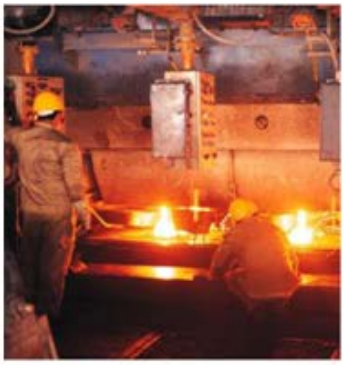
East Tip, Haulbowline Island

Factual Report



Cork
County Council
Comhairle Contae Chorcaí

Márta 2012

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DOCUMENT CONTROL SHEET

Status	Author	Reviewed By	Approved By	Office of Origin	Issue Date
Final	Claire Kelly	Cormac Ó Súilleabháin	Cormac Ó Súilleabháin	Inniscarra	07/03/12

Factual Report Peer Review

Sinclair Knight Merz Enviros (SKME) are providing multi-disciplinary advisory services in relation to the East Tip project including independent peer review. SKME have reviewed the January 2012 Factual Report prepared by Cork County Council.

Cork County Council have obtained, accumulated, researched and reviewed a large volume of data and information relating to Haulbowline Island and in particular East Tip. The purpose of gathering this data together is to provide a valuable resource library to all stakeholders involved with the future reclamation of the East Tip. The data and information processes will continue during the course of the project. All of the current key data relating to early project phases, such as site investigation, have been brought together in this 'Factual Report'. Further, a similar process has been undertaken with respect to mapping and spatial data which has been accumulated into a central GIS database.

SKME have reviewed the Factual Report and confirm that it is a current comprehensive and accurate record of data and information relating to Haulbowline Island and in particular the East Tip. While the data and information are focussed on providing a resource for the initial project phases it is understood that the document will evolve and expand as required to take account of new information that either becomes available, that results from works undertaken or as a result of ongoing research.

The approach of gathering a defensible baseline and evidence base of information will support good communication and reduce any project based risks while providing a full history of works and actions undertaken at the site.

CCC have been wise to invest the time at the outset in gathering such a comprehensive collection of reports and this will bring considerable benefits to the project, team and stakeholders. This approach is considered to be exemplary and represents best practice.

The Factual Report brings together many reports spanning a considerable period where the legislation, regulations, guidance and best practice have changed and may not be representative of approaches taken today. Although every effort has been made to provide some context, the reader should be careful in their use of the data and information and where there is any doubt should refer to the original report or seek the advice of Cork County Council and their advisors.

William Kirk – Project Manager

07 February 2012

SKME

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Appendices

Advice Note: Please note that some Appendices may contain data relating to areas outside the East Tip. The reader should cross reference the borehole and trial pit numbers with relevant location map.

1.0. Introduction

1.1. Background

Numerous studies have been carried out on the East Tip and the site of the former steelworks and thus a comprehensive body of data pertaining to both areas already exists. However, these data are scattered across numerous sources with no single comprehensive body of data relating to the East Tip existing. The objective of this document is therefore to present all data relevant to the East Tip in a consolidated volume. This entailed reviewing and collating data from 29 no. separate sources including: internal reports; reports prepared on behalf of the Irish Ispat Ltd, the Department of Environment, Community and Local Government and the Naval Service; a peer review; and a report prepared by Friends of the Irish Environment, a non government organisation (Table 1.1).

This document is a factual report and any observations or conclusions contained there-in do not represent the opinion of Cork County Council but are those of the authors of the respective primary source documents. The content of this report does not purport to be an interpretation of the historical data and is solely a reproduction of this information. Any conclusions drawn are those extracted from the original reports i.e. the opinion of the author of the relevant report and not that of Cork County Council.

The focus of this factual report is the East Tip of Haulbowline Island and therefore site investigation information, environmental assessments, etc specific to this area only have been included. Terminology used throughout the report is taken directly from the original reports and does not necessarily represent Cork County Council's interpretation. The purpose of this document is to provide a consolidated report of the investigations and studies that have been carried out to date on the East Tip. The report also provides information in relation to historical development of the East Tip. Cork County Council accepts no liability for any reliance placed on this report by any third party.

1.2. Context

It is imperative that this report is considered and used in context and thus the following must be noted by the reader:

- The reader should be aware that the information and data contained within this report is compiled from a number of reports from 1995 to the current date. Each of these reports and the data/information used in this factual report will be of varying degrees of quality, accuracy and reliability. The factual report should be used as a starting point to identify what information is available. Cork County Council accepts no liability for any reliance placed on this report, nor any data or information contained within by any third party.

- The entire East Tip area (any land reclaimed or otherwise above low tide mark) is owned by the Irish State. It is understood that there are no leases, arrangements, conditions or agreements which applies now or in the future associated with the land. Further, it is understood that the Bridge and access routes to the East Tip are also owned and maintained by the Irish State.

- The site may have been subject to historical agreements relating to planning or waste management licensing. It is understood that the East Tip area is no longer subject to any requirements, arrangements or agreements that may relate to any of these historical licences, permits and authorisations

Table 1.1

Ref	Year	Report Title	Source
1	2010	Geo-Environmental Report, Main Site, Haulbowline	WYG
2	2010	Annual Dust Impact Assessment Report 2010	WYG
3	2009	Annual Dust Impact Assessment Report 2008-2009	WYG
4	2009	Annual Dust Impact Assessment Report 2009	WYG
5	2008	Environmental Health and Safety Site Assessment for Naval, Base, Haulbowline	RPS
6	2008	Former Irish Steel Plant, Haulbowline Island, Environmental Report Volume 1 & Volume 2	WYG
7	2008	Site Clearance @ The Former Steelworks Site on Haulbowline Island	CCC
8	2008	Groundwaterand GasMonitoring Assessement	WYG
9	2008	Dust Impact Assessment Report 2008	WYG
10	2008	Peer Review Report	Sirius
11	2008	Geotechnical Assessment Report. Reinstatement of contractor excavation, East Tip	WYG
12	2005	Examination of 29 Slag Samples from the Former Steelworks at Haulbowline	TRS
13	2005	Factual Geo Environmental Report Contamination and Geotechnical Assessment 2005	WYG
14	2005	Interpretive Geo Environmental Report Contamination and Geotechnical Assessment 2005	
15	2002	Environmental Assessment of Irish Ispat Ltd, Haulbowline, Co. Cork	OCM
16	2002	Phase One Investigation ans Assessment at Haulbowline Island. First Draft	Enviros
17	1998	Report on Site Investigation Irish Ispat Ltd, Haulbowline, Co Cork	KTC
18	1995	Irish Steel East Tip, Haulbowline Island Environmental Investigation	KTC
19		Use of Slag from the Former Steelworks Site on Haulbowline on Road Works	
20		Environmental Management Costs	
21		East Tip Wastes	
22	2006	Haulbowline Island, Parallel Review of Investigation	HC
23	2009	Toxic Island, Industrial Contamination of the Former Site of the Irish Steel Plant	FOIE
24	2009	Crane Store, Haulbowline Naval Base, Report of Ground Investigation	PG
25	2008	Seveso II Classification fo the East Tip Site of the Former Irish Steel Plant, Haulbowline	WYG
26		Cost Estimate for East Tip Backfilling	WYG
27	2001	EPA Inspectors Report on IPC Licence 498 for Irish Ispat Ltd.	EPA
28	2001	IPC Licence 498 for Irish Ispat Ltd	EPA
29	2001	Objection to Proposed Determination for Irish Ispat 498	EPA

- Cork County Council wish to emphasise that the volumes or proportions indicated are estimates given in the reports at the time of writing and may not be reflective of the current position within the East Tip. In addition, no formal quantification of the waste types has been undertaken at the site to date. Further, the classifications of non-hazardous and hazardous are descriptions of the steelworks waste streams and may not be reflective of the classification of the East Tip which at present is subject to investigation and regulatory dialogue.

- Chemical analytical screening values have been included within this factual report. The screening values used relate to those applied by the consultants at the time of their work and reporting and may be reflective of the screening values at the time of writing. The values have been included only for the purpose of providing a basic guide and they should **NOT** be used or referred to out of context as there is no guarantees that the values are appropriate then or now. Planned site investigation and quantitative risk assessment work is intended to provide a more appropriate context.

1.3. Report Structure

A summary of the contents of the various chapters contained in this report is outlined below:

Chapter 2 summaries the historical information contained in the various reports and studies carried out on the site to date. This includes information relating to the historical development of the site, operations on the site, geology and hydrogeology as well as a list of the site investigation works carried out.

Chapter 3 summarises the geotechnical site investigation works that have been carried out on the site to date and includes details of boreholes, trial pits, etc as well as results of the various in-situ and laboratory testing carried out on the soils and materials encountered on the site.

Chapter 4 contains details of the water analysis carried out on the site to date and covers groundwater, surface water and marine water testing and analysis.

Chapter 5 summarises the analysis carried out on the waste material deposited on the site over the years in addition to any available testing and analysis of the alluvium layer.

Chapter 6 details landfill gas monitoring analysis that was carried out on the East Tip site in 2005 and 2006.

Chapter 7 is a bibliography and contains a list of the various reports and studies referenced in this document.

Chapter 8 contains a glossary of terms used in this document

2.0. Background Information

2.1. Haulbowline Island and Harbour

2.1.1. Site Description

Haulbowline Island is located within Cork Harbour, between Cobh to the north and Ringaskiddy to the south. It is connected to the mainland at Ringaskiddy via a bridge which transverses Rocky Island. Spike Island is located to the south east and was previously connected to Haulbowline via a causeway. The main shipping lane, 20m deep, passes to the north of the Island and the Spit Bank, an area of shallow water less than 0.5m deep at low tide, extends approximately 80m eastwards from its eastern fringes. A site location map is presented in Figure 2.1.

The entire East Tip area (any land reclaimed or otherwise above low tide mark) is owned by the Irish State. It is understood that there are no leases, arrangements, conditions or agreements which applies now or in the future associated with the land. Further, it is understood that the Bridge and access routes to the East Tip are also owned and maintained by the Irish State.

The Headquarters of the Irish Naval Service is situated on the western portion of the Island with the Naval Dockyard to the east. Separating these is the site of former Irish Ispat Steelworks. The majority of buildings associated with the steel production have been demolished and cleared from the site since 2005. A number of listed buildings were retained. To the east of the Naval Dockyard is the East Tip, an area of land reclaimed from the Spit Bank by infilling with processing waste from the steelworks. A site layout is presented in Plate 2.1. The Coastal and Marine Research Centre (CMRC) which is part of University College Cork is accommodated within Naval Headquarters.

Plate 2.1: Site Layout

Title:	**Figure 2.1: Site Location Map**
Project:	**Haulbowline Project**
Drawn by:	HaulbowlineTeam
Date:	07/11/2011

Scale; **1:35,000 @ A3**

2.1.2. A Brief History of Industry on Haulbowline Island

Haulbowline Island has been in State ownership since 1602 and was shared by the British Boards of Admiralty and Ordnance since 1805. The earliest maps indicated that the Island was confined to the higher ground on the west side of the Island (OCM, 2002). The Island was originally used as a naval supply and dock yard by the Royal Navy in the 18th and 19th centuries and extensive land reclamation occurred during the development of the naval docks. Construction of the dockyard started on the Island in 1865, but was not completed until 1894. The construction involved the extension of the eastern part of the Island using fill material obtained from quarries on the Island itself and the mainland (OCM, 2002). Haulbowline consisted of two Islands linked by a bridge until 1902 when the body of water separating the two land masses was infilled (WYG A, 2008). A magazine was constructed on Rocky Island, and this remained intact until partial demolition during the construction of the road bridge to the mainland in 1966.

According to the Environmental Protection Agency Inspector's Report for the Integrated Pollution Control (IPC) Licence (2001), the Irish Government acquired ownership of the Island in 1923 and the dockyards were maintained by the Commissioners of Public Works. Industries were encouraged to operate on the island to create local employment. The dock and slipway were used for the breaking of ships by Haulbowline Industries from 1928; Cork Dockyard Limited repaired and refitted ships in the dock until 1939; Marine Transport Services Ltd used some boat houses and a slip-way for repair and transport operations; and from 1931 to 1940 Cork Harbour Oil Wharfs had licence to refine crude petroleum using the former naval heavy fuel storage facilities.

The steelworks commenced operations in 1938 with the rolling of imported billets (EA, 2002). The operation closed in 1941, but was restarted in 1942 when the Government provided capital for the purchase of two 35 tonne open hearth furnaces. This operation ceased early in 1947, but the facility was reopened later in 1947 under Irish Steel Holdings Limited, a company owned by the State (OCM, 2002).

The steel plant was set up in the eastern side of the Naval Base making use of a number of the existing buildings. A pickling, galvanizing and corrugation plant was opened in 1954. Initially, the open hearth furnaces were powered by coal gas, which was produced on site in a coal gasification plant (EA, 2002). This was converted to fire on heavy fuel oil in 1956 and the coal gasification plant was subsequently demolished. In 1962, a single 70 tonne oil fired open hearth furnace replaced both of the heavy fuel oil furnaces.

Modernisation of the plant began in 1972 when a 35 tonne electric arc furnace replaced the oil fired open hearth furnace and the electrical substation and transformers were installed to power the furnace. In 1980 the plant was connected to the natural gas supply system operated by Bord Gáis and natural gas was used, principally in the reheat furnace. Gas was distributed throughout the site from an above ground installation.

The galvanizing plant ceased operations in 1981. In the same year a 90 tonne arc furnace was installed and the plant reconfigured to combine fast melting in the arc furnace with continuous casting and a continuous universal mill. A ladle furnace was installed in 1992 (WYG A, 2008).

In 1996, the Irish Government sold the facility to Ispat International, who formed Irish Ispat Limited (IIL) to operate the plant. In 1999, IIL applied to the EPA for an IPC Licence to operate the facility in compliance with the requirements of the Environmental Protection Act 1992. Cork County Council has previously, in 1997, issued a waste permit under the European Communities Waste Regulations to IIL to operate the facility as a scrap metal processing plant (OCM, 2002). IIL went into liquidation on 15th June 2001 and steel production ceased. An IPC licence was issued by the EPA to IIL on 22nd

June 2001 but was declined by the liquidator. Cork County Council has been advised by the EPA that this licence has no current legal standing.

During the period 2005 – 2006 the steel production buildings were demolished and some of the construction and demolition waste deposited on the East Tip. Between 2007 and 2008 the main site was cleared together with steelwork wastes on the surface of the East Tip: it was at this time that unauthorised excavations were carried out on the East Tip (Section 2.2.5).

2.2. Historical Operations on the East Tip

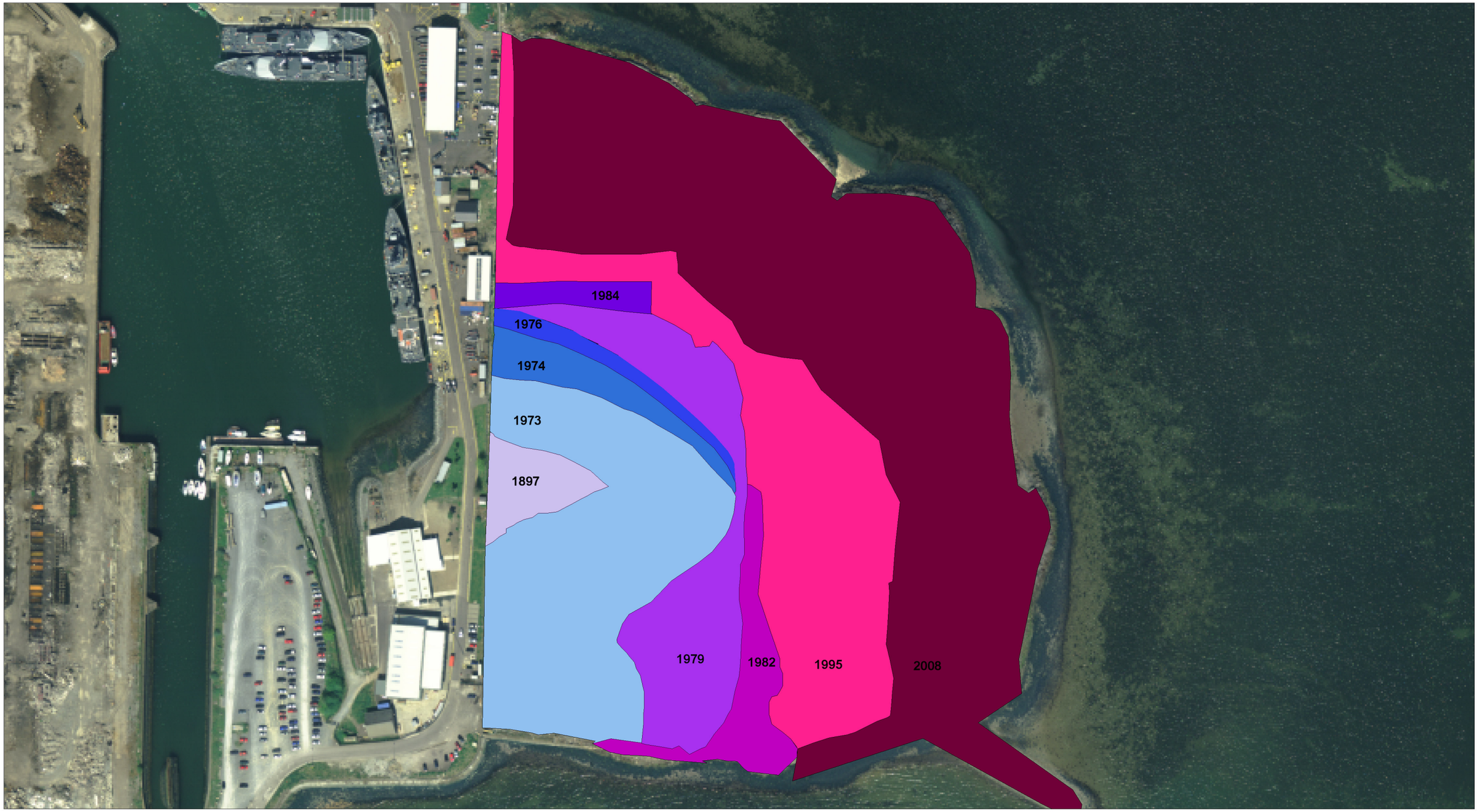
2.2.1. Historical Development of the East Tip

The central and eastern parts of the Haulbowline Island form a wide area of almost level reclaimed land at approximately 3 to 5mAOD with slag heaps rising up to 13mAOD on the East Tip. Since 1865 a large area of made ground has been added on top of the shelf of the Quaternary and alluvium deposits to reclaim land from the sea. This reclaimed ground can be characterised as:

- Various quarry fill (taken from a former limestone quarry on-site used between 1865 and 1926) and wastes generated by the naval dockyards, and
- Process waste from the steelworks, mainly slag and scrap metal

(WYG A, 2008)

The original island was 11.5 ha but by 1998 had grown to 33.5ha with the East Tip having a total area of 7.6ha. By 2002 the East Tip had increased in size by 1.4ha thus encompassing an area of approximately 9ha in total. It may therefore be concluded that the area of the island was 23.5 ha when steel processing started in 1938 and 34.9 ha when production ceased in 2001, an increase of almost 50% (WYG A, 2008). It is thought that the deposition of steel making waste on the East Tip of the Island has been taking place since the 1940's (KTC, 1995) but intensified in the late 1970's (EA, 2002). In 1984, a section along the western perimeter of the East Tip was reclaimed by the Navy as a football pitch (KTC, 1995). Figure 2.2 illustrates a map of the East Tip in 1897 and highlights its subsequent development (KTC, 1995 & Topographical Survey, 2008, Precise Engineering Ltd).



Title:	**Fig 2.2** **Historic Progression**	Legend:	East Tip Historical Progression 2008 1995 1984 1982 1979 1976 1974 1973 1897	**Cork County Council** **Environmental Directorate** **Inniscarra,** **Co. Cork** **Phone: 021 - 4532700** **Fax no. 021 - 4532777**	*Includes Ordnance Survey Ireland data reproduced under OSI Licence number Cork County Council 2010/2006/ CCMA/ Cork County Council* *Unauthorised reproduction infringes Ordnance Survey Ireland and Government of Ireland copyright. © Ordnance Survey Ireland, 2011*
Project:	**Haulbowline Project**				
Drawn by:	HaulbowlineTeam				
Date:	07/11/2011				Scale; **1:2000@A3**

2.2.2. Planning, Permit & Licensing

The site may have been subject to historical agreements relating to planning or waste management licensing. It is understood that the East Tip area is no longer subject to any requirements, arrangements or agreements that may relate to any of these historical licences, permits and authorisations

Planning Permission

Over the lifetime of steel production at the Island, 13 planning permissions have been issued by Cork County Council. The Council granted permission for extension and modification of Irish Steel Holdings in 1977. The mill scale and other suspended matter were to be removed by cyclones or lagoon system and the extracted materials were to be disposed of on the company's disposal dump (the East Tip). Condition 9 stated that the dust collected by the bag filters was to be removed off site for disposal or dumped in a location in County Cork (FIE, 2009).

Permission issued in December 1978 included conditions regulating the type of wastes to be disposed of at the East Tip, the control and monitoring of noise, air, surface water and process waste water emissions (OCM, 2002). The most recent permission, issued in December 1997 relates to the construction of a containing seawall around the East Tip (OCM, 2002).

Waste Permit

Cork County Council issued a Waste Permit to the facility in 1998 to treat waste (i.e. operate a scrap metal processing plant) under the European Communities (Waste) Regulations 1979. The permit set conditions controlling the type of waste to be disposed of at the East Tip, provision of the interceptors on drainage systems, provision of dedicated secondary containment for all drum storage areas, and the investigation of possible ground contamination at the site (OCM, 2002). A copy of the waste permit is provided in Appendix A.

IPC Licence

On 22nd of June 2001 the EPA issued the IPC licence to the facility under the Environmental Protection Agency Act, 1992 to carry out the initial melting or production of iron or steel. This licence issue date was one week after the closure of the facility was announced. The licence supersedes the Waste Permit issued by Cork County Council. A copy of the licence and the Inspectors Report are included in Appendix B.

The licence conditions set controls limits on air, process wastewater emissions and noise. The licence prohibited the landfill of hazardous waste at the East Tip and required an investigation of all former operational areas of the landfill and also required the preparation of a comprehensive landfill decommission plan for the East Tip. The licence also required the biological assessment of the Harbour sediments adjacent to the landfill, the construction of a sea wall around the East Tip and the completion of a hydrogeological investigation of the entire site. A decommission plan was also required to render safe or remove for disposal/recovery, any soil, subsoils, buildings, plant or equipment, or any waste, materials or substances or other matter contained herein or thereon, that may result in environmental pollution (OCM, 2002).

Water Pollution Act Licence

A Water Pollution Act Licence, WP(W) 11/83, was issued by Cork County Council in 1983 for the discharge of cooling water and sewage to the Lower Cork Harbour (EPA Inspectors Report, Reg. No. 498, Dated: 28 February 2001).

Radiological Protection Institute of Ireland

A licence (2218-1895-01) was issued by the Radiological Protection Institute of Ireland under the Radiological Protection Act 1991 for the storage or radioactive materials such as pipe sections. A

licence (1101-0977-01) was also issued for the custody, use and transportation of density gauges and level gauges. In 2002 after operations had ceased these two licences were combined into one licence for the custody of all radioactive sources held. The licence number was 1101-0977-02.1 (OCM, 2002).

2.2.3. Waste Flows to the East Tip

There is no accurate data on the quantity of waste disposed in the East Tip. Annual and/or total quantities of steel process wastes have been recorded in some of the reports prepared to date and these are listed in Table 2.1 below. **Cork County Council** wish to emphasise that the volumes or proportions indicated are estimates given in the reports at the time of writing and may not be reflective of the current position within the East Tip. In addition, no formal quantification of the waste types has been undertaken at the site to date. Further, the classifications of non-hazardous and hazardous are descriptions of the steelworks waste streams and may not be reflective of the classification of the East Tip which at present is subject to investigation and regulatory dialogue.

Table 2.1: Summary of Quantity of Steel Process Wastes Produced

Waste Type	Tonnes per annum	Source of Data	Disposal Route
Slag	45,000	KTC, 1995	
Hot Flume Dust	4,000	KTC, 1995	
Slag	656,600 (total over lifetime)	EA, 2002	
Furnace Slag	45,000	OCM, 2002[1]	Processing on site
Soil	1,500	OCM, 2002[1]	East Tip
Refractory Metals	8,400	OCM, 2002[1]	East Tip
Mill scale	7,500	OCM, 2002[1]	East Tip
Scale Sludge	500	OCM, 2002[1]	East Tip

From 1998 to June 2001 the East Tip grew by 1.4 ha which equates to 80,000 to 90,000m^3 of material being deposited during that time (EA, 2002). During the same period slag was sorted and graded for use as roadstone and it is estimated that approximately 60,000 tonnes of weathered slag was removed from site for this purpose (EA, 2002).

2.2.4. Waste Types present on the East Tip

The East Tip comprises various wastes that largely originated from the steel making processes on Haulbowline Island. Additional waste types were also deposited during its operation (WYG A, 2008). Site investigations (WYG, 2005 & KTC, 1995 & 1998), interviews with former key personnel of Irish Ispat (EA, 2002) and review of key documents (EA, 2002) have contributed to determining the types of waste that have been deposited and these are listed in Table 2.2 below.

Cork County Council wish to emphasise that the volumes or proportions indicated are estimates given in the reports at the time of writing and may not be reflective of the current position within the East Tip. In addition, no formal quantification of the waste types has been undertaken at the site to date. Further, the classifications of non-hazardous and hazardous are descriptions of the steelworks waste streams and may not be reflective of the classification of the East Tip which at present is subject to investigation and regulatory dialogue.

[1] A breakdown of the waste types, volumes & disposal routes, from the O'Callaghan Moran Environmental Assessment Report, were derived from the IPC licence application and an audit report dated 1997.

In 2008, White Young Green estimated the approximate percentage composition of the East Tip waste material but due to the uncontrolled nature of the dumping of waste on the East Tip, the volume ratios determined are only estimates (Figure 2.3). These data were obtained both from personnel who worked on site during operation of the steelworks and historical analytical data relating to the different waste materials.

A broad description of each of the main waste types is provided below and reference made, in parenthesis, to its volume ratio and its classification as hazardous or non-hazardous in the EPA Licence Inspectors Report of 2001. WYG emphasise that the use of the terms hazardous and non-hazardous is in reference to specific regulatory meanings and should not be taken as referring to specific risks that the waste components pose to human health, the environment or ecological receptors (WYG A, 2008).

Table 2.2: List of possible waste types deposited on the East Tip.

Waste Type	**Reference of Relevant Report**
Slag	WYG A 2008, WYG, 2005, OCM,2002, EA, 2002;
Mill Scale	WYG A, 2008, WYG, 2005, OCM, 2002, EA, 2002
Bag House Dust (non-pelletised)	EA, 2002
Navy domestic refuse	EA, 2002
Furnace linings, bricks & electrodes	EA, 2002
Steel skulls	EA, 2002
Ferrous metal	EA, 2002
Hydrocarbons	EA, 2002
Tyres	EA, 2002
Batteries	EA, 2002
Radioactive slag (possible)	EA, 2002
Clarifier sludge disposal	EA, 2002
PCBs	EA, 2002
General factory waste (incl. timber)	EA, 2002
Galvanising / acid sludge wastes	EA, 2002
Laboratory chemicals	OCM, 2002
Wastewater treatment sludges from metal plating waste	OCM, 2002
Construction & demolition waste	OCM, 2002
Extraction chamber dust cake	OCM, 2002
Waste Solvents	OCM, 2002
Fluorescent tubes	OCM, 2002
Mercury vapour lamps	OCM, 2002
Hydraulic fluids	OCM, 2002
Oil emulsion waste containing 5% biodegradable hydraulic fluid	OCM, 2002

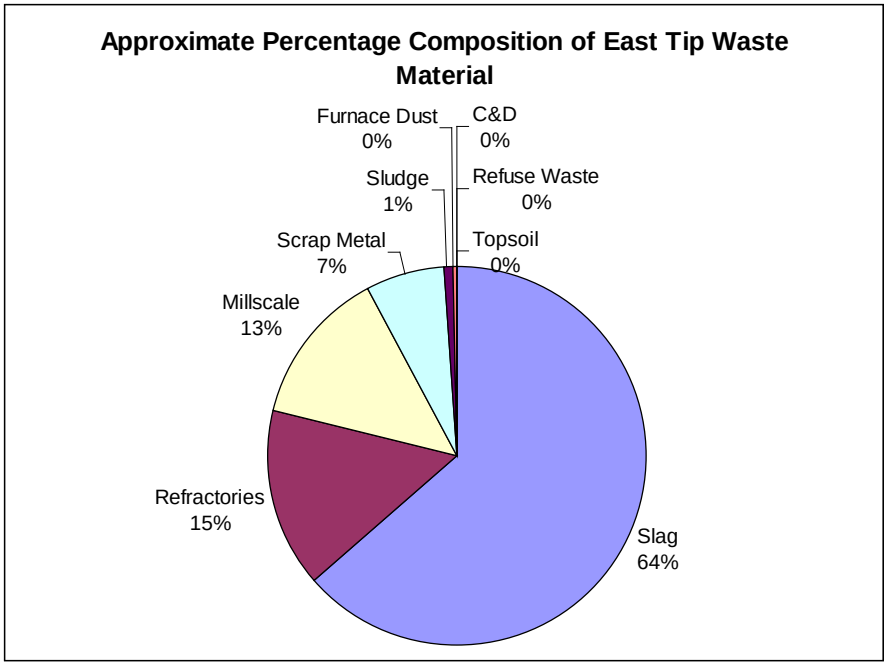


Figure 2.3: Approximate percentage composition of East Tip Waste Material (WYG, 2008)

Slag Waste (~64%) (Non-Hazardous)

Slag material is formed in the steelmaking process when calcium oxide (lime) is added to the steel making furnace to absorb impurities in the scrap metal such as clay, rock and concrete fragments. This addition of the lime generates a molten flux known as slag. The slag was decanted from the steel making furnace to a pit which was taken to the East Tip while still hot where it was placed. The chemical constituents of the slag material are estimated as:

- 30% to 35% iron oxide
- 35% to 50% calcium oxide
- 5% to 15% silica
- 3% to 9% manganese oxide
- 3% to 7% magnesium oxide
- 2% to 6% alumina
- 1% chromium (III) oxide
- 0.5% phosphorous
- 0.5% sulphur

Refractories (~15%) (Non-Hazardous)

Refractories consist mostly of bricks that were used for lining the steel vessels. The bricks used depended on their thermal resistance and chemical properties. The chemical constituents of the bricks generally consisted of calcium, magnesium, aluminium and silicon. Some bricks had magnesite with graphite bonding. The ladle furnace had bricks with linings of silica, alumina and dolomite.

Millscale (~13%) (Potentially Hazardous)

Millscale is formed during oxidisation of steel in process, where material is removed from the steel and washed via flumes with water into a collection pit. The millscale was removed from the pit via a grab and placed on the East Tip. The millscale contains some hydrocarbons due to oil/ greases from process machinery.

The chemical constituent of the millscale material is mostly iron oxide (~98%) with some manganese oxide (1%), calcium oxide (0.6%) and copper oxide (0.4%). This material is recyclable and in 2007 a stockpile (approximately 15,000 to 20,000 tonnes) created by Irish Ispat was screened to make a more homogenous product which is acceptable for recycling, removed off-site and exported to Scandinavia to be used as ore in an iron manufacturing plant. There is currently one screened stockpile on-site.

Scrap Metal (~7%) (Non-Hazardous)
There is waste scrap metal that was dumped across the site within the slag material.

Sludge (~1%) (Hazardous)
Oil, greases and hydraulic fluids from the steel making machinery was collected with the mill scale in tanks known as clarifiers. Each summer the sludge material from these clarifiers was removed to the East Tip where it was allowed to dry before being covered with slag material. There are no records as to where these sludge pits were buried.

Furnace Flue Dust (~ <0.1%) (Hazardous)
Furnace flue dust was deposited on the East Tip until 1980 in a dust form. From 1980, most flue dust was pelletised due to the high lead content and exported to the UK for recycling. Sometimes the dust was placed in bags and stored on the East Tip awaiting transport off-site. The chemical constituents of the dust material are approximately:

- 20% to 25% zinc oxide
- 5% to 8% lead oxide

The remainder consists of other volatile metals (WYG A, 2008). The furnace dust was collected in the air emission abatement filtration system in the Bag House. The initial filtration system was introduced in 1981 and was upgraded in 1992 (OCM, 2002).

Refuse Waste (~ <0.1%) (Non-Hazardous)
It is reported that refuse waste was deposited on the East Tip from the steelworks site and Naval Base. Waste from the steelworks site was deposited up until the plant's closure in 2001 although disposal of waste from the Naval Base had ceased at that stage. The location of the waste is uncertain but it is reported to be present in the area to the north of the pitch and this appears to have been substantiated by site investigations.

Construction and Demolition Waste (~ <0.1%) (Non-Hazardous)
It is reported that construction and demolition waste was deposited on the East Tip from the Naval Base and following demolition of the steelworks.

Topsoil (~ 0.01%) (Non-Hazardous)
There is a stockpile of topsoil on-site that was imported with the aim of extending the pitch northwards.

Radioactive Waste Disposal
Radioactivity was present on the steelworks site in various forms while the plant was in production and, for a time, after it closed. The following is a summary of the sources of radioactivity present:

<u>Caster level gauges used in the steelmaking process</u>
These were shielded caesium-137 sources that were used to control the level of liquid steel in the continuous casting moulds. At the time the plant closed in 2001 there were six of these gauges on site. These were initially dismantled and consigned to a secure area on Rocky Island. Following

closure of the plant there was a requirement on the liquidator to dispose of gauges and they were finally removed offsite in early 2004.

Melting of a radioactive source

In 1990 material containing caesium-137 that had been included in a consignment of scrap metal from Scotland was inadvertently melted. The incident was discovered only when checks were made at Avonmouth (UK) on pelletised furnace dust sent for recycling (i.e. to extract zinc and lead). In response the RPII took soil samples in the vicinity of the steel plant and from the coastline of the Harbour. While traces of radioactivity were recorded they proved to be of fallout origin predominantly due to Chernobyl contamination rather than related to the furnace dust.

Residual radioactive dust in the fume extraction system was removed and bagged for disposal. For a time these bags were stored on the East Tip, prior to being removed to Rocky Island for storage under the auspices of the RPII. Eventually disposal of this dust to the UK was carried out by Rolls-Royce Nuclear Engineering Services Ltd. The RPII then surveyed the East Tip and Rocky Island caverns and confirmed that no external radiation levels above natural background were detected.

Scrap monitoring

Following this incident, radiation detectors were installed to monitor in-coming scrap. Over the years these detected a small number of low-level radioactive items which, if the supplier could not be identified, were also consigned to Rocky Island, from where they were finally removed in 2004 and sent to the USA for decontamination /recycling. The RPII again surveyed the caverns and found only background levels of radiation.

Process monitoring

As part of a laboratory procedure for checking furnace dust and all casts of steel, small calibration sources were used to check the radiation counter. These were also removed to the USA in 2004. In 2005 and 2008 WYG screened all waste/soil samples taken on-site with a MiniRad gamma survey monitor to detect for the presence of radioactive material of which none was detected (WYG A, 2008).

2.2.5. East Tip Contractor Excavation

During site clearance works in 2008 unauthorised excavation works were carried out on the East Tip by a contractor who excavated and removed oily sludge material buried within the slag material (Section 2.2.4). While a number of trial pits were excavated throughout the site the main excavation works occurred to the east of the pitch and extend across an area of approximately 60m by 55m. The surface slag material was removed to expose the underlying sludge which was subsequently removed and mixed with slag material on site prior to being exported for disposal. These works commenced in December 2007 and continued until the contractor was ordered to cease by the Department of Environment, Heritage and Local Government (DoEHLG) in June 2008.

Topographic Survey of East Tip Excavation

A topographic survey of the East Tip area was undertaken in 2005. In July 2008 the surveyors were instructed to update the survey taking account the areas of the East Tip that were excavated by the contractor i.e. the main excavation, 15 trial pits and an area along the boundary northern of the site where a sea breach had been created. The most recent topographical survey of the East Tip is presented in Appendix C. While the sea breach was subsequently repaired in November 2011 the topographical survey has not been updated to take account of these repair works.

The survey indicates that approximately 18,000m^3 of waste material was removed from the main excavation and approximately 460m^3 of waste material removed from the 15 trial pits. Some of this

material remains on site but the majority was exported for disposal. As can be seen from the survey the main excavation is divided into two areas which are excavated to differing depths. The northern section of the excavation has an elevation of approximately 0mOD with the southern section having a depth of in excess of -2mOD in places. From 2008 groundwater level monitoring data, it can be seen that the groundwater level is generally in excess of 1mOD at high tide indicating a water depth of approximately 1m and 3m in the northern and southern excavation areas, respectively. The survey information also indicated that breach along the northern perimeter had resulted in the previous ground level being lowered by approximately 2m. This resulted in an area of the site becoming inundated with sea water under certain tidal and climatic conditions (Plate 2.2). This breach was repaired in November 2011.

Plate 2.2: East Tip Inundated with Seawater

2.2.6. Summary of Site Investigations

1995 Site Investigation

In 1995, K.T. Cullen & Co Ltd were retained by Irish Steel to undertaken an investigation of the East Tip. The purpose of this investigation was to determine if the fill materials comprising the East Tip head have had an adverse environmental impact on sediment and water quality in the vicinity of the tip head.

During the 1995 site investigation:

- 6 no. boreholes (MW1 – MW6) were drilled[2], and
- 12 no. trial pits (TP1 – TP12) were excavated.

The 1995 borehole and trial pit locations are illustrated in Figure 2.4. Borehole logs and trial pit records are provided in Appendix D (KTC, 1995).

1998 Site Investigation
In 1998, K. T, Cullen & Co Ltd was retained by Project Management Ltd to carry out site investigations at the East Tip. The purpose of these investigations was to establish:

(i) the volatile organic compound and polychlorinated biphenyl levels in the waste
(ii) the leachate quantities emanating from the East Tip, and
(iii) the permeability of the East Tip.

To achieve this, 12 no. boreholes (WS-1 – WS-12) were drilled the locations of which are illustrated in Figure 2.4. Borehole logs are provided in Appendix D.

2005 Site Investigation
In 2005, WYG & Glovers were retained by Hyder, on behalf of Cork County Council to undertake an extensive subsurface investigation on the former Irish Steelworks site encompassing the East Tip and the main steelworks site. This report only references the site investigations carried out on the East Tip. The aim of the investigation was to provide an assessment of the geotechnical and environmental subsoil conditions (WYG A, 2005). In total 16 no. boreholes (BH116 – BH131) were installed and 11 no. trial pits (TP121, TP123-TP132) excavated within the East Tip. The 2005 borehole and trial pit locations are illustrated in Figure 2.5. Borehole logs and trial pit records are provided in Appendix D.

2008 Site Investigation
While soil and waste sampling was undertaken by both WYG and RPS in 2008 (Table 1.1) exploratory site investigations were not carried out.

2010 Site Investigation
WYG produced a Geo-Environmental Report in 2010 which related to the main steelworks site only. No additional investigations were carried out on the East Tip.

2011 Geophysics Survey
Cork County Council retained Apex Geoservices in November 2011 to complete a geophysical survey of the East Tip. The aim of this survey was to obtain a profile of the waste, alluvium and glacio-fluvial layer across the site and to confirm depth of bedrock. The results of the survey indicate that the cemented slag ranges in thickness from 3.8m to 16.2m. This in turn was underlain by soft-very soft SILT/CLAY which ranges in thickness from 3.0m to >13.0m. This is followed by firm stiff sandy gravelly CLAY and medium dense-dense SAND/GRAVEL and then limestone bedrock. A copy of the report is contained in Appendix E.

[2] 3 no. additional boreholes (BH1 – BH3) had been previously drilled around the tip edge in May 1995 by Site Investigations Ltd.

Title: **Figure 2.4: Borehole And Trial Pit Locations (1995,1998)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 16/01/2012

Legend:

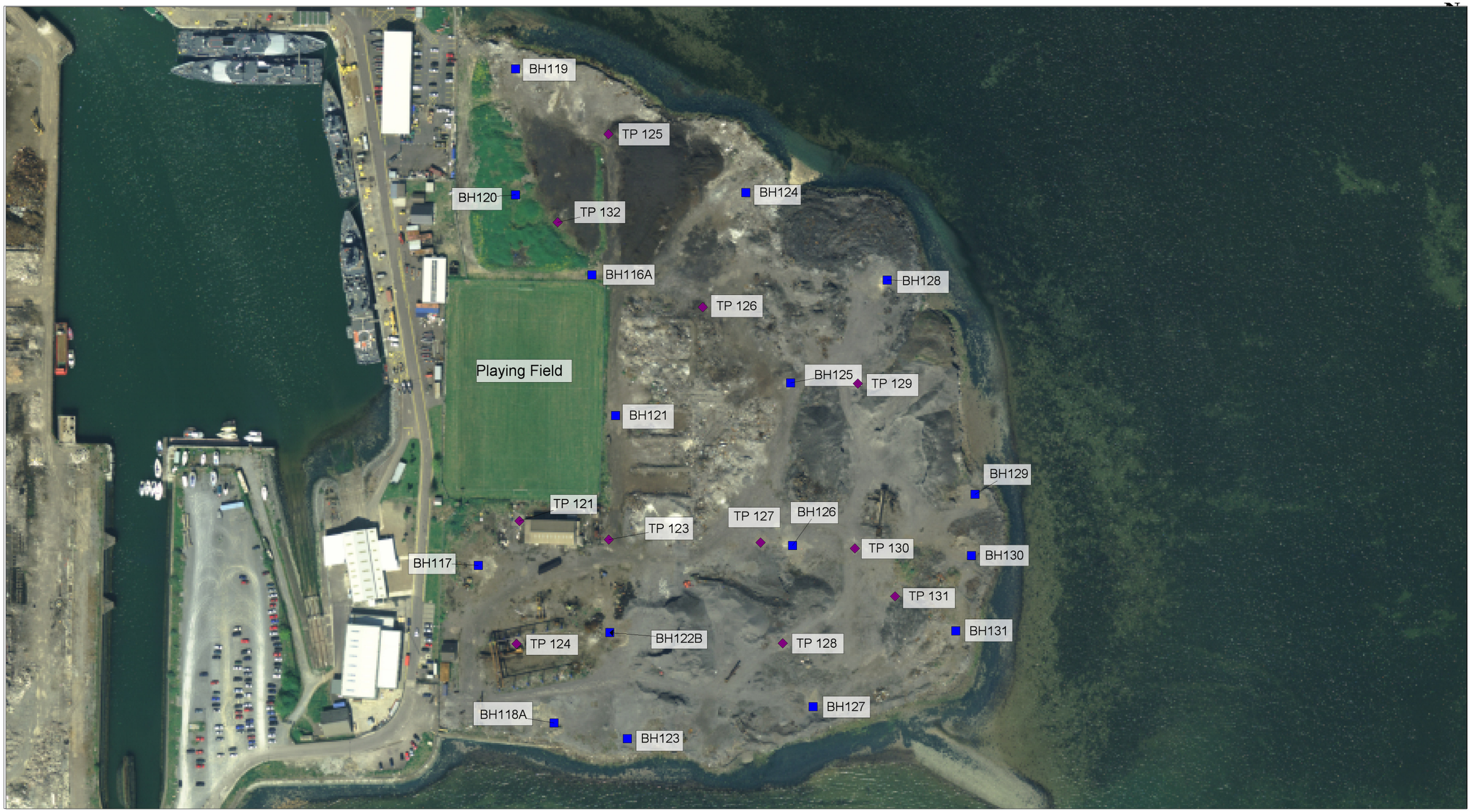
- Boreholes 1995
- Trial Pits 1995
- Boreholes 1998

*Trialpits and Boreholes from 2005 surveys are illustrated in Fig 2.5

Cork County Council
Environmental Directorate
Inniscarra,
Co. Cork

Phone: 021 - 4532700
Fax no. 021 - 4532777

Scale; **1:2000 @ A3**



Title: **Figure 2.5: Borehole And Trial Pit Locations (2005)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 16/01/2012

Legend:

- Trialpits 2005
- Boreholes 2005

*Boreholes and Trialpits from 1995 and 1998 surveys are illustrated in Fig 2.4

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Scale; **1:2000 @ A3**

2.3. Geology and Hydrogeology of Haulbowline Island

The site is underlain by the Waulsortian Limestone Formation which is of Lower Carboniferous age. Structurally the region has been strongly influenced by folding, faulting and low grade metamorphism of the Variscan tectonic event (GSI, 1994). The boreholes drilled as part of the 2005 site investigation on the main steelworks site, East Tip and offshore locations encountered limestone at each of the locations where bedrock was proven. These boreholes encountered limestone bedrock in the East Tip at depths between 12.5mbgl and 36mbgl. The variation in depth to bedrock is due to folding creating synclines and anticlines which not only lead to significant changes in bedrock levels, but possible fracturing due to the folding process. A north south trending syncline was identified in the East Tip.

The elevated ground occupied by Naval Headquarters at the western portion of the Island (12 mAOD) consists of limestone outcrop which falls to the east and the south. It is reported that the majority of the land east of the outcropping bedrock including the area occupied by the former main steelworks site Naval Dockyard and the East Tip have been formed by infilling with quarry materials and waste, mainly from steel production (WYG A, 2008).

The 2005 site investigation carried out at Haulbowline Island determined that the East Tip was underlain by natural marine sediments overlying fluvio-glacial sands and gravel which in turn overlies the limestone bedrock. The depth of waste material varied between 4.0m to 12.4m in thickness with surface stockpiles up to 10 metres above the main East Tip surface level also present (WYG A, 2008). The alluvium has been described, by WYG, as natural grey sandy clay and clayey silt soft alluvial marine sediments and the glacial material as poorly sorted sub-rounded to rounded gravel containing sand, silt with occasional cobbles and boulders (WYG A, 2008).

The vulnerability of the groundwater in the bedrock aquifer depends on: (i) the time of travel of infiltrating water (and contaminants); (ii) the relative quantity of contaminants that can reach the groundwater; and (iii) the contaminant attenuation capacity of the geological materials through which the water and contaminants infiltrate. The GSI has devised a system for classifying the aquifers of Ireland under which the Republic of Ireland's entire land surface is divided into nine aquifer categories. Eight aquifer categories are defined in Groundwater Protection Schemes (DELG/EPA/ GSI, 1999) and they are as follows:

<u>Regionally Important (R) Aquifers</u>

- Karstified bedrock (Rk)
- Fissured bedrock (Rf)
- Extensive sand & gravel (Rg)

<u>Locally Important (L) Aquifers</u>

- Bedrock which is Generally Moderately Productive (Lm)
- Bedrock which is Moderately Productive only in Local Zones (Ll)
- Sand & gravel (Lg)
- Locally important karstified bedrock (Lk)

<u>Poor (P) Aquifers</u>

- Bedrock which is Generally Unproductive except for Local Zones (Pl)
- Bedrock which is Generally Unproductive (Pu)

The massive unbedded fine grained limestone of the Waulsortian Formation which underlies Haulbowline Island is a locally important aquifer which is karstified (Lk). Based on this classification typical groundwater yields could range from 100m^3/day to 400m^3/day. On a local scale for an Island

such as Haulbowline Island, WYG concluded that there is generally a freshwater lens of groundwater beneath the surface but that this is largely influenced by surrounding saline water intrusion and unsuitable for use as a potable water supply.

A perched groundwater body exists on the East Tip within the waste material and underlying natural overburden sediment and it has been demonstrated that it is in hydraulic continuity with the surrounding harbour waters. WYG thus determined therefore that it had a high saline water content although its composition was also influenced by fresh water infiltration from the ground surface and the chemical composition of the waste materials. This perched water does not form an aquifer nor could it be used as a water resource. The main receptor of the perched groundwater is the harbour as seen from water seepages to the foreshore visible at low tide.

Based on drilling results from the East Tip, the vulnerability of the bedrock aquifer underlying the East Tip has been classified by WYG as moderate to low with a more specific classification dependent on the determination of permeability of the overburden sediments. They also determined that the perched groundwater in the overlying waste and overburden sediments is not in direct hydraulic connection with the groundwater in the bedrock aquifer given the thickness of low/moderate permeability of marine sediments present. However, it was surmised that there is likely to be some leakage of perched groundwater to the bedrock aquifer.

According to WYG, any groundwater abstraction wells located on the mainland or other Islands in Cork Harbour are unlikely to be hydraulically connected to the groundwater body beneath Haulbowline Island as groundwater will discharge to the coastline. An abstraction on the mainland is more likely to cause seawater intrusion from the adjacent shoreline before abstracting from an off-shore island. The limestone bedrock aquifer unit beneath Haulbowline Island is orientated in an approximate east-west direction with a different aquifer unit present on the mainland to the north and south of Haulbowline Island (WYG A, 2008).

Groundwater Tidal Influence

The perched groundwater on the site has been found to be tidally influenced although due to the heterogeneity of the waste mass this is not constant across the site. Groundwater level measurements were taken from the monitoring wells at both high and low tide on 05/09/08 and 08/09/08, respectively, and are presented in Table 2.3 below. The groundwater level data was converted to Malin Head Ordnance Datum using levels obtained from a topographic survey (WYG A, 2008).

Table 2.3: Monitoring Well Groundwater Levels at High Tide and Low Tide (WYG, 2008).

Well ID	Total Well Depth (m)	High Tide Groundwater Level mOD, 05/09/08	Low Tide Groundwater Level mOD, 08/09/08
BH116	10.23	0.86	0.51
BH117	9.40	1.91	0.82
BH118	11.52	1.32	-0.13
BH120	10.70	0.62	0.35
BH122*	29.85	1.88	0.28
BH125	11.00	0.90	0.43
BH126	11.60	0.86	0.41
BH127	10.10	1.31	0.11
BH128	11.10	1.18	0.01
BH130	6.65	1.37	0.35

*Note: BH122 is a monitoring well installed in the bedrock aquifer

WYG state that in 2005 the perched groundwater level within the waste material of the East Tip generally ranged between 1m to 5m below the surface of the waste. Taking into account the survey level of the groundwater monitoring well casing and measured water levels, the groundwater level was seen to be between 1.0mAOD and 0.7mAOD as presented in Table 2.4. Dataloggers placed in two monitoring wells (BH118, BH125) recorded tidal variation and the results are presented in graphs below (WYG A, 2005). A tidal range with respect to the perched groundwater level of up to 2.5m was observed in BH118 which is located near the southern shoreline of the East Tip. The tidal influence in the groundwater towards the centre of the East Tip site was seen to be up to 0.75m in monitoring well BH125 located adjacent to the existing excavation on-site. For borehole locations, refer to Section 2.2.6.

Table 2.4: Monitoring Well Groundwater Levels (WYG, 2005)

Borehole Name	Total Depth (m)	SWL (mbtoc)	Casing Survey Level (mOD)	Gw Level mOD	Time	Date
BH116	10.23	3.19	3.45	0.26	11.08	04/10/05
BH117	9.4	2.8	3.52	0.72	9.14	04/10/05
BH118	11.52	4.35	3.4	-0.95	12.49	04/10/05
BH119	9.80	3.62	3.66	0.04	12.09	04/10/05
BH120	10.70	3.75	3.96	0.21	11.33	04/10/05
BH125	11.00	3.81	3.84	0.03	15.12	04/10/05
BH126	11.60	1.16	1.54	0.38	9.29	04/10/05
BH127	10.10	3.70	4	0.30	9.55	04/10/05
BH128	11.10	5.59	4.91	-0.63	15.00	04/10/05
BH130	6.65	4.56	4.78	0.22	10.46	04/10/05
BH122	29.85	4.25	3.1	-1.15	12.40	04/10/05

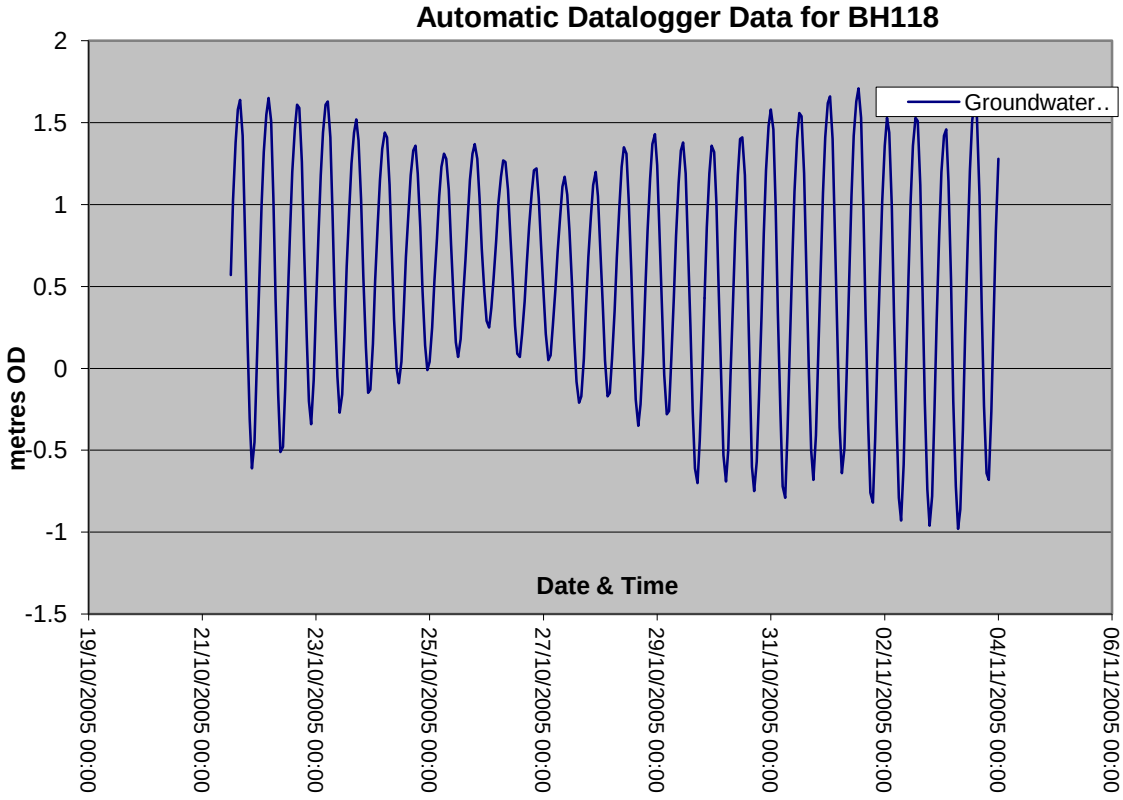

Figure 2.6: Automatic Datalogger Data for BH118 (WYG A, 2005)

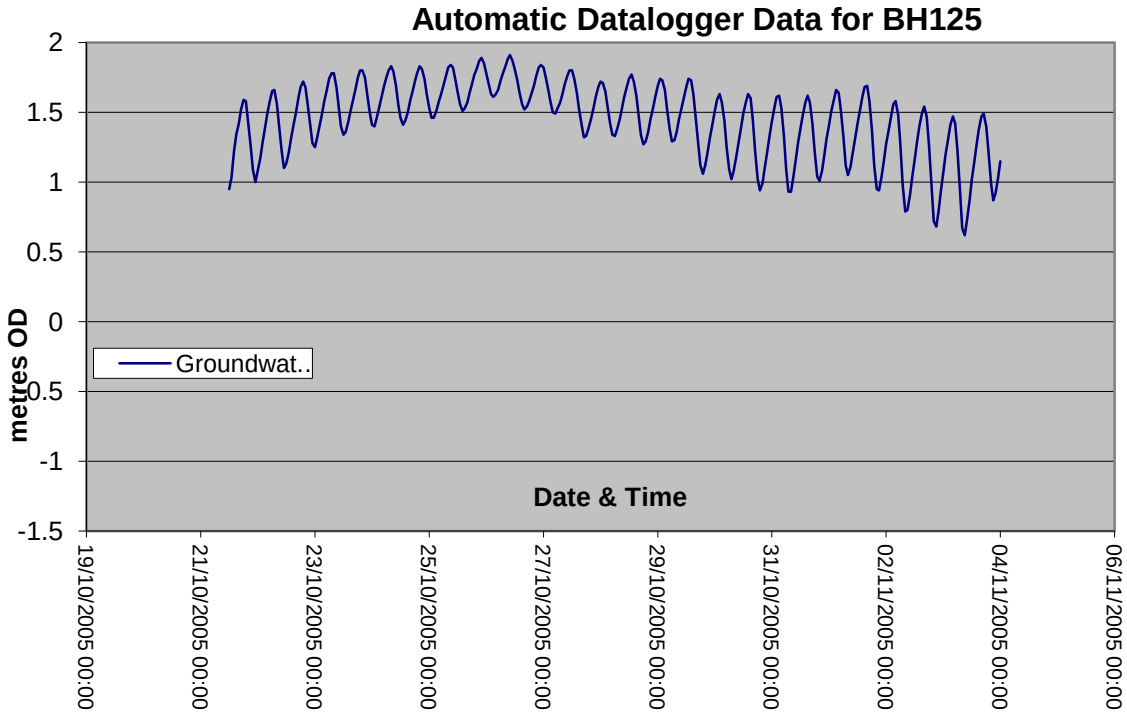

Figure 2.7: Automatic Datalogger Data for BH125 (WYG A, 2005)

A groundwater contour map was produced for the site to determine inferred groundwater flow directions at both low and high tides and is presented in Appendix F. At low tide it can be seen that the perched groundwater migrates in a radial pattern from the central region of the East Tip towards the shoreline where the seepage points of water are visible. At high tide the inferred groundwater flow direction is inland from the marine water on the eastern region of the East Tip. There is some flow from the northern and southern area of the football pitch on the western perimeter of the site towards the shoreline at high tide. These findings concurred with a similar study undertaken by K. T Cullen & Co Ltd (KTC) in 1995 although KTC observed that the data suggested that the fluctuation in groundwater level was not as great and was relatively stagnant over a wide area centred on the site garage.

WYG noted that the perched groundwater level in the waste/overburden and underlying bedrock aquifer did not correspond with the slightly higher water elevation in the bedrock aquifer indicating that the bedrock aquifer is semi-confined (WYG A, 2008).

Bathymetric Survey

WYG commissioned Irish Hydrodata Limited to carry out a bathymetric survey around the East Tip (100m north and south and 300m east) on 14th and 16th September 2005. The survey is presented in 2D and 3D format in Appendix G.

3.0. Geotechnical Analysis

3.1. Introduction

The 2005 site investigation undertaken by WYG included, among its objectives, an assessment of the geotechnical subsoil conditions across the East Tip. In order to achieve this, a number of exploratory boreholes were installed and standard and cone penetration testing was undertaken on in-situ material. In addition trial pits were excavated and geotechnical testing carried out on waste samples in Glovers Site Investigations soils testing laboratory in Northern Ireland.

During shell & auger drilling undisturbed samples of the various layers were obtained using U100 sample tubes and sampler. Small disturbed samples and bulk disturbed samples were also obtained for geotechnical testing. Standard penetration tests (SPTs) were completed at regular intervals in both cohesive and non-cohesive layers where possible. In total sixteen boreholes (BH116 – BH131) were drilled and eleven trial pits (TP121, TP123 - TP132) were excavated on the East Tip during these investigations (WYG A, 2005). The location of these boreholes and trial pits are provided in Figure 2.5.

As part of the 1998 site investigation undertaken by K.T. Cullen & Co Ltd falling head permeability tests were carried out on the waste material while in previous investigations undertaken by the same firm in 1995 four samples of silt sediment underlying the tip head were submitted for physical testing.

This section provides general information on the geotechnical analysis that was carried out and the results of same. Results of the geotechnical laboratory analysis undertaken on waste, soil and sediment samples collected in the field by WYG and KTC are presented in Appendix H.

3.2. In-situ Geotechnical Testing (2005)

A summary of the results of the in-situ standard penetration tests carried out on subsurface material in selected boreholes is provided in Appendix H. The standard penetration test results are also available in boreholes logs provided in Appendix D. Static cone penetration testing (SCPT) was carried out at five locations and the factual report of same is provided in Appendix H.

Nine dissipation tests were carried out at different depths in selected boreholes to assess pore water pressure levels in the subsurface. The tests were conducted in BH121 (3 tests), BH123, BH124 (2 tests), BH129 and BH131 (2 tests). The factual report is provided in Appendix H.

One falling head permeability test was carried out, on the waste fill material in 2005 and another test was carried out in the limestone bedrock (WYG A, 2005).

3.3. Geotechnical Laboratory Testing (2005)

Listed below are the laboratory geotechnical tests completed by Glover Site Investigations. An inventory of the samples taken along with results of the analysis undertaken on waste, soil and sediment samples collected by WYG is contained in Appendix H:

- Moisture Content Determinations – BS1377: Part 2: 1990 Method 3
- Atterberg Limit Tests – BS 1377: Part 2: 1990 Methods 4 & 5
- Particle Size Distribution by Sieving – BS 1377 Part 2: 1990 Method 9.2
- Particle Size Distribution by Sedimentation – BS 1377 Part 2: 1990 Method 9.5

- Unconsolidated Undrained Triaxial Compression Tests – BS !377 Part 7: 1990 Method 8
- One Dimensional Oedometer Consolidation Tests – BS 1377 : Part 5: 1990 Method 3
- pH Determination – BS 1377: Part 3 : 1990 Method 9
- Soluble Sulphate Content – BS 1377 : Part 3: 1990 Method 5
- Organic Matter Content – BS 1377 : Part 3 : 1990 Method 4

3.4. Results of Geotechnical Analysis of Alluvium (1995 & 2005)

1995 Geotechnical Analytical Results (KTC, 1995)

As part of the site investigation of the East Tip, K.T Cullen & Co Ltd, submitted four samples (MW1-2b, MW2-2, MW5-1, MW6-2) of silt sediment underlying the tip head for physical testing to determine the following:

- Natural water content
- Particle size distribution

The sample locations are presented in Figure 3.1. Results of the analysis determined that the natural water content of the silt varied between 21% and 46%. Particle size distribution charts are provided in Appendix H.

2005 Geotechnical Analytical Results

The fine grained alluvial soils typically comprise predominantly grey slightly sandy clay or silt. Particle size distribution analyses undertaken on eight samples taken from the East Tip indicate a fines component averaging 87% but ranging up to 93%. The percentage of sand encountered averaged 13% but ranged up to 18%. Moisture content values ranged between 27% and 92%, averaging 55%. The results of the geotechnical analysis are presented in Appendix H.

Atterberg tests were undertaken on 34 samples of alluvium for which liquid limits ranged between the values of 38% and 108%. Percentages greater than 100 occur where the mass of water in the soil exceeds the dry mass of the soil particles. One of the samples was determined to be non-plastic. For the remaining samples plastic limits ranges from 22% to 32% yielding plasticity indices in the range of 0% to 78%.

A total of 41 standard penetration tests were undertaken within the alluvium stratum with SPT N values ranging between 4 and 28, averaging 8.

Laboratory determinations of undrained shear strength (C_u) on 28 samples indicated C_u values of between 14 and 24kN/m^2, averaging 17kN/m^2.

Oedometer consolidation tests were undertaken on six samples. Maximum coefficient of compressibility (M_v) values ranged between 0.92 and 2.91 m^2/MN and averaged 1.6m^2/MN. The alluvium was thus determined to be of high to very high compressibility. Corresponding coefficient of consolidation (C_v) values ranged between 0.27m^2/yr and 2.21m^2/yr, averaging 0.9m^2/yr. It was stated that M_v values presented on the oedometer test results applied only to the specific pressure range of the relevant loading stage. To establish a parameter that is less dependant on pressure range WYG calculated a dimensionless compression index (C_c) from the slope of the straight line.

Bulk densities determined on thirty-two samples of fine grained alluvium ranged between 1.476 Mg/m^3 and 1.727Mg/m^3 averaging 1.621Mg/m^3.

Title: **Figure 3.1; Silt Sediment Samples (1995 KT Cullen Report)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 16/01/2012

Legend:

+ Silt Sediment Samples

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Scale; **1:2000 @A3**

The percentage of organic matter was determined on eleven samples of the alluvium indicating an average organic content of 1.5% though results ranged between 0.9 and 2.4%. WYG determined that these results indicate that the alluvium is slightly organic.

No direct measurements of permeability have been made on the alluvial deposits to date (Hyder, 2006).

3.5. Results of Geotechnical Analysis of Waste Material (1998 & 2005)

The East Tip comprises mainly of waste originating from the steel making processes (Section 2.2.4). The slag deposits comprise of grey often cemented dense sandy gravel with occasional furnace brick, furnace scalpings, millscale and steel with significant steel obstructions encountered in boreholes (WYG A, 2005).

It was observed by K.T. Cullen & Co Ltd during the site investigations in 1998 that the un-compacted waste near ground surface had a high permeability and that during an extremely wet day no surface runoff was observed. All precipitation was seen to rapidly percolate into the waste. It was thus surmised that the permeability of the waste was highly variable due to the following factors:

1. The nature of the deposited materials varies from fine dust or sludge to coarse metal fragments
2. The shallow waste is much less compacted than the deeper waste and
3. The waste below the water table is flushed by the tide which may allow some dissolving and washing of finer particles.

Falling head permeability tests were carried out on the waste material in both 1998 and 2005 by KTC and WYG, respectively. The results of these tests are presented in Table 3.1 below while the permeability calculations carried out in 1998 are provided in Appendix H. The location of the permeability tests are shown in Figure 2.4 and Figure 2.5.

Table 3.1: Falling Head Permeability Results on Waste Material on East Tip

Location	Year	Layer	Consultant	Permeability m/s
WS-04[3]	1998	Waste Fill	K.T. Cullen	3.8×10^{-6} to 1.1×10^{-5}
MW3[4]	1998	Waste Fill	K.T. Cullen	2.0×10^{-6}
BH-120	2005	Waste Fill	WYG	2.1×10^{-7}

Standard penetration tests N values for the waste body ranged between 7 and an extrapolated upper value of 250. An average N value of 72 was calculated, indicative of very dense material (WYG B, 2005).

[3]Difficulties were encountered when drilling. WS-4 which was drilled to a depth of 2.08mBGL which left the bottom of the hole above the water table. An estimate of the range depth of the water table was made and a range permeability values was calculated.

[4] Due to the tidal effects, the water table was not static, so only the maximum permeability of the waste was calculated.

3.6. Results of Geotechnical Analysis of Glacial Till Deposits (2005)

Glacial till deposits of boulder clay and ablation till were encountered by WYG in some locations beneath the East Tip (WYG B, 2005). As a result SPT tests were undertaken at three locations within the ablation till with an average SPT N value of 15 recorded with results ranging between 5 and 23. In addition SPT tests were undertaken at sixteen locations in the boulder clay and an average SPT N value of 30 was recorded with results ranging from 12 to 55.

The Atterberg tests were carried out on one sample of ablation till and 9 samples of the boulder clay. Within the ablation till, the liquid limit was 42%, the plastic limit was 16 and the plasticity index was 26%. Moisture content was 27%. For the boulder clay, liquid limits ranged between 33% and 47% (averaging 41%), plastic limits between 13% and 27% (15%) and plasticity indices between 20% and 32% (averaging 25%). The moisture content values ranged between 14% and 28% (averaging 19%).

No particle size distribution analyses were undertaken on the till deposits. The geotechnical analytical results are presented in Appendix H.

3.7. Glacial Sands & Gravels Geotechnical Analytical Results (2005)

Particle size distribution (PSD) analysis was undertaken on twenty five selected samples of the glacial sands and gravels. The percentage of fine soils encountered in all instances was less than 5%, and averaged 1%. The percentage of sand ranged between 14% and 95% and the percentage of gravel ranged between 0% and 84%. On average the stratum comprised of 1% fine soils, 33% sand and 66% gravel.

Fifty seven standard penetration tests were undertaken on this stratum with SPT N values ranging from 12 to 123 and averaging 38. It was concurred that these values are indicative of a predominantly medium dense to dense material (WYG B, 2005). The geotechnical analytical results are presented in Appendix H.

3.8. Carboniferous Limestone Geotechnical Analytical Results (2005)

The lowermost stratum that was encountered by WYG during the 2005 site investigation was Carboniferous limestone (WYG B, 2005). The returns from the cable tool holes was classified as typically moderately weak, fine grained, Carboniferous limestone.

SPT tests undertaken at or close to rock head often recorded refusal requiring extrapolation of SPT N values. Values recorded ranged between 46 and 563, averaging 247. WYG state that whilst these values confirm the competency of the rock near rock head it is recommended that these values are not used for design purposes as they will fall outside the range of base data used to derive empirical relationships or that relate to design methods.

WYG also state that it is extremely important to note that the descriptions included on the borehole logs are representative of conditions near rock head only. Furthermore the strength descriptions included are based only upon field observation of fragmented returns from cable tool holes and/or chippings from rotary percussive drilling and drilling resistance reported by the drill operator. The geotechnical analytical results are presented in Appendix H.

4.0. Surface and Groundwater Monitoring

4.1. Introduction

As part of the investigations undertaken on the East Tip the quality of groundwater, marine water and surface water has been monitored. This monitoring has been carried out in order to assess the potential impacts of the East Tip on the various waterbodies. Groundwater samples were obtained from boreholes on the site; marine water samples from the waters surrounding the site and various control points and surface water samples from seepage points at low tide and also from excavations. The water monitoring schedule is provided in Table 4.1.

For the groundwater sampling it appears to Cork County Council that individual strata in the profile were not screened but rather that screens extended over a number of layers in numerous boreholes.

Table 4.1: Water Monitoring Schedule

Water Body	Analysis 2008	Analysis 2007	Analysis 2006	Analysis 2005	Analysis 1995
Groundwater in waste body & subsoils	√ (See Table 4.2)	√ (See Table 4.2)	√ (See Table 4.2)	√ (See Table 4.2)	√
Marine Water	√	√		√	√
Surface Water	√				√
Bedrock Aquifer	√ (See Table 4.2)	√ (See Table 4.2)	√ (See Table 4.2)	√ (See Table 4.2)	

The water monitoring terminology used, in this section, was taken directly from the original reports and is not Cork County Council's interpretation of the hydrogeological setting.

Chemical analytical screening values have been included within this factual report. The screening values used relate to those applied by the consultants at the time of their work and reporting and may be reflective of the screening values at the time of writing. The values have been included only for the purpose of providing a basic guide and they should NOT be used or referred to out of context as there is no guarantees that the values are appropriate then or now. Planned site investigation and quantitative risk assessment work is intended to provide a more appropriate context.

4.2. Groundwater Monitoring

4.2.1. Groundwater Monitoring (1995)

The site investigation carried out by K.T. Cullen & Co on the East Tip in 1995 included groundwater monitoring. Six boreholes were drilled and seven monitoring wells were installed in order to establish the hydraulic regime of the tip head and to sample water entrained in the sediments. MW-3(s) and MW-4 were installed in the waste body and were thus in hydraulical connectivity with the sea water while MW-1, MW-2, MW-3(D), MW-5 and MW-6 were sealed within the sediments (CCC interpret this sediment to be the alluvium). Sampling of the seven monitoring wells was carried out on 28th August 1995 with samples being sent for analysis for a suite of inorganic parameters, TPH and phenol. Results were compared against available environmental quality criteria for water to determine the degree of impact and potential risks in addition to the Dutch Intervention levels. The 1995 groundwater sampling locations are presented in Figure 4.1 and the results of the analysis of the groundwater are presented in Appendix I.

Title: **Figure 4.1: Groundwater Sampling Locations (1995)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 07/11/2011

Legend:

1995 Groundwater Sampling Locations (1995 K.T. Cullen)

Cork County Council
Environmental Directorate
Inniscarra,
Co. Cork

Phone: 021 - 4532700
Fax no. 021 - 4532777

Scale; **1:2,000 @ A3**

Laboratory Analytical Results

- Copper (LoD:0.05mg/l), arsenic (LoD:0.2mg/l), mercury (LoD:0.2mg/l), chromium (LoD:0.05mg/l), zinc (LoD:0.05mg/l), cadmium (LoD:0.02mg/l), lead (LoD:0.2mg/l), nickel (LoD:0.05mg/l) and selenium (LoD:0.2mg/l) were not detected above the laboratory detection limits.
- However, the laboratory detection limits for arsenic, mercury, chromium, and cadmium are above the Dutch Intervention Values of 0.06mg/l, 0.0003mg/l, 0.03mg/l and 0.006mg/l respectively.
- The concentration of boron did not exceed the UK Saline EQS, of 7mg/l in any groundwater sample.
- TPHs and Phenols were not detected above the laboratory detection limits of 0.01mg/l and 0.05mg/l respectively in the samples that were analysed (MW-1, MW-3(S), MW-3(D), MW-4 and MW-6).
- It was noted that the laboratory reported that the trace elements were very difficult to detect due to highly dominant concentration of ions.

It was concluded by KTC that there was very little difference in the chemistry of the water that is in direct connection with the sea (SW-2, MW-3(s) and MW-4) and a sample SW-2 which was sea water. The other samples (MW-1, MW-2, MW-3, MW-5 and MW-6) also appeared to have similar chemistry as the seawater.

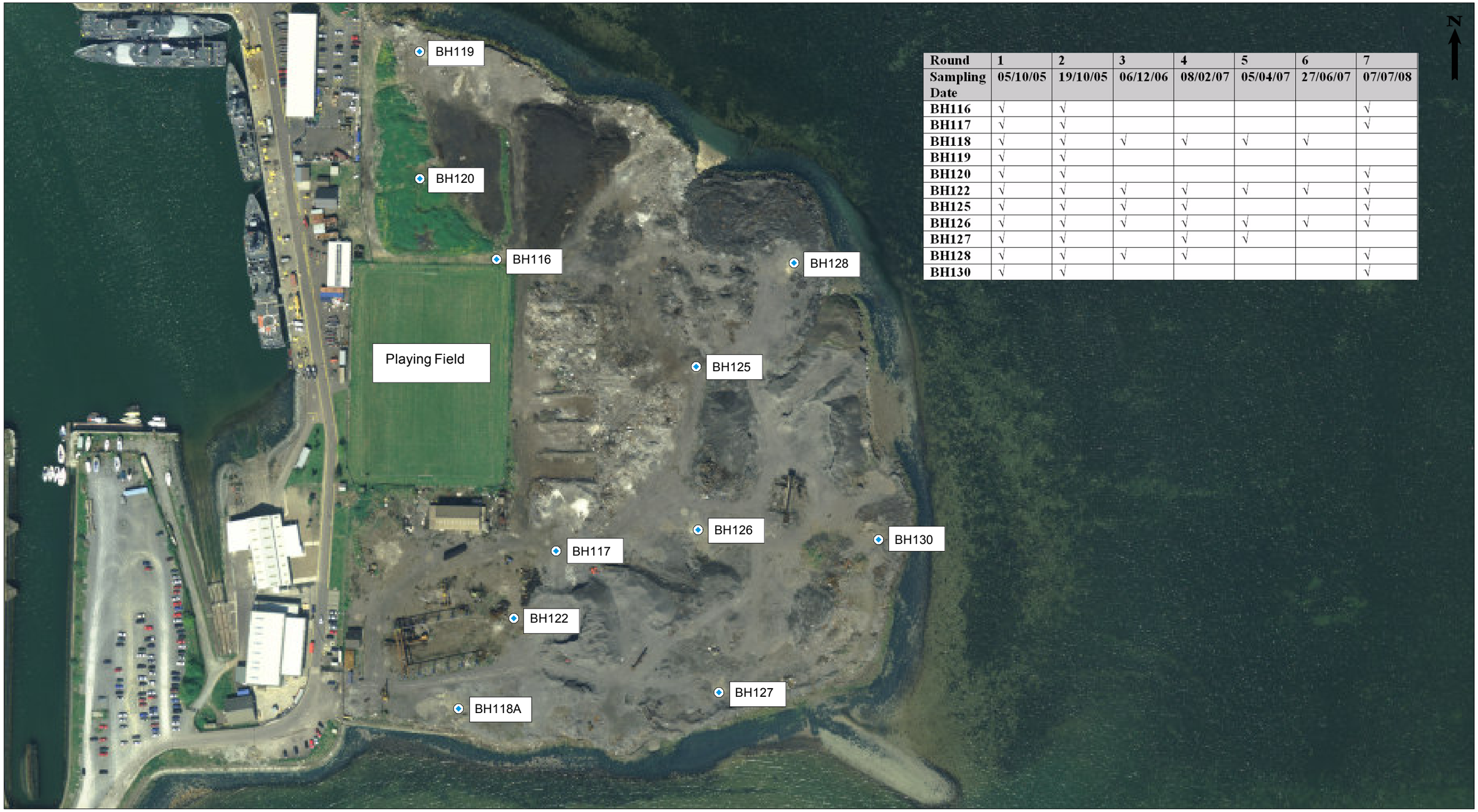
4.2.2. Groundwater Monitoring (2005 to 2008)

Eleven boreholes were installed across the East Tip to facilitate monitoring of groundwater quality underlying the site. One of the boreholes was screened in the limestone bedrock aquifer (BH122) and this is addressed separately in Section 4.2.3 below. Borehole locations are presented in Figure 4.2. In total 7 no. rounds of sampling took place between May 2005 and July 2008 (Table 4.2), Rounds 1, 2 and 7 were undertaken by WYG while Rounds 3 to 6 were undertaken by Glovers. The results of these are presented in this section.

Table 4.2: Sampling schedule

Round	1	2	3	4	5	6	7
Sampling Date	05/10/05	19/10/05	06/12/06	08/02/07	05/04/07	27/06/07	07/07/08
BH116	√	√					√
BH117	√	√					√
BH118	√	√	√	√	√	√	
BH119	√	√					
BH120	√	√					√
BH122[5]	√	√	√	√	√	√	√
BH125	√	√	√	√			√
BH126	√	√	√	√	√	√	√
BH127	√	√		√	√		
BH128	√	√	√	√			√
BH130	√	√					√

[5] Bedrock aquifer



Round	1	2	3	4	5	6	7
Sampling Date	05/10/05	19/10/05	06/12/06	08/02/07	05/04/07	27/06/07	07/07/08
BH116	√	√					√
BH117	√	√					√
BH118	√	√	√	√	√	√	
BH119	√	√					
BH120	√	√					√
BH122	√	√	√	√	√	√	√
BH125	√	√	√	√			√
BH126	√	√	√	√	√	√	√
BH127	√	√		√	√		
BH128	√	√	√	√			√
BH130	√	√					√

Title: **Figure 4.2: Groundwater Sampling Locations (2005-2008)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 07/11/2011

Legend:

- Groundwater Sampling Locations

Cork County Council
Environmental Directorate
Inniscarra,
Co. Cork

Phone: 021 - 4532700
Fax no. 021 - 4532777

Scale; **1:2,000 @ A3**

The results were compared against the UK EA Coastal and Estuarine Environmental Quality Standards. The UK EA derived the Environmental Quality Standards (EQS) to enforce the Dangerous Substances Directive. Pollution by dangerous substances is defined as an exceedance of EQSs in water. The EQS of a substance is based on the toxicity of the substance and defines a concentration in the water below which the substance is not considered to have a polluting effect or cause harm to plants and animals. The UK EQSs for Coastal and Estuarine Environmental Quality Standards have been used, by WYG, as the comparative screening criteria.

The EPA Interim Groundwater Values (EPA IGV) were proposed in the *Interim Report Towards Setting Guideline Values for the Protection of Groundwater In Ireland* (June 2003). As the site's groundwater is brackish, WYG compared the analytical results to these IGV parameters for information purposes only (WYG, 2006).

Certificates of analysis, where supplied by WYG, are contained in Appendix J. A summary table of the groundwater analytical results for each borehole and round is provided in Appendix I.

Groundwater Monitoring Round 1 (WYG, 2005)

Hydrocarbons

- TPHs were detected at 287µg/l in the groundwater in BH120.
- Total PAHs were detected in the groundwater in BH116 (1043µg/l), BH117 (1252µg/l), BH118(2422µg/l), BH119(525µg/l), BH120(424µg/l), BH125(1227µg/l) BH126(329µg/l) and BH130(456µg/l).

Phenols and Cyanide

- There was no detection of phenols above the laboratory detection limit (0.01mg/l).
- There was no detection of total cyanide or free cyanide above their respective laboratory detection limit of 0.05mg/l.

Polychlorinated Biphenyls

- PCBs were not detected above the laboratory detection limit of 26µg/l in any of the samples.

pH

- The pH of samples taken from BH116 (9.22), BH117 (8.75), BH125 (8.52), BH127 (9.17), BH128 (9.24) and BH130 (9.03) was greater that the UK saline EQS of 8.5.
- The pH measured in samples obtained from boreholes BH118, BH119, BH120 and BH126 was within EQS limits.

Volatile Organic Compounds

- There was no detection of VOC above the laboratory detection limits of 1µg/l except for BH120, where p/m-Xylene was detected at 2µg/l and o-Xylene was also detected at 2µg/l.

Metals & Major Ions

A summary of the analytical results is provided in Table 4.3 below. Figures in red denote maximum concentration observed.

Table 4.3: Summary of Round 1 analytical results for metals (WYG, 2005)

Parameter	No. of Samples	Minimum (µg/l)	Maximum (µg/l)	Screening Criteria UK EA EQS (µg/l)	No. Exceeding	Locations Exceeded or Location of Max Conc.
Arsenic	10	31	48	25	10	BH116, BH117, BH118, BH119, BH120, BH125, BH126, BH127, BH128 BH130
Chromium	10	5	20	15	2	BH127, BH130
Chromium VI	10	<30	<30	-	-	-
Copper	10	4	20	5	8	BH116, BH117, BH118, BH119, BH120, BH125, BH126, BH127
Lead	10	2	5	25	0	BH125
Nickel	10	4	26	30	0	BH120
Zinc	10	20	13500	40	5	BH118, BH119, BH126, BH127, BH130
Cadmium	10	<0.4	3.9	2.5	1	BH120
Selenium	10	101	150	-	-	BH118
Mercury	10	<0.05	<0.05	0.3	0	

- The concentration of selenium exceeded the laboratory detection limit of 1µg/l in the ten boreholes sampled.
- Mercury was not detected above the laboratory detection limit of 0.05µg/l and therefore there was no exceedance of the UK Saline EQS.
- There was no detection of chromium VI above the laboratory detection limit of 0.03mg/l. The limit of detection is greater than the screening value for total chromium. The UK Saline EQS value for chromium is 0.015mg/l.

Groundwater Monitoring Round 2 (WYG, 2005)

Hydrocarbons

- TPHs were detected at 29µg/l and 723µg/l in samples obtained from BH127 and BH120, respectively.
- Total PAHs were detected in samples from BH116 (499µg/l), BH117 (417µg/l), BH120 (183µg/l), BH125 (862µg/l) and BH126 (376µg/l).

Phenols and Cyanide

- Phenols were detected above the laboratory detection limit in one sample from BH120 at a concentration of 0.43µg/l.
- Cyanide compounds (total cyanide, free cyanide) were not detected above their respective laboratory detection limit of 0.05mg/l.

Polychlorinated Biphenyls

- PCBs were not detected above the laboratory detection limit of 26µg/l.

pH

- The pH did not exceed the UK saline EQS of 8.5 for any of the samples.

Volatile Organic Compounds

- VOCs were not present above the laboratory detection limits of 1µg/l.

Metals & Major Ions

The summary analytical results are presented in Table 4.4 below. Figures in red denote maximum concentration observed.

Table 4.4: Summary of Round 2 analytical results for metals (WYG, 2005)

Parameter	No. of Samples	Minimum (µg/l)	Maximum (µg/l)	Screening Criteria UK EA EQS (µg/l)	No. Exceeding	Locations Exceeded or Location of Max Conc.
Arsenic	10	11	54	25	9	BH116, BH118, BH119, BH120, BH125, BH126, BH127, BH128 BH130
Chromium	10	46	74	15	10	BH116, BH117, BH118, BH119, BH120, BH125, BH126, BH127, BH128 BH130
Chromium VI	10	<30	40	-	-	BH127
Copper	10	4	8	5	3	BH119, BH120, BH125
Lead	10	1	3	25	0	BH119
Nickel	10	4	25	30	0	BH120
Zinc	10	239	260	40	10	BH116, BH117, BH118, BH119, BH120, BH125, BH126, BH127, BH128 BH130
Cadmium	10	<0.4	1.2	2.5	0	BH118
Selenium	10	34	161	-	-	BH128
Mercury	10	<0.05	<0.05	0.3	0	

- Mercury was not detected above the laboratory detection limit of 0.05µg/l and therefore there was no exceedance of the UK Saline EQS.
- There was a detection of chromium VI above the laboratory detection limit of 30µg/l in one sample from BH127 (40µg/l). The limit of detection (30µg/l) is greater than the screening value for total chromium (15µg/l)

Groundwater Monitoring Round 3 (Glovers, 2006)

Hydrocarbons

- TPHs were not detected above the laboratory detection limits (10µg/l).
- Total PAHs were not detected above the laboratory detection limits (0.01µg/l).

Phenols and Cyanide

- Phenols were not detected above the laboratory detection limit (0.01mg/l) in any of the samples.
- Total cyanide and free cyanide were not detected above their respective laboratory detection limit of 0.05mg/l in any of the samples.

Polychlorinated Biphenyls

- PCBs were not included in the chemical suite of analysis for the Round 3.

Volatile Organic Compounds

- VOCs were not included in the chemical suite of analysis for the Round 3.

Metals & Major Ions

The summary analytical results are presented in Table 4.5 below. Figures in red denote maximum concentration observed.

Table 4.5: Summary of Round 3 analytical results for metals (Glovers, 2006).

Parameter	No. of Samples	Minimum (µg/l)	Maximum (µg/l)	Screening Criteria UK EA EQS (µg/l)	No. Exceeding	Locations Exceeded of location of max conc.
Arsenic	4	24	33	25	3	BH118, BH125, BH128
Chromium	4	3	14	15	0	BH118
Chromium VI	4	<30	<30	-	-	-
Copper	4	3	6	5	1	BH125
Lead	4	1	1	25	0	BH118, BH125, BH126, BH128
Nickel	4	5	12	30	0	BH125
Zinc	4	<3	10	40	0	BH118
Cadmium	4	<0.4	0.8	2.5	0	BH118
Selenium	4	79	109	-	-	BH125
Mercury	4	<0.05	<0.05	0.3	0	

- Selenium concentrations ranged from 79µg/l in BH126 to 109µg/l in BH125.
- Cadmium was detected above the laboratory detection limit in one of the boreholes BH118 (0.8µg/l).
- The concentration of total chromium exceeded the laboratory detection limit in all four boreholes. However, the UK Saline EQS of 15µg/l was not exceeded.
- Mercury was not detected above the laboratory detection limit of 0.05µg/l and therefore there was no exceedance of the UK Saline EQS.

Groundwater Monitoring Round 4 (Glovers, 2007)

Hydrocarbons

- TPHs and PAH were only sampled in two of the boreholes (BH118 & BH125).
- TPHs were not detected above the laboratory detection limits (10µg/l) in the boreholes sampled.
- A Total PAHs concentration of 0.039µg/l was detected in the groundwater sample taken from BH118.

Phenols and Cyanide

- Phenols were not detected above the laboratory detection limit (0.01mg/l) in any of the five boreholes.
- Total cyanide and free cyanide were not detected above their respective laboratory detection limit of 0.05mg/l in any of the samples.

Polychlorinated Biphenyls

- PCBs were not included in the chemical suite of analysis for the Round 4.

Volatile Organic Compounds

- VOCs were not included in the chemical suite of analysis for the Round 4.

Metals & Major Ions

A summary of the analytical results is presented in Table 4.6 below. Figures in red denote maximum concentration observed.

Table 4.6: Summary of Round 4 analytical results for metals (Glovers, 2007).

Parameter	No. of Samples	Minimum (µg/l)	Maximum (µg/l)	Screening Criteria	No. Exceeding	Locations Exceeded or Location of Max Conc.
				UK EA EQS (µg/l)		
Arsenic	5	<1	6	25	0	BH118, BH127
Chromium	5	22	35	15	5	BH118, BH125, BH126, BH127, BH128
Chromium VI	5	<30	30	-	-	BH128
Copper	5	<1	2	5	0	BH118, BH128
Lead	5	<1	1	25	0	BH125
Nickel	5	5	6	30	0	BH118, BH125, BH126, BH127
Zinc	5	9	42	40	1	BH128
Cadmium	5	<0.4	0.7	2.5	0	BH118
Selenium	5	<1	23	10	4	BH118, BH125, BH126, BH127
Mercury	5	<0.05	<0.05	0.3	0	

- Nickel was detected above the laboratory detection limit in all five groundwater samples.
- Mercury was not detected above the laboratory detection limit of 0.05µg/l. Therefore, there was no exceedance of the UK Saline EQS.

Groundwater Monitoring Round 5 (Glovers, 2007)

Hydrocarbons

- TPHs were not detected above the laboratory detection limit (10µg/l).
- PAH (acenaphthylene) was detected in BH 127 at a concentration of 0.025µg/l. There was no other detection above the various laboratory detection limits which ranged from 0.009µg/l to 0.027µ/l.

Phenols and Cyanide

- Phenols were not detected above the laboratory detection limit (0.01mg/l).
- Total cyanide and free cyanide were not detected above their respective laboratory detection limit of 0.05mg/l.

Polychlorinated Biphenyls

- PCBs were not included in the chemical suite of analysis for the Round 5.

Volatile Organic Compounds

- VOCs were not included in the chemical suite of analysis for the Round 5.

Metals & Major Ions

A summary of the analytical results are presented in Table 4.7 below. Figures in red denote maximum concentration observed.

Table 4.7: Summary of Round 5 analytical results for metals Glovers, 2007).

Parameter	No. of Samples	Minimum (µg/l)	Maximum (µg/l)	Screening Criteria	No. Exceeding	Locations Exceeded of Location of Max Conc.
				UK EA EQS (µg/l)		
Arsenic	3	19	34	25	1	BH118
Chromium	3	2	12	15	0	BH118
Chromium VI	3	<30	<30	-	-	-
Copper	3	4	5	5	2	BH126, BH127
Lead	3	2	7	25	0	BH126
Nickel	3	8	14	30	0	BH126, BH127
Zinc	3	10	150	40	2	BH126, BH127
Cadmium	3	<0.4	0.5	2.5	0	BH118
Selenium	3	69	120	10	3	BH118, BH126, BH127
Mercury	3	<0.05	<0.05	0.3	0	

- Cadmium was detected above the laboratory detection limit in one of the boreholes BH118 (0.5µg/l).
- Mercury was not detected above the laboratory detection limit of 0.05µg/l. Therefore, there was no exceedance of the UK Saline EQS.

Groundwater Monitoring Round 6 (Glovers, 2007)

Hydrocarbons

- Hydrocarbons were not included in the chemical suite of analysis for Round 6.

Phenols and Cyanide

- Phenols were not detected above the laboratory detection limit (0.01mg/l) in the two boreholes.
- Total cyanide and free cyanide were not detected above their respective laboratory detection limit of 0.05mg/l in either borehole.

Polychlorinated Biphenyls

- PCBs were not included in the chemical suite of analysis for Round 6.

Volatile Organic Compounds

- VOCs were not included in the chemical suite of analysis for the Round 6.

Metals & Major Ions

A summary of the analytical results is presented in Table 4.8 below. Figures in red denote maximum concentration observed.

Table 4.8: Summary of Round 6 analytical results for metals (Glovers, 2007).

Parameter	No. of Samples	Minimum (µg/l)	Maximum (µg/l)	Screening Criteria UK EA EQS (µg/l)	No. Exceeding	Locations Exceeded or Location of Max Conc.
Arsenic	2	43	51	25	2	BH118, BH126
Chromium	2	23	28	15	2	BH118, BH126
Chromium VI	2	<30	<30	-	-	-
Copper	2	4	5	5	1	BH118
Lead	2	3	4	25	0	BH118
Nickel	2	5	7	30	0	BH118
Zinc	2	9	9	40	2	BH118, BH126
Cadmium	2	1.5	1.8	2.5	0	BH118
Selenium	2	120	150	10	3	BH118
Mercury	2	<0.05	<0.05	0.3	0	

- Mercury was not detected above the laboratory detection limit of 0.05µg/l. Therefore, there was no exceedance of the UK Saline EQS.

Groundwater Monitoring Round 7 (WYG, 2008)

In July 2008, perched groundwater sampling was carried out by WYG from seven existing monitoring wells on the East Tip (BH116, BH117, BH120, BH125, BH126, BH128 and BH130). The sample locations are illustrated in Figure 4.2 while the analytical results for the seven monitoring wells installed in the waste and overburden sediments are presented in Appendix I. As the perched groundwater is not of potable standard and demonstrates hydraulic continuity with the surrounding marine water reference to the surface water quality screening criteria in the analysis of the results was deemed appropriate (WYG, 2008). The relative screening criteria applied are as follows:

- The UK Environmental Agency (EA) Coastal and Estuarine Environmental Quality Standards (EQS).
- The UK EA derived the Environmental Quality Standards (EQS) to enforce the Dangerous Substances Directive. Pollution by dangerous substances is defined as an exceedance of EQSs in water.
- The EPA derived EQS for assessing surface water quality in Ireland, referred to as the EQS. The AA-EQS and MAC-EQS are given as guideline screening criteria for 'other waters' i.e. transitional (brackish) and coastal waters in a consultation paper entitled "The Water Framework Directive (2000/60/EC) and the Dangerous Substances Directive (2006/11/EC): Environmental Objectives (Surface Waters) Regulations 2008" issued on 5th September 2008 by DoEHLG.

Samples were analysed for a broad suite of chemical parameters to assess the quality of the perched groundwater within the waste and overburden materials. The monitoring was carried out in order to determine potential impacts on the surrounding marine water and underlying groundwater in the bedrock aquifer. The analytical results are presented in Appendix I.

Hydrocarbons

- In six of the seven groundwater monitoring wells TPH was not detected (Note: laboratory detection limit was 0.01mg/l). The concentration of TPH total (Aliphatics and Aromatics C5 – C35) was 0.16mg/l in BH116, which is located to the north of the football pitch.
- PAHs were not detected above the laboratory detection limit of 0.01µg/l in six of the seven groundwater monitoring wells. Eight PAH compounds with a combined concentration of 0.383 µg/l were detected in BH116. The individual compound concentrations ranged from 10ng/l (Acenaphthylene, Anthracene, Pyrene) to 226ng/l (Naphthalene).

Phenols and Cyanide

- In BH120, phenol was detected above the laboratory detection limit (0.01mg/l) at a concentration of 0.04mg/l.
- Phenol was not detected in the other monitoring wells.
- Cyanide compounds were not detected in the groundwater monitoring wells. The limit of detections for total cyanide, free cyanide, complex cyanide and thiocyanate are 0.05mg/l, 0.01mg/l, 0.05mg/l and 0.01mg/l respectively.

Polychlorinated Biphenyls

- PCBs were not detected above the laboratory detection limit of 0.01µg/l in six of the seven groundwater monitoring wells. PCB (Congener 28) was detected in BH130 at a concentration of 0.011µg/l.

pH

- The pH of four of the seven groundwater samples were above the UK saline EQS of 8.5: BH117 (8.98), BH125 (9.11), BH128 (9.41) and BH130 (9.40).
- The pH of samples from BH120 and BH126 were within EQS limits.

Volatile Organic Compounds

- Five groundwater monitoring wells were analysed for VOCs.
- There was no detection of VOCs above the laboratory detection limits. The limits of detection range from 0.4µg/l to 10µg/l. For some compounds the limit of detection is above the comparison standard, in particular for the following compounds, 1.2.4-trichlorobenzene, naphthalene, 1.2.3-trichlorobenzene and hexachlorobutadiene.

Metals & Major Ions

A summary of the results is provided in Table 4.9 below. Figures in red denote maximum concentration observed.

Table 4.9: Summary of Analytical Results for Perched Groundwater Metal (WYG, 2008)

Parameter	No. of Samples	Minimum (µg/l)	Maximum (µg/l)	Screening Criteria			No. Exceeding Screening Criteria	Locations Exceeded or Max
				UK EA EQS (µg/l)	AA EQS (µg/l)	MAC EQS (µg/l)		
Arsenic	7	19	120	25	20	-	4	BH116, BH130, BH125 BH128
Chromium	7	9	9	15	-	-	0	BH116, BH120
Chromium VI	7	<30	<30	-	0.6	32	-	-
Copper	7	3	10	5	5	1	1	BH120
Lead	7	5	10	25	7.2	-	1	BH120
Nickel	7	17	60	30	20	-	2	BH125 BH130
Zinc	7	<50	119	40	40	-	2	BH116 BH120
Cadmium	7	<0.4	<50	2.5	0.2	1	-	-
Selenium	7	<50	148	-	-	-	-	BH116
Mercury	7	<0.05	0.05	0.3	0.05	0.07	0	BH116

- Where arsenic, copper, nickel, zinc, chromium and lead were undetected it must be considered that the laboratory detection limit (50µg/l) exceeded the UK EA EQS.
- In five water samples the laboratory detection limit for cadmium was 50µg/l which exceeds the screening criteria.
- There was no detection of chromium VI above the laboratory detection limit of 30µg/l. However, the limit of detection is greater than the screening value.
- Aluminium is present at concentrations ranging from 163µg/l (BH116) to 1460µg/l (BH126).
- Boron, mercury and nitrate were all below their respective EQSs.
- Selenium was detected above the laboratory detection limit (50µg/l) in two wells, BH116 (148µg/l) and BH120 (101µg/l).
- Five of the seven perched groundwater samples had concentrations of Ammonical Nitrogen less than 1mg/l. A concentration of 1.3mg/l was detected in BH116 and a concentration of 21mg/l was detected in BH120.

4.2.3. Bedrock Aquifer Monitoring (2005 to 2008)

The groundwater in the limestone aquifer (BH122) was sampled and analysed at each groundwater monitoring round (Table 4.2). Sampling was undertaken by WYG in 2005 and 2008 while Glovers Site Investigation undertook the sampling regime in 2006 and 2007. The certificates of analysis, where supplied by WYG, are provided in Appendix J. The complete set of results is provided in Appendix I. As with the previous analysis, results were compared against the UK EA Coastal and Estuarine Environmental Quality Standards (EQS).

Hydrocarbons

- Hydrocarbons were included in the suite of analysis for Round 1,2,3,5 and 2008 only.
- There was no detection of speciated TPH or PAH in the bedrock groundwater monitoring well.

Phenols and Cyanides

- No phenols or cyanides were detected in the samples in any of the monitoring rounds.

Polychlorinated Biphenyls

- PCBs were included in the suite of analysis for Round 2 and 2008 only.
- PCBs were not detected above the laboratory detection limit of 0.01µg/l (2008) and 26µg/l.

Metals and Major Ions

A summary of the analytical results are presented in Table 4.10 below.

Table 4.10: Summary of analytical results for metals in BH122 (Limestone Aquifer). Note: Results that equal/exceed the UK EA EQS are shaded.)

Round	Units	UK EA EQS	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	2008	Sample 1**	Sample 2**
Date			05/10/05	19/10/05	06/12/06	08/02/07	05/04/07	27/06/07	07/07/08		
Aluminium	µg/l		-	-	-	-	-	-	87	31.3	70.6
Arsenic	µg/l	25	41	56	20	6	18	52	36	0.4	0.3
Boron	µg/l	7000	2004	2717	1621	3200	1500	3300	4014	50	40
Cadmium	µg/l	2.5	3.5	15.8	1.2	0.7	<0.4	1.9	6.2	0.2	0.1
Chromium	µg/l	15	11	48	3	19	2	28	15	1.4	1.6
Chromium VI*	µg/l	15	<30	<30	<30	<30	70	<30	<30	-	-
Copper	µg/l	5	8	3	3	19	5	7	4	<0.003	<0.003
Iron	µg/l	1000	-	-	-	-	-	-	116	<50	<50
Lead	µg/l	25	2	4	2	2	6	4	1	0.3	1
Magnesium	µg/l		-	-	-	-	-	-	1253000	15100	18500
Manganese	µg/l		-	-	-	-	-	-	25	<10	<10
Mercury	µg/l	0.3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02
Nickel	µg/l	30	23	41	13	6	13	4	13	0.7	1.3
Selenium	µg/l	10	125	150	69	18	67	140	210	1.2	0.6
Zinc	µg/l	40	27	324	<3	28	110	11	39	-	-
Chloride	mg/l	30	16378	15145	-	-	-	17000	18493	68	58.8
Sulphate	mg/l	200	1997	1879	1267	2400	1100	2300	2561	36.8	29.9
Sulphide	mg/l		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.01	-	-
Potassium	mg/l		-	-	-	-	-	-	389.7	8.6	17.8
Sodium	mg/l		-	-	-	-	-	-	6383	31.6	27.3
Phenols	mg/l		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
Total Cyanide	mg/l		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Free Cyanide	mg/l		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.01	-	-

*Where Chromium VI is not detected the limit of detection is greater than the UK EA EQS

** Groundwater sample taken from similar bedrock aquifer not influenced by saline waters.

4.3. Surface Water Monitoring

Surface water sampling from the East Tip was undertaken as part of both the 1995 site investigations and the 2008 environmental assessment. Only one surface water sample was obtained in 1995 and this was from a seepage point along the foreshore. In 2008 surface water samples were taken from the contractor excavation and trial pits (Section 2.2.5) in addition to 3 no. seepage points along the foreshore.

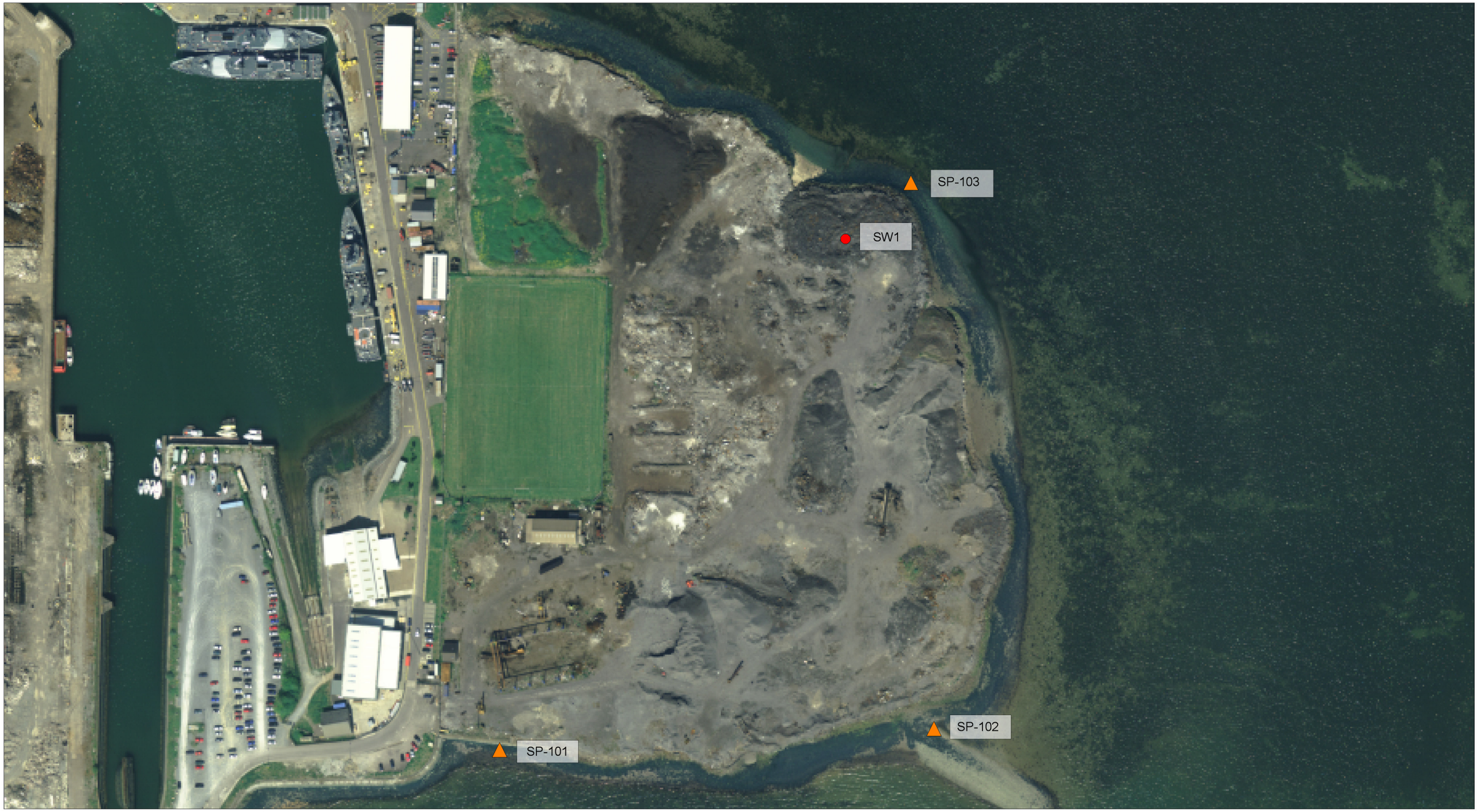
4.3.1. Surface Water Monitoring (1995)

Chemical analysis was carried out on one surface water sample (SW-1) which was obtained from a seep visible on the foreshore as the tide was going out The sample was sent for analysis for a suite of inorganic parameters, TPH and phenol. The location of surface water sample SW-1 is shown in Figure 4.3. The analytical results were compared with available environmental quality criteria for water to determine the degree of impact and potential risks and they were also compared to the Dutch Intervention levels. The results of the analysis of the surface water are presented in Appendix I.

- Copper (LoD:<0.05mg/l), arsenic (LoD:<0.2mg/l), mercury (LoD:<0.2mg/l), chromium (LoD:<0.05mg/l), zinc (LoD:<0.05mg/l), cadmium (LoD:<0.02mg/l), lead (LoD:<0.2mg/l), nickel (LoD:<0.05mg/l) and selenium (LoD:<0.2mg/l) were not detected above the laboratory detection limits.
- However, the laboratory detection limits for arsenic, mercury, chromium, and cadmium are above the Dutch Intervention Values of 0.06mg/l, 0.0003mg/l, 0.03mg/l and 0.006mg/l respectively..
- TPHs and Phenols were not analysed.
- It was noted that the laboratory reported that the trace elements were very difficult to detect due to highly dominant concentration of ions.

4.3.2. Surface Water Sampling from Excavation and Trial Pits (2008)

Three water samples (WS-1 to WS-3) were taken from the surface water on the East Tip at locations shown in Figure 4.4. Samples WS-1 and WS-2 were taken from the main contractor excavation and WS-3 was taken from an area of the site that is normally dry and above the water level in the main excavation. Four of the fifteen contractor trial pits on the East Tip were also sampled (TP101, TP102, TP103 and TP104). Figure 4.4 presents the location of these trial pits. The water in the trial pits was similar to the excavation in that it contained both groundwater and surface water from the seawater that encroached onto the East Tip together with any collected rainfall. Water samples were obtained by taking a grab sample directly from the trial pit. The surface water samples were analysed for a broad suite of chemical parameters and the results are presented in Appendix I. Results were compared against the UK EA coastal and estuarine Environmental Quality Standards (EQS) and the annual average and maximum allowable concentration Environmental Quality Standards sourced from the Draft European Communities Environmental Objectives (Surface Water) Regulations 2008. These regulations have since came into effect on 30 July 2009 (European Communities Environmental Objectives (Surface Water) Regulations 2009. The analytical results were compared to the draft regulations 2008.



Title: **Figure 4.3 Surface Water Sampling Locations 1995 & Foreshore Seepage Water Sampling Locations 2008**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 13/12/2011

Legend:

- Foreshore Seepage Sample
- Surface Water Sample

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Co. Cork

Phone: 021 - 4532700
Fax no. 021 - 4532777

Scale; **1:2000 @ A3**

Title: Figure 4.4:
Surface Water Sampling Locations
From Contractor Excavations
And Trial Pits (2008)

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 07/11/2011

Legend:

Surface Water Samples From Excavations and Trial Pits (2008)

- Surface Water Sample From Excavations
- Surface Water Sample From Trial Pits

Cork County Council
Environmental Directorate
Inniscarra,
Co. Cork

Phone: 021 - 4532700
Fax no. 021 - 4532777

Scale; **1:2000 @ A3**

Hydrocarbons

- TPHs were not detected above the laboratory method detection limit of 0.01mg/l.
- PAHs were not detected above the laboratory detection limit of 0.01µg/l.

Phenols and Cyanide

- Phenol was not detected above the laboratory detection limit (0.01mg/l).
- Cyanide compounds were not detected above the laboratory detection limits in any of the samples. The limit of detection for total cyanide, free cyanide, complex cyanide and thiocyanate is 0.05mg/l, 0.01mg/l, 0.05mg/l and 0.2mg/l respectively.

Polychlorinated Biphenyls

- The analysis of one water sample from TP102 located within the southern region of the main excavation contained three of the seven PCB congeners ranging from 0.012µg/l to 0.128µg/l.
- PCBs were not detected in the remaining six excavation water samples.

pH

- The pH of three of the seven samples was above the UK Saline EQS of 8.5: TP101 (8.72), TP103 (9.29) and TP104 (8.85).

Volatile Organic Compounds

- Samples WS1, WS2, WS3, TP101 and TP104 were analysed for volatile organic compounds.
- VOCs were not detected in WS-1, WS-2, WS-3, TP101 and TP104. (LOD range:<1µg/l to 4µg/l). For a number of compounds in each surface water sample, the limit of detection exceeded the AA-EQS and in some cases the MAC-EQS.
- TP102 and TP103 were not analysed for volatile organic compounds.

Metals and Major Ions

A summary of the analytical results are provided in Table 4.11 below.

- Cadmium concentrations from three of the seven water samples exceeded the draft Irish AA EQS of 0.2µg/l in WS1 (1µg/l), WS2 (1µg/l) and WS3 (0.5µg/l). These concentrations were below the UK EA EQS of 2.3µg/l. Cadmium was not detected in the trial pit samples, however, the laboratory detection limit is greater than the screening criteria.
- Mercury concentrations from WS1 (0.05µg/l) equalled the AA EQS of 0.05µg/l but was below the MAC EQS of 0.07µg/l and the UK EA EQS of 0.3µg/l.
- Nitrate concentrations from TP103 (60.9mg/l) exceeded the UK EA EQS of 15mg/l.
- There were no exceedances of the UK EQS or AA EQS for lead in the excavation water samples. However, the laboratory detection limit for the trial pit samples is greater than the screening criteria.

It should be noted that some of the laboratory detection limits are higher than the reported EQSs. WYG noted that low level metal analysis was not achieved by the laboratory on some samples due to the saline nature of those samples.

Table 4.11: Summary of results of surface water analysis (WYG, 2008).

Parameter	Number of Samples	Min Level (µg/l)	Max Level (µg/l)	Screening Values			Number of Exceedances of Screening Criteria	Location
				UK EA EQS (µg/l)	AA-EQS (µg/l)	MAC-EQS (µg/l)		
Arsenic	7	47	70	25	20	-	5	WS-1, WS-2, WS-3. TP101, TP104
Cadmium	7	0.5	1	2.5	0.2	-	3	WS-1, WS-2, WS-3
Chromium*	7	18	150	15	-	-	5	WS-1, WS-2, WS-3, TP102, TP103
Chromium VI*	7	<30	170	-	0.6	32	4	WS-2, TP101, TP102, TP103
Copper*	7	6	16	5	5	-	3	WS-1, WS-2, WS-3
Mercury	7	<0.05	0.05	0.3	0.05	0.07	1	WS-1
Nickel	7	5	60	30	20	-	2	TP101, TP104
Nitrate as NO_3	7	<0.3	60.9	15	-	-	1	TP103
Zinc	7	32	40	40	40	-	1	WS-1
Lead*	7	<1	<50	25	7.2	-	-	

*Where parameter was not detected the laboratory detection limit is greater than the screening value.

Figures in red denote maximum concentration observed.

4.3.3. Foreshore Seepage Water Sampling (2008)

Seepage water sampling was carried out by WYG at three seepage points SP101, SP102 and SP103 (Figure 4.3). The water samples were collected directly from the seepage points. Samples were analysed for a broad range of chemical parameters. Results were compared against the UK EA coastal and estuarine Environmental Quality Standards (EQS) and the annual average and maximum allowable concentration Environmental Quality Standards sourced from the Draft European Communities Environmental Objectives (Surface Water) Regulations 2008 (WYG A, 2008). The analytical results are presented in Appendix I.

Hydrocarbons

- Speciated TPHs or PAHs were not detected in the seepage water samples. The respective limits of detection are 10µg/l and 10ng/l.

Phenols and Cyanide

- Phenols were not detected above the laboratory detection limit (0.01mg/l) in seepage water samples.
- Cyanide compounds were not detected above the laboratory detection limits in the seepage water samples. The limit of detection for total cyanide, free cyanide complex cyanide and thiocyanate is 0.05mg/l, 0.01mg/l, 0.05mg/l and 0.2mg/l respectively.
- The limit of detection (0.05mg/l) for total cyanide is greater than the AA-EQS of 0.01mg/l.

Polychlorinated Biphenyls

- PCBs were not detected above the laboratory detection limit of 0.01µg/l.

pH

- The pH readings for the three samples were within the Saline EQS standard of 6 to 8.5

Metals and Major Ions

A summary of the analytical results are presented in Table 4.12 below.

- Aluminium is present at concentrations ranging from 750µg/l to 910µg/l.
- Boron, cadmium, lead, copper, mercury, zinc, and nitrate were not detected above the laboratory detection limits. However, some of the laboratory detection limits are higher than the reported EQSs (Table 4.12).
- WYG concluded that chloride, sodium, sulphate, magnesium, calcium, potassium and boron were detected at concentrations indicative of brackish seawater influence on the site.

WYG reported that low level metal analysis was not achieved by the laboratory on some samples due to the saline nature of those samples. It was thus concluded that in circumstances where concentrations were reported as below the limit of detection, while it was not possible to prove that the screening values were not exceeded, it did indicate an absence of gross contamination by a particular compound or element.

Table 4.12: Summary of results of metal analysis for seepage water (WYG, 2008).

Parameter	Number of Samples	Min Level (µg/l)	Max Level (µg/l)	Screening Values			Number of Exceedances of Screening Criteria	Location
				UK EA EQS (µg/l)	AA-EQS (µg/l)	MAC-QS (µg/l)		
Arsenic	3	110	150	25	20	-	3	SP101, SP102, SP103
Cadmium*	3	<50	<50	2.5	0.2	-	-	
Chromium*	3	<50	<50	15	-	-	-	
Chromium VI*	3	<30	<30	-	0.6	32	-	
Copper*	3	<50	<50	5	5	-	-	
Lead*	3	<50	<50	25	7.2			
Nickel	3	50	70	30	20	-	3	SP101, SP102, SP103
Zinc*	3	<50	<50	40	40	-		

Figures in red denote the maximum concentration observed.

*Where parameter was not detected the laboratory detection limit is greater than the screening value.

4.4. Marine Water Sampling

As part of the site investigations in 1995, 2005 and 2008, sampling and analysis of the surrounding marine waters was undertaken. The marine water sampling locations are illustrated in Figure 4.5 and the results of the analysis are presented in Appendix I.

4.4.1. Marine Water Analysis (KTC, 1995)

A single sample of marine water sample SW-2 was sent for analysis by KTC in 1995. The sample was analysed for a suite of inorganic parameters, TPH and phenol and the results compared with available environmental quality criteria for water to determine the degree of impact and potential risks. The results were also compared to the Dutch Intervention levels.

- Copper (LoD:<0.05mg/l), arsenic (LoD:<0.2mg/l), mercury (LoD:<0.2mg/l), chromium (LoD:<0.05mg\l), zinc (LoD:<0.05mg/l), cadmium (LoD:<0.02mg/l), lead (LoD:<0.2mg\l), nickel (LoD:<0.05mg/l) and selenium (LoD:<0.2mg/l) were not detected above the laboratory detection limits.
- However, the laboratory detection limits for arsenic, mercury, chromium, and cadmium are above the Dutch Intervention Values of 0.06mg/l, 0.0003mg/l, 0.03mg/l and 0.006mg/l respectively
- TPHs and Phenols were not analysed.
- KTC noted that the laboratory reported that the trace elements were very difficult to detect due to highly dominant concentration of ions.

4.4.2. Marine Water Analysis (WYG, 2005)

Five marine water samples (SW101 – SW105) were taken from around the East Tip in 2005 by WYG (Figure 4.5). Sample SW-105 was taken at the shore at Ringaskiddy at an area called Paddy's Point as a background sample for comparison. All samples were analysed for a broad suite of chemical parameters and the results are contained in Appendix I. The comparative screening criteria used for the estuary water was the UK Saline Environmental Quality Standards (EQS)

Hydrocarbons

- There was no detection of speciated TPHs in the marine water (LoD: <10µg/l).
- Total PAH concentrations were noted in two samples (SW102, 215ng/l and SW104, 2,621ng/l). The speciated PAH analysis indicates that these are both related to elevated naphthalene.

Polychlorinated Biphenyls

- PCBs were not detected in the marine waters (LOD 26µg/l).

pH and Electrical Conductivity

- pH measurements for all samples were within the UK EQS of between 6.0 and 8.5.
- The electrical conductivity ranges from 40.5mS/cm to 48.2mS/cm.

Volatile Organic Compounds

- VOCs were not detected in the marine waters (LOD 1µg/l).

Metal and Major Ions

A summary of the analytical results are provided in Table 4.13 below.

Title:	**Figure 4.5: Marine Water Sampling Locations (1995, 2005 & 2008)**	Legend:		**Cork County Council** **Environmental Directorate** **Inniscarra,** **Co. Cork**	*Includes Ordnance Survey Ireland data reproduced under OSI Licence number Cork County Council 2010/2006/ CCMA/ Cork County Council*
Project:	**Haulbowline Project**	Marine Water Sampling ● 2008 (6) ● 2005 (5) ● 1995 (1)		**Phone: 021 - 4532700** **Fax no. 021 - 4532777**	*Unauthorised reproduction infringes Ordnance Survey Ireland and Government of Ireland copyright. © Ordnance Survey Ireland, 2011*
Drawn by:	HaulbowlineTeam				
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Table 4.13: Summary of results of metal analysis for marine waters (WYG, 2005)

Parameter	Number of Samples	Min Level (µg/l)	Max Level(µg/l)	UK EA EQS (µg/l)	Number of Exceedances of Screening Criteria	Location of max conc.
Arsenic	5	<1	2.63	25	0	SW105
Cadmium	5	<0.04	0.073	2.5	0	SW105
Chromium	5	0.419	3.56	15	0	SW101
Chromium VI	5	<30	<30	-	0	
Copper	5	0.314	2.37	5	0	SW105
Lead	5	0.382	12.8	25	0	SW105
Mercury	5	<0.008	0.031	0.3	0	SW105
Nickel	5	0.25	0.847	30	0	SW105
Zinc	5	4.76	13.5	40	0	SW105
Selenium	5	<1	<1			

Figures in red denote maximum concentration.

4.4.3. Marine Water Monitoring (WYG, 2008)

Six estuary surface water samples were obtained from Cork Harbour by WYG in 2008. Four were obtained from around Haulbowline Island, including SW02, SW03 and SW04 which were collected from around the East Tip. SW01 was sampled to the south west of the Island. A further two samples, SW05 and SW06, were obtained at off site control locations towards the entrance of the harbour. The locations of the marine water sampling points are presented in Figure 4.5. The comparative screening criteria used was the UK Saline Environmental Quality Standards (EQS) and the Draft European Communities Environmental Objectives (Surface Water) Regulations 2008, AA-EQS and MAC-EQS. All samples were analysed for a broad suite of chemical parameters and the analytical results are contained in Appendix I.

Hydrocarbons

- There was no detection of speciated TPHs in the estuary water (LoD: 10µg/l).
- There was no detection of speciated PAHs in the estuary water (LoD: 10ng/l).

Polychlorinated Biphenyls

- PCBs were not detected (LoD: 0.01µg/l).

pH and Electrical Conductivity

- pH readings of all samples were within the UK EQS of between 6.0 and 8.5.
- The electrical conductivity ranges from 48.39mS/cm to 51.3mS/cm which WYG concludes is typical of saline waters.

Metal and Major Ions

The analytical results are provided in Table 4.14 below.

- Total chromium, chromium VI, copper, lead, zinc, were not detected above the laboratory detection limits in any of the samples. However, the laboratory detection limits are greater than the screening criteria as shown in Table 4.14.
- Mercury concentrations in the four samples taken in the vicinity of Haulbowline Island were at concentrations below the laboratory detection limit. The mercury concentrations at the two control sites were equal to the AA-EQS of 0.05µg/l, but less than the MAC-EQS.

Table 4.14: Summary of Marine Water Analytical Results (WYG,2008)

Parameter	Number of Samples	Min Level (µg/l)	Max Level (µg/l)	Screening Values			Number of Exceedances of Screening Criteria	Location
				UK EA EQS (µg/l)	AA-EQS (µg/l)	MAC-QS (µg/l)		
Arsenic	6	90	160	25	20	-	6	SW01, SW02, SW03, SW04, SW05, SW06
Chromium*	6	<50	<50	15	-	-		
Chromium VI*	6	<30	<30	-	0.6	32		
Copper*	6	<50	<50	5	5	-	-	
Lead*	6	<50	<50	25	7.2			
Mercury	6	<0.05	0.05	0.3	0.05	0.07	2	SW05, SW06
Nickel*	6	<50	70	30	20	-	5	SW02, SW03, SW04, SW05, SW06
Zinc*	6	<50	<50	40	40	-		

Figures in red denote maximum concentration observed

*Where parameter was not detected the laboratory detection limit is greater than the screening value.

As part of the Water Framework Directive (WFD), the Dangerous Substances Screening Programme has been conducted by the *National Dangerous Substances Expert Group* (NDSEG 2008). This sampling programme involved monthly water sampling from a number of rivers and estuaries across Ireland between May 2005 and October 2006. The WFD monitoring did not detect elevated concentrations of arsenic, copper, nickel, zinc and mercury in Cork Harbour throughout the monitoring period. Similarly, other WFD sampling locations recorded significantly lower concentrations of heavy metal parameters than those detected in the present Haulbowline Island study. Table 4.15 is a typical snapshot of the WFD data from April 2006 (WYG A, 2008).

Table 4.15: WFD Data April 2006

	River Shannon Limerick	**Cork Harbour**	**Dublin Bay**
Arsenic µg/	<1.2	<5.2	<0.36
Copper µg/	25	<15	<6
Nickel µg/	<2.3	<17	<3.3
Zinc µg/	<0.22	<1	1.3

5.0. Result of Chemical Analysis of the Waste Body and Alluvium

During the sampling rounds which took place on the East Tip in 1995, 1998, 2005 and 2008 a number of waste samples were sent for chemical analysis. Chemical analysis of the underlying sediment was also carried out in 1995 and 2005. The various site investigation programmes are listed below and the analysis undertaken summarised in Table 5.1

- K. T. Cullen & Co Ltd undertook site investigations in 1995 to determine if the fill materials were having an adverse environmental impact on sediment and water quality around the East Tip.
- K. T. Cullen & Co Ltd undertook further investigations in 1998 to establish:
  (i) the volatile organic compound and polychlorinated biphenyl levels in the waste. soils;
  (ii) the leachate quantities emanating from the East Tip, and;
  (iii) the permeability of the waste material.
- In 2005, WYG and Glovers undertook an extensive subsurface ground investigation to assess the geotechnical and environmental subsoil conditions on the East Tip.
- WYG completed a further environmental assessment of the process waste on the East Tip with the objective of determining whether chemical compounds identified within the waste posed potentially unacceptable risks to human health or environmental receptors in the Cork Harbour.
- RPS was commissioned by the Irish Defence Forces to carry out a shallow soil and air quality assessment of the Naval base site, at Haulbowline Island, Ringaskiddy, Co. Cork. The assessment was undertaken to ensure that Naval operatives and Naval base site visitors were not exposed to health and safety risks posed by site excavation and disposal activities being carried out on the adjacent East Tip site on the island.

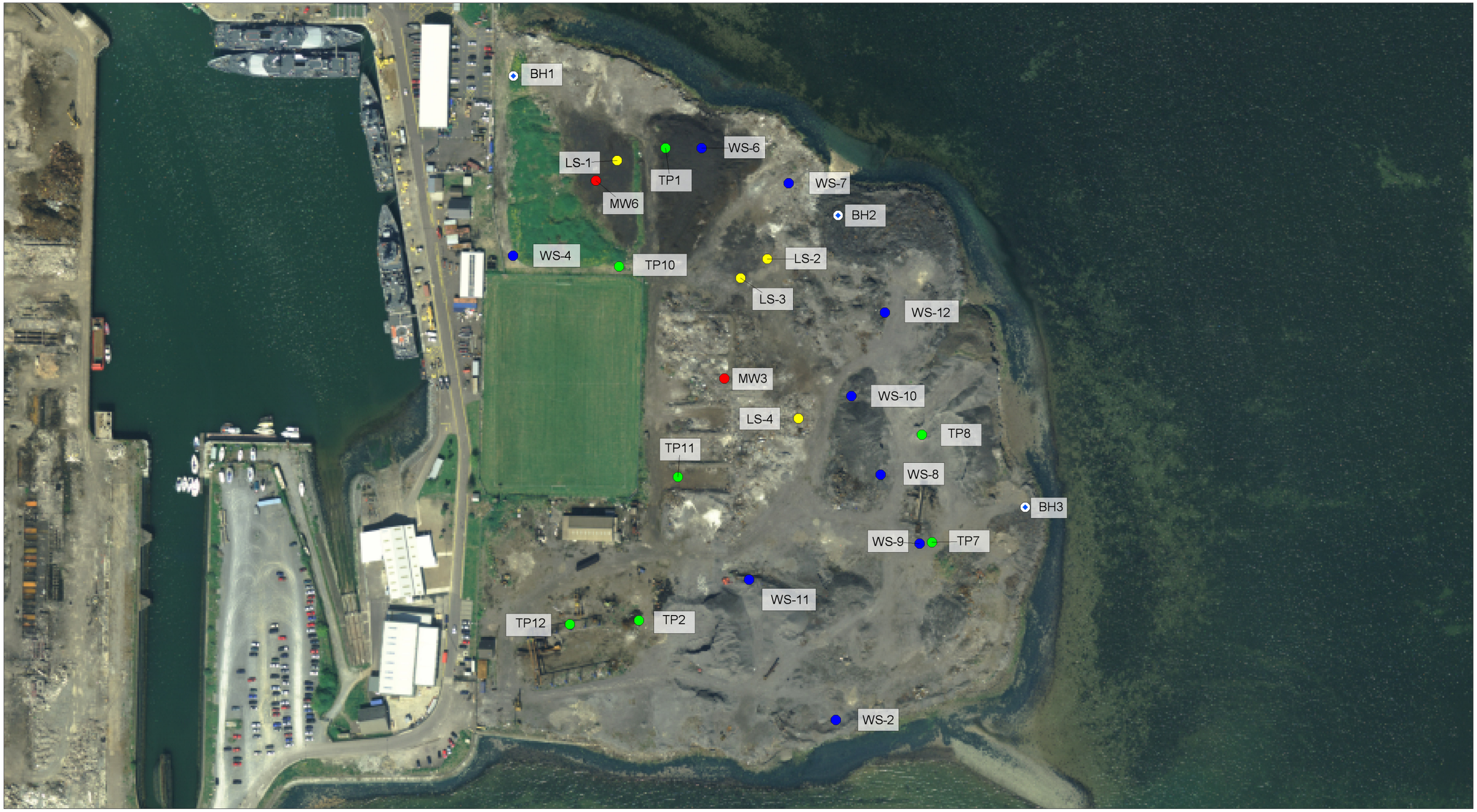
Table 5.1: Summary of waste analysis

Chemical Analysis	KTC, 1995	KTC, 1998	WYG A, 2008	WYG B, 2005	RPS, 2008
Metals	√		√	√	√
Phenols			√	√	
Hydrocarbons	√		√	√	√
PAHs			√	√	√
VOCs		√	√	√	
PCBs		√	√	√	√
Dioxins & Furans			√	√	
Asbestos			√	√	√
Leachability Analysis		√	√	√	

5.1. Results of Waste Analysis

5.1.1. 1995 Site Investigations (KTC)

During the 1995 site investigation 6 no. boreholes (MW1 – MW6) were drilled and 12 no. trial pits (TP1 – TP12) were excavated. Borehole logs are provided in Appendix D. Eight waste samples taken from 7 no. of the trial pits and 2 no. grab samples were submitted for chemical analysis (Table 5.2). Previously in May 1995, waste samples were taken and sent for analysis from 3 no. additional boreholes (BH1 – BH3), which had been drilled (May 1995) by Site Investigations Ltd (Table 5.2). Sample locations are presented in Figure 5.1.



Title: **Figure 5.1: Waste & Leachate Sample Locations (1995, 1998)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 07/11/2011

Legend:

- 1998 Leachate Sample Location (4)
- 1995 Waste Sample Location (7)
- 1998 Waste Sample Location (9)
- 1995 Boreholes (3)
- 1995 Vicinity of Grab Samples (2)

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The results of the analyses were compared against the Dutch Intervention levels or the Canadian and British soil quality criteria, where applicable. The results of the analysis are contained in Appendix K.

Table 5.2: Waste sample analysis inventory for 1995

Sample	Waste Type	Location	Chemical Analysis
TP1A	Made ground	TP1	Heavy Metals
TP2A	Made Ground	TP2	Heavy metals
TP7A	Made ground	TP7	Heavy metals
TP8A	Made ground	TP8	Heavy metals
TP10A	Made ground	TP10	TPH, Heavy metals
TP10B	Made ground	TP10	TPH, Heavy metals
TP11B	Made ground	TP11	Heavy metals
TP12B	Made ground	TP12	TPH, Heavy metals
Sludge	Sludge	Sludge pit near MW-3	TPH, Heavy metals
Dust	Dust	Flume dust stored north of football pitch near MW-6	TPH, Heavy metals
	Slag	BH1	Fe, Zn, Cd, Pb,Hg, Cr
	Slag	BH2	Fe, Zn, Cd, Pb,Hg, Cr
	Slag	BH3	Fe, Zn, Cd, Pb,Hg, Cr

Hydrocarbons

- TPHs were detected in all samples analysed. The concentration of TPH in samples taken from the trial pits ranges from 170mg/kg (TP12B) to 1530mg/kg (TP10A). The sludge and dust samples contained 6.6% and 1.2% respectively.

Metals and Major Ions

- Chromium was detected above the Dutch Intervention Value of 380mg/kg in the eight waste samples taken from the trial pits and the slag samples taken from BH1 and BH2. The concentrations measured ranged from 570mg/kg (TP12B) to 2600mg/kg in (TP2A & TP8A).
- Zinc was detected above the Dutch Intervention Value of 720mg/kg in the eight waste samples taken from the trial pits and the slag sample taken from BH2. The concentrations measured ranged from 1100mg/kg (TP12B) to 12500mg/kg (BH2).
- Cadmium was detected above the Dutch Intervention Value of 12 mg/kg in TP10B (26.8mg/kg).
- Lead was detected above the Dutch Intervention Value of 530mg/kg in three waste samples taken from the trial pits and in the slag samples taken from BH1 and BH2. The concentrations ranged from 550mg/kg (TP12B) to 4380mg/kg (BH2).
- Arsenic, nickel, molybdenum were detected above the laboratory detection limits in all trial pit samples. However, there were no exceedances of the Dutch Intervention Values.
- Copper concentrations exceeded the Dutch Intervention Value of 190mg/kg in all samples taken from the Trial Pits. The concentrations measured ranged from 190mg/kg (TP12B) to 770mg/kg (TP10A).
- The results of the analysis of the sludge showed exceedances of Dutch Intervention Values for copper (2600mg/kg), zinc (2600mg/kg), nickel (790mg/kg), and molybdenum (210mg/kg).
- The results of the analysis of the dust showed exceedances of the Dutch Intervention Values for copper (2200mg/kg) and nickel (520mg/kg).

5.1.2. 1998 Site Investigations (KTC)

During these investigations 12 no. boreholes (WS-1 – WS-12) were drilled and waste samples were collected from 9 no. boreholes (WS-2, WS-4, WS-6 to WS12). Each waste sample was analysed for Volatile Organic Compounds and Polychlorinated Bi-Phenyls. 4 no. leachate samples, (LS-1 to LS-4) were also collected (Section 5.3). Borehole logs and trial pit records are provided in Appendix D while sample locations are presented in Figure 5.1. Results were compared against the Dutch MAC (Maximum Admissible Concentrations) levels, where applicable. The full set of results are provided in Appendix K.

Polychlorinated Biphenyls

- All waste samples were analysed for a suite of seven PCB's.
- All results were below the laboratory detection limit of 1µg/kg, except for WS-11 where 7796 µg/kg was detected for the total seven PCB's.
- This value exceeds the Dutch intervention value of 1000 µg/kg.

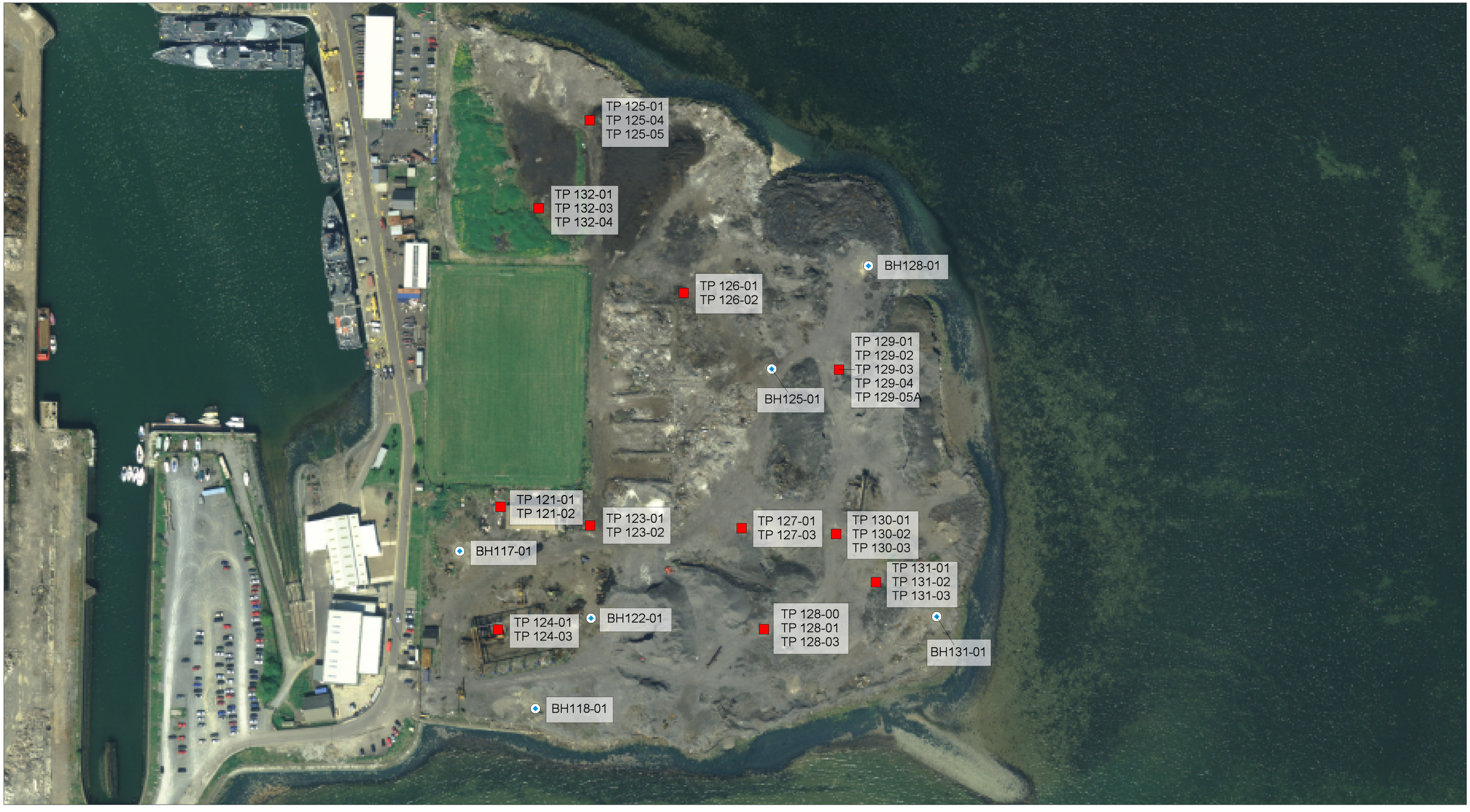
Volatile Organic Compounds

- Waste samples were analysed for a total of 45 volatile organic compounds. All results were below their respective laboratory detection limits except for WS-10, where Dichlormethane was detected at a concentration of 11µg/l.
- However, VOC's not contained in this suite were detected. Total other volatiles were detected in each waste sample and concentrations ranged from 12µg/l (WS-2 & WS-12) to 68µg/l (WS-11). Acetone was detected in WS-7, WS-10 and WS-11 at concentrations of 11, 34 and 268 µg/kg respectively.

5.1.3. 2005 Site Investigations (WYG)

During the 2005 site investigation 16 no. boreholes (BH116 – BH131) were drilled and 11 no. trial pits (TP121, TP123-TP132) were excavated within the East Tip. Borehole logs and trial pit records are provided in Appendix D. A total of 37 no. waste samples were selected for chemical analysis and 16 no. samples were submitted for NRA leachability analysis (Section 5.2.1). An inventory of the waste samples and the analysis completed is presented in Table 5.3 below while sample locations are presented in Figure 5.2.

In order to facilitate the assessment of the results in the context of potential human health risks WYG derived Threshold Screening Values (hereafter referred to as TSV_{2005}) in accordance with the UK framework as set out in the most recent CLR (Contaminated Land Report) documents (CLR7-10, EA/DDEFRA, 2002). In the absence of UK data, for the purposes of this initial screening assessment, reference has been made to European and US guidance in generating TSV_{2005}. As no Irish or UK guidance was available for the assessment of PCBs the screening value is derived from Dutch Human Health SRCs. The Dutch guidance provides SRCs for 7 PCBs; the lowest target value, 170µg/kg, was used as a conservative guide for assessment of the PCB analytical results. With regards to Dioxins and Furans, as no Irish or UK guidance was available, the Dutch Human Health SRCs were used. The threshold screening values and associated derivation tool is provided in Appendix L. Results of the chemical analysis are presented in Appendix K.



Title: **Figure 5.2: Waste Sample Locations (2005)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 07/11/2011

Legend:

- Trial Pits
- Boreholes

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Table 5.3: Inventory of waste sample (WYG, 2005)

BH / TP	Depth	Waste Suite	Full Leachability	Reduced Leachability	Dioxins/ Furans	FOC
TP121-01	0-0.4	√		√		√
TP121-02	1.5	√	√			
TP123-01	0-0.5	√		√		
TP123-02	1.6	√	√			
TP124-01	0-1.0	√				
TP124-03	2.7	√			√	√
TP125-01	0-0.5	√		√		
TP125-04	3.3	√	√			√
TP125-05	0-2	√		√		
TP126-01	0-1	√				√
TP126-02	3-4.2	√			√	
TP127-01	0-0.5	√				√
TP127-03	2.2	√				
TP128-00	1.5	√				
TP128-01	0-0.5	√				√
TP128-03	3.4	√			√	√
TP129-01	0-0.6	√		√		
TP129-02	1.9	√		√	√	
TP129-03	3	√	√			
TP129-04	3.5	√		√		√
TP129-05A	0-2.0	√		√		
TP130-01	0-0.5	√	√			√
TP130-02	1.6	√		√		
TP130-03	2.6	√		√		
TP131-01	0-0.5	√				
TP131-02	1.8	√			√	
TP131-03	2.8	√				√
TP132-01	0-1	√				
TP132-03	2.5-3.5	√			√	
TP132-04	4.2	√				√
BH117-01	4.2	√				
BH118-01	4	√				
BH118A-01	6.5	√				
BH122-01	6	√				
BH125-01	2.5	√				
BH128-01	12	√				
BH131-01	8.0-10	√	√[6]			

Hydrocarbons

- TPHs were detected above the TSV_{2005} in four trial pits. These concentrations of Total TPH ranged from 6543mg/kg at TP126 to 12330mg/kg at TP124. A Total TPH of 10347mg/kg was also detected in BH125 at 2.5m BGL.

[6] Leachate analysis of this waste sample included TPHs, ammoniacal nitrogen and PCB Aroclor 1254 only.

- PAHs were detected above the laboratory detection limit in most trial pits. Where detected, the concentration of Total PAH 16 ranged from 0.31mg/kg (TP132) to 7mg/kg (TP125 at 2.7mbgl). PAHs were detected in three of the boreholes where wastes samples were taken. The concentrations of Total PAHs were 3.25mg/kg (BH118-01), 3.44mg/kg (BH118A-01), 1.01mg/kg (BH122-02) and 2.03mg/kg (BH131-01).
- No PAHs were identified in the waste in the East Tip area at concentrations above the various TSV_{2005}.
- TPH concentrations were noted across the site with the equivalent carbon bands (>12) identified above TSV_{2005} in a number of samples. Total TPH concentrations range from <10mg/kg (TP127-03) to 12330mg/kg (TP124-01).

Phenols & Cyanide Compounds

- Phenols were detected above the laboratory detection limit in six waste samples from four different trial pits and two boreholes. The concentrations ranged from 0.02mg/kg (TP124 & BH117) to 1.1mg/kg (TP126).
- Phenols were not detected above the TSV_{2005} (150mg/kg – 43000mg/kg).
- Thiocyanate was detected at the laboratory detection limit of 1mg/kg in one waste sample (TP126-02). There was no detection of total cyanide, free cyanide and complex cyanide above the laboratory detection limit (1mg/kg).

Polychlorinated Biphenyls

- PCBs were identified above the laboratory detection limit in fifteen waste samples taken from trial pits and one waste sample taken from BH128.
- PCBs were identified above the target value of 170µg/kg in five waste samples in total. The concentrations ranged from 207µg/kg in TP130 to 1544µg/kg in TP125.

pH

- pH exceeds the screening value of 6<pH<9 in 30 of the waste samples taken from the East Tip.
- The arithmetic mean pH value of the samples taken from the East Tip area was 10.5.

Volatile Organic Compounds

- A PID was used during the soil sampling on-site to determine the presence of VOC contamination.
- The most elevated VOC readings using the PID were detected from the following boreholes: BH117 (Naphthalene, 234µg/kg & 1.2.4-Trimethylbenzene, 214µg/kg at 4.2mBGL), BH125 and trial pit, TP123 (744µg/kg of 1.2.4- Trimethylbenzene & 1639µg/kg of Naphthalene at surface).

Dioxins & Furans

- Analysis for dioxins and furans was carried out on six samples.
- Flue dust had been disposed of on the East Tip (Section 2.2.4) and based on the trial hole classifications it was surmised by WYG that such material was present in some trial holes. Relevant samples were thus tested for dioxins/furans.
- On site dioxin concentrations were observed above the laboratory method detection limit (<2ng/kg) in all samples, however, only OCDD (1100ng/kg) in the sample from TP131-02 at 1.8m exceeded the screening value (320ng/kg Residential).

Asbestos

- No asbestos was detected in any of the waste samples.

Metals & Major Ions

A summary of the analytical results is provided in Table 5.4 below. Figures in red denote maximum concentration observed.

Table 5.4: Summary of Waste Analytical Results (WYG, 2005)

Parameter	Number of Samples	Min Level (mg/kg)	Max Level (mg/kg)	WYG TSV_{2005} Commercial & Industrial (mg/kg)	Number of Exceedances	Location Or location of Max Conc.
Arsenic	37	<1	126	500	0	BH125-01
Cadmium	37	<1	52	1400	0	TP121-01
Chromium	37	25	4587	5000	0	TP131-03
Chromium VI	37	<0.3	14.7	-		TP131-01
Copper	37	21	3058	8600	0	TP126-02
Lead	37	8	3043	750	6	TP121-01, TP125-01, TP125-04, TP126-01, TP127-01, BH125-01
Nickel	37	11	770	5000	0	TP126-02
Vanadium	37	4	421	-		TP129-05A
Zinc	37	95	11160	-		TP126-01

- Arsenic was detected above the laboratory detection limit in twenty nine waste samples but there was no exceedance of the TSV_{2005}.
- Cadmium was detected above the laboratory detection limit in twenty three waste samples but there was no exceedance of the TSV_{2005}.
- Chromium was detected above the laboratory detection limit in all waste samples taken from the East Tip but there was no exceedance of the TSV_{2005}.
- Chromium VI was detected above the laboratory detection limit in twenty four of the waste sample taken from the trial pits.
- Copper was detected above the laboratory detection limit in all waste samples taken from the East Tip but there was no exceedance of the TSV_{2005}.
- Lead was detected above the laboratory detection limit in all waste samples and the TSV_{2005} was exceeded in six samples.
- Mercury and Selenium were not detected above the laboratory detection limit (1mg/kg and 3mg/kg respectively) in any of the waste samples taken from the East Tip. The limit of detection does not exceed the TSV_{2005}.
- Nickel was detected above the laboratory detection limit in all waste samples taken from the East Tip but there was no exceedance of the TSV_{2005}.
- Vanadium was detected above the laboratory detection limit in all waste samples.
- Zinc was detected above the laboratory detection limit in all waste samples.

WYG did not test for iron. As $FeSO_4$ is highly soluble it was considered very unlikely to exist on the site.

Waste Statistical Analysis

In accordance with CLR guidance mean and maximum value tests were carried out by WYG for all compounds found to exceed the TSV_{2005} in one or more samples, as considered appropriate. Statistical assessment was undertaken for data within the top metre of the site in order to assess further potential risks to human health as described in CLR 7 (EA/DEFRA). A lead assessment was undertaken using log values as specified in CLEA methodology to allow for use of geometric mean instead of arithmetic mean in calculation of the Soil Guideline Value (SGV). The results of the statistical analysis are presented in Appendix M and Table 5.5 below summaries the conclusions of the statistical assessment.

The entire dataset (e.g. samples taken at all depth including underlying sediments) for the East Tip indicated site wide elevated nickel (95^{th} % UCL> of 105mg/kg) and highly alkaline condition (average pH of 10). Outliers of various PAHs were also identified. Overall the analysis for the full dataset is similar to that for the top one metre dataset and leading WYG to concur that there are no more particularly significant or different impacts at depth. In summary, the statistical analysis for the East Tip, as interpreted by WYG, is as follows:

- Residential with plant uptake
  - Site wide impact by As, Pb, Cd, Ni, and possibly dioxins and furans and
  - Hotspot impacts of Ni, TPH, VOCs and possibly dioxins, furans and PCBs.
- Public Open Space
  - Site wide impact by As, Pb, Ni, and possibly dioxins and furans;
  - Hotspot impacts of Ni, TPH, VOCs and possibly dioxins, furans and PCBs.
- Commercial/Industrial
  - No site wide impacts; and
  - Hotspot impacts of TPH and possibly dioxins, furans and PCBs.

Table 5.5: Summary of statistical analysis of waste results (2005)- East Tip Top 1 metre

Contaminant	Total No. Samples Analysed	TSV_{2005} Res +plant uptake (mg/kg)	TSV_{2005} Res without plant uptake (mg/kg)	2005 WYG TSV_{2005} Commercial & Industrial	95th percentile (excluding outliers) mg/kg	Outliers	Assessment Res +Plant uptake	Assessment Public Open Space (Res without plant uptake)	Assessment Commercial & Industrial
Arsenic	13	20	20	500	34.7	-	Site wide impact	Site wide impact	
Cadmium	13	8***	30	1400	10.0	-	Site wide impact	No impact	
Lead**	13	450	450	750	726	-	Site wide impact	Site wide impact	No significant impact
Nickel	13	50	75	5000	176	TP125 707mg/kg	Site wide impact	Site wide impact	No significant impact
pH Value	13	<6, >9	<6, >9	<6, >9	(mean 10.5)	-	Alkaline Conditions	Alkaline conditions	Alkaline conditions
Aliphatics>C12-C16	13	580	580	17580	17	TP123, TP124	2 outliers*	2 outliers*	2 outliers*
Aliphatics>C16C-21	13	580	580	580	80				
Aliphatics>C21-35	13	580	580	580	308				
Aliphatics>C35-40	13				35				
Aliphatics>C21-C40	13	1100	1100	1100	102				
PCBs (vs Aroclor 1254)	13	170	170	170	72	-	No significant impact	No significant impact	No significant impact

*From site observations and chemical data it was considered, by WYG, that there was likely to be additional outliers/hotspot impacts of hydrocarbons and PCBs in particular which were not identified at this stage. PCBs were noted in particular in BH117, TP123, TP125, TP130 and in deep samples from BH128 and BH131, which although not clustered or identified as outliers of the statistical distribution across the site, may be indicative of localised more significant impacts.

**Lead assessment undertaken using log values as specified in CLEA methodology to allow for use of geometric mean instead of arithmetic mean in calculation of SGV.

***TSV_{2005} for cadmium based on a pH of 8, thus for this site with an average pH of between 9 and 10, this value is considered conservative by WYG.

5.1.4. 2008 Site Investigations (WYG)

During the 2008 site investigation 4 no. discrete samples and nine composite samples were obtained from the East Tip (Figure 5.3); composite samples were taken from a grid of nine areas of approximately one hectare (Area A to Area I). The four discrete samples and two composite samples were also subjected to leachability analysis to determine the potential impact on surrounding waters (Section 5.2.2). Table 5.6 below presents a list of the waste analysis undertaken as interpreted from WYG, A, 2008. The results of the laboratory analysis are provided in Appendix K.

Table 5.6: Summary of waste analysis undertaken (WYG, 2008)

Sample	Sample Type	Waste Type	Location	Chemical Analysis	Leachability Analysis	Dioxins & Furans	VOCs
Dis-101	Discrete	Oily Sludge	Main contractor excavation	√	√	√	√
Dis-102	Discrete	Oily Sludge	Main contractor excavation	√	√		
Dis-103	Discrete	Slag waste	Stockpile	√	√	√	√
Dis-104	Discrete	Millscale	Stockpile	√	√	√	√
Area A	Composite	Surface waste	Area A	√		√	√
Area B	Composite	Surface waste	Area B	√			
Area C	Composite	Surface waste	Area C	√	√		
Area D	Composite	Surface waste	Area D	√			
Area E	Composite	Surface waste	Area E	√			
Area F	Composite	Surface waste	Area F	√	√		
Area G	Composite	Surface waste	Area G	√			
Area H	Composite	Surface waste	Area H	√			
Area I	Composite	Surface waste	Area I	√		√	√

In order to assess the environmental risk posed by potential contaminants within the waste material and groundwater, WYG undertook an initial screen of the laboratory results (in accordance with CLR (Contaminated Land Report) 11) using Tier 1 Threshold Screening Values. WYG Threshold Screening Values (hereafter referred to as TSV_{2008}) are human health generic assessment criteria derived by WYG based on guidance issued for England and Wales by Defra and the Environment Agency. These values were considered by WYG most appropriate for the site and are conservative for on-site exposures for the current land use. The analytical results of these near surface East Tip waste materials are compared against the WYG TSV_{2008} for commercial/industrial use. The WYG TSV_{2008} (dated 18/09/2007) used in the 2008 WYG report are included in Appendix L.

No Irish or UK Guidance was available to facilitate the assessment of the results for PCBs and as an indicative guide the Dutch Human Health SRCs were used. The Dutch guidance provides SRCs for 7

Title: **Figure 5.3 Surface Waste Sampling Locations (WYG 2008)**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 13/12/2011

Legend:

- Discrete Waste Samples (2008 WYG Report)
- Composite Waste Sampling Transects (2008 WYG Report)
- Composite Waste Areas
- Excavation Area

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Scale; **1:2,000 @ A3**

PCBs; the lowest target value of 170Lg/kg was used by WYG as a conservative guide for assessment of the PCB analytical results.

This screening value for Dioxins and Furans was not available in the 2005 investigation and was derived in 2007 (TSV_{2008}) as outlined in Appendix L.

Hydrocarbons

- There was no exceedance of the relevant TSV_{2008} (range 2.5mg/kg (Benzene) – 260000mg/kg (Aliphatics >C12-C16)) for speciated TPH which includes the oily sludge material in the existing excavation on-site.
- There were some elevated TPH concentrations; however, these were made up of specific carbon bands (Predominantly C16 – C35 Aliphatics) which were determined not to volatilise.
- C16 – C35 Aliphatics were detected above the laboratory detection limits in three of the discrete samples (DIS101, DIS102, DIS103) and two of the composite samples (Area A & Area E). The concentrations in the composite samples were 40mg/kg in Area A and 356mg/kg in Area E. The concentrations in the discrete samples were 187mg/kg (DIS101), 1252mg/kg (DIS102) and 60mg/kg (DIS103).
- C21-C35 Aliphatics were detected above the laboratory detection limits in all discrete samples and all composite waste samples (Area A to Area I). The concentrations in the discrete samples ranged from 992mg/kg (DIS104) to 15058mg/kg (DIS102). The concentrations in the composite samples ranged from 275mg/kg (Area B) to 777mg/kg (Area A).
- PAHs were detected at concentrations ranging from 0.694mg/kg (Area B) to 6.207mg/kg (Area H) in the nine composite samples of the waste material.
- All PAHs were below their respective TSV_{2008}.
- There was no detection of PAHs above the laboratory detection level of 1Lg/kg in the discrete samples.

Phenols and Cyanide

- Phenol was detected above the laboratory detection limit six of the composite samples (Area A – Area F). The concentrations ranged from 0.02mg/kg (Area B) to 0.05mg/kg (Area F).
- Phenol was detected above the laboratory detection limit in the discrete millscale[7] sample DIS-104 (0.02mg/kg) and both discrete sludge samples DIS101 (0.01mg/kg) and DIS102 (0.07mg/kg). These concentrations are significantly less than the TSV_{2008} of 43,000mg/kg.
- There was no detection of total cyanide, free cyanide, complex cyanide or thiocyanate in any of the composite or discrete samples. The respective limits of detection are 1mg/kg, 0.5mg/kg, 2.5mg/kg and 1mg/kg.

Polychlorinated Biphenyls

- PCBs were identified above the laboratory detection limit in all nine composite samples and in one Discrete sample (DIS103).
- The concentration of total PCBs in the composite samples ranged from 13µg/kg in Area B to 254µg/kg in Area F. Area F was the only composite sample that exceeded the TSV_{2008}, which is 170µg/kg.

[7] WYG A, 2008, Section 5.2.1 states that phenol was detected in the discrete slag sample; however, on inspection of Table 23 East Tip Waste Analytical Results, WYG B, 2008, phenol was detected in DIS104 and not DIS103. This was confirmed with Alcontrol Laboratories Ireland Table of Results Ref No:08-B04167/01

- There was no detection of PCBs in the two discrete samples of the sludge material or mill scale waste, with a low detection of 19µg/kg in the slag discrete sample, DIS103. The limit of detection is 1µg/kg.

pH

- pH readings within the nine composite waste samples and discrete samples of the slag and millscale exceeded the TSV_{2008} of 8.5.
- The pH in the composite waste samples ranged from 9.5 (Area I) to 10.02 (Area G).
- The pH of the discrete samples DIS103 and DIS104 were 10.86 and 9.61, respectively.
- The two discrete sludge samples taken from the main excavation had pH readings within the TSV_{2008} range of 6<pH<8.5.

Volatile Organic Compounds

- VOCs were analysed from two composite waste samples (Area A and Area I) and three discrete waste samples (Dis101, Dis103 and Dis104)
- There was no detection of VOCs above the laboratory detection limit of 1µg/kg, in any of the samples analysed.

Dioxins & Furans

- Dioxins and Furans were analysed from two composite waste samples (Area A and Area I) and three discrete waste samples (Dis101, Dis103 and Dis104).
- All analysed compounds were detected but none exceeded the TSV_{2008} of 1300ng/kg for 2,3,7,8 TCDD.

Asbestos

- No asbestos was detected in any of the slag samples.

Metals & Major Ions

A summary of the analytical results is provided in Table 5.7 below. Figures in red denote maximum concentration observed.

Table 5.7: Summary of results of analysis composite & discrete waste samples (WYG, 2008)

Parameter	No. of samples	Min (mg/kg)	Max (mg/kg)	WYG TSV_{2008} C&I	No. Exceeding	Locations or Max
Arsenic	13	<1	93	500	0	DIS102
Chromium	13	559	2402	5000	0	Area F
Chromium VI	13	<0.1	0.4	5000	0	DIS103
Copper	13	290	2660	-	-	DIS101
Lead	13	98	2186	750	7	Area C,D,E,G,H,I, DIS103
Nickel	13	44	883	5000	0	DIS101
Zinc	13	619	12520	-	-	Area I

- Arsenic was detected above the laboratory detection limit in eight of the nine composite samples and all four discrete samples.
- The concentration of arsenic ranged from 8mg/kg (Area B) to 57mg/kg (Area I) in the composite waste samples. The range in the discrete samples was from 22mg/kg (DIS103) to 93mg/kg (DIS102).

- Cadmium was detected above the laboratory detection limit in eight of the nine composite samples and in one of the discrete samples (DIS103). However, the concentrations of cadmium did not exceed the TSV_{2008} of 1400mg/kg.
- The concentration of cadmium in the composite waste samples ranged from 2mg/kg (Area B) to 32mg/kg (Area I).
- The concentration of cadmium in DIS103 was 14mg/kg.
- Chromium was detected in all nine composite waste samples and all four discrete samples.
- Chromium VI was detected in six of the composite waste samples and one of the discrete samples (DIS103).
- Copper was detected above the laboratory detection limit in all nine composite samples and in all four discrete samples.
- Iron was detected at levels greater than 32,000mg/kg in all composite waste samples and all discrete samples.
- Lead was detected in all composite waste samples and all discrete samples.
- WYG concluded that the source of this lead is likely to be from the waste material from the steelworks site such as the furnace dust prior a change in work practices (i.e. it was subsequently pelletised and exported from the site – Section 2.2.4).
- Mercury was not detected above the laboratory detection limit (1mg/kg) in any of the samples.
- Other metal elements which do not have a TSV_{2008} and were detected above the respective laboratory detection limits include;

    - Aluminium (3,111mg/kg in Area I to 17,180mg/kg in Area B)
    - Calcium (17,440mg/kg in Area I to 943,300mg/kg in Area C)
    - Magnesium (4,831mg/kg in Area I to 43,070mg/kg in Area G)
    - Manganese (6,362mg/kg in Area I to 23,330mg/kg in Area F)
    - Zinc (619mg/kg in Area F to 12,520mg/kg in Area I)
    - Molybdenum (33mg/kg in Area F to 251mg/kg in DIS101)
    - Selenium (ranges up to 13mg/kg in Area F)
    - Vanadium (6mg/kg in DIS101 & DIS102 to 395mg/kg in Area F)

5.1.5. 2008 Site Investigations (RPS)

A shallow soil investigation was carried out by RPS in July 2008 which consisted of the analysis of hand-dug surface soil samples of the Naval football pitch on the East Tip. 18 no. soil samples were taken from 13 no. locations (HP01 to HP13) and sampling locations are presented in Figure 5.4. Samples were collected from two horizon depths; ground level to 0.01mbgl and 0.01mbgl to 0.05mbgl. The following information was recorded during the excavation of the hand-dug pits:

- Material descriptions;
- Visual evidence and extent of contamination; and,
- Olfactory evidence of contamination.

The suite of tests undertaken was selected based on previous land use and existing information to assess the potential risks posed to human health and included, *inter alia*, analysis for heavy metals, asbestos, polychlorinated biphenyls (PCBs), Volatile Organic Compounds (VOCs) and hydrocarbons. The laboratory analytical results are presented in Appendix K.

Heavy Metals

Heavy metals were observed at varying concentrations across the pitch. Table 5.8 provides the minimum and maximum concentrations detected and the number of exceedances of the screening criteria.

Title:	**Figure 5.4: Shallow Soil Sample Locations (RPS 2008)**
Project:	**Haulbowline Project**
Drawn by:	HaulbowlineTeam
Date:	07/11/2011

Legend:

- Shallow Soil Sample Locations (RPS 2008)

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Scale; **1:2,000 @ A3**

Table 5.8: Heavy metal concentrations in samples taken from Naval football pitch (RPS, 2008)

Metal	Minimum (mg/kg)	Maximum (mg/kg)	No. Of Exceedances	Screening Criteria Exceeded (mg/kg)
Arsenic	8.7	12	0	
Barium	34	120	0	
Cadmium	0.52	1.6	7	Dutch Target Value (0.8)
Chromium	37	68	0	
Chromium VI	0.3	3.7	0	
Cobalt	9.8	16	13	Dutch Target Value (9)
Copper	27	66	0	
Lead	66	270	8	Dutch Target Value (85)
Mercury	<0.25	0.77	0	
Nickel	17	32	0	
Selenium	<0.3	0.53	0	
Vanadium	22	28	0	
Zinc	190	540	7	Former CLEA Guidelines for Residential with plant uptake

Cyanide Compounds

- Free cyanide was not detected above the laboratory detection limit in any of the samples.
- Total cyanide was detected at one location (HP04) at a concentration of 4.5mg/kg.
- Thiocyanate was detected above the laboratory detection limit in eight of the samples. The maximum concentration was 0.79mg/kg (HP13).

Polychlorinated Biphenyls

- PCBs were detected above the laboratory detection limit in seven samples. Total PCB concentrations ranged from 7mg/kg to 14.3mg/kg (HP10).

Polycyclic Aromatic Hydrocarbons

- Individual PAHs were detected above the laboratory detection limit (0.1mg/kg) in four samples, HP04 (0.14mg/kg, naphthalene), HP07 (0.1mg/kg, naphthalene & 0.12mg/kg, phenanthrene), HP09 (0.15mg/kg, naphthalene), HP10 (2.2mg/kg total).

Total Petroleum Hydrocarbons

- TPHs were detected above the laboratory detection limit in fifteen samples. The TPH (>C6 – C40) concentrations ranged from 55mg/kg (HP04) to 770mg/kg (HP05).
- Due to the lighter, more mobile fractions observed on the football pitch, this area was subjected to more detailed analysis.
- Two samples (HP05 and HP11) from the football pitch were subjected to additional analysis of TPH. The results are provided in Appendix K.

Volatile Organic Compounds

- VOCs were not recorded at concentrations above the laboratory detection limit of 0.1mg/kg.

Asbestos

- Asbestos was not detected in any soil sample.

5.2. Results of Leachability Tests on Waste Samples

5.2.1. 2005 Leachability Tests (WYG)

16 no. samples were submitted for NRA (National River Authority (UK)) leachability analysis by WYG as part of their investigations in 2005. Six of the samples were analysed for the full suite, less VOCs, while the remaining ten samples were analysed for the reduced suite (less VOCs, PAH, TPH and ammonical nitrogen. A sample inventory is provided in Table 5.3 above. The selection of waste samples for analysis was based on the requirement to characterise material encountered during the investigation in terms of environmental contamination and potential migration to both on and off-site receptors. The results of these tests were assessed by direct comparison with the UK Environment Quality Standards (EQS) for saline waters. Where EU standards for shellfisheries were more stringent than the saline EQS standards, these were used. The analytical results for the leachability tests are presented in Appendix N.

Hydrocarbons

- TPHs were only detected in the leachate from one waste sample from TP123-02 (260µg/l total).
- PAHs were detected above the laboratory detection limit, in the leachate from eleven waste samples. The leachate from the following waste samples exhibited the highest concentrations:
    - TP123-01: Naphthalene (11937ng/l), Acenaphthene (1279ng/l), Fluorene (2628ng/l, Phenanthrene (5993ng/l)
    - TP121-02: Acenaphthene (1277ng/l), Phenanthrene (3703ng/l), Fluoranthene (2712ng/l)
- The Total PAH 16 ranged from 258ng/l (TP129-01) to 23,304ng/l (TP123-01).

Phenols and Cyanide

- Phenols and cyanide compounds were not detected above the laboratory detection limit (0.01mg/l and 0.05mg/l respectively) in the leachate from any of the waste samples

Polychlorinated Biphenyls

- There was no detection of PCBs above the laboratory detection limit (26µg/l) in the leachate of any of the six waste samples.

pH

- The pH readings of the leachate from the waste samples ranged from 7.47 to 11.96 with three samples exceeding the EQS of 8.5.

Metals and Major Ions

- Fifteen waste samples obtained from trial pits were analysed for heavy metals. The leachate from waste sample BH131-01 was not submitted for analysis for heavy metals.
- Arsenic was detected above the laboratory detection limit in seven of the fifteen samples analysed. The maximum concentration of arsenic recorded was 3µg/l (TP121-01).
- Cadmium was not detected above the laboratory detection limit (0.4µg/l) in any of the leachate samples.
- Chromium was detected in all leachate from the waste samples and exceeded the Saline EQS of 15µg/l in twelve samples. In these twelve samples concentrations ranged from 31µg/l (TP121-02) to 204µg/l (TP129-01).
- Chromium VI was detected above the laboratory detection limit (0.03mg/l) in twelve samples. The concentrations ranged from 0.04mg/l (TP123-02) to 0.22mg/l (TP129-01). The laboratory detection limit is greater than the total chromium Saline EQS of 0.015mg/l.
- Copper was detected above the Saline EQS of 5µg/l in eleven samples. In these samples, concentrations ranged from 5µg/l (TP129-01) to 266µg/l (TP130-03).

- Lead was detected above the laboratory detection limit in thirteen samples, with three samples exceeding the Saline EQS of 25µg/l, TP125-01 (25µg/l), TP130-02 (28µg/l) and TP130-03 (31µg/l).
- Nickel was detected above the laboratory detection limit in all samples but none exceeded the Saline EQS of 30µg/l.
- Selenium was detected above the laboratory detection limit in fourteen samples. Concentrations ranged from 1µg/l (TP125-05) to 6µg/l (TP125-01 & TP125-04).
- Zinc was detected in all leachate samples. Two samples exceeded the Saline EQS of 40µg/l, TP125-01 (53µg/l) and TP129-04 (57µg/l).
- Mercury was detected above the laboratory detection limit in two leachate samples, TP121-01 (0.12µg/l) and TP121-02 (0.08µg/l). However, the concentrations did not exceed the Saline EQS of 0.3µg/l.

5.2.2. 2008 Leachability Tests (WYG)

Two methods of leachate analysis, CEN (European Committee for Standardisation) and NRA, were carried out on the four discrete samples and two of the composite waste samples (Area C & Area F) to assess the potential for elevated compounds and elements to leach from the waste materials into the surrounding waters. Results from the CEN tests were compared against the suite of parameters as per the landfill acceptance criteria for KTK's non-hazardous landfill in Co. Kildare and for the inert landfill operated by Murphy Environmental (Murphy's), Hollywood Great, Co. Dublin while results of the NRA test were compared against the UK EA Coastal & Estuarine Environmental Quality Standards (EQS) and the AA-EQS & MAC-EQS sourced from the Draft European Communities Environmental Objectives (Surface Waters) Regulations 2008. The analytical results for the leachability analysis are presented in Appendix N.

Hydrocarbons

- Speciated TPHs and PAHs were not detected above the laboratory detection limit in the composite waste or discrete samples for either the CEN (LoD: 0.01mg/kg, 0.0001mg/kg) or NRA (LoD: 0.01mg/l, 10ng/l) leachate methods.

Phenols and Cyanide

- Phenols and cyanide compounds were not detected above the laboratory detection limit in the composite waste or discrete samples for either the CEN (LoD: 0.1mg/kg, 0.5mg/kg) or NRA (LoD: 0.01mg/l, 0.05mg/l) leachate methods.

Polychlorinated Biphenyls

- PCBs were not detected above the laboratory detection limit (10ng/l) in the composite waste or discrete samples for the NRA leachate method.
- Two PCB Congeners (28, 52), were detected above the laboratory detection limit in the composite waste sample from Area F for the CEN leachate method. The concentration for the PCB total was 0.027mg/kg.

pH

- CEN leachate analysis
  - The pH readings of the two composite waste samples were 10.49 and 9.94 for Area C and Area F, respectively.
  - The pH readings of the Discrete samples range from 7.56 (DIS101) to 12.01 (DIS103).
- NRA Leachate Analysis
  - The pH readings of the two composite waste samples are 10.14 and 9.75 for Area C and Area F, respectively.
  - The pH readings of the discrete samples range from 7.77 (DIS103) to 9.23 (DIS104).

Metals and Major Ions

CEN Leachate Analysis

- For the two composite surface waste samples (Area C and F) there were exceedances of the inert landfill acceptance criteria (Murphys's Landfill) for total chromium in Area C (1.07mg/kg) and Chloride in Area F (1646mg/kg). There were no exceedances for the non-hazardous parameters (KTK Landfill) analysed.
- DIS101 has an exceedance of the inert landfill acceptance criteria for antimony (0.9mg/kg), nickel (4mg/kg), chloride (1798mg/kg) and sulphate (1573mg/kg). DIS101 does not exceed any parameter of the non-hazardous landfill acceptance criteria.
- DIS102 has an exceedance of the inert landfill acceptance criteria for nickel (0.53mg/kg) and chloride (823mg/kg). DIS102 does not exceed any parameter of the non-hazardous landfill acceptance criteria.
- DIS103 has an exceedance of the non-hazardous landfill acceptance criteria for antimony (1.2mg/kg). There is also an exceedance of the inert landfill acceptance criteria for chromium (1.4mg/kg).
- Chromium VI was detected in the leachate from DIS103 (0.9mg/kg). Cr VI was not detected in the leachate from any other sample.
- DIS104 has an exceedance of the non hazardous landfill acceptance criteria and the inert landfill acceptance criteria for selenium (0.7mg/kg).

NRA Leachate Analysis

- For the two composite waste samples (Area C & Area F), the chromium concentrations of 99µg/l and 17µ/l, respectively, exceeded the UK EA EQS.
- The concentration of copper in Area A and Area F of 6µg/l and 5µg/l, respectively, also exceeded the UK EA EQS.
- Molybdenum was detected in the leachate of composite waste samples in Area C and Area F with concentrations of 17µg/l and 13µg/l recorded, respectively.
- The leachate from DIS101 exceeded the UK EA EQS for copper (90µg/l), nickel (310µg/l), vanadium (130µg/l) and zinc (60µg/l). Chromium and chromium VI were not detected above the laboratory detection limit of 50µg/l and 30µg/l which is above the UK EA EQS of 15µg/l for total chromium.
- The leachate from DIS102 exceeded the UK EA EQS for copper (28µg/l) and nickel (41µg/l). Total chromium was detected at 4µg/l but the detection limit for chromium VI was 30µg/l.
- The leachate from DIS103 exceeded the UK EA EQS for copper (140µg/l), nickel (390µg/l), vanadium (110µg/l) and zinc (100µ/l). Chromium and chromium VI were not detected above the laboratory detection limit of 50µg/l and 30µg/l which is above the UK EA EQS of 15µg/l for total chromium.
- The leachate for DIS104 did not exceed the UK EA EQS for any parameter. Chromium and chromium VI were not detected above the laboratory detection limit of 50µg/l and 30µg/l which is above the UK EA EQS of 15µg/l for total chromium.

2008 leachability summary tables are provided in Appendix N.

5.2.3. Leachability Results from Composite Slag Samples (WYG, 2008)

A total of eight composite slag samples (S1 – S8) were taken by WYG in July 2008 from the near surface slag wastes material across the East Tip (Figure 5.5) and underwent analysis in accordance with the CEN leachability test.

Title: **Figure 5.5: Slag Waste Stockpile Sampling Locations**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 07/11/2011

Legend:

- Slag Waste Zones
- Slag Waste Sample

(Based on WYG 2008 Geotechnical Assessment Report)

Cork County Council
Environmental Directorate
Inniscarra,
Co. Cork

Phone: 021 - 4532700
Fax no. 021 - 4532777

Scale; **1:2,000@A3**

The analytical results of the composite slag material was compared against the waste acceptance criteria for KTK's non-hazardous landfill in Co. Kildare and for the inert landfill operated by Murphy Environmental (Murphy's), Hollywood Great, Co. Dublin. The required acceptance criteria for both the inert and non-hazardous landfills are compared against the eight slag samples taken from across the East Tip. CEN Leachate analysis results for the eight slag samples in relation to the landfill acceptance criteria were as follows:

Murphy Environmental Inert Landfill

- There was one exceedance of selenium in area S1 (1.0mg/kg),
- There was one exceedance of total dissolved solids in area S2 (4680mg/kg),
- There was one exceedance of mercury in area S3 (0.5mg/kg)
- There was one exceedance of antimony in area S7 (0.08mg/kg).

KTK Non-Hazardous Landfill

- There was one exceedance of selenium in area S1 (1.0mg/kg)
- There was one exceedance of mercury in area S3 (0.5mg/kg).
- Following discussions, by WYG, with the landfill operator, Tom Finnegan, on the 26th August 2008 it was concluded that six of the eight waste slag material stockpiles, S2, S4, S5, S6, S7 and S8, could be accepted at KTK Landfill.

The analytical results are provided in Appendix N.

5.3. Results of Analysis of Leachate Samples (KTC, 1998)

During their 1998 site investigations KTC collected 4 no. leachate samples, (LS-1 to LS-4) and these were analysed for a suite of chemical and inorganic parameters including metals, major ions and cations. The analytical results are provided in Appendix N. Results were compared against Irish Water Quality Standards, SI No. 293 of 1988 and only the parameters which exceeded the relevant Maximum Admissible Concentration (MAC) levels for potable water; (Irish Water Quality Standards SI No. 293 of 1988) were discussed:

- Iron levels in all of the four leachate samples exceeded the MAC level of 0.2mg/l. The concentration ranged from 0.53ppm (LS-4) to 4.32ppm (LS-2).
- Levels of manganese detected in samples from LS-1(0.12ppm), LS-2(0.48ppm) and LS-3(0.12ppm) exceeded the MAC level of 0.05mg/l.
- The level of nickel detected in LS-2 (0.12ppm) exceeded the respective MAC value of 0.05mg/l.
- Only levels of nitrite detected in LS-3(0.49ppm) exceeded the MAC value of 0.1 mg/l.
- The pH MAC value for water was exceeded twice. The water sample from leachate sample LS-2 had a pH of 5.24 while the sample from LS-4 had a pH of 10.04.
- Cadmium, chromium, copper, mercury, zinc and lead were not detected above their respective laboratory detection limits of 0.05ppm.

5.4. Waste Analytical Results from Composite Slag Samples (WYG, 2008)

A total of eight composite slag samples (S1 – S8) were taken by WYG in July 2008 from the near surface slag wastes material across the East Tip (Figure 5.5) and underwent chemical analysis for hydrocarbons, PAHs and PCBs.

The analytical results of the composite slag material was compared against the waste acceptance criteria for KTK's non-hazardous landfill in Co. Kildare and for the inert landfill operated by Murphy Environmental (Murphy's), Hollywood Great, Co. Dublin. The required acceptance criteria for both the inert and non-hazardous landfills are compared against the eight slag samples taken from across the East Tip.

The analytical results are provided in Appendix K.

- DRO were detected in all slag samples with concentrations ranging from 135mg/kg (S5) to 666mg/kg (S6). There was no exceedance of the non hazardous landfill acceptance criteria. An acceptance value is not provided for the inert landfill criteria.
- No other hydrocarbons analysed were detected.
- PAHs were detected in all slag samples; however, there was no exceedance of the non-hazardous or inert landfill acceptance criteria for Total PAHs.
- PCBs were detected in six samples (S2, S4 - S8). The total PCB concentrations ranged from 17µg/kg in S5 to 388µg/kg in S6 However, there was no exceedance of the inert landfill acceptance criteria for PCBs (total of 7 congeners, 1000µg/kg).

5.5. Slag Expansivity Assessment (WYG, 2005)

Twenty nine samples of furnace slag selected to broadly cover the East Tip were sent to Thomas Research Services Ltd laboratory in Lincolnshire, England, for Phase I to III Slag Analysis. The purpose of the exercise was to identify the range and relative concentrations of any iron and steelmaking slags present in the samples and to assess their ability to expand. The dominant constituents of the samples were basic steel slag and millscale with minor amounts of basic refractory material.

The samples were crushed, dried and made into 29 resin bound blocks. A petrological examination was made of the 29 polished blocks using reflected light microscopy. Further analysis was carried out on nine selected samples to look for evidence of previous expansion. The analyses included thermal analysis, analysis for free lime, analysis for free magnesia and TRS accelerated expansion test.

The results of the testing showed the basic steel slag and basic refractory material to have significant potential for future expansion with a maximum expansion of just under 12%. Use of the material fill beneath roads or buildings was not recommended as it is likely to result in significant structural damage. The slag may have potential use as a bound roadstone following significant processing in the form of crushing and weathering to produce a suitable product. A specialist report, including interpretation of the slag's properties by Thomas Research Services Ltd is included in Appendix O.

5.6. Results of Alluvium Analysis

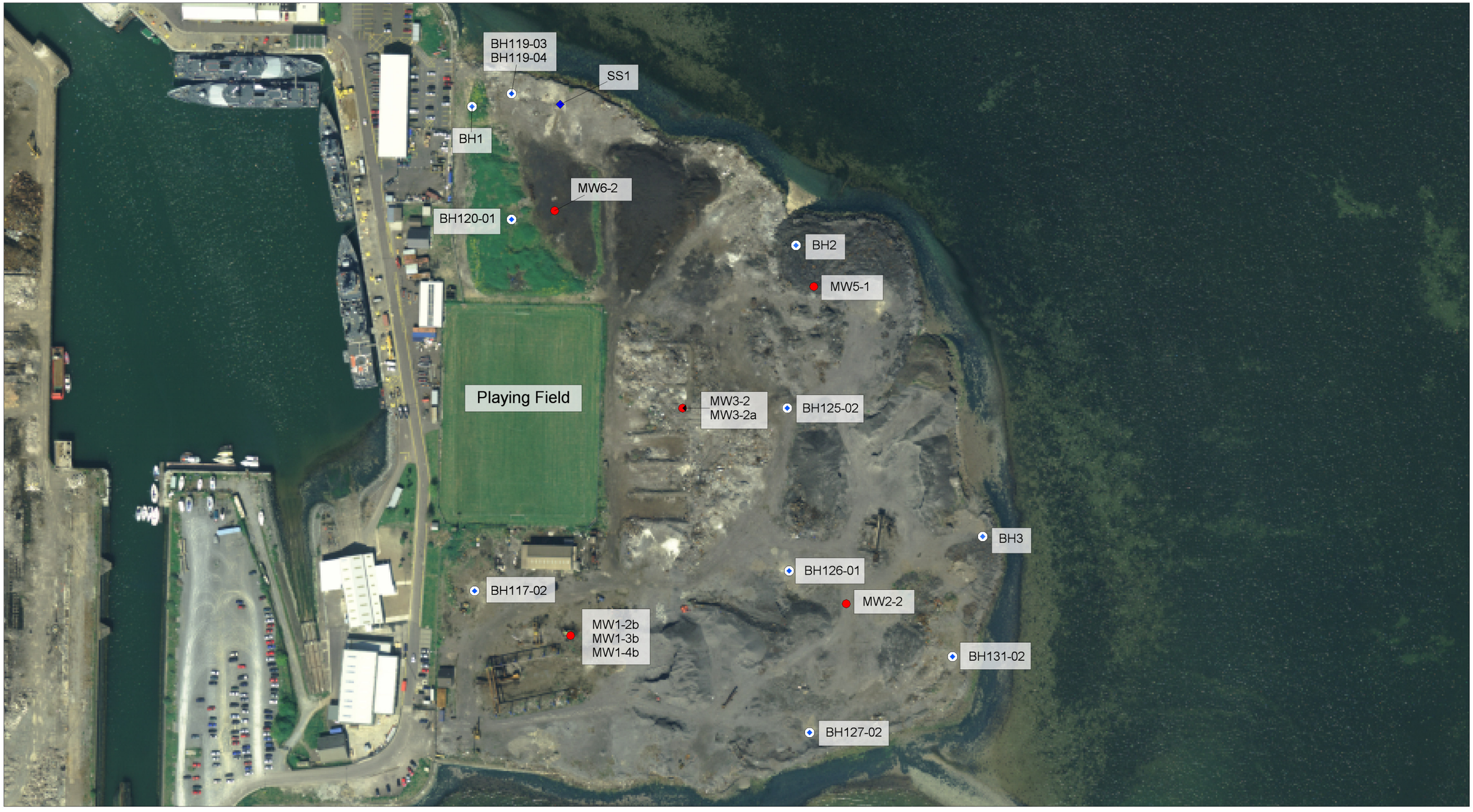
5.6.1. 1995 Alluvium Analysis (KTC)

As part of the K.T. Cullen & Co Ltd site investigation of the East Tip, a total of 15 U_{100}, 4 split spoon and 8 grab samples were taken from the sediment underlying the waste. Selected samples were sent for physical and chemical analysis to determine if the alluvium had been contaminated by waste material disposed on the East Tip. Seven samples of sediment (MW1-2b, MW1-3b, MW1-4b, MW2-2, MW3-2a, MW5-1 and MW6-2) recovered from boreholes were analysed for metals, total petroleum hydrocarbons and organic content. One sample (SS1) was recovered from the exposed sediment at the edge of the tip at low tide and one sample of sediment was obtained near the shore at Ringaskiddy. Additionally, three sediment samples taken from BH1, BH2 and BH3 by Site Investigations in May 1995 were analysed for iron, zinc, lead, cadmium, mercury and chromium. The sample depths are provided in Table 5.9. The sample locations are provided in Figure 5.6 and the analytical results are provided in Appendix P. A summary of these results is provided below:

Table 5.9: Sediment sample depth (KYC, 1995)

Sediment Sample	Depth of Sample mBGL	Location of Sample
MW1-2b[8] include note(reference in logs unclear)	7.20 – 7.65	Alluvium
MW1-3b[10]	8.00 - 8.50	Alluvium
MW1-4b[10]	8.90 – 9.47	Alluvium
MW2-2	10.0 - 10.6	Alluvium
MW3-2a	8.60 – 9.20	Alluvium
MW5-1	3.60 – 4.20	Alluvium
MW6-2	6.00 – 6.60	Alluvium
BH1	7.5	Alluvium
BH2	8.0	Alluvium
BH3	9.0	Alluvium

[8] The sample reference is unclear in the boreholes logs and therefore the depth of sample may not be accurate



Title: **Figure 5.6: Alluvium Samples 1995, 2005**

Project: **Haulbowline Project**

Drawn by: HaulbowlineTeam

Date: 12/01/2012

Legend:

- Sediment Sample
- Borehole
- Monitoring Well

Cork County Council
Environmental Directorate
Inniscarra,
Co. Cork

Phone: 021 - 4532700
Fax no. 021 - 4532777

Scale; **1:2000@A3**

Hydrocarbons

- TPH was detected in three sediment samples, MW1-2b (20.4mg/kg), MW3-2a (8.5mg/kg) and MW6-2(2.8mg/kg).
- TPH was also detected in SS1 (140mg/kg) and the sediment sample taken from the shore at Ringaskiddy (14.5mg/kg).

Heavy Metals

- Arsenic was detected in the seven samples taken from boreholes MW1, MW2, MW3, MW5, & MW6. Concentrations ranged from 6mg/kg to 8mg/kg. Arsenic was also detected in SS1 (6mg/kg). The highest concentration was observed in the Ringaskiddy sample (12mg/kg).
- Chromium was detected in all 12 samples. Concentrations ranged from 15mg/kg, in sample SS1, to 1500mg/kg in sample MW2-2.
- Iron concentrations ranged from 1.6mg/kg (MW1-4b) to 530mg/kg (BH3).
- Copper was detected in the seven samples taken from boreholes MW1-MW3, MW-5 & MW-6. Concentrations ranged from 10mg/kg to 100mg/kg in sample MW2-2. Copper was also observed in SS1 (10mg/kg) and the Ringaskiddy sample (40mg/kg).
- Zinc was detected in all 12 samples. Concentrations ranged from 55mg/kg in sample MW1-4b to 290mg/kg in sample MW6-2.
- Cadmium was detected above the laboratory detection limit in two samples. The concentration of cadmium in samples MW1-2b and MW6-2 was 0.5mg/kg and 1.2mg/kg respectively.
- Lead was detected in all 12 samples. Concentrations ranged from 10mg/kg in sample MW1-4b, to 140mg/kg in the sample taken from BH2.
- Nickel was detected in the seven samples taken from boreholes MW1, MW2, MW3, MW-5 & MW-6. Concentrations ranged from 25mg/kg (MW1-2b, MW1-3b, MW1-4b) to 55mg/kg in sample MW6-2. Nickel was also detected in SS1 (15mg/kg) and the Ringaskiddy sample (30mg/kg).
- Molybdenum was detected the all seven samples taken for boreholes MW-1, MW-2, MW-3, MW-5 & MW-6. Concentrations ranged from 13mg/kg (MW1-2b) to 31mg/kg in sample (MW2-2). Molybdenum was not detected above the laboratory detection (10mg/kg) limit in SS1, however, it was detected in the Ringaskiddy sample (17mg/kg).

Organic Content

- Organic content was observed in five samples MW1-2b (3.2%), MW3-2a (6.2%), MW6-2 (5.5%), SS1 (1.8%) and the Ringaskiddy sample (2.6%).

5.6.2. 2005 Alluvium Analysis (WYG)

During the 2005 site investigation, samples of the alluvium where taken from boreholes within the East Tip to determine the extent to which contamination had leached, however, an interpretation of the chemical analysis was not carried out.

WYG made no distinction between the waste samples and the alluvium samples in the 2005 Report (WYG B, 2005). For the interpretative analysis of the results WYG grouped the waste samples and subsoil samples. For this report, an effort has been made to separate the analytical results of the waste samples and the subsoil samples.

A total of eight alluvium samples were selected for chemical analysis. The alluvium samples were not submitted for NRA leachability analysis. Sample locations are presented in Figure 5.6 and an inventory the analysis performed is presented in Table 5.10.

Table 5.10: Inventory of alluvium sample analysis (WYG, 2005)

BH / TP	Sample Depth	Location	Alluvium Suite	Full Leachabilty	Reduced Leachability	Dioxins/ Furans	FOC
BH117-02	6.5	Interface of fill & alluvium	√				
BH119-03	7.2	Interface of fill & alluvium	√				
BH119-04	8.7	Alluvium	√				√
BH120-01	7	Alluvium	√				
BH125-02	10.3	Interface of fill & alluvium	√				
BH126-01	5	Alluvium	√				
BH127-02	7.75	Interface of fill & alluvium	√				√
BH131-02	15	Alluvium	√				

In order to assess the soil analyses results with regards to potential human health risks WYG derived TSV_{2005} in accordance with the UK framework set out in the most recent CLR (Contaminated Land Report) documents (CLR7-10, EA/DDEFRA, 2002). In the absence of UK data, for the purposes of this initial screening assessment, reference was made to European and US guidance in generating TSV_{2005}.

As no Irish or UK guidance was available relating to PCBs the PCB screening values are derived from Dutch Human Health SRCs. The Dutch guidance provides SRCs for 7 PCBs and the lowest target value was used as a conservative guide for assessment of the PCB analytical results. Similarly no Irish or UK guidance was available for dioxins & furans and as an indicative guide the Dutch Human Health SRCs were used. The threshold screening values and associated derivation tool is provided in Appendix L and the results of the analysis of the alluvium samples are provided in Appendix P. The borehole logs are provided in Appendix D.

Hydrocarbons

- PAHs were detected above the laboratory detection limit in samples taken from BH119 and BH120. The PAH 16 total was 46.97mg/kg and 0.7mg/kg in sample BH119-03 and BH119-04 respectively. The PAH 16 total was 1.66mg/kg in sample BH120-01.
- TPHs were not detected above the laboratory detection limit (10mg/kg) in any of the samples.
- A concentration of 41mg/kg for total extractable hydrocarbons was obtained from sample BH125-02.

Phenols & Cyanide

- Phenols were not detected above the laboratory detection limit (0.01mg/kg) in any of the samples.
- Thiocyanate and total cyanide were detected above the laboratory detection limit in sample BH126-01. The concentration of thiocyanate and total cyanide was 3mg/kg and 1mg/kg, respectively.

Polychlorinated Biphenyls

- PCBs were not detected above the laboratory detection limit of 20mg/kg in any of the samples.

pH

- The pH value ranged from 7.58 to 9.53.
- The arithmetic mean pH value of the samples taken was 8.38.

Volatile Organic Compounds

- A PID was used during the soil sampling on-site to determine the presence of VOC contamination.
- VOCs were not detected in any of the samples.

Dioxins & Furans

- Analysis for dioxins and furans was not carried out on any of the alluvium samples.

Metals & Major Ions

- Arsenic was detected above the laboratory detection limit in seven samples. Arsenic concentrations ranged from 2mg/kg (BH119-04, BH126-01 & BH127-02) to 7mg/kg (BH120-01).
- Cadmium and mercury were not detected above the laboratory detection limit of 1mg/kg in any of the samples.
- Selenium was not detected above the laboratory detection limit of 3mg/kg in any of the seven samples.
- Chromium was detected above the laboratory detection limit in all eight samples. Chromium concentrations ranged from 27mg/kg (BH119-03) to 1593mg/kg (BH131-02).
- Hexavalent chromium was not detected above the laboratory detection limit of 0.3mg/kg in any of the samples.
- Copper was detected above the laboratory detection limit in seven of the samples and the concentrations ranged from 3mg/kg (BH119-03) to 834 (BH125-02).
- Lead was detected above the laboratory detection limit in all eight samples. Concentrations ranged from 7mg/kg (BH117-02) to 36mg/kg (BH125-02).
- Nickel was detected above the laboratory detection limit in all eight samples. Concentrations ranged from 12mg/kg (BH119-03) and 72mg/kg (BH125-02).
- Vanadium was detected above the laboratory detection limit in all eight samples. Concentrations ranged from 18mg/kg (BH119-03) to 181mg/kg (BH131-02).
- Zinc was detected above the laboratory detection limit in all eight samples. Concentrations ranged from 53mg/kg (BH119-03) to 221mg/kg (BH125-02).
- WYG did not test for iron. As $FeSO_4$ is highly soluble it was considered very unlikely to exist on the site.

Asbestos

- Asbestos was not detected in any of the alluvium samples.

6.0 Gas Monitoring

6.1 Sampling Strategy

As part of the 2005 site investigations, undertaken by WYG, gas sampling of selected boreholes was carried out. Gas samples were taken from boreholes using a Gresham pump on the 28th September and analysed for bulk gases including methane, carbon dioxide, oxygen, and nitrogen, as well as other gases in the $C_2 – C_7$ range. Gas from the boreholes was also analysed in situ using a landfill gas analyser on the 18th October 2005. The landfill gas analyser field measurements and laboratory results are presented in Appendix Q. The gas samples were analysed for carbon dioxide, hydrogen, hydrogen sulphide, methane, oxygen, ethane, propane, carbon monoxide, flow and atmospheric pressure. Further gas monitoring was carried out in 2006 and 2007 by Glovers Site Investigation Ltd. To date, Cork County Council has not been able to obtain the 2007 analytical results. An outline of the sampling inventory is presented in Table 6.1

Table 6.1: Gas sample inventory (2005)

Borehole Name	Analytical Gas Sampling	Field Gas Sampling
BH116	√	√
BH117	√	√
BH118	√	√
BH119	√	√
BH120	√	√
BH125	√	√
BH126	√	√
BH127	√	√
BH128	√	√
BH130	√	√
Bedrock Monitoring Well		
BH122		√

WYG outlined the existing criteria set out by the EPA which is generally for a landfill setting. There are specific trigger values for methane and carbon dioxide at 1.0% v/v and 1.5% v/v respectively. Other important values when interpreting landfill gas concentrations are the lower (LEL) and higher (HEL) explosive limits of methane of 5% v/v and 15%, respectively.

6.2 Results of Field Tests

In October 2005 methane was recorded in BH116 (8.0% v/v) and BH126 (12.0% v/v). Carbon dioxide was recorded in BH125 (0.1% v/v). High positive flows of up to 29l/hr were observed at BH126 while gas flows in the remaining boreholes ranged from 0.1l/hr (BH127) to 1.6l/hr (BH120).

Weekly monitoring was carried out between 2nd March 2006 and 7th June 2006 (WTG, 2008). Methane was typically recorded every week in Borehole BH116 and BH126 with concentrations ranging from 0% v/v to 14%v/v in BH116 and from 2 % v/v to 28 % v/v in BH126. Methane was also detected in BH119 on four occasions and concentrations ranged from 0.1% v/v to 1 % v/v.

6.3 Results of Laboratory Analysis (Gresham Pump Sampling)

- Levels of methane were detected at six of the boreholes sampled. The highest concentrations were observed at BH116 (22.1%) and BH126 (80.6%). The remaining concentrations ranged from 0.4% (BH127) to 0.8% (BH130).
- Carbon dioxide was detected at two of the boreholes sampled, BH116 (0.3%) and BH117 (0.4%).
- The levels of oxygen detected ranged from .3.3% at BH126 to 21% at BH128.
- In 2005 hydrogen sulphide was not detected at any of the boreholes sampled.
- Carbon Monoxide was detected in nine boreholes sampled and concentrations range from 1ppm at BH117 to 37ppm at BH125.
- Ethane was detected at two locations with a maximum concentration of 2 ppm v/v at BH125.
- Propane was detected at three locations. The concentrations ranged from 1ppm v/v at BH120 to 158 ppm v/v at BH126.
- n-Butane was detected at two locations with a maximum concentration of 9 ppm v/v (BH125).
- Isopentane was detected at BH125 with a concentration of 12ppm v/v.
- Pentane was detected at BH125 with a concentration of 17 ppm v/v.
- Hexane was detected at three locations. The concentrations ranged from 2 ppm v/v at BH127 to 13 ppm v/v at BH125.
- Heptane was detected at two locations with the maximum concentrations of 7 ppm v/v at BH126.

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8.0 Glossary

ABBREVIATIONS

AST Above Ground Storage Tank
BH Borehole
BS British Standard
CIRIA Construction Industry Research and Information Association
CLEA Contaminated Land Exposure Assessment
CLR Contaminated Land Report
COD Chemical Oxygen Demand
Cork Co. Co. Cork County Council
CPT Cone Penetration Test
CMRC Coastal and Marine Research Centre
DEFRA Department for Environment Food and Rural Affairs
DHHS Department of Health and Human Services (US)
DoE Department of the Environment
DoEHLG Department of Environment Heritage and Local Government
DQRA Detailed Quantitative Risk Assessment
EA Environment Agency
ELS Environmental Laboratory Services
ESB Electricity Supply Board
EPA Environmental Protection Agency
EQS Environmental Quality Standards
Glovers Glovers Site Investigations
GPS Global Positioning System
GSI Geological Survey of Ireland
HDPE High Density Polyethylene
HEL Higher Explosive Limit
HAS Health and Safety Authority
Hyder Hyder Consulting (UK) Limited
IGVs Interim Guideline Values
ICP Inductively Coupled Plasma (ICP) spectrometry
INAB Irish National Accreditation Board
IPPC Integrated Pollution Prevention and Control
KTC K.T. Cullen & Co Ltd
LEL Lower Explosive Limit
mAOD Meters Above Ordnance Datum
mBGL Metres Below Ground Level
mBOD Meters Below Ordnance Datum
mbtoc Metres Below Top of Casing
MDL Method detection limit
MDS Multi dimensional scale
NPWS National Parks and Wildlife Service
NRA National River Authority
OD Ordnance Datum
OELVs Occupational Exposure Limit Values
PAHs Polycyclic aromatic hydrocarbons
PCA Principal component analysis
PCBs Polychlorinated biphenyls
pNHA Proposed Natural Heritage Area
PSD Particle size distribution

PSP Paralytic shellfish poisoning
QRA Quantitative Risk Assessment
REC Resource & Environmental Consultants
SAC Special Area of Conservation
SAL Scientific Analysis Laboratories
SCPT Static Cone Penetration Test
SGV Soil Guideline Values
SI Site Investigation
SPA Special Protected Area
SRCs Serious Risk Concentrations
TA Luft Technische Anleitung zur Reinhaltung derLuft
TOX Toxicology reports (TOX series)
Total Chromium Trivalent and hexavalent chromium
TP Trial pit
TPH Total Petroleum Hydrocarbons
TSVs Tier 1 Screening Values
UCL Upper Confidence Limit
UKAS United Kingdom Accreditation Service
UK EA EQS United Kingdom (UK) Environment Agency (EA) Environmental Quality Standard (EQS).
US EPA United States Environmental Protection Agency
VOCs Volatile organic compounds
WHO World Health Organization
WRAS Water Regulations Advisory Scheme
WYG White Young Green Environmental (Ireland) Limited

UNITS

G A gram is one one-thousandth of a kilogram. g/l Grams/litre is a measurement of concentration used to measure how many grams of a certain substance there are present in one litre of liquid.

Kg Kilogram is the base unit of mass in the International System of Units. 1kg is 1000 grams.

Km Kilometre is 1000 metres.

L Litre is a unit of volume. It is defined as a special name for a cubic decimetre (1 L = 1 dm3). Hence 1 L ≡ 0.001 m3.

l/hr Litre per hour. The SI derived unit for volume flow rate is the cubic meter/second. 1 cubic meter/second is equal to 3.6E+6 litre/hour.

m Metre is a unit of length.

mg Milligram. An SI unit of mass, equivalent to one thousandth of a gram.

mg/kg Milligram/kilogram is equal to one ppm (see definition of ppm below).

mg/l Milligram/litre is a measure of density. It is equal to one ppm.

mg/m3 Milligrams per metre cubed is mass in volume

mS/cm MicroSiemens/centimetre

ml Millilitre is a thousandth of a litre in the metric system.

m/s Metres per second is an SI derived unit of both speed (scalar) and velocity (vector quantity which specifies both magnitude and a specific direction), defined by distance in metres divided by time in seconds.

m2/s Metres squared per second is the SI derived unit of angular momentum, defined by distance or displacement in metres multiplied by distance again in metres and divided by time in seconds.

N/m2 One Newton (N) per square meter (m2) is one Pascal (Pa) and is a unit of pressure. ng/kg nanogram/kilogram is equal to 1 ppt (see definition of ppt below).

ng/l nanogram/litre is equal to 1 ppt (see definition of ppt below).

pH potential of hydrogen ion activity.

ppb Parts per billion denotes one part per 1,000,000,000 parts, one part in 109, and a value of 1 × 10–9.

ppm Parts per million is a measure of concentration that is used where low levels of concentration are significant. The ppm value is equivalent to the absolute fractional amount multiplied by one million (106).

Ppt Parts per trillion is equivalent to the absolute fractional amount multiplied by one trillion (1012).

% v/v Percent volume per volume describes the volume of the solute in ml per 100 ml of the resulting solution.

µg Microgram is 1/1,000,000 of a gram (1 × 10-6), or 1/1000 of a milligram.

µg/l Microgram/litre. One microgram of a substance dissolved in each litre of water. This unit is equal to parts per billion (ppb) since one litre of water is equal in weight to one billion micrograms.

GLOSSARY

Abiotic are non-living chemical and physical factors in the environment.

Anticline

Anticlines are folded rock layers in which the oldest rock lies in the centre or core.

Aquifer A unit of rock or an unconsolidated deposit is called an aquifer when it can yield usable quantity of water.

Bergerhoff dust deposition gauge an instrument which is designed to measure dust deposition.

Bioaccumulation occurs when an organism absorbs a toxic substance at a rate greater than that at which the substance is lost.

Biotic means relating to, produced by, or caused by living organisms.

Biotype A biotope is an area that is uniform in environmental conditions and in its distribution of animal and plant life.

Caesium-137 Caesium-137 (also spelled cesium) is a radioactive isotope of Caesium which is a soft, silverygold alkali metal.

Carboniferous The Carboniferous is a geologic period and system that extends from the end of the Devonian period, about 359.2 ± 2.5 Ma (million years ago), to the beginning of the Permian period, about 299.0 ± 0.8 Ma.

Conceptual Mode A conceptual model represents the characteristics of a site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors (pollutant linkages).

Congeners Congeners are related chemicals. There are 209 congeners of polychlorinated biphenyls.

Contaminant a substance that is in, on or under the land and has the potential to cause harm or to cause pollution of the surrounding environment.

Cyanide Cyanide is any chemical compound that contains the cyano group (C≡N), which consists of a carbon atom triple-bonded to a nitrogen atom.

Dioxins and Furans 'Dioxins' is a collective term for the category of 75 polychlorinated dibenzo-para-dioxin compounds (PCDDs) and 135 polychlorinated dibenzofuran compounds (PCDFs). Seventeen PCDD and PCDF compounds are likely to be of toxicological significance. The most toxic of these is 2,3,7,8-tetrachlorodibenzo-pdioxin (2,3,7,8-TCDD). The toxicity of each compound depends on the number and position of the chlorine atoms within the molecules.

Electrical conductivity is a measure of a material's ability to conduct an electric current.

EPA Environmental Protection Agency. The agency protects the environment through its licensing, enforcement and monitoring activities in Ireland.

EPA EQS AA Environmental Protection Agency Environmental Quality Standard Annual Average. This means that for each representative monitoring point within the water body, the arithmetic mean of the concentrations measured over a 12 month monitoring period does not exceed the standard.

EPA EQS MAC Environmental Protection Agency Environmental Quality Standard Maximum Allowable Concentration. This means for each representative monitoring point within the water body no measured concentration exceeds the standard.

Eutrophication is an increase in chemical nutrients - typically compounds containing nitrogen or phosphorus - in an ecosystem, and may occur on land or in water.

Foreshore Also known as the intertidal zone, the foreshore is the area that is exposed to the air at low tide and submerged at high tide.

Geotextiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain.

Groundwater Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations.

Groundwater abstraction is the process of taking water from a ground source, either temporarily or permanently.

ICP Inductively Coupled Plasma spectrometry is a technique for elemental analysis which is applicable to most elements over a wide range of concentrations.

Leachate A solution resulting from leaching, as of soluble constituents from soil, landfill, etc., by downward percolating ground water.

Mass spectrometry is an analytical technique that identifies the chemical composition of a compound or sample based on the mass-to-charge ratio of charged particles.

Millscale Mill scale is a milling waste generated while rolling the metal in metal extrusion industries.

Normalisation is any process that makes something more normal, which typically means conforming to some regularity or rule, or returning from some state of abnormality.

Overburden describes all soil and ancillary material above the bedrock horizon in a given area.

PAHs Polycyclic aromatic hydrocarbons are chemical compounds that consist of fused aromatic rings and do not contain heteroatoms or carry substituents. They are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat.

Paralytic shellfish poisoning (PSP) PSP is an accumulation of toxins in shellfish produced by microscopic algae, such as dinoflagellates and diatoms, and cyanobacteria.

Particulate Matter (PM10) Particulate Matter (PM) less than ten micrometres in size (PM10).

Pathway a route or means by which a receptor can be exposed to, or affected by, a contaminant.

PCBs Polychlorinated Biphenyls are a class of organic compounds with 1 to 10 chlorine atoms attached to biphenyl which is a molecule composed of two benzene rings each containing six carbon atoms. The chemical formula for all PCBs is C12H10-xClx.

Perched Groundwater Perched Groundwater is a zone of saturation in the waste material/overburden that is discontinuous from the bedrock aquifer.

Phenol Phenol is both a manufactured chemical and a natural substance. It is a toxic, colourless crystalline solid with a sweet tarry odour.

Pollutant linkage The relationship between a contaminant, pathway and receptor.

Quaternary The Quaternary Period is the geologic time period after the Neogene Period roughly 2.588 million years ago to the present.

Receptor is something that could be adversely affected by a contaminant, such as people, an ecological system, property or a water body.

Refractory A refractory is a material that retains its strength at high temperatures.

Respirable Crystalline Silica Respirable crystalline silica is a basic component of soil, sand, granite, and many other minerals. It is primarily a quartz dust occurring in industrial and occupational settings.

SGV Soil Guideline Values are a series of measurements and values used by the United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA) to measure contamination of the soil.

Slag Slag is the by-product of smelting ore to purify metals.

Syncline Synclines are folded rock layers which have the youngest rock in its centre or core.

TA Luft Technische Anleitung zur Reinhaltung der Luft is a German air pollution control regulation.

Tectonic is a field of study within geology concerned generally with the structures within the crust of the Earth.

TOX Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans (TOX Series).

TPH Total Petroleum Hydrocarbons is a term used to describe a large family of several hundred chemical compounds that originally come from crude oil.

Variscan The Variscan (or Hercynian) orogeny is a geologic mountain-building event caused by continental collision.

VOCs Volatile Organic Compound(s) are organic chemical compounds that have high enough vapour pressures under normal conditions to significantly vaporize and enter the atmosphere.

Waulsortian Limestone Formation Waulsortian Limestone consists of poorly bedded, dense, pale grey mudstone-wackestone and fine-grained packstonegrainstone.

Windrose A windrose is a graphic tool used to give a succinct view of how wind speed and direction are typically distributed at a particular location.