in Victoria is unknown, but there is some evidence from reproductive condition that spawning occurs offshore (Jenkins 1986). An alternative explanation for the absence of larvae is that spawning is very localised within the Bay and that larvae have not yet been detected due to limited spatial sampling (Jenkins 1986). If this were the case, the species may be susceptible to the impacts of dredging if dredging were to occur in or close to that one localised area.

Species Found in Seagrass, Soft Sediment and Reef Habitats

Red mullet (Upeneichthys porosus) This species occurs on sand, sponge and bryozoan-covered bottoms, on seagrass beds and at the edges of shallow reefs in coastal waters and bays to depths of just more than 40 m (Gomon *et al.* 1994; Edgar *et al.* 1982). Adults spawn in the marine or estuarine environments and the juveniles occur in estuarine habitats (Parry *et al.* 1990). The time of spawning is unknown.

Rock flathead (Platycephalus laevigatus) In Victorian waters, the species is found only in bays and inlets west of, and including, Corner Inlet (Hall and MacDonald 1986). There is no information on rock flathead spawning in Port Phillip Bay, but rock flathead from Corner Inlet are known to spawn from November to December (Nicholson 1992; Klumpp and Nichols 1983). In Western Port, they use sand areas as a nursery habitat until the juveniles reach approximately 20 mm in size, following which seagrass beds are used (Edgar and Shaw 1995). Algae-covered reefs have also been shown to be an important (PPBFMPBP 1996; Parliament of Victoria 1991).

Species Mostly Found on Reef Habitats

Gummy shark (Mustelus antarcticus) ovulate from October to December and give birth to live young (pups) approximately 13 months later. Juveniles are commonly found in Port Phillip Bay but they appear to be widely distributed and no well-defined nursery areas have been identified (Parry *et al.* 1990). Winstanley (1981) records their preferred habitat as low-profile reefs and sponge- and bryozoan-covered substrates, but they have been taken over both seagrass and sandy areas in Port Phillip Bay (Brown and Davies 1991).

Snapper (Chrysophrys auratus) is a predatory demersal fish, found in areas as diverse as the shallow waters of estuaries and bays to the edge of the continental shelf at depths in excess of 200 m (MacDonald 1982). Snapper generally migrate into shallow water for spawning, which is concentrated well inside the Bay, mostly on reefs between St Kilda and Ricketts Point (Parry, personal communication). Snapper and flathead eggs are abundant in the north-eastern region of the Bay over summer (Jenkins 1986; PPBFMPBP 1996). Ripe gonads or spawning activity are observed from late October until early March.

They have been noted to be serial spawners (Jenkins 1986; MacDonald 1982; Nicholson 1992), with the number of batches spawned varying between five and 60 and increasing with the length of the individual (Crossland 1977a, 1977b).There are two stocks of snapper; the western stock which extends from central Victoria (Western Port) to eastern South Australia and includes Port Phillip Bay, and the eastern stock which extends from eastern Victoria (Mallacoota) to northern New South Wales (Sanders 1974). Adults (4+ years) of the western stock migrate seasonally into the Bay during spring, returning west in late autumn (Nicholson 1992; Parry *et al.* 1995; Winstanley 1981). Juveniles appear to be resident in the Bay for at least the first two years of life (Parry, personal observation).

Species Mostly Found on Reef and Soft Sediment Habitats

Angel shark (Squatina australis) is usually sighted lying motionless on sandy bottoms near reefs (Hutchins and Swainston 1986). It buries itself in sand in shallow to deep coastal waters along reef fringes (Kuiter 1996). A demersal inhabitant over sand or rock at depths between 15 and 256 m, but mainly down to about 100 m. It is a live-bearing species (Gomon *et al.* 1994), but the time of birth is unknown.

Common gurnard perch (Neosebastes scorpaenoides) Also referred to as the ruddy gurnard perch, it is the most common inshore representative of this genus, usually found in shallow depths on sandy patches and particularly sponge areas among rocky reefs (Kuiter 1993; Gomon *et al.* 1994). Most common in Bass Strait waters from shallow estuaries to deep offshore reefs less than ~140 m. The time of spawning in Port Phillip Bay is unknown.

Mulloway (Argyrosomus hololepidotus) (also referred to as Jewfish) are usually seen offshore on seamounts or in large caves with islands, hovering in schools in shelter or currents (Kuiter 1996). The species undertakes seasonal movements along the coast as well as in and out of estuaries, possibly in response to the seasonal movements of their prey, such as pilchards (Gomon *et al.* 1994). The species is presumed to spawn in inshore waters; larvae and juveniles use nearshore areas and estuaries as nursery areas. The time of spawning in south-eastern Australian waters is not known. Based on growth and age estimates of *A. hololepidotus* in South Africa, it appears that the species spawns in spring–summer in the Hawkesbury River on the south-eastern Australian coast (Gray and McDonall 1993). Historically large (~2 m length) fish were taken in Hobsons Bay (A. McAdam, personal communication, 1996) and small fish still occur in the Yarra estuary (Walker *et al.* 1997).

Species Mostly Found on Soft Sediment Habitats

Greenback Flounder (Rhombosolea tapirina) Spawning occurs offshore during periods of protracted cold water between June and October (Jenkins 1986; May and Jenkins 1992). Settlement is continuous from July to October which suggests relatively continuous spawning or discontinuous spawning with a variable duration of larval life (May and Jenkins 1992). *R. tapirina* show similar seasonal migration between depth zones as the long-snouted flounder, being more abundant in deep water throughout the winter/spring period and in shallow water in summer/autumn (Parry *et al.* 1995). Swan Bay supports higher populations than Port Phillip Bay. It is an example of a nursery area which provides conditions of enhanced rates of growth and possibly survival. Metamorphosing larvae migrate to shallow, unvegetated habitats, which are utilised in the early juvenile stage (Edgar and Shaw 1995; Jenkins *et al.* 1993). Adult *R. tapirina* have also been found in close association with seagrass beds (PPBFMPBP 1996; Klumpp and Nichols 1983; Brown and Davies 1991).

Long-snouted flounder (Ammotretis rostratus) are commonly referred to by fisherman as sole. Spawning occurs over a protracted period of cold water from April to October, with the greatest abundance of eggs being collected in May. Eggs are distributed throughout the Bay (Jenkins 1986). Throughout the period summer to autumn, the species is most abundant in shallow regions, whereas there is a greater abundance in deeper regions in winter/spring, suggesting that they migrate seasonally between these regions (Parry *et al.* 1995). They are associated with unvegetated habitats throughout their postsettlement lives (Edgar and Shaw 1995), with adults being most abundant towards the entrance of the Bay (Anon. 1973).

Sand flathead (Platycephalus bassensis) are bottom-dwelling, non-migratory fish which have the highest biomass of any fish in Port Phillip, except in shallow regions (Officer and Parry 1996). Spawning in Port Phillip Bay is mainly during September–October, but their preferred breeding habitats are unknown (PPBFMPBP 1996; Nicholson 1992). They occur in unvegetated habitats throughout their postsettlement lives (Edgar and Shaw 1995). This species is most abundant on the muddy bottom of the central basin of the Bay at depths of 15 to 25 m (Anon. 1973; PPBFMPBP 1996; Nicholson 1992; Hall and MacDonald 1986; Parry *et al.* 1995).

Species Mostly Found in Estuarine Habitats

Estuaries in Port Phillip Bay are limited in extent and most have been severely modified and are dredged regularly. The Yarra forms the largest estuary in Port Phillip Bay; this has been deepened and altered extensively for port development.

Australian grayling (Prototroctes maraena) The grayling was described by Lake (1971) as one of the four most seriously threatened freshwater fishes on the Australian continent and more recently was described by Koehn and O'Connor (1990) as vulnerable. This species is included on NRE's *List of Threatened Fauna of Victoria* 1995 and is listed as threatened fauna under the *Flora and Fauna Guarantee Act*. The Australian grayling is a schooling species and is the largest native salmoniform fish inhabiting coastal drainages of south-eastern Australia and Tasmania (Bishop and Bell 1978).

Spawning in this species is short and synchronised, with most fish having completed their spawning phase within a period of two to three weeks (Harvey and Harrington 1989; Berra 1984). Gonadal development begins in mid March, peaks in late April and declines in early May. Grayling may reach a stage of maturity close to spawning, but will not spawn until conditions are suitable. Spawning, which may be triggered by an increase in water levels (Jackson and Koehn 1988), occurs in freshwater, where the eggs settle in the small spaces between the gravel of the stream bed. Following hatching two to three weeks later (Michaelis 1985), the young are swept downstream to brackish water in estuaries or into the ocean. The newly hatched larvae remain in the estuary or ocean for the next six months (Bacher and O'Brien 1989).

In October to November, they return to freshwater where they spend the remainder of their lives. Small grayling (47–51 mm SL) were collected in estuarine waters from the mouth of the Arthur River (15 October 1978) and near the mouth of the Pieman River (18 October 1978) (Jackson and Koehn 1988). Thus, the time at which this species is most vulnerable to dredging activities is the six months following spawning, from May to November, when the juveniles are located in estuaries and the ocean (Berra 1982; Bishop and Bell 1978).

Castelnau (1873) reported that this species, once plentiful in the Yarra River, had all but disappeared, but it has been recorded in the upper reaches of the Yarra in more recent times (McDowall 1976, Koehn, personal communication, 1997). However, the apparent scarcity of this species in the Yarra may be due to the absence of comprehensive sampling for grayling in these waters (Bell *et al.* 1980).

Black bream (Acanthopagrus butcheri) Also known as southern bream (Kuiter 1993). This species occurs in estuarine and coastal waters entering rivers with low salinities, but apparently prefers brackish conditions (Gomon *et al.* 1994). Spawning occurs between October and early December and has been shown to take place in the salt wedge of the Gippsland Lakes estuary, although some spawning may occur in freshwater habitats upstream from the salt wedge (Parry *et al.* 1990). Studies of black bream in the Nicholson River shows that their preferred spawning habitat is among shoreline growth of *Zostera* spp. which provides both good cover and nursery area (McCarraher 1986).

Broad-finned galaxias (Galaxias brevispinus) Adults spawn in freshwater in autumn or early winter. Larvae go to sea after hatching. Late larval and early juvenile stages migrate upstream from September to November. The conservation status of this species is potentially threatened (Koehn and O'Connor 1990), but it is not included on NRE's *List of Threatened Fauna of Victoria* 1995.

Common galaxias (Galaxias maculatus) Adults migrate to estuaries to spawn. Larvae are washed to sea and have been found in the Barwon estuary during freshwater floods during June and August. Juveniles (often termed whitebait – although southern anchovies are also sold in Victoria under this common name) migrate back to freshwater from September to November and from late October to November in the Barwon River. Shoals of juveniles move upstream primarily during daylight, when they move in the upper levels of the water column in the shadow of the river bank with the incoming tide (Koehn and O'Connor 1990).

Long-finned eel (Anguilla reinhardtii) Has a similar life history to the short-finned eel (below). Seaward migrations of adults (silver eels) peak on the last quarter moon phase between dusk and mid-night before the moon rises. Mature adults leave the Barwon River estuary in December through to February (Koehn and O'Connor 1990). Glass eels enter estuaries between January and late May.

Pouched lamprey (Geotria australis) has a similar life-history to short-headed lamprey (below). They spawn in freshwater from October to December and metamorphose into downstream migrants between February and late June, after which they migrate to sea. Adults migrate to their freshwater spawning grounds from mid September to late November (Koehn and O'Connor 1990).

Sea mullet (Mugil cephalus) lives in estuarine to nearly fresh waters as adults (Gomon *et al.* 1994). Sexually mature sea mullet congregate in large schools in estuaries during late summer and early autumn and may remain in the estuary for some time before moving out to sea to spawn (Parry *et al.* 1990). In south-western Australia they are known to spawn from March to September (Chubb *et al.* 1981). The spawning site in Port Phillip Bay is uncertain. Eggs and larvae drift from the spawning ground for two to three months until they are 20–30 mm long when they enter estuaries. Juveniles proceed up the estuary and into freshwater where they remain for at least two years (Parry *et al.* 1990)

Short-finned eel (Anguilla australis) Adults spawn in deep water off the Queensland coast. Larvae are carried from the spawning grounds by the east Australian current and migrate into estuaries as glass eels. They migrate further upstream and metamorphose into brown elvers and then silver eels, which may live in freshwater for 20 years, before migrating seawards. Seaward migrations peak on the last quarter moon phase between dusk and mid-night before the moon rises. Mature adults leave the Barwon River estuary from December to February (Koehn and O'Connor 1990). Glass eels enter estuaries from May in eastern Victoria to late October in the west, and between May and July in the Barwon River (Koehn and O'Connor 1990).

Short-headed lamprey (Mordacia mordax) Adult lampreys are external parasites of marine fish while their larvae occur in freshwater where they burrow in sand and filter feed on microscopic algae, diatoms and detritus. Adults ascend coastal streams to spawn in freshwater from July to January with a peak between early September and late November, after which they probably die. Juveniles migrate to sea predominantly at night, mostly between August and September (Koehn and O'Connor 1990).

Southern anchovy (Angraulis australis) Schools of southern anchovies are most often encountered in surface waters, although they can be found at depths of up to 20 m (Hall and MacDonald 1986). Anchovies require areas with some freshwater input for successful spawning and the survival of young fish. Because of this, Hobsons Bay at the mouth of the Yarra River is probably the most important spawning and nursery area for anchovies in Victorian waters (Parliament of Victoria 1991). Spawning takes place mainly from late spring to early autumn (October to March) in the Bay. A peak abundance of eggs occurs in January (Arnott and McKinnon 1985). Concentrations of anchovy eggs are greatest in the northern areas of the Bay, and peak concentrations decline significantly towards the southern areas of the Bay (Neira and Tait 1996). Hence, juveniles are found furthest from the open ocean, individuals two years and older are found closer to the sea in areas such as Geelong, and the older fish (greater than 2.5 years) are found towards the mouth of the Bay where there is a tendency to develop a two-phase life involving both the Bay and open sea waters, migrating out to sea in winter and returning in the spring (Blackburn 1950). This tendency increases with age.

Spotted galaxias (Galaxias truttaceus) Adults spawn in their typical freshwater habitat in early May to early June. Larvae are probably washed to sea. Juveniles return to freshwater in late October to early January with the peak in November and during mid October in the Barwon River. The conservation status of this species is potentially threatened (Koehn and O'Connor 1990). This species was included on NRE's *List of Threatened Fauna of Victoria* 1995, but was not included in NRE's most recent listing of *Threatened Vertebrate Fauna in Victoria–1999*.

Tasmanian mudfish (Galaxias cleaveri) This species is only recorded in Victoria from Wilsons Promontory and near Lorne. The lifecycle of this species is not well-known, but they appear to spawn in late winter to early spring; they return to freshwater in spring when they are two months old. The conservation status of this species is 'vulnerable' (Koehn and O'Connor 1990). This species is included on NRE's *List of Threatened Fauna of Victoria* 1995 and is listed as threatened fauna under the *Flora and Fauna Guarantee Act.*

Tupong (Pseudaphritis urvilli) Adults migrate downstream into estuaries to spawn between April and mid August in the Gellibrand River. Juveniles remain in lower reaches under tidal influence for nine months, after which there is a gradual movement upstream towards the middle reaches (Koehn and O'Connor 1990).

APPENDIX 7: CHECKLIST OF ISSUES REQUIRING CONSIDERATION FOR LAND DISPOSAL

Onshore disposal is preferable where spoil is seriously contaminated, and when fine sediments could otherwise impact sensitive environments such as seagrass habitats.

1. Sediment Contamination

- Classify dredge spoil on the basis of chemical contaminants, as described in table 12 and *Classification of Wastes* (EPA Publication 448).
- When chemical contaminants exceed the low screening level, and toxicity or other tests indicate that levels are of concern, an assessment of the costs and benefits of a range of disposal options, including land disposal should be conducted.
- When concentrations of chemical contaminants exceed the maximum screening level proponents **will** be required to assess the costs and benefits of a range of disposal options, including land disposal.
- Prior to land disposal spoil must be dry enough for removal by spade.
- If the spoil is classified prescribed industrial waste the management requirements outlined in *Classification of Wastes* (EPA Publication 448) must be followed.

2. Acid Sulfate Soils

- Prior to dredging, an assessment of the potential for dredge spoil to be classified as acid sulfate soil in accordance with *Industrial Waste Management Policy (Waste Acid Sulfate Soil)* 1999 should be conducted.
- Dredge spoil that is classified as acid sulfate soil will require management in accordance with the Policy.
- Procedures for the identification, assessment and management of acid sulfate soil are described in *Acid Sulfate Soil and Rock* (EPA Publication 655).

3. Establish a Suitable Dewatering Facility

For land disposal to be practical using a cutter suction dredge, a dewatering facility must be established that is:

- Within approximately 1 km of the dredging, or within 3 km, if the additional expense of a booster station is justified.
- Large enough for containment bunds suitable for dewatering to be constructed.
- Able to be secured so that quicksand-like properties of fines present no safety risks.
- Sited and operated so that seawater maybe discharged back into the sea or an estuary rather than into a freshwater stream

4. Control Water Quality of Discharge

- The turbidity of water discharged from a dewatering facility should be controlled by increasing the length of travel of water, to maximise settlement of solids within the discharge area, and by use of silt screens when necessary.

- The turbidity of the discharge should be monitored to ensure that excessive sediment is not discharged.
- Monitoring should be intensive initially and be reduced if turbidity is effectively controlled by settlement within the bund.

APPENDIX 8: FORMAT FOR SUBMISSION OF ELECTRONIC MONITORING DATA TO EPA

EPA has compiled a database of monitoring data for dredging projects that have been undertaken in Victorian waters. In order to maintain and update the database EPA requests that all proponents submit their monitoring data to EPA when an application is made for *Coastal Management Act* 1995 consent.

The data will be available to proponents when they are compiling the site history information required for dredging consent. The following tables outline the format to be used. An electronic version of the table is available from the EPA website http:\www.epa.vic.gov.au. Data should be submitted on an Excel Spreadsheet in an electronic format on either a 3.5 inch disk accompanying the *Coastal Management Act* 1995 application or e-mailed to dredge.master@epa.vic.gov.au

Table 22: Dredging monitoring database fields

SITE ID	SAMPLE DATETIME	COLLECTION CONTRACTOR	SAMPLLE REPLICATE	SAMPLE QUALITY CONTROL	SAMPLING METHOD ID	TOTAL WATER DEPTH	UPPER SAMPLE DEPTH	LOWER SAMPLE DEPTH	LABORATORY	LABORATORY REFERENCE	PHASE	PARAMETER ID	PARAMETER METHOD ID	ANALYSIS DUPLICATE	QUALIFIER	PARAMETER VALUE
123	01/01/99 12:00	AWT/WES	1	NORM	CORE	12.00	12.00	12.10	CAAC		S	TBT	5004	1	=	0.015

SITE ID:	Numeric site identifier (position coordinates must accompany Site Ids – refer to Application Form)
SAMPLE DATETIME:	Datetime of sample collection.
COLLECTION CONTRACTOR:	Contractor responsible for sample collection.
SAMPLE REPLICATE:	Always '1' unless more than one sample taken at same Datetime.
SAMPLE QUALITY CONTROL:	List type of QC.
SAMPLING METHOD ID:	Method by which the sample was collected.
TOTAL WATER DEPTH:	Total water depth (m) of sampling site at time of sample collection.
UPPER SAMPLE DEPTH:	Total depth from water surface of upper sediment stratum.
LOWER SAMPLE DEPTH:	Total depth from water surface of lower sediment stratum.
LABORATORY:	Laboratory responsible for sample analysis.
LABORATORY REFERENCE:	Responsible laboratory's reference number.
PHASE:	Always 'S' to denote sediment.
PARAMETER ID:	Parameter analysed.
PARAMETER METHOD ID:	Parameter Method includes Limit of Detection and Unit of Measure – refer to table 8.
ANALYSIS DUPLICATE:	Always '1' unless the parameter was measured more than once from the same sample replicate.
QUALIFIER:	Associated with Parameter Value. Can be one of either '<, =, ~'.
PARAMETER VALUE:	Reported value for Parameter of interest.

GLOSSARY

Algal bloom

A large population density of a phytoplankton. Such blooms are normal, but become of concern when the species in bloom is toxic.

Anaerobic sediments

Sediments lacking oxygen. They usually contain high levels of iron sulphide, causing them to be black in colour. Anaerobic sediments release hydrogen sulphide (rotten-egg gas) when exposed to air.

BACI

An experimental design to assess environmental impacts involving measurements **B**efore and **A**fter an impact on both **C**ontrol (unimpacted) and **I**mpacted sites.

Blank

Sample processed and analysed in the same way as sediments to determine contamination from sample container, reagents and sampling, and analytical process.

Background
Concentration of contaminant that is commonly found in the local *concentration* environment near the dump site prior to spoil disposal. But not the concentration in previously dumped spoil.
Beach renourishment

The process of adding sand to a beach to alleviate erosion or to improve an amenity.

Benthic community

The assemblage of organisms that live in and on the seafloor.

Bio-available

Able to enter an organism through its cells, skin, gills or gut and thereby cause an impact. In contrast, contaminants which are not bio-available may, for example, form part of the insoluble crystalline matrix of a mineral and will not impact organisms.

Bund

A wall constructed to retain spoil, etc.

Capital dredging

Dredging to create new channels or to enlarge or deepen existing channels and port areas.

Capping

The deliberate covering of contaminated sediment on the seabed with clean sediment to contain the contamination.

Contaminants

Substances (elements, compounds, particles, etc.) that are present in the sediments to be dredged and have the potential to cause adverse biological effects.

Control site

A site chosen as part of a monitoring program or experiment to enable background variation to be distinguished from the effects the monitoring or experiment is designed to detect.

CMA

C*oastal* **M***anagement* **A***ct* 1995

CSD

Cutter **s**uction **d**redger (see appendix 2).

Demersal fish

Fish that live near the seabed.

Density flow

The movement of material (eg dredge spoil) under the influence of gravity. Flow properties are typically those of a heavy liquid.

Disposal

The process of placement at sea or on land of material removed from the dredge site.

Draghead

The intake of a trailing suction hopper dredge.

Dredging

The excavation of material to provide and/or increase the dimensions of a waterway, or to obtain subaqueous material, excluding fishing activities such as trawling and shellfish dredging.

Dredging strategy

See section 2.1.

Elutriation test

Procedure for estimating the concentration of contaminants that could be released during sea dumping. Based on concentration of contaminant in seawater after a mixture of one part sediment is shaken with four times its volume of seawater for an hour and left to settle for a further hour.

Fluidisation

The process that changes the properties of solids (eg clays) so that they behave like liquids.

Geometric mean

A measure of the central tendency. The geometric mean of n quantities equals the nth root of the product of the quantities.

Impact

Environmental change (usually biological) that has occurred as a result of dredging activity. The extent of the change may be considered unacceptable and may require some intervention by regulatory authorities.

Low screening level

Concentration of a substance in the sediment below which toxic effects on organisms are not expected.

Macrofauna

Animals large enough to be retained on a one mm sieve.

Maintenance dredging

Dredging to ensure that existing channels, berths or construction works are maintained at their design specifications.

Material

Any substance recovered by dredging (also known as spoil or dredge spoil).

Maximum screening level

Concentration of contaminant in sediment above which adverse effects on organisms are likely.

NTU

Nephelometric **t**urbidity **u**nits, the most commonly used units for measurement of turbidity.

PAR

Photosynthetically **a**ctive **r**adiation. That part of the spectrum of light able to be used as an energy source by plants.

Pollution

Human introduction, directly or indirectly, of substances or energy into marine environments, including estuaries, resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities such as fishing, the impairment of quality for use of seawater and the reduction of amenities.

Porosity

A measure of the space between grains of sediment.

Proponent

The agency or organisation proposing any dredging or disposal operation.

Pseudofaeces

Sediment that is filtered from water by mussels that is not ingested but entrained in mucous strings and expelled. Produced in large quantities in turbid water.

Responsible authority

The Victorian Environment Protection Authority (EPA) and Department of Natural Resources and Environment (NRE) or other organisation to which authority has been delegated to evaluate dredging applications.

Spoil

Material obtained by dredging.

Spoil ground

Location at which dredged material is disposed in an aquatic environment.

Toxicity

Degree of being poisonous or otherwise harmful to plant, animal or human life.

Toxicity testing

Procedures that evaluate the toxic effects of substances on organisms.

TSHD

Trailing **s**uction **h**opper **d**redge (see appendix 2).

Turbidity

A measure of the clarity of water.

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