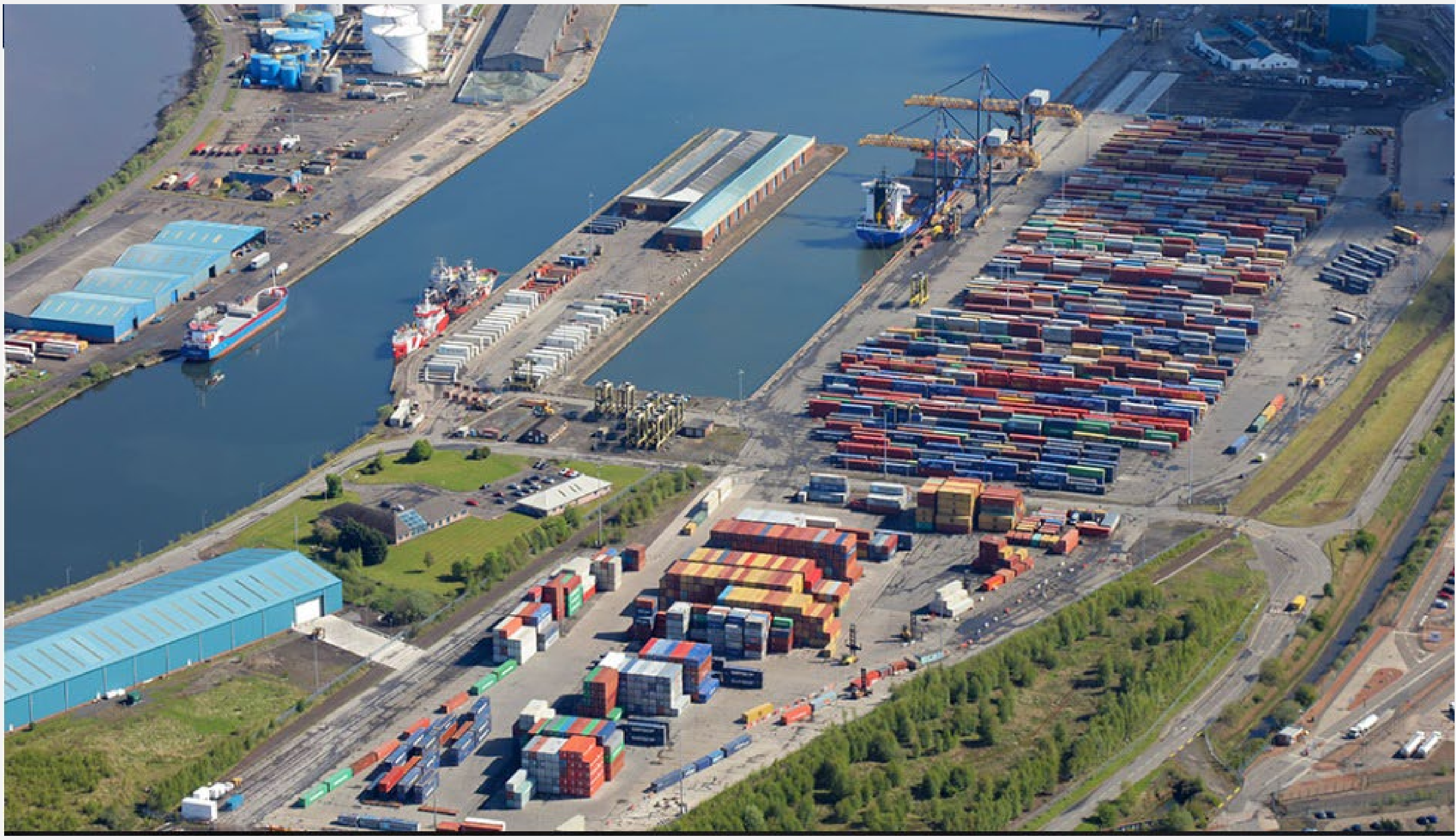


Port of Grangemouth Maintenance Dredge Spoil Disposal License Application 2022

Best Practicable Environmental Option Report 2022

26 August 2022

Project No: 0352017

The business of sustainability

Document title	Port of Grangemouth Maintenance Dredge Spoil Disposal License Application
Document subtitle	Best Practicable Environmental Option Report 2022
Project No.	0352017
Date	26 August 2022
Version	1.1
Author	ERM
Client Name	Forth Ports Ltd

Document history						
				ERM approval to issue		
Version	Revision	Author	Reviewed by	Name	Date	Comments
Draft	00	ERM	Mark Irvine	Mark Irvine	22/08/22	For client review
Draft	01	ERM	Mark Irvine	Mark Irvine	26/08/22	For submission

Port of Grangemouth Maintenance Dredge Spoil Disposal License Application 2022

Best Practicable Environmental Option Report 2022

Approved for Issue by ERM

[redacted]

Mark Irvine
Technical Director

Environmental Resources Management Limited
6th Floor
102 West Port
Edinburgh
EH3 9DN

CONTENTS

List of Tables

List of Figures

1. INTRODUCTION

1.1 Background

This report has been prepared by Environmental Resources Management Ltd (ERM) on behalf of Forth Ports Ltd (Forth Ports) in support of a Marine Licence application for disposal of dredged sediments at sea from maintenance dredging activities at the Port of Grangemouth.

Under the *Marine (Scotland) Act 2010,* a Marine Licence issued by Marine Scotland is required for the deposit of substances or articles within waters adjacent to Scotland. Under Part 4, Section 27(2), Marine Scotland has an obligation to consider the availability of practical alternatives when considering applications involving disposal of material at sea. Applications for a Marine Licence to dispose of dredged spoil at sea require a Best Practicable Environmental Option (BPEO) (1) assessment, demonstrating that alternatives to sea disposal have been investigated and that sea disposal does not pose an unacceptable risk to the marine environment and other legitimate users. This report compares various options for the disposal of maintenance dredge material from the Port of Grangemouth and identifies the BPEO.

Marine Licences for maintenance dredging activities are currently valid in Scotland for up to three years (2). Forth Ports currently has a maintenance disposal licence (07120/20/0) to maintain a safe navigable depth which covers the period 1 February 2020 to 31 January 2023. This current application is to cover the period from 1 February 2023 to 31 January 2026.

1.2 The Need for Dredge Spoil Disposal

The Port of Grangemouth is located on the south bank of the Forth Estuary; adjacent to the Grangemouth petrochemical complex where the principal cargos handled include:

- containers;
- grain and dry bulks;
- liquid bulks;
- oil and gas; and
- paper and forest products.

The entrance to the port is accessed from the Bellmouth, through lock gates and into the docks. The Bellmouth is protected by open piled lead-in jetties (see *Figure 1.1* for port and dredging areas).

The Bellmouth lies immediately west of the Kinneil mudflats and east of the Skinflats mudflats. The resuspension of sediment from a variety of sources within the Firth of Forth and Forth Estuary, the action of the waves on the mudflats and turbulence created by the movement of the tide against the west lead-in jetty contribute to the movement of suspended sediments into the Bellmouth area (3). This causes the Bellmouth area to silt up and, if the maintenance dredging did not take place, the Bellmouth would silt up at a rate of approximately two metres per month, rapidly becoming un-navigable. To maintain access to the port Forth Ports requires to dredge the Bellmouth area monthly.

Within the port, water is pumped in from the Forth Estuary to maintain a static dock level resulting in an accumulation of sediment over time within the port. An estimated 20,000 m^3 of silt accumulates within the locks and port annually and requires periodic dredging (in addition to the material from Bellmouth area) to maintain the passage through the channels to the docks.

(1) The term BPEO was derived by the Royal Commission on Environmental Pollution who described it as a procedure which "establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole, at an acceptable cost, in the long term as well as in the short-term.
(2) Marine (Scotland) Act 2010, Part 4 Marine Licencing. General Guidance for Applicants. Available online http://www.scotland.gov.uk/Resource/0043/00435338.pdf
(3) HR Wallingford, Forth Ports Siltation and Dredging Study, 1998.

In line with Section 13 of Scotland's National Marine Plan (Marine Planning Policy Transport 4) the dredging operations and disposal of the dredged material will continue to maintain and support the sustainable development of the Port of Grangemouth. The maintenance of the Port of Grangemouth is essential to enable it to continue to operate as Scotland's largest container port by allowing large vessels to safely navigate the shallower waters of the Firth of Forth, in turn supporting the national economy.

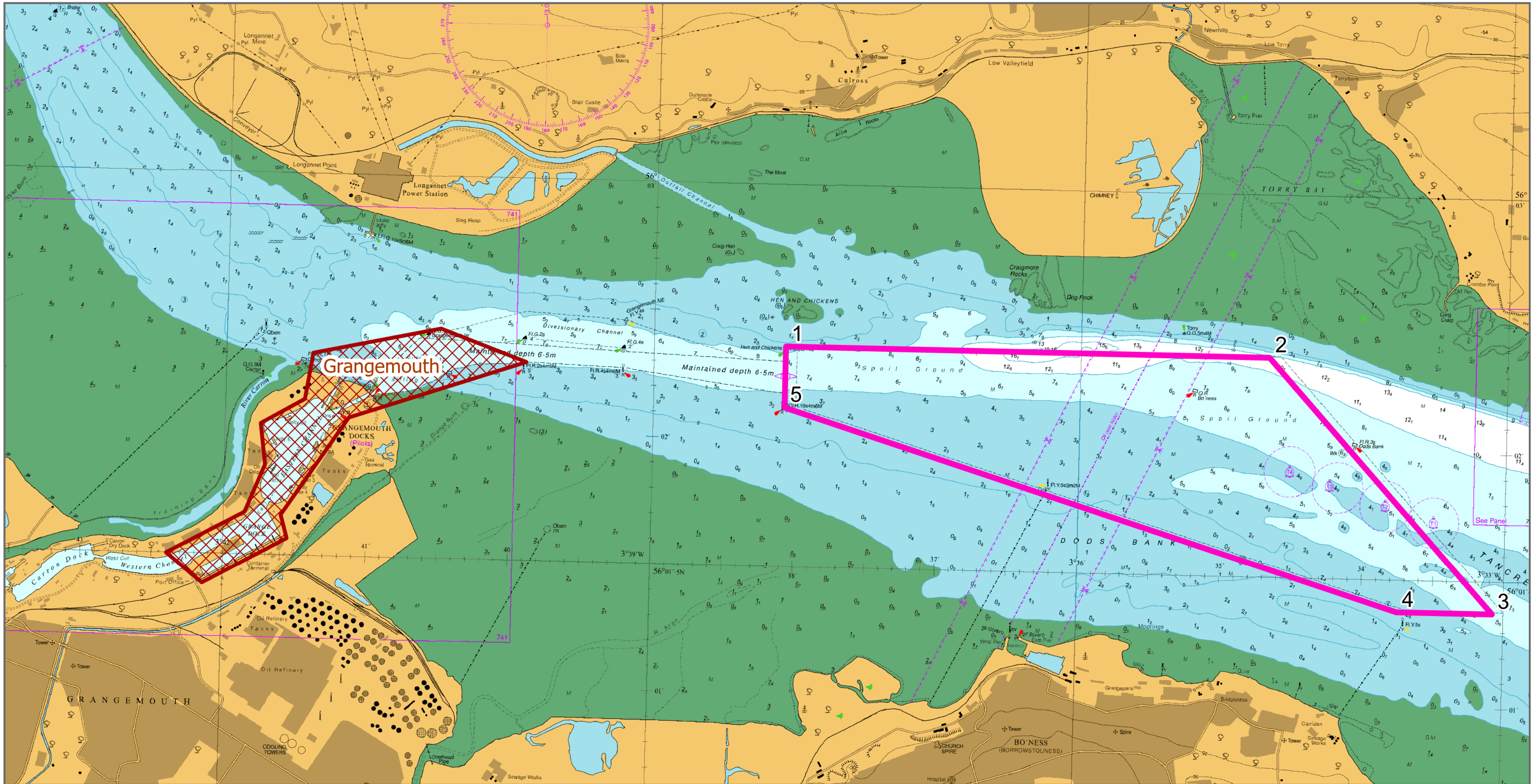
Forth Ports undertakes routine dredging at Grangemouth Dock and requires to dispose of up to 1,700,000 m^3 of material per annum. Should Forth Ports consider the 'Do Nothing' approach, and not undertake any dredge disposal operations it would be unable to continue with its routine dredging operations, it is anticipated that the Port of Grangemouth would become inaccessible to most of the commercial vessel traffic within a matter of weeks. There would be serious concerns raised over navigational safety as the risk to vessels of grounding significantly increased.

Without the ability to accommodate these vessels, the economy of the local area would decrease and there would be a wider national effect as organisations reliant on vessels accessing the Port of Grangemouth would not be able to continue normal operations. Given the ongoing dredging requirements and therefore the need for disposal of the dredged material, the do nothing option is not considered further in this BPEO.

1.2.1 Previous Dredge Spoil Disposal Activities

The Port of Grangemouth has been dredged since the 1910s on a continual basis with Forth Ports taking over the port in the late 1960s. To maintain access to the Port of Grangemouth, Forth Ports previously dredged the Bellmouth area from Monday to Friday, early morning to late evening for 48 weeks of the year. Between 1967 and 2000 this was mainly undertaken using the trailing suction dredger *Abbotsgrange* or a chartered suction trailer dredger if the *Abbotsgrange* was not available.

Since January 2001, Forth Ports have contracted United Kingdom Dredging (UKD) for the majority of operations within the Forth Estuary. The *UKD Marlin* (*Figure 1.2*) is a trailing suction dredger, with a hopper capacity of 3,000 m^3, which is double that of the *Abbotsgrange.* In addition, the grab hopper dredgers the Wyre Sands and Admiral Day (Figure 1.2) are sometimes used.



Maintanence Dredging Site

Boness Disposal Site

0 250 500 750 1,000

Metres

N

Figure 1.1

Grangemouth Maintenance Dredge Area and Disposal Site

SCALE: See Scale Bar	VERSION: A04
SIZE: A4	DRAWN: HD
PROJECT: 0352017	CHECKED: GB
DATE: 12/04/2022	APPROVED: MI

CLIENT:

Forth Ports Ltd.

PROJECTION: British National Grid

SOURCE:
Not to be used for Navigation.

Path: \\UKLDCFS01\Data\Edinburgh\Projects\0352017 Forth Ports Grangemouth2016.MI\2022 survey&BPEO\00 GIS\Maps\0352017_Grangemouth_A03\0352017_Grangemouth_A03.aprx

Figure 1.2 Dredge Vessel - UKD Marlin

https://www.ukdredging.co.uk/UKD_Fleet/UKD_Marlin/

Figure 1.3 Dredge Vessel – Wyre Sands and Admiral Day

http://www.wyremarineservices.co.uk/fleet-and-equipment.html

1.3 Proposed Dredge Spoil Disposal Operations

The intended dredging and dredged material disposal operations to maintain the Bellmouth, Eastern Channel and inner docks areas are estimated to require four 24-hour days per month with the *UKD Marlin* trailing suction dredger or similar sized vessel. The time required for one cycle (dredging - travelling - discharging - travelling) is approximately 1 hour and 30 minutes. There are time restrictions getting in and out of the lock and delays due to other shipping movements meaning that longer periods are required for some dredging loads.

For the current Marine Licence dredging in the Caron Dock at the western end of the dock complex was not permitted due to elevated levels of some contaminants in the sediments above Marine Scotland Action Levels (see Appendix A for explanation of Action levels). The sediment sampling undertaken for the current Marine Licence application confirmed elevated concentrations of some metals (mainly mercury) in the Carron Dock and the western approach channel to it. Supplementary sampling for analysis of metals was then undertaken to provide more detailed information on the areas affected. The result of the initial sampling and the supplementary sampling are presented in Appendix A. For the current Marine Licence application Forth Ports have excluded the area with highest concentrations of mercury and other metals such as copper, lead and zinc. If maintenance dredging in these areas is required to maintain a navigable water depth, then a separate Marine Licence application will be submitted.

One sample from Grange Dock also has elevated concentrations of mercury above Action Level 2. Additional sampling, one sample at the same location as the original sample and two samples at 25 m distance from the original sample station showed that the elevated concentrations above Action Level 2 were restricted to the original sample site. Forth Ports propose to avoid dredging within 25 m of the sample station above Action Level 2 (Station G19-2022 on Figure A1.1 in Appendix A)

The boundary co-ordinates of the proposed dredge areas are presented in *Table 1.1* and illustrated in *Figure 1.1.*

Table 1.1 Coordinates of Proposed Dredge Sites at Grangemouth

Node	Co-ordinates	
A	56°1.382' N	3°42.140' W
B	56°1.498' N	3°42.396' W
C	56°1.665' N	3°41.852' W
D	56°1.853' N	3°41.716' W
E	56°2.015' N	3°41.753' W
F	56°2.114' N	3°41.447' W
G	56°2.296' N	3°41.395' W
H	56°2.403' N	3°40.503' W
I	56°2.280' N	3°39.899' W
J	56°2.045' N	3°41.136' W
K	56°1.657' N	3°41.598' W
L	56°1.565' N	3°41.552' W

Coordinates in WGS84, UTM Zone 30N, degrees decimal minutes

It is proposed that the dredged material continues to be disposed of at sea at the existing licenced marine disposal site at Bo’ness. The Bo’ness spoil ground is situated approximately 1.5 nautical miles east of the Port of Grangemouth and has been used by Forth Ports for dredge spoil disposal from Grangemouth for over 25 years. The water depth within the spoil disposal ground ranges from 0.1 m below Chart Datum (CD) along the southern edge and increases to 17 m below CD along the northern edge. The boundary co-ordinates of the spoil ground are presented in *Table 1.2* and illustrated in *Figure 1.1.*

Table 1.2 Coordinates of Bo'ness Spoil Disposal Ground

Node	Coordinates	
1	56°2.365' N	3°38.080' W
2	56°2.365' N	3°34.684' W
3	56°1.375' N	3°33.083' W
4	56°1.375' N	3°33.754' W
5	56°2.125' N	3°38.080' W

Coordinates in WGS84, UTM Zone 30N, degrees decimal minutes

The volume of dredged material deposited at the Bo’ness spoil ground from the Port of Grangemouth from 1997 to 2022 ranged from 781,967 to 1,253,600 m^3 per annum as presented in *Table 1.3.* Larger volumes may be required in some years due to variation in sediment deposition rates, hence a higher volume applied for than the previous maximum disposal volume. As the majority of sediments dredged annually are from the Bellmouth area, the reduction in the overall application area has not decreased to total application volume.

Table 1.3 Dredge Spoil Disposal at Bo'ness Spoil Ground from Grangemouth (1997 to August 2022)

Year	Quantity (m^3)
1997	911,509
1998	921,670
1999	931,062
2000	967,801
2001	823,624
2002	781,967
2003	821,019
2004	834,131
2005	991,276
2006	801,209
2007	920,639
2008	979,537
2009	876,955
2010	808,744
2011	999,538
2012	1,084,760
2013	1,253,600
2014	1,029,611
2015	1,188,021
2016	1,231,497
2017	1,038,961
2018	987,594
2019	847,803
2020	881,917
2021	964,920
2022 (to August)	516,793

Data source: Forth Ports Ltd August 2022

1.4 Description of Sediment to be Dredged

In line with Marine Scotland guidelines on pre-dredge sampling protocol (1), a survey programme was undertaken on the 29th and 30th March 2022 to sample the sediments within Grangemouth Harbour and the Bellmouth. This survey programme was reviewed and agreed with Marine Scotland.

A hand held van-Veen grab was used to take a surface sample from 11 stations in the Bellmouth area and 18 stations from within the dock complex. Sediments were analysed by Socotec UK Ltd for:

- sediment particle size distribution;
- sediment water/solids content and density;
- total organic carbon (TOC);
- a suite of metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead, zinc);
- Tributyl Tin and Dibutyl Tin (TBT and DBT);

(1) Guidance for the sampling and analysis of sediment and dredged material to be submitted in support of applications for sea disposal of dredged material. Available online http://www.scotland.gov.uk/Resource/0044/00443832.pdf

- Poly Chlorinated Biphenyls (PCB); and
- Polycyclic Aromatic Hydrocarbons (PAH).

Following the analysis of the sediment samples from the initial survey, a supplementary survey was undertaken on 20th June 2020 to collect three samples at each of three locations to check the concentration of metals in the areas where elevated concentrations were recorded. For metal analysis there were a total of 38 sample stations.

The physico-chemical analysis is presented in *Appendix A.*

The sediment to be dredged from the dock areas and Bellmouth is material that has been deposited since previous maintenance dredging activities and is composed of soft, estuarine sandy mud with small fractions of gravel in some samples. The concentration of most metals in some samples were above the Marine Scotland Action Level 1(1) but below Action Level 2, with the exception of mercury in seven of the initial samples and copper, lead and zinc in one sample. The mean concentrations of metals from all samples analysed were above Action Level 1 but below Action Level 2 (except for arsenic and cadmium which were below Action Level 1). PCB concentrations were above Action Level 1 in nine of the initial 29 stations sampled. TBT concentrations were above Action Level 1 in four of the initial 29 stations sampled. Concentrations of most of the PAHs analysed for were above Action Level 1 for most samples.

Sediment analysis data from Bo'ness disposal site from 2015 is presented in *Appendix A,* along with data from other spoil disposal sites. Concentrations of metals and PCBs are found to be similar to those from the other spoil disposal sites in the Firth of Forth.

1.5 Scope of the Study

This report provides an appraisal of available disposal options and short-lists those that are considered to be practicable. Options are reviewed according to the Waste Hierarchy, as outlined in the European Waste Framework Directive (2008/98/EC) (2). The options on the short-list are then reviewed against strategic, environmental and cost considerations. The options are then compared and the BPEO identified.

The remainder of this report is structured as follows.

- *Section 2* describes the BPEO assessment method.
- *Section 3* describes each of the available disposal options and summarises their respective advantages and disadvantages and short-lists feasible options.
- *Section 4* compares the short-listed disposal options.
- *Section 5* identifies the BPEO.

Further supporting information is provided in the three Appendixes.

- *Appendix A:* Sediment Sample Chemical Analysis Results.
- *Appendix B:* Environmental Impacts of Disposal Operations.
- *Appendix C:* Consultee Responses.

(1) Action Levels for metals, PCBs, TBT and PAHs are used by Marine Scotland to assess the suitability for disposal of sediments at sea.
(2) Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098

2. BPEO ASSESSMENT METHOD

2.1 Introduction

The BPEO study was undertaken using the following method.

- Identification of potential disposal options.
- Preliminary appraisal and short-listing of options based on practicability.
- Assessment of the short-listed options based on:
  - strategic considerations;
  - environmental considerations *i.e.* what the environmental impacts would be; and
  - cost, in terms of capital and maintenance/operating costs.
- Comparison of the relative merits and performance of the options and identification of the BPEO.

Information was obtained through literature review and consultation with the following consultees.

- Crown Estate Scotland;
- Falkirk Council;
- Forth District Salmon Fishery Board (FDSFB);
- Maritime and Coastguard Agency (MCA).
- Northern Lighthouse Board (NLB);
- Scottish Environment Protection Agency (SEPA); and
- NatureScot (NS).

2.2 Identification of Options

The following seven potential treatment/disposal options for the dredged material were identified:

1. beach nourishment;
2. coastal reclamation and construction fill;
3. spreading on agricultural land;
4. sacrificial landfill;
5. incineration;
6. other disposal options and reuse; and
7. sea disposal.

2.3 Preliminary Appraisal

A preliminary appraisal of each of the options identified above was undertaken, including an assessment of the practicability of each option with regard to availability of disposal sites. Following the preliminary appraisal those options that are considered to be practicable were short-listed for further consideration.

2.4 Assessment of Options

The short-listed options were then subject to detailed assessment. The parameters which were used to assess the short-listed options are described below.

2.4.1 Strategic Considerations

Strategic considerations included the following.

- Operational feasibility - whether the option is technically practicable.
- Availability of sites/facilities - whether there are any sites or facilities which can take the dredge spoil.
- Security of option - whether Forth Ports will have control over all stages of the disposal.
- Established practice - whether technologies and techniques proposed are established and therefore whether the performance and potential difficulties of the technologies and techniques can be anticipated.
- General public acceptability - whether the public are likely to object to or support the proposals.
- Likely Agency acceptability - whether public agencies are likely to have any major concerns when consulted on the Marine Licence application.
- Legislative implications - assessing compliance with relevant legislation and the potential management control required.

2.4.2 Health, Safety and Environmental Considerations

The factors used to assess the health, safety and environmental performance of the options are summarised below.

- Public health. Assessing whether there would be any risk of a detrimental effect on public health, based on predicted pathways and receptors.
- Safety. Considering potential sources of hazard and probability that there would be any risk to the general public or workers.
- Contamination/pollution. Evaluating whether there is potential for pollution or contamination that could result in failure to meet Water Quality Objectives and Standards (EQSs: the amount or concentration of a substance that should not be exceeded in an environmental system). Contamination is defined as the presence of an unwanted constituent in the natural environment whilst pollution is the introduction of contaminants into the natural environment that causes adverse change.
- Ecological impact. Assessing the significance of any potential impact on important habitats or species, including designed sites.
- Interference with other legitimate users. Considering whether there are likely to be impacts on other activities, such as users of the Forth Estuary, ports or roads.
- Amenity/aesthetic. Assessing whether there is likely to be a visual or noise impact resulting from the disposal or any impact on local amenity.

2.4.3 Cost Considerations

Cost of disposing of dredged material was considered in terms of the capital costs (construction of facilities and equipment hire /purchase costs) and operational costs (transport costs and disposal costs, including site operation).

2.5 Comparison of Options

The performance of each option was evaluated on a scale from Low to High according to definitions presented in *Table 2.1*. Intermediate grades (Low to Medium and Medium to High) were also used where the assessment was marginal between Low, Medium or High. The results of the assessment process are presented in *Section 3* and *Section 4.*

Table 2.1 Definitions of Performance

Consideration	High	Medium	Low
Strategic Considerations			
Operational Feasibility	Practical, easy to operate and achievable as process is robust and established. Low number of stages and each stage easy to control.	Some practical difficulties. Moderate number of stages with some difficulties.	Major practical difficulties. Large number of steps with some major difficulties.
Availability of Sites/Facilities	Suitable site/facility available within 1 km of the port by road and 10 km by sea.	Suitable site/facility available within 10 km of the port by road and 20 km by sea.	No suitable sites/facilities within the vicinity (over 10 km by road and 20 km by sea).
Security of option	In complete operational control of Forth Ports.	Is mainly in control of Forth Ports with some outside involvement for which there are alternative sources of supply.	Has elements that are out of Forth Ports control for which there are no practical alternative sources of supply.
Established Practice	Technology and techniques are clearly established with no foreseeable significant problems.	Technology and techniques have been tested but not applied to dredge material.	Technologies and techniques are untested and unforeseen problems are likely.
General Public Acceptability	Likely to be generally acceptable to the public based on reaction to similar developments.	Unlikely to provoke a strong negative or positive reaction based on reaction to similar developments.	Likely to provoke a strong negative reaction based on reaction to similar operations.
Likely Agency Acceptability	Likely to be generally acceptable to statutory bodies after consultation.	Statutory bodies may have some concerns that may be overcome through further consultation.	Statutory bodies may have major concerns that may not be overcome through consultation.
Legislative Implications	Would easily comply with legislation with a low level of management and physical control.	Requires some control/intervention to achieve compliance.	Requires a high level of management control and intervention to achieve compliance.
Health, Safety and Environmental Considerations			
Safety	No significant risk to workers and the general public.	Low risk to workers and the general public which is easily controlled.	Moderate to high risk to workers and general public.
Public Health	Will not cause workers or public to be exposed to substances potentially hazardous to health.	May cause some low level intermittent exposure to substances potentially hazardous to health.	Risk of exposing workers and general public to substances potentially hazardous to health.
Pollution/Contamination	Compliant with emission standards and water quality objectives. Low risk of harm from substances released to environment.	Environmental quality standards may be approached or breached occasionally. Some risk of harm to environment.	Environmental quality standards may be breached regularly and there is a moderate or high risk of harm to environment.

Consideration	High	Medium	Low
Ecological Impact	Priority species and habitats under the UK Biodiversity Action Plan and qualifying features and species under the EU Habitats and Birds Directives will not be affected.	Priority species and habitats under the UK Biodiversity Action Plan and qualifying features and species under the EU Habitats and Birds Directives may be slightly affected.	Priority species and habitats under the UK Biodiversity Action Plan and qualifying features and species under the EU Habitats and Birds Directive are likely to be significantly affected.
Interference with other Legitimate Activities	Little potential for interference with other activities.	Some potential for interference with other activities.	High potential for interference with other activities.
Amenity/Aesthetic	No significant impact on local amenity or aesthetic qualities.	Potential for impacts of moderate significance on local amenity or aesthetic qualities.	Potential for impacts of high significance on local amenity or aesthetic qualities.
Cost			
Capital and maintenance	£5 m or less.	Between £5 m and £10 m.	More than £10 m.

3. DESCRIPTION AND PRELIMINARY ASSESSMENT OF AVAILABLE DISPOSAL OPTIONS

3.1 Introduction

This section describes the identified disposal options and makes a preliminary assessment of each based on overall practicality. There are a number of steps that are common to some of the land-based options and these are described in *Section 3.2* to avoid repetition. The section concludes by identifying those options that are short-listed for further consideration in the BPEO process.

The seven identified disposal options are:

1. beach nourishment;
2. coastal reclamation;
3. spreading on agricultural land;
4. sacrificial landfill;
5. incineration;
6. other disposal options and reuse; and
7. disposal at sea.

3.2 Common Steps to Land-Based Disposal Options

The disposal options that have land-based components include:

- beach nourishment (if material transported by road);
- coastal reclamation and construction fill (if material transported by road);
- spreading on agricultural land;
- sacrificial landfill;
- incineration; and
- other disposal options and reuse (such as brick making/concrete aggregate/topsoil production).

The steps that are common to the land-based disposal options are:

- landing the dredge material;
- storage of dredge material;
- dewatering the dredge material; and
- loading and transport for disposal.

These steps are described below along with some discussion of the practicalities of undertaking these steps at the Port of Grangemouth.

3.2.1 Landing the Dredged Material

All of the land based options require transport to on-shore facilities. This could be via a pumped discharge, conveyor or grab. As Forth Ports does not have suitable facilities at Grangemouth or elsewhere within the Firth of Forth area, for landing dredged material, a new coastal landing facility would be required to enable the material to be landed.

3.2.2 Storage of Dredged Material

Once the dredged material has been landed, it will require storage prior to onward transport for final disposal. A storage facility may therefore require construction at the site, capable of retaining the dredged material and associated run-off and dust.

3.2.3 Dewatering the Dredged Material

The land disposal options require dewatering of the dredged material either to make transport more feasible or to create a material which is suitable for disposal to land or incineration *i.e*, disposal of a more solid sludge rather than a liquid. Forth Ports confirmed that the hopper contents are likely to average 20% solids (by volume) and range from 30% to 15% solids *i.e*, solids to liquid ratio will decrease as dredging operations progress and only isolated pockets of sediments remain resulting in an increased uptake of water.

There are three approaches that are typically used for drying marine sediments: construction of settling lagoons, use of a mobile centrifuge unit and filter press as described below.

Settling Lagoons

Settling lagoons are likely to be large, ring-dammed structures into which the dredged material would be pumped. These could be built within the intertidal area or on land. The material would be piled up in the lagoon and the water drained out under gravity. The lagoons would have a drainage system to collect the water and watery sludge from the dredged material for further treatment (usually by hydrocyclone, see below) or to be transported offsite for disposal. The lagoons must be of sufficient size to contain the dredged material prior to transport. They must also be accessible by road and must have facilities to load the dredged material into tankers or sealed heavy goods vehicles (HGVs) for movement to the disposal/treatment centre. To minimise the distance the wet dredge material has to be transported from the dredger they must be located near the quayside.

Setting up settling lagoons would require assessment to ensure that any leachate from them would not contaminate groundwater and a licence would be required from SEPA under the *Water Environment (Controlled Activities) Regulations (2011)*. Forth Ports advise that the potential to be able to find appropriate space to create lagoons close to the port is considered to be very low. As some of the samples from the sediments to be dredged contain metals, TBT, PCBs and PAHs (see *Appendix A* for sample analysis data) it might be additionally necessary to construct the lagoons with special liners to retain the contaminants and consider treatment of the supernatant water draining out of the lagoons.

Centrifuge or Hydrocyclone System

The use of a centrifuge or hydrocyclone system to dewater the material to a level suitable for disposal to landfill (approximately 10% water content) may be required, depending on the final water content of the recovered material. One mobile unit system was reported as being capable of treating up to 150 m^3hr^{-1} depending on unit size and material solids content. Other systems may be available that can process material at different rates, however, for the purposes of this assessment a rate of 150 m^3 hr^{-1} has been used. This is typically only an option for firmer sediments made up of fine sands and muds, such as those from stations within the docks at the Port of Grangemouth. If material can be dried at a rate of 150 m^3hr^{-1}, to dewater a total volume of approximately 1,700,000 m^3 would require approximately 67 weeks (operating 24 hours a day, 7 days a week). Other units with lower throughputs could take longer.

Filter Press

A filter press is a tool used to separate solids and liquids using the principle of pressure. The press is filled with the spoil, building up pressure before the spoil is strained through filter cloths by force. The remaining dried spoil can then be removed from the filter press and taken away for disposal.

A filter press is a tool used to separate solids and liquids using the principle of pressure. The press is filled with the spoil, building up pressure before the spoil is strained through filter cloths by force. The remaining dried spoil can then be removed from the filter press and taken away for disposal. Processing rates would be similar to that of a centrifuge.

3.2.4 Loading and Transport for Disposal

A loading facility would be required adjacent to the storage or dewatering area to load the material into covered HGVs for transport to treatment/disposal sites. The required infrastructure would include hard standing to allow a fleet of HGVs to be loaded by mechanical excavators. Although some areas of hard standing are available at the Port of Grangemouth, there are no storage or dewatering sites in Grangemouth.

Assuming the materials can be dried to a water content of 10% (by volume) at the Port of Grangemouth, the estimated 1,589,500 m^3 (1) of dried materials would require transport for disposal, either to an incinerator, to agricultural land, to landfill or to a reclamation project. The length of journey required would depend on the location of the deposit/incineration sites.

A volume of 1,589,000 m^3 of dried (to 10% water content) material equates to approximately 1,827,350 tonnes (2). Assuming 20 tonne capacity sealed HGVs are used, this would equate to 91,368 return trips or 182,736 vehicle movements.

The significance of the number of movements will be dependent upon the distance to the disposal/treatment site and the existing volume of HGVs on the haulage routes. The access road to the Port of Grangemouth exits onto the trunk road network where the HGV count is estimated as 385,805 per year (averaged 2018 data (3)). The additional HGV movements as a result of the dredging operations would increase this current level by approximately 56% per year. There may also be an issue with regard to increase in HGV traffic flows if minor roads are used to reach disposal/treatment sites.

3.2.5 Disposal/Treatment Issues

Neither method of the drying process (*e.g.* lagoons or centrifuge) is likely to reduce the concentration of PCBs, PAHs, metals, TBT and salt present within the dredged material. This may restrict disposal and reuse options and as the material has elevated levels of some contaminants, pre-treatment may be required prior to disposal on land.

Where an option involves disposal on land there is an issue of classification of the dredged material. Once the material has been removed from the harbour for disposal on land it will be classed as waste. The waste then requires disposal at a licensed waste management facility and to be transported by a registered waste carrier. In the waste hierarchy set out in the *Waste Management Licensing (Scotland) Regulations, 2011*, dredged spoil is coded as 17 05 05 (Mirror Hazardous) or 17 05 06 (Mirror Non-hazardous), depending on the concentrations of particular contaminants. If landfill is identified as the disposal route for this waste then further analysis may be required to ensure that the material meets the Waste Acceptance Criteria for hazardous landfill.

The saline nature of the sediment also restricts its application on land, as without going through a washing process it will not be able to support any form of terrestrial flora growth.

(1) 1,700,000 m^3 total spoil at 85% solids content equals 1,445,000 m^3 plus 144,500 m^3 (10% water content) equals 1,589,500 m^3.
(2) Based on a weight of 1.15 tonnes per m^3 of dredge spoil.
(3) Traffic counts Scotland. Data for the A904 outside the Port of Grangemouth. https://roadtraffic.dft.gov.uk/manualcountpoints/40965 Accessed 05/08/2019. Pre-COVID-19 data used.

3.3 Beach Nourishment

3.3.1 Process Description

Beach nourishment involves the disposal of the dredged material on a beach directly from the dredging vessel or, if dewatering was required, the spoil would be brought ashore and dewatered prior to transport or placement on the beach using earth moving plant.

3.3.2 Suitable Sites for Beach Nourishment

Beach nourishment requires materials of a similar composition to the existing beach materials and usually involves clean sand or gravel. The sediment from within the proposed dredge area comprises fine material (*ie* sandy muds, see Appendix A for details). The sediment from the Port of Grangemouth is not suitable for beach recharge due to the particle size distribution and the presence of contaminants such as metals, including TBT, and organics (PAHs and PCBs). Given the incompatibility of the fine sediment material with sandy beach sediments at the potential receiving site, the contaminant concentrations in the material to be dredged and the conservation status of the Firth of Forth and Forth Estuary, beach nourishment is not likely to be a practical option.

3.4 Coastal Reclamation and Construction Fill

3.4.1 Process Description

This section considers the use of the dredged material in coastal reclamation projects or as fill material inland. Depending on the potential site, reclamation or fill could involve landing, storage, dewatering, transport and possibly desalination. Coastal use directly from the dredging vessel would be preferable as this would involve pumping or spraying the material directly from the dredger or barge to the site where it was needed and would avoid handling and transporting the material on land.

3.4.2 Suitable Sites for Reclamation

Forth Ports, Marine Scotland and Falkirk Council are the most likely bodies to be responsible for or aware of reclamation projects in the Firth of Forth. No sites for coastal reclamation have been identified through the consultation process as requiring any of the dredged material at a time that fits with the dredging programme. In addition, the dredged material would not be suitable for many reclamation sites due to the low compressive strength properties of fine sediments. The spoil could be pumped into bunded lagoons at the edge of the Firth of Forth to create land that could be used for development, agricultural or similar purposes.

The majority of the intertidal area falls within the Firth of Forth Site of Special Scientific Interest (SSSI) and Outer Firth of Forth and St Andrews Bay Complex Special Protection Area (SPA). The SPA is a large estuarine/marine site consisting of the two adjacent Firths of Forth and Tay. NS has previously expressed the view on similar BPEO assessments that further loss of intertidal habitats is not considered a realistic option.

3.4.3 Construction Material

Use as fill in inland construction projects would not be appropriate because of low compressive strength properties of fine sediments and the need for landing, drying and transport of the dredged material. If landing, drying and transport were feasible then it may be that the material could be used for quarry/landfill capping. However, the potential presence of contaminants in the dredged material and its high salt content makes this option unattractive.

3.5 Spreading on Agricultural Land

3.5.1 Process Description

SEPA has previously confirmed that the disposal or recycling of marine dredged material on agricultural land does not fall within the exemptions under Paragraph 7 of Schedule 1 of the *Waste Management Licensing (Scotland) Regulations, 2011*, and the activity would therefore require to be licensed. Planning permission may also be required from the local authority. In support of the application to dispose of the dredged material to agricultural land, evidence that the material would not cause pollution of the environment or harm to human health would need to be provided.

The disposal of marine spoil to agricultural land would involve landing, dewatering, storage, desalination and transport for disposal. Dewatering the dredged material in lagoons, centrifugal drier or filter press would remove some of the salt; however it is likely that the desalination would still be required. Desalination could be achieved by placing the spoil in lagoons, layering it with sharp sand, spraying water over the material and allowing leaching of the salt back into the Firth of Forth.

Approximately 200,000 tonnes of sludge are recycled to agricultural land per annum across Scotland. Forth Ports are seeking to dispose of approximately 1,589,000 m^3 of dewatered material (approximately 1,827,350 tonnes at 1.15 tonnes m^{-3}) of dried material, equating to approximately 1,080% of the current volume of annually recycled sludge in Scotland.

As the material from Grangemouth has a low organic carbon content (an average of approximately 4.27% from the sediment sample analysis) spreading dredged material from Grangemouth on agricultural land is not considered a practicable option.

In addition, the material sampled at Grangemouth has contamination from some metals, TBT, PCBs and PAHs above Action Level 1 so the spoil cannot be applied to land without confirmation from SEPA that levels of these contaminants are acceptable. Some samples had concentrations of contaminants above Action Level 2 for some metals, particularly from the Carron Dock and Western Channel areas, however these areas are being excluded from the current Marine Licence application.

3.6 Sacrificial Landfill

3.6.1 Process Description

The type of landfill site which can take the spoil is dependent upon the classification of the waste. As discussed in Section 3.2.5 above, it is understood that the waste would be classified as non-hazardous rather than inert and therefore a suitably licensed landfill site with sufficient capacity is required.

3.6.2 Available Landfill Sites

Subsequent to implementation of the *Landfill Allowance Scheme (Scotland) Regulations 2005* and re-evaluation of landfill licences, there are currently two sites within an hour's drive from the Port of Grangemouth able to accept the material. A suitable landfill site is located at Avondale Landfill, Polmont, approximately seven kilometres southeast of the Port of Grangemouth. However, the Avondale site is not large enough to accommodate all of the dredged material and would only consider taking some of the dredged material upon closure of one or all of the phases within the plant.

Fife Council landfill site in Cupar, approximately 45 miles north of Grangemouth, also has the capability to accept non-hazardous material, although not the volume required [1].

(1) SEPA Landfill sites and capacity report for Scotland, 2014.

3.6.3 Taxes and Royalties

The material will be exempt from landfill tax under the terms of the Landfill Tax (Scotland) Act 2014 issued by the Scottish Government that specifies that dredged material from any inland waters, including harbours and their approaches, are not subject to landfill tax.

3.7 Incineration

3.7.1 Process Description

Incineration would involve landing the dredged material, dewatering, possibly storing it and transporting it to either an existing incinerator or a newly constructed incinerator. The ash would then require disposal. Options for disposal of ash include landfill, reclamation and spreading on agricultural land.

The organic content of the dredged material is assumed to be low (based on the 2022 samples which had an average percentage of organic carbon of 4.27% and range of 0.86 to 5.53%) and therefore there is only a small combustible component within the material. It is anticipated that incineration would result in a reduction in volume of the dried spoil by only 15% *i.e.,* 5% organics plus 10% water content. Incinerator operators generally require material to have an organic content above 20% to ensure efficient combustion and would most likely reject material with an organic content below this threshold (1).

A further consideration is that the material to be dredged contains some metals, TBT, PCBs and PAHs above Action Level 1 (and some metals above Action Level 2). Following incineration the leaching potential of metals would be reduced, however, the ash would still be contaminated. Pre-treatment is likely to be required for the removal of metals. Emissions to atmosphere from the incineration processes would also require to be controlled by SEPA under the *Environmental Protection Act 1990.*

3.7.2 Available Incinerator Sites

There are no appropriate waste incinerators in Scotland that could accept the dredged material. The nearest incinerator is at Ellesmere Port, Merseyside (approximately 408 km south) and transport would be costly and is unlikely to be practicable.

3.8 Other Disposal Options and Reuse

The other disposal options are re-injection into the tidal flats via a pipeline and reuse in brick making, concrete aggregate or topsoil production processes.

3.8.1 Re-injection

This would involve the construction of a pipeline to take the dredged material to a high tide point on the Kinneal mudflats and injecting it at velocity back into the mudflats. The advantage of this is that it effectively returns the sediment to its source. In addition to the high costs associated with the construction and operation of the pipeline, a disadvantage is that the re-injection at velocity would be likely to have an adverse impact on the protected mudflat habitat through disturbance and erosion and may affect the ornithological interest of the mudflats.

3.8.2 Brick Making/Concrete Aggregate/Topsoil Production

There are processes by which marine sediments can be made into bricks or can be used to form concrete aggregate. The advantage is that the materials can be beneficially used and metals are sealed into the bricks or aggregate, although there are issues with the salt content for brick making and concrete construction material. Previous consultations between Forth Ports and a brick making

(1) Baldovie Waste to Energy Plant, pers comm, January 2014

factory confirmed that the mineralogy of the material would not be appropriate for brick making and the contamination by salt would be unacceptable for any construction material.

Almost no agricultural species can grow in salty soils and very few in brackish soils. The salinity of the dredged sediment would require to be reduced naturally by rainwater or by a dewatering process before consideration for use as topsoil. The best topsoil is a mixture of sand, silt, clay and organic matter and must be clean for use in the production of food crops (1). This option would not be feasible at the Port of Grangemouth due to lack of necessary handling facilities and the potential contamination levels in the dredged spoil. In addition, there is no known demand for this material to be used in topsoil production.

3.9 Disposal to Sea

3.9.1 Process Description

Disposal at sea involves the dredge material being transported to a licensed disposal site in a dredging vessel. This approach takes place at sea and does not require the landing of any materials. Since the BPEO process commenced in 1997, disposal to sea has been the BPEO for the spoil arising from the maintenance dredge at Grangemouth, and at the other ports and harbours with the Forth Estuary and Firth. It involves the dredger sailing to a licenced disposal site and releasing the materials, usually by lowering the excavator head into the water or through bottom doors. A differential global positioning system (dGPS) would be used to position the vessel in the disposal area and records of the spoil discharge locations would be retained.

3.9.2 Available Sites

There are seven licenced marine disposal sites in the Forth Estuary and Firth of Forth; Bo'ness, Oxcars, Blae Rock, Kirkcaldy, Methil and two sites designated at Narrow Deep. For the dredging operations at Grangemouth, Forth Ports would propose to use the Bo'ness spoil ground located 1.4 nautical miles from the Port of Grangemouth. This site has historically been used for the disposal of dredged material from Grangemouth and is the closest site to the port, thus minimising the distance for vessel transport.

The current disposal operations relocate the spoil to the easternmost edge of the Kinneil mudflats. The same mudflats are eroded at their western end and the mud deposited into the Bellmouth. The dredged material is therefore likely to have similar properties to the seabed material at the disposal site.

The baseline environmental conditions and potential environmental impacts at the disposal site are described in *Appendix B*.

3.10 Conclusion

The description of the available options allows options that are evidently impracticable to be ruled out. This is summarised in *Table 3.3.* The assessment of the short-listed options taken forward for further consideration is presented in *Section 4.*

(1) Permanent International Association of Navigation Congresses. Permanent Technical Committee II. Working Group 19. 1992. Beneficial Uses of Dredged Material, Issue 19.

Table 3.1 Short-listing of Options

Option	Assessment	Result
Beach Nourishment	This option does not appear to be practicable. This option does not appear to be practicable. There are no beaches within the Forth Estuary or the Firth of Forth, identified by Forth Ports, consultees or in the NCCA (2017) [(1)] report that require nourishment with this type of sediment material.	Discard
Coastal Reclamation and Construction Fill	This option may be practical. The salt content, poor load bearing properties and the potential concentration of contaminants limits the available options for reuse of the dredged material.	Short-list
Spreading on Agricultural Land	This option does not appear to be practicable. The material is not desirable for disposal on agricultural land due to potentially containing concentrations of contaminants and having a low organic content. Furthermore, desalination, storage, dewatering and transport of this material are impractical. Disposal on agricultural land would require a Waste Management Licence and evidence that there would be no harm to human health.	Discard
Sacrificial Landfill	This option is practicable and there are two local sites. There is a large number of steps involved in storage, dewatering and transport. Landfill site operators may be unwilling to accept the material due to the sediment composition.	Short-list
Incineration	This option does not appear to be practicable. The material is not suited to incineration due to low organic content (<5%) and large volume of spoil involved. If incinerated, volume would only slightly reduce and there are no available incinerators in Scotland that could take this amount of material.	Discard
Other Uses	This option may be practicable in the form of brick making, concrete aggregate and topsoil production.	Short-list
Disposal at Sea	This option is practicable and has been the BPEO for the previous two dredging campaigns at the Port of Grangemouth.	Short-list

(1) Fitton JM, Rennie AF and Hansom JD (2017). Dynamic Coast - National Coastal Change Assessment: Cell 2- Fife Ness to Cairnbulg Point. CRW1014/2.

4. ASSESSMENT OF SHORT-LISTED DISPOSAL OPTIONS

4.1 Introduction

This section presents an assessment of each option against the assessment definitions of performance listed in *Table 2.1*.

The environmental effects of disposal at sea are addressed in *Appendix B.*

4.2 Coastal Reclamation and Construction Fill

4.2.1 Strategic Considerations

Operational Feasibility

The reuse of the dredged material for reclamation will involve either direct pumping from the dredger into the disposal site or landing and drying the material and desalination for disposal on land by HGV. This option may be practicable if disposal sites were available adjacent to or close to the Firth of Forth.

Classification: Medium

Availability of Sites

No coastal sites within the Firth of Forth requiring this grade of material for reclamation or construction fill have been identified by Forth Ports, consultees or in the latest Dynamic Coast – National Coastal Change Assessment (2017) [(1)].

Classification: Low

Security of Option

No sites have been identified as belonging to Forth Ports, so disposal to reclamation sites is out with their control and could present practical problems, such as scheduling in sediment delivery with proposed dredging programme.

Classification: Low to Medium

Established Practice

The use of suitable dredged materials, such as marine aggregates, in coastal reclamation and construction fill is common practice and the technologies and techniques to move such material are well established. However, the use of maintenance dredge spoil for such activities is not common.

Classification: Low-Medium

General Public Acceptability

Use of the dredged material for reclamation or construction fill is likely to be acceptable to the general public. There may be some concerns regarding the contamination levels in the dredge spoil and the volume of material to be transported by HGVs for reasons relating to air quality and proximity to residential areas. Transport by sea is likely to be viewed as more favourable than transport by land.

Classification: Medium to High

Likely Agency Acceptability

Use of the dredged material for reclamation or construction fill is likely to be acceptable to public agencies. There may be some concerns regarding the contamination levels in the dredge spoil with respect to the future use of any reclaimed areas, and the volume of material to be transported by HGVs for reasons relating to air quality and proximity to residential areas.

(1) Fitton, J.M., Rennie, A.F., and Hansom, J.D. (2017) Dynamic Coast - National Coastal Change Assessment: Cell 2 - Fife Ness to Cairnbulg Point, CRW2014/2

Classification: Medium to High

Legislative Implications

The disposal of dredged material from Grangemouth directly from the dredger to a reclamation site requires a Marine Licence from Marine Scotland under Section 20(1) of the Marine (Scotland) Act 2010.

Once the material has been removed from the Port of Grangemouth for disposal on land it will be classed as waste under the *Waste Management Licensing (Scotland) Regulations, 2011* and the disposal will therefore require a waste management licence and an exemption for reclamation works. As well as a Marine Licence for the construction works, consent will be required from the planning authority and a levy paid to the Crown Estate Scotland.

Classification: Medium to High

4.2.2 Health, Safety and Environmental Considerations

Public Health

Slight risks to public health are anticipated due to intermittent increase in HGV traffic.

Classification: Medium to High

Safety

Transferring the dredged material ashore has risks associated with operational activities, all of which have mitigation measures in place. Should the dredged material be transported by HGV, there may be an increase in safety risks associated with the movement of materials for disposal, particularly if tankers/sealed HGVs travel through populated areas and along minor roads.

Classification: Medium

Pollution / Contamination

The material may be classified as hazardous or non-hazardous (*i.e*. not inert) due to the concentration of contaminants with respect to land based disposal, however, further analysis would be required to confirm this and run-off and leaching would need to be controlled. There may be localised and temporary deterioration in air quality as a result of HGV movements.

Classification: Medium

Ecological Impacts

There are unlikely to be any ecological risks resulting from the use of dredged materials for reclamation, assuming any contaminants are contained within the site and there would be no significant impact on national or local priority species or habitats. If the site was to be used for terrestrial habitat creation, then the salt levels would limit plant growth.

Classification: Medium to High

Interference with Other Legitimate Activities

The disposal of dredged material is unlikely to interfere with other activities unless the reclamation site is in a port area, in which case the dredger may interfere with other port users, or if the area to be reclaimed was used for recreation. If HGVs are used to transport the dredged material, they may affect other road users.

Classification: Medium to High

Amenity/Aesthetic

If the dredged material is disposed of directly from the dredger there is no risk to amenities/aesthetics. If disposed of by HGV, landing, storage and transport may result in an impact to both amenities and aesthetics of the area.

Classification: Medium to High

4.2.3 Cost Considerations

If the dredged material was pumped directly ashore there would be no further capital costs. The estimated operational costs below would apply:

- operational costs for the operation of the dredger - £1 m per annum;
- Pumping material to site – approximately £14.88 million pumping costs (£8.75 per m^3 (1) for 1,700,000 m^3).

Total: £15.88 m.

Classification: Low

If the dredged material was pumped directly ashore there would be no further capital costs. If the dredged material was transported by road, the estimated costs below would apply.

- operational costs for the operation of the dredger - £1.4 m per annum;
- a discharge berth for the dredger with a storage facility - £3.5 m;
- lagoons to settle dredged material and possibly desalinate - £2.5 m; or
- dockside centrifuge facility capable of dewatering and desalinating 1,700,000 m^3 of silt per annum - £20-£30 m;
- loading and transport (sealed HGVs) – assuming the disposal site is less than one hour drive away and based on one HGV transporting 20 tonnes material at a cost of £100/hour(2): £9.14 m.

Total £16.54 m to £46.54 m.

Classification: Low

4.3 Sacrificial Landfill

4.3.1 Strategic Considerations

Operational Feasibility

Disposal to landfill would require the landing, storage and drying of the dredged materials prior to transporting to a landfill facility. Approximately 1,827,350 tonnes of dried material would require transport. This option has practical difficulties relating to drying the dredged material and transport of material to a landfill site.

Classification: Low to Medium

Availability of Sites / Facilities

The nearest suitable site is located at Avondale Landfill, Polmont, approximately 7 km from the Port of Grangemouth, however as discussed above, due to the dredged sediment composition and volume, Avondale would be unable to receive any of the material. In addition, the timing of receipt of material would need to fit in with its operational requirements when closing exiting landfill cells(3).

Under the *Landfill (Scotland) Regulations, 2003* the presence of contaminants will classify the material as *non-hazardous* rather than *inert* and consequently reduces the number of available landfill sites capable of accepting this material.

Classification: Low

Security of Option

(1) Based on previous consultation with contractors.
(2) Estimated cost based on consultation with HGV operator at £50/hour and estimated cost of loading at £50/hour.
(3) Avondale pers comm, February 2016.

Whilst Forth Ports have control over the dredging operations, it would have no control over the continued availability of landfill space for the material or the disposal route.

Classification: Low to Medium

Established Practice

Dredged material is sometimes disposed of to landfill for small one-off dredging operations, however it is not established practice to routinely dispose of large quantities of dredged material in this way. Landfill sites require the dredged material to be dried to 10% water content before acceptance. It is unlikely that this is a practice that would be acceptable if there are other viable alternatives.

Classification: Low to Medium

General Public Acceptability

Disposal of the material to landfill is likely to be acceptable to the general public. However, the transport of the dredged material from the Port of Grangemouth to potential landfill sites may be unacceptable to residents and other road users.

Classification: Medium to High

Likely Agency Acceptability

Scotland's Zero Waste Plan (2010) establishes the direction of the Scottish Executive's policies for sustainable waste management. One such policy is to reduce landfilling of waste to 5% of all wastes by 2025 and as such there may be objection to dredged material routinely requiring space in landfill. Disposal to nearby landfill sites is likely to be acceptable to SEPA provided the materials are regarded as suitable for landfill, however, the acceptability would depend on the quantities to be disposed of and further assessment and classification of hazardous substances.

Classification: Medium to High

Legislative Implications

The material would be controlled waste material for the purposes of transport, storage and disposal. As such, Section 34(7) of The Environmental Protection Act 1990 and Regulation 6 of the Pollution Prevention and Control (Scotland) Regulations 2012 will apply and compliance is likely to be possible. The disposal of the material will also require a waste management licence under Waste Management Licensing (Scotland) Regulations 2011.

Classification: Medium

4.3.2 Health, Safety and Environmental Consideration

Public Health

There may be a slight risk to public health due to the significant increase in HGV traffic may arise.

Classification: Medium

Safety

There may be an increase in safety risks associated with the movement of materials for disposal, particularly if tankers/sealed HGVs travel through populated areas and along minor roads.

Classification: Medium

Pollution/Contamination

There may be a small risk of leaching of contaminants being disposed of in landfill, however, these should be contained on site.

Classification: Medium to High

Ecological Impacts

Although there is a small risk of contaminants leaching out from the dredged material, this would be at very low concentrations and is unlikely to cause significant harm to the local ecology. The salt content in the material may prevent plant growth unless covered in a topsoil.

Classification: Medium to High

Interference with Other Legitimate Activities

The increase in HGV movements may interfere with other road users. Baseline traffic data for the A904 in the vicinity of the Port of Grangemouth indicates that in 2018 HGVs made up an average of 10% of all traffic of road traffic in and around Grangemouth. As a result of the proposed disposal to landfill, the total HGV movements would increase to 17% of all traffic in the vicinity of Grangemouth. Depending on the landing and storage arrangements there may be potential for interference with other harbour users.

Classification: Medium

Amenity/Aesthetic

The movement of HGVs through the area will have an impact on local amenity through noise, vibration, visual impacts and road congestion. This risk also applies to the disposal site.

Classification: Medium

4.3.3 Cost Considerations

Capital would be required to purchase new equipment. Estimates of the cost of this equipment are:

- operational costs for the operation of the dredger - £1.4 m per annum;
- a discharge berth for the dredger with a storage facility - £3.5 m;
- lagoons to settle dredged material and possibly desalinate - £2.5 m; or
- dockside centrifuge facility capable of dewatering and desalinating 1,700,000 m^3: £20 m - £30 m;
- loading and transport (sealed HGVs) – assuming the disposal site is less than one hour drive away and based on one HGV transporting 20 tonnes material at a cost of £100/hour(1): £9.14 m; and
- a Waste Management Licence.

Total £16.54 m to £46.54 m.

Classification: Low

4.4 Other Disposal Options and Reuse

4.4.1 Strategic Considerations

Operational Feasibility

Reuse for brick making, concrete aggregate or topsoil production would require the landing, storage and drying of the dredged materials prior to transporting to a landfill facility. Approximately 1,827,350 tonnes of dried material would require transport. There are practical difficulties relating to handling the dredged material at the Grangemouth site. The availability of suitable factories/facilities to process the dredged material and markets for the final products are also considerations.

Classification: Low to Medium

Availability of Sites/Facilities

(1) Estimated cost based on consultation with HGV operator at £50/hour and estimated cost of loading at £50/hour.

There are no known sites or facilities to receive the dredged material for other uses such as topsoil production, brick making or other construction materials.

Classification: Low

Security of Option

Although Forth Ports would have control over the dredging and landing, they would not have control over the continued acceptance of the materials for making bricks or aggregate.

Classification: Low to Medium

Established Practice

Use of excavated materials for brick making or concrete aggregate is common practice but use of marine material is not and it is generally not feasible due to the level of salinity and the composition of the material. Whilst topsoil has been made from dredged material in the past it is not common practice.

Classification: Low to Medium

General Public Acceptability

Making bricks, concrete or topsoil is likely to be publicly acceptable depending on the end use. However, the transport of the material over a large distance may not be acceptable to residents and other road users.

Classification: Medium to High

Likely Agency Acceptability

It is likely that brick making, concrete production and topsoil production would be acceptable to agencies and considered a positive activity. However, the contaminant levels in the samples would make using the material for topsoil unattractive.

Classification: Medium to High

Legislative Implications

SEPA would control emissions from brick making factories under the provisions of the Environmental Protection Act 1990. A waste management licence would also be required for their transport and storage under the Waste Management Licensing (Scotland) Regulations 2011.

Classification: Medium

4.4.2 Health, Safety and Environmental Considerations

Public Health

Slight risks to public health are anticipated due to the short-term increase in HGV traffic.

Classification: Medium

Safety

There are unlikely to be any significant safety risks associated with making bricks, concrete or topsoil with the exception that there may be an increase in safety risks associated with use of plant and manual handling of materials as well as the movement of materials, particularly if HGVs travel through settlements and along minor roads.

Classification: Medium

Pollution / Contamination

The contaminant levels in the dredged material would make using the material for topsoil unattractive. Pollution from plant emissions is not likely to be an issue provided emissions are controlled in accordance with licences.

Classification: Medium to High

Ecological Impacts

Making bricks or concrete should have no adverse ecological effects, provided the materials were decontaminated and desalinated before use.

Classification: High

Interference with Other Legitimate Activities

There is a slight risk that movement of the material would impact other road users.

Classification: Medium to High

Amenity/Aesthetic

The movement of HGVs through the area will have an impact on local amenity through noise, vibration, visual impacts and road congestion. This risk also applies to the disposal site.

Classification: Medium

4.4.3 Cost Considerations

An estimate of costs is provided below.

Capital would be required to purchase new equipment. Estimates of the cost of this equipment are:

- operational costs for the operation of the dredger - £1.4 m per annum;
- a discharge berth for the dredger with a storage facility - £3.5 m;
- lagoons to settle dredged material and possibly desalinate - £2.5 m; or
- dockside centrifuge facility capable of dewatering and desalinating 1,700,000 m^3: £20 m - £30 m; and
- loading and transport (sealed HGVs) – assuming the disposal site is less than one hour drive away and based on one HGV transporting 20 tonnes material at a cost of £100/hour(1): £9.14 m.

Total £16.54 m to £46.54 m.

Classification: Low

4.5 SEA DISPOSAL

4.5.1 Strategic Considerations

Operational Feasibility

Operationally disposal at the Bo'ness site is comparatively simple as it does not require the landing, storage and drying of the spoil and all the necessary procedures are understood. As the present discharge route, it has been proven and all necessary equipment and logistical arrangements are in place.

Classification: High

Availability of Sites / Facilities

(1) Estimated cost based on consultation with HGV operator at £50/hour and estimated cost of loading at £50/hour.

The sites/facilities which are required for the sea disposal option are those which are already used. No other disposal sites west of the bridges have been indicated by Forth Ports as available at this time for the Grangemouth dredged material.

Classification: High

Security of Option

Forth Ports will have full control over all stages in the dredging and disposal process assuming they receive a disposal licence.

Classification: Medium to High

Established Practice

Disposal at Bo'ness disposal site is the current established practice for the disposal of the dredged spoil from Grangemouth.

Classification: High

General Public Acceptability

Forth Ports has confirmed that similar disposal operations from other docks and harbours in the Firth of Forth and Forth Estuary have not attracted any appreciable comment. Dredging operations are unlikely to affect members of the general public, with the possible exception of some recreational users when the vessel is transiting to and from the disposal site.

Classification: High

Likely Agency Acceptability

Consultations with the regulatory bodies to date indicate that there is no objection to Sea Disposal at Bo'ness (comments made by consultees are provided in Appendix C).

SEPA has no objection should there be no other suitable reuse options. Marine Scotland has not expressed an objection to the continued use of Bo'ness disposal site. The Crown Estate did not raise an objection and will generally consent to disposal of dredged material at sea on the condition that all other relevant consents are obtained. Scottish Natural Heritage and the National Lighthouse Board did not highlight any objections to spoil disposal at sea.

The Forth District Salmon Fishery Board (FDSFB) highlighted concerns surrounding time of year of disposal coinciding with seaward migration of salmon smolts and requested that disposal is avoided during June and July. Due to the rate of sedimentation in the Bellmouth this cessation of dredging for a period of two months would not be possible. The suspended sediment maxima in the Forth Estuary is in the upper estuary in summer, where the smolts migrate through, and short term and localised increases in suspended sediment at the Bo'ness spoil ground is not considered to present a barrier to migration. This issue is addressed in *Appendix B*.

Classification: Medium to High

Legislative Implications

A Marine Licence will be required from Marine Scotland and provided that the BPEO is satisfactory, and the statutory consultees do not object, it is established practice that a Marine Licence will be issued. Compliance should not therefore demand significant management control. Permission will be required from The Crown Estate for disposal of spoil to The Crown Estate owned sea bed, and under the provisions of the Marine (Scotland) Act 2010 it has the right to veto any consent for works in tidal waters which may constitute a hazard to navigation.

Classification: Medium to High

4.5.2 Health, Safety and Environmental Considerations

Safety

The operations are undertaken at sea, therefore members of the public are not likely to be exposed to risk from the disposal activities. The contractor appointed to undertake the dredging and disposal may be subject to a health, safety and environmental audit by Forth Ports.

Classification: High

Public Health

The risk of members of the general public being exposed to contamination from the dredged material is regarded as low. Commercial species of demersal fish are not taken from the area and no food chain links between sediment contamination or contamination liberated into the water column, and human consumers leading to impacts on public health are considered unlikely.

Classification: Medium to High

Pollution/Contamination

The effects on water quality of the disposal operations and the potential for impacts on sediment contamination may cause the occasional exceedance of Environmental Quality Standards and Objectives although this will be localised and short-term.

Classification: Medium

Ecological Impacts

The disposal operations may affect the benthic fauna in proximity to the disposal site due to sediment drifting from the disposal area itself. It is anticipated that there will not be any significant impact on the Forth marine ecosystem as a whole given the scale and duration of effects. There may be some localised and short-term effects such as displacement on migrating fish due to increased suspended sediments caused by the discharge of dredged material into the water column, but these impacts are not predicted to prevent migration, cause mortalities or affect the viability of fish populations. This is discussed in *Section 4.5.1* and *Appendix B*. Under the proposed disposal proposals, cumulative impacts with other operations are not predicted to create a significant impact to the Firth of Forth SPA, Forth Islands SPA, Firth of Forth SSSI, SACs farther afield or marine ecosystems.

The ecological impacts of disposal of dredged material to sea is addressed in *Appendix B.*

Classification: Medium to High.

Interference with Other Legitimate Activities

The disposal activities may cause some disruption to other users of the estuary the dredging works contribute to the functioning of the Port of Grangemouth and are controlled directly by Forth Ports resulting in overall positive impacts. In addition, historic operations at Bo'ness have not resulted in any reported disruption to other Forth Estuary users.

Classification: High

Amenity/Aesthetic

The disposal activities may cause some short term disruption to other users of the Forth Estuary but the proposals will contribute to the normal functioning of the Port of Grangemouth and maintain its capacity to accommodate larger vessels.

Classification: Medium to High

4.5.3 Cost Considerations

There would be no capital required to purchase new equipment.

Operational costs for the operation of the dredger are approximately £1.4 million per annum.

Classification: High

5. Summary of the BPEO

5.1 Introduction

This section summarises the assessment of options against the criteria described in Chapter 2: *Table 2.1* and identifies the BPEO.

5.2 Comparison of Options

Seven options were initially considered for the disposal of the dredged spoil from the Port of Grangemouth. These were reduced to a short-list of four options based on practicality. A summary of the key considerations with regard to each of the four short-listed options is provided below and illustrated in *Table 5.1*.

5.2.1 Sacrificial Landfill

Operationally, disposal to landfill will be achievable but problematic. The dredged materials would require landing and drying in specially constructed facilities and would then require transport in sealed HGVs to an appropriate landfill site. There are limited sites available to take the material, and a full analysis of the contaminants in the material would be required by the operators before final acceptance.

Whilst small amounts of dredged sediment material are sometimes disposed of to landfill, it is not common practice and Forth Ports would not have the security of controlling the disposal route. The public and agencies are likely to find this disposal acceptable, but there may be concerns relating to transport and Scotland's Zero Waste Plan (2010) which favours a reduction in the volume of material disposed by landfill (to 5% of all wastes by 2025).

The requirement for transport will result in some safety and public health risks and interference with legitimate activities and there is low risk of ecological disturbance. There would be an increase in traffic volume due to HGV movements, along with elevated carbon dioxide emissions. The costs of this option outweigh the other short-listed options, due to the requirement for construction of a landing and storage facility, a drying facility and high transport costs.

5.2.2 Coastal Reclamation and Construction Fill

Operationally coastal reclamation and construction fill would be possible. The sediment is primarily sandy mud, with some gravel fractions with low compressive strength properties, making it unsuitable for most types of construction. In addition, the presence of some metals, TBT, PCBs and PAHs classes it as non-hazardous (1) rather than inert which restricts its suitability for application on land.

Currently there are no significant areas of coastal reclamation planned in the Firth of Forth or Forth Estuary. The costs of this option would be high due to the requirement for construction of a landing and storage facility, a drying facility and transport costs.

5.2.3 Other Disposal Options and Reuse

Operationally this option would be achievable but there would be difficulties associated with the requirement to land, store, dry and transport the material. Forth Ports would have limited control over the option and it is not common practice to use marine dredged material for these purposes. It is likely to be viewed as an attractive option by the public and agencies and no legislative issues are anticipated. There would be potential for benefit through substitution of recycled material for primary minerals.

Environmental and public health and safety concerns associated with this option are linked to transport of the materials and are anticipated to be minimal. There will be no significant impact on amenity and little interference with other legitimate users. As with Sacrificial Landfill, Coastal

(1) Waste Classification (2015). Guidance on the classification and assessment of waste (1st edition 2015). Technical Guidance WM3.

Reclamation and Construction Fill, capital costs would be high because of the need for landing, storage and drying facilities and transport costs.

The mineralogical composition and salinity of the material limit its suitability for use for brick making, as concrete aggregate or in topsoil production as it would require treatment to desalinate and decontaminate the material.

5.2.4 Sea Disposal

Operationally few problems are anticipated with disposal at Bo'ness and this site is has been historically used for disposal of dredged materials from Grangemouth and other harbours and docks within the Firth of Forth and Forth Estuary. It is anticipated that this option will be acceptable to both public and agencies. Forth Ports would have full control over the dredging process through the appointment of contractors and risks to safety and public health are anticipated to be low.

There will be some short-term effects on water quality during disposal, such as raised turbidity and suspended sediment levels, which may have slight ecological effects but these are considered to be of minor significance. There is unlikely to be interference with other legitimate activities and there is not anticipated to be any impact on local amenity.

5.3 Identification of the BPEO

The assessment of options highlights the major operational difficulties associated with the landfill and other use options that primarily relate to lack of available sites and facilities and the nature of the material. There are also major costs associated with the need to construct landing, storage and drying facilities at the Port of Grangemouth.

The areas with elevated metal concentrations above Action Level 2 have been excluded from the Marine Licence application area or will be avoided during dredging operations. The concentrations of contaminants analysed for in the areas to be dredged are similar to the results from previous surveys at Grangemouth and other ports in the Forth Estuary and Firth of Forth where disposal at sea has been the agreed BPEO. The proposed project supports the objectives set out in Scotland's National Marine Plan and will continue to maintain and support the sustainable development of the Port of Grangemouth and enable it to continue to operate as Scotland's largest container port and, in turn, supporting the national economy.

Disposal at sea will keep the dredged material within the ecosystem, maintaining the sediment budget for the area. In line with guidance from Marine Scotland, the Best Practicable Environmental Option is identified as the disposal at a licensed sea disposal site. The preferred site for this is the Bo'ness disposal site.

Table 5.1 Summary of Assessment of Options

Consideration	Coastal Reclamation and Construction Fill	Sacrificial Landfill	Other Disposal Options and Reuse	Sea Disposal
Operational feasibility	Medium	Low to Medium	Low to Medium	High
Availability of sites/facilities	Low	Low	Low	High
Security of option	Low to Medium	Low to Medium	Low to Medium	Medium to High
Established practice	Low to Medium	Low to Medium	Low to Medium	High
General public acceptability	Medium to High	Medium to High	Medium to High	High
Likely agency acceptability	Medium to High	Medium to High	Medium to High	Medium to High
Legislative implications	Medium	Medium	Medium	Medium to High
Safety	Medium	Medium	Medium	High
Public health	Medium	Medium	Medium	Medium to High
Pollution / contamination	Medium	Medium	Medium	Medium
Ecological impact	Medium to High	Medium to High	High	Medium to High
Interference with other activities	Medium to High	Medium	Medium to High	High
Amenity / aesthetic	Medium to High	Medium	Medium	Medium to High
Capital and maintenance costs	Low	Low	Low	High

Key: Performance of Options	
Low	
Low to Medium	
Medium	
Medium to High	
High	

APPENDIX A SEDIMENT SAMPLE CHEMICAL ANALYSIS

A1 GRANGEMOUTH SEDIMENT SAMPLE DATA

A1.1 Introduction

Samples of the seabed sediments to be dredged were collected from the harbour and approach channel seabed by ERM and Forth Ports on 29th and 30th March 2022 and were analysed by Socotec UK Ltd.

The survey plan followed the Marine Scotland guidance and was agreed with Marine Scotland. Based on the dredging depths of up to 1 m and estimated dredge volumes, surface samples from 29 sample stations were required. Following the initial analysis additional samples were collected by Forth Ports from locations where elevated levels of some metals were recorded. An additional nine samples were collected on the 20th June 2022 for metal analysis by Socotec. Sample station locations for all samples are presented in *Figure A1.1*.

Samples were taken using a van Veen grab and the sample retrieved from each survey station was subsampled on deck and stored in pre-cleaned sample containers provided by Socotec.

Each sample was labelled with a unique sample ID and a field log was kept to record the sample location, date and time sample was taken. Sediment photographs are presented in *Figure A1.2*. Photographs were not available for all samples.

Samples were sent by courier to the analytical laboratory for following chemical analysis:

- sediment particle size distribution;
- sediment solids content and density;
- total organic carbon (TOC);
- a suite of metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead, zinc);
- Tributyl Tin (TBT);
- Poly Chlorinated Biphenyls (PCB); and
- Polycyclic Aromatic Hydrocarbons (PAH).

Marine Scotland Action Levels are discussed in Section A1.2 and the sediment sample data are presented in Section A1.3 to Section A1.8. *Table A1.1* presents the locations of the sediment samples taken from the Port of Grangemouth. As stated in Chapter 1, the areas where samples 23 to 29 and 33 to 38 were collected from are being excluded from the Marine Licence Application area.

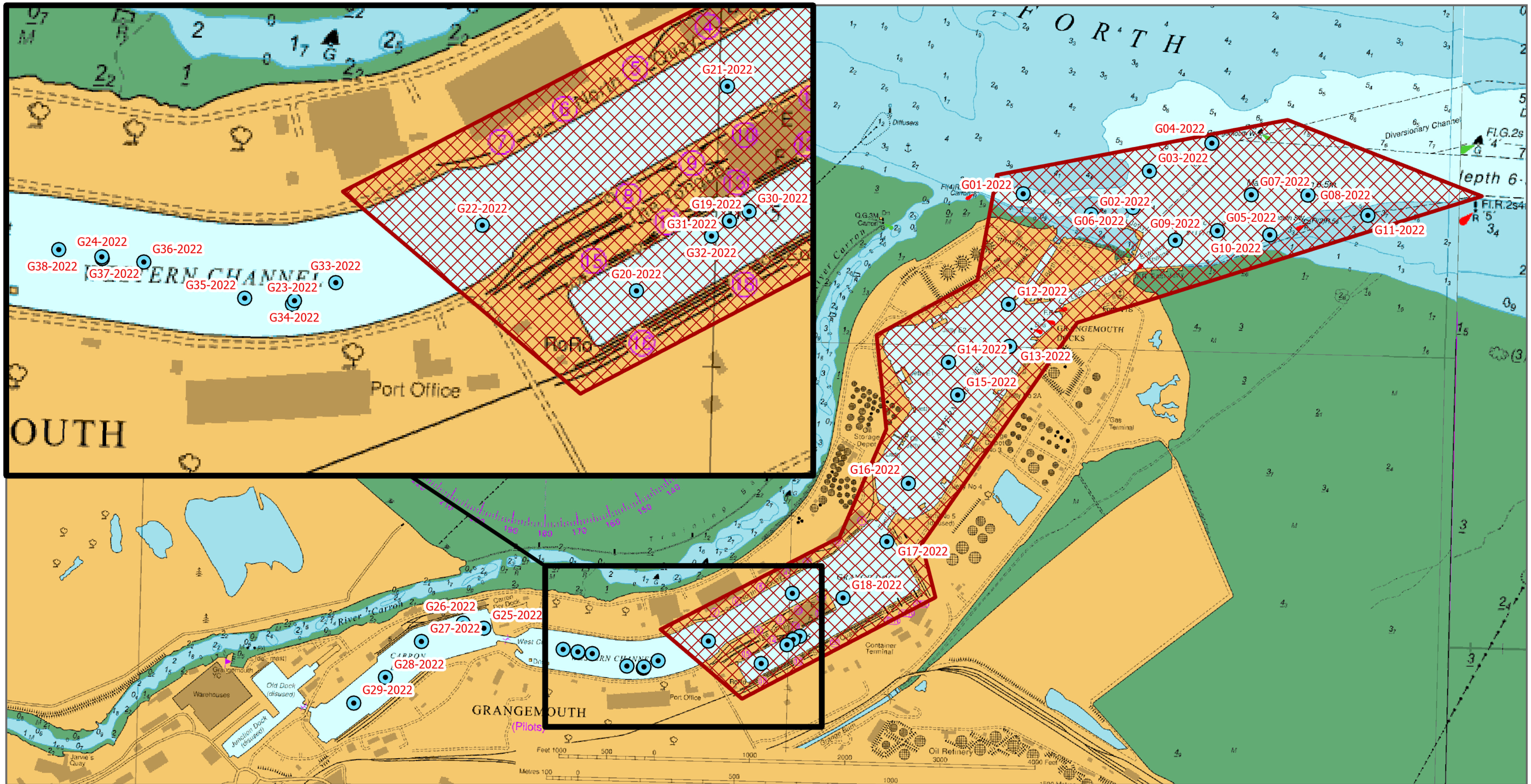
Table A1.1 Location of Initial Sediment Samples

Station name	Latitude	Longitude
Bellmouth		
G01-2022	56°2.265'	3°41.312'
G02-2022	56°2.232'	3°41.101'
G03-2022	56°2.309'	3°40.925'
G04-2022	56°2.360'	3°40.735'
G05-2022	56°2.209'	3°40.711'
G06-2022	56°2.246'	3°40.973'
G07-2022	56°2.273'	3°40.610'
G08-2022	56°2.274'	3°40.435'
G09-2022	56°2.191'	3°40.840'
G10-2022	56°2.204'	3°40.550'
G11-2022	56°2.242'	3°40.249'
Eastern Channel		
G12-2022	56°2.074'	3°41.349'
G13-2022	56°2.001'	3°41.343'
G14-2022	56°1.971'	3°41.530'
G15-2022	56°1.915'	3°41.499'
G16-2022	56°1.761'	3°41.644'
Grange Dock		
G17-2022	56°1.660'	3°41.706'
G18-2022	56°1.560'	3°41.836'
G19-2022	56°1.486'	3°41.987'
G20-2022	56°1.444'	3°42.083'
G21-2022	56°1.566'	3°41.993'
G22-2022	56°1.480'	3°42.248'
Western Channel		
G23-2022	56°1.431'	3°42.446'
G24-2022	56°1.455'	3°42.648'
Carron Dock		
G25-2022	56°1.493'	3°42.940'
G26-2022	56°1.500'	3°43.004'
G27-2022	56°1.467'	3°43.131'
G28-2022	56°1.404'	3°43.239'
G29-2022	56°1.358'	3°43.335'

Table A1.2 Location of Additional Sediment Samples

Station name	Latitude	Longitude
Grange Dock		
G30-2022	56°1.492'	3°41.967'
G31-2022	56°1.486'	3°41.987'
G32-2022	56°1.477'	3°42.006'
G33-2022	56°1.444'	3°42.401'
G34-2022	56°1.433'	3°42.444'
G35-2022	56°1.434'	3°42.497'
Western Channel		
G36-2022	56°1.453'	3°42.604'
G37-2022	56°1.456'	3°42.649'
G38-2022	56°1.460'	3°42.694'

Coordinates in degrees, decimal minutes, WGS84



Sample Location

Maintanence Dredging Site

0 100 200 300 400 500
Metres

N

Figure A1.1

Port of Grangemouth Sample Stations

SCALE: See Scale Bar	VERSION: A01
SIZE: A4	DRAWN: HD
PROJECT: 0352017	CHECKED: GB
DATE: 12/04/2022	APPROVED: MI

ERM

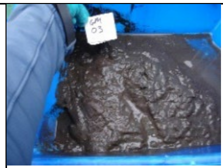
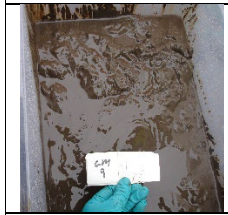
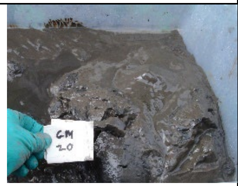
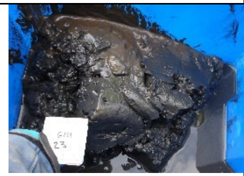
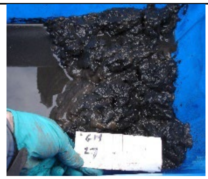
CLIENT:

Forth Ports Ltd.

PROJECTION: British National Grid

Path: \\UKLDCFS01\Data\Edinburgh\Projects\0352017 Forth Ports Grangemouth2016.MI\2022 survey&BPEO\00 GIS\Maps\0352017_Grangemouth_A03\0352017_Grangemouth_A03.aprx

Figure A1.2 Photographs of Sediment Samples

No Photo							
G01-2022	**G02-2022**	**G03-2022**	**G04-2022**	**G05-2022**	**G06-2022**	**G07-2022**	**G08-2022**
	No Photo	No Photo					
G09-2022	**G10-2022**	**G11-2022**	**G12-2022**	**G13-2022**	**G14-2022**	**G15-2022**	**G16-2022**
							
G17-2022	**G18-2022**	**G19-2022**	**G20-2022**	**G21-2022**	**G22-2022**	**G23-2022**	**G24-2022**
							
G25-2022	**G26-2022**	**G27-2022**	**G28-2022**	**G29-2022**			

Photographs were not available for all samples

A1.2 Marine Scotland Action Levels

Table A1.3 and *Table A1.4* set out the Action Levels for metals, PCBs, TBT and PAHs used by Marine Scotland to assess the suitability for disposal of sediments at sea.

In general, contaminant levels in dredged material below Action Level 1 are of no concern and are unlikely to influence the licensing decision. A breach of Action Level 1 does not automatically preclude disposal at sea but usually requires further consideration before a decision can be made. Dredged material with contaminant levels above Action Level 2 is generally considered unsuitable for normal sea disposal but may be suitable for other management options such as treatment or seabed burial/capping, unless a compelling case can be made for normal sea disposal.

Table A1.3 Marine Scotland Action Levels: Metals

Metal	AL1 ($mgkg^{-1}$ dry weight)	AL2 ($mgkg^{-1}$ dry weight)
Arsenic	20	70
Cadmium	0.4	4
Chromium	50	370
Copper	30	300
Mercury	0.25	1.5
Nickel	30	150
Lead	50	400
Zinc	130	600

Table A1.4 Marine Scotland Action Levels: PCBs, TBT and PAHs

Determinand	AL1 ($mgkg^{-1}$ dry weight)	AL2 ($mgkg^{-1}$ dry weight)
ICES 7 PCBs	0.02	0.18
TBT	0.10	0.50
PAHs		
Naphthalene	0.10	
Phenanthrene	0.10	
Anthracene	0.10	
Fluoranthene	0.10	
Pyrene	0.10	
Benz[a]anthracene	0.10	
Chrysene/Triphenylene	0.10	
Benzofluoranthenes	0.10	
Benzo[a]pyrene	0.10	
Indenopyrene	0.10	
Benzoperylene	0.10	
Acenaphthylene	0.10	
Acenaphthene	0.10	
Fluorene	0.10	
Dibenz[a,h]anthracene	0.01	
Total PAHs	100	

A1.3 Metal Results

Concentrations of metals are presented in *Table A1.5*. Levels above Marine Scotland Action Level 1 are highlighted in blue and concentrations above Action Level 2 are highlighted in red. The mean and range of concentration of metals for all samples analysed are presented as well as the mean and range of concentrations of metals from samples collected within the Marine Licence application area.

Table A1.6 provides a comparison of metal data from samples analysed between 1988 and 2022. The ranges in results for all metals over the period for which there is available sample data are large. Mean mercury (Hg) levels were higher than Action Level 2 (1.5 mg kg^{-1}) on three occasions: 989, 1999 and 2003.

Table A1.5 Metals (mg kg^{-1} Dry Weight) from Port of Grangemouth 2022

Station	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Bellmouth								
G01-2022	13.2	0.20	50.6	27.9	0.59	27.3	44.8	118
G02-2022	13.9	0.15	52.8	27.4	0.61	27.7	46.5	120
G03-2022	17.7	0.22	55.0	29.8	0.63	29.1	51.8	126
G04-2022	16.1	0.17	51.1	27.6	0.55	26.9	45.4	116
G05-2022	16.2	0.20	57.5	30.5	0.67	29.8	52.6	130
G06-2022	13.8	0.17	49.8	26.2	0.58	26.1	44.9	113
G07-2022	17.8	0.20	56.1	32.1	0.62	29.2	54.7	139
G08-2022	16.4	0.19	54.6	30.3	0.66	27.8	50.9	121
G09-2022	17.9	0.20	63.1	33.6	0.74	32.2	57.2	144
G10-2022	16.8	0.19	62.1	32.4	0.69	31.9	54.2	139
G11-2022	14.1	0.17	53.1	25.9	0.58	27.6	46.4	117
Eastern Channel								
G12-2022	16.5	0.15	59.5	40.4	0.72	30.3	52.4	145
G13-2022	15.6	0.20	59.8	40.5	0.72	30.7	53.5	145
G14-2022	4.3	<0.04	16.6	11.8	0.18	8.2	13.6	39.1
G15-2022	14.0	0.16	56.9	39.8	0.70	29.0	52.4	140
G16-2022	17.6	0.29	84.8	70.4	1.37	36.1	76.4	223
Grange Dock								
G17-2022	13.9	0.23	63.3	66.9	0.91	32.2	66.0	185
G18-2022	21.4	0.18	47.3	37.5	0.28	35.3	24.0	105
G19-2022	18.0	0.52	76.4	95.2	1.92	35.5	171	302
G30-2022*	14.8	0.32	68.1	92.4	1.39	34.6	165	256
G31-2022*	16	0.31	71.8	95.6	1.6	35.8	108	266
G32-2022*	16.5	0.31	74.1	95.9	1.35	39.9	158	301
G20-2022	15.2	0.46	60.9	85.6	1.23	29.9	127	309
G21-2022	14.8	0.28	74.5	92.8	1.18	35.1	74.9	225
G22-2022	13.9	0.32	72.3	97.0	1.33	31.9	81.8	241
G23-2022	16.2	0.27	84.1	104	1.63	34.5	79.9	237
G33-2022*	16.6	0.23	92.4	120	1.66	36.8	91.2	285
G34-2022*	17.1	0.22	90.4	108	1.54	38.9	81.2	249
G35-2022*	19.1	0.31	135	145	2.9	38.9	112	328
Western Channel								
G24-2022	24.8	0.60	128	140	5.20	34.2	135	351
G36-2022*	21.7	0.43	159	144	6.66	37.4	169	295
G37-2022*	17.7	0.25	109	150	2.35	39.1	104	314
G38-2022*	21.7	0.37	105	95	4.05	37.7	125	242
Carron Dock								
G25-2022	19.0	0.41	97.0	389	2.16	37.4	446	2178
G26-2022	15.2	0.28	79.8	143	1.69	33.5	108	314
G27-2022	17.6	0.30	84.6	147	1.99	36.3	125	290
G28-2022	14.7	0.26	73.8	118	1.75	33.0	119	243
G29-2022	12.8	0.21	62.4	93.0	1.18	31.6	88.1	198
Mean and Range of all Samples								
Mean	16.33	0.27	73.49	83.72	1.49	32.35	93.6	257.61
Range	4.3-24.8	0.2-0.6	16.6-159	11.8-389	0.2-6.7	8.2-39.94	13.6-446	39.1-2178

Station	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Mean and Range for Samples in Application Area (Stations 1-22 and 30-32)								
Mean	15.46	0.24	59.68	51.42	0.87	30.40	70.94	170.60
Range	4.3-21.4	0.15-0.52	16.6-84.8	11.8-97	0.18-1.92	8.2-39.9	13.6-171	39.1-309

As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Hg = Mercury, Ni = Nickel, Pb = Lead and Zn = Zinc.

Table A1.6 Metals (mg kg^{-1} Dry Weight) from the Port of Grangemouth 1988 to 2022

Year		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1988	Mean	17.5	0.3	91.6	41.8	1.3	24.5	53.6	116.0
	Range	8.6-43.6	0.0-0.5	25.5-170.0	4.8-74.4	0.2-2.8	12.0-36.4	15.8-92.0	48.6-185.0
1989	Mean	13.0	0.1	120.6	65.4	1.8	29.1	72.8	173.7
	Range	0.1-29.8	0.0-0.7	19.1-211.0	8.1-94.1	0.2-3.8	9.6-36.8	23.5-93.4	69.5-337.0
1990	Mean	11.7	0.0	83.9	65.6	1.1	27.7	72.8	158.8
	Range	8.2-14.1	0.0	71.1-112.0	52.0-88.3	0.0-2.3	25.1-29.1	54.5-89.4	122.0-231.0
1991	Mean	7.7	0.5	64.8	47.5	ND	26.3	70.4	135.7
	Range	0.0-20.0	0.0-0.8	18.2-80.4	14.4-59.2	ND	10.3-34.3	37.2-83.3	84.0-156.0
1993	Mean	10.9	0.0	52.5	50.8	1.2	29.0	72.6	142.1
	Range	10.5-11.3	0.0	45.2-72.6	39.6-71.4	0.9-1.8	25.7-34.8	58.9-90.2	119.0-208.0
1994	Mean	7.2	0.1	67.1	50.6	1.2	33.0	70.5	130.7
	Range	3.6-18.1	0.1-0.1	20.4-94.6	14.6-65.8	0.3-1.6	19.6-40.3	49.1-86.8	89.4-176.0
1999	Mean	16.7	0.2	73.2	53.5	1.7	44.3	71.3	157.1
	Range	8.3-18.8	0.1-0.3	47.1-93.3	34.6-76.3	0.7-3.8	18.6-80.7	49.4-88.2	95.5-236.0
2000	Mean	14.4	0.1	67.4	47.4	1.1	30.8	63.8	124.5
	Range	3.4-17.3	0.0-0.3	11.9-102	10.9-79.9	0.0-2.0	14.2-37.8	9.3-79.9	28.9-197.0
2001	Mean	16.6	0.2	75.2	47.7	1.3	36.0	80.4	142.7
	Range	14.4-18.2	0.1-0.3	60.7-117	36.4-79.3	1.0-3.3	31.7-40.6	68.4-94.3	122.0-185.0
2003	Mean	15.8	0.2	69	48.9	1.5	33.4	74.5	144.5
	Range	14.7-17.5	0.2-0.2	62.4-80.7	41.4-63.7	1.4-1.6	30.5-37.4	67.6-84.5	127.4-181.7
2004	Mean	17.2	0.1	69.7	44.1	1.2	34.2	75.4	148.9
	Range	14.8-18.5	0.0-0.4	56.4-79.9	34.1-57.1	0.9-1.4	29.6-36.9	64.8-79.0	122.6-179.5
2006	Mean	17.3	BDL	56.7	32.2	0.5	25.9	55.2	111.1
	Range	11.4-37.3	BDL	10.7-86.9	3.0-55.6	0.1-0.7	7.6-35.9	17.5-76.8	36.1-167.6
2007	Mean	14.4	BDL	68.8	41.1	0.8	32.5	62.2	128.8
	Range	11.9-16.1	BDL	53.1-83.8	27.2-89.7	0.5-1.2	27.3-36.9	49.0-77.9	103.0-190.0
2008	Mean	15.0	BDL	72.5	41.2	0.9	36.3	69.5	142.5
	Range	14.8-15.1	BDL	69.4-75.5	34.7-47.6	0.7-1.0	34.6-37.9	65.0-74.0	127.0-158.0
2010	Mean	16.0	0.2	68.4	41.0	1.3	33.7	73.0	156.7
	Range	15.5-16.6	0.2-0.2	56.2-80.6	29.1-52.8	1.0-1.6	30.2-37.3	64.3-81.8	126.8-186.7
2011	Mean	16.6	0.2	78.5	37.4	1.2	35.4	81.3	157.9
	Range	16.4-16.8	0.2-0.2	75.8-81.3	35.7-40.2	1.1-1.2	34.4-36.9	79.9-83.6	153.5-166.2
2016	Mean	16.7	0.1	75.2	48.9	0.7	34.9	65.2	165.3
	Range	12.4-20.2	0.1-0.2	42.1-117	14.6-353	0.3-1.4	20.7-49.5	36.6-209	79.5-743.0
2019	Mean	16.9	0.3	64.2	86.8	0.9	33.0	73.6	213.7
	Range	12.5-33.2	0.1-1.2	29.0-121	15.8-326	0.2-3.1	18.5-41.3	30.0-174.0	82.3-549.0
2022	Mean	15.46	0.24	59.68	51.42	0.87	30.40	70.94	170.60
	Range	4.3-21.4	0.15-0.5	16.6-84.8	11.8-97	0.18-1.9	8.2-39.9	13.6-171	39.1-309
1998-2022	**Mean**	**14.63**	**0.18**	**73.3**	**51.4**	**1.18**	**32.2**	**71.1**	**153.1**
	Range	**0.0-43.6**	**0.0-1.2**	**10.7-211**	**3.0-353**	**0.0-1.8**	**7.6-80.6**	**9.3-209**	**28.9-743**

A1.4 Polychlorinated Biphenyls Results

Polychlorinated biphenyls (PCBs) are organic compounds comprising a biphenyl group (composed of two benzene rings) with between one and ten bonded chlorine atoms. PCBs are highly toxic, persistent pollutants and are readily bioaccumulated in animals. Although production in the UK ceased in the 1970s, PCBs still enter the marine ecosystem through the disposal of industrial plant, emissions from old electrical equipment and from landfill sites (1).

Dry weight concentrations of ICES 7 PCBs from samples collected in 2022 are presented in *Table A1.7*. Nine stations exceeded Action Level 1 (0.02 mg kg^{-1}) for the sum of the ICES 7 PCBs, all of which were located in the inner docks (Stations G19-2022, G20-2022 and G22-2022 to G28-2022). Station G25-2022 had highest ICES 7 PCB concentration. No ICES 7 PCB levels exceed Action Level 2 (0.18 mg kg^{-1}) in any of the samples. The mean concentration of PCBs in the samples analysed within the Marine Licence Application Area (Station 1-22) is below Action Level 1.

Table A1.7 PCBs (mg kg^{-1} Dry Weight) from the Port of Grangemouth 2022

Station	Sum of ICES 7 PCB Concentrations
G01-2022	0.00546
G02-2022	0.00627
G03-2022	0.00448
G04-2022	0.00422
G05-2022	0.00663
G06-2022	0.00635
G07-2022	0.00635
G08-2022	0.00542
G09-2022	0.00619
G10-2022	0.00624
G11-2022	0.00562
G12-2022	0.00676
G13-2022	0.00705
G14-2022	0.00706
G15-2022	0.01025
G16-2022	0.01621
G17-2022	0.01344
G18-2022	0.00237
G19-2022	0.03801
G20-2022	0.04699
G21-2022	0.01711
G22-2022	0.02244
G23-2022	0.02417
G24-2022	0.07378
G25-2022	0.13141
G26-2022	0.03305
G27-2022	0.0303
G28-2022	0.02212

(1) Forth Replacement Crossing: Environmental Statement 2009. Available online from http://www.transportscotland.gov.uk/strategy-and-research/publications-and-consultations/j11223-081.htm

Station	Sum of ICES 7 PCB Concentrations
G29-2022	0.01744
Men and Range for all Samples Analysed	
Mean	**0.02011**
Range	**0.00237- 0.13141**
Mean and Range for Samples within Application Area (Stations 1-22)	
Mean	**0.011**
Range	**0.00237-0.04699**

ICES 7 PCB congeners (with IUPAC numbers): 28 - 2,4,4' - Trichlorobiphenyl, 52 - 2,2',5,5' - Tetrachlorobiphenyl, 101 - 2, 2', 4, 5, 5' - Pentachlorobiphenyl, 118 - 2, 3', 4, 4', 5 - Pentachlorobiphenyl, 138 - 2, 2', 3, 4, 4', 5' - Hexachlorobiphenyl, 153 - 2, 2', 4, 4', 5, 5' - Hexachlorobiphenyl, 180 - 2, 2', 3, 4, 4', 5, 5' - Heptachlorobiphenyl.

Mean dry weight concentrations of PCBs from samples collected between 1994 and 2022 are presented in *Table A1.8.* Levels above Marine Scotland Action Level 1 for the mean PCB concentrations are highlighted in blue.

Table A1.8 PCBs from the Port of Grangemouth (mg kg^{-1} Dry Weight) 1994 - 2022

Year	Sum of ICES 7 PCB Concentrations
1994	0.020
1999	0.016
2001	0.010
2004	0.013
2006	0.007
2007	0.012
2008	0.008
2010	0.020
2016	0.009
2019	0.030
2022	0.011
Mean 1994-2022	**0.0142**
Range 1994-2022	**0.007- 0.030**

ICES 7 PCB congeners (with IUPAC numbers): 28 - 2,4,4' - Trichlorobiphenyl, 52 - 2,2',5,5' - Tetrachlorobiphenyl, 101 - 2, 2', 4, 5, 5' - Pentachlorobiphenyl, 118 - 2, 3', 4, 4', 5 - Pentachlorobiphenyl, 138 - 2, 2', 3, 4, 4', 5' - Hexachlorobiphenyl, 153 - 2, 2', 4, 4', 5, 5' - Hexachlorobiphenyl, 180 - 2, 2', 3, 4, 4', 5, 5' - Heptachlorobiphenyl.

A1.5 Polycyclic Aromatic Hydrocarbons

Levels of PAHs are presented in *Table A1.9.* Levels above Marine Scotland Action Level 1 for individual PAHs are highlighted in blue. The Total Hydrocarbon (THC) concentrations are also reported (in $mgkg^{-1}$). There are no Action Levels for THC. A comparison of mean dry weight concentrations of PAHs from samples collected between 2003 and 2022 are presented in *Table* A1.10. Levels above Marine Scotland Action Level 1 for individual PAHs are highlighted in blue.

Table A1.9 Analysis of PAHs from the Port of Grangemouth in 2002 (ug kg^{-1} Dry Weight)

Station	G01-2022	G02-2022	G03-2022	G04-2022	G05-2022	G06-2022	G07-2022	G08-2022	G09-2022	G10-2022	G11-2022	G12-2022	G13-2022	G14-2022	G15-2022
LMW PAH															
Acenaphthene	38.4	44.9	31.8	26.7	32.6	24.8	29.4	27.9	26.9	21.4	24.1	39.3	31.8	45.9	39.2
Acenaphthylene	39	44.6	44.8	36.3	37.3	35.9	44.6	30.9	33.6	27.6	32.4	55.4	35.8	58.9	48.3
Anthracene	118	139	114	93.9	117	101	114	106	110	85.6	107	157	136	165	152
Fluorene	69	76.9	70.3	54.8	68.7	54.9	69.6	57.3	55.7	41.6	50.8	81.8	67.1	89.7	76.5
Naphthalene	150	172	164	151	208	194	203	185	162	122	152	230	170	215	209
Phenanthrene	273	304	247	214	291	250	258	218	240	191	227	329	298	360	324
HMW PAH															
Benzo(a)anthracene	217	256	199	179	229	179	200	171	173	142	172	250	227	278	255
Benzo(a)pyrene	231	249	223	190	248	190	236	182	182	137	174	276	251	297	284
Benzo(b)fluoranthene	275	281	251	210	298	229	296	244	219	174	214	337	270	341	320
Benzo(ghi)perylene	275	263	257	212	265	227	255	243	212	171	209	321	258	328	317
Benzo(k)fluoranthene	142	153	120	106	143	116	155	116	101	93.2	114	173	135	185	170
Chrysene	244	295	212	192	252	165	185	203	201	156	195	282	246	309	281
Dibenzo(ah)anthracene	47.4	47.8	41.8	38.8	39.1	36.3	42.5	38.6	27.8	26	33.7	43.5	43.6	53.9	54.4
Fluoranthene	358	421	314	271	353	285	305	267	305	247	299	437	408	494	441
Indeno(1,2,3-c,d)pyrene	243	233	210	173	222	187	212	197	158	124	164	247	211	284	257
Pyrene	427	518	392	339	443	355	388	344	391	310	375	545	494	606	554
THC (mg kg^{-1})	278	339	368	290	243	208	215	230	323	306	329	592	416	514	553

Table A1.9 Cont

Station	G16-2022	G17-2022	G18-2022	G19-2022	G20-2022	G21-2022	G22-2022	G23-2022	G24-2022	G25-2022	G26-2022	G27-2022	G28-2022	G29-2022
LMW PAH														
Acenaphthene	45.2	9890	21.8	234	117	73	86	110	619	310	376	555	276	628
Acenaphthylene	72.9	449	9.19	85.7	44.2	51.3	53.2	70.1	144	47.7	64.3	72.2	55.3	42.4
Anthracene	176	15800	40.1	782	298	183	217	266	1190	464	583	812	556	581
Fluorene	82.7	6780	18.7	258	125	83.5	103	118	490	222	286	394	245	325
Naphthalene	190	10600	24.3	434	220	157	189	242	524	264	344	412	243	282
Phenanthrene	295	45600	109	1080	604	366	471	556	2870	1450	1660	2460	1450	1590
HMW PAH														
Benzo(a)anthracene	235	29300	76.3	1210	561	362	374	477	2020	1130	1290	2000	1190	1160
Benzo(a)pyrene	277	30100	84.7	1510	741	433	475	639	2340	1410	1700	2600	1420	1380
Benzo(b)fluoranthene	305	24200	75	1410	723	484	503	644	1940	1290	1550	2330	1200	1110
Benzo(ghi)perylene	297	16100	69	1170	633	440	472	588	1190	1060	1290	1860	977	952
Benzo(k)fluoranthene	154	18300	41.9	784	375	225	249	373	1580	709	752	1100	611	605
Chrysene	268	28700	73.1	1290	604	387	402	538	2200	1200	1340	2110	1000	918
Dibenzo(ah)anthracene	52.2	1900	15.3	209	138	90.3	96.5	109	203	231	192	408	200	215
Fluoranthene	450	58800	113	1770	868	592	631	805	3870	2060	2310	3660	2030	2200
Indeno(1,2,3-c,d)pyrene	257	13800	51.8	1160	611	428	455	533	938	1130	1370	2020	1070	1030
Pyrene	594	53500	113	38.3	1060	747	771	1050	4620	2100	2450	3780	2140	2100
THC (mg kg^{-1})	672	2300	339	2560	1240	892	1010	917	2680	928	1040	1160	788	577

LMW = Low Molecular Weight. HMW = High Molecular Weight. THC = Total Hydrocarbons

Table A1.10 PAHs (µg kg^{-1} Dry Weight) from the Port of Grangemouth 2003 to 2022

	Sample Year							
PAH	**2003**	**2004**	**2006**	**2007**	**2010**	**2016**	**2019**	**2022**
LMW PAH								
Acenaphthene	-	-	-	-	-	96.6	334.6	497.8
Acenaphthylene	-	-	-	-	-	17.9	84.8	62.3
Anthracene	221.9	180.8	134.7	77.2	182.6	203.4	524.0	877.8
Fluorene	109.9	89.5	61.5	38.1	76.5	120.2	271.9	383.4
Naphthalene	280.8	277.1	190.0	123.5	185.5	226.1	353.1	659.2
Phenanthrene	522.4	449.8	310.8	172.5	389.5	577.9	1,366.2	2388.6
HMW PAH								
Benzo(a)anthracene	355.1	370.2	230.4	125.8	343.6	433.2	977.2	1602.1
Benzo(a)pyrene	371.0	241.2	277.0	166.0	364.6	448.2	1,181.5	1680.5
Benzo(b)fluoranthene	-	-	-	-	-	-	1,068.1	1439.0
Benzo(e) pyrene	-	-	-	-	-	-	801.0	-
Benzo(ghi)perylene	520.1	364.5	242.1	151.9	346.9	339.5	814.7	1045.2
Benzo(k)fluoranthene	-	-	-	-	-	-	524.0	1006.9
Chrysene + Triphenylene	480.8	390.4	269.4	132.2	375.7	333.1	-	-
Chrysene	-	-	-	-	-	-	1,029.0	1597.4
Dibenzo(ah)anthracene	-	-	-	-	-	78.4	168.0	141.7
Fluoranthene	637.1	568.0	418.3	234.2	595.9	787.9	1,838.6	3110.4
Indeno(1,2,3-c,d)pyrene	376.2	395.7	238.4	171.6	335.2	348.0	821.2	903.9
Perylene	-	-	-	-	-	-	399.2	-
Pyrene	788.6	643.9	523.7	284.6	695.3	727.4	1,956.7	2,877.5

LMW = Low Molecular Weight. HMW = High Molecular Weight

A1.6 Tributyltin

Tributyltin (TBT) is a highly toxic compound historically used as an anti-biofouling agent in paint used to coat the hulls of vessels. It is also toxic to non-target organisms and is linked to immune-suppression and imposex (1) in snails and bivalves. TBT was also used in various industrial processes as a biocide and can enter the marine environmental through effluent discharges. In some cases, TBT can also be persistent in the marine environment.

Mean dry weight concentrations of TBT from the samples collected in 2022 are presented in *Table* A1.11. Four stations had concentrations above Action Level 1. All samples were below Action Level 2. A comparison of data from 2006 to 2022 presented in *Table A1.12.* Mean concentrations of TBT from all samples above Marine Scotland Action Level 1 (0.1 mg kg^{-1}) were recorded in 2016 and 2019.

(1) The development of male characteristics in females

Table A1.11 TBT (mg kg^{-1} Dry Weight) from the Port of Grangemouth 2022

Station	TBT
G01-2022	<0.005
G02-2022	<0.005
G03-2022	<0.005
G04-2022	<0.005
G05-2022	<0.005
G06-2022	<0.005
G07-2022	<0.005
G08-2022	<0.005
G09-2022	<0.005
G10-2022	<0.005
G11-2022	<0.005
G12-2022	<0.005
G13-2022	<0.005
G14-2022	<0.005
G15-2022	<0.005
G16-2022	0.0498
G17-2022	0.0204
G18-2022	<0.005
G19-2022	0.0453
G20-2022	0.0579
G21-2022	0.0441
G22-2022	0.0571
G23-2022	0.0725
G24-2022	0.0647
G25-2022	0.33
G26-2022	0.262
G27-2022	0.349
G28-2022	0.142
G29-2022	0.059
Mean and Range for All Samples Analysed	
Mean	**0.056**
Range	**<0.005 - 0.349**
Mean and Range for Samples within Application Area (Stations 1-22)	
Mean	**0.0161**
Range	**<0.005-0.0579**

Note for concentrations <0.005 the value of 0.005 has been used to calculate the mean.

Table A1.12 TBT from the Port of Grangemouth 2003-2022

Year	Mean TBT Concentration (mg kg^{-1} dry weight)
2003	0.042
2004	0.018
2006	0.034
2007	0.019
2008	<0.014
2016	0.309
2019	0.216
2022	0.0161
Mean 2003-2022	**0.084**
Range 2003-2022	**<0.014 - 0.309**

A1.7 Sediment Particle Size Analysis

Sediment Particle Size Analysis (PSA) was undertaken on 29 sediment samples taken from the Port of Grangemouth and Bellmouth in 2022. Sediments were predominantly muddy, with smaller fractions of gravel and sand.

- Gravel is defined as >2 mm,
- Sand is defined as >63 µm<2 mm, and
- Mud (silts and clays) is defined as <63 µm.

The sandy-mud material is typical of a relatively low energy harbour environment. The samples with gravel fractions were from the Bellmouth. *Table A1.13* and *Figure A1.3* present the 2022 data.

Sediment contamination is typically higher in sediments less than 63 µm diameter *e.g.* silts and clays due to the increased surface area providing more adhesion sites for contaminants than the same volume of sand or gravel.

Table A1.13 Grangemouth Docks and Bellmouth Sediment PSA and TOC Data

Parameter	Sample Station														
	G01-2022	G02-2022	G03-2022	G04-2022	G05-2022	G06-2022	G07-2022	G08-2022	G09-2022	G10-2022	G11-2022	G12-2022	G13-2022	G14-2022	G15-2022
Textural Group Classification	Sandy Mud	Sandy Mud	Gravelly Mud	Sandy Mud	Sandy Mud	Sandy Mud	Sandy Mud	Slightly Gravelly Sandy Mud	Sandy Mud	Sandy Mud	Sandy Mud	Sandy Mud	Sandy Mud	Sandy Mud	Mud
Folk and Ward Description	Coarse Silt	Coarse Silt	Very Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Coarse Silt	Medium Silt
Folk and Ward Sorting	Poorly Sorted	Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted
Mean µm	19.45	19.6	35.00	26.01	23.31	25.24	21.65	23.92	25.09	24.96	19.37	18.96	17.34	16.70	15.15
Mean phi	5.684	5.676	4.836	5.265	5.423	5.308	5.530	5.386	5.317	5.324	5.690	5.721	5.850	5.904	6.044
Sorting Coefficient	1.773	1.864	3.051	2.338	1.930	2.016	2.050	2.075	1.883	1.830	1.897	1.822	1.927	1.689	1.655
Skewness	0.068	0.107	-0.250	0.027	0.080	0.065	0.073	0.023	0.062	0.088	0.143	0.079	0.092	0.116	0.118
Kurtosis	1.023	1.016	1.328	0.988	0.997	0.979	0.999	1.001	0.992	0.985	1.002	1.040	1.060	0.993	1.024
Gravel (%)	0.0	0.0	7.3	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sand (%)	16.0	17.2	24.5	27.5	23.1	25.6	22.3	21.6	24.6	23.7	17.3	15.8	14.8	11.0	7.9
Mud (silts and clays) (%)	84.0	82.8	68.2	72.5	76.9	74.4	77.7	76.0	75.4	76.3	82.7	84.2	85.2	89.0	92.1
Total Organic Carbon (%)	4.41	4.35	3.39	3.34	4.69	4.17	4.39	3.97	5.02	4.97	3.88	5.41	5.01	5.35	5.29
Solids (%) @120°C	43.6	40.9	49.3	47.9	36.2	34.9	34.5	38.3	38.4	31.7	40.4	35.7	38	39.6	36.1
Density (mg m^{-3})	2.63	2.64	2.66	2.69	2.6	2.63	2.66	2.66	2.6	2.64	2.68	2.62	2.63	2.64	2.67

Table A1.14 cont.

Parameter	Sample Station													
	G16-2022	G17-2022	G18-2022	G19-2022	G20-2022	G21-2022	G22-2022	G23-2022	G24-2022	G25-2022	G26-2022	G27-2022	G28-2022	G29-2022
Textural Group Classification	Sandy Mud	Slightly Gravelly Sandy Mud	Slightly Gravelly Mud	Gravelly Mud	Sandy Mud	Mud	Mud	Sandy Mud	Slightly Gravelly Mud	Sandy Mud	Sandy Mud	Sandy Mud	Slightly Gravelly Sandy Mud	Sandy Mud
Folk and Ward Description	Coarse Silt	Coarse Silt	Medium Silt	Coarse Silt	Medium Silt	Medium Silt	Medium Silt	Medium Silt	Medium Silt	Coarse Silt	Coarse Silt	Medium Silt	Medium Silt	Medium Silt
Folk and Ward Sorting	Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Poorly Sorted	Poorly Sorted	Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted	Very Poorly Sorted
Mean µm	15.74	17.05	15.25	22.87	14.11	11.09	12.41	13.75	13.01	17.98	18.96	13.15	15.26	14.25
Mean phi	5.990	5.874	6.035	5.450	6.147	6.494	6.332	6.185	6.265	5.798	5.721	6.249	6.034	6.132
Sorting Coefficient	1.859	2.759	2.123	3.278	2.069	1.978	1.888	1.938	2.679	2.145	2.062	2.120	2.235	2.147
Skewness	0.026	-0.105	0.293	-0.287	0.019	0.103	-0.036	-0.001	-0.113	-0.033	-0.020	-0.043	-0.031	0.043
Kurtosis	1.135	1.426	1.148	1.693	1.147	1.132	1.214	1.189	1.617	1.004	1.028	1.127	1.043	0.987
Gravel (%)	0.0	4.1	3.5	10.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	2.9	0.0
Sand (%)	11.3	15.7	8.0	13.7	11.7	5.9	7.2	10.8	9.0	20.0	20.0	13.0	14.8	15.6
Mud (silts and clays) (%)	88.7	80.2	88.4	76.3	88.3	94.1	92.8	89.2	87.4	80.0	80.0	87.0	82.4	84.4
Total Organic Carbon (%)	5.53	2.95	0.86	5.1	3.63	3.88	4.72	4.52	4.44	5.12	4.59	5.19	3.33	2.46
Solids (%) @120ºC	38.9	55.7	60.5	50.7	44.8	42.6	30.2	35.5	43	47.9	35.7	41.5	48.3	53.9
Density (mg m^{-3})	2.57	2.69	2.75	2.65	2.65	2.66	2.64	2.64	2.61	2.65	2.57	2.63	2.66	2.62

Figure A1.3 Port of Grangemouth and Bellmouth Sediment PSA 2022

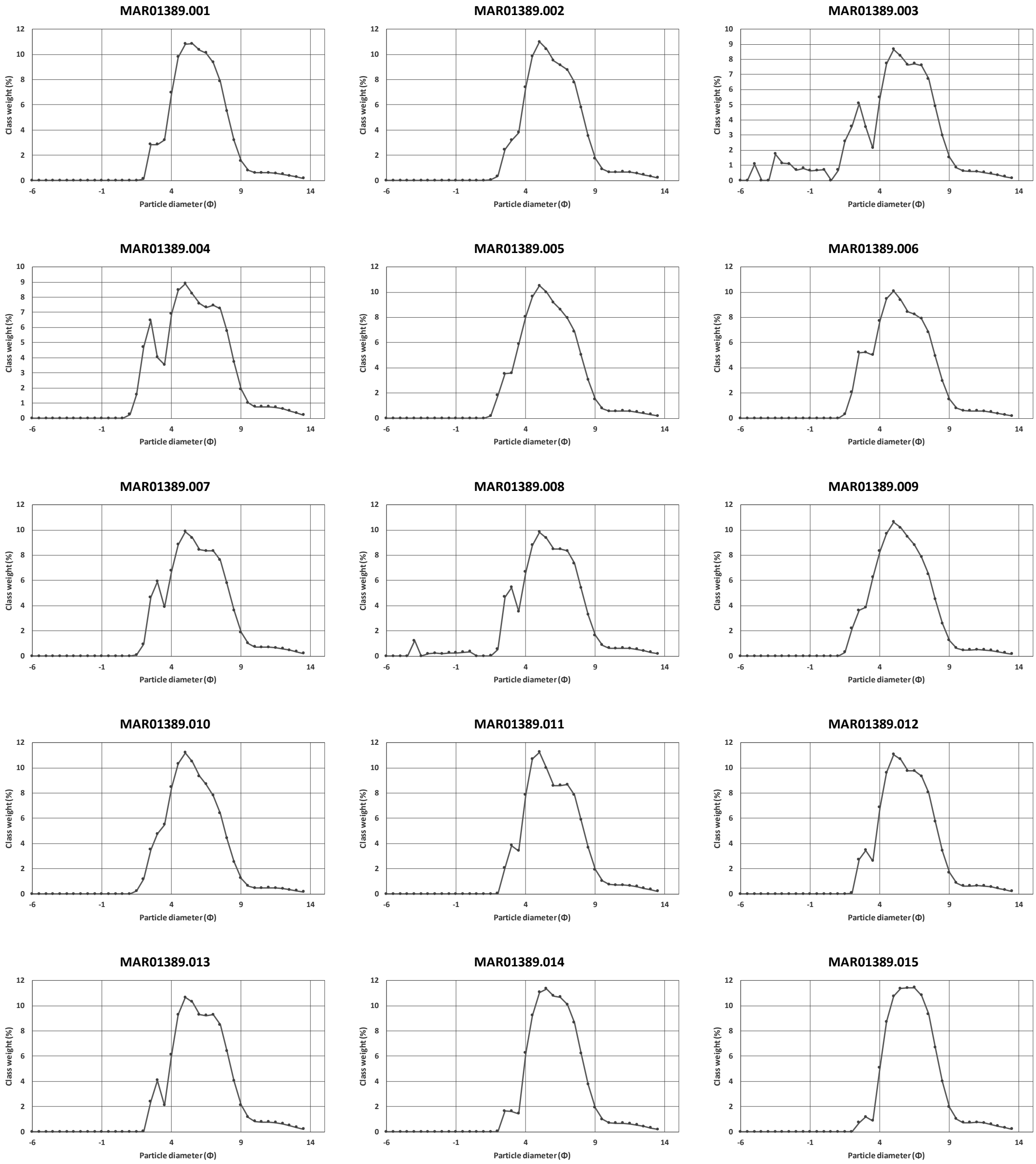
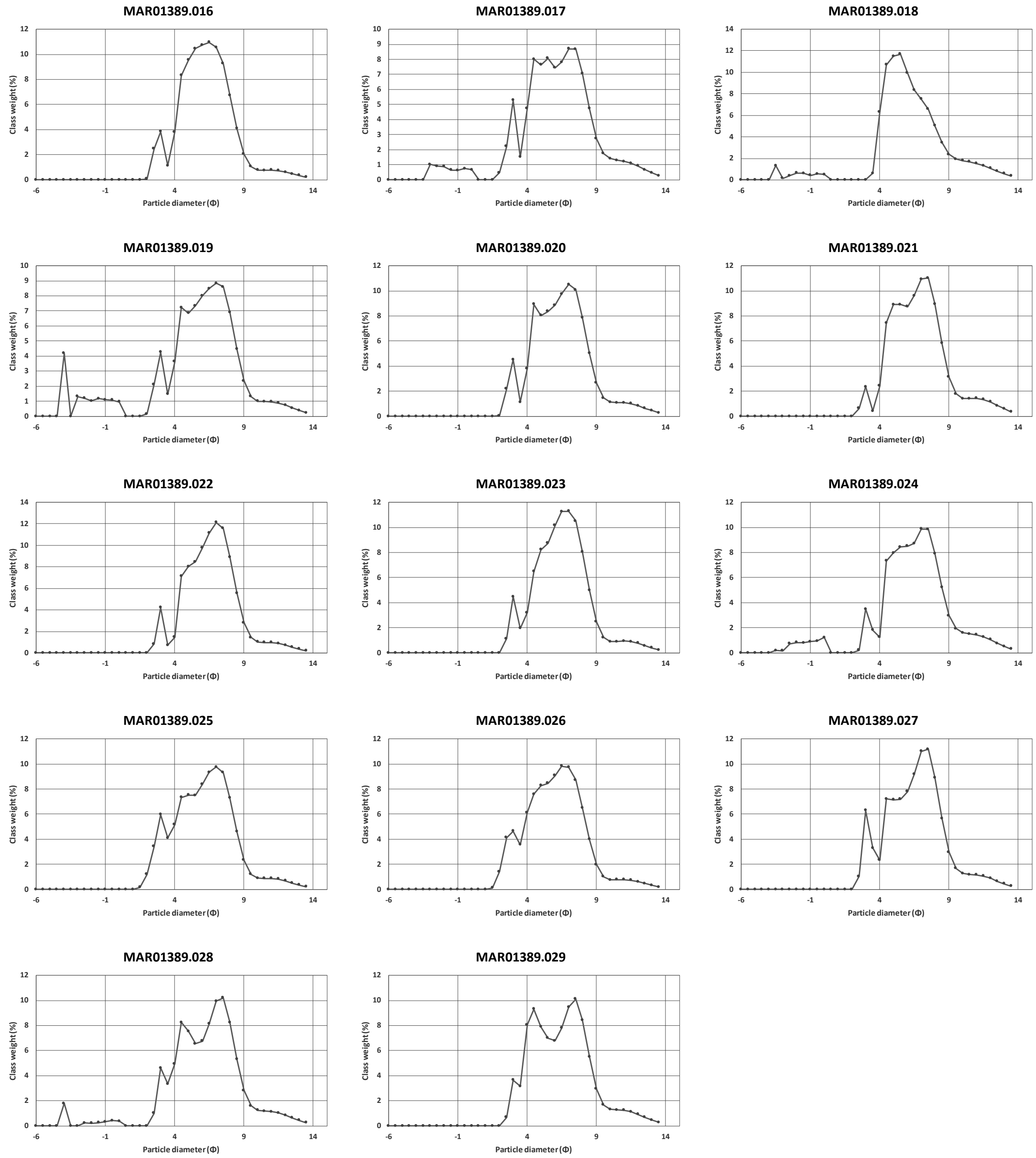


Figure A1.3 Cont.



A2 SPOIL GROUND SEDIMENT SAMPLE DATA

Table A2.1 presents metal and PCB concentration data from sediment sampled from within Bo'ness spoil ground and from five other spoil ground sites within the Firth of Forth and Forth Estuary for comparison. Levels above Marine Scotland Action Level 1 for metals and PCBs are highlighted in blue and above Action Level 2 in red.

Table A2.1 Metals and PCBs (mg kg^{-1}) from Firth of Forth and Forth Estuary Spoil Grounds

Site Name	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Sum ICES 7 PCBs
Bo'ness 2015	18.6	0.1	59.6	26.5	0.7	27.5	54.2	114.0	0.000
(*n=5*)									
Oxcars 2015	15.7	0.3	79.6	41.6	1.0	35.8	78.1	141.7	0.008
(*n=3*)									
Narrow Deep 2015	52.2	11.7	0.2	63.8	24.6	0.6	30.0	58.4	0.030
(*n=5*)									
Methil 2015	8.7	0.1	18.0	9.6	<0.06	11.2	14.5	72.8	0.000
(*n=1*)									
Kirkcaldy 2015	8.9	0.1	43.1	17.0	0.2	22.0	30.6	62.9	0.000
(*n=3*)									
Blae Rock 2011	17.2	0.1	39.6	21.9	0.5	21.4	52.1	80.3	0.001
(*n=6*)									

* Data provided by Marine Scotland (2019)
Key: n = the number of samples analysed (where known)

The metal data in *Table A0.1* indicate that concentrations of metals and PCBs within sediment samples from the Bo'ness spoil ground are comparable with those from the other Forth Estuary and Firth of Forth spoil grounds sampled. Both metals and PCBs are lower than the original material dredged from Grangemouth (refer to *Table A1.5, Table A1.7* and *Table A1.8*), which would be expected from a dispersive spoil ground such as Bo'ness.

Note that monitoring of spoil grounds is not mandatory therefore, the data presented in *Table A2.*1 are the most recent data available.

APPENDIX B ENVIRONMENTAL IMPACTS OF DISPOSAL OPERATIONS

B1 INTRODUCTION

This Appendix addresses the environmental impacts of the disposal of dredged material from the maintenance dredging at Port of Grangemouth at the licenced Bo'ness disposal site in the Forth Estuary. Impacts on water quality, sediment quality, and habitats and species are considered. *Table B1.1* presents the impact summary.

As the Marine Licence application is for disposal of the dredged material, impacts of the dredging activities are not addressed, other than in the context of Bathing Waters and cumulative impacts from existing and proposed dredging and disposal activities, and other activities and developments.

Dredging operations at Grangemouth and the associated vessel traffic between the port and the Bo'ness disposal ground during disposal operations are likely to be over approximately four days per month throughout the year. Potential impacts on general vessel movements within the Forth Estuary due to the disposal operations are not considered to be significant as commercial traffic in the main channel is controlled by Forth Ports' standard operating procedures.

B2 IMPACTS OF DISPOSAL

B2.1 Introduction

The identification and assessment of environmental impacts of dredged material in this Appendix follows recent guidance from the Environment Agency, Clearing the Waters for All [(1)].

As described in *Section 1.3* it is proposed that approximately 1,700,000 m^3 (wet weight comprising approximately 255,000 m^3 water and 1,445,000 m^3 solids) of material would be disposed at Bo'ness over a period of approximately four days per month, totalling 48 days per annum.

The material to be dredged and disposed consists primarily of sandy mud, with some gravelly fractions. The concentrations of contaminants in the material sampled are presented in *Appendix A*. In 2022, samples were taken from 29 stations (G01-2022 to G29-2022) with additional metal analysis from nine stations (G30-2022 to G38-2022). As stated in Chapter 1 the area with the highest metal concentrations will be excluded from the Marine Licence application area. The results from the analysis of samples from within the application area are summarised below.

- The mean concentrations of metals were all above Action Level 1 but below Action Level 2 for most stations except for arsenic and cadmium, which were below Action Level 1 for most stations. This pattern was observed in the previous data from samples analysed from the Port of Grangemouth. Concentrations of mercury above Action Level 2 were recorded from station G19-2022 and supplementary station G31-2022 (the sample location as G19-2020). The mercury concentrations at the two supplementary stations within 25 metres of these stations (G30-2022 and G32-2020) were below Action Level 2.
- The concentration of total PCBs was below Action Level 1 in most stations with exception of stations G19-2022, G20-2022 and G22-2022.
- For individual PAHs most were above Action Level 1, including the sample stations in the Bellmouth area outside the port lock. This pattern was observed in the previous data from samples analysed from the Port of Grangemouth
- TBT concentrations were below Action Level 1 at stations within the Marine Licence application area.

Metal and PCB concentration data from sediment sampled in the Bo'ness spoil ground in 2015 are presented in *Appendix A* and indicate that levels are similar those from other spoil grounds within the Firth of Forth.

(1)Best, M (2016). Clearing the Waters for All: WFD guidance for developers and regulators in estuarine and coastal waters. Environment Agency.

B2.2 Impacts on Water and Sediment Quality

There are no designated bathing waters within 2 km of the dredging or disposal sites. The nearest is Aberdour Harbour which is approximately 25 km from the dredging site and approximately 20 km from the disposal site.

Coastal water quality in the Firth of Forth is currently Good in the outer Firth, with the exception of the area around Portobello and Musselburgh, which is classified as Poor. It is classified as Good in the lower estuary to Muirhouses and Moderate upstream in the estuary to Kincardine bridge [(1)].

The salinity in the Firth of Forth averages 33‰, decreasing into the Forth Estuary under the influence of freshwater inputs. In the Firth of Forth, dissolved oxygen concentrations show little variation with depth and are approximately 90-95% but may be lower during periods of high summer water temperatures [(2)].

The levels of suspended sediments in the Firth of Forth vary with seasonal weather conditions. There is no available data for suspended sediment levels at the Bo'ness spoil disposal site, however, data from SEPA cited in the Transport Scotland (2009) report showed sediment concentrations from June, between 2000 and 2008 at Kincardine was 130 mgl^{-1} and from Longannet was 16 mgl^{-1}. Data available from Middle Bank, located approximately 12 nm downstream from Bo'ness during dredging operations in 2008 [(3)] recorded the baseline mean suspended solids concentrations between 8.87 mg l^{-1} and 10.3 mg l^{-1} (mean 9.1 mgl^{-1}).

The material disposed at Bo'ness will fall to the seabed by gravity and consist of cohesive lumps of dredged material. Fine sediment will be liberated as it sloughs off the descending material and when the clumps reach the seabed. Field measurements of suspended solids in surface waters following similar disposal operations indicate that less than 5% of the discharged material escapes the descending density jet [(4)].

There are no data available on the concentration or dispersion of suspended solids from the disposal operations at Bo'ness, however, the Forth Replacement Crossing studies (Transport Scotland 2009)[5] showed that increases in suspended sediment concentrations from dredging works were short-lived and localised [(6)]. Increases in suspended sediments associated with the disposal operations at Bo'ness are considered to be small scale in comparison with the range of suspended sediment concentrations in the Forth Estuary and will be confined to the immediate area of the spoil disposal ground. The fraction of the disposed material that suspended in the water column will disperse with the tidal currents at the disposal site and cumulative effects on water quality in the Forth Estuary from the disposal operations are not likely.

Any increased nutrient levels from suspended sediments from disposal operations may stimulate local algal production, although the effects are predicted to be short-term and confined to the immediate area of the disposal operations. Nitrogen is generally regarded to be the limiting nutrient in estuarine and marine systems and in its reduced form (ammoniacal nitrogen) is also toxic to fish. Because of the reduced (oxygen demanding) nature of seabed sediments, nitrogenous nutrients are likely to be in this form.

The oxidation of anoxic sediments released into the water column has been shown to reduce oxygen concentrations by up to 58% [(7)]. Based on the background levels this may reduce the oxygen saturation to between 40 and 50% (equating to approximately 4 to 5 mg l^{-1}). Therefore, if the disposal operations occurred during a period of 'naturally' low dissolved oxygen it is possible that the Water

(1)Water Framework Directive (WFD) Waterbody Classification 2007-2017 (SEPA) https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=1110. Now controlled through the Environment (EU Exit) (Scotland) (Amendment etc.) Regulations 2019.
(2) SEPA (1998). Winter Nutrient Distribution in the Firth of Forth, 1987 - 1997. Report TW 01/98, January 1998.
(3) ERM, 2008. Middle Bank Aggregate Production Licence: Monitoring Report. A report for Westminster Gravels Ltd.
(4) Kennish M.J. 1992. Ecology of Estuaries Anthropogenic Effects Dredging and Dredged Spoil Disposal p 357-397
(5) Transport Scotland, 2009. Forth Replacement Crossing: Environmental Statement.
(6) Transport Scotland, 2009. Forth Replacement Crossing: Environmental Statement.
(7) Brown C. 1968. Observations on Dredging and Dissolved Oxygen in a Tidal Waterway. Water Resources Research Vol 4, No 6, p1381.

Quality standards for EC Freshwater Fisheries Directive of oxygen concentration greater than 6 mg l^{-1} would not be met [(1)]. It is predicted that this would be short-lived, due to the limited period over which disposal is intended to occur and localised based on previous dredge plume studies. The impacts are not considered to be significant given the generally high dissolved oxygen levels anticipated at the disposal site, the low levels of organic carbon in the dredged sediments (less than 5%) and the extent of the area potentially affected.

Although there may be some release of contaminants such as metals, PCBs, TBT and PAHs into the water column during disposal operations the majority of the dredged material will descend to the seabed rapidly. Sediment bound contaminants liberated during the disposal operations will rapidly become complexed with particulate matter in the water column and be re-deposited on the seabed. Previous studies have shown that metal concentrations in the water column remained consistent following sediment disposal [(1)]. In addition, the natural sedimentation in the Firth of Forth aids the removal of contaminants from the water column and incorporates them in the seabed sediments.

The PAHs in the sediment comprise both low molecular weight (LMW) (two and three benzene rings) and high molecular weight (HMW) (more than 3 benzene rings) compounds. The PAHs that were in concentrations above Action Level 1 comprised both LMW and HMW PAHs. PAHs tend not to be volatile and poorly soluble and therefore readily absorb onto particulate matter in the water column and are incorporated into marine sediments. The HMW PAHs are generally less water soluble, less acutely toxic and slower to biodegrade (*i.e.,* more persistent) than the LMW PAHs.

The ratios of individual PAHs have been used to determine the likely anthropogenic source of PAHs in the environment: *e.g.* from combustion sources (pyrolytic) or petroleum hydrocarbons (petrogenic). Petrogenic PAHs are often characterised by phenanthrene to anthracene (Ph/An) values greater than 10, whereas pyrolytic PAH from combustion processes are characterised by Ph/An ratios less than 10. The ratio of and fluoranthene to pyrene (Fl/Py) of less than 1 generally indicate petrogenic source and those with ratios greater than 1 generally come from pyrolytic sources [(2)].

For all the sediment samples analysed from Grangemouth the Ph/An ratios were between 1.4 and 3.1 and the Fl/Py ratios were between 0.8 and 1.1 (with the exception of station G19-2022 which had a ratio of 46.2). This suggests that these contaminants are from both combustion and petroleum hydrocarbon sources. This pattern has been identified in other ports in the Firth of Forth and Forth Estuary indicating that these sources of PAHs are in the sediments from the wider Forth Estuary and Firth of Forth sediment circulation system.

There was a large reduction in point source discharges of hydrocarbons and metals within the Forth Estuary and the Firth of Forth between the mid-1980s and 1990s [(3)]. Reduction and improved regulation of point source discharges has improved many aspects of the Forth system: inputs of organic material have declined and there has been an associated rise in dissolved oxygen during summer in the upper Forth Estuary. The rise in dissolved oxygen has led to increasing numbers of smelt caught in the upper estuary and to increasing inputs of nitrate generated by nitrification in the suspended sediment maxima of the estuary during summer. In winter, conservative mixing of nutrients is seen and there has been little change in winter nutrient concentrations in the Forth Estuary and Firth of Forth. Trace metal and trace organic inputs have been reduced so that aqueous concentrations have fallen rapidly [(4)]. With efforts focussed on improving the water quality of the Firth of Forth in more recent years, point source discharges have continued to decrease and the water quality of the Firth of Forth has continued to improve as a result [(5)].

(1) UKTAG 2010. Water Framework Directive: An approach to the Revoked Directives:- the Freshwater Fish Directive, the Shellfish Directive and the Dangerous Substances Directive. Available online from: http://www.wfduk.org/resources%20/approach-revoked-directives-%E2%80%93-freshwater-fish-directive-shellfish-directive-and-dangerous

(2)Y.W. Qiu, G. Zhang, G.Q. Liu, L.L. Guo, X.D. Li, O. Wai. Polycyclic aromatic hydrocarbons (PAHs) in the water column and sediment core of Deep Bay, South China. Estuar. Coast. Shelf Sci., 83 (1) (2009), pp. 60-66.

(3) SEPA, 1998. Trace Metals in the Forth 1986 - 1996. Available online from http://www.sepa.org.uk/science_and_research/data_and_reports/water/forth_estuary_trace_metals.aspx

(4) Dobson, J., Edwards, A., Hill, A. et al. *Senckenbergiana maritima* (2001) 31: 187. https://doi.org/10.1007/BF03043028

(5) SEPA, 2014. Scottish bathing waters 2013-2014. Available online http://www.sepa.org.uk/media/39125/scottish-bathing-waters-report-2013-2014.pdf

It is therefore not anticipated that the disposal operation at the Bo'ness spoil disposal ground will introduce significant amounts of contamination into the water column. Disposal of the dredged material may result in a localised and short-term increase in the levels of some contaminants within the seabed sediments at the spoil disposal ground; however, the deposited fine sediments will disperse over time. Considering the short-term, localised and intermittent increase in the levels of some contaminants in the water column will not affect the overall water body quality statuses of the Forth Estuary and the Firth of Forth.

B2.3 Impacts on Benthic Ecology

The benthic macrofaunal communities recorded in proximity to Bo'ness disposal site are expected to be typical for estuarine conditions and not considered to be of high conservation significance due to the wide distribution, low diversity and lack of any rare or notable species (1).

The impact on benthic communities will depend on the comparative rates of natural deposition and the deposition due to the dredging disposal operations. It is anticipated that the deposition of dredged material at the Bo'ness disposal site may result in the loss (burial) of the benthos within and in the immediate vicinity of the 'deposition zone' within the disposal site. Localised impoverishment of the fauna (in terms of abundance and diversity) is likely along the axis of tidal flow as a result of secondary impacts comprising sediment deposition subsequent to the disposal activities. However, benthic communities in this area will be accustomed to a degree of sediment deposition from ongoing maintenance dredge spoil disposal operations at Bo'ness, natural levels of suspended sediment deposition and current induced seabed sediment dispersion along the axis of tidal flow.

Given the relatively homogenous nature of benthic communities (2) in this part of the Forth Estuary and their exposure to the naturally high levels of suspended levels during periods of low river flow and availability of similar habitat within the Firth of Forth, the spatial extent of predicted sediment related impacts to benthos (and resultant impact on prey availability for foraging seabirds) are unlikely to be significant. Dredge spoil from ports and harbours within the Firth of Forth and Forth Estuary has been deposited within the Bo'ness spoil ground for over 20 years and significant impacts on benthic ecology outside of the disposal ground are not predicted.

B2.4 Impacts on Seabirds

The Firth of Forth Special Protection Area (SPA), Forth Islands SPA and the Outer Firth of Forth and St Andrews Bay Complex SPA are designated (3) for rare, vulnerable and regularly occurring migratory bird species.

There are three potential effects of the disposal of dredge material at sea on seabirds; increased suspended solids, release of contaminated particulates and physical disturbance of birds by the dredging vessel. These effects could potentially have a significant effect on the qualifying interests of the SPAs by reducing prey availability and disturbing bird behaviour and breeding patterns. The vessel used for disposal of the material will be travelling to and from the Port of Grangemouth and the disposal site during the four days per month dredging campaign, a round trip of approximately 3.0 nautical miles.

The SPAs support breeding seabirds which forage over a wide area. The disposal of the dredged material will result in localised increases in suspended sediment which may reduce the ability of fish-eating birds to forage around the spoil disposal ground due to impaired visibility. However, the area affected is a small percentage of the total available foraging habitat, with alternative sources of prey available close by.

(1) Elliot M & Kingston P F (1987). The Sublittoral Benthic Fauna of the Estuary and Firth of Forth, Scotland. Proceedings of the Royal Society of Edinburgh, 93B, pp 449-465
(2) Elliot M & Kingston P F (1987). The Sublittoral Benthic Fauna of the Estuary and Firth of Forth, Scotland. Proceedings of the Royal Society of Edinburgh, 93B, pp 449-465
(3) The *Conservation (Natural Habitats, &c.) (EU Exit) (Scotland) (Amendment) Regulations, 2019*.

Bo'ness is an established and long term spoil ground with disposal activities being ongoing at the time that the SPAs were designated. Given that disposal was an existing activity and ongoing disposal is at a similar scale to previous disposal activities it is considered that the proposals will not have significant effects on the qualifying interest of the SPAs.

B2.5 Impacts on Fish

The River Teith Special Area of Conservation (SAC), the Isle of May SAC and the Moray Firth SAC are designated under the Habitats Directive [(1)] for their habitats and fish species of European importance.

Atlantic salmon, river lamprey and sea lamprey inhabit and migrate up and down the Firth of Forth and Forth Estuary to reach spawning grounds in the River Teith SAC and may therefore pass the Bo'ness disposal site. The Forth District Salmon Fishery Board has advised that salmon smolts are likely to be passing through the lower estuary during June and July. The river lamprey grows to maturity in estuarine environments and between October and December moves into fresh water to spawn in clean rivers and streams. The sea lamprey spends most of its life at sea, only returning to freshwater to spawn around April and May.

A potential effect of disposal at sea is for increased levels of suspended solids to disturb fish migration routes and areas they occupy. The proposals are not likely to have a significant effect on fish for the following reasons.

- The concentration of suspended sediment at which the passage of salmonid fish is affected has been observed to be approximately 500 mg l^{-1} [(2)]. Studies in the US, looking at a variety of salmonid species, illustrates that fatalities to smolts (50%) can occur at high suspended sediment concentrations over extended periods (*e.g.,* exposure of between 488 to 19,364 mg l^{-1} for 96 hrs) [(3)]. The natural suspended sediment maxima in the Forth Estuary is in the upper estuary with mean concentrations over forty times higher than in the Firth of Forth (130 mg l^{-1} at Kincardine [(4)] and average 3 mgl^{-1} at Gunnet Ledge [(5)]).
- The disposal activities will take place at the Bo'ness spoil ground within the Forth Estuary which represents a small area where sea lamprey and salmon smolts may be present or may pass through. The fish species that may be present are mobile and able to avoid the relativity small area of elevated suspended sediments during and immediately after disposal operations. The suspended sediment maxima in the Forth Estuary is in the upper estuary with mean concentrations approximately eight times higher than in the lower estuary (130 mgl^{-1} at Kincardine and 16 mgl^{-1} from Longannet) [6] and higher than the recorded elevation in suspended sediment concentrations recorded during the Middle Bank dredging and disposal operations.
- The dredging process is not continuous: the time required for one cycle (dredging - travelling - discharging - travelling) is approximately 1 hour and 30 minutes. Additional delays to avoid interactions with other vessels are common, *e.g*, the dredger returning from the disposal site may be instructed by Vessel Traffic Services to wait outside the harbour to allow other vessels to enter/leave. A localised, short-term and non- continuous increase in suspended sediment concentration is not anticipated to affect the migration of adult salmon, smolts or other fish species, based on the evidence of studies on the effects of suspended sediments on salmonids.

A localised, short-term and non-continuous increase in suspended sediment concentrations affecting a small proportion of the width of the Firth of Forth is not anticipated to affect the migration of adult

(1) European Communities (1992) Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna.
(2) Redding M.J. and Schreck C.B. 1987, Physiological effects on coho salmon and steelhead of exposure to suspended solids, Transactions of the American Fisheries Society, Vol 116 pp737-747
(3) Bash J, Berman, C and Bolton S. 2001. Effects of Turbidity and Suspended Solids on Salmonids. Prepared for Washington State Transportation Commission, Department of Transportation and U.S. Department of Transportation, Federal Highway Administration
(4) Transport Scotland, 2009. Forth Replacement Crossing: Environmental Statement.
(5) SEPA monitoring buoy data from Gunnet Ledge, Firth of Forth, available online from http://www.sepa.org.uk/environment/environmental-data/monitoring-buoys-network/gunnet-ledge/
(6) Transport Scotland, 2009. Forth Replacement Crossing: Environmental Statement.

salmon, smolts or other fish species, based on the evidence of studies on the effects of suspended sediments on salmonids and the predicted suspended sediments concentrations resulting from the disposal operations. It has been reported that Atlantic salmon numbers have been decreasing in Scotland and farther afield over the ten years from 2210 to 2019 (1), including in areas in Scotland where there have been no dredge spoil disposal operations. Forth Ports' dredge spoil disposal operations have been ongoing at Bo'ness for over 20 years, covering the periods of much higher salmon numbers indicating that there is no causal link between the ongoing spoil disposal activities and a broad scale decline in salmon numbers. Seasonal restrictions to operational requirements to dispose of dredged material at the Bo'ness spoil disposal ground are therefore not considered to be justified.

B2.5 Impacts on Marine Mammals

The Isle of May SAC, in the outer Firth of Forth, is designated for its populations of grey seal. Grey seals forage widely and may forage at the Bo'ness spoil ground. Potential effects on grey seals resulting from the disposal activities are disturbance and noise due to vessel movements and disposal activities and displacement of prey species as a result of increased levels of suspended sediment at the disposal site.

The proposals are not likely to have a significant effect on grey seals for the following reasons.

- The small area of potential foraging affected by disposal activities at the Bo'ness disposal site.
- The short duration of disposal activities (up to four days per month).
- The small increase in total vessel movements associated with the disposal activities in relation to total vessel movements within the Firth of Forth.
- The long term existing disposal operations in the area which pre-date the site designation.

Bottlenose dolphins are a Habitats Directive Appendix II species and are resident in the Moray Firth SAC. They are infrequent summer visitors to the Firth of Forth, mainly between June and September (2).

Vessel movements and noise have the potential to disturb or displace marine mammals and disposal activities have the potential to displace prey species within and in the vicinity of the Bo'ness spoil disposal ground. The proposals are not likely to have a significant effect on bottlenose dolphins for the following reasons.

- The distance between the disposal site and the SAC is large and the proportion of the bottlenose dolphin population anticipated to pass through the area affected by disposal activities is anticipated to be low.
- The extent of vessel movements associated with the disposal activities relative to total vessel movements within the Firth of Forth.
- The short duration of disposal activities each month (four days).
- The relatively low speed and direct line of travel of dredge vessel movements to and from the spoil disposal ground (*i.e.,* no fast moving and erratic vessel movements).
- The long-term existing disposal operations in the area which pre-date the site designation.

(1) https://www.britishecologicalsociety.org/understanding-decline-atlantic-salmon-catches-scotland/#:~:text=The%20Scottish%20Government%20has%20collected,the%20previous%205%2Dyear%20average. [accessed February 2022]
(2) Evans P. G. H. Chapter 5.15 Whales, Dolphins and Porpoises. In Coasts and Areas of the United Kingdom. Region 4 South- east Scotland: Montrose to Eyemouth, ed by J H Barne, C F Robson, S Kaznowska, J P Doody, N C Davidson and A L Buck, pp 129-132. JNCC (Coastal Directories Series).

B2.6 *Summary of Impacts*

Table B1.1 presents a summary of the impacts and an assessment of significance of the impacts in relation to the sensitivity/importance of the receiving site.

Table B1.1 Summary of Significance of Impacts

Receptor	Impact Significance Justification	Impact Significance
Water quality at disposal site	Disposal will be periodic and sediment will descend to the seabed rapidly. Suspended sediments will disperse with the tide and any impacts will be localised and short-term.	Not Significant
Sediment quality at disposal site	Increase in the levels of some contaminants will be localised and short-term and the deposited sediment will disperse within the open water system over time.	Not Significant
Benthic ecology at disposal site	Bo'ness is designated as a disposal site. Disposal will occur over a relatively short period and similar habitat is available in close proximity to the site.	Not Significant
Seabirds	Proposed disposal operations are over a relatively short period each month and the area affected is a small percentage of the total available foraging habitat, with alternative sources of prey available close by. Both SPAs were designated after the Bo'ness spoil site was designated, and have not been impacted by historic and ongoing disposal operations.	Not Significant
Marine mammals and fish	Proposed disposal operations are over a short period of time and the area affected is a small percentage of the total available foraging habitat, with alternative sources of prey available close by. The volume of dredger vessel traffic will not be significant in relation to the existing traffic in the Firth of Forth. The SACs were designated after the Narrow Deep spoil disposal ground was designated and have not been impacted by historic and ongoing disposal operations.	Not Significant

B3 CUMULATIVE EFFECTS WITHIN THE FIRTH OF FORTH AND FORTH ESTUARY

B3.1 *Introduction*

The potential impacts of the sea disposal option have been assessed within *Section B2* in isolation from other activities within the Firth of Forth and Forth Estuary. The impacts associated with the sea disposal option are not predicted to result in adverse effects on the integrity of the SPAs and SACs, however, it is possible that cumulative impacts with other projects could result in significant impacts.

For the purposes of this report a working definition of cumulative impacts as 'impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions, together with the project' (1) has been adopted. The assessment of potential cumulative impacts has been restricted to activities and proposed activities with the potential to directly impact the water and / or sediment quality and disturbance within the SPAs and SACs. The other activities considered

(1) European Union. Guidelines for the Assessment of Indirect and Cumulative Impacts, as well as Impact Interactions, DG XI Brussels Downloaded from http://ec.europa.eu/environment/eia/eia-support.htm

therefore include those that are at some distance from the activities at the Bo'ness spoil disposal ground but are within the foraging range of species that may utilise both areas.

B3.2 Past and Current Activities within the Firth of Forth and Forth Estuary

B3.2.1 Introduction

The Firth of Forth and Forth Estuary has previously experienced pollution from a number of industrial sources and sewage discharges, such as the petro-chemical operations at Grangemouth and the sewage works at Seafield. The Imperial Chemical Industries (ICI) chemical plant previously based in Grangemouth is also known to have been a source of mercury into the Forth Estuary, as have the coal fired power stations, such as Longannet (1). Over the past 40-50 years, however, most of these pollution sources have been controlled or eliminated altogether.

Additional improvements to sewage works and other effluent treatment plants upstream have improved the condition of the water coming down the estuary into the Firth of Forth.

In addition, there are unknown and diffuse sources of discharges into the Forth Estuary, Firth of Forth and riverine inputs to these areas, for example from agricultural run-off and unrecorded drainage outfalls.

B3.2.2 Petro-Chemicals and Power Generation

The INEOS refinery and wider petro-chemical complex at Grangemouth are historically a dominant source of oil related PAHs in the Forth Estuary and the Firth of Forth.

The Longannet coal-fired power station on the north bank of the estuary closed in March 2016 and is currently being demolished. The historic release of combustion related PAHs and mercury from this source will have contributed to the PAH and mercury loading within the Forth Estuary and Firth of Forth (1) (2). Water from the Firth of Forth was abstracted and used as cooling water by the power station before being discharged back into the Firth of Forth.

Methil power station was a small base load coal slurry-fired power station, located on the south side of the mouth of the River Leven, where the river enters the Firth of Forth at Methil. The power station started operations in 1965 and was decommissioned in 2000, finally being demolished in 2011. Water from the Firth of Forth was abstracted and used as cooling water by the power station before being discharged back into the Firth of Forth.

Cockenzie power station was a coal-fired power station located on the southern shore of the Firth of Forth near to Cockenzie and Port Seaton. It generated electricity between 1967 and 2013, with demolition of the station completed in 2015. Water was abstracted from and discharged back into the Firth of Forth in the same way it was for Longannet and Methil.

B3.2.3 Commercial Fishing Activity

The sandeel fishery on the Wee Bankie, at the mouth of the Firth of Forth, has been closed since 2000 on seabird conservation grounds. The initial five-year period was reviewed and extended following the reduction in numbers of some seabird species observed during a 2004 count (reduced sandeel numbers may be linked) within the Firth of Forth (3).

Improved water quality in the Firth of Forth has led to a resumption of cockle fishing, particularly on the Fife coast. Uncontrolled cockling could impact upon wintering bird populations by causing loss of

(1) Lee D.S., Nemitz, E., Fowler D., Hill P. and Clegg S. 2020. Sources Sinks and Levels of Atmospheric Mercury in the UK. DERA/AS/PTD/CR000114.

(2) Richardson D.M., Davies I.M., Moffat C.F., Pollard P. and Stagg R.M. 2001. Biliary PAH metabolites and EROD activity in flounder (*Platichthys flesus)* from a contaminated estuarine environment. J. Environ. Monit., **3**, 610-615.

(3) Marine Scotland (2012). The Distribution of Zooplankton Prey of Forage Fish in the Firth of Forth Area, East Coast of Scotland. Available online http://www.scotland.gov.uk/Publications/2012/08/2345/1.

prey species, directly (removal of cockles) and indirectly (damage to non-target species). A Special Nature Conservation Order (SNCO) was implemented under the *Conservation (Natural Habitats) Regulations 1994* to the outer Firth of Forth, including Forth Bridge to Granton Harbour and from Leith Docks to Joppa. This Order, implemented in March 2003, was revoked and reissued in 2006, and still stands (1).

B3.3 Other Dredging Disposal Activities

In addition to the intended maintenance dredging activities at the Port of Grangemouth with proposed disposal at Bo'ness, Forth Ports manages five other dredging operations within the Forth Estuary and Firth of Forth. The operations comprise the following.

- Trailer suction dredging in Leith with disposal at Narrow Deep B spoil disposal ground: maximum volume for maintenance dredging is 90,000 m^3 per annum. Dredging is undertaken over one to two days per month, six months of the year.
- Grab/backhoe dredging at Newhaven with disposal at Oxcars spoil disposal ground: maximum capacity for maintenance dredging is 15,000 m^3 per annum, undertaken over four weeks, usually in spring.
- Trailer suction dredging in Rosyth with disposal at Oxcars spoil disposal ground: maximum volume for maintenance dredging is 400,000 m^3 per annum. Dredging is typically undertaken over three days per month, every other month.
- Trailer suction or grab dredger Methil approach channel with disposal at Methil spoil disposal ground: maximum volume for maintenance dredging is 12,500 m^3. Dredging is undertaken annually.
- Grab dredger and plough at Kirkcaldy with disposal at Kirkcaldy spoil disposal ground: maximum volume for maintenance volume for dredging is 5,000 m^3. Dredging is undertaken annually.

The actual timing of dredging and volumes required to be dredged during each campaign depend on operational requirements and sedimentation rates (for example due to storm events, which can happen at any time of year).

Other recent, ongoing or planned licenced dredging activities in the Firth of Forth include the following (note these are based on planned or licenced activities so actual volumes dredged may be lower and dates may have been delayed due to Covid-19).

- Forth Ports currently has a planning application under consideration for the development of the Leith Outer Berth to accommodate vessels that are unable to enter the lock gates into the Port of Leith. The proposal would involve the removal of 101,000 m^3 of material from the Leith outer berth with disposal at the Narrow Deep B soil disposal ground.
- Babcock Marine at Rosyth had a Marine Licence for maintenance dredging of up to 100,000 tonnes between March 2019 and March 2020 with disposal at Oxcars B.
- Capital dredge of up to 33,800 tonnes using a plough dredger at Port Edgar within the confines of the marina between April 2021 and April 2022 with disposal to the entrance to the marina.
- Maintenance dredging at Pittenweem Harbour, with disposal of 27,334 tonnes at Anstruther spoil disposal ground between August 2019 and August 2020.
- Trailer suction and backhoe dredging with self-propelled barge at Defence Munitions Crombie, maximum quantity of disposed material is 22,000 m^3 per annum for maintenance (2) (although this has not been undertaken annually), with disposal at Bo'ness spoil disposal ground.

(1) http://gateway.snh.gov.uk/sitelink/siteinfo.jsp?pa_code=8499

(2) Rosyth International Container Terminal. Operational In-combination Assessment of Maintenance Dredging and Implications for the River Teith SAC. Jacobs, 2011.

- Maintenance dredging at Granton Harbour by agitation of 5,904 tonnes per annum between August 2021 and August 2023. Previous licence to dredge 86,980 m^3 at Granton Harbour with disposal at Bo'ness or Narrow Deep spoil disposal ground between August 2019 and July 2022.
- Maintenance dredging using land-based plant of 1,200 tonnes over two years at Dysart Harbour, Fife, with disposal on the adjacent foreshore where it is dispersed on the incoming tide (July 2019 to July 2021).
- Capital dredging and sea disposal of 225,000 tonnes from deepening the berth pockets at one of the quays at the Fife Energy Park at Methil. The licence covered the period 10 April and 3 September 2021. Disposal of the dredged sediment material was to be disposed at the Methil spoil disposal ground with material with larger rock fractions to be disposed of at Narrow Deep.

Ongoing maintenance dredging spoil disposal operations require licence renewals every three years by Marine Scotland. Potential impacts are therefore assessed and reviewed every three years prior to granting a Marine Licence. The historical disposal route for spoil from all listed dredging operations has been deposition at sea, and to date, no environmental impacts, other than direct impacts within the spoil disposal grounds, have been reported.

Work began on the Forth Replacement Crossing at the end of 2011, and capital dredging works for the bridge support foundations started at the beginning of 2012. The purpose of the dredging was to create access for the construction of the foundations for the structures which will support the new bridge. In total 180,000 m^3 of silt and sand was dredged from the seabed to form access channels for bridge foundation works between 2011 and 2016 (1) and the spoil was disposed of at the Oxcars spoil disposal ground. For the larger dredged rock material, the Blae Rock spoil disposal ground was used.

B3.4 Foreseeable Future Activities within the Firth of Forth

There is one existing and one proposed single turbine wind farm developments in the Firth of Forth, offshore from Methil

- Levenmouth Demonstration Turbine

  The Offshore Renewable Energy (ORE) Catapult's seven megawatt wind turbine was completed in 2013 and is located 50 m from the coast connected to the land by a ramp. The tower stands at 110 m and is 195 m to the top of the blade. Samsung had previously owned the wind turbine demonstrator, before selling to ORE Catapult in December 2015. In 2018 the licence to permit the turbine was extended to 2029.

- Forthwind Demonstration Project

  Forthwind has proposed to install a single turbine with a generating capacity of up to 20 megawatts and a meteorological mast 1.5 km offshore from the coast at Methil. The current application replaces the previous two turbine scheme, approved in 2016. The project is at the EIA scoping stage.

There are three large scale offshore windfarm development sites in the outer Firth of Forth area. These sites are at some distance from Bo'ness spoil disposal ground (circa 75 to 115 km) but are within the foraging areas of the qualifying features of the SPAs and SACs. In addition, there will be power export cables laid on the seabed from the windfarm sites to coastal substations within the Firth of Forth. Other potential windfarm sites in the outer Firth of Forth area are at a concept/early planning stage.

- Neart na Gaoithe Offshore Wind Farm

  NnG Offshore Wind was granted consent by the Scottish Government in 2018 to build a 448 megawatt offshore wind farm in the outer Firth of Forth comprising up to 54 wind turbines up to

(1) Hochtief (UK) Construction (2016). Forth Road Bridge Replacement - Queensferry Crossing. Available online http://www.hochtief-construction.co.uk/bridges_Forth_Road.shtml

208 m high occupying an area of approximately 105 km^2. Construction commenced in 2020 with seabed preparations being undertaken prior to piling works. An onshore operations and maintenance base at Eyemouth received planning permission in September 2020. The wind farm is expected to be operational in 2023.

- Inch Cape Offshore Wind Farm

  Consent was granted for the proposed Inch Cape Offshore Wind Farm in October 2014. Consent was delayed following an objection lodged by the Royal Society for the Protection of Birds and final approval was given in 2017. A revised scope of design was granted by Scottish Ministers in June 2019. This scope reduced the number of wind turbine generators from 110 to 72. The turbines will occupy an area of 150 km^2. The windfarm will connect to the National Grid at Cockenzie (with the closest part of the cable route being approximately 10 km from Narrow Deep). Construction is expected to begin in 2022. Once fully operational the wind farm will have an export capacity of approximately 1,000 megawatts.

- Seagreen Offshore Wind Farm

  Scottish and Southern Electric (SSE) and TotalEnergies joint venture partnership Seagreen Wind Energy was awarded the exclusive development rights for the Firth of Forth Zone by Crown Estate Scotland. The zone covers an area of 2,852 km^2 in the outer Firth of Forth. Seagreen was awarded consent by the Scottish Government in October 2014 to develop the northern part of the Firth of Forth Zone to generate up to 1,050 megawatts of power from up to 150 turbines. The design was updated and approved in 2018 to comprise fewer, larger wind turbines. Currently the plan is for 1075 MW from 114 turbines which are currently under construction with one turbine being connected to the grid in August 2022 and the current phase is expected to be fully operational by the second quarter of 2023. Montrose port is the location for the operations and maintenance base and the export cable will go to Dundee. A further phase of 36 turbines in proposed with the export cable going to Cockenzie.

B3.5 Conclusions

Potential cumulative impacts associated with the above activities can be broadly categorised as comprising suspension of sediments during dredge spoil disposal operations and construction activities resulting in loss or smothering of benthos, the discharge of contaminants with the potential to impact both water and sediment quality, and the disturbance to seabirds and mammals from piling operations and vessel movements.

None of the dredging operations listed in *Section B3.3* dispose of dredged material at Bo’ness spoil ground. Other dredging and disposal activities and the windfarm construction activities are at some distance from the Bo’ness spoil disposal ground and no significant cumulative impacts from suspended sediments, noise and other vessel movements from these activities on the Bo’ness site are considered likely.

The dredge spoil disposal operations at the Bo’ness spoil disposal ground pre-date the SPA and SAC designations and there is no evidence to suggest that the past and current disposal operations at Bo’ness spoil disposal ground managed by Forth Ports have impacted the integrity of designated sites, supported species, or resulted in other significant environmental impacts either alone or cumulatively with other activities in the area.

APPENDIX C CONSULTEE RESPONSES (EXTRACTS FROM LETTERS/EMAILS RECEIVED)

C1 NATURESCOT

I can confirm that we have nothing to add to our previous comments in relation to the use of Bo'ness spoil disposal ground, and also that we are not aware of any current options for potential beneficial reuse of the material.

C2 SEPA

Our initial thought is that the dredged material would be classified as waste.

https://www.sepa.org.uk/regulations/waste/guidance/

As such, the material would require sampling, analysing and assessing as outlined in the Waste Classification WM3 technical Guidance.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1021051/Waste_classification_technical_guidance_WM3.pdf

Generally, the re-use of such materials would only be possible for materials classified as non-hazardous waste.

There may be the potential to re-use the wase under a Waste Exemption. The requirements for these vary depending on the volumes at any given time, the intended end-use and the suitability of the waste for this end-use (both regarding waste classification and the material composition). Under a Waste Exemption, it is imperative that the waste has an intended end-use prior to its excavation and that the exercise is not for disposal purposes only. Further information on Waste Exemptions can be found at the following link:

https://www.sepa.org.uk/regulations/waste/activities-exempt-from-waste-management-licensing/

In addition to the above, any intended end-use for the waste should not present a risk to the environment (water and groundwater) or human health.

C3 NORTHERN LIGHTHOUSE BOARD

We note that the works are for a 3 year period and focus on maintaining safe navigable water depth throughout the port.

Northern Lighthouse Board has no objections to the proposed dredging and/ or disposal of dredged spoil to the charted and approved spoil ground at Bo'ness, and will respond formally to the Marine Licence application, however we would advise the following:

- **Forth Ports Ltd** issue marine safety information as considered appropriate prior to the commencement of each dredge campaign.
- **Forth Ports Ltd** advise the UK Hydrographic Office (sdr@ukho.gov.uk) of any revised water depths in order that chart updates are completed.

ERM has over 160 offices across the following countries and territories worldwide

Argentina	New Zealand
Australia	Norway
Belgium	Panama
Brazil	Peru
Canada	Poland
Chile	Portugal
China	Puerto Rico
Colombia	Romania
France	Russia
Germany	Singapore
Hong Kong	South Africa
India	South Korea
Indonesia	Spain
Ireland	Sweden
Italy	Switzerland
Japan	Taiwan
Kazakhstan	Thailand
Kenya	UAE
Malaysia	UK
Mexico	US
The Netherlands	Vietnam

ERM's Edinburgh Office

6th Floor
102 West Port
Edinburgh
EH3 9DN

T: 0131 221 6750

www.erm.com

The business of sustainability

ERM