Montrose Port Authority

Maintenance Dredging BPEO

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Innovative Thinking - Sustainable Solutions

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Peter Whitehead	Heidi Roberts	Damon O'Brien
[Redacted]	[Redacted]	[Redacted]

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Notice

ABPmer
Quayside Suite, Medina Chambers, Town Quay, Southampton, Hampshire SO14 2AQ
T: +44 (0) 2380 711844 W: http://www.abpmer.co.uk/

Summary

The commercial viability of the Port of Montrose relies on maintenance dredging of the navigation channel and harbour. The most recent marine licence expired in 2018. This report provides a Waste Hierarchy Assessment (WHA) to determine the Best Practicable Environmental Option (BPEO) for use/disposal of the dredged material as required for the marine licence.

The report has been updated following comments from reviewers commissioned by Marine Scotland. The comments focused on the assessment of options for using material beneficially to reduce the rate of coastal erosion in Montrose Bay and its consideration in the BPEO. The opportunities for beneficial use have been considered in more detail but the conclusions of the WHA and the BPEO have not changed.

It is recognised that the material has the potential to be placed beneficially to reduce the rate of coastal erosion but that the operational cost is 6-7 times higher in addition to the significant technical and licensing/consenting issues which would need to be overcome (with associated costs).

We recommend that Angus Council work with the Montrose Port Authority (MPA) to use the dredging beneficially as part of any future coastal erosion risk management scheme. However, disposing of the material on the beach is not the BPEO for the Port of Montrose.

Without a beneficial use scheme available now, disposal is the only viable option at the existing Lunan Bay disposal site. No issues of note have been reported from the previous disposal operations at the existing licenced disposal site in Lunan Bay (Montrose FO010). This location is still considered to be the optimum location. Disposal to land would be very expensive, impractical, not environmentally sustainable, and therefore considered unviable.

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1 Introduction

1.1 Background

The Montrose Port Authority (MPA) facilities are approximately 1.8 km from the open sea (North Sea), accessed by a dredged channel. The Port of Montrose handles all types of vessels up to about 25,000 tonnes deadweight. To accommodate these vessels the entrance channel was deepened to 5.5 m below Chart Datum (CD) and the quayside berth pockets to 8 m below CD to provide safe navigation. As a result, the depths in the navigation channel, the berths and turning area within the harbour need to be maintained by dredging as required, with campaigns nominally one to three times a year.

Freshwater flows from the River South Esk pass through a relatively shallow and muddy 9 km^2 intertidal basin (known as Montrose Basin) before passing through the harbour and navigation channel and exiting into the North Sea. The channel is bordered to the south by a rocky peninsula (Scurdie Ness) and to the north by the intertidal shallow spit system known as Annat Bank, which comprises an area of sand and gravel where tidal flows are predominantly to the south. This configuration is shown in Figure 1.

Sediment deposits in the Harbour and navigation channel predominantly from three mechanisms:

- Silt from the River Esk, predominantly in the Inner Harbour berths and on Scaup Bank which grows across the vessel manoeuvring area to and from the berths;
- Sand, predominantly moving southwards from and over Annat Bank in the strong flood flows particularly on large spring tides. This sand collects on the north side of the Outer Channel and then moves across the channel. Additional sand moves along the axis of the channel from the sea, with the strong flood flows distributing sandy sediments into the mid- channel and into the Inner Harbour;
- Storm disturbed sand and gravel, moved onshore to Annat Bank and then further disturbed into the channel.

These mechanisms for sedimentation create the continual requirement for maintenance dredging, with storm conditions creating the variation in magnitude and timing of the requirement. As a result, consent is required for the disposal of the maintenance dredge arisings managed via a Marine Disposal Licence. Montrose Port Authority has powers to dredge under the Montrose Harbour Acts and Orders 1837 to 2003, subject to consent from Scottish Ministers.

This disposal was licenced by The Marine (Scotland) Act 2010, Part 4 Marine Licence Reference 05450/16/0 until 29 April 2018. This licence allowed up to 100,000 m^3 to be deposited by the method of vessel bottom disposal at the licenced deposit Area Montrose, FO010 (Figure 2). A renewal licence application was submitted to the Marine Laboratory, Aberdeen (the licencing authority on behalf of the Scottish Minister) (Marine Scotland Licensing Operations Team (MSLOT) in April 2018 with the previous version of this Best Practicable Environmental Option (BPEO) Report (ABPmer, 2018) and Coastal Process Assessment (ABPmer, 2017). The licence was not approved on the basis that MS-LOT did not agree with the selected option in the BPEO (sending all the dredge arisings to Lunan Bay for disposal), as they considered there to be other potential practicable uses such as nourishment of Montrose Beach and Annat Bank'. A one-year marine licence for disposal at Lunan Bay was granted on 7th December 2018 (Reference 06819/18/0) whilst further BPEO considerations are made. This document has been updated to include these further considerations.

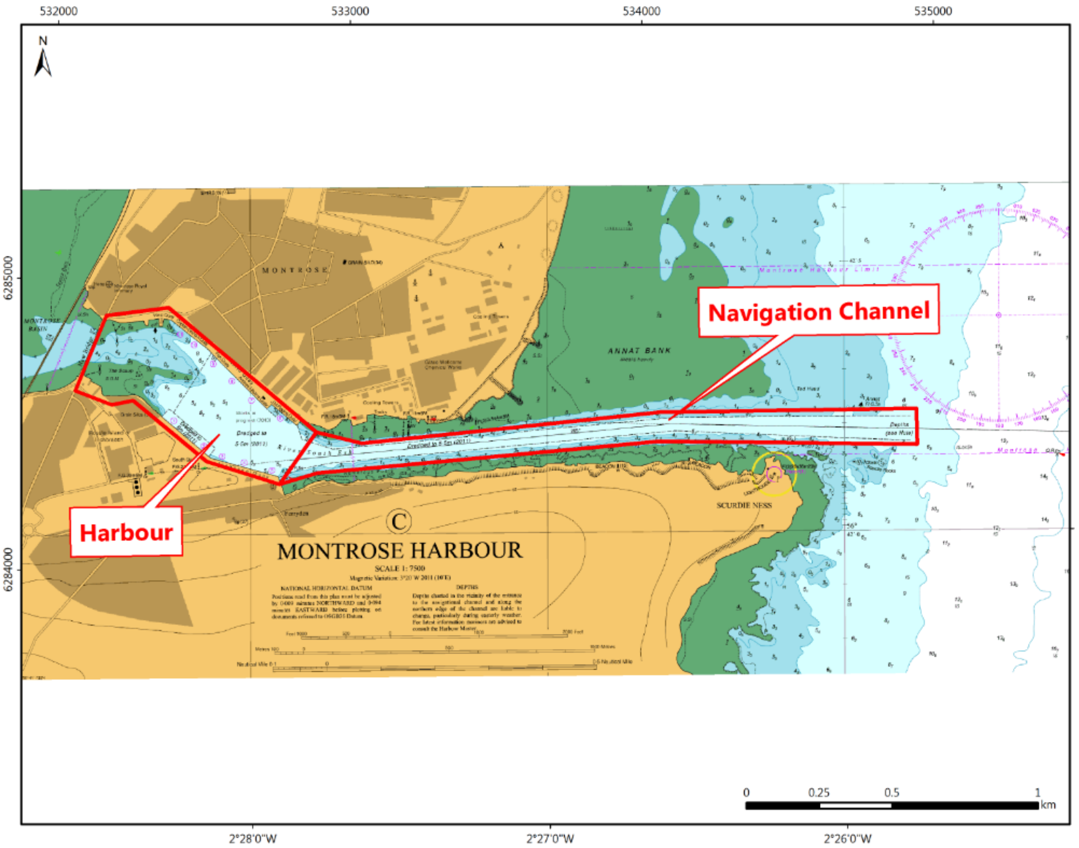


Figure 1 Configuration of Montrose Harbour and navigation channel showing dredge area

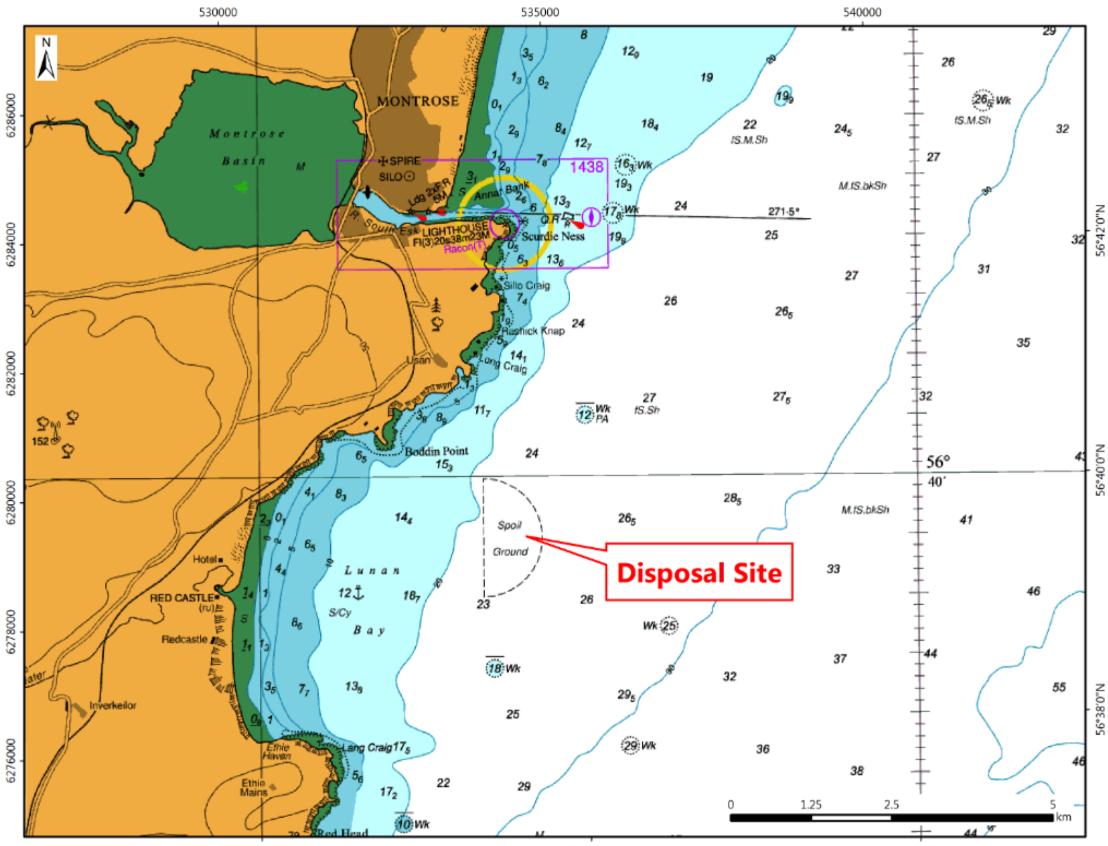


Figure 2. Licenced disposal site location (Montrose, FO010)

1.2 Report scope

This report provides a Waste Hierarchy Assessment (WHA) to determine the BPEO for the use/disposal of the dredged material that is required for a Marine Licence under Marine (Scotland) Act, 2010. The assessment has considered:

- Previous BPEO assessments;
- Previous and on-going consultation with:
  - Scottish Natural Heritage (SNH);
  - The Crown Estate;
  - Marine Scotland Licensing and Operations Team (MSLOT);
  - Angus Council; and
  - Scottish Environmental Protection Agency (SEPA);
- Results of a Sediment Tracer Study, undertaken by Angus Council, (Partrac, 2016);
- Coastal Process Assessment with respect to the Port of Montrose and surrounding area (ABPmer, 2018); and
- Responses from Marine Scotland on the previous application and supporting documents

This information is assessed to determine the current BPEO considering the options for practicality, environmental implications and cost benefit.

The report is structured as follows:

Section 1: Introduction;

Section 2: Sets out the dredge requirement;

Section 3: Provides a review of the policy;

Section 4: Outlines the dredge material characterisation;

Section 5: Describes the dredge options;

Section 6: Waste Hierarchy Assessment;

Section 7: Provides an operational cost comparison for potential options; and

Section 8: Presents the overall WHA and BPEO conclusion.

2 Dredge Requirement

Since 2010 the maintenance dredging requirement to maintain depths for a sufficient period to 5.5 m and 8 m below CD in the channel and berths respectively has averaged just under 60,000 m^3 per year, varying between no dredging in 2013 to over 108,000 m^3 in 2016. When dredging is required campaigns generally last between 4 and 7 days. Historically dredging has been required at a frequency of between 9 and 18 months but the greater requirement to maintain depths for longer periods has increased the frequency of dredging. The licenced dredge returns since 2010 are provided in Appendix A. For optimum working and rate of sediment removal in the available working window the dredging is required to be undertaken by a small to medium size Trailing Suction Hopper Dredger (TSHD), with a loaded draught of around 5.6 m, with maximum hopper capacity of about 2,300-2,900 m^3. Given the material type ranging from silt to gravel, the *in situ* volume removed is likely to be highly variable and only be in the order of 1,000 m^3 on average per load. A larger dredger is tidally restricted and smaller dredgers are unable to remove the quantity of sediment required on average over a single tide operational window.

On each campaign dredging normally commences in the navigation channel and then moves into the Inner Harbour and is generally confined to the period starting about 2 hours after LW to about 2 hours after HW, i.e. predominantly on the flood flows. Most dredging is undertaken on the neap tides, extending into mid tide ranges (up to HW elevations of 4.3 m above CD). Spring tide flow rates vary between 4.5 – 5.5 knots (pers comm, Harbour Master-MPA), which prevents dredging as the flows ‘push’ the dredger towards the banks, creating the risk of the dredger being forced over the draghead, effectively an unsafe situation. The dredger trails at an average speed of about 3 knots over the ground the average time to fill the hopper varies according to the material type between approximately 1 – 1.5 hours. Once filled the dredger sails to the Lunan Bay licenced disposal site (Montrose FO010), see Figure 2. This is a round trip of *circa* 6 nautical miles from the outer end of the navigation channel. The transit to and from the disposal site, including the disposal operation through bottom opening doors takes approximately 0.75 – 1 hour, giving an overall dredge cycle time ranging from 1.75 to 2.5 hours.

3 Policy Review

Dredged material is classed as a waste material once removed and is strictly controlled as it enters the waste stream. Beneficial use and disposal of dredged material at sea are controlled Under the London Convention 1972, the 1996 Protocol, the OSPAR Convention 1992 and the revised EU Waste Framework Directive (2008/98/EC). Under the Marine (Scotland) Act 2010 alternatives to disposal of the dredged material are to be explored and documented in the form of a BPEO assessment. Should this assessment identify a practical alternative to disposal of dredged material, this option should be further considered before consent for disposal at sea (or land) is made. Any identified locations for use and/or disposal also need to take account of the UK Government Sustainable Development Strategy and the Marine Policy Statement (see Section 3.1).

3.1 Marine policy statement

The UK Government Sustainable Development Strategy sets out the need for all Government policy to be in line with the principles of sustainable development (HMG, 2005). These principles are expressed through the five high-level marine objectives which take forward the UK vision for the marine environment of 'clean, healthy, safe, productive and biologically diverse oceans and seas'. These high-level objectives are: (1) Achieving a sustainable marine economy; (2) Ensuring a strong healthy and just society; (3) Living within environmental limits; (4) Promoting good governance; and (5) Using sound science responsibly.

It is becoming increasingly important that space within the marine environment is utilised effectively to ensure activities can be undertaken in a sustainable manner with minimal conflict between users. The Marine Policy Statement (MPS) indicates that, 'The Marine Plan should identify areas of constraint and locations where a range of activities may be accommodated. This will reduce real and potential conflict, maximise compatibility between marine activities and encourage co-existence of multiple uses' (Defra, 2011).

The policy specifically states that dredging 'is essential to the functioning of ports and marinas (Section 3.6.3) and the disposal can have 'benefit in maintaining sedimentary systems' and suitable material at appropriate locations can have 'benefit in providing material for alternative uses, such as construction, beach nourishment or salt marsh restoration' (Section 3.6.4).

The Port of Montrose lies at the northern end of the regional Forth and Tay Marine Plan Area, whilst most of Montrose Bay is in the North East [Scotland] Marine Plan Area. Currently there is no specific Marine Plans for these two regional areas and therefore decisions in the interim must be made in accordance with the National Marine Plan (Scottish Government, 2015). Furthermore, compliance with the principles documented in the UK's Sustainable Development Strategy should be guaranteed for any locations considered for re-use and/or disposal.

3.2 Scotland's National Marine Plan

The Scotland National Marine Plan notes that marine licence 'applications will be considered in accordance with the objectives and policies of the plan with a presumption in favour of sustainable development and use of the marine environment'. The marine licensing process is also to reach a 'balanced view on whether an individual project should be consented' taking careful account of the use of the development and economic benefit in an appropriate and proportionate manner.

The policies and sections within Scotland's National Marine Plan that are relevant to dredging and disposal activities, and their applicability to maintenance dredging at the Port of Montrose, are described below along with the relevant assessment made in this and supporting documents:

- Policy GEN 8 Coastal process and flooding: *'Developments and activities in the marine environment should be resilient to coastal change and flooding, and not have unacceptable adverse impact on coastal processes or contribute to coastal flooding.'*

  The Coastal Process Assessment (ABPmer, 2019) demonstrates that although the dredging and disposal operations remove sediment from the Bay, there is no compelling evidence to suggest this material would quantifiably reduce the ongoing rate of erosion. The Assessment concludes that most of the change is a function of the natural variation of combined wave and tidal processes on the beach and dune system. The maintenance dredging and disposal do not, therefore, result in an 'unacceptable adverse impact on coastal processes or contribute to coastal flooding';

- Policy TRANSPORT 4: *'Maintenance, repair and sustainable development of port and harbour facilities in support of other sectors should be supported in marine planning and decision making.'*

  This policy supports the need for dredging at the Port of Montrose to maintain the navigation channel;

- Section 13.13*: 'Dredging is an essential activity to maintain existing shipping channels, establish safe approaches to new ports or open up routes to old ports. Dredged material may be disposed of at licensed marine disposal sites or used for alternative purposes such as land reclamation or coastal nourishment, if suitable, to minimise seabed disposal. Licensed areas may change – normally as a result of disuse, monitoring information or the need for sites in additional locations. The consideration of both dredged navigation channels and disposal sites in marine planning and decision making is important to support safe access to ports and the disposal of dredged material in appropriate locations.'*

  Various options for use and disposal of the dredged material have been considered in the waste hierarchy assessment, presented in Section 6 of this BPEO. The use of the material for land reclamation and beach nourishment are not considered suitable, and disposal at sea remains the BPEO;

- Section 13.24 Ports and harbours: *'The main interactions expected in coming years are with commercial shipping freight and continued support of sectors such as fishing, aquaculture and aggregates. Emerging and growth industries such as renewables and tourism and recreational usage, including usage by cruise liners, will also be important.' 'Dredging, and the disposal of dredged material, may impact on other sea users on a temporary basis, and dredged areas and disposal sites may not be compatible with other specific uses.'*

  As reported in Section 6.3.2 of this BPEO, Montrose Port Authority has had no adverse reports from previous disposal activity at the Lunan Bay disposal site, and it is understood that these operations have not had any significant adverse effects on other users of the sea;

- 13.28 Habitat Loss/damage: *'Dredging to maintain navigation channels can cause loss or damage to habitats and species and exposure of buried archaeological remains. Dredging may increase if ship size increases and deeper and wider navigation channels are required, and also as a result of port expansion to support the renewables industry. Moorings, anchoring and chain rotation can damage sensitive habitats and disturb upper layers of seabed sediment and potentially heritage assets. Dredging and moorings are licensable activities and therefore their environmental impacts are assessed through licensing procedures.'*

  As reported in Section 6.3.2 of this BPEO, Montrose Port Authority has had no adverse reports from the on-going maintenance dredging or disposal activity and it is understood that these operations have not had any significant adverse effects on the receiving environment.

In summary, the BPEO of continued disposal of dredged material at Lunan Bay disposal site is in accordance with Scotland's National Marine Plan.

3.3 Angus Shoreline Management Plan (SMP2)

The Angus Shoreline Management Plan (SMP2) (Halcrow, 2016) provides a large-scale assessment of the risks associated with erosion and flooding at the coast, and presents policies to help manage these risks to people and to the developed, historic and natural environment in a sustainable manner.

The SMP2 identifies, in Section 3.9.14, the requirement to minimise the impact of policies on marine operations and activities including those at Montrose Port.

Section 2.1 describes the preferred plans and policies for Management Unit 1 – Montrose. It states: *'Along the Montrose Golf Links frontage the plan is to manage erosion of the dunes through a managed realignment policy to maintain the integrity of the dunes as a natural defence while maintaining protection to the majority of the golf course into the long term. Assuming material is suitable and available, there is an opportunity for beneficial use of River South Esk dredgings as recharge material along the frontage to help maintain beach levels and manage dune erosion.'*

Various options for use and disposal of the maintenance dredged material have been considered in the waste hierarchy assessment, as presented in Section 6 of this BPEO. The use of the material for land reclamation and beach nourishment are not considered suitable, and disposal at sea remains the BPEO.

3.4 Waste policy

Waste policy and, consequently, the WHA (and therefore the determination of the BPEO) are strongly governed by the waste hierarchy set out in Article 4 of the Waste Framework Directive. The waste hierarchy (Figure 3) ranks waste management options according to what is best for the environment and comprises the following in order of most to least favoured (top to bottom):

- Prevention;
- Re-use;
- Recycle;
- Other recovery; and
- Disposal.

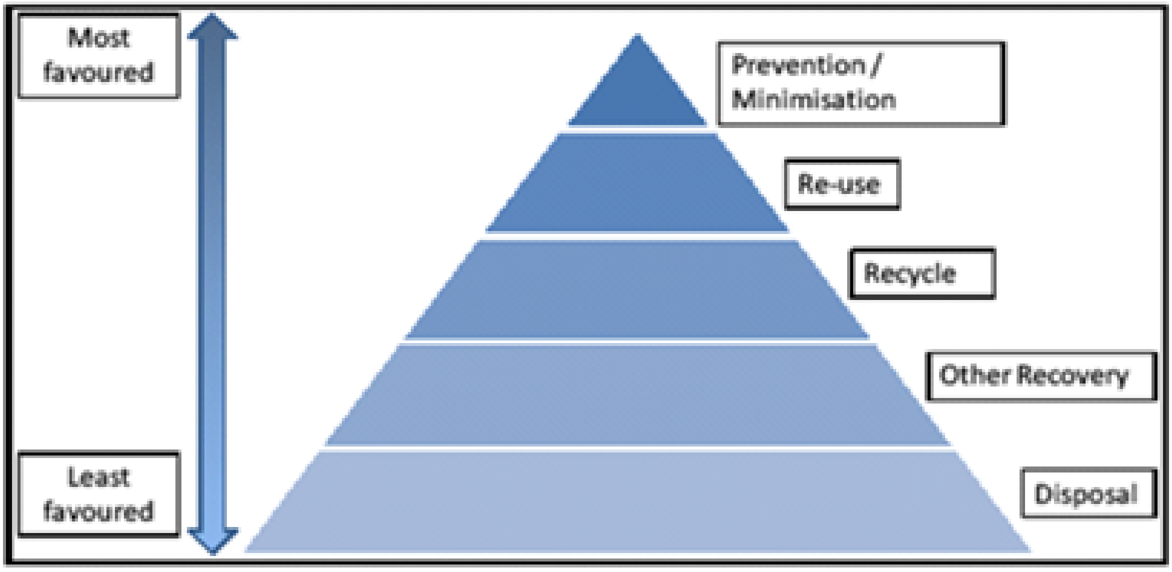


Figure 3. Waste framework hierarchy

The waste hierarchy places emphasis on waste prevention or minimisation of waste, followed where possible by re-use of the material. For any dredging project, the *in situ* characteristics of the material (physical and chemical), the method and frequency of dredging (and any subsequent processing), determines its characteristics for consent through the waste hierarchy (Section 4). This understanding is central for consideration of management options and determination of the BPEO for dealing with the management of dredged material.

Where prevention of the dredging is not possible, then the volume to be dredged should be minimised, then options for re-use of the material, recycling and other methods of recovery must be considered in the first instance. In the context of dredge material this could include, for example:

- Engineering uses, such as:
  - Aggregate for the construction industry;
  - Land creation and improvement;
  - Beach nourishment;
  - Construction of offshore berms;
  - Capping material; and
  - Temporary disposal at sea (e.g. in an aggregate site) for future re-use.
- Agriculture and product uses:
  - Aquaculture; and
  - Construction material.
- Environmental enhancement:
  - Intertidal feeding/creation, e.g. islands for birds, mudflat and saltmarsh creation, fisheries habitat and wetland restoration.
- Post treatment of the dredge material to change its character prior to determining a potential use, for example:
  - Dewatering to create consolidated sediments;
  - Separation basins; to separate sediments into different size classes for different uses;
  - Soil manufacturing; and
  - Physio-chemical treatments of contaminated sediments.

Following such treatments, the material may be able to be used for example, as top soil or bricks etc.

Should no practical and cost-effective solutions be identified, final options for the disposal of the dredged material are considered. These include:

- Marine disposal in licenced deposit sites; and
- Land based disposal in terrestrial landfill (possibly after treatment such as incineration).

Each of the stages in the waste hierarchy has been considered in turn, where practical, for the management of the dredge arisings within this assessment. This has also taken into account the respective policies as outlined above.

4 Dredge Material Characterisation

4.1 Physical

The material to be dredged is mixed comprising of mud (silt/clay), fine to coarse sand and a small proportion (*circa* 1%) of gravel. The relative mix varies both with location along the channel and harbour and with time. Larger proportions of finer sediments are associated with periods of heavy rainfall and snowmelt, particularly on spring tides, whereas the proportion of gravel is likely to be higher following storm events. The proportion of sand tends to be higher during 'normal' weather conditions. Historical analysis of survey depths indicates that each dredge campaign removes in general between 0.5–1 m of sediments.

Previous particle size analysis (PSA) has been undertaken on the sediments to be dredged in the channel and in the harbour. This grading is shown in Table 1.

4.2 Chemical

4.2.1 Historic contamination

Chemical analysis of surface bed samples is available for the same locations as for the PSA analysis (Table 1), collected in 2012 and 2013. Chemical sample analysis was also undertaken in 2013 and 2014 specifically in Berths 6/7 (with depth) and Berth 10 respectively. The chemical analysis test reports are provided in Port of Montrose (2015) and presented and compared with the Scottish Government Action Levels and Canadian Sediment Quality Guidelines for PAH's in Appendix B.

The surface samples from 2012 showed no individual contaminant concentrations that were greater than Action Level 1 (Scottish Government, 2017) for the prescribed suite of heavy metals, Tributyltin (TBT), ICES 7 PCB's and the 16 PAH's. In 2013 a small amount of TBT was recorded within the berth sample along with the PAH Anthracene, but only marginally exceeded Action Level 1. The samples from Berth 10 indicated a small elevation in concentrations of hydrocarbons, but again only marginally exceeding Action Level 1, with no other contamination that would cause concern. The cores analysed for Berths 6 and 7 showed a marginal contamination (above Action Level 1) through significant depth for both heavy metals (mainly Lead and Zinc) and the Benzo derivative PAH's.

The current dredge licence was granted with similar contamination levels, therefore the sediment to be dredged and disposed is likely to be considered 'safe' for disposal in the marine environment.

4.2.2 Present contamination

Results from chemical analysis on ten samples obtained on 23 January 2018 show that all samples were below Action Level 1 (Scottish Government, 2017) for prescribed TBT, hydrocarbons and ICES 7 PCB's (Envirocentre, 2018). The full sets of results are tabulated in Appendix B and allow comparison with previous data sets. Heavy metals; specifically, Chromium (61.5 µg/kg), Copper (47.3 µg/kg) and Nickel (57.8 µg/kg) were found to marginally exceed Action Level 1 at Sample 3 located at Berth 1 but well below the stated values for Action Level 2.

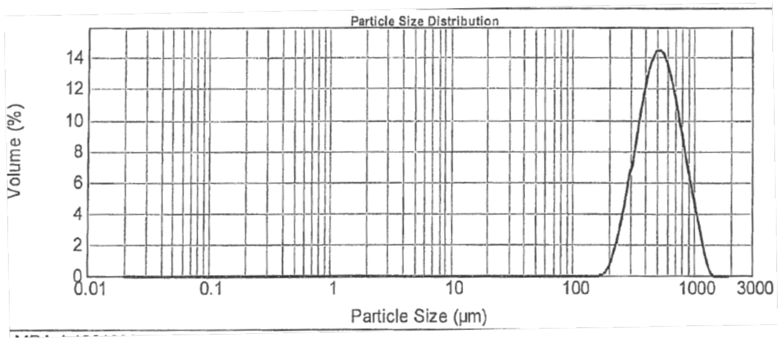
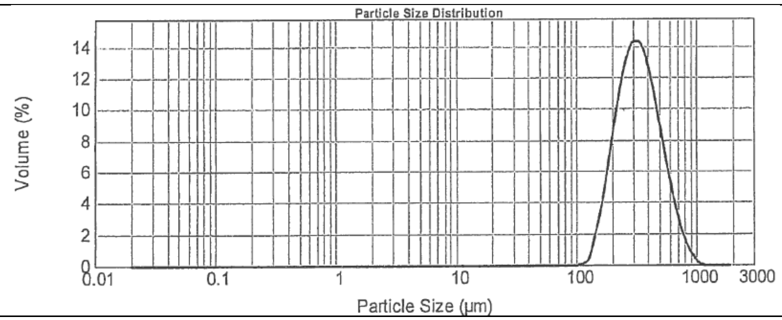
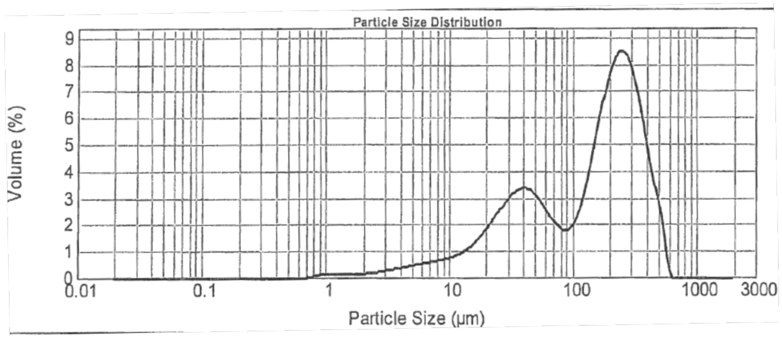
It is noted that these levels are an increase since 2012 at Berth 1. The Envirocentre, 2018 report notes this is an area where "large anchor chains are unloaded" and infers, this may be a cause of the contamination.

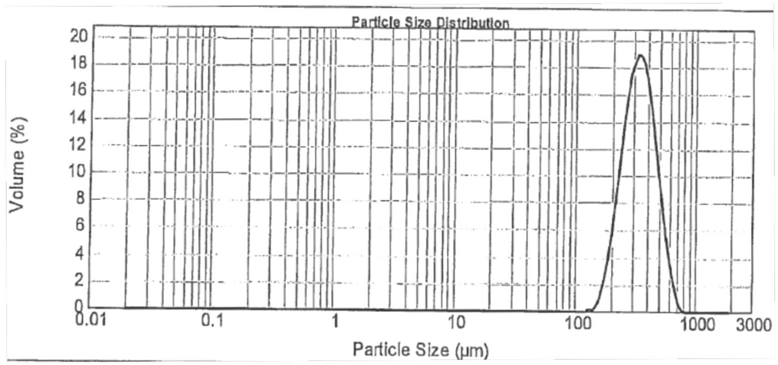
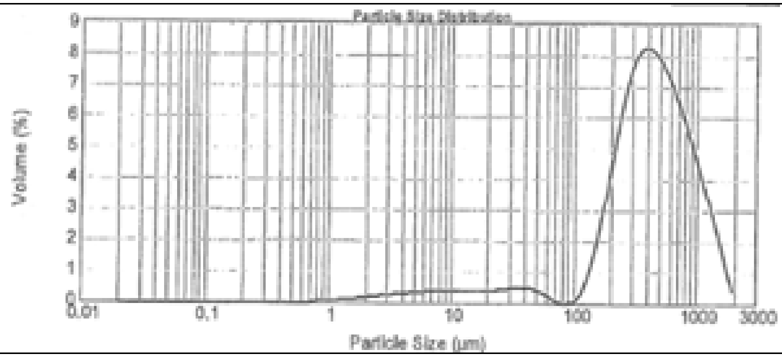
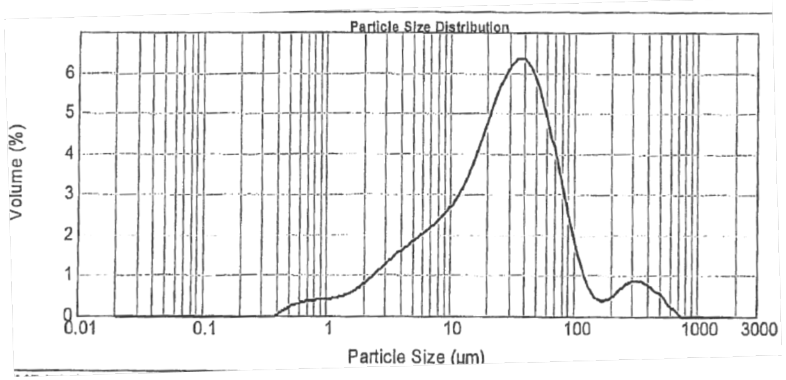
Elsewhere in the port, the results of the chemical analysis suggest that sediment quality may be improving. In the areas surrounding Berths 10 and 11 levels of PAHs within the latest samples have generally decreased below Action Level 1 from the 2014 samples. However, it should be noted that Sample 1 (8.05 µg/kg) and Sample 6 (6.98 µg/kg) are between the Canadian Interim guideline TEL and PEL levels for Diben(ah)anthracene (DBENZAH) and therefore may have a small biological effect. Heavy metal contamination levels have remained relatively consistent.

Similar improvements in sediment quality are suggested surrounding Berths 6 and 7, where recorded levels of both heavy metals and PAH's have generally decreased to below Action Level 1 in comparable samples/boreholes collected in 2014 and 2018. The exception to this is DBENZAH, which has slightly increased and currently exceeds Action Level 1 at 10.90 µg/kg (threshold of 10.00 µg/kg). At present no higher threshold exists, however the exceedance is so marginal that it should not affect a decision acceptability of disposal of the sediment to sea.

Overall, the latest chemical sampling suggests that sediment contamination in the port has reduced from an already low level, compared to past sample analyses. There is no reason stop disposal of sediment in the marine environment, should this remain BPEO.

Table 1. Dredge Sediment Particle Size

Sample Location	Particle Size (µm)			Comment	Distribution
	D10	D50	D90		
2012 Samples					
1 Main channel	315	525	884	Well sorted medium to coarse sand	
2 Inner harbour Channel	200	331	573	Well sorted medium sand	
3 Berths ½	19	168	375	Bimodal mud (coarse silt (with clay) and predominantly fine sand	

2013 Samples					
1 Main channel	226	337	501	Well sorted medium and coarse sand	
2 Inner harbour Channel	140	418	511	Predominantly fine to coarse sand, small proportion of mud and gravel	
3 Berths ½	4	28	91	Predominantly mud with small proportion of fine sand	

2018 Samples					Contribution (%)		
					Gravel	Sand	Silt
1 Berths 10/11	-	-	-	Sandy silt	0.0	40.2	59.8
2 Inner Harbour channel	-	-	-	Mixed gravel and cobble	No PSA conducted		
3 Berths ½	-	-	-	Mixed clay with cobble	No PSA conducted		
4 Inner Harbour channel	-	-	-	Predominantly fine to coarse sand, small proportion of silt and cobble	15.5	51.4	33.1
5 Berth 6	-	-	-	Mixed sand and sandy silt	6.7	40.0	53.3
6 Berth 4	-	-	-	Mixed fine sand and silt with contribution of gravel and cobble	15.5	40.3	44.2
7 Inner Harbour channel	-	-	-	Predominantly sand with small proportion of silt and gravel	0.1	97.1	2.8
8 Navigation Channel	-	-	-	Fine to medium sand	0.0	100.0	0.0
9 Navigation Channel	-	-	-	Fine to medium sand	0.0	100.0	0.0
10 Navigation Channel	-	-	-	Fine to medium sand with cobble	1.7	98.3	0.0
Analysis did not provide particle size distribution curves							

5 Dredge Options

The composition of the sediment to be dredged, as described in Section 4 and the area over which it needs to be removed indicates the optimum method for dredging is to use a Trailer Suction Hopper Dredger (TSHD) which has been used for maintenance dredging for a number of years. This could be supported by a grab dredger (or backhoe dredger and barges) in the more confined areas of the berthing pockets. All dredge methods would allow vessel bottom disposal.

The TSHD uses suction to raise loosened material from the bed through a pipe connected to a centrifugal pump. Suction alone may not be sufficient to remove the sand. It is likely therefore the dredger draghead will include ‘ripping teeth’ and water jets to help loosen the sediments. The requirement, or not for water jetting, will depend on the length of time between maintenance campaigns in the approach channel and the sediment type. The TSHD is the most efficient method when working with fine substrates such as mud, silt, sand and loose gravel as the material can be easily remobilised into suspension. The TSHD also has the potential to pump out the sediment, either in the form of 'rainbowing' or through a pipe onto land or a beach. The size of the channel and harbour along with the tidal range restricts the dredger (particularly a TSHD) to the small/medium size. The dredgers currently used with loaded draught of 5.6 m are considered to be the optimum size as they are close to the maximum size that can work for the longest periods of the tidal cycle. As noted in Section 2, due to the high spring tide flows dredging is restricted to periods of 4 – 7 days on predominantly neap tides with high water (HW) levels less than 4.3 m above Chart Datum (CD).

Other dredge methods that could be considered are:

- A cutter suction dredger (CSD), pumping through a pipe to nearby beach/disposal location or to a 'dewatering' confined area on land. Alternatively, it could load barges for disposal similar to a TSHD. This method has significant practical disadvantages compared to a TSHD. For mostly the dredger is essentially stationary, requiring ‘spud legs’ on the channel/ harbour bed and cables to anchors to allow movement along and across the channel. The CSD would therefore effectively block the channel to commercial navigation whilst dredging and would take significant time to move anchors, move away for vessels and then reset anchors to continue dredging. The dredge 'downtime’ would therefore be substantial;

- Water Injection Dredging (WID**)** could be an option for consideration, however, this method is primarily designed for mud and fine sediments. The coarseness of the sand will mean a high settling velocity, so the sediment flow created by the WID would quickly resettle down the channel. There is therefore the potential to create 'bars' or areas of shallower depth along the channel before the sand can be removed completely. Thus, during the dredge operation, the Least Available Depth (LAD) of the channel/harbour would have significant potential to reduce further before the dredge is complete.

  The method also has little or no control on where the sediment would end up. Most is likely to settle near the end of the channel or moved onto Annat Bank. This would create an increased supply of sediment with the potential to quickly return to the channel, particularly during storms and spring tide flood flows. Under this scenario the method would also tend to increase the potential sedimentation rate. On this basis, the method would create a negative impact with repeat to future channel maintenance;

- Sediment could also be 'agitated 'into the water column on the outgoing tide. Again, such a method would only be effective on spring tide ebb flows. The effects of this method of dredging would be essentially the same as for WID, but with even less certainty of benefit in maintaining the channel.

This assessment of dredge methods, taking account of the location, extent of required dredging, the range of material types as well as the tide and flow restriction indicates that a TSHD is the optimum method for maintaining depths at the Port of Montrose, both currently and for the longer term.

6 Waste Hierarchy Assessment

As described in Section 3.4 the waste hierarchy ranks waste management options according to the best environmental practice. The following section discusses the options, with respect to the management of the sand and silt arising from maintenance dredging of the Port of Montrose and the navigation channel.

6.1 Prevention

There are three main alternatives for the prevention of generating waste material, including:

1) Do Nothing (i.e. do not undertake maintenance dredging);
2) Reduce the dredging requirement; and
3) Reduce the disposal requirement.

The main approach to avoiding the generation of waste would be to not undertake the proposed maintenance dredging. To cease all maintenance dredging would, however, ultimately restrict the maximum size of vessel that could safely navigate to the Port of Montrose and therefore limit the competitiveness of the Port, eliminating existing trades which provide 'just in time' goods to a wider hinterland. Maintenance dredging is therefore seen as essential for the ongoing operations of the Port of Montrose which supports the employment of *circa* 400 people directly on the port estate and *circa* 4,800 jobs (hauliers, suppliers etc.) in the Montrose area and further into north east Scotland.

The maintenance dredging (and therefore disposal) requirement has been optimised/minimised to facilitate safe and efficient navigation of vessels up to *circa* 25,000 tonnes (deadweight), or vessel draughts up to about 8 m, albeit tidally restricted. This means a minimum depth required in the channel of 5.5 m below CD. Channel depths are monitored by pre-and post-dredge surveys, however the decision to 'call' for a dredge campaign is based on regular spot depth surveys at 2 – 3 month intervals (or following storms) at 10 strategic locations within the harbour and channel, where sedimentation tends to occur.

This method of monitoring means the dredger is only called when necessary. In recent years this has varied from 0 to 3 times per year. Additionally, the monitoring method along with the detailed pre-and post-dredge surveys allow specific areas of the Port to be 'targeted' to maximise efficiency and minimise the dredge volume (hence disposal quantity) required.

As discussed in Section 5, the use of WID has also been considered to minimise the need for a separate waste disposal activity. However, the coarse sediments to be removed are not conducive for use of the method and the sediment is likely to settle in areas which would create an increased supply of sediment to return to the channel. This would effectively increase the future maintenance requirement. The method is therefore not considered viable.

In summary, all measures to prevent and/or reduce the volume of waste generated by the project have been fully considered and the present dredge management provides the minimum dredge requirement for the existing trade through the Port.

6.2 Re-use, recycling and other recovery

Potential options have been identified for uses of the dredge arisings from the Port of Montrose. These include, for example, habitat creation, engineering projects (e.g. land reclamation), agricultural land improvement, land reclamation, beach replenishment and other forms of recovery, such as for aggregates or building materials (following treatment). These options are reviewed below with respect to the maintenance dredge arisings.

6.2.1 Re-use

Spreading on agricultural land

The dredge material comprises predominantly sand with a smaller quantity of silt, which may have a low contaminant content, predominantly hydrocarbons. The dredge arisings will also contain a considerable volume of saline water. In a de-watered state, the average volume of annual dredging would cover a 12 ha area to a depth of 0.5 m.

The Montrose area is surrounded by extremely fertile land and as the material would have a high water and saline content the expected dredge spoil is not suitable for soil conditioning or spreading on agricultural land without extensive treatment. The logistics moving the material to any site would be like that described for sacrificial land disposal, in Section 6.3.1, below. Consequentially, this option for re use of the dredge arisings is not practical even for a small proportion of the material and therefore can be discounted as a method for managing the maintenance dredge arisings.

Land reclamation

At present, there are no areas within the Port of Montrose or the local vicinity being developed which require dredged material for land reclamation purposes. This option is therefore discounted, however the sand and gravels, particularly from the outer channel area would be suitable as engineering fill in the future should there be a local need and practicality of delivery on the timescale required for dredging.

6.2.2 Recycling

Beach nourishment/replenishment

Coastal erosion, beach and sand dune recession has occurred throughout Montrose Bay in common with much of Eastern Scotland. Shoreline change analysis back to 1903 has identified morphological variability across Montrose Bay through time, with both phases of erosion and accretion. The overall trend across the Bay is erosion. Erosion (represented by recession of the dune front) has dominated during the last 30 years in the area of the Montrose Golf Links. In this time, small defences have been constructed. There has been little change in the middle of the Bay and accretion towards the north end (ABPmer, 2019).

Analysis undertaken for the Dynamic Coast – Scotland's National Coastal Change Assessment (NCCA[1]) (Hansom *et al*, 2017) shows that a net erosional trend has been evident throughout the 1900's, particularly within the southern half of the Bay, including Annat Bank.

[1] http://www.dynamiccoast.com/

Recent information extracted from the NCCA webviewer indicates that foreshore erosion continues at present, however, from the limited information available, the erosion rate has not significantly changed pre and post 1971, whereas the dune front erosion appears to have accelerated particularly at the Montrose Golf Links over the last *circa* 30 years. One factor for this increase in erosion is likely to be due to an increase in episodic erosion events, predominantly because of wave activity from the east and southeast, 'drawing' down beach sediment and taking it predominantly offshore, (ABPmer, 2019).

Also significant is the coastal defence works that have been undertaken south of the Faulds and south of the identified sediment divide (Hansom *et al.,* 2017 and ABPmer 2019) during this period. The amount of sediment that moves south across the divide is considered to be small (most moving to the north) and the coastal defence works would have reduced the supply of sediment to the fronting beach within the area to the south of the Faulds.

Suggestions have been made that the maintenance dredge material from the Port of Montrose could be used beneficially as beach nourishment/replenishment within Montrose Bay. A tracer study of the movement of sediment deposited nearshore within Montrose Bay (Partrac, 2016) indicated that very little deposited sediment reached the dune/defence toe and only a relatively small proportion of the deposited sediment was monitored in the intertidal area, suggesting a large proportion being lost or settled offshore.

The study also indicated that if benefit were to be gained without recirculation into the navigation channel, the location would need to be *circa* 600 m north of the trial deposit location which may not provide the associated benefits for erosion risk management of the Montrose Golf Links.

The coastal process assessment (ABPmer, 2019) was undertaken with the primary aim of defining a potential nourishment location whereby recirculation of sediment to the navigation channel was minimised. Changing the primary aim to reducing current coastal erosion, the approximate location of the trial deposit would be suitable, although a proportion of sediment (amount unknown, but likely to be relatively small) would return to the dredged channel.

The trial deposit (Partrac, 2016) was placed as far inshore as possible by a smaller draught dredger than normally used for the maintenance campaigns. The study indicates that benefits for reducing coastal erosion will result from the sediment being placed considerably further inshore, well within the beach closure depth, and ideally close to, or above, the high water mark adjacent to the toe of the dunes/defence. The options for replenishment of this kind are to:

- Pump the material high up the beach and re-profile with excavators; or
- Rainbow or side discharge from a TSHD

In both cases the material may have a beneficial effect but the likely percentage of material which would be retained on the beach/beach closure depth, and hence contribute to a reduction in erosion cannot be quantified.

As noted above TSHD dredging is the optimum method for maintaining the Port and its' navigation channel (see Section 5). However, the method mixes large volumes of water to 'transport' the sediment through the suction pipe to the vessel hopper. This type of dredger usually has the facility to pump out through a pipe to the shore, although this is a more costly and time-consuming process in comparison to bottom disposal at a licenced deposit ground. Some dredgers have the facility to rainbow discharge the sediment from the bow of the dredger. It should be noted that the dredgers used under the current maintenance dredge contract do not have this feature.

Pumping to beach

Pumping direct from the dredge location is not practical as the dredger would have to be connected to a pipe, either from a quay or a mooring point within the channel which would effectively block the channel during the pumping operation. Also, a pipe would need to be run along the foreshore for *circa* 2.5 km and would need to be deployed and removed each time the replenishment was required. A pump booster station may also be required to pump the sand efficiently over such distances. Intervention of this kind would significantly damage the existing beach and restrict recreational use far beyond the area of replenishment. The infrastructure required for the deployment would also be significant and costly to implement. The feasibility of running a pipeline directly to a suitable replenishment site would therefore be unrealistic due to distance and logistics of maintaining system integrity in public areas with the inherent risk of leakage or damage.

The only viable method of shore transfer is therefore via pumping either direct from the dredger at a mooring point offshore via a floating pipeline. The pipe outlet would be set as close as possible to the coast defence /dune toe, without allowing the transport water to erode the existing beach or dune. The sediment would then have to be profiled by land based mechanical plant. Again, the pumping infrastructure, albeit shorter than for direct transfer would need to be deployed and removed at the time of each replenishment, or dredge campaign, at considerable additional cost (compared to sea disposal) and at reduced dredge efficiency.

In addition to the transport considerations, careful control of the disposal option would be required for beach replenishment with only sands and gravels potentially allowed to be deposited on the frontage. Material containing river mud, i.e. from the harbour area, would still require transportation to the licenced disposal site (Lunan Bay) or used elsewhere, as separation of these material fractions would not be possible on the dredger. Based on the area dredged (e.g. harbour area), the dredger crew would have to decide whether to deposit at the beach replenishment site or Lunan Bay. In addition, the dredging operation would have to be sufficiently controlled to minimise mixed loads and maximise the material available for beach replenishment.

Beach replenishment of this kind has been used in the past (2006) when sand from Montrose was used at Aberdeen (86,000 m^3). Montrose Port Authority would be positive to similar opportunities in the future where beach replenishment schemes are being developed by third parties.

Rainbowing/side discharge

Under the current dredge contract, the dredgers used do not have ‘rainbowing’ ability so could only side discharge. The optimum dredger size has been established with a draught of between 5 and 6 m, with all dredging being undertaken on neap tides. Allowing for underkeel clearance the depth to the bed would need to be at least 2 m below Chart Datum (CD) at High Water (HW) and 4 m below CD at Low Water (LW). Given the bathymetry of the Bay (Admiralty Chart 210) the closest the dredger could discharge its load would be *circa* 600 - 675 m from the High Water Mark (HWM) at MHWN and around 700 m at MLWN. At these distances from the coastline any material deposited would be within the tidal streams, with the majority well outside the beach closure depth and therefore not significantly influenced by wave activity. Consequently, very little of the material would build up on the beach to help reduce the wave energy for erosion at the dune face, hence there would be little, if any, effect on the rate of coastal recession.

For any likely benefit with respect to the coastal erosion the sediment would need to be placed further inshore, hence the requirement of a smaller draught dredger with ‘rainbowing’ capacity. For example, such a dredger could be the Sospan Dau. This vessel is often used for such operations and has a loaded draught of 3.3 m, but only has about half the hopper volume of the current dredgers used. This dredger could just reach the CD contour at MHWN (*circa* 225 m from the HWM), but would be over 550 m off at MLWN. 'Rainbowing' could project the material on average 40 – 80 m from the vessel. The dredging requirement would require the 'rainbowing' to occur at any state of tide, which would take *circa* 2-3 hours each load. Given the mean neap tidal characteristics the vessel would be on average over 100 m from the LWM. Consequently, most of the sand would still be deposited in the subtidal area, near or beyond the beach closure depth. No material would be discharged directly adjacent to the dune toe. Unless the sand was moved up the beach by land based plant, which could only work around LW, much of the material would be lost offshore and only a small proportion moved onto the beach, should appropriate wave conditions occur at or just after the time of the 'rainbowing'.

For rainbowing to be considered as a method for alternative use of the dredged material, the dredge would have to be spread over two (or more) neap tide periods rather than one. This would increase dredge costs (due to increased mobilisation/demobilisation and fuel costs (whilst pumping and in transit)) and would mean that navigation depths would not be restored for a longer time period. Additionally, it is unlikely that the dredger would find another short-term project locally during the spring tide period therefore Montrose Port Authority are likely to have to meet the cost of 'stand-by' time between neap tides. This could be a significant additional cost.

To maximise any benefit, land based plant beach re-profiling would be required similar to the pipe discharge method. The difference is the sand would be around, or close to the LWM, restricting the use of land based plant to a short period on each tide. A large proportion of the sand is unlikely to be reached by the land based plant, thus natural processes would need to be relied upon the move the sediment where it would have benefit. Without land based re-profiling therefore any benefit in reducing coastal recession at the Montrose Golf Links would be minimal. Any benefit with respect to reducing coastal erosion would be considerably less than for the pipe discharge method as there would be greater direct loss of sediment off and alongshore and there would be less volume of material to help protect the toe of the dunes/defence.

Other considerations

The dredge material in the outer navigation channel (sand and gravel) is of a grade suitable for beach nourishment/replenishment, albeit it may be of a different particle size grading from the natural beach in Montrose Bay. Providing the dredged material did not contain a significant proportion of river mud, it is believed that there would be no objections to the material being used for beach replenishment. Scottish Natural Heritage (SNH) has previously advised that it considers this option as an acceptable alternative to disposal at sea, providing the material is similar in nature to that prevailing at the replenishment site.

The material from the harbour is unlikely to be suitable as the sand is mixed with fluvial derived silt and clay sediments that are likely to change the nature of the beach. As a result, it is unlikely that all material from a dredge would be suitable for beach replenishment and therefore a dredge disposal site would still need to be retained.

For beach replenishment by both methods described above to be considered the BPEO for management of the maintenance dredge material the following consents, and assessment are required:

- Consent of Marine Scotland is required for works in tidal waters under Marine (Scotland) Act 2010. An existing consent is currently in place for maintenance dredging works which prescribes bottom disposal at the Lunan Bay disposal site. An amendment to the consent would be required for beach replenishment to be consented;

- Consent to dispose of material to the foreshore or seabed from both Marine Scotland and Crown Estate. The Crown Estate, generally, may be happy to issue consent, providing all other statutory consents are in place and subject to negotiation of a disposal fee;
- Local acceptability of the use of the dredged material as beach replenishment;
- Assessment of the environmental implications of a beach recharge at the identified location and the potential effects of any dispersion on the Site of Special Scientific Interest (SSSI) at the mouth of the River Esk and the National Nature Reserve (NNR) to the north.

As noted above the tracer study and physical process assessment has indicated that there is potential benefit in placing the material on the beach/upper foreshore to reduce the rate of coastal erosion in the Bay. The benefits are more likely to arise when sand and gravel is placed high in the tidal frame at the toe of the existing defence and *circa* a least 2.5 km north of the navigation channel to avoid potential for short term recirculation.

Any scheme would need in addition consultation with:

- Angus Council; and
- Beach Stakeholder Committee.

It should be noted that when using sediment beneficially to reduce coastal erosion, experience has shown that even with support from all parties it is extremely difficult to implement without significant investment due to consent and licensing requirements. For coastal erosion risk management, such schemes are promoted by a coastal defence authority through the shoreline management process thereby securing grant-in-aid. Of the relatively few projects carried out in the UK the onus has been typically on the receiver to demonstrate the need of the work and to have the consents in place so that all regulatory parties are agreed as to the appropriateness of the work. This has been the case for example at Horsey Island, Allfleet's Marsh (Wallasea) or on the Mersea Islands (proposed). In such instances, the supplier (Port of Harwich) has been able to offer material at a discounted rate reflecting the costs saving brought about by reduced transit distances.

Taking all the above strategic, operational, environmental and commercial considerations into account, beach replenishment by pipeline from an offshore mooring point or rainbowing is discounted as the BPEO at the current time due to:

- Timescale issues relating to the efficiency of maintaining depths in the navigation channel taking account of the neap only tidal operational restrictions for the dredge. Dredging the same quantity (as presently required) would take considerably longer, therefore the dredging requirement is unlikely to be achieved over a neap tide campaign, therefore the maintained channel depth would reduce requiring further dredge campaigns and the length of the vessel access window for the larger ships would be reduced;
- Not all sediment could be used (for replenishment), so disposal at the existing deposit ground would still be required for the silt material and mixed sediments;
- Significant land based plant would be required during each replenishment to re-profile the sand once pumped/rainbowed ashore;
- The limited data available on coastal erosion rates indicate that the rate of erosion has not changed since the introduction of dredging and construction of coastal defences in the 1970s (ABPmer, 2019), the associated benefit of maintaining the dredge sediment within the Bay system is therefore uncertain. Any benefit will be dependent upon the exact location, timing and material contained in the nourishment and would need to continue in the long term before any erosion benefit could be quantified. The cost would be expensive and considered impractical for the Port, particularly for the rainbowing method;

- Dredging costs will be significantly increased by both methods (see an approximate dredge cost comparison in Section 7).

Consideration of the available options for re-use, recycling and other forms of recovery of the maintenance dredge arisings from the Port of Montrose, have not indicated any viable practical and commercial alternatives for use of the dredged material at the current time.

The BPEO is therefore considered to be disposal of the maintenance dredged sand, silt and gravel either to land or sea. These options are considered in Section 6.3.

6.3 Disposal

6.3.1 Sacrificial landfill

The nature of the dredged material (a mixture of sand, silt and gravel) is unsuitable for sacrificial landfill without involving an extensive transport and treatment process. Disposal to landfill would involve a complicated material handling operation involving sea to land transfer, de-watering, loading to trucks and transport to site. In addition, there would need to be a change in dredger type, for example from a TSHD designed for maintenance dredging to one designed for aggregate recovery or a change to a mechanical form of dredger, unless a settling lagoon could be constructed.

Each existing dredger load would produce *circa* 1,000 m^3 of 'semi- wet' material after water has been 'weired-off' from the dredger or de-watered in a settling lagoon on land. This volume equates to *circa* 50-60 lorry loads of material produced at the quayside in a time of 1 – 2 hours to several hours depending on the method of de-watering the dredge arisings. Given the current maximum production rate of about 12,000 m^3 day (i.e. *circa* 12 vessel loads), the de-watering process and transfer to lorries would not be able to keep up with the production rate even with a 'conveyor belt like' fleet of lorries. Consequently, a temporary store on land (or within a settling lagoon) would be required in order not to reduce the dredge efficiency further, given that the production is already likely to be at least halved due to the unloading process compared to disposal at sea. This reduction in efficiency would have considerable consequence with respect to being able to maintain channel depths, given the existing tidal restrictions noted in Section 2.

Previous consideration has been given to the construction of bunded holding lagoons within the Harbour Area. These would need to be above MHWS. Two quays and associated back up areas would also be required. This would result in the loss of valuable operational areas within the port for the duration of the dredging and transfer operations affecting the Port Authority both economically and commercially. This could lead to loss of both present and future trade.

Additionally, there is no single landfill site identified that would be able to take all the material produced from the dredging operations. The resulting dredged material would have to be distributed to various sites within the Angus area. Those sites identified would be accessed by lorries travelling from the Port on public roads through the towns of Montrose, Brechin and Forfar. The minimum estimated number of vehicle trips necessary to transport material to landfill would be in the order of 2,600 at a rate of up to *circa* 700 lorries per day whilst maintenance dredging occurs.

The number and availability of suitable vehicles to transport wet dredge material and transport by road is not known. However, inevitably such an operation would involve some spillage of the dredge material. This would not be acceptable to the public. In addition, the Local Authority and Police have indicated that they would consider any loss of dredge material from vehicles as a hazard to road safety for which the Port Authority could be held liable in the event of an accident/environmental incident.

Landfill space, generally is becoming more valuable because of increased demand and decreased availability. Owners and operators of sites are reluctant to sacrifice space for inert material thus shortening the life of their site and reducing capacity for industrial and domestic controlled wastes. This would place increased pressure to open further sites in the locality, which is unlikely to be favoured by either local authorities or the public.

In view of the reasons noted above, it is concluded that the transfer of the dredged material to landfill is not a practical option and therefore can be discounted as a method of managing the maintenance dredge arisings.

6.3.2 Sea

Existing licenced disposal area

The maintenance dredged material has been disposed for many years at the licenced disposal area named Montrose FO010 in Lunan Bay to the south of the Port. The location is shown on Figure 2. The volume and material type dredged, along with contaminant levels have not changed, therefore continuation of the current practice remains a viable option.

As noted in Section 6.1 the current practice is managed to minimise the dredging requirement by the optimum dredge method (TSHD) for the current commercial trade, and this is considered not likely to change in the near future.

Montrose Port Authority has had no adverse reports from previous disposal activity and it is understood that these operations have not appeared to have any significant adverse effect on the receiving environment in terms of contaminated load or on the benthic communities. This is even though:

- Disposal to the Deposit Ground will have a slight effect on other marine activities in the area during periods of transport and disposal of the dredged material. Currently disposal occurs for up to a total of 12 days per year, split between up to three separate campaigns;
- The sediment is disposed from bottom opening doors (i.e. at the draught of the dredger below the surface) is a mixture of sand, silt and gravel, the majority of which will settle quickly to the bed and will be dispersed over a longer period, probably initiated by wave disturbance;
- The finer sediment fractions do have the potential to contain some contamination, but at levels that currently are not considered to be a pollutant to cause a hazard risk to the environment around the disposal location. Predominantly, however, the material disposed is inert, therefore there is unlikely to be a risk to commercial fishing interests, which operate in the local area. There is therefore minimal risk of contaminants entering the food chain and causing a threat to public health;
- The most significant environmental effect is due to smothering of the seabed; however this is only likely near to the designated disposal area. During the actual disposal, and for a short period thereafter no more than a few tides), there could be a marginal reduction in water quality, which is likely to be temporary and transient increase in suspended sediment concentrations, which reduce quickly away from the site.

The main effects of the disposal are short term and transient in nature and therefore reasonable to assume that the continuing the dredging and disposal operations will not have a long-term effect on the environment. Current effects are considered to be minimal with anecdotal evidence from local fishermen suggesting that the disposal site becomes a rich feeding ground during sea disposal operations. It is because the discharge of material potentially releases seabed organisms into the water column with associated feeding activity during such operations. In effect, this can be considered a small environmental benefit.

Overall, the current maintenance dredge practice:

- Is optimal for maintaining navigation to the Port for the current trade mix and the physical processes occurring which cause the sedimentation and affect the efficiency of the maintenance dredge operation;
- Has caused small temporary impacts near the disposal site, but has not caused a significant risk to the natural environment, or uses and users of the area; and
- The proposed future disposal volumes and material types are similar to those historically disposed.

Consequentially, disposal to sea at the current location remains a viable and practicable option.

Alternative disposal area

A beach nourishment scheme to use the dredged material beneficially with a similar cost structure for the Montrose Port Authority to that which currently exists would require the characterisation and licensing of a new disposal location within Montrose Bay. A new disposal site would require a minimum depth *circa* 6 m below Chart Datum to accommodate the size of the TSHD (vessel required to efficiently remove the dredged material over neap tides). Using the Admiralty Chart the closest the dredged material could be deposited is *circa* 1 km from the HWM, approximately 775 m offshore from the lower edge of the intertidal, on all states of the neap tide.

Such a disposal location could be found within *circa* 2 nautical miles of the navigation channel entrance, compared to 3 nautical miles to the existing Lunan Bay deposit ground. Based on a 9 knot dredger service speed the round trip to the deposit ground would be reduced from around 0.75 - 1 hour to around 0.5 hours, assuming bottom disposal at both locations. This would reduce fuel costs in the order of £700 - £1,000 per year.

The site would need to be licenced for disposal requiring a site characterisation to include an understanding of the flow, wave and sediment regime in the water column and on the sea bed along with a baseline ecological characterisation of the site. In addition, Environmental Impact Assessment (EIA) and a Habitats Regulations Assessment (HRA) may be required. Such a site would be dispersive and therefore there may be a requirement to undertake numerical modelling, particularly with respect to the dispersal of the dredge plume and potential impact to the internationally designated sites.

Such site investigations and assessments (exclusive of modelling) could take a year to complete and cost in the order of £100,000. In addition, there are likely to be on-going monitoring requirements for a newly designated disposal site, which could cost annually in the region of £25,000 and potentially significantly more. On this basis, the relative payback to Montrose Port Authority would not result for over 100 years.

7 Cost Implications

The above review of options for the management of dredged material from the Port of Montrose with respect to the WHA has indicated that there are no alternative options that do not have significant operational implications for Montrose Port Authority, compared to the disposal of the dredged sediment. The current method of dredging and disposal is considered near optimal and disposal to land is not operationally viable.

7.1 Operational cost evaluation

Table 2 compares an estimate of the relative operating costs of the current disposal method to using the material for beach replenishment pumped from a dredger moored offshore and rainbowing the material as described in the previous sections. This comparison assumes all material can be used and the method of replenishment does not impact the port operations.

Table 2. Operating Costs (£/m^3)

Activity Description	Sea Disposal at Montrose FO010 Licenced Disposal Site or a new site in Montrose Bay	Beach Replenishment Pumped from a Moored Dredger	Beach Replenishment by Rainbowing
Dredging	£2 – 4/ m^3 *	£2.5 - 5/ m^3 **	£3 – 6/ m^3 **
Pumping ashore	n/a	£5 - 8/ m^3	£12-14/ m^3 rainbowing
Mooring and floating pipe infrastructure, deployment and removal	n/a	£5 - 10/ m^3	n/a
Beach profiling	n/a	£2/ m^3	£2/ m^3
Total	**£2 – 4/ m^3**	**£14.5 - 25/ m^3**	**£17 – 22/ m^3**

* Includes transport and bottom disposal
** Includes for increased dredge campaign requirement

Beach replenishment has been considered and could provide local environmental benefit. The replenishment requires placement at the upper beach/dune toe to be effective and could not accommodate all the material types dredged. The practicalities of such placement is likely to compromise the current commercial operations.

The cost comparison in Table 2 suggests that if beach replenishment is practically feasible the disposal cost will be *circa* 6-7 times greater than for the current sea disposal option. This cost differential excludes the associated licensing costs discussed above which are suggested to be in the order of £100,000 as a minimum as discussed above.

8 Conclusion

The WHA and BPEO has not identified any immediate uses of the maintenance dredge sands, silt and gravel or potential methods of recovery. It is recognised that the material has the potential to be placed beneficially to reduce the rate of coastal erosion but that the operational cost is 6-7 times higher in addition to the significant technical and consenting issues (and associated costs) which would need to be overcome.

Montrose Port Authority is willing to work with Angus Council to explore whether the dredged material could be used beneficially as part of any future coastal erosion risk management scheme. However, disposing of the material on the beach is not the BPEO for the Port of Montrose.

Without a beneficial use scheme available now, disposal is the only option at the existing Lunan Bay disposal site.

Disposal to land would not be practicable or environmentally sound and would be very expensive and is therefore not a viable option. The current method of disposal in the marine environment at a licenced disposal ground is considered to remain the BPEO. No issues of note have been reported from the previous disposal operations at the existing licenced disposal site in Lunan Bay (Montrose FO010), therefore this location would still be considered as the optimum location.

9 References

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10 Abbreviations/Acronyms

AL	Action Level
AL1	Action Level 1
AL2	Action Level 2
BPEO	Best Practicable Environmental Option
CCME	Canadian Council of Ministers of the Environment
CD	Chart Datum
CSD	Cutter Suction Dredger
DBENZAH	Diben(ah)anthracene
DBT	Dibutyltin
Defra	Department for Environment, Food and Rural Affairs
EC	European Commission
EU	European Union
HMG	Her Majesty's Government
HRA	Habitats Regulations Assessment
HW	High Water
HWM	High Water Mark
ICES	International Council for the Exploration of the Sea
ID	Identity
ISQGs	Interim Sediment Quality Guidelines
LAD	Least Available Depth
LW	Low Water
LWM	Low Water Mark
MHWS	Mean High Water Springs
MPA	Montrose Port Authority
MPS	Marine Policy Statement
MSLOT	Marine Scotland Licencing and Operations Team
MV	Motor Vessel/Motor Ship
NCCA	National Coastal Change Assessment
NNR	National Nature Reserve
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated Biphenyl
PEL	Probable Effect Level
PSA	Particle Size Analysis
SEPA	Scottish Environmental Protection Agency
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
TBT	Tributyltin
TEL	Threshold Effect Level
TSHD	Trailer Suction Hopper Dredging
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
UKD	UK Dredging
WHA	Waste Hierarchy Assessment
WID	Water Injection Dredging

Cardinal points/directions are used unless otherwise stated.
SI units are used unless otherwise stated.

Appendices





Innovative Thinking - Sustainable Solutions

ABP mer

A Dredge and Disposal Quantities 2010 to 2017

MPA Dredging Quantities 2010 to 2017

LICENSE VALIDITY DATES	START DATE	END DATE	DURATION (DAYS)	AMOUNT M^3	AMOUNT METRIC TONNES	VESSEL
01/04/2010 TO 31/03/2011	04/04/2010	10/04/2010	7	84,139	197,970	UKD MARLIN
04/04/2011 TO 03/04/2012	08/04/2011	14/04/2011	7	92,683	152,927	UKD MARLIN
15/05/2012 TO 14/05/2013	21/09/2012	26/09/2012	6	52,704	121,728	UKD MARLIN/MARGARETHE FIGHTER
28/04/2014 TO 27/04/2015	29/04/2014	03/05/2014	5	27,083	62,552	BOSKALIS WM DEO GLORIA
26/11/2014 TO 27/04/2015	05/03/2015	08/03/2015	4	1,540	2541	MV SHEARWATER
AS ABOVE	13/03/2015	17/03/2015	5	47,139	77,779	UKD MARLIN
04/04/2016 TO 29/04/2018	16/02/2016	21/02/2016	6	48,382	124,090	UKD MARLIN
30/04/2015 TO 29/04/2018	12/06/2016	15/06/2016	4	31,452	80,860	UKD MARLIN
AS ABOVE	08/11/2016	11/11/2016	4	28,557	52,130	UKD ORCA
""	20/03/2017	23/03/2017	4	47,228	103,200	UKD MARLIN

All figures are directly from
dredger logs where available

B Sediment Quality

Sediment samples from Montrose Harbour and navigation channel were collected in 2012, 2013, 2014 and 2018 from various locations. The individual chemical analysis results for heavy metals, PCB's, TBT and Polyaromatic Hydrocarbons (PAH) are compared with the Marine Scotland Action Levels (AL) in Table B3 to Table B12 for the different years and locations. The Marine Scotland AL's are presented in Table B1.

Additionally, samples have been compared to the Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guidelines (ISQG's) for PAH's, providing another level of analysis for hydrocarbons. These guidelines[2] are provided in Table B2 and have two specific thresholds defined below:

- The Threshold Effect Level (TEL) represents the concentration below which adverse biological effects are expected to occur rarely; and
- The Probable Effect Level (PEL) defines the level above which adverse effects are expected to occur frequently.

2 http://ceqg-rcqe.ccme.ca/download/en/317

Table B1. Marine Scotland Action Levels

Contaminant	Marine Scotland Action Levels (mg/kg dry weight)	
	AL1	AL2
Arsenic	20	70
Cadmium	0.4	4
Chromium	50	370
Copper	30	300
Lead	50	400
Mercury	0.25	1.5
Nickel	30	150
Zinc	130	600
Organotins (Tributyltin, Dibutyltin, Monobutyltin)	0.1	0.5
Polychlorinated biphenyls (Sum of ICES 7)	0.02	0.18

Table B2. Canadian Interim Sediment Quality Guidelines

Contaminant	Marine Scotland AL1 (Note No Upper Level)	Canadian Interim Sediment Quality Guidelines			
	AL1	TEL		PEL	
	(mg/kg dry weight)	mg/kg	µg/kg	mg/kg	µg/kg
Acenaphthene	0.1	0.00671	6.71	0.0889	88.9
Acenaphthylene	0.1	0.00587	5.87	0.128	128
Anthracene	0.1	0.0469	46.9	0.245	245
Benzo(a)anthracene	0.1	0.0748	74.8	0.693	693
Benzo(a)pyrene	0.1	0.0888	88.8	0.763	763
Benzo(b)fluoranthene	0.1	No value	No value	No value	No value
Benzo(k)fluoranthene	0.1	No value	No value	No value	No value
Benzo(g,h,i)perylene	0.1	No value	No value	No value	No value
Chrysene	0.1	0.108	108	0.846	846
Dibenzo(a,h)anthracene	0.01	0.00622	6.22	0.135	135
Fluoranthene	0.1	0.113	113	1.494	1494
Fluorene	0.1	0.0212	21.2	0.144	144
Ideno(1,2,3cd)pyrene	0.1	No value	No value	No value	No value
Naphthalene	0.1	0.0346	34.6	0.391	391
Phenanthrene	0.1	0.0867	86.7	0.544	544
Pyrene	0.1	0.153	153	1.398	1398
Total Hydrocarbons	100	No value	No value	No value	No value

Table B3. Sediment Samples – Metals, PCBs and TBT (2012)

Contaminant	Sample Location ID		
	MPA 1 (2012) Main Channel	MPA 2 (2012) Inner Harbour Channel	MPA 3 (2012) Berths 1/2
Arsenic (mg/kg)	4.74	3.26	7.08
Cadmium (mg/kg)	<0.0009	<0.0009	0.0871
Chromium (mg/kg)	5.37	7.32	29.16
Copper (mg/kg)	1.71	2.94	18.24
Lead (mg/kg)	2.50	3.59	18.92
Mercury (mg/kg)	<0.01	<0.01	<0.01
Nickel (mg/kg)	5.50	9.09	23.26
Zinc (mg/kg)	9.97	16.38	60.00
Tributyltin (µg/kg)	<1	<1	10
PCB 28 (µg/kg)	<1	<1	<1
PCB 52 (µg/kg)	<1	<1	<1
PCB 101 (µg/kg)	<1	<1	<1
PCB 118 (µg/kg)	<1	<1	<1
PCB 153 (µg/kg)	<1	<1	<1
PCB 138 (µg/kg)	<1	<1	<1
PCB 180 (µg/kg)	<1	<1	<1
Key			
Below Marine Scotland Action Level 1			(green)
Between Marine Scotland Action Level 1 and Action Level 2			(amber)
Above Marine Scotland Action Level 2			(red)

Table B4. Sediment Samples – PAHs (2012)

Contaminant	Sample Location ID		
	MPA 1 (2012) Main Channel	MPA 2 (2012) Inner Harbour Channel	MPA 3 (2012) Berths 1/2
Acenaphthene (µg/kg)	<0.01	<0.01	<0.01
Acenaphthylene (µg/kg)	<0.01	<0.01	<0.01
Anthracene (µg/kg)	<0.01	<0.01	<0.01
Benzo(a)anthracene (µg/kg)	<0.01	<0.01	0.01
Benzo(a)pyrene (µg/kg)	<0.01	<0.01	<0.01
Benzo (g,h,i)perylene (µg/kg)	<0.01	<0.01	<0.01
Benzo(b)fluoranthrene (µg/kg)	<0.01	<0.01	<0.01
Benzo(k) fluoranthrene (µg/kg)	<0.01	<0.01	<0.01
Chrysene (µg/kg)	<0.01	<0.01	0.01
Dibenzo(a,h)anthracene (µg/kg)	<0.01	<0.01	<0.01
Fluoranthene (µg/kg)	<0.01	<0.01	0.01
Fluorene (µg/kg)	<0.01	<0.01	<0.01
Indeno(1,2,3-cd)pyrene (µg/kg)	<0.01	<0.01	<0.01
Naphthalene (µg/kg)	<0.01	<0.01	<0.01
Phenanthrene (µg/kg)	<0.01	<0.01	<0.01
Pyrene (µg/kg)	<0.01	<0.01	0.01
Total 16 PAH's	-	-	-
Key			
Below TEL			(green)
Between TEL and PEL			(amber)
Above PEL			(red)

Table B5. Sediment Samples – Metals, PCBs and TBT (2013)

Contaminant	Sample Location ID		
	MPA 1 (2013) Main Channel	MPA 2 (2013) Inner Harbour Channel	MPA 3 (2013) Berths 1/2
Arsenic (mg/kg)	5.33	11.06	13.75
Cadmium (mg/kg)	0.009	0.158	0.232
Chromium (mg/kg)	5.07	33.15	31.36
Copper (mg/kg)	1.86	15.53	14.26
Lead (mg/kg)	2.79	21.91	23.76
Mercury (mg/kg)	<0.02	0.09	0.10
Nickel (mg/kg)	5.68	22.47	23.79
Zinc (mg/kg)	10.39	68.79	75.06
Tributyltin (μg/kg)	<10	<10	158
PCB 28 (μg/kg)	<1	<1	<1
PCB 52 (μg/kg)	<1	<1	<1
PCB 101 (μg/kg)	<1	<1	<1
PCB 118 (μg/kg)	<1	<1	<1
PCB 153 (μg/kg)	<1	<1	<1
PCB 138 (μg/kg)	<1	<1	<1
PCB 180 (μg/kg)	<1	<1	<1
Key			
Below Marine Scotland Action Level 1			(green)
Between Marine Scotland Action Level 1 and Action Level 2			(amber)
Above Marine Scotland Action Level 2			(red)

Table B6. Sediment Samples – PAHs (2013)

Contaminant	Sample Location ID		
	MPA 1 (2013) Main Channel	MPA 2 (2013) Inner Harbour Channel	MPA 3 (2013) Berths 1/2
Acenaphthene (μg/kg)	<1	1	5
Acenaphthylene (μg/kg)	<1	<1	2
Anthracene (μg/kg)	53	<1	153
Benzo(a)anthracene (μg/kg)	<1	2	31
Benzo(a)pyrene (μg/kg)	<1	2	48
Benzo (g,h,i)perylene (μg/kg)	<1	<1	59
Benzo(b)fluoranthrene (μg/kg)	1	4	55
Benzo(k) fluoranthrene (μg/kg)	1	5	47
Chrysene (μg/kg)	1	1	42
Dibenzo(a,h)anthracene (μg/kg)	<1	<1	12
Fluoranthene (μg/kg)	1	5	58
Fluorene (μg/kg)	<1	<1	7
Indeno(1,2,3-cd)pyrene (μg/kg)	<1	2	47
Naphthalene (μg/kg)	<1	<1	9
Phenanthrene (μg/kg)	<1	<1	35
Pyrene (μg/kg)	1	4	47
Total 16 PAH's	58	31	657
Key			
Below TEL			(green)
Between TEL and PEL			(amber)
Above PEL			(red)

Table B7. Sediment Samples Berth 10 – Metals, PCBs and TBT (2014)

Contaminant	Berth 10 Sample Location ID		
	Sample 1 (2014) 56° 42.386N 02° 28.245W	Sample 2 (2014) 56° 42.370N 02° 28.199W	Sample 3 (2014) 58° 42.349N
Arsenic (mg/kg)	12.3	12.1	13.2
Cadmium (mg/kg)	0.13	0.11	0.11
Chromium (mg/kg)	31.9	32.4	34.5
Copper (mg/kg)	11.7	11.8	11.5
Lead (mg/kg)	17.3	18.02	20.4
Mercury (mg/kg)	0.05	0.04	0.05
Nickel (mg/kg)	20.2	20.5	21.6
Zinc (mg/kg)	61.4	57.6	60.6
Tributyltin (µg/kg)	<50	<50	<50
PCB 28 (µg/kg)	<1	<1	<1
PCB 52 (µg/kg)	<1	<1	<1
PCB 101 (µg/kg)	<1	<1	<1
PCB 118 (µg/kg)	<1	<1	<1
PCB 153 (µg/kg)	<1	<1	<1
PCB 138 (µg/kg)	<1	<1	<1
PCB 180 (µg/kg)	<1	<1	<1
Key			
Below Marine Scotland Action Level 1			
Between Marine Scotland Action Level 1 and Action Level 2			
Above Marine Scotland Action Level 2			

Table B8. Sediment Samples Berth 10 – PAHs (2014)

Contaminant	Berth 10 Sample Location ID		
	Sample 1 (2014) 56° 42.386N 02° 28.245W	Sample 2 (2014) 56° 42.370N 02° 28.199W	Sample 3 (2014) 58° 42.349N
Acenaphthene (µg/kg)	14	6	4
Acenaphthylene (µg/kg)	3	2	<1
Anthracene (µg/kg)	24	11	10
Benzo(a)anthracene (µg/kg)	73	42	26
Benzo(a)pyrene (µg/kg)	188	107	69
Benzo (g,h,i)perylene (µg/kg)	200	126	80
Benzo(b)fluoranthrene (µg/kg)	222	143	82
Benzo(k) fluoranthrene (µg/kg)	86	54	33
Chrysene (µg/kg)	194	108	76
Dibenzo(a,h)anthracene (µg/kg)	<1	<1	<1
Fluoranthene (µg/kg)	167	84	60
Fluorene (µg/kg)	18	10	13
Indeno(1,2,3-cd)pyrene (µg/kg)	95	76	27
Naphthalene (µg/kg)	27	15	55
Phenanthrene (µg/kg)	105	47	50
Pyrene (µg/kg)	132	72	47
Total 16 PAH's	1547	903	633
Key			
Below TEL			
Between TEL and PEL			
Above PEL			

Table B9. Sediment Samples from Boreholes at Berths 6 and 7 – Metals and TBT (2013)

Contaminant	Berth 6 and 7 Borehole Location ID											
	Borehole 1 (2013)		Borehole 2 (2013)		Borehole 3A (2013)		Borehole 4 (2013)			Borehole 5 (2013)		
	1 m	3 m	1 m	3 m	0.2 m	3 m	2 m	6 m	9 m	1 m	4 m	10 m
Arsenic (mg/kg)	14.5	21.9	17.4	12.8	15.9	19.0	14.3	15.4	10.4	15.2	16.4	16.1
Cadmium (mg/kg)	0.12	0.12	0.12	0.08	0.25	0.11	0.09	0.15	0.07	0.41	0.46	0.12
Chromium (mg/kg)	71.3	72.9	55.1	49.8	62.0	72.3	53.5	42.4	58.7	51.5	56.9	58.3
Copper (mg/kg)	46.5	54.2	25.4	32.8	42.9	49.0	22.6	128.6	21.4	60.1	95.5	26.3
Lead (mg/kg)	19.6	21.0	19.8	12.1	24.2	17.9	28.0	349.2	32.6	256.5	246.5	18.5
Mercury (mg/kg)	0.04	0.03	0.02	<0.02	0.03	<0.02	0.05	0.27	0.04	0.10	0.13	<0.02
Nickel (mg/kg)	64.2	68.9	50.6	43.5	47.5	66.3	40.6	34.5	35.8	35.6	34.5	38.2
Zinc (mg/kg)	105.7	104.2	90.0	70.1	98.3	118.0	146.0	146.5	152.9	244.2	319.8	127.2
Tributyltin (µg/kg)	24	18	39	1	159	<1	<1	7	1	3	4	<1

Key	
Below Marine Scotland Action Level 1	(green)
Between Marine Scotland Action Level 1 and Action Level 2	(amber)
Above Marine Scotland Action Level 2	(red)

Table B10. Sediment Samples from Boreholes at Berths 6 and 7 – PAH (2013)

Contaminant	Berth 6 and 7 Borehole Location ID											
	Borehole 1 (2013)		<Borehole 2 (2013)		Borehole 3A (2013)		Borehole 4 (2013)			Borehole 5 (2013)		
	1 m	3 m	1 m	3 m	0.2 m	3 m	2 m	6 m	9 m	1 m	4 m	10 m
Acenaphthene (µg/kg)	<1	<1	<1	<1	6	1	2	4	1	4	3	<1
Acenaphthylene (µg/kg)	<1	<1	<1	<1	<1	<1	<1	1	<1	1	1	<1
Anthracene (µg/kg)	3	7	<1	3	6	7	2	16	<1	12	7	3
Benzo(a)anthracene (µg/kg)	<1	<1	<1	1	94	<1	17	106	2	99	57	<1
Benzo(a)pyrene (µg/kg)	<1	5	<1	<1	100	2	21	115	2	182	125	<1
Benzo (g,h,i)perylene (µg/kg)	<1	<1	<1	<1	43	<1	9	47	<1	142	77	<1
Benzo(b)fluoranthrene (µg/kg)	<1	<1	<1	<1	282	<1	48	267	3	422	293	<1
Benzo(k) fluoranthrene (µg/kg)	<1	<1	<1	<1	81	<1	13	76	1	121	84	<1
Chrysene (µg/kg)	<1	1	<1	2	82	1	19	90	3	100	62	<1
Dibenzo(a,h)anthracene (µg/kg)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluoranthene (µg/kg)	1	1	<1	3	82	2	22	120	6	107	77	<1
Fluorene (µg/kg)	2	3	<1	4	6	1	4	9	2	5	5	<1
Indeno(1,2,3-cd)pyrene (µg/kg)	<1	<1	<1	<1	47	<1	2	53	<1	155	92	<1
Naphthalene (µg/kg)	13	17	8	12	18	15	13	21	2	73	32	7
Phenanthrene (µg/kg)	2	5	<1	10	37	1	27	66	8	67	51	1
Pyrene (µg/kg)	<1	1	<1	4	73	2	24	128	7	108	81	<1
Total 16 PAH's	20	39	8	38	955	31	223	1119	37	1599	1044	11

Key	
Below TEL	
Between TEL and PEL	
Above PEL	

Table B11. Sediment Samples – Metals, PCBs and TBT (2018)

Contaminant	Sample Location ID								
	Sample 1 (2018)	Sample 3 (2018)	Sample 4 (2018)	Sample 5 (2018)	Sample 6 (2018)	Sample 7 (2018)	Sample 8 (2018)	Sample 9 (2018)	Sample 10 (2018)
	56° 42.373N 02° 28.249W	56° 42.196N 02° 28.215W	56° 42.212N 02° 28.055W	56° 42.218N 02° 27.914W	56° 42.128N 02° 28.009W	56° 42.151N 02° 27.831W	56° 42.162N 02° 27.270W	56° 42.201N 02° 26.794W	56° 42.196N 02° 26.418W
Arsenic (mg/kg)	9.8	14.9	7.9	9.9	9.0	7.1	7.1	7.2	7.4
Cadmium (mg/kg)	0.17	0.12	0.08	0.10	0.08	0.06	<0.04	0.06	0.07
Chromium (mg/kg)	35.6	61.5	25.5	34.3	31.9	20.9	17.6	17.3	18.9
Copper (mg/kg)	17.4	47.3	14.1	18.5	20.0	11.3	9.1	9.6	11.0
Lead (mg/kg)	19.1	15.8	11.3	18.4	17.2	8.6	7.1	6.5	7.4
Mercury (mg/kg)	0.10	0.07	0.11	0.10	0.09	0.06	0.05	0.05	0.05
Nickel (mg/kg)	25.0	57.8	21.5	24.4	22.0	15.7	13.9	13.8	15.1
Zinc (mg/kg)	61.9	97.3	48.4	61.2	65.3	33.7	27.7	27.9	28.6
Tributyltin (µg/kg)	<1	<5	<1	<1	<1	<1	<1	<1	<1
PCB 28 (µg/kg)	0.3	0.2	0.1	0.2	0.2	<0.08	<0.08	<0.08	<0.08
PCB 52 (µg/kg)	0.2	0.1	0.1	0.1	0.1	<0.08	<0.08	<0.08	<0.08
PCB 101 (µg/kg)	0.1	0.2	<0.08	0.08	0.08	<0.08	<0.08	<0.08	<0.08
PCB 118 (µg/kg)	0.1	0.2	<0.08	0.1	0.1	<0.08	<0.08	<0.08	<0.08
PCB 153 (µg/kg)	0.2	0.95	0.08	0.2	0.1	<0.08	<0.08	<0.08	<0.08
PCB 138 (µg/kg)	0.2	0.8	0.08	0.2	0.1	<0.08	<0.08	<0.08	<0.08
PCB 180 (µg/kg)	<0.08	0.7	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Key	
Below Marine Scotland Action Level 1	(green)
Between Marine Scotland Action Level 1 and Action Level 2	(amber)
Above Marine Scotland Action Level 2	(red)

Table B12. Sediment Samples – PAH (2018)

Contaminant	Sample Location ID								
	Sample 1 (2018)	Sample 3 (2018)	Sample 4 (2018)	Sample 5 (2018)	Sample 6 (2018)	Sample 7 (2018)	Sample 8 (2018)	Sample 9 (2018)	Sample 10 (2018)
	56° 42.373N 02° 28.249W	56° 42.196N 02° 28.215W	56° 42.212N 02° 28.055W	56° 42.218N 02° 27.914W	56° 42.128N 02° 28.009W	56° 42.151N 02° 27.831W	56° 42.162N 02° 27.270W	56° 42.201N 02° 26.794W	56° 42.196N 02° 26.418W
Acenaphthene (µg/kg)	4.52	<1	2.99	5.05	4.06	<1	<1	<1	<1
Acenaphthylene (µg/kg)	3.53	1.14	1.54	5.04	2.43	<1	<1	<1	<1
Anthracene (µg/kg)	11.50	2.18	5.90	13.00	8.10	<1	<1	<1	<1
Benzo(a)anthracene (µg/kg)	37.8	9.4	19.2	49.4	30.1	<1	<1	<1	<1
Benzo(a)pyrene (µg/kg)	43.30	9.79	18.30	56.40	36.10	<1	<1	<1	<1
Benzo (g,h,i)perylene (µg/kg)	43.70	8.66	10.80	61.00	41.30	<1	<1	<1	<1
Benzo(b)fluoranthrene (µg/kg)	54.4	10.3	18.3	76.8	48.7	<1	<1	<1	<1
Benzo(k) fluoranthrene (µg/kg)	24.20	4.42	7.67	28.90	18.80	<1	<1	<1	<1
Chrysene (µg/kg)	42.4	10.1	20.1	57.5	34.1	<1	<1	<1	<1
Dibenzo(a,h)anthracene (µg/kg)	8.05	1.45	2.41	**10.90**	6.98	<1	<1	<1	<1
Fluoranthene (µg/kg)	60.8	15.0	31.4	80.5	40.5	<1	<1	<1	<1
Fluorene (µg/kg)	5.81	1.26	3.64	8.18	4.69	<1	<1	<1	<1
Indeno(1,2,3-cd)pyrene (µg/kg)	47.00	8.04	11.10	61.40	42.10	<1	<1	<1	<1
Naphthalene (µg/kg)	12.70	2.45	1.53	13.10	7.89	<1	<1	<1	<1
Phenanthrene (µg/kg)	42.20	7.35	23.20	50.00	32.10	<1	<1	<1	<1
Pyrene (µg/kg)	63.1	14.7	28.3	80.6	40.4	<1	<1	<1	<1

Key	
Below Action Level 1 (Marine Scotland)	Value
Above Action Level 1 (Marine Scotland)	**Value**
Below TEL	
Between TEL and PEL	
Above PEL	

Contact Us

ABPmer

Quayside Suite,
Medina Chambers
Town Quay, Southampton
SO14 2AQ

T +44 (0) 23 8071 1840
F +44 (0) 23 8071 1841
E enquiries@abpmer.co.uk

www.abpmer.co.uk

ABP mer