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Generic Quantitative Risk Assessment

Proposed Dredging and Reclamation Works at Howth Fishery Harbour, Co. Dublin


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1 INTRODUCTION

1.1 PURPOSE OF ASSESSMENT

Malachy Walsh & Partners, (MWP) on behalf of the Department of Agriculture, Food and the Marine (DAFM) undertook a Generic Quantitative Risk Assessment (GQRA) relating to the quality of sediments intended to be dredged from inside the Howth Fishery Harbour Centre (Howth FHC) and subsequently solidified/stabilised and the potential impact of using the treated material as engineering backfill as part of the development.

1.2 SCOPE OF WORK

The scope of work within this GQRA is as follows:

- A review of the chemical data obtained from sediment and tank test samples;
- Defining the conceptual site model including identification of key chemical determinants and a review of potential pathways and receptors in the context of the proposed development;
- Calculation of temporary seawater concentrations that may develop during dredging activities;
- Development of a risk assessment model to quantify the impact of dilution on source concentrations and leachable concentrations obtained from the tank test data (i.e., to assess the risks posed by stabilised material once it has been placed within the land reclamation area);
- The presentation of the conceptual model, modelling methodology and risk assessment results in a concise report.

2 SITE DESCRIPTION

Howth Harbour is situated on the north side of Howth Peninsula, to the north of Dublin Bay (Figure 1). The harbour itself comprises of three main areas; a trawler basin entered between two bull-noses to the north, swing moorings area to the east and the yacht club marina.

For the purposes of the dredging project, the harbour is considered to comprise of five areas (Figure 2):

1. Trawler Basin;
2. Harbour Approach Channel;
3. Mooring area;
4. Marina Approach Channel;
5. Marina Area.

Howth Harbour operates as a Fishery Harbour Centre under the Department of Agriculture, Food and the Marine. The core fishing fleet is in the order of 65 vessels, and there is significant marine leisure activity, including the Howth Yacht Club and the Howth Sailing and Boating Club. There are also a number of restaurants and shops along the West Pier. Fish processing and boat repair works are also undertaken at the harbour.

Figure 1 Site location map

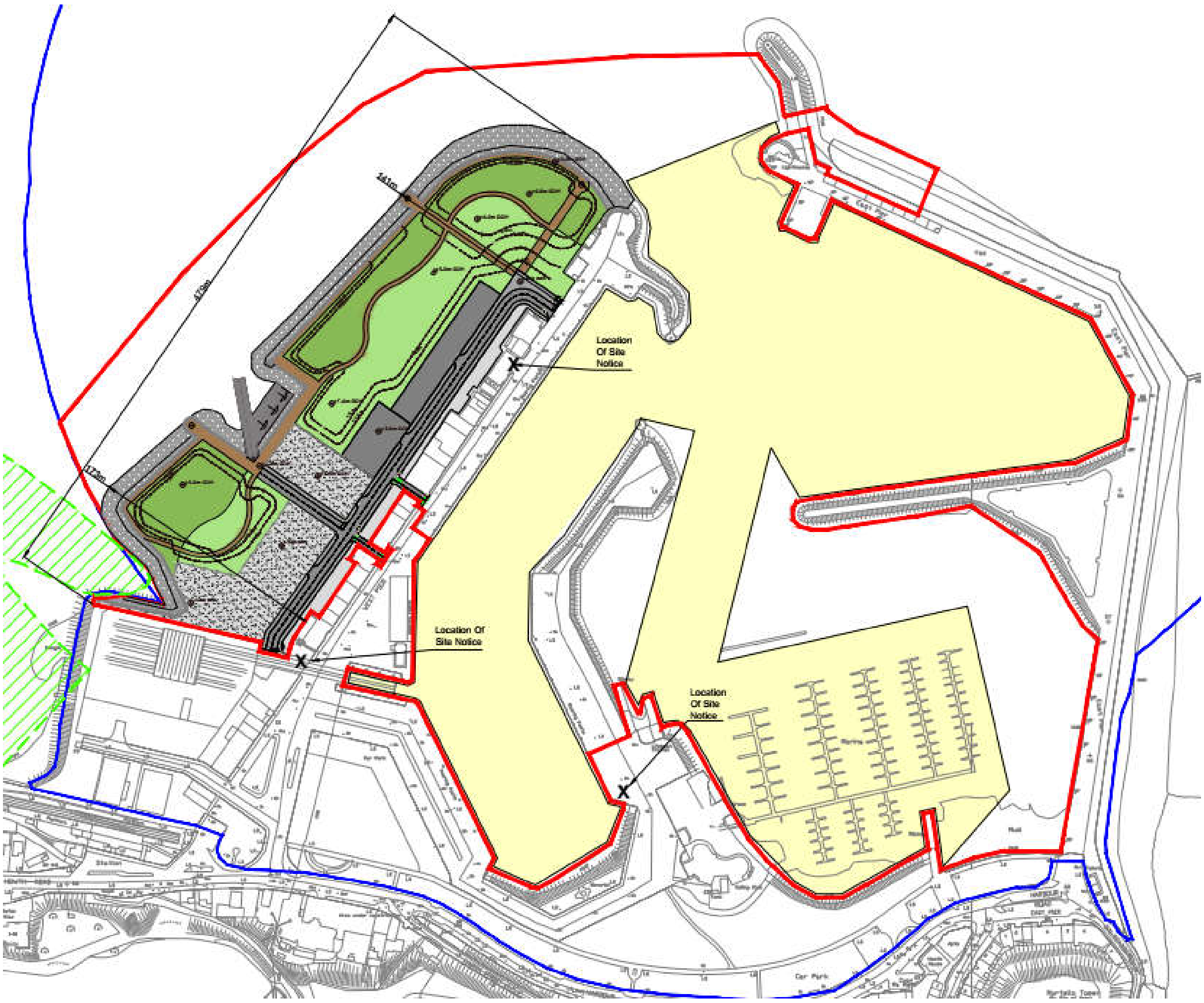


Figure 2: Extract from Project Drawing showing the proposed reclamation area west of the West Pier and the dredge area in yellow. Drawing no. 19934-5002 Site Layout Plan.

The proposed site is situated in proximity to several Special Protection Areas (SPA) and Special Areas of Conservation (SAC), the closest of which is Baldoyle SAC, located adjacent to the site.

The 2019 site investigation found the soil in the reclamation area comprised fine to medium brown SAND with underlying fine to course grey, silty gravelly SAND. Underneath the sand strata, material described as grey, slightly gravelly CLAY with some cobble and shell content was encountered. Bedrock encountered is predominantly described as strong grey limestone.

The soils described within the dredge footprint were found to consist of very soft to soft, black, slightly sandy slightly gravelly SILT. The black silt had an organic odour to it. The bedrock immediately to the south of the site at Howth and extending west towards Dublin city are mostly sedimentary in nature, dominated by limestone and shale.

The harbour is situated in the Irish Sea (EPA code HA 09). In accordance with the Water Framework Directive, the water quality of the waterbody is given as a ‘good status that is not at risk’. There is no aquifer classified under the harbour but the aquifer to the south of the site has been classed in the Aquifer Category LI (Locally Important). The bedrock aquifer is a locally important aquifer with the bedrock moderately productive only in local zones. Groundwater at the site is expected to be brackish / saline and unsuitable for potable supply.

2.1 PROJECT DESCRIPTION

Howth Fishery Harbour Centre (Howth FHC) was last dredged in the 1980s, and due to build-up of siltation, it is necessary to dredge the existing basins & approach channels in Howth Harbour in order to provide safe access, navigation and berthing to the vessels currently using the harbour, and to provide for appropriate maintenance of same into the future through a programme of measurement and maintenance dredging. Some dredging has occurred in late 2020 with the Middle Pier works but it is minor and does not address the main siltation issue.

The project consisted of the proposed dredging of circa 240,000m^3 of marine sediment from Howth Harbour, and the treatment and re-use of the material to the west of the West pier in order to create and additional circa 48,000 square metres of land area.

The aim of the overall project is to increase the depth of water in order to provide safe access and harbour, to the largest range of vessel size and type on the widest range of tides, within the structural parameters of the existing harbour quay structures and where possible to treat and beneficially re-use dredge material in an environmentally sustainable and cost effective manner.

The proposed development involves the following main elements:

- Dredging the harbour;
- Reclaiming land on the west side of the west pier using dredge material (see **Figure 3**);
- Coastal protection works to the perimeter of the reclaimed area;
- Landscaping on the reclaimed area;
- Construction of pavements e.g. footways, roadways and parking areas;
- Construction of slipway for access to the water;
- Provision of storage areas for harbour activities;
- Provision of services.

Figure 3 Proposed land reclamation area. The figure is an extract from Drawing no. 19934-5002 Site Layout Plan

3 ENVIRONMENTAL SITE INVESTIGATION

3.1 SITE INVESTIGATION NOVEMBER 2015

A site investigation was carried out in November 2015, to inform proposed works on the middle pier. These works on middle pier are now ongoing in 2021. 32 no. sediment samples were taken from throughout the harbour and analysed for parameters including Dibutyltin (DBT), Tributyltin (TBT), and heavy metals such as arsenic, copper, lead and mercury. The proposed works at middle pier included the use of stabilised dredged material as part of the construction of the Pier wall. A GQRA was carried out on the proposal in support of the respective planning application and waste facility permit application.

3.2 SITE INVESTIGATION DECEMBER 2019

3.2.1 Specific Sediment Sampling December 2019

During the 2019 site investigation by Priority Geotechnical Ltd., two cable percussion boreholes and three rotary boreholes were completed. 26 environmental samples were also taken within the footprint of the proposed dredge area. The depths of the environmental samples in the sediment ranged from 0-1m and 1-2m below seabed. A total of 23 sediment samples from SP1 - SP23 were sent for laboratory. See **Figure 4** for the location that the samples (marked SP) were taken. All 23 of the sediment samples underwent analysis by a full accredited chemical laboratory for heavy metals, Organotins (TBT and DBT), Polycyclic Aromatic Hydrocarbons (PAH's), Hydrocarbons (THC), Polychlorinated Biphenyls (PCB's) and pesticides. 10 of these samples underwent analysis for Waste Acceptance Criteria (WAC) parameters. All sampling and testing was agreed with the Marine Institute before the start of the investigation.

The full site investigation report including the sediment analysis results are presented in **Appendix 2** of the EIAR accompanying the planning application**.**

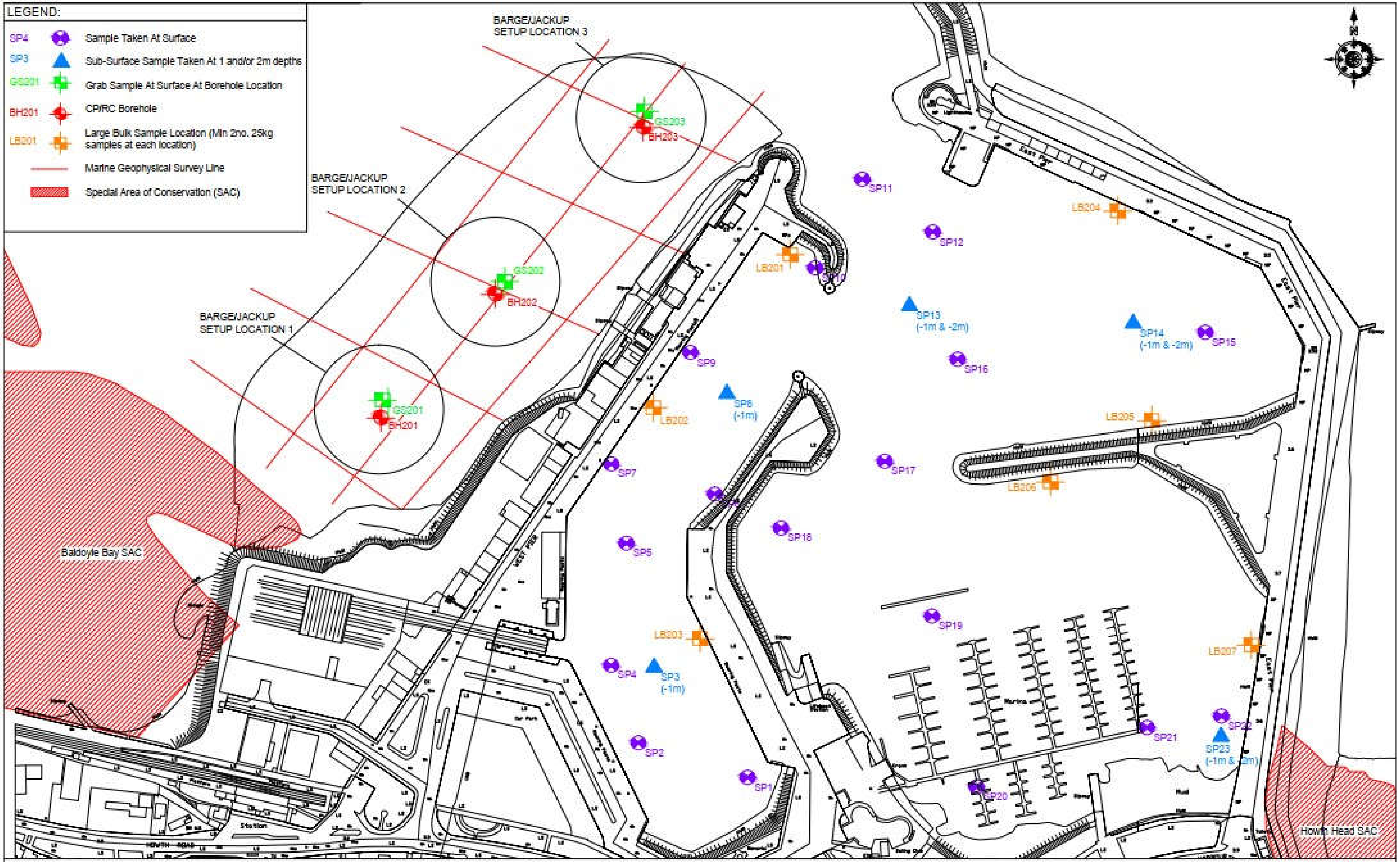


Figure 1. Site Investigation borehole locations 2019

3.3 ASSESSMENT OF DREDGE SEDIMENT MATERIAL FOR DISPOSAL AT SEA

Generic assessment criteria for sediment quality have been developed by the Irish Marine Institute (MI) in the MI Guidelines on the *"Assessment of Dredged Material for the Disposal in Irish Waters (2006)".* The guidelines, which are designed to assess the suitability of disposing of dredged material at sea, identify a Lower Level 1 and Upper Level 2 of contamination which characterises the marine sediments into three categories or classes of potential contamination:

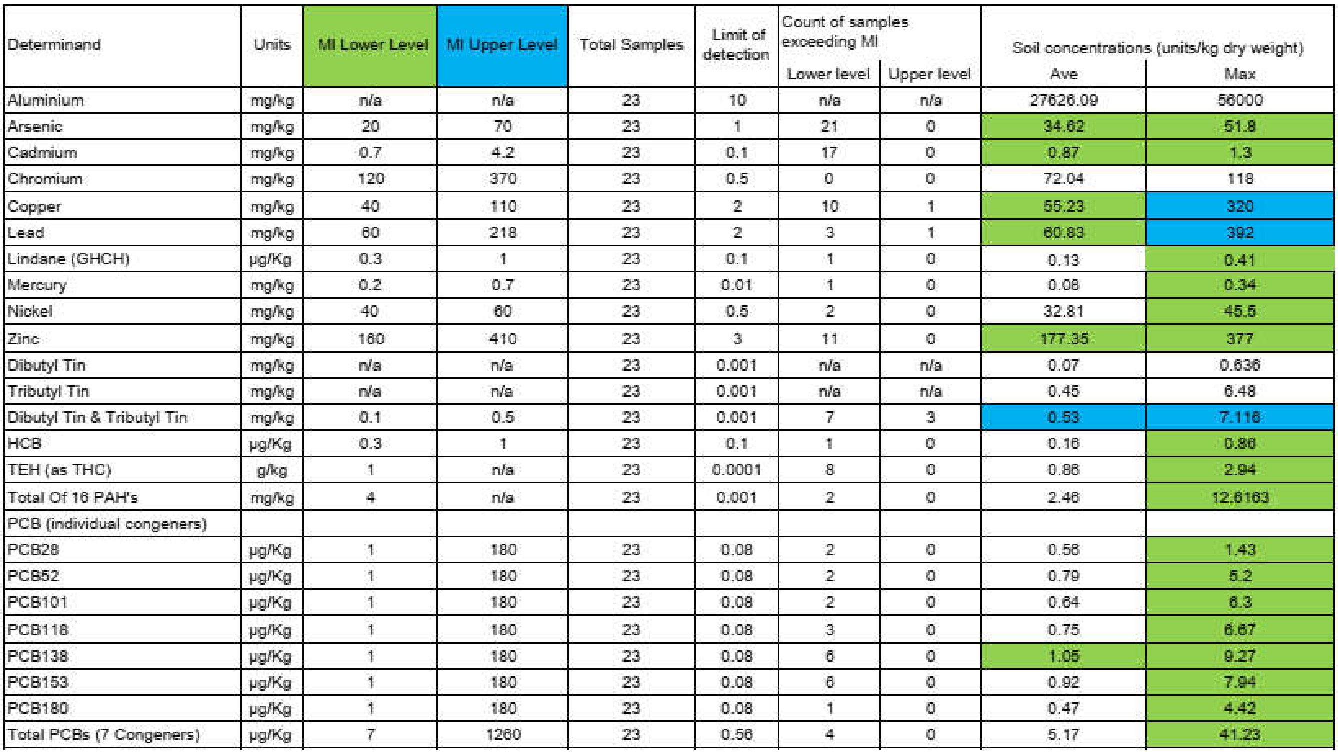
1. Class 1: Where contamination concentrations are less than Level 1 the sediment is considered to be uncontaminated - with no biological effects likely.

2. Class 2: Where contamination concentrations are between Level 1 and Level 2 the sediment is considered to be marginally contaminated; further sampling and analysis should be considered to delineate problem areas, if possible.

3. Class 3: Where contamination concentrations are above Level 2 the sediment is considered to be heavily contaminated and very likely to cause biological effects/toxicity to marine organisms. The MI guidelines recommend that alternative management options are considered for this level.

The 23 no. sediment samples were compared to the MI lower and upper levels and a summary of the results is presented in **Table 1** below.

Table 1. Analysis results compared to MI lower and upper levels



Determinand	Units	MI Lower Level	MI Upper Level	Total Samples	Limit of detection	Count of samples exceeding MI		Soil concentrations (units/kg dry weight)	
						Lower level	Upper level	Ave	Max
Aluminium	mg/kg	n/a	n/a	23	10	n/a	n/a	27626.09	56000
Arsenic	mg/kg	20	70	23	1	21	0	34.62	51.8
Cadmium	mg/kg	0.7	4.2	23	0.1	17	0	0.87	1.3
Chromium	mg/kg	120	370	23	0.5	0	0	72.04	118
Copper	mg/kg	40	110	23	2	10	1	55.23	320
Lead	mg/kg	60	218	23	2	3	1	60.83	392
Lindane (GHCH)	µg/Kg	0.3	1	23	0.1	1	0	0.13	0.41
Mercury	mg/kg	0.2	0.7	23	0.01	1	0	0.08	0.34
Nickel	mg/kg	40	60	23	0.5	2	0	32.81	45.5
Zinc	mg/kg	160	410	23	3	11	0	177.35	377
Dibutyl Tin	mg/kg	n/a	n/a	23	0.001	n/a	n/a	0.07	0.636
Tributyl Tin	mg/kg	n/a	n/a	23	0.001	n/a	n/a	0.45	6.48
Dibutyl Tin & Tributyl Tin	mg/kg	0.1	0.5	23	0.001	7	3	0.53	7.116
HCB	µg/Kg	0.3	1	23	0.1	1	0	0.16	0.86
TEH (as THC)	g/kg	1	n/a	23	0.0001	8	0	0.86	2.94
Total Of 16 PAH's	mg/kg	4	n/a	23	0.001	2	0	2.46	12.6163
PCB (individual congeners)									
PCB28	µg/Kg	1	180	23	0.08	2	0	0.56	1.43
PCB52	µg/Kg	1	180	23	0.08	2	0	0.79	5.2
PCB101	µg/Kg	1	180	23	0.08	2	0	0.64	6.3
PCB118	µg/Kg	1	180	23	0.08	3	0	0.75	6.67
PCB138	µg/Kg	1	180	23	0.08	6	0	1.05	9.27
PCB153	µg/Kg	1	180	23	0.08	6	0	0.92	7.94
PCB180	µg/Kg	1	180	23	0.08	1	0	0.47	4.42
Total PCBs (7 Congeners)	µg/Kg	7	1260	23	0.56	4	0	5.17	41.23

The analysis results (full results are presented in **Table A, Appendix 1** attached below) show that all samples are in Class 2 except for 3 of the samples which are in Class 3. The class 3 contaminants of concern were DBT, TBT, copper and lead. The class 3 exceedances happened in SP08, SP12 and SP23 which are widely spread across the harbour indicating that the class 3 material is not localised within the harbour.

The widespread nature of the contamination concentrations exceeding the Class 2 and 3 levels indicates that the sediment material is not suitable for conventional dumping at sea.

3.3.1 Stabilised and Solidified Sediment Monolith Testing December 2019

Sub samples from the 23 sediment samples were mixed together to create 12 samples of sediment that were then stabilised and solidified (S/S) with binder. The S/S treatment process is explained in more detail in section 4, but the binder is a mixture of cement and Ground Granulated Blastfurnace Slag (GGBS). Variety in sediment location and binder content was undertaken to find the best range of binder mixes for engineering and environmental purposes. Cylinders or monoliths of the stabilised and solidified sediment underwent monolithic tank testing as per NEN 7375:2004. “The Tank Test” or NEN 7375:2004 Leaching Characteristics of Moulded or Monolithic Building and Waste Materials is a Dutch leaching characterisation standard. The purpose of the test is to simulate the leaching of inorganic components from moulded and monolithic materials under anaerobic conditions as a function of time. Water from the tank was tested for the contaminants of concern (metals, DBT and TBT) to determine the leachability of the different monolithic samples. Testing on the leachability of the monolith was carried out over 8 different periods of time as per the NEN 7375:2004 standard. Some of the monolith samples were discarded later in the process as better mixes were identified, with 7 samples making it to the final stages of testing.

The full analysis results from the laboratory are presented in the geotechnical report in **Appendix 2** of the EIAR**.**

4 CONCEPTUAL SITE MODEL

The conceptual site model (CSM) is a written or pictorial representation or working description of an environmental system on the site and the surrounding area and its purpose serves to draw together, (1) the potential sources of contamination (hazards) that may be present on or surrounding the site that have the potential to cause harm or pollution to the surrounding environment,(2) identifies the sensitive receptors, such as flora/fauna, water, etc. that may impacted by a given source, and (3) identifies the pertinent pathways or route that may be present between and link the two.

The potential pollutant linkages and nature of the sources, pathways and receptors are site specific and will vary depending on such things as site history, ground and water conditions, and current and proposed end uses of a particular site.

While each of these elements can occur independently an environmental risk can only exist if all three elements of the Source - Pathway – Receptor linkage are present. If one element is missing, then there is no pollutant linkage and no associated environmental risk can occur.

For the Howth FHC Dredge project, the Conceptual Site Model for the QRA looks at both:

1. the short term sediment dredging scenario, and
2. the longer term reuse of the stabilised sediment in the reclaimed land.

4.1 POTENTIAL SOURCES OF CONTAMINATION

Marine sediments arise from both natural and man-made sources. As a watercourse or storm drain enters a harbour it loses energy and deposits the sediment or suspended solids, onto the harbour floor. Tidal and wave activity can be an additional source of sediment and can also move sediment within the harbour.

Sediments generally contain metal concentrations which are orders of magnitude greater than in the overlying water column (Shropp et al. 1990). Due to the enclosed nature of Howth Harbour it is subject to enhanced anthropogenic impacts as a result of restricted transport and dispersal of contaminants. The marine sediment within Howth Harbour will also contain matter which arrives naturally, from the local water course, and from man-made sources such as stormwater discharges from the adjacent land and any industries (manufacturing, commercial, marine), which are located around the harbour and from ship and boats using the harbour.

The small sized grains (<0.025mm fraction) of sediment is one of the major sinks for contaminants introduced to waters. This is a natural phenomenon and is largely due to the presence of mineral clays with organic coatings and iron and manganese (oxy-) hydroxide coatings. The clays scavenge dissolved trace metals from the water column and bind the metals into the sediment.

Additionally, there is a tendency for organic compounds which do not dissolve in water to accumulate in sediment by sorption (taken up by) natural organic matter. The extent of sorption will depend, in part, on the organic matter content of the specific sediment. The quantity of organic matter in sediment tends to vary naturally across a harbour.

The completed site investigations and sediment analysis have identified the occasional presence of some elevated heavy metals such as Arsenic (As), Cadmium (Cd), Lead (Pb), Copper (Cu) Mercury (Hg), Nickel (Ni), Zinc (Zn) and Organotin Compounds such as Tributyltin (TBT) and Dibutyltin (DBT), with some minor elevated Polychlorinated Biphenyls (PCBs) and Polycyclic Aromatic Hydrocarbons (PAHs), in the upper unconsolidated sediments from the sea floor down to between 1m to 2m into the marine sediments. These analytes are considered potentially detrimental to the aquatic environment as they are persistent, toxic and bio-accumulate in the food chain. They pose a potential source of aqueous contamination if in situ sediments are disturbed during dredging and backfilling works. The main source of these contaminants is probably from past fishery maintenance activity including use of anti fouling agents which contained organotins, now banned.

The fine sediments disturbed by the dredging and reclamation activity also pose a potential contamination risk as elevated concentrations of Total Suspended Solids (TSS) can be detrimental to aquatic organisms as they restrict natural light, can clog fish gills, and (as mentioned previously), the sediments themselves act as a potential source of heavy metals in the environment.

Dredging Sediment Source

A hydrodynamic assessment (see **Appendix 4** of the EIAR on the project) was carried out as part of the EIAR. The assessment states that during the dredging process some sediment will go into the water column at the dredging location. The heavier particles will settle quickly and near the dredging location while some smaller particles will travel further out of the harbour before settling out. The hydrodynamic assessment states there will be residual impacts in the form of temporary increased levels of suspended sediment during dredging. The receptor of concern was considered to be the area to the west of the harbour close to Claremont Beach within the Baldoyle SAC. However, the increases in levels of suspended sediments during the dredging are considered small, they are temporary in the sense that they depend on the stage of the tide, the dredging will be intermittent, and the overall dredging campaign will last less than 18 months.

The hydrodynamic model calculated the deposition of sediments at the Baldoyle SAC to the west of the harbour. The contamination within this deposition is calculated and assessed for risk in section 3.1 of this report.

Table 3 in section 5 below presents the leachate results of the sediment samples from within the harbour. The results show a slight exceedance of the EQS in arsenic but in general the contaminants have not gone into the aquas phase in a gross manor. It is considered that the contaminants of concern are bound within the fine sediments themselves and only a proportion of any potential contamination will go into the aqueous phase due to sorption; subsequent dilution effects would reduce Tributyl Tin concentrations below the AA EQS values almost instantaneous within the inner harbour waters.

Stabilised and Solidified Sediment Source

In order to re-use the dredged sediment as engineering backfill material it needs to be stabilised and solidified and this process will also have the advantage of greatly reducing the polluting potential of the dredged sediments.

Stabilisation/solidification (S/S) is a widely used remediation technology that relies on the reaction of a binder and sediment to reduce the potential mobility of contaminants. The process of stabilisation involves the addition of substances (reagents) to a contaminated material which produce more chemically stable constituents while solidification involves the addition of reagents to a contaminated material to impart physical stability to contain the contaminants in a solid mass and also reduce the interaction with external agents such as air, surface waters, rainfall, etc. The process of stabilising and solidifying the contaminated dredged sediments will effectively provide an attenuation medium for any contaminants with the key process being retardation.

The treated dredge sediments samples for Howth FHC dredge were tested and exhibit very low permeability characteristics in the order of 5x10-11m/s (ref. **Appendix 2.2 Geotech Lab Report**, Volume 3 of the EIAR)

It is assumed that the outer surface layer of the S/S sediment once placed in the reclamation areas will have some interaction with ground waters. The S/S sediment exhibits very low permeability. There will be some permeation of water into the very outer surface layer of the S/S sediment. This will lead to a very small amount of contaminants leaching into the ground water at the reclamation area. This leaching was tested during the monolithic tank tests, where the water that the S/S sediment monolith was submerged in was tested for leaching contaminants. This leaching behaviour would be permanent over the life of the reclamation area. It is expected that the leaching will decrease over the life of the stabilised material as the outer surface layers of the S/S sediment get washed by the leaching and the contaminants within the outer layers decrease due to the leaching action. The contaminants inside the reclamation area and away from the outer layers would be protected by the very low permeability of the S/S sediment and not be effected by leaching.

For this project the S/S sediment will greatly limit water infiltration through the mass of treated dredge material and thus limit the potential contaminant flux to the water. The reclamation area includes the construction of a perimeter embankment and rock armour revetment which includes the placement of a Geosynthetic Clay Liner (GCL) that will further reduce the connectivity of the waters with the treated material as well as protecting the treated sediment from normal tidal flows and any potential erosive current or wave action.

For the purpose of this risk assessment the GCL is removed from calculations in the long term leaching and the risk is assessed as if it was not there. This is a conservative approach to the risk assessment. This is done to take into account the long term scenario of the end of life of the membrane.

There is a risk of the S/S sediments breaking out of the containment area before it cures and also there is a risk of leaching of contaminants from the viscous uncured S/S sediments in the few days before it cures. There is also a risk of the initial washout leaching to be higher than the long term leaching during the first few days of the life of the cured S/S sediment. The risk assessment does take into account the short term use of the perimeter embankment and rock armour revetment and the GCL for initial containment of liquid S/S sediment and initial contaminant leaching washout.

This risk assessment uses the results from the monolithic tank test to calculate the potential leaching of contaminants from the S/S sediment into the receiving waters.

Other Contaminant Sources

As well as the potential for contamination from the dredged sediments, there are potential sources of contamination during the construction works from the machinery/equipment (including fuels and oils), and/or raw materials (i.e. cement), used in the dredging, stabilisation and backfilling works.

4.2 POTENTIAL ENVIRONMENTAL PATHWAYS

The primary pathway for the mobilisation of potential contamination is in sea water during both the short term dredging and reclamation processes and also in the longer term interaction between the sea water and ground water interacting with stabilised material in the reclamation area.

During the dredging the contaminants can be suspended in the water column and be carried around the harbour or out of the harbour on the ebbing tide. The results of detailed modelling of potential sediment plume from dredging activities are presented in the hydrodynamic assessment (**appendix 4** of the EIAR).

Figure 5 below, presents the potential pathways with regard to the S/S sediments in the reclamation area. Initially when the material is pumped into the reclamation rea it will be in a liquid form. The revetment wall and the GCL barrier will stop the treated sediment from entering into the sea. Within about 7 days the treated material will harden.

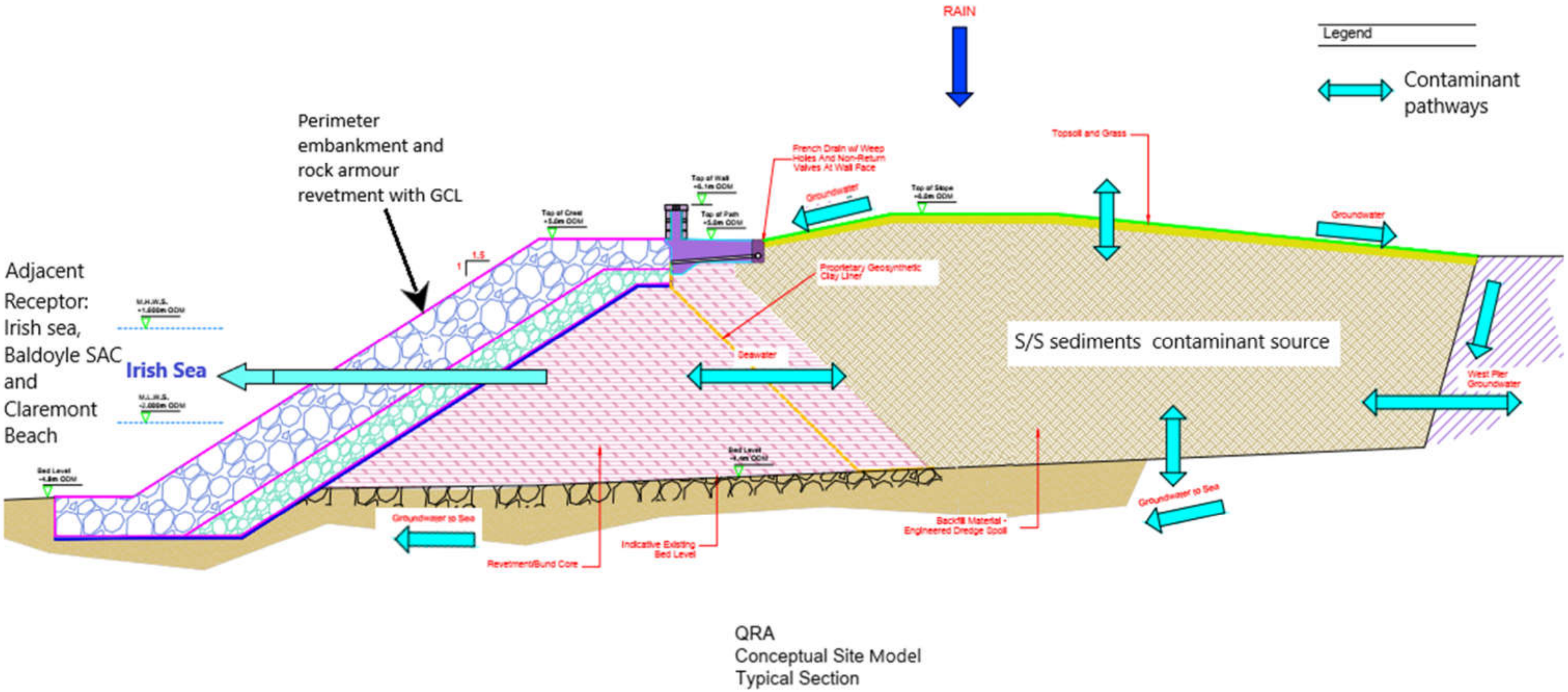


Figure 5 Conceptual Site Model for stabilised and solidified sediments in the reclamation area (not to scale).

The impermeable barrier surrounding the S/S sediments will block the pathway between it and the ground/sea water. This barrier will have a given life span and the S/S sediments are permanent. The following pathways assume the impermeable barrier is not there (to account for the end of life of the barrier into the future). The pathways for potential contaminants from the treated sediment source are as follows:

1. Rainwater in the reclamation area, saturating the top surface layer and running off the reclamation area or percolating down the side of the S/S sediments and reaching the sea water.
2. Ground water (made from rainwater and permeating sea water) coming into contact with the S/S sediment and then flowing towards the revetment wall and the sea
3. sea water coming into contact with the S/S sediments along the revetment wall and then flowing through the wall and into the sea.

There will be retardation of leachate flow from the surface of the monolith on all sides due to subsoils and low ground water flow around the monolith. The direction of flow is the path of least resistance, towards the sea, as the existing west pier will be on the harbour side of the reclaimed land.

The pathway for the contaminants is then into the revetment core and the outer rock armour before entering the sea. The pore space within the revetment core and rock armour acts as a mixing zone where the contaminants are mixed with sea water via tidal and current action. The contaminants then leave the revetment wall and enter the sea.

The dilution factor used in this assessment derives from the calculated volume of sea water moving through the revetment wall. This water will mix with the leachate from the S/S sediment and then the contaminants will enter the sea. There will be some retardation of current flow through the revetment wall but considering that there is 40% pore space in the outer wall this retardation will be factors lower than the retardation of the leachate flow.

Air is not considered to be a potential pathway as no vapours or gases will occur and the potential for dust is very limited as the process is completed in a wet environment.

4.3 POTENTIAL ENVIRONMENTAL RECEPTORS

The primary sensitive environmental receptors are identified as marine flora and fauna in the vicinity of the works and in particular the Baldoyle SAC adjacent to the reclamation area.

Human receptors are considered to be at potential short term risk due to potential dermal contact and/or accidental ingestion of dredged sediments during the construction phase.

No relevant groundwater receptors have been identified; the bedrock under the site is not classified by the Geological Survey of Ireland (GSI) as an aquifer due to its location in the sea.

Table 2: Conceptual Site Model Potential Source, Pathway and Receptors

Source	Pathway	Receptors
Contaminants in sediments & construction materials (i.e. cement, hydrocarbons etc.)	Direct dermal contact, inhalation and/or ingestion	Site users during construction phase
Sediment and contaminants mobilised in sediment during dredging	Sea water movements within the inner and outer harbour	Flora & Fauna of the Inner and outer Harbour, including the Baldoyle SAC.
Contaminants dissolved in water during dredging		
Treated sediments in the reclamation area behind the perimeter embankment and rock armour revetment	Rainfall ingress into the stabilised sediment mass and subsequent leachate generation Sea water and groundwater movements around the reclamation area.	

5 QUANTITATIVE RISK ASSESSMENT

5.1 ENVIRONMENTAL RISK DURING DREDGING

5.1.1 Contaminants in solution during dredging

Table 3 below presents the results of 10 sediment samples that underwent waste acceptance criteria (WAC) testing. The leachate results were compared to the relevant Environmental Quality Standards (EQS) in order to assess the level of potential contaminants going into solution in the water during the dredging process. The EQS are from the European Communities Environmental Objectives (Surface Waters) Regulations 2009 and amended Regulations in 2015. The WAC testing produces metal results in solution or dissolved metals, the EQS for metals are also dissolved levels in solution.

The results show three exceedances of the EQS in Arsenic. As the limit of detection for Chromium was higher than the Annual Average (AA) EQS, the results for all the samples have been conservatively considered to exceed the AA EQS. However, all samples tested had Chromium levels below the Maximum Allowable Concentration EQS. As the limit of detection for Phenol was higher than both the Annual Average (AA) EQS and the Maximum Allowable Concentration EQS, the results for all the samples have been conservatively considered to exceed the AA EQS for Phenol.

The WAC eluate laboratory results are by their nature conservative as small volumes of liquid are diluted with the sediment sample (10:1 liquid:solid ratio). In the dredging environment the volume of water in the harbour is very large and it would be expected that the parameters elevated above the EQS would be diluted below the surface water EQS instantaneously and in close proximity to the dredging works.

Table 3
Howth FHC
WAC analysis on leachate from sediment compared to EQS
December 2019 Site investigation results

Determinand	EQS Source	AA EQS (mg/l)	MAC EQS (mg/l)	sample no.	Limit of Detection	Units	SP01	SP03	SP05	SP10	SP12	SP14	SP17	SP19	SP20	SP21
Arsenic (WAC)*	1	0.0200	n/a	10	0.001	mg/l	0.18	0.018	0.065	0.004	0.002	0.003	0.004	0.003	0.013	0.033
Cadmium (WAC)*	2	0.0002	0.00150	10	0.00002	mg/l	0.00003	<0.00002	<0.00002	0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Chromium (WAC)*	1	0.0006	0.03200	10	0.001	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (WAC)*	1	0.0050	n/a	10	0.001	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (WAC)*	2	0.0013	0.01400	10	0.001	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (WAC)*	2	n/a	0.00007	10	0.00003	mg/l	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003
Nickel (WAC)*	2	0.0086	0.03400	10	0.001	mg/l	0.002	0.002	0.001	0.001	<0.001	0.001	0.001	<0.001	0.001	0.034
Selenium (WAC)*		-	-	10	0.001	mg/l	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Zinc (WAC)*	1	0.0400	n/a	10	0.002	mg/l	0.006	0.006	0.003	0.012	0.006	0.003	0.003	0.002	0.004	0.006
Phenol	1	0.0080	0.04600	10	0.05	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Flouride	1	n/a	1.50000	10	0.1	mg/l	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.4	0.5	0.5

Notes;

*	Dissolved metals in water
EQS 1	European Communities Environmental Objectives (Surface Waters) Regulations 2009
EQS 2	European Union Environmental Objectives (Surface Waters) (ammendment
AA EQS	Annual Average Environmental
MAC EQS	Maximum Allowable Concentration Environmental Quality Standard

5.1.2 Contaminants in the bulk soil sediment during dredging

The bulk of the contaminants will be bound in the solid sediments and will not go into solution. The hydrodynamic assessment identified the most impacted area for dredge deposition outside the harbour as the eastern most part of Claremont beach within the Baldoyle SAC. The hydrodynamic assessment calculated an average of 3mg/l and a maximum of 18mg/l of suspended solids in the waters at this location. **Table 4** below presents the average and maximum contaminant concentrations from the harbour sediment samples. It then presents the predicted contaminant levels in the waters at the eastern end of Claremont Beach and compares the water results to the relevant EQS.

Table 4 Baldoyle SAC waters compared to EQS

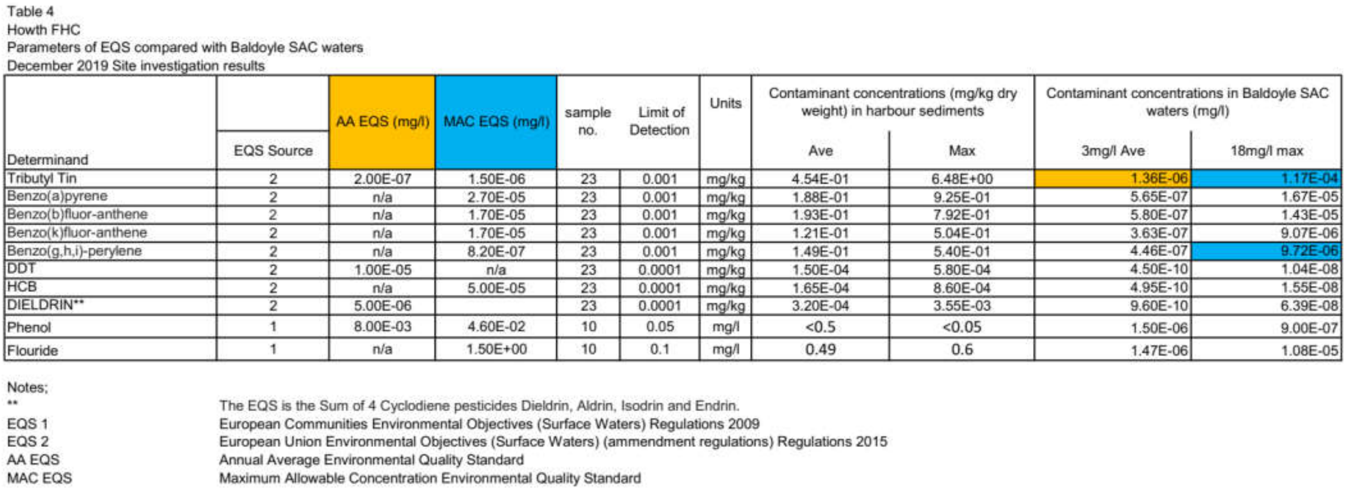


Table 4
Howth FHC
Parameters of EQS compared with Baldoyle SAC waters
December 2019 Site investigation results

Determinand	EQS Source	AA EQS (mg/l)	MAC EQS (mg/l)	sample no.	Limit of Detection	Units	Contaminant concentrations (mg/kg dry weight) in harbour sediments		Contaminant concentrations in Baldoyle SAC waters (mg/l)	
							Ave	Max	3mg/l Ave	18mg/l max
Tributyl Tin	2	2.00E-07	1.50E-06	23	0.001	mg/kg	4.54E-01	6.48E+00	1.36E-06	1.17E-04
Benzo(a)pyrene	2	n/a	2.70E-05	23	0.001	mg/kg	1.88E-01	9.25E-01	5.65E-07	1.67E-05
Benzo(b)fluor-anthene	2	n/a	1.70E-05	23	0.001	mg/kg	1.93E-01	7.92E-01	5.80E-07	1.43E-05
Benzo(k)fluor-anthene	2	n/a	1.70E-05	23	0.001	mg/kg	1.21E-01	5.04E-01	3.63E-07	9.07E-06
Benzo(g,h,i)-perylene	2	n/a	8.20E-07	23	0.001	mg/kg	1.49E-01	5.40E-01	4.46E-07	9.72E-06
DDT	2	1.00E-05	n/a	23	0.0001	mg/kg	1.50E-04	5.80E-04	4.50E-10	1.04E-08
HCB	2	n/a	5.00E-05	23	0.0001	mg/kg	1.65E-04	8.60E-04	4.95E-10	1.55E-08
DIELDRIN**	2	5.00E-06		23	0.0001	mg/kg	3.20E-04	3.55E-03	9.60E-10	6.39E-08
Phenol	1	8.00E-03	4.60E-02	10	0.05	mg/l	<0.5	<0.05	1.50E-06	9.00E-07
Flouride	1	n/a	1.50E+00	10	0.1	mg/l	0.49	0.6	1.47E-06	1.08E-05

Notes;	
**	The EQS is the Sum of 4 Cyclodiene pesticides Dieldrin, Aldrin, Isodrin and Endrin.
EQS 1	European Communities Environmental Objectives (Surface Waters) Regulations 2009
EQS 2	European Union Environmental Objectives (Surface Waters) (ammendment regulations) Regulations 2015
AA EQS	Annual Average Environmental Quality Standard
MAC EQS	Maximum Allowable Concentration Environmental Quality Standard

Two parameters are found to be above the EQS. The calculated average level of Tributyltin (TBT) is 6.8 times over the Annual Average (AA) EQS and 78 times over the Maximum Allowable Concentration (MAC) EQS. Benzo(g,h,i)-perylene exceeds the MAC EQS by a factor of 11.8. These exceedances are addressed below in **Section 5.1.3.**

The hydrodynamic assessment calculated a net annual deposition of 0.4mm of sediments on the eastern side of Claremont Beach.

The metals are not included here as the metal EQS are for dissolved metals are in solution and these have been addressed in **Section 3.1.1** and **Table 3** above.

5.1.3 Assessment of dredging risk

Inner Harbour

The above analysis and data (**Sections 5.1.1** and **Table 3**) presents minor exceedances of the EQS with metals in solution that will occur at the point of dredging. These metals in solution will be immediately diluted with the surrounding water in the immediate area of the dredging works. As a result of this immediate dilution, the area outside of the dredging works area will be below the EQS for metals and will not pose a risk to the environment.

There will be some residual sediment remaining in the inner harbour after completion of the dredging as some boundary areas will not be dredged and there will be limited loss of sediment during the dredging process. The risk on the environment in the inner harbour of this remaining residual sediment is considered low.

Outer Harbour

The hydrodynamic assessment calculated the highest concentrations of suspended solids and deposition in a sensitive area outside the harbour will be on the eastern end of Claremont Beach. There are two separate risks to be assessed, deposition and suspended solids.

The hydrodynamic assessment calculated a net annual deposition of 0.4mm of sediments on the eastern side of Claremont Beach. This is a minute deposition value and indicative of the fine material that deposits during slack tides and then taken away on the next tide which carries and distributes it much further from the vicinity of the beach. This modelled deposition assumes no tide/current or wave action to remove the sediment. On a daily basis, wave, tide and current action will remove any deposited sediment and move it further on dissipating it over a further wider area and reducing the environmental risk from deposition outside the harbour. The risk to the environment from the deposition of sediment on sensitive areas outside of the harbour is low.

Table 5 above presents the data on the calculated concentrations of contaminants in the waters on the eastern end of Claremont Beach due to the suspended solids. The AA EQS was exceeded for TBT by a factor of 6.8. While the MAC EQS for TBT was exceeded by 78 times. The MAC EQS exceedance is calculated from the highest TBT concentration result in sediments in one particular sampling location within the harbour. This is a highly conservative calculation based on the highest concentration detected from one grab sample taken in the harbour. The calculations do not take into account environmental mitigation measures proposed for the project. This conservative assessment indicates a high risk to the receiving environment prior to mitigation measures implemented.

The calculations in **Table 5** are based on a conservative Hydrodynamic assessment and unmitigated dredging. Mitigations are required in order to address the exceedances and are as follows;

- Environment buckets to be fitted to the dredge digger;
- Silt curtains to be placed around the dredge area;
- Monitoring of the waters outside the harbour in line with agreed parameters and limits from the licencing authority; and
- Where monitoring indicates exceedances of the agreed limits, then alternative dredging methods and closer monitoring of dredging will be implemented to obtain compliance with the given limits.

Mitigations will reduce the impact from both deposition and suspended solids. Once mitigations are in place there will be a low risk to the environment from the dredging works for the short term duration of the dredging.

Human Health risk during dredging

The main risk to Human health during the dredging works would be through the direct contact of contaminated sediments with humans (inhalation of dust, Ingestion or dermal absorption). This will be a low risk during the construction phase through proper handling, PPE and dust mitigation measures as carried out normally on a construction site.

As discussed earlier, some sediments will be lost out of the harbour during the dredging works. The hydrodynamic assessment calculated the highest concentrations of suspended solids in an area of concern will be at the eastern end of Claremont Beach. Claremont Beach is also a popular swimming beach. In relation to sea swimmers on Claremont Beach, two contaminants of concern for human health are TBT and Benzo(g,h,i)-perylene. They are both addressed below along with the risk from metals.

The maximum concentration of TBT at Claremont Beach will be in the modelled 18mg/l of suspended solids in the waters. This equates to a predicted concentration of 1.17E-04mg/l of TBT (**Table 5** above) in the waters at the time of maximum concentration.

The WHO[1] derives a health based value (HBV) of 1.5 µg/l for the sum of TBT, DBT, TPT and DOT in drinking water. The concentration of TBT in the water at Claremont Beach will be a maximum of 0.117µg/l. Considering that TBT is the main contaminant of concern and it is over a factor of 10 below the HBV, TBT is not considered a risk to human health within the suspended solids at Claremont Beach.

For Benzo(g,h,i)-perylene the drinking water limit is included in the Specified PAH compounds and the total for the sum of the compounds is 0.1 µg/l. **Table 6** below presents the concentration of the specified PAH compounds in the waters at Claremont Beach and compares them to the drinking water limits. The predicted concentration for PAHs are within the relevant limits.

Table 6 below presents the concentration of metals of concern in the Baldoyle waters. It indicates that the two metals (copper and Lead) that have concentrations higher than the MI upper level in the harbour sediments are below the drinking water standards in the waters at Claremont Beach. It has been shown from discussion (**section 3.1.1**) on **Table 3** that any minor exceedances shown in **Table 3** (analysis on the bulk harbour sediment) will be gone once the sediment reaches a diluted level of 18mg/l at Claremont Beach and the EQS will be met. Once the EQS is met it can be assumed there will be no risk to human health from the metals.

The calculations on risk to human health have been undertaken without mitigation included. Taking all of the above into account, there will be no risk to human health at Claremont Beach from the dredging works.

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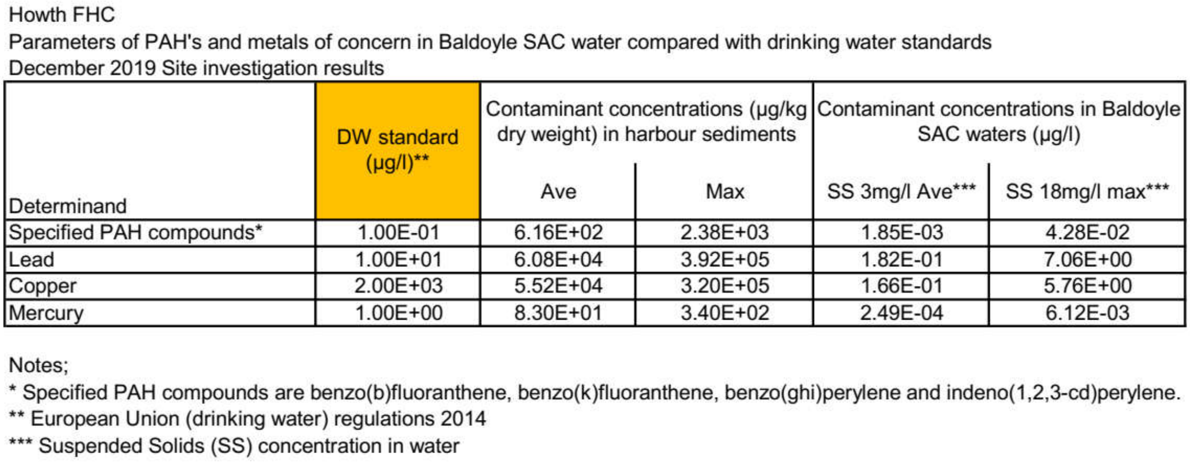
[1] WHO 2020, Organotins in drinking water. Background document for development of WHO guidelines for drinking water quality. Doc ref. no. WHO/HEP/ECH/WSH/2020.7

Table 5 Specified PAH compounds and metals of concern in Baldoyle SAC waters compared to drinking water standards.



Howth FHC
Parameters of PAH's and metals of concern in Baldoyle SAC water compared with drinking water standards
December 2019 Site investigation results

Determinand	DW standard (µg/l)**	Contaminant concentrations (µg/kg dry weight) in harbour sediments		Contaminant concentrations in Baldoyle SAC waters (µg/l)	
		Ave	Max	SS 3mg/l Ave***	SS 18mg/l max***
Specified PAH compounds*	1.00E-01	6.16E+02	2.38E+03	1.85E-03	4.28E-02
Lead	1.00E+01	6.08E+04	3.92E+05	1.82E-01	7.06E+00
Copper	2.00E+03	5.52E+04	3.20E+05	1.66E-01	5.76E+00
Mercury	1.00E+00	8.30E+01	3.40E+02	2.49E-04	6.12E-03

Notes;
* Specified PAH compounds are benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)perylene.
** European Union (drinking water) regulations 2014
*** Suspended Solids (SS) concentration in water

5.2 ENVIRONMENTAL RISK OF STABILISED/SOLIDIFIED SEDIMENTS IN RECLAMATION AREA

It is proposed to add cement and Ground Granulated Blastfurnace Slag (GGBS) to stabilise and solidify all the fine grained dredge material and to reuse it as engineering fill in the reclamation area.

This is a common and accepted method of treatment for re-use of contaminated and uncontaminated dredged sediments and has been completed successfully at a number of locations in the UK and Europe. Previous assessments of contaminated dredge material in Ireland has shown that mixing the sediments with cements, clays and other materials will successfully contain the potentially polluting parameters and prevent them leaching back into the environment (for example Dublin Port Assessment of re-use of contaminated dredge material by RPS in 2015). Guidance has been published on treatment and reuse of dredge material, including the Irish EPA document *'Guidance on the Beneficial Use of Dredge Material in Ireland'* 2013 and the UK Environment Agency *Guidance on the use of Stabilisation/Solidification for the Treatment of Contaminated Soil*, (UK EA 2004).

For the Howth FHC project, 12treated sediment samples were monolith tank tested during the project design stage. The samples contained different mixes of binder to test which mix worked best for this project. The 12 mixes were narrowed down to 7. The 7 monoliths all reportedly behaved in a similar manner in terms of their solidity in the water. Test results for the analysis of the 7 monoliths under the NEN 7375:2004 standard are presented in the geotechnical report in **Appendix 2 of the EIAR**.

Due to the similar behaviours in all 7 mixes, two mixes were chosen to inform this risk assessment and they are representative of the mixes that will be used in the project. The two mixes are 5MXM90 and bMXM91.

5.2.1 Calculation of dilution within the revetment wall

The CSM outlines how leachate from the stabilised material could potentially enter into the revetment wall where it mixes with sea water within the pore space of the revetment wall (the mixing zone). The pore space within the revetment core and rock armour could act as a mixing zone where the leachate is mixed with sea water via tidal and current action. The size of the mixing zone used to calculate the dilution is conservatively based on the cross section of the west face perimeter embankment and rock armour revetment which is smaller than the north face. The calculation on the dilution factor is presented in **Table B Appendix 1** attached below.

5.2.2 Assessment of risk of the stabilised and solidified sediments.

Table 6 below presents the predicted leaching data, based on the dilution factor and compares the results to the EQS. The calculations assume no retardation of flow in the current through the revetment wall. The calculations also assume no retardation of leachate flow through the ground or impermeable barrier. The calculation assumes the whole monolith is placed under water with no retardation occurring. This is a situation that will not occur, as outlined in the CSM, but is replicating the NEN 7375:2004 testing model. These are highly conservative assumptions.

The CSM indicates there will be retardation in both the current flow through the revetment wall and ground water flow around the stabilised sediment. There will be retardation of leachate from the surface of the monolith on all sides due to subsoils and low ground water flow around the monolith. There will be some retardation of current through the revetment wall but considering that there is 40% pore space in the outer wall this retardation would be lower than the groundwater flow around the monolith. This results in a highly conservative calculation of the concentration of leachate entering the sea.

The most representative sample test to calculate the potential leaching from the monolith is the test result from the 28 day P8 test within the NEN 7375:2004 standard. This test was the longest leaching period and gave the most opportunity for leaching to occur. The result was non detect, so the leaching calculation assumes a conservative level of concentration equal to the limit of detection, even though the actual concentration is somewhere below the limit of detection. The results are presented in **Table 6** below.

Table 6 P8 (28 day) leachate results compared to the EQS

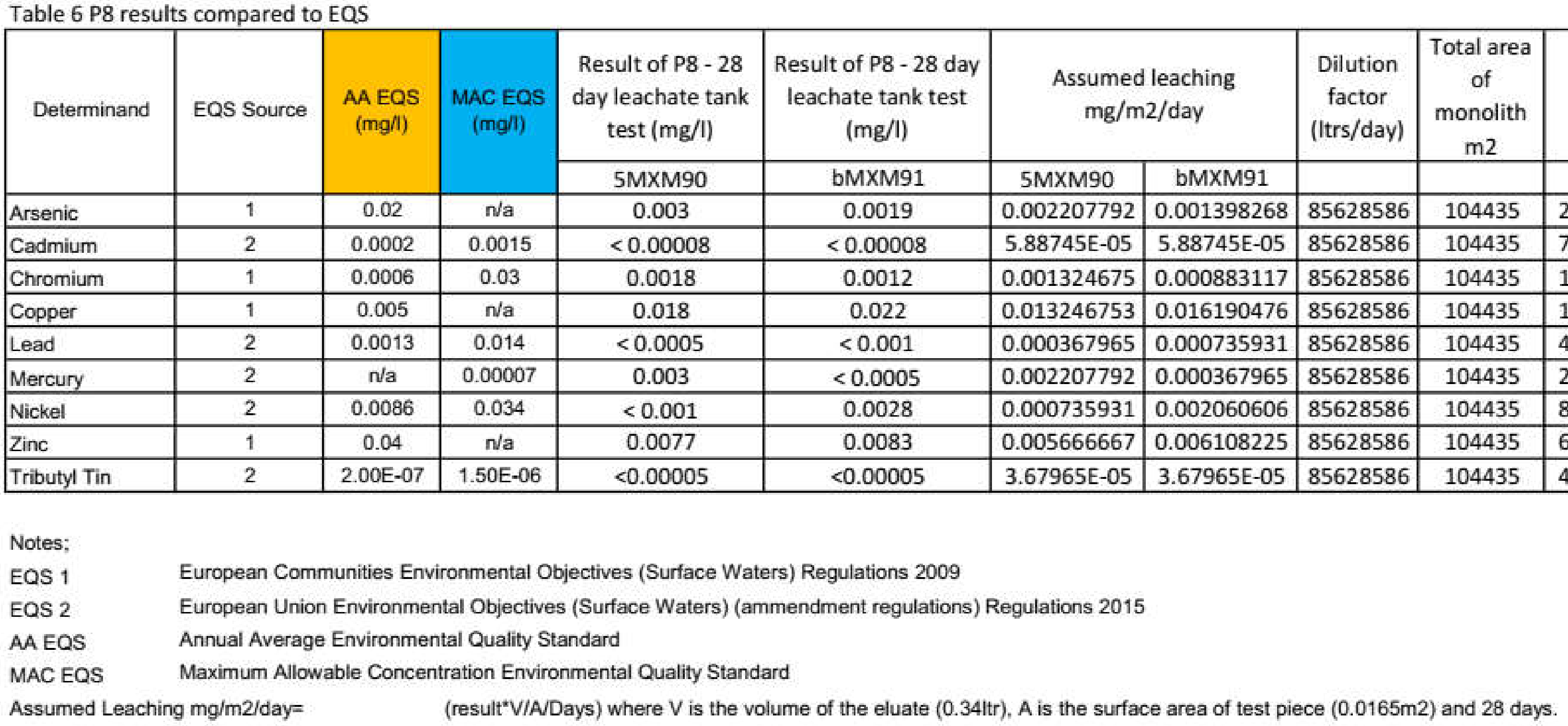


Table 6 P8 results compared to EQS

Determinand	EQS Source	AA EQS (mg/l)	MAC EQS (mg/l)	Result of P8 - 28 day leachate tank test (mg/l)	Result of P8 - 28 day leachate tank test (mg/l)	Assumed leaching mg/m2/day		Dilution factor (ltrs/day)	Total area of monolith m2	final concentration mg/l	
				5MXM90	bMXM91	5MXM90	bMXM91			5MXM90	bMXM91
Arsenic	1	0.02	n/a	0.003	0.0019	0.002207792	0.001398268	85628586	104435	2.69268E-06	1.70537E-06
Cadmium	2	0.0002	0.0015	< 0.00008	< 0.00008	5.88745E-05	5.88745E-05	85628586	104435	7.18049E-08	7.18049E-08
Chromium	1	0.0006	0.03	0.0018	0.0012	0.001324675	0.000883117	85628586	104435	1.61561E-06	1.07707E-06
Copper	1	0.005	n/a	0.018	0.022	0.013246753	0.016190476	85628586	104435	1.61561E-05	1.97464E-05
Lead	2	0.0013	0.014	< 0.0005	< 0.001	0.000367965	0.000735931	85628586	104435	4.48781E-07	8.97562E-07
Mercury	2	n/a	0.00007	0.003	< 0.0005	0.002207792	0.000367965	85628586	104435	2.69268E-06	4.48781E-07
Nickel	2	0.0086	0.034	< 0.001	0.0028	0.000735931	0.002060606	85628586	104435	8.97562E-07	2.51317E-06
Zinc	1	0.04	n/a	0.0077	0.0083	0.005666667	0.006108225	85628586	104435	6.91122E-06	7.44976E-06
Tributyl Tin	2	2.00E-07	1.50E-06	<0.00005	<0.00005	3.67965E-05	3.67965E-05	85628586	104435	4.48781E-08	4.48781E-08

Notes;

EQS 1	European Communities Environmental Objectives (Surface Waters) Regulations 2009
EQS 2	European Union Environmental Objectives (Surface Waters) (ammendment regulations) Regulations 2015
AA EQS	Annual Average Environmental Quality Standard
MAC EQS	Maximum Allowable Concentration Environmental Quality Standard
Assumed Leaching mg/m2/day=	(result*V/A/Days) where V is the volume of the eluate (0.34ltr), A is the surface area of test piece (0.0165m2) and 28 days.

Table 6 presents a predicted level of TBT concentration (the main contaminant of concern) in the water leaving the revetment wall to be about 4.5 times lower than the EQS.

The calculations carried out in **Table 6** are based on the most conservative data possible. They assume limits of detection as actual levels of concentration. The results are based on no retardation of groundwater around the stabilised and solidified sediments and are also based on a reclamation area completed submerged in water, again with no retardation from the complete submersion. Taking these highly conservative assumptions into account , it is considered that the leachate leaving the revetment wall will be at least 4.5 times below the EQS for the contaminant of concern (TBT) and that the risk to the environment from this will be low.

5.3 RESULTS OF THE QUANTITATIVE RISK ASSESSMENT

Table 7 below summarises the source, pathways and receptors, It outlines the mitigations and risk level.

Dredging

Within the harbour, the dredging will be a low risk to the environment within the inner harbour. The residual sediments will have the same properties as the current sediment within the harbour.

During dredging works, it has been predicted that some suspended solids will leave the harbour. There is a direct pathway for the suspended solids to exit the harbour and follow the current to the at risk receptor of concern (the Baldoyle SAC and Claremont Beach). This is a direct source, pathway and receptor link. These suspended solids will contain some contaminants of concern. Some EQS are exceeded in the sensitive receptors due to dredging. Mitigations are outlined in **section 5.1.3** in order to address the exceedances. Once mitigations are implemented the dredging works will be a low short term risk to water quality and marine life.

Stabilised and Solidified Sediments

Mixing of the dredge sediments with different percentages and types of binder indicated that the potential leachability of any contaminants would be greatly reduced. This is due to the treated S/S sediments having a very low permeability. The connectivity of the treated sediments with the open waters would be reduced further by the very low permeability of the Geosynthetic Clay Liner (GCL) contained in the perimeter embankment and rock armour revetment. The calculations indicate that if the maximum leaching of contaminants were to occur, their dilution in the mixing zone of the internal pore space of the revetment wall would result in no concentrations of potentially polluting parameters greater than the EQS entering the sea in the short or long term. The low level of potential leaching that will occur will happen over the long term. It is expected that the leaching behaviour will reduce with time as the outer surface layers of the S/S sediments are leached. The S/S sediment will be a permanent low risk to water quality and marine life.

Table 7: Conceptual Site Model and Risk Assessment

Source	Pathway	Receptors	S-P-R Linkage Post Mitigation	Post Mitigation Risk
Contaminants in sediments & construction materials (i.e. cement, hydrocarbons etc.)	Direct dermal contact, inhalation and/or ingestion	Site users during construction phase	After mitigation measures S-P-R linkage is possible; Accidental release or spill.	**Low**
Suspended sediment and contaminants mobilised in sediment during dredging	Sea water movements within the Inner Harbour	Flora & Fauna in the marine waters of the Inner Harbour and the Baldoyle SAC on the western side of the harbour. Bathers at Claremont Beach	After mitigation measures S-P-R linkage is possible; Suspended solids and loss of sediment into the water column will be reduced by mitigation measures but not eliminated.	**Low**
Contaminants dissolved in water during dredging				
Treated sediments in the reclamation area.	Rainfall ingress into the stabilised sediment mass and subsequent leachate generation. Sea water / ground water movements within and around the reclamation area.		After mitigation measures S-P-R linkage is possible; The S/S sediments in the reclamation area will permanently leach a minute amount of contaminants that are below the EQSs and the S-P-R linkage will remain.	

6 CONCLUSION

It is proposed to dredge sediment from the inner Howth FHC harbour and reuse the stabilised sediments to reclaim land to the west of the West Pier. As part of the works all fine grained dredged sediments will be dewatered and treated with binder in order to use the material as engineered backfill.

Certain heavy metals, tributyl tin and to a lesser degree, PCBs and PAHs have been identified in the shallow sediments at sample locations within the proposed dredge area. Conservative modelling of the potential mobilisation of these potential pollutants during the dredge phase indicates that the relevant EQSs may be exceeded for two parameters at Claremont Beach outside of the harbour. Considering the factor of safety built into the assessment and the proposed mitigation measures to be employed, the risk to water quality, marine life and human health from the dredging will be low.

The solidification and stabilisation of the fine sediment material to be used in the land reclamation will greatly reduce its potential leachability and permeability. Additionally, the perimeter embankment and rock armour revetment will act as a physical barrier between the placed material and the sea water.

Predicted calculations of leachate concentrations from the treated sediments entering the sea indicate that no concentrations of potentially polluting parameters will be above the relevant Surface Water EQS and no potential receptors are at risk from the post treatment phase of works.

The impact of the dredging works is considered to be a low short term risk to water quality and marine life. The impact of the S/S sediment is considered to be a low permanent risk to water quality and marine life.

Appendix 1

Table A MI and Harbour sediments

Table B Dilution calculation

Table A Appendix 1.

Howth FHC

Parameters of Marine Institute compared with sediment dry weight results

December 2019 Site investigation results

						Soil concentrations (dry weight)										
Determinand	Units	MI Lower Level	MI Upper Level	Total Samples	< LOD	SP01	SP02	SP03	SP04	SP05	SP06	SP07	SP08	SP09	SP10	SP11
Aluminium	mg/kg	n/a	n/a	23	10	52300	48900	44000	49000	50500	49000	8400	12500	11600	11700	6200
Arsenic	mg/kg	20	70	23	1	31.1	33.8	30.4	28.1	29.3	26.7	30.3	32.4	38.1	37.1	38.0
Cadmium	mg/kg	0.7	4.2	23	0.1	1.1	1.0	1.0	1.1	0.9	1.2	0.8	1.3	1.0	0.8	0.6
Chromium	mg/kg	120	370	23	0.5	81.0	79.0	58.2	72.1	76.3	80.0	118	72.3	72.4	77.1	34.7
Copper	mg/kg	40	110	23	2	110	47.1	33.9	75.8	61.2	45.6	93.4	38.7	54.8	34.1	15.1
Lead	mg/kg	60	218	23	2	46.2	54.8	42.8	46.7	44.8	59.2	101	67.7	51.4	34.5	24.1
Lindane (GHCH)	µg/Kg	0.3	1	23	0.1	<0.1	0.10	<0.1	0.23	<0.1	0.41	<0.1	<0.1	<0.1	<0.1	<0.1
Mercury	mg/kg	0.2	0.7	23	0.01	0.06	0.08	0.09	0.06	0.07	0.10	0.06	0.12	0.07	0.05	0.03
Nickel	mg/kg	40	60	23	0.5	34.7	34.5	38.1	31.3	32.4	33.4	45.5	41.8	36.0	39.3	15.9
Zinc	mg/kg	160	410	23	3	256	196	145	228	255	244	333	188	377	148	63.0
Dibutyl Tin	mg/kg	n/a	n/a	23	0.001	0.0247	0.0175	0.005	0.0267	0.0219	0.248	0.0243	0.636	0.0164	0.005	0.005
Tributyl Tin	mg/kg	n/a	n/a	23	0.001	0.0878	0.0842	0.0428	0.0886	0.086	1.03	0.111	6.48	0.0725	0.0257	0.005
Dibutyl Tin & Tributyl Tin	mg/kg	0.1	0.5	23	0.001	0.1125	0.1017	0.0478	0.1153	0.1079	1.278	0.1353	7.116	0.0889	0.0307	0.01
HCB	µg/Kg	0.3	1	23	0.1	0.12	0.12	0.11	0.22	0.13	0.13	0.11	<0.1	0.12	0.86	<0.1
TEH (as THC)	g/kg	1	n/a	23	0.0001	2.94	1.26	0.527	1.7	1.14	2.89	1.33	1.25	1.12	0.937	0.103
Total Of 16 PAH's	mg/kg	4	n/a	23	0.001	1.1134	1.8367	1.1776	8.7636	0.76043	12.6163	0.87761	2.0321	2.12783	0.81171	0.43975
PCB (individual congeners)																
PCB28	µg/Kg	1	180	23	0.08	0.41	0.64	0.67	0.46	0.45	0.73	0.47	0.82	0.44	0.35	0.17
PCB52	µg/Kg	1	180	23	0.08	0.39	0.54	0.74	0.46	0.44	0.71	0.94	2.26	0.39	0.31	0.16
PCB101	µg/Kg	1	180	23	0.08	0.38	0.38	0.90	0.46	0.24	0.77	1.09	0.96	0.27	0.18	<0.08
PCB118	µg/Kg	1	180	23	0.08	0.66	0.61	0.83	0.64	0.46	1.01	1.20	0.89	0.51	0.28	<0.08
PCB138	µg/Kg	1	180	23	0.08	0.74	0.71	1.85	1.40	0.54	1.46	1.58	1.43	0.50	0.35	0.12
PCB153	µg/Kg	1	180	23	0.08	0.61	0.66	1.70	1.23	0.44	1.28	1.40	1.18	0.48	0.35	0.11
PCB180	µg/Kg	1	180	23	0.08	0.25	0.27	0.90	0.82	0.19	0.72	0.62	0.48	0.17	0.14	<0.08
Total PCBs (7 Congeners)	µg/Kg	7	1260	23	0.56	3.44	3.81	7.59	5.47	2.76	6.68	7.3	8.02	2.76	1.96	0.8

Table A Appendix 1.

Howth FHC

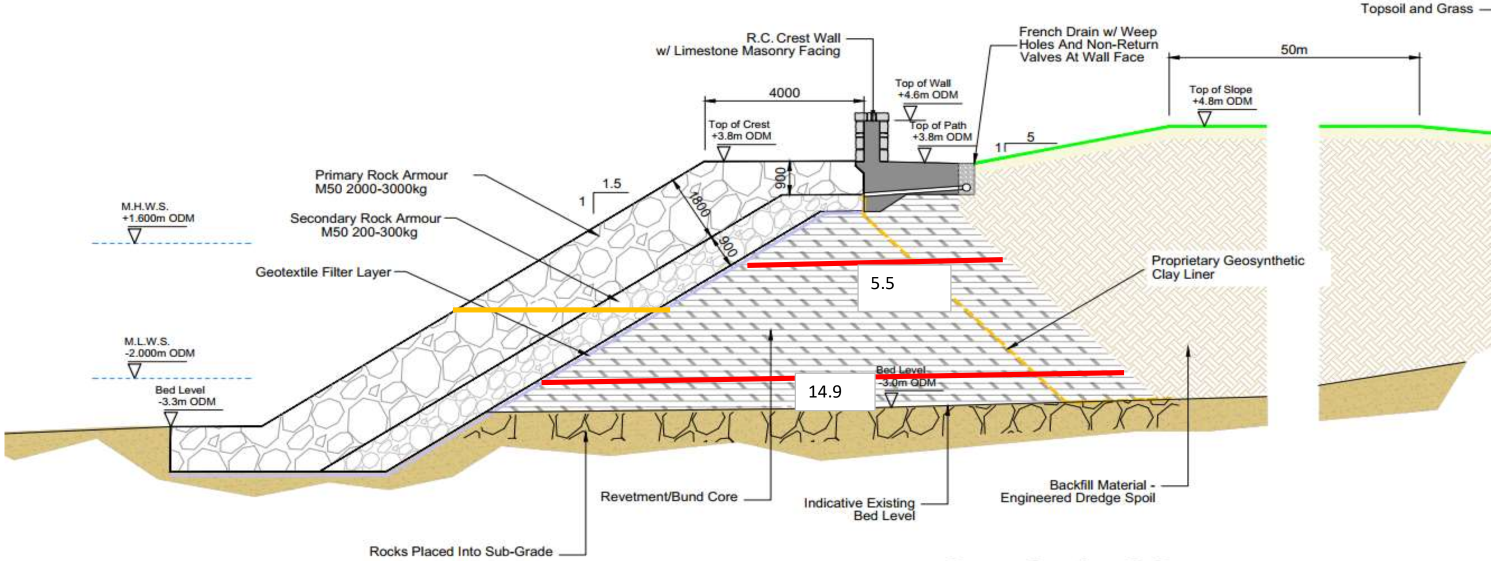
Parameters of Marine Institute compared with sediment dry weight results

December 2019 Site investigation results

																			Count of samples exceeding MI	
Determinand	Units	MI Lower Level	MI Upper Level	Total Samples	< LOD	SP12	SP13	SP14	SP15	SP16	SP17	SP18	SP19	SP20	SP21	SP22	SP23	Ave	Max	Lower level	Upper level
Aluminium	mg/kg	n/a	n/a	23	10	11500	12300	12400	12100	10500	11600	12300	11400	53600	56000	51600	36000	27626.09	56000	n/a	n/a
Arsenic	mg/kg	20	70	23	1	43.2	45.9	40.9	40.4	37.1	38.2	36.7	37.1	11.2	18.5	51.8	40.0	34.62	51.8	21	0
Cadmium	mg/kg	0.7	4.2	23	0.1	0.9	1.1	1.0	1.0	0.8	0.8	0.7	0.8	0.5	0.6	0.4	0.7	0.87	1.3	17	0
Chromium	mg/kg	120	370	23	0.5	72.2	76.2	75.2	69.4	62.1	69.5	75.7	72.7	62.0	65.1	81.8	53.9	72.04	118	0	0
Copper	mg/kg	40	110	23	2	44.7	33.7	32.4	28.2	21.8	25.4	29.9	26.6	44.2	42.2	11.5	320	55.23	320	10	1
Lead	mg/kg	60	218	23	2	46.7	61.6	50.6	38.0	34.3	36.7	39.1	38.2	36.9	38.7	13.1	392	60.83	392	3	1
Lindane (GHCH)	µg/Kg	0.3	1	23	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	0.25	0.13	0.41	1	0
Mercury	mg/kg	0.2	0.7	23	0.01	0.08	0.13	0.09	0.06	0.05	0.06	0.05	0.05	0.07	0.08	0.06	0.34	0.08	0.34	1	0
Nickel	mg/kg	40	60	23	0.5	30.4	38.8	33.2	31.5	27.6	32.5	32.0	33.1	27.7	29.3	30.0	25.7	32.81	45.5	2	0
Zinc	mg/kg	160	410	23	3	153	165	171	125	110	137	133	123	126	137	17.1	249	177.35	377	11	0
Dibutyl Tin	mg/kg	n/a	n/a	23	0.001	0.088	0.0269	0.0121	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0089	0.459	0.07	0.636	n/a	n/a
Tributyl Tin	mg/kg	n/a	n/a	23	0.001	0.669	0.0914	0.0433	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0169	1.47	0.45	6.48	n/a	n/a
Dibutyl Tin & Tributyl Tin	mg/kg	0.1	0.5	23	0.001	0.757	0.1183	0.0554	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.0258	1.929	0.53	7.116	7	3
HCB	µg/Kg	0.3	1	23	0.1	0.10	0.13	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	0.13	<0.1	0.25	0.28	0.16	0.86	1	0
TEH (as THC)	g/kg	1	n/a	23	0.0001	0.601	0.77	0.5	0.356	0.297	0.221	0.235	0.282	0.385	0.321	0.0122	0.496	0.86	2.94	8	0
Total Of 16 PAH's	mg/kg	4	n/a	23	0.001	1.19327	2.6303	1.64742	0.90881	0.8089	1.681	0.78204	0.73622	1.01624	0.96979	1.94089	9.7126	2.46	12.6163	2	0
PCB (individual congeners)																					
PCB28	µg/Kg	1	180	23	0.08	0.49	0.91	0.34	0.32	0.27	0.39	0.40	0.44	0.50	0.47	1.37	1.43	0.56	1.43	2	0
PCB52	µg/Kg	1	180	23	0.08	0.43	0.85	0.29	0.22	0.19	0.34	0.40	0.39	0.43	0.39	1.63	5.20	0.79	5.2	2	0
PCB101	µg/Kg	1	180	23	0.08	0.29	0.57	0.18	0.14	0.14	0.15	0.20	0.20	0.26	0.26	0.34	6.30	0.64	6.3	2	0
PCB118	µg/Kg	1	180	23	0.08	0.40	0.61	0.29	0.24	0.17	0.20	0.30	0.28	0.44	0.33	0.09	6.67	0.75	6.67	3	0
PCB138	µg/Kg	1	180	23	0.08	0.58	0.79	0.35	0.25	0.27	0.30	0.32	0.34	0.48	0.34	0.13	9.27	1.05	9.27	6	0
PCB153	µg/Kg	1	180	23	0.08	0.53	0.86	0.30	0.25	0.20	0.17	0.28	0.28	0.35	0.36	0.10	7.94	0.92	7.94	6	0
PCB180	µg/Kg	1	180	23	0.08	0.37	0.37	0.14	0.11	0.08	<0.08	0.09	0.13	0.13	<0.08	<0.08	4.42	0.47	4.42	1	0
Total PCBs (7 Congeners)	µg/Kg	7	1260	23	0.56	3.09	4.96	1.89	1.53	1.32	1.63	1.99	2.06	2.59	2.23	3.74	41.23	5.17	41.23	4	0

Table B; Dilution factor for stabilised sediment

Current Calculation		
Curent m/s	0.109	
West revetment		
	Outer rock armour	core
Average sea level ODM	-0.2	-0.2
Average width (m)	5.21	9.4
Avg depth (m)	3.1	3
Cross sectional area m2	16.151	26.32
Porosity	0.4	0.1
area of water m2	6.4604	2.632
Volume of water per second in revetment m3	0.7041836	0.286888
per day m3	60841.463	24787.12
Total current dilution cal		
Total volume of water in current (m3)	85628.5862	
Dilution factor (l)	85628586.2	



Cross Section B-B
Typical Revetment Section West Face
Scale 1:100