Paramount Park Entertainment Resort

Phase I Geo-environmental and Geotechnical Risk Assessment

London Resort Company Holdings

23 December 2014

ATKINS

Plan Design Enable

Notice

This document and its contents have been prepared and are intended solely for London Resort Company Holdings' information and use in relation to their proposed land holding on the Swanscombe Peninsula.

Atkins Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

Document History

Job number: 5134008			**Document ref: 5134008/Phase 1/FinalRev3.0**			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 1.0	WORKING DRAFT	N Dayes L Dombowsky H Fisher J Pendleton	D Montgomery T Radford	J Apted R Slade	JE Steeds	14 November 2014
Rev 2.0	WORKING DRAFT	N Dayes L Dombowsky H Fisher J Pendleton	D Montgomery T Radford	J Apted R Slade	JE Steeds	28 November 2014
Rev 3.0	FINAL	N Dayes L Dombowsky H Fisher J Pendleton	T Radford	J Apted R Slade	JE Steeds	23 December 2014

Client Signoff

Client	London Resort Company Holdings
Project	Paramount Park Entertainment Resort
Document title	Paramount Park Entertainment Resort Phase 1 Geo-environmental and Geotechnical Risk Assessment
Job no.	5134008
Copy no.	
Document reference	5134008/Phase 1/FinalRev3.0

Table of Contents

Chapter		Pages
List of Abbreviations		**vi**
Executive Summary		**viii**
Introduction		viii
Geo-Environmental Methodology		viii
Geotechnical Methodology		viii
Risk Characterisation Summary		viii
1.	**Introduction**	**1**
1.1.	Background	2
1.2.	Aims and Objectives	2
1.3.	Scope of Work	2
2.	**Methodology**	**4**
2.1.	Information Sources	5
2.2.	Geo-environmental Methodology	5
2.3.	Geotechnical Methodology	7
2.4.	Unexploded Ordnance Risk Assessment	10
2.5.	Assumptions and Limitations	10
3.	**Regional Geology and Hydrogeology**	**11**
3.2.	Geology	13
3.3.	Geological Section	17
3.4.	Hydrogeology	18
4.	**Zone 1**	**19**
4.1.	Zone Characterisation	20
4.2.	Environmental Context	22
4.3.	Preliminary Geo-environmental Conceptual Site Model	27
4.4.	Preliminary Geotechnical Risk Assessment	29
4.5.	Zone 1 Summary	34
5.	**Zone 2**	**35**
5.1.	Zone Characterisation	36
5.2.	Environmental Context	38
5.3.	Information Gained from Public Records	43
5.4.	Preliminary Geo-environmental Conceptual Site Model	46
5.5.	Preliminary Geotechnical Risk Assessment	49
5.6.	Zone 2 Summary	54
6.	**Zone 3**	**55**
6.1.	Zone Characterisation	56
6.2.	Environmental Context	59
6.3.	Preliminary Geo-environmental Conceptual Site Model	67
6.4.	Geotechnical Context	73
6.5.	Zone 3 Summary	78
7.	**Zone 4**	**79**
7.1.	Zone Characterisation	80
7.2.	Environmental Context	83
7.3.	Information Gained from Public Records	90
7.4.	Preliminary Geo-environmental Conceptual Site Model	94
7.5.	Zone 4 Summary	103
8.	**Zone 5**	**104**

8.1. Zone Characterisation 105
8.2. Environmental Context 107
8.3. Information Gained from Public Records 111
8.4. Preliminary Geo-environmental Conceptual Site Model 114
8.5. Preliminary Geotechnical Risk Assessment 120
8.6. Zone 5 Summary 125

9. Zone 6 126
9.1. Zone Characterisation 127
9.2. Environmental Context 131
9.3. Preliminary Geo-environmental Conceptual Site Model 136
9.4. Geotechnical Context 143
9.5. Zone 6 Summary 148

10. References 149

Figures

Appendices

Appendix A. Unexploded Ordnance Report

Appendix B. Site Walkover Photographs

Appendix C. Summary of Borehole Records
C.1. List of Borehole Records
C.2. Borehole Map for Zone 1

Appendix D. Screening Sheets

Tables

Table 2-1 Estimation of the Level of Risk by Comparison of Consequence and Probability 6
Table 2-2 Exploratory Hole Grading Scheme 7
Table 2-3 Assessment of Likelihood 8
Table 2-4 Assessment of Severity 8
Table 2-5 Perceived Degree of Risk 9
Table 3-1 Regional Stratigraphy of the Swanscombe Peninsula Site 12
Table 3-2 Stratigraphic Column of the Chalk 15
Table 3-3 Summary of Seaford Chalk and Lewes Nodular Chalk Formation Characteristics 17
Table 4-1 Historical Land Uses Relating to Zone 1 21
Table 4-2 Expected Stratigraphy within Zone 1 22
Table 4-3 Natural Moisture Content in CKD on Broadness Marsh 23
Table 4-4 A Summary of the Soil Properties of Alluvium in Broadness Marsh (43) 24
Table 4-5 Environmental Permits, Incidents and Registers within 1 km of Zone 1 26
Table 4-6 Landfills and Other Waste Sites within 1 km of Zone 1 26
Table 4-7 Preliminary Conceptual Site Model for Zone 1 28
Table 4-8 Potential Geological and Geotechnical Hazards in Zone 1 29
Table 4-9 Geotechnical Risk Register for Zone 1 32
Table 5-1 Historical Land Uses Relating to Zone 2 37
Table 5-2 Expected Stratigraphy beneath Zone 2 39
Table 5-3 Natural Moisture Content in CKD on Broadness Marsh 39
Table 5-4 A Summary of the Soil Properties in Broadness Marsh (43) 40
Table 5-5 Environmental Permits, Incidents and Registers within Zone 2 41
Table 5-6 Records of Pollution Incidents within Zone 2 41
Table 5-7 Environmental Permits, Incidents and Registers Located at the End of the Jetty 42
Table 5-8 Landfill and Waste Management Permits within 1 km of Zone 2 42
Table 5-9 Preliminary Conceptual Site Model for Zone 2 47
Table 5-10 Potential Geological and Geotechnical Hazards in Zone 2 49
Table 5-11 Geotechnical Risk Register for Zone 2 52
Table 6-1 Historical Land Uses Relating to Zone 3 57

Table 6-2 Expected Stratigraphy Below Zone 3 60
Table 6-3 Licensed Discharge Consents Related to Zone 3 62
Table 6-4 Records of National Incidents Recording System, List 2, Associated with Zone 3 63
Table 6-5 Potentially Contaminative Industrial Sites within Zone 3 64
Table 6-6 Ground Gas Concentrations per Area (2004) 66
Table 6-7 Preliminary Conceptual Site Model for Zone 3 69
Table 6-8 Potential Geological and Geotechnical Hazards in Zone 3 73
Table 6-9 Preliminary Geotechnical Hazard Assessment for Zone 3 76
Table 7-1 Historical Land Use Relating to Zone 4 81
Table 7-2 Expected Stratigraphy beneath Zone 4 84
Table 7-3 Environmental Permits, Incidents and Registers Located within Zone 4 86
Table 7-4 Licensed Discharge Consents within Zone 4 87
Table 7-5 Active Environmental Permits, Incidents and Registers Located within 500 m of Zone 4 87
Table 7-6 Pollution Incidents within Zone 4 88
Table 7-7 Landfill and Waste Management Permits within Zone 4 89
Table 7-8 Summary of Atkins Soil Screening 92
Table 7-9 Summary of Exceedances by Constituents within Groundwater 93
Table 7-10 Preliminary Conceptual Site Model for Zone 4 96
Table 7-11 Potential Geological and Geotechnical Hazards in Zone 4 99
Table 7-12 Geotechnical Risk Register for Zone 4 101
Table 8-1 Historical Land Uses Relating to Zone 5 106
Table 8-2 Expected Stratigraphy Below Zone 5 108
Table 8-3 Records of Part B Enforcements within Zone 5 110
Table 8-4 Licensed Discharge Consents Related to Zone 5 110
Table 8-5 Potentially Contaminative Industrial Sites within Zone 5 111
Table 8-6 Ground Gas Concentrations per Area (2004) 113
Table 8-7 Preliminary Conceptual Site Model for Zone 5 115
Table 8-8 Geotechnical Risk Register for Zone 5 123
Table 9-1 Historical Land Uses Relating to Zone 6 128
Table 9-2 Expected Stratigraphy beneath Zone 6 131
Table 9-3 Historical Quarries in Zone 6 134
Table 9-4 Discharge Consents within 1 km of Zone 6 135
Table 9-5 Records of Pollution Incidents within 1 km of Zone 6 135
Table 9-6 Preliminary Conceptual Site Model for Zone 6 139
Table 9-7 Potential Geological and Geotechnical Hazards in Zone 6 143
Table 9-8 Geotechnical Risk Register for Zone 6 146

Figures

Figure 001 Site Layout Plan
Figure 002 Environmental Permit Boundaries
Figure 003 Geo-Environmental Hazards and Constraints Plan
Figure 004 Geotechnical Hazards and Constraints Plan
Figure 005 Borehole Grade Map
Figure 006 Borehole Depth Map
Figure 007 Geological Section A-A’
Figure 008 Zone 1: Key Features
Figure 009 Zones 1 & 2: Schematic Conceptual Site Model
Figure 010 Zone 2: Key Features
Figure 011 Zone 3: Key Features
Figure 012 Zones 3 & 5: Schematic Conceptual Site Model
Figure 013 Zone 4: Key Features
Figure 014 Zone 4: Schematic Conceptual Site Model
Figure 015 Zone 5: Key Features
Figure 016 Zone 6: Schematic Conceptual Site Model
Figure 017 Zone 6: Key Features

List of Abbreviations

Abbreviation	Definition
AOD	above Ordnance Datum
Atkins	Atkins Limited
BGS	British Geological Survey
BH	borehole
BRE	Building Research Establishment
BS	British Standard
CIRIA	Construction Industry Research and Information Association
CKD	cement kiln dust
CLEA	Contaminated Land Exposure Assessment
CLR	Contaminated Land Report
CSM	Conceptual Site Model
CTRL	Channel Tunnel Rail Link
CWG	Criteria Working Group
DWS	Drinking Water Standard
EIA	Environmental Impact Assessment
EP	Environmental Permit
EQS	Environmental Quality Standard
GAC	Generic Assessment Criteria
GQRA	generic quantitative risk assessment
ha	hectare(s)
HS1	High Speed 1
IPPC	Integrated Pollution Prevention and Control
IRZ	Impact Risk Zone
Lafarge	Lafarge Cement UK
LPPC	Local Pollution Prevention and Control
LRCH	London Resort Company Holdings
MAGIC	Multi-Agency Geographic Information for the Countryside
MDL	method detection limit
NaFRA	National Flood Risk Assessment
NGR	National Grid Reference
NIRS	National Incident Recording System
NSIP	Nationally Significant Infrastructure Project
NVZ	nitrate vulnerable zone
OS	Ordnance Survey
PAH	polycyclic aromatic hydrocarbon
PPC	Pollution Prevention and Control
PPL	potential pollutant linkage
R&D20	The Environment Agency's Remedial Targets Methodology called 'Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources'
RTD	River Terrace Deposits
SGV	Soil Guideline Values
SPT	Standard Penetration Test
SPZ	Source Protection Zone
SSAC	Site-Specific Assessment Criteria
SSSI	Site of Special Scientific Interest
SSV	soil screening value
SVOC	semi-volatile organic compound
TP	trial pit
TPH	total petroleum hydrocarbon

UCL	Upper Confidence Limit
UXO	unexploded ordnance
VOC	volatile organic compound
WML	Waste Management Licence
WS	window sample

Executive Summary

Introduction

Atkins Limited (Atkins) has been appointed by London Resort Company Holdings (LRCH) to complete Phase 1 of a two stage pre-planning ground engineering assessment of a 400 hectare (ha) area located within the Swanscombe Peninsula; herein referred to as the 'site'. The site is being considered for redevelopment as a large-scale entertainment resort.

The assessment is required to support a future planning application in accordance with the Planning Act 2008 for a Nationally Significant Infrastructure Project (NSIP) for the London Paramount Park site and to provide the information necessary to enable the consultations and submissions required under the NSIP process.

This Phase 1 assessment has been based on subdividing the site into six zones based on previous land use patterns and current ownership. The site location and zoning are shown on Figure 001.

Within this Executive Summary, synopses of both the geo-environmental and geotechnical assessments are provided on a zone by zone basis and presented graphically in Figure 003 and Figure 004 in the Figures section of the report. Further more detailed descriptions and assessments of each of the zones are provided in the main body of the report.

Geo-Environmental Methodology

A review of both historical data and the geo-environmental site setting was undertaken in order to inform an assessment of potential land contamination liabilities. Based on this information, the potential for land contamination both on and surrounding the site has been evaluated and a preliminary assessment of the potential environmental risks has been completed. While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition.

Geotechnical Methodology

An assessment of the geological and geotechnical constraints within each zone has been undertaken by reviewing the ground conditions and assessing the potential for an adverse consequence. This information has been evaluated and reviewed to determine a risk level for each constraint identified. In turn, the number and extent of constraints for each zone have been assessed to allow a comparative level of risk for each zone to be presented.

Risk Characterisation Summary

Zone 1

Geo-environmental Summary

Zone 1 located in the most northerly part of the Swanscombe Peninsula, historically comprises Broadness Marsh and has been used for the deposition of dredging from the River Thames and subsequently for extensive landfilling with cement kiln dust (CKD) waste by Blue Circle/Lafarge Cement UK (Lafarge) throughout the entire zone. The zone is largely unused currently other than for informal access by walkers etc and also includes an unmanned Port of London Authority radar/weather station and electricity pylons which support a cable crossing of the River Thames. A number of occupied houseboats are moored in the natural inlet in the north-western part of the Zone.

The CKD disposal is understood to have commenced in 1977 and the waste management licence (WML) for the site was surrendered in 1992. The CKD wastes are understood to be between 4-7m thick. The landfill operated on a dilute and disperse basis and there has been no formal restoration of the site although it was used for agriculture for a period during the 1990s.

Lafarge currently collect and treat leachate which is generated within the zone and which is both highly alkaline and contains elevated concentrations of copper which are understood to derive from the dredged materials which were historically deposited at the site rather than the CKD waste. The treated effluent is discharged to the River Thames from Bell Wharf (located in Zone 2) and is subject to a current discharge consent issued by the Environment Agency. At the time of writing Lafarge was in the process of constructing an upgraded leachate treatment system.

The CKD wastes and dredged materials represent the main sources of potential soil and groundwater contamination within the zone and are considered to present a moderate level of risk to controlled waters receptors including the River Thames and local groundwater resources. Under the current land uses, risks to human health are considered to be low or moderate to low. The geo-environmental constraints for Zone 1 are displayed on Figure 003.

Geotechnical Summary

Within Zone 1 the general geological stratigraphy is Made Ground, consisting of CKD and river dredgings, overlying alluvium interbedded with peat. These beds in turn overlie River Terrace Deposits (RTD), with White Chalk bedrock underlying the entire site. The area is general flat lying with the River Thames bordering the zone on the west, north and east.

Geotechnical constraints of a substantial risk include aggressive ground conditions, created by the high alkalinity of the CKD and the high sulphate content of the alluvium and peat. The alluvium and peat are also known to be highly weak and compressible deposits, meaning loading of the beds could lead to differential settlement. The bearing capacity of these deposits are also likely to be low, however information about the bearing capacity of CKD is unknown. It is anticipated that there will be a number of buried services crossing the zone and in addition two large high voltage pylons lie within the Zone 1 boundary, and given their size, will likely have very deep foundations.

Constraints determined as of medium risk include groundwater levels in the zone which are understood to be highly variable in depth, although generally shallow and within the CKD. The River Thames is brackish in this area, so the groundwater is likely to be saline and there is also a risk that the Tidal River or Creek deposits found on the banks of the Thames will be loose and unconsolidated resulting in a risk of Running Sand. The geotechnical constraints for Zone 1 are displayed on Figure 004.

Zone 2

Geo-environmental Summary

Zone 2, located in the north-western/central section of the Swanscombe Peninsula, historically comprised marshes prior to clay extraction in parts of the zone and subsequently landfilling, predominantly with CKD wastes associated with the adjacent cement industry. There were also some industrial uses in the south-western corner of the zone including cement manufacture and a small gasworks. The High Speed 1 (HS1) rail link crosses the zone partially in tunnel and the tunnel portal is located in the south-eastern corner of the zone. A disused sewage treatment works is also present in the centre of the zone.

Landfilling with CKD wastes has been undertaken in two main phases – North Pit and South Pit and Surge Pile. North Pit comprised the initial phase of landfilling which took place in the north-western part of the zone in a former clay pit. North Pit is thought to have been landfilled in the mid 1970s and the WML was surrendered prior to 1994. South Pit and Surge Pile landfill comprises three phases (Phases 1-3) and was first licensed in 1977 to accept CKD and a range of other wastes from the Blue Circle/Lafarge Northfleet cement works. Phase 1, which was completed by 1985, was also constructed within a former clay pit and is currently in the closure phase of its existing WML/Environmental Permit (EP). Phase 2 in the south-eastern corner of the zone, although within the land area covered by the original WML, has not been subject to landfilling due to the construction of the HS1 tunnel portal in this area. Phase 3 was constructed as a land raise on the pre-existing natural marshland and was re-permitted in 2004 as a result of CKD being reclassified by the Environment Agency as hazardous waste and to accommodate ongoing CKD disposal from the Northfleet cement works. Phase 3 was completed and restored in 2009/2010. There is an active leachate management system in place for Phase 3 which at the time of writing was being upgraded by Lafarge. All of the landfilled areas in this zone operated on a dilute and disperse basis with no engineered containment.

The CKD wastes represent the main source of potential soil and groundwater contamination within the zone and there are also likely to be further contamination sources associated with the former industrial uses in the south-western corner and the disused sewage treatment works. These are considered to present a moderate level of risk to controlled waters receptors including the River Thames and local groundwater resources. Under the current land uses, risks to human health are considered to be low or moderate. The geo-environmental constraints for Zone 2 are displayed on Figure 003.

Geotechnical Summary

The geological stratigraphy of Zone 2 consists of Made Ground covering much of the zone, consisting mainly of CKD. Below the CKD is alluvium interbedded with peat, then River Terrace deposits, all underlain by White Chalk bedrock.

In Zone 2, the geotechnical constraints determined as of a substantial risk concern similar issues to those in Zone 1. The CKD has a high alkalinity and is likely to create ground conditions which are aggressive to concrete. The alluvium and peat have a high sulphate content, which will likely contribute to the aggressive conditions. The alluvium and peat are also compressible, creating a risk of differential settlement. As previously noted, the bearing capacity of the CKD is unknown, however in the alluvium and peat beds the capacity is expected to be low. No information on buried services has been found for Zone 2; however, it is highly likely that services will be present. Historical maps show tramlines and buildings around the south and west borders of the Zone, which have now been demolished or removed, but there remains a high probability of historic foundations still being present. Constraints are also posed by current infrastructure in the zone, including the HS1 Thames tunnel which passes through the zone, oriented North-west to South-east, and emerges at a portal in the south-eastern corner of the zone and has an associated above ground exclusion zone. A disused sewage works is also found within Zone 2, which will have associated foundations and services.

Medium risk constraints will include a running sand from the Tidal River or Creek deposits found on the banks of the river Thames, as well as high groundwater levels, which are also variable across the zone. The groundwater is expected to be saline due to the brackish nature of the Thames in this area. The geotechnical constraints for Zone 2 are displayed on Figure 004

Zone 3

Geo-environmental Summary

Zone 3, located on the western side of the Swanscombe Peninsula, mainly comprises undeveloped marshland in the northern part of the zone (Zone 3A), whilst the smaller southern part (Zone 3B) has historically been used for cement manufacture, as a whiting works, chalk extraction and landfilling and currently supports a range of light industrial and waste recycling operations.

The landfilled area was used as a works tip for the adjacent Blue Circle/Lafarge Northfleet cement works and is understood to have accepted a range of waste materials including CKD and also demolition materials from the works possibly including asbestos. The landfill is understood to have operated between 1980 and 1993 and does not have a current WML/EP.

Within the undeveloped northern Zone 3A no significant potential sources of soil and groundwater contamination have been identified and, hence, risks to both environmental and human health receptors are considered to be low. Within the southern Zone 3B, risks to both controlled waters and current human health receptors are considered to be moderate. The geo-environmental constraints for Zone 3 are displayed on Figure 003.

Geotechnical Summary

In Zone 3, the geological stratigraphy generally consists of alluvium interbedded with peat, overlying River Terrace deposits and White Chalk bedrock. In the south, Head deposits are identified above the bedrock, and there is Made Ground present, infilling a historical quarry and associated with the glass recovery company and engineering/welding works present in Zone 3B.

Substantial risks within Zone 3 are associated primarily with the beds of peat and alluvium. These beds are highly weak and compressible, which can pose a risk of settlement leading to subsidence, in addition the

bearing capacity of these geological units is also expected to be low. It is anticipated that buried services will be encountered within Zone 3, although locations are unknown. The historical maps have identified various buildings in Zone 3 which have now been demolished, but the foundations may remain.

Medium risk constraints include aggressive ground conditions created by the high sulphate content in the alluvium and peat as well as issues associated with the historical works in the sub-Zone 3B. Groundwater levels are undetermined in the zone, although considering the variable and shallow nature of levels in Zone 2, it is assumed that the groundwater regime in Zone 3 is very similar. As previously noted, the River Thames is brackish in this area. The geotechnical constraints for Zone 3 are displayed on Figure 004

Zone 4

Geo-environmental Summary

Zone 4 is located in the eastern section of the Swanscombe Peninsula site and is split into three distinct sections, a northern section (Zone 4A) which has historically and is currently marsh and agricultural land (also referred to as Botany Marshes), a central section (Zone 4B), formerly partially quarried, which comprises a series of commercial/industrial areas and a southern section (Zone 4C) which comprises an area of former quarried and partially in-filled open land, known as the Sportsfield. Zone 4B currently comprises the Northfleet and Kent Kraft Industrial Estates and the eastern section of Manor Way Business Park which are characterised by small to medium sized commercial and industrial units including a car breakers, skip hire/storage company and waste transfer station. The HS1 rail line runs in a north westerly to south easterly orientation, above ground, through the south-east corner of Zone 4A and middle of Zone 4B.

London Road (A226) is situated on a chalk spine which runs west to east and forms the boundary between Zones 4B and 4C. The North Kent Railway line is located on a further chalk spine on the southern boundary of Zone 4C with Zone 6. Interconnecting chalk spines are present on Pilgrim's Road which runs partially on the boundary between Zone 4B and Zone 5 and between Zone 4C and Zone 5 where All Saints Church (a listed building), a few houses and a pub (The George and the Dragon) are located. In places these spines are cut through with historical tunnels which provided access for previous land uses.

Whilst Zone 4A has not been subject to development and has remained marshland, Zone 4B has undergone substantial changes including development as a tar distillery, paper mills, a chemical works, various tramways and electricity substations. Part of an in-filled chalk pit (Pilgrims Pit) and in-filled former lagoon are also present in the north western/northern sections of Zone 4B. Part of Zone 4C was historically in-filled and a rifle range was previously present in the western section.

The principal potential sources of soil and groundwater contamination are considered to be the former tar distillery, paper mills and chemical works alongside current operations in the industrial estates, all within Zone 4B. Risks associated with these features are assessed as moderate in terms of human health receptors (which include site workers, visitors and trespassers) and high in terms of controlled waters receptors, primarily the Principal Chalk aquifer. Risks to current human health and controlled waters receptors in Zone 4C are assessed as moderate and moderate/low with all risks associated with Zone 4A considered low. The geo-environmental constraints for Zone 4 are displayed on Figure 003.

Geotechnical Summary

The general geological stratigraphy of Zone 4 can be split by the sub-sections. In sub-Zone 4A, Alluvium interbedded with peat is found overlying RTD, all of which is underlain by White Chalk bedrock. In Zones 4B and 4C, Made Ground is found directly overlying the White Chalk, and towards the east of 4B, Head deposits are found below the Made Ground.

In Zone 4, the geology is variable, so the constraints vary between sub-Zones. In Zone 4A, substantial constraints include highly compressible beds of peat and alluvium, which can result in differential settlement; these geological units also have a low bearing capacity. In Zones 4B and 4C, rockfall from the Chalk spines is a major hazard, which is potentially being exacerbated by undercutting of the cliffs by local businesses. Dissolution features have also been identified in the spine that carries the A226, meaning there is a risk of subsidence damage or collapse. In Zone 4B, there is a recently infilled reservoir, and the Sportsfield quarry in Zone 4C has previously been infilled. As the infill material for these areas is either unknown or to be verified therefore there may be unidentified issues associated with variable composition or aggressive

chemicals. Buried services are expected to cross the site, but are currently unidentified. Foundations associated with demolished buildings are also likely to be encountered.

The medium risk constraints in Zone 4 are mainly related to the groundwater regime, as levels are highly variable, especially in the sports field quarry, and the water is expected to be saline, leading to an increased rate of corrosion to foundations. The alluvium and peat in Zone 4A have a high sulphate content, which could create aggressive ground conditions for concrete. The geotechnical constraints for Zone 4 are displayed on Figure 004

Zone 5

Geo-environmental Summary

Zone 5, located in the central section of the site/Swanscombe Peninsula, to the west of Zone 4, comprises industrial/commercial, retail and open space land uses on former chalk quarried land between the chalk spines of London Road, the North Kent Railway and Pilgrim's Road. Zone 5A, the northern section, comprises the western portion of Manor Way Business Park which consists of small to medium sized industrial units including a haulage company and electrical substation and commercial units and some retail outlets on London Road (A226). The southern portion of the zone, Zone 5B, comprises an open area which is a part in-filled former quarry off Crayland's Lane, to the south of London Road. In this section of the zone, there are a number of tunnels and associated roadways through the chalk spine upon which London Road is located.

Historically Zone 5A was part of the Portland Cement Works and also included railway tracks/tramways, an electricity substation, part of the former paper works and mills and part of the in-filled Pilgrim's Pit in the north eastern section. Zone 5B is understood to have been part in-filled by arisings from the HS1 development, which runs through the adjacent Zone 4.

Previous ground investigation and assessment associated with a former masterplan development for part of Zone 5A identified risks associated with asbestos containing materials in Made Ground, a hotspot of oil contamination in the north western section and elevated ground gas concentrations. Risks to controlled waters receptors were not deemed to be significant following risk assessment modelling.

The main potential sources of soil and groundwater contamination in the zone are the historical uses as a cement works and in-filled Pilgrim's Pit plus current industrial uses in Manor Way Business Park. Moderate risks have been assigned to current human health receptors via migration of ground gases into confined spaces and inhalation, ingestion and dermal contact with contaminated soils/dusts. Moderate risks were also assigned to controlled waters receptors via leaching and migration to the Principal Chalk aquifer. The geo-environmental constraints for Zone 5 are displayed on Figure 003.

Geotechnical Summary

Within Zone 5, the general geological stratigraphy consists of Made Ground over White Chalk bedrock. On the western zone boundary, Head deposits lie in-between the Made Ground and the Chalk, and on the northern boundary a thin bed of alluvium is recorded.

In Zone 5, significant development constraints have been identified relating to the chalk spines carrying the A226 and the railway. These spines pose a risk of rockfall, which may be being increased by undercutting of the cliffs by local businesses. Unidentified infill material in Zone 5B is expected to be partially supporting the spine, so removal of this material will increase the rockfall risk. The infill material may also pose risks, as the composition is unknown. It is expected to mainly consist of Chalk spoil from the construction of the HS1 Thames tunnel, but this is unconfirmed. Dissolution features have been identified in the spine, which can lead to subsidence. Man-made tunnels travel through the chalk as well. These tunnels can create a preferential water path, which will lead to increased weathering of the Chalk, and potential subsidence problems.

Constraints associated with high groundwater and saline groundwater have been assessed as low risk. The geotechnical constraints for Zone 5 are displayed on Figure 004

Zone 6

Geo-environmental Summary

Zone 6, located in the southern section of the site, comprises predominantly in-filled former chalk pits bordered to the east by the HS1 railway and to the west by Swanscombe town and High Street. The northern part of Zone 6 (Zone 6A) is known as Bamber Pit and is a permitted landfill (ref. WML P/01/16) within a former chalk quarry, now in the aftercare period. Bamber Pit received mixed wastes, predominantly associated with the adjacent paper industries, from 1974 until the mid 1980s. An active landfill gas extraction system is present in the western section of the landfill which manages the landfill gas risks associated with the adjacent properties in Swanscombe.

To the south of Bamber Pit is a further partially in-filled, non permitted, quarry (referred to as Bamber Pit South and also known as Baker's Hole) which includes a small pond in the north eastern section (Swanscombe Pond). It is understood this area received only inert natural deposits and that in-filling only took place over part of the site. A footpath/cycleway is present running west to east on the southern boundary of Bamber Pit South between here and a further in-filled quarry, Northfleet Landfill, to the south. The path/cycleway provides access from Swanscombe town across the HS1 rail lines to the residential area to the east.

The southern part of the zone (Zone 6B) comprises Northfleet Landfill, a further permitted landfill (ref. WML BLU002 19375) in the aftercare period, operated by Lafarge. Northfleet Landfill was active between 1984 and 2006 and received mixed household, industrial and commercial wastes, latterly restricted to inert wastes. An active gas extraction and flaring system is present and operates full-time on site with the plant located in the southern section of the landfill. There is an easement along the boundary of Northfleet Landfill with the HS1 land. A car park, an access roadway and related infrastructure for Ebbsfleet International Station are located in the eastern section of Zone 6B. Ebbsfleet International Station is located immediately east of the site with the access link road off the A2260 present in the south eastern section. A Site of Special Scientific Interest (SSSI), known as Baker's Hole, is located in the eastern section of Zone 6B. This is an important local archaeological site dating back to Palaeolithic times. Electricity pylons also traverse the landfill in a south westerly to north easterly alignment.

The principal sources of contamination in Zone 6 relate to the Bamber Pit and Northfleet Landfills and include landfill gas and leachate generation and contact with the waste materials themselves, though recognising both sites are secure from the general public. As such current risks to human health from both sites have been assessed as low to moderate/low whilst risks to controlled waters receptors via leaching/migration of contamination from the waste into the aquifers and lateral migration of contaminated groundwater are considered moderate for Bamber Pit and high for Northfleet Landfill. Risks to the Baker's Hole SSSI are assessed as moderate/low. The geo-environmental constraints for Zone 6 are displayed on Figure 003.

Geotechnical Summary

Zone 6 is largely covered by Made Ground, consisting of landfill. Along the eastern boundary, Head deposits are found, and a few boreholes in Northfleet Landfill have identified possible River Terrace deposits. The entire zone is underlain by White Chalk bedrock. Along the small Chalk spine on the partition between Zones 6A and 6B, Boyn Hill Gravel has been recorded.

Substantial constraints within Zone 6 have been identified as relating to the historical landfilling activity which has taken place in Bamber Pit and Northfleet Landfill. Oily residue and butyric acid have been identified in the landfills, meaning there is a high chance that the ground will act aggressively towards concrete. The landfills are also highly variable in composition, meaning compression and differential settlement under load is expected. Buried services are anticipated to be found within the Zone possibly associated with the infrastructure for Ebbsfleet International Station, in the South-west of the Zone. The landfills should also have a leachate and gas collection system in place, posing another risk of buried services. The Head deposits in the east are likely to have a low bearing capacity.

Medium constraints are likely to include chalk dissolution features within the chalk spines. There is also at least one tunnel present underneath the railway spine, which as previously noted could create a preferential water path leading to more dissolution features. The spines also pose a risk of rockfall, although they are

currently being supported by the infill material and should the material be removed the risk will increase. The geotechnical constraints for Zone 6 are displayed on Figure 004

1. Introduction

1.1. Background

Atkins Limited (Atkins) has been appointed by London Resort Company Holdings (LRCH) to complete Phase 1 of a two stage pre-planning ground engineering assessment of a 400 hectare (ha) area located within the Swanscombe Peninsula, which is a triangular landmass in a meander of the River Thames. The peninsula measures roughly 27 km north to south, by 2 km east to west, comprising an area of low lying marshland. Swanscombe Peninsula is herein referred to as the 'site'. The site is being considered for redevelopment as a large-scale entertainment resort. The site location is shown on Figure 001.

The terms of reference for the assessment are as provided by Buro Happold on behalf of LRCH in the document entitled "London Paramount – Pre-planning Ground Engineering Studies – Scope of Work" and as interpreted by Atkins in our proposal submitted to LRCH on 17 September 2014.

1.2. Aims and Objectives

The assessment is required to support a future planning application in accordance with the Planning Act 2008 for a Nationally Significant Infrastructure Project (NSIP) for the London Paramount Park site and to provide the information necessary to enable the consultations and submissions required under the NSIP process. In addition the assessment is also intended to inform:

- liability and also financial exposure;
- baseline conditions for relevant chapters in the Environmental Statement; and
- the need for and scope of further more detailed studies (including site investigation).

The specific technical objectives for Phase 1 of the assessment as set out in the Scope of Work are to undertake the following activities:

- collation and review of existing reports and data pertinent to the site and the objectives;
- determination of land use history by review of historical maps, data provided by landowners and other publically available data;
- determination of ground conditions (geo-environmental and geotechnical) by review of published maps, existing site investigation reports and data from the Environment Agency and other authoritative sources;
- determination of regulatory compliance by review of public register information from Local Authorities and the Environment Agency;
- perform a desk based unexploded ordnance (UXO) risk assessment;
- undertake a site walkover survey to confirm current site uses, to identify surrounding land uses which could impact upon the site and to determine possible constraints on any future site investigations; and
- preparation of a Phase 1 desk study (this report) to include the construction of an initial Conceptual Site Model (CSM), a Contamination Preliminary Risk Assessment, a preliminary geotechnical risk assessment, together with the identification of the need for, nature and scope of subsequent works necessary to enable safe development. The scope and extent of subsequent intrusive works are captured separately.

In accordance with the above objectives and scope, the potential for land contamination both on and surrounding the site has been evaluated and a preliminary assessment of the potential environmental risks has been completed. In addition, potential geological and geotechnical constraints and risks have been identified and a preliminary assessment of the ground engineering implications of the potential ground conditions on-site has been completed. While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition. This approach has been adopted as detailed development plans are currently still in preparation and would inform a more detailed risk assessment than currently being undertaken. Consideration of potential development constraints beyond geotechnical and land contamination issues, such as ecological or archaeological aspects, is outside the scope of this assessment and should be addressed separately by LCRH.

1.3. Scope of Work

This Phase 1 assessment has been based on subdividing the site into six zones (see Figure 001), based on previous land use patterns and current ownership and as agreed with Buro Happold (acting as LRCH's agent). The relevant report sections for each zone comprising the following:

- a discussion of the current zone status and key associated environmental influences observable by general inspection around the site;
- a review of the historical land use of the zone and immediate surrounding area;
- a review of the current environmental setting and sensitivity of the zone based on a review of published information;
- a discussion of the anticipated ground and groundwater conditions of the zone and immediate surrounding area based on published information;
- a preliminary CSM which describes the relationship between potential sources of contamination (both on- and off-zone), receptors and exposure pathways for the site as it is currently;
- a preliminary land contamination risk assessment prepared with reference to the proposed development, summarising the results of the above; and
- a preliminary geotechnical assessment summarising the available sources of information, including ground engineering and geotechnical risk assessments.

The relevant current EPs are shown in Figure 002. No intrusive ground investigation has been carried out by Atkins as of the date of this report.

2. Methodology

2.1. Information Sources

To support this Phase 1 assessment, information has been obtained from the following sources:

- current topographic Ordnance Survey (OS) mapping;
- GroundSure reports (GeoInsight (1), EnviroInsight (2), MapInsight (3) and FloodInsight(4));
- information provided by the British Geological Survey (BGS) website (5)(6)(7)(8);
- the Environment Agency website (9);
- the Multi-Agency Geographic Information for the Countryside (MAGIC) website (10);
- information contained on the Google Maps website (11);
- previous site investigations (as cited);
- zone-specific information obtained during a site walkover that occurred on 23 October 2014;
- liaison with the Environment Agency and both Dartford Borough Council and Gravesham Borough Council (as cited);
- information supplied by Network Rail regarding High Speed 1 (HS1) (this information is still awaited and has therefore not been included herein);
- information supplied by Lafarge Cement UK (Lafarge) and their agent Mr Peter Coveney of CMS-Enviro (as cited);
- a detailed UXO risk assessment (12) (Appendix A); and
- technical papers and published literature (as cited).

2.2. Geo-environmental Methodology

2.2.1. Environmental Assessment/ Preliminary Conceptual Site Model

2.2.1.1. Introduction

Primary guidance for assessing and managing land contamination is presented in Contaminated Land Report (CLR) 11 (13) and the Code of Practice for Investigation of Potentially Contaminated Sites British Standard (BS) 10175 (14).

This report has been prepared in line with the National Planning Policy Framework 2012 (15) which states that:

- the site should be suitable for its new use, taking account of ground conditions and land instability, including from natural hazards or former activities, and pollution arising from previous uses;
- the development is suitable for its location, i.e. unacceptable risks from pollution and land instability are prevented and that unacceptable risks to human health, buildings and the environment are mitigated; and
- where a site is affected by contamination or land stability issues, responsibility for securing a safe development rests with the developer and/or landowner.

Best practice guidance is given by the Environment Agency and Defra in CLR 11 (13), which follows the approach outlined in Guidelines for Environmental Risk Assessment and Management (16). CLR 11 provides a technical framework for application of a risk management process when dealing with land affected by contamination. This preliminary assessment has taken due account of the assessment framework and guidance given within these documents.

A preliminary geo-environmental hazards and constraints plan is presented in Figure 003.

2.2.1.2. Risk Assessment and the 'Contaminant-Pathway-Receptor Model'

Risk assessment generally involves the identification and characterisation of the hazard source or contaminant (that has the potential to cause harm), the exposure pathway(s) for the hazard, and the effect of the exposure on a receptor. Where all three elements are present (source, pathway and receptor), or are likely to be present, they are described as potential pollutant linkages (PPLs), which can then be subjected to the risk assessment and risk management process.

The approach used for this study is that which is conventional for a Phase 1 assessment, i.e. qualitative, employing professional judgement to assess the likely nature of the potential hazard sources, pathways and receptors. Qualitative risk assessment is an established approach, in the first instance, to assessing risk, particularly when investigation data are not available. This is frequently followed by ground investigation works, in order to understand better actual site conditions and enable further detailed risk assessment to be undertaken. Based on desk-based information alone, it is not possible to 'prove' the contamination status of the site, although some localised information has been obtained and has therefore been included within this desk based study and report.

Preliminary CSMs have been developed for each zone, based on available information, to assist in the assessment of potential land contamination. Under current guidance (17) and based on Atkins' experience of similar sites, contaminants are identified (within the chapters for each zone) which are likely to be present in concentrations that could cause harm and may pose a potential risk to human health, the water environment, ecosystems or the integrity of construction or building materials. High harm or risk sources are based on two scenarios (i) high hazard or toxicity with low level exposure, or (ii) low toxicity but high level of exposure and the ability to do harm.

While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition and for the current site users in terms of human health related risks. This approach was taken as detailed development plans are not currently available, and would inform a more detailed risk assessment than currently being undertaken.

2.2.1.3. The Preliminary Conceptual Site Models

For some zones, historical and zone-specific data have been screened against relevant criteria, to assess the level of risk associated with the Zone and the locations of possible hotspots of historical contamination. Where this has been undertaken, it will be clearly stated within the report chapter. Similarly, any evidence of potential contamination, revealed during the site walkover, has been used to formulate the zone-specific preliminary CSMs.

Preliminary CSMs have been created for each development zone, along with a preliminary assessment of risk with respect to each identified PPL, for the site in its current use with no mitigation measures applied. The risk categorisations presented on the zone-specific preliminary CSMs are based on an assessment of the potential consequence of each PPL occurring, along with the likelihood that each PPL will occur, in accordance with the framework provided in Construction Industry Research and Information Association (CIRIA) 552 (C552) (18).

Contaminated land risk is a function of the probability and the consequence and is defined using the risk matrix in Table 2-1.

Table 2-1 Estimation of the Level of Risk by Comparison of Consequence and Probability

		Consequence			
Probability		**Severe**	**Medium**	**Mild**	**Minor**
	High likelihood	Very High Risk	High Risk	Moderate Risk	Moderate/Low Risk
	Likely	High Risk	Moderate Risk	Moderate/Low Risk	Low Risk
	Low likelihood	Moderate Risk	Moderate/Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate/Low Risk	Low Risk	Very Low Risk	Very Low Risk

The description of the classified risks as per C552 (18):

- **Very High:** There is a high probability that severe harm could arise to a designated receptor from an identified hazard, or there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability.

- **High:** Harm is likely to arise to a designated receptor. Realisation of the risk is likely to present a substantial liability.
- **Moderate:** It is possible that harm could arise to a designated receptor. However, it is either relatively unlikely that any such harm would be severe or, if any harm were to occur, it is more likely that the harm would be relatively mild.
- **Low:** It is possible that harm could arise to a designated receptor, but it is likely that this harm, if realised, would be mild.
- **Very Low:** There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

2.3. Geotechnical Methodology

The geotechnical assessment of the site undertaken in this report is in accordance with BS EN 1997: Part 2 (2007) (19) and the UK national annex (BS 5930) (20). Where the primary objectives of the desk study are stated as: to evaluate the ground conditions based on the existing information and to plan the scope of the subsequent stages of investigation. Through reference to topographical maps, geological maps and descriptions, records of previous site use, aerial photos, previous site investigations and site walkovers. A preliminary geotechnical constraints plan is presented as Figure 004. This compares the number and extent of geotechnical and geological constraints within of all the zones to show a comparative level of risk across the site.

2.3.1. Historical Borehole Data

A number of historical borehole records have been viewed in the context of this desk study. As the published historical data can be of varying quality, each log has been graded in terms of its usefulness using the criteria set out in Table 2-2.

Table 2-2 Exploratory Hole Grading Scheme

Category	Criteria	Grade
Legibility	Readable	A
	Illegible	C
Quality of Logging	Logs provide geological and geotechnical information (e.g. strength)	A
	Logs provide geological information (e.g. chalk)	B
	Logs do not provide useful information	C
Co-ordinates and Elevation	Co-ordinates and Elevations provided	A
	Co-ordinates provided no elevation	B
	No location information	C

The overall grade for a log is the lowest score achieve in any category. Grade A logs were given priority for use in building up the conceptual ground model; Grade B logs were used with professional judgement and Grade C logs were not used.

Most of the logs have been sourced from the BGS Borehole Viewer, but some were found in Halcrow (2004). Multiple borehole logs have been provided through the Lafarge data room, relating to Northfleet landfill, however these logs have no geographical co-ordinates or elevation data, meaning they were classified as grade C logs. Because of this we were unable to utilise them in the writing of this report, but have been used to enhance our general understanding of the area. A Borehole Grade Map is presented as Figure 005 and a Borehole Depth Map is presented as Figure 006.

2.3.2. Geological and Geotechnical Constraints

Potential geological and geotechnical constraints have been identified from reviewing the readily available technical literature and a qualitative assessment made based on our engineering judgement.

2.3.3. Geotechnical Risk

For the purpose of this report, Geotechnical Risk is defined as the possibility of an adverse consequence arising from a ground hazard or circumstance.

The Geotechnical Risk Register takes into account the identified geotechnical constraints given above, along with additional project details to ensure that all significant geotechnical risks are identified, recorded, analysed and controlled. The geotechnical risks are discussed in terms of probability, severity and risk, as defined below:

***Likelihood (L)**: The perceived likelihood of the identified geotechnical hazard actually occurring (defined as a rating in Table 2-3).*

***Severity (S)**: The perceived severity, in terms of safety, financial, temporal, legal, or operational consequence, of the occurrence of the identified geotechnical hazard on the identified receptor(s) (defined as a rating in Table 2-4).*

***Risk (R)**: The perceived level of concern which should be assigned to the identified hazard, based on the likelihood of occurrence, and taking into due account the perceived severity of the impact (defined as a risk number in Table 2-5).*

The Geotechnical Risk Register and terminology adopted for this project is based on the guidance given by C.R.I. Clayton (21) and the Highways Agency (22) on managing geotechnical risk. It is a semi-quantitative assessment based on engineering judgement. The classification of probability and severity used in this Geotechnical Risk Register are summarised in Table 2-3 and Table 2-4 respectively. The risk uses the equation:

Degree of Risk (R) = Likelihood (L) x Severity (S)

The explanation of the Degree of Risk is given in Table 2-5, which gives the assessed risk level and appropriate actions.

Table 2-3 Assessment of Likelihood

Scale	Likelihood	Chance
4	Probable	> 50%
3	Likely	10% - 50%
2	Unlikely	1% - 10%
1	Negligible	< 1%

Table 2-4 Assessment of Severity

Scale	Severity	Capital Cost	Programme	Safety
4	Very High	Unsustainable costs.	Unsustainable delay.	Unsustainable chance of injury or illness.
3	High	Increased construction costs.	Increased delay to programme.	Increased chance of injury or illness.
2	Low	Small impact to costs.	Small delay to programme.	Small chance of injury or illness.
1	Very Low	Negligible impact on costs.	Negligible delay to programme.	Negligible chance of injury or illness.

Table 2-5 Perceived Degree of Risk

Risk Number	Risk Ranking	Action Required
13 to 16	High (H)	Work must not start until risk has been reduced. If risk cannot be reduced, work should not begin.
9 to 12	Substantial (S)	Work must not start until risk has been reduced. Additional Resource required.
5 to 8	Medium (M)	Consider more cost-effective solutions or improvements at no extra cost.
1 to 4	Low (L)	None

The hazards identified for this project are set out in the Geotechnical Risk Register, which is a 'live' document and will need to be updated regularly. A précis of the Geotechnical Risk Register as it stood at the time of issue of this document is set out in the following section.

2.3.3.1. Risk Matrix

The matrix below shows the risk number and risk ranking.

Likelihood		Severity	
4	Probable	4	Very High
3	Likely	3	High
2	Unlikely	2	Low
1	Negligible	1	Very Low

Likelihood	Severity 1	2	3	4
1	1 Low	2 Low	3 Low	4 Low
2	2 Low	4 Low	6 Medium	8 Medium
3	3 Low	6 Medium	9 Substantial	12 Substantial
4	4 Low	8 Medium	12 Substantial	16 High

2.3.4. Risk Register

The Geotechnical Risk Register comprises an initial assessment of the risks identified, prior to the application of risk mitigation measures, and shows how the risks can be reduced by the application of the measures. It does not consider the site in terms of any specific development proposals.

2.3.4.1. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant.

2.3.4.2. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks can be revised and assessed as either “medium” or “low”. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in others the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

2.4. Unexploded Ordnance Risk Assessment

A detailed UXO risk assessment for the site was commissioned by Atkins and completed by 6 Alpha (12). The report follows the requirements of C681 ‘UXO – A guide for the Construction Industry’ (23) and presents an overall assessment of risk for the wider site, together with recommended risk mitigation measures for earthworks including intrusive ground investigation. The report presents the overall risk for the site as ‘High’ based on the potential threat associated with German World War II air dropped high explosive bombs, incendiary devices and British anti-aircraft artillery projectiles together with a lesser threat from small arms ammunition associated with former rifle ranges on the wider site. The full report is presented in Appendix A.

2.5. Assumptions and Limitations

The current assessment has been based on the collation and evaluation of readily available documentary and anecdotal information provided by the Environment Agency, BGS, GroundSure and other data sources made available to Atkins, as detailed in Section 2.1. Some of the opinions presented herein are based on unconfirmed data and information from third parties which cannot be fully verified and, as such, no responsibility can be taken for its accuracy.

The preliminary CSMs have been developed from the available background information and the site walkover. Based upon these sources of information, a number of PPLs have been identified and are discussed herein. Not all sources of contamination, pathways or receptors may have been identified from the information sources utilised. Alternatively, sources which do not exist may have been assumed.

It should be noted that this study has been undertaken to a relatively high level specification and that the data searches are still on-going.

This report should be read in light of the legislation, statutory requirements and/or industry good practice applicable at the time of the works being undertaken. Any subsequent changes in this legislation, guidance or design may necessitate the findings to be reassessed in the light of these circumstances.

The assessment is based only on that information which was available to Atkins up to the 12 December 2014.

3. Regional Geology and Hydrogeology

3.1.1. General

This section describes in some detail the geological setting of the area. The purpose of establishing the geology is to provide a proper understanding of the lithology and diagenesis of the site. These factors control the engineering properties of the soils.

3.1.2. Regional Geology

The regional stratigraphy as described in the BGS Memoir for London and the Thames Valley is outlined in Table 3-1 below.

Table 3-1 Regional Stratigraphy of the Swanscombe Peninsula Site

Type	Period	Series	Group	Strata	Description*
Superficial	Quaternary	Holocene		Made Ground	Variable composition, man-made deposit.
				Worked Ground	Chalk, clay, sand or sand and gravel pits with little or no fill (BGS sheet map TQ57SE, 1996)
				Alluvium	Normally soft to firm consolidated, compressible silty clay but contains layers of silty, sand, peat and a basal gravel.
				Tidal Deposits	Silts and muds
				Peat	Organic rich clay which is an accumulation of a wet, dark brown partially decomposed vegetation.
				Boyn Hill Gravels Member	Sand and gravel with possible lenses of silt, clay or peat.
				Taplow Gravels Member	Sand and gravel, locally with lenses of silty, clay or peat.
				Head	Composed of gravels, sands and clay, proportions dependent on the upslope lithologies. It is a well graded deposit formed from downslope movement and creep.
Bedrock	Palaeogene	Palaeocene		Thanet Formation	Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.
	Cretaceous	Upper Cretaceous	White Chalk Group	Seaford Chalk Formation	It is a firm white Cretaceous Chalk with conspicuous semi-continuous nodular and tabular flint seams. It contains layers of hard ground and thin marl seams are present in the lower portions of the formation.
				Lewes Nodular Chalk	A hard to very hard nodular chalk with hardground layers interbedded with soft to medium hard chalks and marls.

*taken from the BGS Lexicon of Named Rock Units (8).

3.1.3. Structure

The site is situated on the edge of the London basin in the North Downs; this is the northern edge of the Wealden anticline. This is the faulted region of the London platform; faults trending about east to west dissect the bedrock. The site is situated in a down thrown block between two normal faults trending east to west.

3.2. Geology

Geological maps and boreholes from previous intrusive investigations were used to determine the local geology across the site.

3.2.1. Anthropogenic Deposits

3.2.1.1. Made Ground

Made Ground, is technically termed by the BGS as 'Artificial Ground' and can be broken down into a number of categories:

- Made Ground – Areas where material is known to have been placed by man on the pre-existing (natural or artificial) land surface (including engineering fill)
- Worked Ground – Areas where the pre-existing (natural or artificial) land surface is known to have been excavated by man.
- Infilled Ground – Areas where the pre-existing (natural or artificial) land surface has been excavated (Worked Ground) and subsequently partially or wholly backfilled (Made Ground)

For the purposes of this report reference is solely made to the term 'Made Ground'.

Made Ground varies in composition across the site, towards the north of the site it is composed predominately of cement kiln dust (CKD) due to industrial land use. Towards the south in Zone 5 and Zone 6, the Made Ground consists of material which comprises chalk, clay, sand and gravels which have been used predominately to backfill pits and quarries. In Zone 6, the landfill is composed of Thanet Sand from local quarries and domestic and industrial waste.

3.2.1.2. Cement Kiln Dust

CKD is a significant by product of the cement manufacturing process. It generally comprises a fine powdery material which is highly alkaline. A number of technical papers have been produced by the Cement Association in the USA in terms of the properties of CKD and beneficial uses of CKD in particular in stabilising clay soils.

The composition and properties of CKD are highly dependent on the nature of the design, operation and materials used in the cement kiln in which it is produced (24). As a result of this the chemical and physical properties of CKD should be assessed on an individual site basis. The alkalinity of CKD is linked to the particle size fraction, and so finer grained CKDs have a higher alkali content (25) and, in general it can be described as fine grained and self-cementing and generally has a pH of over 12 (26).

Site-specific data on the CKD is given in the relevant zone sub-sections.

3.2.2. Superficial Deposits

3.2.2.1. Alluvium

Alluvium covers a large portion of the Swanscombe Peninsula. These deposits are predominately silty clay and clayey silt with the development of some coarser grained units (27). The basal portions of the alluvium contain clasts of chalk ranging from silt to granule in size, sourced from the underlying formation. It is within these deposits the peat units are observed.

Alluvium is a highly variable material and will require site specific investigation to obtain geotechnical parameters suitable for use at each locality. It is expected to exhibit low strength and high to very high compressibility. Typically, alluvium comprises clay of low permeability but lenses and/or layers of higher permeability associated with the presence of granular material may be present.

3.2.2.2. Peat

There are two prominent layers of peat observed in multiple borehole records. The layers appear to match with BGS records from Thurrock, roughly 1 km west of the site. These correlations indicate a large continuous extent of the peat units at -4 m and -8 m above Ordnance Datum (AOD). This corresponds to approximately 8 m and 12 m bgl.

3.2.2.3. Head

Head is extremely variable although the composition closely mirrors that of the material origin. Head deposits can also contain relic features from their parent materials and consequently can be difficult to identify. Where Head is present in areas underlain by the Chalk it is likely to comprise stony pebbly clay although some deposits may be more gravelly (28).

Head is anticipated to be encountered in small pockets across the site formed from the Chalk bedrock. Its composition is sandy silty and angular to sub-angular flints. These units are sometimes referred to as coombe rock and contain chalk clasts in a clay and chalk cement (27).

This unit is typically a poor and unpredictable engineering material and may become unstable in excavations and slopes(29). There are no published geotechnical engineering parameters.

3.2.2.4. River Terrace Deposits

Both the Taplow and Boyne Hill Gravels are present at the site. The latter formed first and so is found on top of the chalk ridge. The Taplow Gravels are the youngest terrace gravels on site, they are not exposed at the surface due to the expansive cover of alluvial and tidal deposits.

3.2.2.5. Boyn Hill Gravels Member

The Boyn Hill Gravel member is composed of predominately coarse granular material with various lenses of silts, clays and peats. There is an abundant presence of flint within the deposits. It is one of the oldest River Terrace Deposits (RTD) and so sits high up in the sequence (27). During its deposition the Thames had an extensive floodplain as it flowed north-west to south-east across the site, therefore the channels of finer material will be orientated towards the south-east.

It is anticipated this unit will exhibit a high friction angle, low compressibility and moderate to high permeability.

3.2.2.5.1. Taplow Gravels Member

The Taplow Gravels member is composed predominately of coarse granular material with various lenses of silts, clays and peat. There is an abundant presence of flint within the deposits. During its deposition the Thames had a similar course to that of today and so the finer grained channels will be aligned roughly eastward.

It is anticipated this unit will exhibit a high friction angle, low compressibility and moderate to high permeability.

3.2.3. Bedrock Geology

3.2.3.1. Chalk

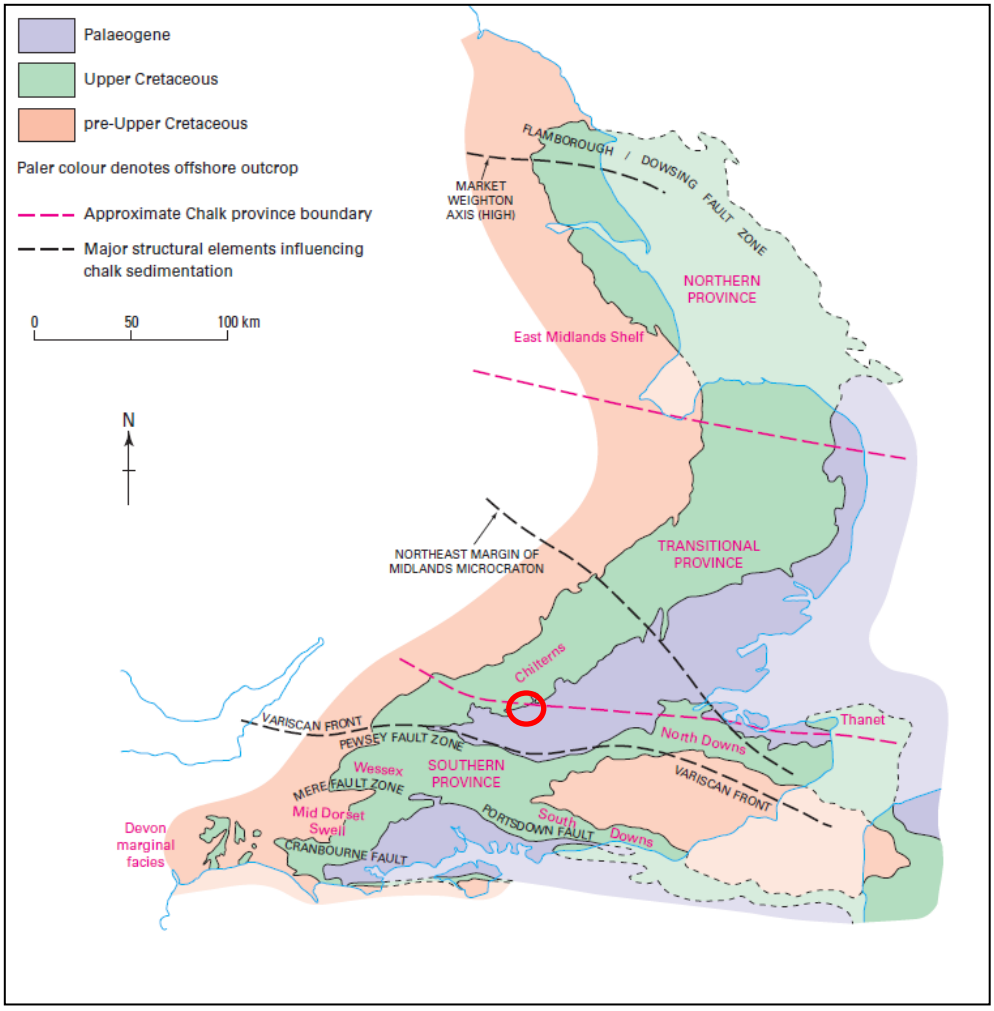
Generally chalk is a very pure white, ultra-fine grained calcium carbonate limestone with flints (nodular, tabular and sheet), marls and hardgrounds. It forms the downlands of southern England, including the North Downs and is shown on the BGS map to extend to 190-250 m thick. Stratigraphically the chalk is divided into the White Chalk group and the Grey Chalk group, this replaces the terminology of the Lower, Middle and Upper Chalk. It is also divided into three lithological and biogeographical provinces. Mortimore et al. (30) state the geological stratigraphy and province area of the chalk (lithostratigraphy) is fundamental to understanding the geotechnical characteristics of the rock.

The Swanscombe Peninsula is located on the southern boundary of the Transitional Province, with the local chalk forming part of the White Chalk Subgroup, in particular the Seaford and Lewes formations. Available borehole records do not indicate which formation and no detailed face logging has been undertaken to confirm the stratigraphy of the chalk exposures on site, consequently information is given for both formations including details on specific flint bands and belts which may impact the geotechnical engineering of the area.

Table 3-2 Stratigraphic Column of the Chalk

Transitional Province			
Old Group	**Group**	**Formation**	**Thickness (m)**
Upper Chalk	White Chalk Subgroup	Seaford Chalk	70
		Lewes Nodular Chalk	20-40

Figure 1. Chalk Group Provinces of England (31)



Note: The red circle shows the approximate location of the site.

3.2.3.2. Dissolution Features

The Seaford Chalk has been periglacially fractured close to the surface, it also contains deeply penetrating dissolution pipes (32) down to depths around 10 m (30).The pipes generally range between the Whitakers Three Inch Flint down to the Bedwell's Columnar Flint (32). These features are infilled with superficial deposits. Dissolution features have been noted on site during the walkover study, in the chalk spines of the A226 and the railway. The Groundsure Report (1) has also identified dissolution features both on site and near to the site boundary.

3.2.3.3. Weathering Zone

Chalk exhibits a highly variable and extensive weathering profile. The process of weathering can both soften and harden chalk. Soft remoulded chalks develop around blocks of chalk in valley floors where water is confined to specific bedding layers such a marl seam or sheet or tabular flint. Softening also occurs around

dissolution features where water flow is higher than the surrounding chalk. Hardening of chalk occurs where carbonate cement has been deposited via the percolation of water.

The CIRIA Classification (33) details the weathering grades for chalk from Grade A to Grade D. It is based on three factors most likely to influence the behaviours of the soil mass namely:

- hardness of the intact chalk (measured in terms of dry density);
- bedding/Discontinuity spacing and pattern; and
- discontinuity aperture.

The chalks which have been buried beneath thick sequences of Paleogene deposits are typically categorised as Grade A, this is due to the tight nature of the vertical joints within the rockmass, compared with the exposed chalks near the Thames will deep weathering zones and dissolution features, producing a rating of Grade D (30).

3.2.3.4. Seaford Chalk Formation

The Seaford Chalk Formation is a firm White Chalk with conspicuous semi-continuous nodular to tabular flint seams. The flint nodules within this unit are large to very large with hard grounds and thin marls present in the lower beds (31). Due to weathering of the bedrock during the quaternary interglacial (prior to the deposition of Terrace gravels) there is typically an upper 1-2 m of structureless chalk at the top of the unit (34) encountered beneath areas with superficial cover. The structureless chalk grades into highly fractured, competent chalk.

The Seaford Chalk can be subdivided into three beds; the Haven Brow Beds, the Cuckmere beds and the Belle Tout Beds, these are distinguished by marker beds and indicate variations in the properties of the chalk (28).

The Haven Brow Beds (about 14 m to 16 m in thickness), contain regular flint bands throughout and are described as weak to very weak and of low density. The unit has closely spaced clean closed joints which are predominately sub vertical. Within this unit is the Bedwell's Columnar Flint marker bed, this marks a 3 m portion of columnar flints which run to the base of the bed. Dissolution pipes have been observed through these units in the upper portion of local quarries (30).

Beneath the Bedwell's columnar flint lies the Cuckmere Beds (about 12 m to 15 m in thickness) which contain regular flint bands, described as extremely weak to very weak. The unit contains sub vertical joint sets near the top of the formation which transition into widely spaces sets at roughly 70°. This bed has the lowest density of the formation as described by (30). Towards the base of the formation the flints are better developed, they are overlain by dissolution features which have been in filled by silty clays, this is due to the flints forming aquicludes within the chalk. The base of the bed is marked by the Seven Sisters Flint band.

Below the Seven Sisters Flint lies the Belle Tout Beds (about 16 m to 18 m in thickness) which contains regular flint and marl bands is described as very weak to weak and contains heavily slickenside steeply inclined dipping joints at 70°. These inclined shears have commonly been in filled by sheeted flints (30). The chalk is firm but shelly varying from medium to low density. The marl units are most prominent in a central band within the bed. The Shoreham 2 Marl bed marks the base of the Seaford Chalk Formation.

3.2.3.5. Lewes Nodular Chalk Formation

The transition in formation is represented by a change in lithology. The Lewes Nodular Chalk consists of alternating very weak to moderately strong and very strong nodular chalk and hard ground. The joint sets are variable in position and are widely spaced. Flint bands are frequent throughout the Formation. Towards the base of the formation is the coarse hard rough high density nodular chalk zone (roughly 5 m thick). The marl seams throughout are roughly 0.1 m in thickness.

The higher portion of the formation contains numerous nodular flint layers which almost interlock to form laterally continuous bands with abundant cavities present above (27). Sheeted flints are also present in layers subparallel or strongly discordant to the bedding.

3.2.3.6. Engineering Parameters

A comparison of some of the key engineering geology factors of the two units are shown in Table 3-3.

Table 3-3 Summary of Seaford Chalk and Lewes Nodular Chalk Formation Characteristics

Geology	Hardness	Fracturing	Water	Stability
Seaford Chalk Formation	Very soft to medium hard	Medium spaced regular jointing	High storage capacity, main aquifer	Problems where soft (flow slides)
Lewes Nodular Chalk Formation	Alternating from very soft to very hard, some massive bands	Nodular chalk, fracturing and widely spaced conjugate joints	Low capacity except near faults	Rock slide problems

3.3. Geological Section

The geological sections have been produced based on the available borehole records and the BGS 1:10,000 geological maps using surface expression and strata dip information where available to derive a schematic geological section and capture strata succession with depth. One cross section has been produced: Figure 007.

3.3.1. Idealised Ground Model

The BGS idealised ground model for section along the course of the River Thames is general, but enables the key stratigraphic relationships to be considered for the site and the implications to geotechnical engineering design. The site is located adjacent to the River Thames and is likely to have a similar ground model.

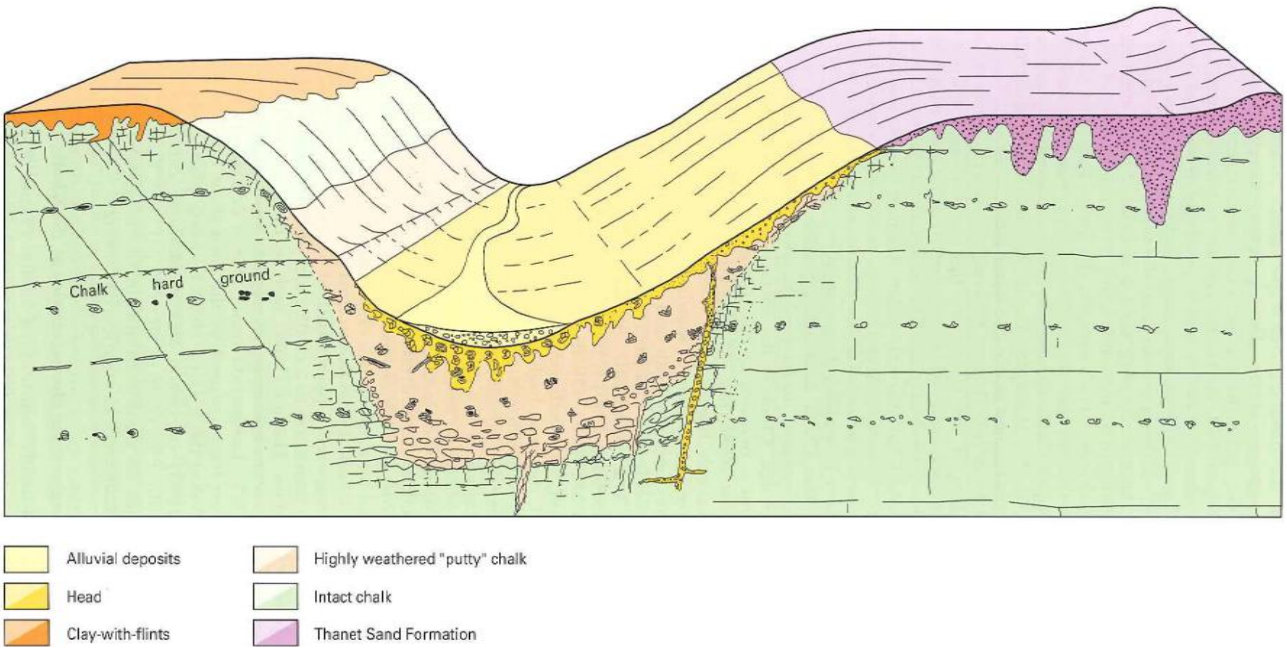


Figure A - Idealised ground model for a section along of the course of the Thames in east London (BGS, 2004)

The primary observation is the depth of the weathering profile expected beneath the areas close to the Thames and how the structure of the chalk will dictate the lateral variability of this. Another characteristic is the dissolution features which will form along joint sets and zones of preferential flow, this may be hollows or in filled with superficial material.

The model shows that the slopes from the chalk ridges down into the River Thames flood plain will have been affected by periglacial processes and natural downslope movement of material, this will result in the

formation of head deposits. The head deposits will be encountered sub surface below the expansive alluvium deposits.

Terrace Gravels lie unconformably on top of the chalk ridges, such as the Boyn Hill Gravel member (shown as the Thanet Sand Formation in the ground model). The contact between the superficial and bedrock deposits will be erosive, leading the variability in the depth of the contact; this will be dictated by variability of the strength of the chalk and the flow of the Thames during deposition.

3.4. Hydrogeology

The Alluvium and Head superficial deposits across the northern portion of the site (covering Zones 1 and 2, the majority of Zone 3, the northern half of Zone 4 and the eastern edge of Zone 6) are classified as Secondary (undifferentiated) aquifers, whilst the Boyn Hill Gravel Member superficial deposits (which underlies a very small part of Zone 5 and the north-western edge of Zone 6) are classified as a Secondary 'A' aquifer (9). The remainder of the site (the majority of Zone 6, the majority of Zone 5, and the southern half of Zone 4) are not classified as having a superficial aquifer.

The chalk bedrock underlying the entire site is classified as a Principal aquifer (9).

The BGS Hydrogeological Maps suggest that regional groundwater flow in the area is north, towards the River Thames (7), although the map is from 1968 and may now be out of date.

Refer to the individual zone chapters for zone-specific information about the local hydrogeology.

4. Zone 1

4.1. Zone Characterisation

4.1.1. Location

Zone 1 is located in the northernmost part of the Swanscombe Peninsula and is centred on approximate National Grid Reference (NGR) 560711, 176301 (TQ 60711 76301). Zone 1 is adjacent and to the north of Zones 2 and 4 and forms the tip of the peninsula with the River Thames adjacent to the north, north-west and north-east. Zone 1 is partially located in the borough of Dartford, in the western part of the site and partly located in the borough of Gravesham, in the eastern part of the site. The zone has an approximate area of 53 ha.

4.1.2. Zone Description

Zone 1 is referred to as 'Broadness Salt Marsh' and labelled as such on current topographical maps. The site is generally low lying and with an undulating topography due to historical landfilling (Broadness Landfill), predominantly with CKD, and has an elevation ranging from approximately 7 to 9 m AOD. The zone is now characterised by scrub land with some un-manned industrial uses (including a Port of London Authority radar station and weather station in the north-western section and electricity transmission pylons) and derelict former industrial structures. Electricity pylons, including an atypically large pylon, to enable cables to cross the River Thames, are present in the southern section of the zone. There are a number of access tracks/roadways and land drainage present, including the Swanscombe main drain on the southern boundary. There is an off-site area of boats and dwellings within a natural cove of the river in the north-western section of Zone 1, and it is understood the boats are occupied by a small community.

The zone is currently owned and operated by Lafarge whose land holdings extend into the adjacent Zone 2. A leachate management compound in the north-eastern section of the zone is operated by a sub-contractor to Lafarge and treats leachate from the Broadness Landfill which is collected via a series of four pumping stations and associated collection pipework. The leachate management system comprises the pumping stations and pipework, two lagoons, a control room, blower room, compressor room and ancillary structures together with a wetland area (formerly a reed bed). Collected leachate is stored in the first lagoon, aerated via a series of pipes before passing into the second lagoon for subsequent aeration and then to the wetland area where it is filtered through the shallow soils to a series of collection pipes prior to monitoring and discharge, under appropriate consent, to the River Thames (with the discharge point being the jetty to the north-west of the zone, within Zone 2 (discharge permit reference WR3237 and CATM.3237). The discharge consent allows a maximum daily discharge of 75 m^3 from the system. The management system is designed to lower the pH of the leachate together with the concentrations of certain metals (particularly copper), the latter required to meet the limits set on discharge to the River Thames. When excess leachate is collected which the system cannot process this is fed back to a 'soakaway' (an area excavated within the CKD which has been back-filled with shredded tyres to provide a permeable medium) within the landfill in the north-central section. It is understood that Lafarge (from a site visit undertaken on 23 October 2014 – see below) is currently upgrading the treatment system involving aeration using carbon dioxide. The upgraded system is required to speed up the treatment process and limit the volume of excess leachate which is piped to the soakaway. The upgraded system is due to become operational in early 2016. Further details regarding this discharge consent can be found in Section 4.2.10.

The leachate management compound and the radar station are secure; however, the majority of the site is accessible to the public and is understood to be a popular destination for walkers. There is a coastal path along the northern, western and eastern boundaries of the site which is understood to be used by walkers and bird-watchers. The site cover is approximately 99 % soft standing (grass/scrub land with some small trees/shrubs) and approximately 1 % hardstanding. The hardstanding comprises small areas of concrete near the leachate treatment system, radar station, and at the base of the electricity pylons.

For site walkover photographs, please see Appendix B. The current layout of the zone is shown on Figure 001, and key features, current and historical, are shown on Figure 008.

4.1.3. Zone-Specific Data Sources

A site walkover with Lafarge was undertaken across the site, on 23 October 2014. Atkins also attended a separate meeting with Lafarge in order to understand the context of the site. A review of planning submissions was undertaken and identified a planning support statement for the leachate treatment plant within Zone 1. Therefore, the following information sources were available:

- SLR. Broadness Marsh Leachate/Percolate Treatment Plant, Swanscombe, Kent. Section 73 Application to amend Conditions 2 of Planning Permission DA/06/200. Planning Support Statement. Reference 402.01288.00020. October 2014 (35);
- Lafarge Tarmac. Lafarge Tarmac Swanscombe Broadness and South Pit landfill; Northfleet landfill – Environmental Overview – March 2014 – Updated October 2014 (36);
- Historical borehole records provided by the BGS;
- AMEC, Percolate Treatment Discharge Review, January 2011 (37);
- AMEC, Percolate Treatment Discharge Review, February 2009 (38);
- AMEC, Percolate Treatment Discharge Review, November and December 2009 (39);
- information provided by the Client includes the Geotechnical and Land Raise Strategy Report by Halcrow (40) as well as borehole records for the Broadness Marsh CKD Tip undertaken by Harrison & Co in 1995 and Jackson Drilling Ltd in 2005; and
- additional various data as supplied by CMS-Enviro following a meeting held on 4 December 2014 (41).

In addition a historical site investigation report was identified through the BGS borehole record viewer for HS1 Preliminary Ground Investigation Stage II. At the time of writing this report, the information from the HS1 site investigation report had not been made available.

4.1.4. Surrounding Land Uses

The River Thames is located to the north, east and west of Zone 1. Beyond the River Thames to the north is the town of Grays. Northfleet Industrial Estate is adjacent to the east/south-east of the zone, with the River Thames and docks and shipyards associated with Tilbury Docks beyond. The area of Northfleet Industrial Estate directly east of Zone 1 comprises a Cemex plant/industrial area with associated stockpiles, storage containers, jetty, shipping facilities, silos and mixers. Zones 2 and 4 of the wider site, comprising the Lafarge land holdings including Botany Marshes, are located to the south. Beyond the River Thames to the west is an industrial area associated with West Thurrock.

4.1.5. Historical Land Uses

For the adjacent historical land uses of Zones 2 and 4, reference should be made to their respective Chapters. A review of historical land uses from available historical mapping provided by GroundSure has been undertaken (3) and is summarised in Table 4-1. Only off-site historical features (i.e. not within another zone of the site) have been included in Table 4-1.

Table 4-1 Historical Land Uses Relating to Zone 1

Dates and Scales	Within Zone 1	Off-site and within 1 km of the Zone
1865-1966 1:10,560 **1897-1951** 1:2,500	Bell Wharf is shown in the south-western corner of the zone and at the boundary of Zones 1 and 2. Bell Wharf has rail infrastructure and tanks. The remainder of the zone is labelled as Broadness Salt Marsh and has a number of saltings, meandering surface water features and inlets from the River Thames. A track forms the boundary between Zone 1 and Zone 2.	On the opposite bank of the River Thames (between 800 m and 1 km from the zone) are a number of industrial activities including a coal wharf, brickworks, a malthouse, ulmate of ammonia works, engineering works, cement works, and a steam corn mill. Broadness Lighthouse is located near the northernmost peninsula, just off-site to the north of Zone 1.
1973-1986 1:10,560 **1966–1992** 1:2,500 **1992-2014** 1:10,000	All visible natural surface water features within Zone 1 are no longer shown and appear to have been infilled. Modified surface water features including ponds and land drainage are now located within the zone. Electricity pylons, a radar station and access roads are shown on-zone.	Fewer industrial activities are present to the north of the zone, although some to the north-west still remain. There are now residential properties to the north of the site. Northfleet Industrial Estate has developed to the east of Zone 1 and includes a jetty, a conveyor system, a depot and a number of other buildings and structures. Ponds are shown adjacent to the south-eastern boundary of Zone 1, where there were previously no surface water features.

4.1.5.1. Summary of Historical Land uses

Zone 1 was shown as the Broadness Salt Marsh from the earliest map (1865-1866 OS Map) and remained as such until c. 1970, when the surface water features and salt marshes were infilled with waste by-products from the adjacent cement industry (predominantly CKD) and, it is understood, dredgings from the River Thames. The zone is on the northernmost part of the peninsula and is therefore surrounded on three sides by the River Thames. Anecdotal information suggests that the site was used temporarily for agriculture (wheat production and cattle grazing) during the 1990s.

A number of potentially contaminative activities were located off the zone; however they were generally located on the opposite side of the Thames and between 800 m to 1 km away from the zone. Northfleet Industrial Estate was developed adjacent to the east of the zone in c. 1970 and includes a wharf, a conveyor system, tanks and a jetty. There was a large cement works located in the southern part of Zone 2 which was owned and operated by Blue Circle Industries, later Lafarge, and was the source of the CKD deposited in Zone 1.

4.2. Environmental Context

4.2.1. Historical Borehole Records

Records of the available historical exploratory holes have been collated and reviewed using the borehole records detailed above and those available through the BGS borehole record viewer. In total 16 trial pit logs (from the HS1 investigation) and 15 borehole logs (from the Broadness Marsh CKD Tip investigation) with depths varying from 6.5 m to 32.5 m were available. These are summarised in Appendix C.

Of the borehole logs identified, all were categorised as Grade B and all the trial pit logs as Grade A. The information within these logs has been used to verify the published geological mapping information and inform the findings of this report.

4.2.2. Geology

The 1:10,000 BGS geological map, sheet TQ67NW (Grays), Solid and Drift edition (1996) shows the geological succession within Zone 1 to be Made Ground underlain by Alluvium and undifferentiated White Chalk. Towards the riverside edge of Zone 1 the superficial deposits are indicated as Tidal River or Creek Deposits. No faults are shown.

Table 4-2 Expected Stratigraphy within Zone 1

Formation	Typical Thickness (m)	Description
Made Ground	7	Weakly cemented, sandy silt, with a high proportion of CKD and some gravel
Alluvium	15	Soft to firm organic clay to silt, interbedded with peat
Tidal River or Creek Deposits	Unknown	Mainly silt and clay; locally may contain peat, sand and gravel
RTD	6	Coarse to fine flint gravel with median to coarse sand to clayey sand
Chalk	>6	Moderately weak to hard White Chalk with beds of flint in the upper 5 m

Note: typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness is marked as unknown, the bed has not been proven, and is only expected, and so a value for the thickness is not known.

4.2.3. Geomorphology

Zone 1 is located at the tip of the Swanscombe Peninsula which is a triangular landmass in a meander of the River Thames with dimensions of approximately 2.7 km by 2 km. Swanscombe Peninsula forms an area of low lying marshland, with Broadness Marsh in particular making up Zone 1.

The superficial deposits of RTD underlying Alluvium have been attributed to rising and falling sea levels during climatic changes from the Pleistocene to modern day (40).

OS topographic maps, aerial photographs and Environment Agency maps show a wide embankment feature (approximately 8 m AOD), compared to the surrounding area which has an elevation of approximately 3 m AOD, roughly 100 m from the edge of the River Thames's low water mark, skirting Zone 1. This is a flood defence system of artificially raised ground, infilled primarily with CKD.

4.2.4. Ground Conditions

A general description of the all the geological units including the CKD is presented in Section 3.2.1.2, along with geotechnical parameters reproduced from CIRIA guidance and other technical papers.

Descriptions and geotechnical parameters provided in the following sections have been obtained from the site-specific information sources detailed above. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 1, the information is provided for guidance only and it is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain site-specific design parameters.

4.2.4.1. Made Ground

All 16 trial pit records from the HS1 investigation record the Made Ground as a Flue Ash By-Product (CKD), described generally as 'Pink and cream weakly cemented silty fine to coarse sand with much to fine coarse gravel size fragment. Cement odour.'

The borehole logs from the Broadness Marsh investigation record the Made Ground as predominately comprising CKD. CKD is recorded on all the borehole logs suggestive of a laterally extensive layer being present across Zone 1. It is described as 'Light brown fine slightly granular CKD with frequent pea gravel sized compacted nodules' and is recorded as being present from just below ground surface (0.10 m bgl) and is between 4.25 m (BH09) and 7.6 m (BH13) thick, becoming damp with depth.

Underneath the CKD the borehole logs record a layer of dredgings, described as very soft wet black organic silt. The dredged materials vary from 1.0 m (BH04) to 6.0 m (BH01) thick.

Halcrow states that the Made Ground is a mixture of CKD and other wastes from the cement works, as well as dredging from the River Thames. All the trial pit logs describe the Made Ground as being a pink to cream weakly cemented sandy silt believed to be CKD, with much to no gravel (42).

The natural moisture content of the CKD, as recorded by Halcrow Group Limited (42) generally increases with depth. However, as seen in Table 4-3 below, it is highly variable both laterally and with depth. The data were collected in 1997 during the Rail Link Engineering (RLE) investigation for HS1.

Table 4-3 Natural Moisture Content in CKD on Broadness Marsh

Depth (m)	Moisture Content (%)
0.5	15 - 30
1.0	17 - 72
1.5	19 - 70
2.0	46 - 96

Compaction tests on the CKD were undertaken as part of the RLE investigation, these gave maximum dry density values in the range of 1.10 to 1.30 mg/m^3, with an optimum moisture content in the range of 40 to 50 %. Results from variable head permeability tests suggested that the CKD has a high permeability with water draining within one hour from the start of the test.

The CKD in Broadness Marsh has been recorded as having a pH of 12.6 to 13.1 which is typical of CKD in general. Chemical testing identifies the CKD as having high Sulphate and Magnesium contents.

4.2.4.2. Alluvium

The alluvium is described in the borehole logs as grey to brown organic clay interbedded with peat and is proven to be up to 14 m thick (BH09).

A bed of peat approximately 1 m thick at 13.2 m bgl, is recorded in boreholes TQ7NW566 and BH9 as well as being observed by Wessex Archaeology (2006) at the mouth of Broadness Creek (560412, 176528), during a Rapid Coastal Zone Assessment Survey. Another peat bed, at approximately 17.8 m bgl, is noted in BH9. These beds are believed to be laterally persistent across the majority of the zone, as borehole records in Zone 2 and in Thurrock (across the Thames River to the north-west of Zone 1) also observe them.

A summary of soil properties determined from testing on alluvium in the Broadness Marsh area for Blue Circle (43) is given below in Table 4-4. The sample locations and depths are unknown.

Table 4-4 A Summary of the Soil Properties of Alluvium in Broadness Marsh (43)

Soil Property	Range
Moisture Content (%)	70-169
Liquid Limit (%)	100-198
Plasticity Index (%)	70-138
Undrained Shear Strength (kPa)	3-17.5
Effective Angle of Friction (^{o})	16-22

The results of the Atterberg and triaxial strength tests indicate the alluvial clay has a high plasticity, and the high moisture content indicates organic material, likely to be peat.

4.2.4.3. Tidal River and Creek deposits

No site-specific historical ground investigation has been undertaken in the narrow band shown on the geological map as being underlain by Tidal River and Creek deposits. The BGS Lexicon of Named Rock Units (8) describes this unit as comprising a variable lithology, which is formed mainly of silt and clay; locally may contain peat, sand and gravel; infilling tidal rivers or creeks. It is likely that any investigation which has encountered these deposits will have recorded the material as alluvium.

4.2.4.4. River Terrace Deposits

RTD of predominantly gravel with some medium to coarse sand, are evident in BH9 at 20.1 m bgl, overlying the chalk. Further boreholes to this depth are not available for Zone 1, however borehole logs in Zone 3 also note the presence of these deposits, therefore it is possible to determine that these are laterally extensive across the zone. The gravels are recorded as 6 m thick and are described as ‘coarse to fine, angular to rounded predominantly chert gravel with medium to coarse sand, occasional shell fragments present throughout’.

4.2.4.5. White Chalk Group

Chalk bedrock underlies the site and is recorded in BH09 as being present at 26.1 m bgl. The chalk is described as ‘Hard white chalk with bands of large flints within the upper 0.5 m. (No putty chalk present)’. The base of BH09 was at 32.5 m bgl, proving 6.4 m of chalk. No other available records penetrated the chalk.

4.2.5. Hydrology and Hydrogeology

4.2.5.1. Surface Water

The River Thames is located along the north, east and western shore of Zone 1. Historical maps from the years 1869 to 1966 show Zone 1 to be a wetland dominated by streams, which, apart from Broadness Creek, are no longer observable in maps or aerial photography after 1970. Broadness Creek is a haven currently located along the western shore of Zone 1 with dimensions of approximately 200 m by 20 m. At least four drains are currently present in Zone 1, two of which lead to leachate lagoons located in the east and south-east corner of the zone.

4.2.5.2. Groundwater

Historical borehole data indicate that the groundwater is likely to be encountered at 3 m below existing ground level. Groundwater in the superficial deposits, particularly the RTD (a Secondary (undifferentiated) aquifer), is likely to be controlled by river-tidal processes, and is expected to be subject to saline intrusion.

Information provided by the Environment Agency (9) concludes that the chalk is a Principal aquifer and is an important aquifer in the region with water movement being primarily controlled by fractures in the rock.

4.2.5.3. Groundwater Abstractions

A medium size groundwater abstraction is located approximately 5 m outside Zone 1 to the east, currently used for mineral washing by Cemex UK Materials Ltd and spray irrigation by Lafarge. The maximum annual abstraction is between 26,300 m^3 and 1,186,000 m^3 from the chalk. No other groundwater or surface water abstractions are located within 1 km of this zone.

4.2.5.4. Groundwater Vulnerability

Information provided by the Environment Agency (9) concludes that Zone 1 is located in a Source Protection Zone (SPZ) 3: total catchment area, although the abstraction to which this refers is not explicitly clear.

4.2.6. Mineral Abstractions

There is no evidence of recent or historic mining or quarrying in Zone 1. However, it is important to note that mining of the chalk and gravel in the form of ancient deneholes and quarries is recorded further inland, including in Zones 2, 3, 4, 5 and 6.

4.2.7. Flood Risk

Based on the Groundsure FloodInsight (4), the area of Zone 1 adjacent to the River Thames is classified as an Environment Agency National Flood Risk Assessment (NaFRA) rating of “high” (1 in 30 or greater chance of flooding in any given year). The remainder of Zone 1 has a NaFRA rating of “low” (From 1 in 1000 to 1 in 100 chance of flooding in any given year) due to flood defences located on Zone 1. There have been historical flood events in the area. There are flood defences along the north, eastern and western boundaries of Zone 1.

Further details regarding flood risk can be found in Buro Happold’s Flood Risk Assessment (in preparation).

4.2.8. Designated Environmentally Sensitive Sites

There are no designated environmentally sensitive sites within 1 km of Zone 1, excluding those found within other zones on the wider site. Zone 1 is within a Site of Special Scientific Interest (SSSI) Impact Risk Zone (IRZ) for an SSSI located on the opposite side of the River Thames. This SSSI is “West Thurrock Lagoon and Marshes”, which is located 1.3 km north-west of the zone, and is designated as having an “unfavourable declining” condition at the closest point to the zone, There is also a groundwater nitrate vulnerable zone (NVZ), 955 m south of Zone 1.

4.2.9. Environmental Permits, Incidents and Registers

According to the Groundsure EnviroInsight (2), there have been two pollution incidents within Zone 1. The first occurred on 24 October 2002 and involved suspended solids (contaminated water). The second occurred on 23 January 2003 and involved landfill leachate (contaminated water).

A number of discharge consents and other EPs exist which refer to an area located 140 m north-west of Zone 1, at the end of the adjacent disused jetty (refer to Zone 2 information in Chapter 5). These consents/permits relate to the leachate discharge point located on the jetty. This discharge point is still active and is used for discharge of leachate generated from Broadness Landfill following treatment via the treatment system in the north-eastern section of the zone. The permits relating to this discharge point are summarised in Table 5-7 within Chapter 5 for Zone 2.

Active, or important historical, EPs, incidents and registers within 1 km of the zone, excluding those found within, or closer to, other zones on the wider site, have been summarised in Table 4-5.

Table 4-5 Environmental Permits, Incidents and Registers within 1 km of Zone 1

Direction and Distance from Site	Operator	Type of Permit, Incident and/or Register	Status	Additional Information
80 m east	Ready Mixed Cement	Integrated Pollution Prevention and Control (IPPC) Activity	Current	Process: batching of ready mixed cement
80 m east	Cemex Concrete Products	IPPC Activity	Current	Process: batching of ready mixed concrete
81 m east	NTC Lumber (Southern) Ltd.	IPPC Activity	Historical	Timber treatment process
179 m south-east	Lagoon Outlet	Discharge Consent	Active	Effluent type: trade discharges

4.2.10. Landfills and Other Waste Sites

The available records identify one historical landfill within Zone 1, which is the closed Broadness Landfill. There were two other landfills located within 1 km of Zone 1, excluding those located in other zones on the wider site. These landfills are summarised in Table 4-6.

Table 4-6 Landfills and Other Waste Sites within 1 km of Zone 1

Location	Landfill Name and Type	Operator	Waste Type	Dates of Operation
Zone 1	Broadness, Historical Landfill	Blue Circle Industries Ltd.	Inert, industrial	Licence issued – 15 August 1977 Licence surrendered – 2 November 1992
211 m south-east	Botany Road, Historical Landfill	Britannia Refined Metals	Inert, industrial, special	Licence issued – 14 June 1977 Licence surrendered – 19 September 2002
280 m south-east	Botany Road, Industrial Waste Landfill	Britannia Refined Metals	Factory curtilage	Licence issued – 14 June 1997 Licence expired – 27 July 1998

Lafarge (and formerly Blue Circle Industries Ltd.) has used Broadness Marsh as a landfill area for the disposal of CKD (36). Broadness Landfill does not have a current EP or Waste Management Licence (WML); however there is a discharge consent in place for treated effluent from the landfill (Ref. WR3237/CATM.3237). Broadness Landfill has been used as a landfill since before the introduction of landfill licensing in the mid 1970s. The actual date that deposition of CKD waste commenced at Broadness is unknown. The WML licence for Broadness was issued in 1977 and surrendered in 1992. Lafarge has indicated that this was the earliest disposal area for CKD of their current land holdings on Swanscombe Peninsula. The CKD was deposited onto the marsh base of river dredgings with CKD bunds. As noted above, there is presently a leachate management system comprising a collection system, holding/treatment lagoons and a wetland filtration area in the north-eastern section adjacent to the River Thames. As noted, an upgrade to the system is in progress as of the date of this report and a planning application was lodged in October 2014 to modify the system and the Broadness Marsh Landfill (35). The application indicates that raw leachate is presently pumped from the landfill into two existing lagoons. The leachate in the lagoons is then aerated by blowers to reduce the pH. As noted, Lafarge are upgrading the leachate management system and replacing the method of pH control from aeration to a combination of aeration and CO_2 dosing. The total volume discharged to the receiving waters during 2011 was 1129 m^3 at a daily average of 25 m^3 (37). The volume dosed onto the wetland system was 1603 m^3 in 2011 with a daily average of 36 m^3. There are known to be elevated copper concentrations within the landfill leachate which are currently treated via filtration of the leachate through the wetland area. Lafarge considers the source of the copper to be the river dredgings which is underlying the CKD material. CKD is known to be highly alkaline and often corrosive. Leachate from

CKD landfills typically exceeds a pH of 12.5. The composition of CKD leachate may increase the mobility of certain metals.

4.3. Preliminary Geo-environmental Conceptual Site Model

4.3.1. Introduction

The approach used for the creation of the preliminary CSM is detailed in Section 4.3. Identified zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Table 4-7. Off-site sources and receptors located outside of Zone 5 have not been included herein.

While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition and for the current site users in terms of human health related risks. This approach was taken as detailed development plans are currently in development and would inform a more detailed risk assessment than currently being undertaken.

4.3.2. Potential Sources

One potential source in Zone 1 was identified from the background searches, data review and site walkover observations for Zone 1. The identified source in Zone 1 is the landfill comprising the majority of the site and used for the deposition of CKD and previously for river dredgings. The principal media, which represent a source associated with the landfill are the leachate, the CKD/waste itself and the potential for ground gas generation.

4.3.3. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres;
- inhalation of soil- or groundwater-derived vapours;
- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- leaching from CKD/waste materials to groundwater followed by lateral migration of contamination within groundwater;
- leaching/migration of contaminants from soils;
- direct surface water run-off and sub-surface flow to surface waters;
- lateral migration of contaminated groundwater; and
- vertical migration of contaminated groundwater.

4.3.4. Potential Receptors

The potential receptors identified are:

- the Secondary (undifferentiated) aquifer within the superficial deposits beneath the zone;
- the Principal aquifer within the bedrock beneath the zone;
- the River Thames adjacent to the north, west and east of Zone 1;
- zone visitors and zone workers; and
- trespassers.

A schematic CSM for Zone 1 is shown in Figure 009.

Table 4-7 Preliminary Conceptual Site Model for Zone 1

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
Potential contaminants in soil/groundwater, originating from the following Zone 1 sources: • Contamination resulting from Broadness Landfill which received CKD and other deposits. *Potential contaminants include highly alkaline pH, metals (particularly copper) and other contaminants.*	Site visitors, site workers, and trespassers	Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	**Unlikely** The site has a soil cover and has been used for agriculture/grazing for many years. The site is currently unmanned and visitors to the site will be infrequent.	**Low Risk**
		Inhalation of soil- or groundwater-derived vapours	**Medium**	**Unlikely** The material placed in the landfill is known to comprise CKD which is unlikely to produce significant vapours. Some river dredgings were placed on site which may have comprised some organic material however it is unlikely to be in sufficient quantities to cause harm via inhalation in outdoor air. The only known indoor spaces are containers located in Zone 1 and are associated with the leachate treatment container. These foundation of these buildings are suspended above the ground, which would prevent ingress of vapours, therefore the likelihood is considered to be low.	**Low Risk**
		Migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** The deposited waste has a low biodegradable content and is not viewed as a significant gas source.	**Moderate/Low Risk**
	Controlled waters – River Thames	Leaching/migration of contaminants from soils	**Medium**	**Likely** Leachate collection and treatment measures are in place, with a discharge consent to discharge the leachate at the end of the jetty. Without the continued operation of the leachate collection and treatment measures, there would likely be migration of contamination into controlled waters receptors.	**Moderate Risk**
		Lateral migration of contaminated groundwater			
		Direct surface water run-off and sub-surface flow to surface waters			
	Controlled waters – Secondary (undifferentiated) and Principal aquifer beneath the site	Leaching/migration of contaminants from soils	**Medium**		
		Vertical migration to the Principal aquifer beneath the site	**Medium**		

4.4. Preliminary Geotechnical Risk Assessment

4.4.1. Geological and Geotechnical hazards

Table 4-8 describes some of the geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 4-8 Potential Geological and Geotechnical Hazards in Zone 1

Hazard	Description	Comment
Aggressive ground conditions	The Building Research Establishment (BRE) Special Digest (44) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	CKD covers the majority of Zone 1. The pH of the CKD is known to be highly alkaline and often caustic.
Buried foundations	Buried foundations can cause a delay to construction and incur additional costs.	There are no known large buildings present in Zone 1, confirmed by Google Earth and historical maps. There are two large electricity pylons in the Zone, which will likely have their own deep foundations.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	There is known to be a drainage network across Broadness landfill, leading to the leachate treatment works in the north-east. There are electricity cables, discharge pipes, disused pipes, leachate pipes and soakaway pipes across the site.
CKD	CKD is a significant by product of the cement manufacturing process. CKD is currently considered a hazardous product due to its high pH content.	Widespread deposition of CKD across the site. Potential for re-use subject to further study and testing. Internal settlement and compaction of the CKD is unlikely.
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	No evidence of historical quarrying has been identified in Zone 1. The zone has been subject to widespread landfilling.
Perched/high water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking construction.	Historically observed water levels are found at an average of 3 m bgl. Due to the lack of appropriate data, it is unknown whether this is a high water table or if it is a perched water table. The clay-rich beds of peat and alluvium would likely be able to support a perched water table.
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	According to the GroundSure Report (1) there is a moderate chance of running sand along the coast, with low risk throughout the rest of the zone, most probably associated with the Tidal River and Creek deposits.
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel.	The Swanscombe Peninsula is located in a brackish water zone of the Thames, meaning the

Hazard	Description	Comment
	Appropriate control measures will need to be taken.	groundwater is likely to be slightly saline. Groundwater is likely to be controlled by tidal river processes therefore levels are variable throughout the day.
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying lengths of piles.	The area is unlikely to have been quarried, but erosion and weathering from periglacial and fluvial processes will be a concern.
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The superficial deposits in Zone 1, particularly the clay, alluvium and peat will have low bearing capacity values. CKD has been recorded as being self-cementing in some cases, however the properties of it are known to vary significantly based on the exact composition and manufacturing process. There are dredgings from the River Thames underlying the CKD, of which the properties are unknown.
Weak compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Peat and alluvium are present in Zone 1. These soils appear to be weak and could deform and fail as a result of the loads imposed on them.

4.4.2. Geotechnical Risk Register

The Geotechnical Risk Register is presented as Table 4-9 below. It comprises an initial assessment of the risks outlined in Table 4-8, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. It does not consider the site in terms of any specific development proposals.

In most cases the mitigation measures will be sufficient to reduce the risk to a “low” ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be “substantial” are:

- aggressive ground;
- buried foundations;
- buried services;
- CKD;
- historical works;
- weak compressive ground; and
- weak bearing materials.

Most of the other risks are rated as “medium” to “low.”

4.4.3. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in-situ* and laboratory testing;
- planned methodology for the earthworks; and
- consideration of geotechnical issues during preliminary and detailed design.

4.4.4. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be “low”. However, it should be recognised that some residual risks remain, as described below.

Table 4-9 Geotechnical Risk Register for Zone 1

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
1	Aggressive ground conditions	4	3	3	1	12	12	4	S	Ground investigation to confirm extent and thickness of CKD. Use BRE Special Digest 1 (44) to determine the concrete class from sulphate and pH results. Use appropriate concrete protection.	4	2	2	1	8	8	4	M
2	Buried foundations	3	3	3	1	9	9	3	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	1	L
3	Buried services	3	3	3	3	9	9	9	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	CKD	4	3	3	1	12	12	4	S	Review historical records and licence areas to confirm CKD extent. Ground investigation to confirm extent and thickness of CKD. Classify and use appropriately.	4	2	2	1	8	8	4	M
5	Historical works	3	3	3	1	9	9	3	S	(See buried foundation and buried services)	2	2	2	1	4	4	2	L
6	Perched/high groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	3	1	1	1	3	3	3	L
7	Running sand	2	3	3	1	6	6	2	M	Ground investigation to confirm geological succession and geotechnical properties across the site	1	2	2	2	2	2	2	L

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
8	Saline groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	3	1	1	1	3	3	3	L
9	Variable rockhead	3	3	3	1	9	9	3	M	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
10	Weak bearing materials	4	3	3	1	12	12	4	S	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
11	Weak, compressible ground	4	3	3	1	12	12	4	S	Ground investigation to confirm extent and thickness alluvium and Tidal River and Creek deposits. Where necessary consider appropriately in geotechnical design.	3	2	2	1	6	6	2	M

4.5. Zone 1 Summary

4.5.1. Geo-environmental Summary

Zone 1, located in the most northerly part of the Swanscombe Peninsula, historically comprises Broadness Marsh and has been used for the deposition of dredging from the River Thames and subsequently for extensive landfilling with CKD waste by Blue Circle/Lafarge throughout the entire zone. The zone is largely unused currently other than for informal access by walkers etc and also includes an unmanned Port of London Authority radar/weather station and electricity pylons which support a cable crossing of the River Thames. A number of occupied houseboats are moored in the natural inlet in the northwestern part of the Zone.

The CKD disposal is understood to have commenced in 1977 and the WML for the site was surrendered in 1992. The CKD wastes are understood to be between 4-7m thick. The landfill operated on a dilute and disperse basis and there has been no formal restoration of the site although it was used for agriculture for a period during the 1990s.

Lafarge currently collect and treat leachate which is generated within the zone and which is both highly alkaline and contains elevated concentrations of copper which are understood to derive from the dredged materials which were historically deposited at the site rather than the CKD waste. The treated effluent is discharged to the River Thames from Bell Wharf (located in Zone 2) and is subject to a current discharge consent issued by the Environment Agency. At the time of writing Lafarge was in the process of constructing an upgraded leachate treatment system.

The CKD wastes and dredged materials represent the main sources of potential soil and groundwater contamination within the zone and are considered to present a moderate level of risk to controlled waters receptors including the River Thames and local groundwater resources. Under the current land uses, risks to human health are considered to be low or moderate to low.

4.5.2. Geotechnical Summary

Within Zone 1 the general geological stratigraphy is Made Ground, consisting of CKD and river dredgings, overlying alluvium interbedded with peat. These beds in turn overlie River Terrace Deposits (RTD), with White Chalk bedrock underlying the entire site. The area is general flat lying with the River Thames bordering the zone on the west, north and east.

Geotechnical constraints of a substantial risk include aggressive ground conditions, created by the high alkalinity of the CKD and the high sulphate content of the alluvium and peat. The alluvium and peat are also known to be highly weak and compressible deposits, meaning loading of the beds could lead to differential settlement. The bearing capacity of these deposits are also likely to be low, however information about the bearing capacity of CKD is unknown. It is anticipated that there will be a number of buried services crossing the zone and in addition two large high voltage pylons lie within the Zone 1 boundary, and given their size, will likely have very deep foundations.

Constraints determined as of medium risk include groundwater levels in the zone which are understood to be highly variable in depth, although generally shallow and within the CKD. The River Thames is brackish in this area, so the groundwater is likely to be saline and there is also a risk that the Tidal River or Creek deposits found on the banks of the Thames will be loose and unconsolidated resulting in a risk of Running Sand.

5. Zone 2

5.1. Zone Characterisation

5.1.1. Location

Zone 2 is located in the centre of the wider site in the north-western section of the Swanscombe Peninsula and is approximately centred on NGR 560437, 175636. The site has an approximate area of 58 ha and is located within the borough of Dartford.

5.1.2. Zone Description

The ground elevation is highly variable across the zone, with an undulating land surface ranging from approximately 1 m AOD to 6 m AOD. Zone 2 was previously marshes prior to phased landfilling with wastes from the adjacent cement industry, predominantly comprising CKD. The area was divided into several permitted landfills, as a result of the phased infilling, known as “North Pit” and “South Pit and Surge Pile”. All of these landfills were constructed on a ‘dilute and disperse’ basis i.e. there is no formal engineered containment to any of the landfilled areas.

North Pit landfill was a former clay pit and the first area within Zone 2 to be landfilled with CKD waste. The WML for this area was handed back pre 1994 and there is currently no ongoing monitoring or management of this area. It is understood whilst that no formal restoration works have taken place in this area it has naturally re-vegetated since the cessation of disposal activities.

The South Pit and Surge Pile landfill is divided into Phase 1, Phase 2 and Phase 3. Phase 1 was a former clay pit and Phase 3 was a land raise with CKD wastes deposited on the existing ground surface. It is understood that no infilling has occurred within Phase 2 although this area was included within the boundary of the EP. The site is currently owned and managed by Lafarge and has been generally restored with soil cover and is currently disused scrub land, characterised by undulating topography, grass/scrub with some small trees. The EPs for the South Pit and Surge Pile landfills are still active and this area of the zone is currently in the aftercare phase.

There were also ‘cement pits’ located on the western boundary of Zone 3 and details of infilling are not known. A disused and now derelict sewage treatment works is located near the centre of the zone. There is an active sewage pumping station located along the southern boundary of Zone 2. The HS1 railway runs in a north-west to south-east orientation in tunnel under Zone 2 and emerges at a portal in the south-central section of the zone, although the portal itself is outside the study site.

A derelict pier, known as Bell Wharf, is present in the north-western part of Zone 2. There are a number of roads, tracks and land drains across Zone 2, including the Swanscombe main drain. There is also a leachate collection system for the South Pit and Surge Pile landfill site which discharges to foul sewer. Works are currently ongoing, sub-contracted by Lafarge, to upgrade the leachate collection system around Phase 3 of the South Pit and Surge Pile landfill. The building foundations from the former cement works are present in the south-western corner of Zone 2.

A site walkover was undertaken on 23 October 2014, the photographs of which can be found in Appendix B. The boundary is Zone 2 is shown on Figure 001, the environmental permit boundaries within Zone 2 are shown on Figure 002, and the key features of Zone 2, both historical and current, can be found on Figure 010.

5.1.3. Zone-Specific Data Sources

A number of zone-specific data sources have been used to collate this. Information held by the Environment Agency was requested and has been included herein. The following information sources were available:

- Lafarge Tarmac. Lafarge Tarmac Swanscombe Broadness and South Pit landfill; Northfleet landfill – Environmental Overview – March 2014 – Updated October 2014;
- Halcrow Group Limited. Swanscombe Peninsula West Phase 1 Contamination Interpretive [sic] Report – January 2004;
- Halcrow Group Limited. Swanscombe Peninsula West Geotechnical and Land Raise Strategy Report, 2004;

- SLR, Construction and operation of a Leachate Disposal Plant, Planning Supporting Statement, September 2014;
- PPC Permit Application: EAWML 19373 South Pit Phase 3 Landfill, October 20014 (including various supporting technical reports) (45); and
- additional various data as supplied by CMS-Enviro following a meeting held on 4 December 2014.

5.1.4. Surrounding Land Uses

The majority of Zone 2 is surrounded by other site zones including Zone 1 to the north, Zone 4 to the east, Zone 5 to the south and Zone 3 to the west. The River Thames is adjacent to part of the north-western boundary of Zone 2, where the disused Bell Wharf jetty is still present.

5.1.5. Historical Land Uses

Zones 1, 3, 4 and 5 are adjacent to Zone 2, for features located in these zones, please consult their respective report chapters. The only off-site areas not within a different zone of the site are the River Thames and HS1, where it emerges from the running tunnel beneath the Thames to run above ground. From an historical land use perspective, the River Thames has not greatly changed since the earliest available maps. HS1 was constructed between the 1990s and 2007. A summary of historical land uses within Zone 2 is presented in Table 5-1 (3).

Table 5-1 Historical Land Uses Relating to Zone 2

Dates and Scales	Within Zone 2
1865-1888 1:10,560 **1865-1872** 1:2,500	The site generally comprises Swanscombe Marshes and associated drains. A track on an embankment runs along the northern boundary of Zone 2. A tramway is shown in the western part of Zone 2, between a cement works and Bell Wharf. There are 'cement pits' between the lines of the tramway tracks. The south-western part of Zone 2 is part of a cement works and includes buildings and associated rail siding. Bell Wharf and rail sidings are located in the north-western corner of Zone 2.
1897 1:2,500	The cement pits are no longer shown. Additional railways between Bell Wharf and the cement works are shown.
1907-1923 1:10,560 **1907-1909** 1:2,500	There have been excavations (considered to be clay pits) close to the western boundary of Zone 2, adjacent to Zone 3. A gasworks is shown in the south-western corner with one large circular structure, likely a gas holder.
1932-1939 1:2,500 **1932-1938** 1:10,560	A sewage treatment works, comprising sludge beds and tanks is located near to the centre of Zone 2. The gasworks is no longer shown. There are additional buildings associated with the cement works on site including railway tracks and tanks. An aerial cable runs north-west to south-east between the Zone 2 and Zone 3 boundary. There are storage tanks associated with Bell Wharf and a tank located near the centre of the tramway between Bell Wharf and the cement works.
1946-1955 1:10,560 **1951-1952** 1:2,500	Further storage tanks are shown associated with Bell Wharf. A large pond is shown near the centre of Zone 2, in the location of the present day North Pit landfill and South Pit and Surge Pile Phase 1 landfill. An electricity substation is located by the cement works in the south-western corner.
1961-1995 1:2,500 **1966** 1:10,560 **1973-1995**	The pond is now labelled as a refuse tip (considered to be the North Pit landfill and the South Pit and Surge Pile Phase 1 landfill). The sewage treatment works have been expanded.

Dates and Scales	Within Zone 2
1:10,000	
2002 1:10,000	The buildings associated with the cement works to the south-west, including the electricity substation and various storage tanks are no longer shown. A sewage pumping station is located in the southern part of Zone 2. Infilling is shown in the north-eastern part of Zone 2 at the location of South Pit and Surge Pile Phase 3.
2010 1:10,000	The railway tracks to the west are no longer shown. HS1 has been constructed and is shown passing beneath the site with the above ground portal and railway line located in the south-eastern section of the zone.

5.1.5.1. Summary of Historical Land Uses

The western part of Zone 2 was used as a tramway between a cement works (located in the south-western corner of the zone and the north of Zone 5) and Bell Wharf (located in the north-western section of the zone). There were a number of 'cement pits' located between the tramway tracks. The cement works in the south-western part of Zone 2 included buildings and railway tracks/siding. A gasworks was located in the south-western corner of Zone 2, believed to be associated with the cement works. There were storage tanks associated with Bell Wharf, the railway sidings and the gasworks. An electricity substation was located in Zone 2, near the southern boundary with Zone 5 and was associated with the cement works.

The majority of Zone 2 was subsequently infilled with CKD material from the cement works located in the south-western part of the zone as well as CKD waste which was imported from Westbury cement works into Phase 3. The infilling was undertaken in a number of phases to create the landfills known as North Pit, South Pit and Surge Pile Phase 1 and 3. There was also a sewage treatment works located near the centre of Zone 2, between South Pit and Surge Pile Phase 1 and Phase 2.

Unlike in Zone 1, there is no evidence of historical dredgings from the River Thames having been deposited in this zone.

5.2. Environmental Context

5.2.1. Historical Borehole Records

The BGS borehole record viewer has been used to collect records of all available historical exploratory holes for review. In total 18 borehole logs have been identified, with depths ranging between 10 m and 60 m.

All the boreholes for Zone 2 were conducted between 1994 and 1997; 12 were categorised as Grade A and 6 were categorised as Grade B. No borehole logs were Grade C. The information from the Grade A and B logs have been used to verify the geological maps and to inform the findings of this report.

5.2.2. Historical Reports

Information provided by the Client includes the Geotechnical and Land Raise Strategy Report by Halcrow (42). In addition to this, a historical site investigation report was identified through the BGS borehole record viewer for the Channel Tunnel Rail Link (CTRL) (referred to herein as HS1) Preliminary Ground Investigation Stage II. At the time of writing this report the raw data from the Halcrow report and the information from the HS1 site investigation report had not been made available.

5.2.3. Geology

The 1:10,000 BGS geological maps of the area, sheet TQ67NW - Grays (1994) shows the local geological succession to be Made Ground, underlain by alluvium and undifferentiated RTD. The bedrock at this zone consists of undifferentiated White Chalk (see Table 5-2). No faults are recorded in or around Zone 2.

Table 5-2 Expected Stratigraphy beneath Zone 2

Strata	Typical Thickness (m)	Description
Made Ground	7	Weakly cemented, sandy silt, with a high proportion of CKD and some gravel
Alluvium	7	Soft to firm organic clay, to silt interbedded with peat
RTD	6	Coarse to fine flint gravel, with medium to coarse sand to clayey sand
Chalk	>6	Moderately weak to hard White Chalk, with beds of flint in the upper 5 m

Note: typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness is marked as unknown, the bed has not been proven, and is only expected, and so a value for the thickness is not known.

5.2.4. Geomorphology

Zone 2 is located approximately in the centre of Swanscombe Peninsula. The area of Zone 2 is an artificial landscape comprising raised areas of CKD, with an average elevation of about 3.5 m AOD based on the walkover study, available borehole logs and topographic maps.

5.2.5. Ground Conditions

Descriptions and geotechnical parameters provided in the following sections have been obtained from the information sources listed above. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 2, so the information provided is for guidance only and it is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain site specific design parameters.

5.2.5.1. Made Ground

The Made Ground is recorded in the borehole logs from Broadness Marsh (to the North) as comprising an ashy CKD Dust and clinker. The CKD is described as a grey to pink silt, weakly to strongly cemented with some nodules of gravel sized pink siltstone. As noted above previously in the chapter, there is no evidence to suggest river dredgings were deposited on Zone 2.

The natural moisture content of the CKD, as recorded by Halcrow(42), generally increases with depth. However, as seen in Table 5-3 below, it is highly variable both laterally and with depth. The data was collected in 1997 for Broadness Marsh (Zone 1) as part of the RLE investigation; therefore it may not reflect the ground conditions for Zone 2.

Table 5-3 Natural Moisture Content in CKD on Broadness Marsh

Depth (m)	Moisture Content (%)
0.5	15 - 30
1.0	17 - 72
1.5	19 - 70
2.0	46 - 96

Compaction tests on the CKD also undertaken during the RLE investigation, gave maximum dry density values in the range of 1.10 to 1.30 mg/m^3, with an optimum moisture content in the range of 40 to 50 %. Results from variable head permeability tests suggested that the CKD has a high permeability with water draining within one hour from the start of the test.

The CKD in Broadness Marsh has been recorded as having a pH of 12.6 to 13.1, which is typical of CKD in general. Chemical testing identifies the CKD as having high sulphate and magnesium contents.

5.2.5.2. Alluvium

The alluvium is recorded in the BGS borehole logs as blue and greenish grey to dark grey coloured clay, with rare wood fragments and a strong organic odour. On average, the alluvium beds measure 8 m thick, although they vary between about 4 m and 12 m. The alluvium is interbedded with two major layers of peat, generally located at 4 m and 8 m deep. These beds are identified in some boreholes from Zone 2, as well as boreholes from Zone 1 and have been correlated across the River Thames. From this information, the beds are thought to be laterally continuous across much of Zone 1, 2 and 3. There are borehole logs showing an additional two layers of peat in the area, however in more recent boreholes, these sections of ground are described as clay with some peat **(46)**.

A summary of soil properties determined (43) from testing on alluvium in the Broadness Marsh area in Zone 1 for Blue Circle is given below in Table 5-4. This is outside of Zone 2 but the alluvial layers are similar across the two zones, so the data may still be relevant. The sample locations are unknown.

Table 5-4 A Summary of the Soil Properties in Broadness Marsh (43)

Soil Property	Range
Moisture Content (%)	70-169
Liquid Limit (%)	100-198
Plasticity Index (%)	70-138
Undrained Shear Strength (kPa)	3-17.5
Effective Angle of Friction (^{o})	16-22

The results of the Atterberg and Triaxial Strength Tests indicate the alluvial clay has a high plasticity, and the high moisture content and Plasticity Index indicates organic material, likely to be peat.

5.2.5.3. River Terrace Deposits

The RTD are found overlying the White Chalk in the majority of the boreholes located in Zone 2. The deposits are considered to be laterally extensive across the zone, with a thickness of about 7 m, and are typically described as being very dense flint gravel with a fine to coarse sand matrix. Geotechnical parameters are not available for these deposits.

5.2.5.4. White Chalk Group

The Chalk bedrock underlying Zone 2 is from the Seaford Chalk Formation and the Newhaven Chalk Formation (undifferentiated). Borehole records characterise the chalk as a weak to moderately weak strength and it is slightly to moderately weathered. There are many flint bands within the chalk which are up to 150 mm thick. Marl beds have also been observed in the deeper boreholes in this zone.

5.2.6. Hydrology and Hydrogeology

5.2.6.1. Surface Water

The River Thames borders the north-western coast of this zone; however for the most part, the perimeter is connected to other parts of the peninsula. A historical map from the year 1898 shows that the zone is a large marshland, although with very little surface water. Modern maps however, show surface drains added to regulate the CKD landfill.

5.2.6.2. Groundwater

From the information provided in available borehole logs, it has been concluded that groundwater is likely to be encountered at about 11 m bgl, although in some areas it may be as high as 1.6 m bgl in the Made Ground. The RTD are expected to be saturated. Groundwater in the superficial deposits is likely to be controlled by river-tidal processes due to the proximity to the river Thames. The River Thames is also brackish in this area, meaning the groundwater is likely to be saline. Information provided by the Environment Agency concludes that the chalk is the major aquifer in the region with water movement being primarily controlled by fractures in the rock (9).

5.2.6.3. Groundwater Abstractions

A medium size groundwater abstraction is located approximately 500 m to the east of Zone 2, currently licensed for mineral washing by Cemex UK Materials Ltd and spray irrigation by Lafarge. The maximum annual abstraction is 1,186,000 $m^3$and 26,300 m^3 for the respective purposes. No other groundwater or surface water abstractions are located within 1 km of this zone.

5.2.6.4. Groundwater Vulnerability

Information provided by the Environment Agency (2014) concludes that the eastern half of Zone 2 is located in a SPZ 3: total catchment area.

5.2.7. Flood Risk

Zone 2 is generally at high risk of flooding though benefits from flood defences. It is within an Environment Agency Zone 2 Flood Plain and has a NaFRA rating of High (1 in 30 or greater) chance of flooding in any given year. The south-eastern part of Zone 3, adjacent to Zone 2, falls within a Zone 3 Flood Plain. There have been historical flood events in this area (47).

Further details regarding flood risk can be found in Buro Happold's Flood Risk Assessment (in preparation).

5.2.8. Mineral Abstractions

There are some unspecified pits in the area of Zone 2. The material extracted from these pits is not identified in literature, but given the geology and the history of cement production in the area, the pits were likely for excavating alluvial clay.

5.2.9. Designated Environmentally Sensitive Sites

There are no designated environmentally sensitive sites within 1 km of Zone 2, excluding those found within other zones on-site.

5.2.10. Environmental Permits, Incidents and Registers

Active, or important historical EPs, incidents and registers within Zone 2 have been summarised in Table 5-5 (2).

Table 5-5 Environmental Permits, Incidents and Registers within Zone 2

Operator	Type of Permit, Incident and/or Register	Status	Additional Information
Croxton & Garry	Local Pollution Prevention and Control (LPPC) (Part B)	Historical Permit	Cement/lime/mortar process
Swanscombe Sewage Treatment Works	Discharge Consent	Effective Date: 8/2/1984 Revocation Date: 18/6/1990	Sewage discharges
Swanscombe Pumping Station	Discharge Consent	Effective Date: 31/3/2010	Effluent type: sewage discharges, pumping station, water company

Records of pollution events within Zone 2 are presented in Table 5-6.

Table 5-6 Records of Pollution Incidents within Zone 2

Incident Date	Pollutant	Impacts
Occurred on 9/10/2003	Contaminated water	Category 3: Minor impact to land
Occurred on 8/1/2007	Crude Sewage	Category 2: Significant impact to water

There are a number of discharge consents and other EPs for an area located 140 m north-west of Zone 1, and just outside of the boundary of Zone 2 at the end of the adjacent disused jetty associated with Bell Wharf (2). The discharge consents relate to landfill discharge from the landfills within Zone 1 (Broadness Landfill). Leachate from Zone 2 is not discharged at this point, and is discharged to foul sewer. The jetty is part of Zone 2 and the permits relating to this discharge point are summarised in Table 5-7.

Table 5-7 Environmental Permits, Incidents and Registers Located at the End of the Jetty

Owner	Type of Permit, Incident and/or Register	Status	Additional Information
Various iterations of Lafarge Tarmac including Blue Circle Industries plc.	List 2 Dangerous Substance Inventory Site	Active	Authorised substances: chromium, copper, lead, nickel, zinc
	Red List Discharge Consents	Active	Discharge types: manufacture of cement, lime plaster, and industrial waste site Effluent type: trade discharges (process), waste sites (unspecified)
	List 1 Dangerous Substance Inventory Site	Active	Authorised substances: mercury (other)
	Discharge Consent (3 permits)	First permit became effective on 13/5/1998, latest permit is still active	Effluent type: trade discharges

5.2.11. Landfills and Other Waste Sites

The majority of the site has been used as landfill. Part of the area was excavated as a clay pit and these later formed North Pit and South Pit and Surge Pile Phase 1 landfills. South Pit Phase 3, which is a land raise rather than a backfilled clay pit, has recently been re-permitted. South Pit Phase 2 landfill was permitted but was not infilled. The landfills were used for the disposal of CKD and other demolition waste from the adjacent cement works and other cement plants.

A summary of the landfill and waste management permits is presented in Table 5-8, below (2).

Table 5-8 Landfill and Waste Management Permits within 1 km of Zone 2

Licence/ Reference Number	Type	Landfill Name and Type	Operator	Waste Type	Dates of Operation
Landfill reference: 19373 EPR/RP3039SZ	Part A(1) and IPPC Authorised Activities Permit	South Pit Phase 3 Landfill	Lafarge Tarmac Cement and Lime Limited	Waste landfilling up to >10 tonnes daily with capacity of >25,000 tonnes excluding inert waste	Issued 28 May 2014 and remains effective
WML P/01/11A	Industrial waste landfill	South Pit and Surge Pile	Lafarge Tarmac Cement and Lime	A7 Industrial waste: factory curtilage	Permit still operational
WML P/01/11A	Industrial waste landfill	South Pit and Surge Pile	Lafarge Cement UK Ltd.	Factory curtilage	Licence Issued 30 May 1977

Licence/ Reference Number	Type	Landfill Name and Type	Operator	Waste Type	Dates of Operation
WML P/01/11A	Historical landfill	South Pit	Blue Circle	Inert, industrial waste	Licence issued 14 June 1977 Permit still operational
EPR/KP3998HW	Licensed waste site	South Pit and Surge Pile	Blue Circle Industries plc	Industrial waste landfill: factory curtilage with a size of over 75,000 tonnes	Licence issued 30 May 1977 Licence modified 29 April 1994
EPR/KP3998HW	Licensed waste site	South Pit and Surge Pile	Lafarge	Industrial waste landfill: factory curtilage with a size of over 75,000 tonnes	Licence issued 30 May 1977 Licence modified 22 November 2013
WML P/1/11	Historical landfill	North Pit	Lafarge	Unknown	Unknown

5.2.11.1. North Pit

North Pit landfill is located within a former clay pit. The first landfilling of CKD waste in Zone 2 occurred in North Pit under WML P1/11. The precise dates of infilling are not known, however infilling is understood to have occurred here prior to the licensing of South Pit and Surge Pile landfill (WML P/1/11A) in 1977. The permit was surrendered prior to 1994 (36). There is no known ongoing monitoring or aftercare of North Pit and relatively little information is available on ground conditions in this area.

5.2.11.2. South Pit and Surge Pile

Following infilling at North Pit, a large part of Zone 2 was licensed on 30 May 1977 under WML P/01/11A. The licence allowed for the deposition of CKD, metal scrap, scrap rubber, waste filter cloths, empty bags, sacks and containers, snowcem (cement paint) waste and non-toxic excavation and demolition waste. The area under this licence/permit comprises Phase 1, Phase 2 and Phase 3 of the South Pit and Surge Pile landfill. Phase 2 was not infilled due to the HS1 development in that area. Prior to infilling, clay excavation took place within the area comprising Phase 1 to a depth of 6 m (41) and a proportion of the waste materials within Phase 1 is understood to be within the saturated zone. South Pit and Surge Pile Phase 1 and Phase 2 are currently subject to a closure notice for WML P/01/11A issued by the Agency of 8 December 2008.

Phase 3 was re-permitted in 2004 under an IPPC Permit Reference RP3039SZ to support ongoing CKD disposal and the site was classified as a hazardous waste landfill due to the waste categorisation of CKD having been revised from non-hazardous to hazardous by the Environment Agency (36). Waste disposal within Phase 3 was completed in 2009. No known excavations or quarrying have taken place within Phase 3, which was constructed as a land raise with wastes being deposited on the existing marsh land surface. The surface elevation of Phase 3 is between 6 and 13 m AOD (36).

There is no basal or side lining containment engineering system for Phase 3. There is a leachate collection and treatment system in place for Phase 3 which is believed to discharge to foul sewer. There is also a separate leachate collection and treatment system in place for Broadness Marsh (Zone 1) which discharges at the end of the jetty associated with Bell Wharf, which is located in Zone 2. Surface water drainage across Phase 3 also discharges at the end of the jetty.

Works are currently underway (23 October 2014) to replace/upgrade sections of the leachate collection system and treatment plant around the perimeter of Phase 3. Unlike Broadness landfill in Zone 1, leachate from landfills in Zone 2 does not contain elevated copper concentrations

5.3. Information Gained from Public Records

5.3.1. Previous Ground Investigation

A 2004 masterplan for the Swanscombe Peninsula was available from Dartford Borough Council. Part of Zone 2, along with Zone 3 and part of Zone 5, had been put forward as a large-scale new development to include 1,750 mixed dwellings, general commercial and industrial developments including offices, warehousing, retail, financial and professional services, restaurants, primary schools and a number of other community facilities with associated infrastructure and services within this area.

An Environmental Impact Assessment (EIA) and an Environmental Statement were undertaken. Through this process, a land contamination report (48) was also produced subsequent to intrusive ground investigations undertaken across the zone.

The following works were undertaken within Zone 2:

- 6 No. mechanically excavated trial pits (TP);
- 4 No. window sampling locations (WS); and
- 2 No. cable percussion boreholes (BH).

The investigation was undertaken in order to assess part of the Swanscombe Peninsula for the proposed mixed-use development. The development planning was later halted. “Phase 1” was segregated into five distinct areas:

- Swanscombe Cement Works and Whiting Works (Area 1);
- Swanscombe Gas Works Perimeter (Area 2);
- Lovers Lane Pit (known as Swanscombe Cement Landfill by the Environment Agency and referred to as such throughout this report) (Area 3);
- Black Duck Marsh (marked as Swanscombe Marshes on historical and current maps, and referred to as such throughout this report) (Area 4); and
- Sea Wall (Area 5).

The report is available on the Dartford Borough Council planning portal.

The Swanscombe Gas Works Perimeter (Area 2) falls into Zone 2. Risk assessments for human health and controlled waters were undertaken using legislation and best practice applicable at the time, including Soil Guideline Values (SGVs) and Site-Specific Assessment Criteria (SSAC) were developed. A Controlled Waters Risk Assessment was undertaken using the Environment Agency Remedial Targets Methodology (R&D20) (‘Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources’) tiered approach.

5.3.1.1. Human Health Risk Assessment

The laboratory results from the ground investigation are unavailable and thus, a direct reassessment of the data has not been possible. Based on the conclusions from the human health investigation undertaken by Halcrow, the ground investigation found three samples with elevated arsenic, although the concentrations were below the SGV (500 mg/kg). The maximum lead concentration within the top 1 m was 650 mg/kg at TP81 (located to the north-west of the gasworks near the south-western boundary of Zone 2). All of the soils had concentrations of lead below the SGV for commercial/industrial sites. The 95 % Upper Confidence Limit (UCL) of the mean for the top 1 m were below the SGV for residential developments.

There were two exceedances of the SGV for residential developments with gardens by chromium. No samples exceeded the SGV for commercial/industrial end uses for chromium. There was one exceedance of the SGV for residential developments by nickel, however the 95 % UCL of the mean for nickel was below the SGV for residential developments. Toluene was detected in six locations with a maximum of 0.14 mg/kg. Samples from TP90 (located south-east of TP81, north-west of the former gasworks) were noted as having elevated concentrations of “possible oil” with a maximum tentative concentration of 5,700 mg/kg. The Halcrow report does not specify what compounds were measured. Polycyclic aromatic hydrocarbon (PAH) concentrations taken from TP90 were noted as “not elevated”.

5.3.1.2. Controlled Waters

The laboratory results from the ground investigation are unavailable and thus, a direct reassessment of the data has not been possible. Based on the conclusions from the Halcrow report, there were volatile organic compounds (VOCs) detected at a concentration of 0.313 mg/l in soil-derived leachate samples and semi-volatile organic compounds (SVOCs) detected at a concentration of 0.616 mg/l. A hydrocarbon odour was noted in TP92 (to the west of the former gasworks), and there were elevated concentrations of cyclohexane in the Made Ground. An unidentified “oil” was reported at a concentration of 3.857 mg/l within soil-derived leachate samples from TP92 at a depth of 1.8 m. Total petroleum hydrocarbon (TPHs) were detected in groundwater within the Made Ground and the chalk at a concentration of 0.630 mg/l, VOCs were detected at a concentration of 0.175 mg/l and SVOCs were detected at a concentration of 2.200 mg/l.

5.3.1.3. Ground Gas

One ground gas monitoring point was installed to the west of the historical gasworks. Methane was not detected above the method detection limit (MDL) and carbon dioxide was recorded as 3.2 % v/v.

5.3.2. Leachate Disposal Plant

In September 2014, SLR submitted a planning application (49) for the construction of a leachate disposal plant on behalf of Lafarge. The proposed system included a methane stripping and pH control tank, two leachate storage tanks, a tanker loading and a discharge to sewer system and a 20” ISO shipping container housing control equipment, including the blowers and discharge pumps. The planning supporting statement does not include details of a leachate collection system within the landfill.

5.3.3. South Pit Phase 3 Landfill Environmental Performance Annual Report January-December 2011

Lafarge has provided an Environmental Performance Annual Report for South Pit and Surge Pile Phase 3 (41). Landfill gas monitoring has been undertaken at boreholes installed within the waste and just outside of the waste. The maximum concentration of methane detected in 2011 was 81.4 % v/v and the maximum carbon dioxide detected was 24.3 %. No flow data were collected. The elevated concentrations of methane and carbon dioxide were both detected within a monitoring point located to the west of South Pit and Surge Pile Phase 3 and at the corner of South Pit and Surge Pile Phase 1. From discussions held with Mr Peter Coveney on 4 December 2014, it is understood that, where elevated methane concentrations have been recorded, these relate to monitoring installations with response zones installed in the underlying/surrounding natural ground and hence reflect the presence of naturally occurring marsh gas rather than landfill gas.

5.3.4. South Pit Phase 3 Landfill Pollution Prevention and Control Permit Application

A ground investigation was carried out to inform the construction of HS1 (45). The ground investigation was undertaken in 1996 and comprised soil, groundwater and surface water analysis. The chemical data were not available and are from 18 years ago, and, consequently, Atkins is unable to undertake a screening of the data. However, the Pollution Prevention and Control (PPC) Permit Application included a screening of the results with (now outdated) guidance and there were exceedances of the selected screening criteria by heavy metals, sulphate, and TPH within the Made Ground and exceedances by boron and sulphate in the alluvium. The water samples were also screened and there were exceedances by heavy metals, ammoniacal nitrogen, sulphate, sulphide and chloride.

5.3.5. Leachate Level Management

A leachate level management report (50) was produced in December 2013 due to a breach/anticipated breach of permit conditions relating to leachate management at South Pit Phase 3 landfill. The permit compliance limit is 5.5 m of leachate head above the base of the waste. The leachate level monitored was between 1.96 to <3.27 m AOD (4.83 to 6.13 m above the base of the waste). Groundwater contours for boreholes installed within the RTD/Chalk indicate groundwater flow is north, towards the River Thames.

5.4. Preliminary Geo-environmental Conceptual Site Model

5.4.1. Introduction

The approach used for the creation of the preliminary CSM is detailed in Section 2.2.1. Identified Zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Table 5-9. Only Zone 2 sources and receptors have been considered.

While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition and for the current site users in terms of human health related risks. This approach was taken as detailed development plans are still in development, and would inform a more detailed risk assessment than currently being undertaken.

5.4.2. Potential Sources

The potential sources in Zone 2 identified from the background searches, data review and site walkover observations for the site are as follows:

- North Pit landfill, where CKD was deposited under WML P/1/11 and is not currently monitored or maintained;
- South Pit and Surge Pile Phase 1 which was infilled with CKD and general waste under permit WML P/1/11A; and
- South Pit and Surge Pile Phase 3 which was infilled with CKD and is currently classified as a hazardous waste landfill under EPR/RP3039SZ.

South Pit and Surge Pile Phase 2 was not considered a potential source because though it was permitted, no waste was deposited due to HS1. Other sources include:

- derelict sewage works and operational sewage pumping station;
- Bell Wharf and associated storage tanks;
- cement works and associated infrastructure (electricity substation, railway sidings, former cement pits and associated tanks between Bell Wharf and the former cement works); and
- former gasworks.

5.4.3. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres;
- inhalation of soil- or groundwater-derived vapours;
- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- leaching from CKD/waste materials to groundwater followed by lateral migration of contamination within groundwater;
- leaching/migration of contaminants from soils to controlled waters receptors;
- direct surface water run-off and sub-surface flow to surface waters;
- lateral migration of contaminated groundwater; and
- vertical migration of contaminated groundwater.

5.4.4. Potential Receptors

The potential receptors identified are:

- the Secondary (undifferentiated) aquifer within the superficial deposits beneath the zone;
- the Principal aquifer within the bedrock beneath the zone;
- the River Thames adjacent to the north-west;
- zone visitors and workers; and
- trespassers.

A schematic CSM for Zone 2 is presented as Figure 009.

Table 5-9 Preliminary Conceptual Site Model for Zone 2

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
Potential contaminants in soil/groundwater, originating from Zone 2 sources: • Contamination resulting from historical landfills such as South Pit and Surge Pile Phases 1 and 3 and North Pit Landfill, cement works, gasworks, railways, sewage works and other potentially contaminative land uses. *Potential contamination includes highly alkaline pH, metals (particularly copper), PAHs, TPH and other contaminants.*	Zone visitors, workers and trespassers	Migration and accumulation of ground gases followed by inhalation or ignition, causing asphyxiation and/or explosion.	**Medium**	**Unlikely** The permit WML P01/11/A allowed for the deposition of CKD along with waste which could potentially generate ground gas including paper sacks and bags, excavation and demolition waste. There is the potential for ground gas as the biodegradable waste within the landfill decomposes. There were a number of structures developed on Zone 2 outside of the area of infilling including the former railways, cement works buildings and Bell Wharf.. However overall these CKD waste landfills are not considered to represent a significant source of landfill gas. Elevated concentrations of methane have been recorded in natural marshy soils which are extensive within the zone.	**Low Risk**
		Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	**Likely** An engineered cap was placed over Phase 3 of the South Pit and Surge Pile Landfill. The capping systems of the remaining landfills in Zone 2 are not known. Furthermore, the former gasworks, and tanks associated with Bell Wharf, along with the other structures associated with the cement works and Bell Wharf may have potential contamination within the Made Ground.	**Moderate Risk**
		Inhalation of soil- or groundwater-derived vapours	**Medium**	**Unlikely** There are currently no buildings within Zone 2, except the derelict sewage works which is not expected to be occupied. Any visitors are unlikely to be on site for a duration which would cause unacceptable risks from inhalation of vapours.	**Low Risk**
	Controlled waters – River Thames	Leaching from CKD/waste materials to groundwater followed by lateral migration of contamination within groundwater	**Medium**	**Likely** Leachate and treatment measures are in place for Phase 3 of the South Pit and Surge Pile landfill, however without the continued operation of the leachate collection and treatment measures, there would likely be contamination into controlled waters receptors. An upgrade and replacement of the leachate management system is ongoing.	**Moderate Risk**
		Lateral migration of contaminated groundwater	**Medium**		**Moderate Risk**

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
		Direct surface water run-off and sub-surface flow to surface waters	**Medium**	There was no known remediation of the former gasworks located in Zone 2 and structures associated with the gasworks may remain *in situ*. There were a number of circular structures associated with Bell Wharf, adjacent to the River Thames. In addition to the former gasworks and Bell Wharf, contamination from the CKD and other landfills may be migrating into controlled waters receptors.	**Moderate Risk**
	Controlled waters – Secondary (undifferentiated) and Principal aquifer beneath the zone	Leaching/migration of contaminants from soils to controlled waters receptors	**Medium**		**Moderate Risk**
		Vertical migration of contaminated groundwater	**Medium**		**Moderate Risk**

5.5. Preliminary Geotechnical Risk Assessment

5.5.1. Geological and Geotechnical Hazards

Table 5-10 describes some of the geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 5-10 Potential Geological and Geotechnical Hazards in Zone 2

Hazard	Description	Comment
Aggressive ground conditions	The BRE Special Digest (44) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	CKD covers the majority of Zone 2. The pH of the CKD is known to be highly alkaline and often caustic.
Buried foundations	Buried foundations can cause a delay to construction and incur additional costs.	A number of buildings and other major infrastructure are present on site. The HS1 Thames Tunnel crosses the Thames near to the site, and travels underground through Zone 2, emerging in the south-eastern corner. It is assumed there is a protected corridor above the HS1 tunnel. There is also a disused sewage treatment plant in the centre of the zone. In the south-western corner of Zone 2, there was a former gasworks and cement works. A large number of foundations are visible from the aerial photographs.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	The presence of a number of buildings across the site infers that buried services will be present, mostly likely to be associated with the disused sewage works and disused gas works There are electricity cables and drainage pipes associated with the leachate treatment. The HS1 is also located beneath this site.
CKD	CKD is a significant by product of the cement manufacturing process. CKD is currently considered a hazardous product due to its high pH content.	Widespread deposition of CKD across the site. Internal settlement and compaction of the CKD is unlikely, however it is suggested by Peter Coveney that the CKD is sinking in Phase 3 of the South Pit and Surge Pile landfill, causing settlement of the underlying strata.
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	There is evidence in historical maps of the zone that a railway used to run along the western boundary, but it is no longer present. There is also a disused sewage treatment works located roughly in the middle of the site. Bell Wharf is a pier and hard standing located on the north-western coast of the zone. Much of the northern and western areas of the map have been subject to large-scale CKD deposition.

Hazard	Description	Comment
Perched/high water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking construction.	The average groundwater depth in the BGS borehole logs is 11 m but is the northern area it has been recorded as 1.6 m bgl. There may be a perched water table within the superficial deposits of CKD and alluvium.
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	According to the GroundSure Report (2014) there is a moderate chance of running sand along the coast, most probably associated with the Tidal River and Creek deposits, with low risk throughout the rest of the zone.
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel. Appropriate control measures will need to be taken.	The Swanscombe Peninsula is located in a brackish water zone of the Thames, meaning the groundwater is likely to be slightly saline. Groundwater is likely to be controlled by tidal river processes therefore levels are variable throughout the day.
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying lengths of piles.	The area is unlikely to have been quarried, but erosion and weathering from periglacial and fluvial processes will be a concern
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The superficial deposits in Zone 2, particularly the clay, alluvium and peat will have low bearing capacity values. CKD has been recorded as being self-cementing in some cases, however the properties of it are known to vary significantly based on the exact composition and manufacturing process.
Weak, compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Peat and alluvium are present in Zone 2. These soils appear to be weak and could deform and fail as a result of the loads imposed on them.

5.5.2. Geotechnical Risk Register

The Geotechnical Risk Register is presented as Table 5-11 below. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a “low” ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be substantial are:

- aggressive ground conditions;
- buried foundations;
- buried services;
- CKD;
- weak bearing materials;
- weak compressible ground; and
- variable rockhead.

Most of the other risks are rated as “moderate” to “low”.

5.5.3. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in-situ* and laboratory testing;
- planned methodology for the earthworks; and
- detailed design for the temporary construction roads.

5.5.4. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be “low”. However, it should be recognised that some residual risks remain, as described below.

Table 5-11 Geotechnical Risk Register for Zone 2

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
1	Aggressive ground conditions	4	3	3	1	12	12	4	S	Ground investigation to confirm extent and thickness of CKD. Use BRE Special Digest 1 (44) to determine the concrete class from sulphate and pH results. Use appropriate concrete protection.	4	2	2	1	8	8	4	M
2	Buried foundations	3	3	3	1	9	9	3	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	1	L
3	Buried services	3	3	3	3	9	9	9	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	CKD	4	3	3	1	12	12	4	S	Review historical records and licence areas to confirm CKD extent. Ground investigation to confirm extent and thickness of CKD. Classify and use appropriately.	4	2	2	1	8	8	4	M
5	Historical works	2	3	3	1	6	6	2	M	See buried foundation and buried services.	2	2	2	1	4	4	2	L
6	Perched/high groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	3	1	1	1	3	3	3	L
7	Running sand	2	3	3	1	6	6	2	M	Ground investigation to confirm geological succession and geotechnical properties across the site	1	2	2	2	2	2	2	L
8	Saline groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be	3	1	1	1	3	3	3	L

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
										taken into account.								
9	Variable rockhead	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
10	Weak bearing materials	4	3	3	1	12	12	4	S	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
11	Weak compressible ground	4	3	3	1	12	12	4	S	Ground investigation to confirm extent and thickness alluvium and Tidal River and Creek deposits. Where necessary consider appropriately in geotechnical design.	3	2	2	1	6	6	2	M

5.6. Zone 2 Summary

5.6.1. Geo-environmental Summary

Zone 2, located in the north-western/central section of the Swanscombe Peninsula, historically comprised marshes prior to clay extraction in parts of the zone and subsequently landfilling, predominantly with CKD wastes associated with the adjacent cement industry. There were also some industrial uses in the south-western corner of the zone including cement manufacture and a small gasworks. The HS1 rail link crosses the zone partially in tunnel and the tunnel portal is located in the south-eastern corner of the zone. A disused sewage treatment works is also present in the centre of the zone.

Landfilling with CKD wastes has been undertaken in two main phases – North Pit and South Pit and Surge Pile. North Pit comprised the initial phase of landfilling which took place in the north-western part of the zone in a former clay pit. North Pit is thought to have been landfilled in the mid 1970s and the WML was surrendered prior to 1994. South Pit and Surge Pile landfill comprises three phases (Phases 1-3) and was first licensed in 1977 to accept CKD and a range of other wastes from the Blue Circle/Lafarge Northfleet cement works. Phase 1, which was completed by 1985, was also constructed within a former clay pit and is currently in the closure phase of its existing WML/EP. Phase 2 in the south-eastern corner of the zone, although within the land area covered by the original WML, has not been subject to landfilling due to the construction of the HS1 tunnel portal in this area. Phase 3 was constructed as a land raise on the pre-existing natural marshland and was re-permitted in 2004 as a result of CKD being reclassified by the Environment Agency as hazardous waste and to accommodate ongoing CKD disposal from the Northfleet cement works. Phase 3 was completed and restored in 2009/2010. There is an active leachate management system in place for Phase 3 which at the time of writing was being upgraded by Lafarge. All of the landfilled areas in this zone operated on a dilute and disperse basis with no engineered containment.

The CKD wastes represent the main source of potential soil and groundwater contamination within the zone and there are also likely to be further contamination sources associated with the former industrial uses in the south-western corner and the disused sewage treatment works. These are considered to present a moderate level of risk to controlled waters receptors including the River Thames and local groundwater resources. Under the current land uses, risks to human health are considered to be low or moderate.

5.6.2. Geotechnical Summary

The geological stratigraphy of Zone 2 consists of Made Ground covering much of the zone, consisting mainly of CKD. Below the CKD is alluvium interbedded with peat, then River Terrace deposits, all underlain by White Chalk bedrock.

In Zone 2, the geotechnical constraints determined as of a substantial risk concern similar issues to those in Zone 1. The CKD has a high alkalinity and is likely to create ground conditions which are aggressive to concrete. The alluvium and peat have a high sulphate content, which will likely contribute to the aggressive conditions. The alluvium and peat are also compressible, creating a risk of differential settlement. As previously noted, the bearing capacity of the CKD is unknown, however in the alluvium and peat beds the capacity is expected to be low. No information on buried services has been found for Zone 2; however, it is highly likely that services will be present. Historical maps show tramlines and buildings around the south and west borders of the Zone, which have now been demolished or removed, but there remains a high probability of historic foundations still being present. Constraints are also posed by current infrastructure in the zone, including the HS1 Thames tunnel which passes through the zone, oriented North-west to South-east, and emerges at a portal in the south-eastern corner of the zone and has an associated above ground exclusion zone. A disused sewage works is also found within Zone 2, which will have associated foundations and services.

Medium risk constraints will include a running sand from the Tidal River or Creek deposits found on the banks of the river Thames, as well as high groundwater levels, which are also variable across the zone. The groundwater is expected to be saline due to the brackish nature of the Thames in this area.

6. Zone 3

6.1. Zone Characterisation

6.1.1. Location

Zone 3 covers an area of approximately 37.5 ha and is located in the western part of the site, to the east of the Ingress Park residential development. The approximate NGR for the centre of the zone is TQ 59858 75376. The zone is located within the Dartford Borough Council administrative area.

6.1.2. Zone Description

The southern part of the zone comprises a works premises operated by “Basic Engineering Co Ltd”; a welding company selling welding equipment and providing welding services. The remainder of the site comprises ’Swanscombe Marshes’ (also referred to as ‘Black Duck Marsh’ in past literature), which is open marshland intersected by drainage channels. For ease of reference throughout this Chapter, the northern part of the zone is referred to as Zone 3A whilst the southern part is referred to as Zone 3B.

The elevation of the zone generally slopes from south to north, towards the River Thames, and ranges from approximately 0.1 to 7.5 m AOD. The ground surface of the zone is uneven, and comprises numerous drainage ditches. Zone 3B includes quite dense vegetation, whilst Zone 3A is predominantly open marshland.

The current layout of Zone 3, delineating Zone 3A and Zone 3B, is shown on Figure 001, environmental permit boundaries are shown on Figure 002, and key features, both historical and current, are shown on Figure 011. Photographs from the recent site walkover can be found in Appendix B.

6.1.3. Zone-Specific Data Sources

A couple of zone-specific data sources have been used. The following information sources were available:

- historical borehole records provided by the BGS;
- information provided by Dartford Borough Council, notably the Swanscombe Peninsula Environmental Statement and the Phase 1 Contamination Interpretative Report (48) (51) ; and
- information provided by the Environment Agency.

In addition, an historical site investigation report was identified through the BGS borehole record viewer for HS1 Preliminary Ground Investigation Stage II. At the time of writing, the information from the HS1 site investigation report had not been made available.

6.1.4. Surrounding Land Uses

Zone 3 is bounded by the land uses listed below - please note, all distances given are approximate (3)(10)(11).

- **North –** the northern boundary of the zone is formed by the bank of the River Thames. On the far side of the River Thames is “West Thurrock Lagoon & Marshes” (an SSSI) to the north-west, with industrial land uses beyond.
- **East –** the entire eastern border of Zone 3 comprises the western boundary of Zone 2 (see Chapter 5 for further details regarding the land use of this zone).
- **South –** Zone 5 is located adjacent to the south-eastern boundary of Zone 3 (see Chapter 8 for further details regarding the land use of this zone), and beyond this lies residential development. The area to the south-west of the zone comprises a former quarry site that has since filled with water.
- **West –** the Crest Nicholson “Ingress Park” residential development comprises the land immediately west of the zone, which was former open space with the same name. This residential development is set amongst 30 ha of landscaped grounds.

6.1.5. Historical Land Uses

The historical land uses of Zone 3 and its immediately surrounding area is provided below in Table 6-1, with a brief summary highlighting all key facts provided in Section 6.1.5.1.

Table 6-1 Historical Land Uses Relating to Zone 3

Dates and Scales	Within Zone 3	Within 1 km of the Zone
1865-1866 1:10,560 **1865-1872** 1:2,500	Zone 3 generally comprises fields. There are tramway tracks associated with a cement works within Zone 5, to the south-east of the zone, which extend partly across the south-eastern portion of the zone (3B). Chalk pits are present within the eastern portion of the Zone (including 3A and 3B), linked to the cement works to the south by tramway tracks.	A railway line (North Kent Line) is present approximately 100 m to the south of the zone and a tram road forms the zone's eastern boundary. The zone's northern boundary (3A) comprises the high water mark of the River Thames, and the remainder of the surrounding area is low-density residential (such as Swanscombe to the south) or open space (including "Ingress Park" to the west). There are a number of gravel pits, chalk pits, sand and gravel pits and other excavations within 1 km of the zone; typically to the south.
1888-1895 1:10,560	The zone is labelled as comprising part of "Swanscombe Marshes", as is the adjacent Zone 2 (see Section 5). There are a number of small ponds across the south-central part of the zone. Within Zone 3B (south of the ponds) there are chalk pits and a whiting works. A barge yard wharf is present along the western boundary of the zone and there is a cricket ground towards the centre. Unidentified buildings are present along the zone's eastern and south-eastern boundaries which appear to be associated with either the adjacent cement works or the whiting works.	No significant changes.
1897-1909 1:2,500 **1907-1923** 1:10,560	The scale of excavation within the chalk pits in the southern portion of the zone has increased. The cement works within Zone 5 has expanded such that there are now many railway features and buildings associated with the works located in Zone 3B including a number of associated tanks and other circular structures. However, the chalk pits on the eastern portion of the zone are no longer shown.	A small gasworks is shown approximately 60 m east of the zone, on the boundary between Zones 2 and 5: see Sections 5 and 8. A large area of paper mills ("Ingress Abbey Paper Mills") is shown adjacent to the western boundary of Zone 3. A more extensive area of chalk pits is visible to the south of the zone.
1931-1966 1:10,560 **1932-1970** 1:2,500 **1971-1974** 1:10,000 **1952-1975** 1:1,250	The cricket ground has expanded to include more sports grounds, including football grounds located near the centre of the zone. The grounds on the western portion of the zone are called "Empire Sports Ground". The barge yard is no longer shown. Tanks are shown within the whiting works in the southern portion of the zone, up until the 1952-1954 [1:2,500 scale] map onwards. Other buildings are still present towards the south-eastern corner of the zone. The majority of the pits across Zone 3B are either marked as disused or are no longer shown, and appear to have been infilled. The tramway tracks on the eastern portion of the zone have extended however. Unidentified works (including silos) are	A small sewage treatment works is shown within Zone 2: see Section 5. Ingress Abbey Paper Mills are now called "Empire Paper Mills" and includes additional tram tracks, a travelling crane along the pier and a number of tanks. By 1952, the paper mills were also shown to comprise a pumping station, a pump house and filter beds. These were no longer present by 1969-1971, leaving the tanks remaining and an additional hopper. A large area in Zone 2 to the east appears to have been excavated and subsequently filled with water. This water body changes in extent significantly, between 1966 and 1973-74, when it becomes partially infilled ('slag heap' as per the map legend). The area of chalk pits to the south has

Dates and Scales	Within Zone 3	Within 1 km of the Zone
	shown in the south-eastern corner of Zone 3B, in the location of the former whiting works. An electricity substation and conveyor is shown in the south-eastern part of Zone 3B, associated with the cement works which extend outside of the zone to the south-east.	expanded further.
1979-1992 1:1,250 **1989-1992** 1:1,250 **1982-1995** 1:10,000	The cricket grounds are no longer shown from 1974-75. The south-western part Zone 3B is shown as a tip from 1992 on the historical maps. This tip is in an area referred to as "Lovers Lane Pit" in previous reports. During this period (1980-1993), although not mapped, the south-central part of the zone contained a landfill operated by Blue Circle Industries Plc, called "Swanscombe Cement Landfill". Although it is not entirely clear from the records available, Lovers Lane Pit and Swanscombe Cement Landfill are believed to be alternative names for the same landfill site, which is referred to as Swanscombe Cement Landfill herein.	Works are located adjacent to the south-western boundary of Zone 3. They are shown to contain tanks and silos. The water-filled area of Zone 2 to the east has again changed extent and is significantly smaller than in 1982. The infilling ('slag heap') is no longer marked as an individual feature.
2002 1:10,000	The majority of the railways in the zone, associated with the cement works in Zone 5, are no longer shown.	A small sewage pumping station is shown to the east of the zone, towards the south of Zone 2 and immediately north of Zone 5. The mill to the west of the site is no longer present. Zone 2 is again showing an infilled area ('slag heap').
2010-2014 1:10,000	No significant changes.	The works directly to the south-western boundary of Zone 3 are no longer shown. The small sewage pumping station to the east of the zone, towards the south of Zone 2, is no longer shown. The other sewage works towards the east of the zone (towards the centre of Zone 2) is also not shown. The Crest Nicholson "Ingress Park" residential development is present to the west of the site, in the location of the former park (also called Ingress Park) and Empire Paper Mills.

Notes: For land uses adjacent to the northern and eastern parts of the zone (Zone 2), see Chapter 5, and for land uses adjacent to the southern part of the zone (Zone 5), see Chapter 8.

6.1.5.1. Summary of Historical Land uses

6.1.5.1.1. Zone 3A

The majority of the zone comprises marshland ("Swanscombe Marshes") and has historically remained so, with some use as sports fields. From the earliest historical map provided within the GroundSure MapInsight (3), Zone 3A was shown to comprise predominantly open ground, intersected by tramway tracks along its eastern portion. Chalk pits were also present during this time, along the eastern boundary of Zone 3A.

By 1888-1895, unidentified buildings were present along Zone 3A's eastern boundary and the southern part of Zone 3A (central part of Zone 3), comprised a cricket ground. Additional railway tracks were then visible on the eastern portion of the zone from between 1897 and 1907, associated with the cement works to the south-east. Overall, little significant development has occurred within Zone 3A.

6.1.5.1.2. Zone 3B

From the earliest historical map provided within the GroundSure MapInsight (3), Zone 3B was shown to comprise predominantly open ground. The zone was intersected by tramway tracks within its south-eastern portion, associated with a cement works to the south-east, within the neighbouring Zone 5, which extended partly across the zone boundary.

6.1.5.1.3. By 1888-1895, unidentified buildings were present along Zone 3B's south-eastern boundary, small ponds were present across the central portion of the zone, the south-western part of the zone comprised chalk pits and the southern area was a whiting works. The whiting works were shown to contain tanks and silos before they stopped being mapped from the 1952-1954 maps onwards, and an electricity substation and conveyor was shown on the south-eastern part of the zone. The whiting works was replaced with subsequent buildings, likely related to the existing cement works in the area. "Swanscombe Cement Landfill" (otherwise known as "Lovers Lane Pit") was also present in the southern part of the zone, between 1980 and 1993, operated by Blue Circle Industries Plc.Surrounding Area

In terms of the development history of the surrounding areas, Zone 2 borders Zone 3 to the east, whilst Zone 5 is present to the south-east, and the history of both can be found in their individual chapters (see Sections 5 and 8 respectively). On the 1865-1866 map provided, the remainder of the surrounding areas not within the study area comprised a park with the same name as the residential area that is currently in the same location ("Ingress Park") to the west, quarries and more residential areas to the south. The Ingress Park residential development was first shown on a historical map from 2010.

Potentially contaminative land uses within the vicinity of Zone 3, historical and current have included the railway line approximately 100 m south, the cement works to the south-east that extended onto the zone itself, excavations/chalk pits (that were subsequently backfilled with undefined materials), a small gasworks approximately 60 m east, paper mills ("Ingress Abbey Paper Mills" and later "Empire Paper Mills") to the west (complete with tanks, a pumping station, a pump house, filter beds and a hopper), unidentified works to the south-west (with tanks and silos), and sewage disposal works and a sewage pumping station in Zone 2 to the east.

6.2. Environmental Context

6.2.1. Historical Borehole Records

One borehole log and a total of four trial pit logs have been identified for Zone 3 from the BGS borehole viewer. The log from the single borehole is not available online and so only basic information about it is known. The trial pits are all located in the south-eastern corner of Zone 3A, and there is not any intrusive data for Zone 3B included on the BGS website. Therefore for the purposes of this report much of the information must be inferred from borehole logs located near to the boundary of Zone 3.

Of all the boreholes identified within the zone; all of the trial pits were Grade B and the borehole log was Grade C. The information from the Grade B logs has been used to verify the published geological maps and to inform the findings of this report.

6.2.2. Historical Reports

Information provided by the Client includes the Geotechnical and Land Raise Strategy Report by Halcrow (42). In addition to this, a historical site investigation report was identified through the BGS borehole record viewer for the HS1 Preliminary Ground Investigation Stage II. At the time of writing this report, the information from the HS1 site investigation report had not been made available.

6.2.3. Geology

The 1:10,000 BGS geological maps of the area, sheets TQ67NW (Grays) and TQ57NE (West Thurrock) (1994) show the geology of this zone to be alluvium and head overlying RTD, with bedrock of undifferentiated White Chalk Along the coast, Tidal River Deposits are also recorded (see Table 6-2). Made Ground is also found in the south of the zone. No faults are recorded in or around Zone 3.

Table 6-2 Expected Stratigraphy Below Zone 3

Strata	Typical Thickness (m)	Description
Made Ground	2	Weakly cemented, sandy silt, with a high proportion of CKD and some gravel
Head	3	Very silty and sandy clay, with some gravel
Alluvium	>2	Soft to firm, organic clay to silt, interbedded with peat
RTD	Unknown	Coarse to fine flint gravel, with medium t coarse sand to clayey sand
Chalk	>0	Moderately weak to hard White Chalk, with beds of flint in the upper 5 m

Note: typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness is marked as unknown, the bed has not been proven, and is only expected, and so a value for the thickness is not known.

6.2.4. Geomorphology

Zone 3 is located on the western edge of Swanscombe Peninsula, which is a triangular landmass in a meander of the River Thames. The peninsula measures roughly 2.7 km north to south by 2 km east to west. The northern part of the zone, Zone 3A, has previously been known as Black Duck Marsh on historical maps and in Halcrow's 2004 report (42), although it is referred to as Swanscombe Marshes in recent literature and herein.

Zone 3 appears to be mostly flat ground, and has an average elevation of 3.3 m AOD based on available borehole logs and topographic maps. Surface drains run across much of the northern part of the site, and flood defence berms can be seen along the north-western edge.

6.2.5. Ground Conditions

Descriptions and geotechnical parameters provided in the following sections have been obtained from Halcrow's Land Raise Strategy Report (42) and from the trial pit logs. Much of the descriptions have also been inferred from nearby boreholes, as there is very limited data available specifically for Zone 3. As it has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 3, the information is provided for guidance only and it is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain site specific design parameters.

6.2.5.1. Made Ground

Made Ground has been described in this zone as being sequences of firm silty sandy clay to silty (often ashy) sand, to a depth of roughly 2.4 m bgl. Gravel of flint, chalk and brick has been found throughout, as well as glass, metal sheeting, clinker gravel and slag. In trial pit TQ57NE1180, a steel rail track with sleepers was observed at 1.7 m below ground level.

There is an area of landfilling in the western part of Zone 3B, known as Swanscombe Cement Works Landfill (also referred to as Lover's Lane Landfill). The composition of waste is unknown; however, it is likely to have included CKD as well as general waste and demolition waste.

6.2.5.2. Head

No borehole information is available for this unit; however the BGS describe this unit as comprising of poorly sorted gravel, sand and clay depending on upslope source and distance from source. In this case, it is reasonable to assume the gravel will comprise of Chalk and flint.

6.2.5.3. Alluvium

The alluvium which underlies the Made Ground has been described as two beds: the uppermost bed is detailed as being soft, closely fissured organic clay, with some occasional, peaty, organic pockets and shell fragments. This bed reaches an average depth of 3 m bgl. The second bed is described as peat. The trial pit logs do not reach a depth past 4 m; therefore further information is not available. However, due to the zones proximity to Zone 2, it is reasonable to assume that a second bed of peat is likely to be present at further depth.

6.2.5.4. River Terrace Deposits

No borehole information is available for the unit in this area; however it is highly likely to be the same unit as the one found in Zones 1 and 2, and so should exhibit similar composition and structure.

6.2.5.5. White Chalk

No borehole information is available for this unit; however the BGS Lexicon of Named Rock Units (8) describes this unit as comprising of very fine grained White Chalk with bands of flint. The degree of weathering, and therefore strength, is believed to decrease with depth. The chalk outcrops at the surface in the south of this zone.

6.2.6. Hydrology and Hydrogeology

6.2.6.1. Surface Water

The surface water features map, contained in the GroundSure FloodInsight (4), shows there to be numerous watercourses/surface drains across Zone 3, as would be expected for marshland. This is confirmed by online mapping, and the most significant of these watercourses appears to be that within Zone 3A, with an alignment parallel to the northern zone boundary.

There are many other surface watercourses within the area surrounding the zone, but these are mostly within Zones 2 and 4. These are identified as drains on online maps (10), and were highly evident during the site walkover. The zone is bordered by the River Thames on its north-western edge.

6.2.6.2. Groundwater

Due to the limited extent of the trial pits and the lack of boreholes in the majority of Zone 3, it is not clear where the groundwater table lies. However in the southern region where the trial pits are located, the groundwater is found between 1.00 and 3.50 m bgl. This is on the boundary of the zone and the level may vary across the rest of the zone. Groundwater in the superficial deposits is likely to be controlled by river-tidal processes, and since the Thames is brackish in this area the groundwater can be expected to be partially saline. Information provided by the Environment Agency concludes that the chalk is the major aquifer in the region with water movement being primarily controlled by fractures in the rock (9).

6.2.6.3. Groundwater Abstractions

A medium size groundwater abstraction is located almost 1 km to the north-east of Zone 3, currently licensed for mineral washing by Cemex UK Materials Ltd and spray irrigation by Lafarge. The maximum annual abstraction is 1,186,000 m^3 and 26,300 m^3 for the respective purposes. No other groundwater or surface water abstractions are located within 1 km of this zone.

6.2.6.4. Groundwater Vulnerability

Zone 3 is not located within a SPZ.

6.2.7. Mineral Abstractions

There is evidence of chalk pits in the south-western corner of Zone 3B, centred at coordinates TQ 559653, 175189. These pits can be observed in historical OS maps from between 1895 and 1915, and are still visible in current aerial photography.

There have been recorded instances of deneholes dug into the chalk in several places in the area surrounding Zone 3, including at Gravesend and Tilbury. While there are no recorded instances in Zone 3 itself, the chalk bedrock means the possibility of undiscovered deneholes should be noted.

6.2.8. Flood Risk

This section summarises the flood risk associated with Zone 3, using details from the GroundSure FloodInsight report (4).

The “Environment Agency Flood Map for Planning (from rivers and the sea)”, included within the GroundSure FloodInsight report (4), shows that Zone 3 is in an area at risk of flooding, within a floodplain relating to tidal events, and confirms the zone benefits from flood defences placed along the northern boundary. While the majority of Zones 3A and 3B are classified as having a “low” NaFRA rating, a strip along

the northern boundary of Zone 3A has a “high” rating, whilst the remaining area of the zones (parts of the western portion) are classified as having no risk.

In terms of historical flood events, Zone 3A has been affected by two floods recorded by the Environment Agency. A small section of the eastern portion of the zone was affected by a fluvial flood from 14th September 1968, which resulted from the channel capacity of a river being exceeded. Zone 3A was also affected by tidal flooding between 1st and 5th February 1953, due to the flood defences being overtopped.

Scattered patches of Zone 3A and Zone 3B are at risk of pluvial flooding and, although “significant” risks were identified across the zone, the majority of these risks were deemed “low” (4).

The majority of zones 3A and 3B is considered, by the BGS, to have limited potential for groundwater flooding, although isolated parts of it have been identified as having potential for groundwater flooding of property below ground level.

Further details regarding flood risk can be found in Buro Happold’s Flood Risk Assessment (in preparation).

6.2.9. Designated Environmentally Sensitive Sites

There are no designated environmentally sensitive sites within Zone 3 (2). The zone is, however, within an SSSI IRZ, which may have implications for the proposed development, as it relates to “all planning applications with a new/additional footprint of greater than 500 m^2 outside of existing settlements/urban areas” (10).

There are no scheduled monuments within the site boundary. There is one Grade II listed building located on the north-western boundary of Zone 3B, named “Boundary Stone, Lovers Lane” within Ingress Park to the west. The Ingress Park residential area that extends westwards of the zone comprises numerous Grade II listed buildings.

The 44.35 ha “West Thurrock Lagoon & Marshes” SSSI is situated approximately 1 km north-west of Zone 3A, on the other side of the River Thames, and the majority of it is in “unfavourable declining” condition.

6.2.10. Environmental Permits, Incidents and Registers

There are four licensed discharge consents relating to Zone 3 highlighted within the GroundSure EnviroInsight Report (2): two on the eastern portion of the zone and two on the northern (all within Zone 3A). Two of the entries relate to discharges from HS1 and are believed to be duplicates for a single discharge consent. These are listed in Table 6-3 below.

Table 6-3 Licensed Discharge Consents Related to Zone 3

Location within the Zone	Address	Effluent Type	Receiving Water	Status
East (Zone 3A)	Swanscombe Ceo, Manor Way Wps, Swanscombe, Kent, DA10 0PP	Sewage discharges – pumping	Tributary of Thames Estuary	Revoked on 13/07/2009
	Swanscombe Wastewater Pumping Station, Swanscombe Marshes, Kent		Saline estuary	Revoked on 28/01/2009
North (Zone 3A)	Channel Tunnel Rail Link Site, Swanscombe Marsh, Swanscombe, Kent	Unspecified	Tidal River Thames	Revoked on 29/08/2002
				Revoked (date unknown)

In terms of off-site discharge consents that are located closer to Zone 3 than any of the other zones, two are located 310 m north-west of Zone 3B, at Greenhithe. Of these, one was related to sewage discharges and

another related to trade effluent discharges (specifically coolant), and they were revoked in April 1998 and September 1990, respectively.

There are three records of List 2 entries within the National Incident Recording System (NIRS), which lists impacts to water, land and air. Of these, only one was deemed to have a "significant" impact to water, whereas the remaining entries were deemed to have either a "minor" impact or "no impact". These entries are detailed in Table 6-4 below.

Table 6-4 Records of National Incidents Recording System, List 2, Associated with Zone 3

Location within Zone	Incident Date	Pollutant	Impacts
East (Zone 3A)	22/04/2003	Inert materials and wastes: soils and clay	Water: Category 3 (minor) Land: Category 3 (minor) Air: Category 4 (no impact)
East (Zone 3B)	08/02/2002	Sewage materials: crude sewage	Water: Category 2 (significant) Land: Category 4 (no impact) Air: Category 4 (no impact)
North-west (Zone 3A)	05/03/2003	Natural ochre	Water: Category 3 (minor) Land: Category 4 (no impact) Air: Category 4 (no impact)

There are no significant List 2 NIRS entries off-site, within the vicinity of the zone. No List 1 NIRS entries are recorded on or off the zone.

For all other off-zone entries relating to EPs, incidents and registers, see the pertinent sections relating to the other zones.

6.2.11. Landfills and Other Waste Sites

The Environment Agency website (9) identifies a historical landfill in the central area of Zone 3B (known as "Swanscombe Cement Landfill", as discussed in Table 6-1). This landfill was located on Manor Way, Swanscombe, and received inert waste between 2nd January 1980 and 26th March 1993. It was operated by Blue Circle Industries Plc and was undoubtedly associated with the former cement works to the south-east of the zone (mainly within Zone 5), which extended into the zone itself. In historical reports, this landfill has been referred to as "Lovers Lane Pit", and is shown as being located slightly further to the south-west, along the south-western boundary of Zone 3B. Elevated pH and alkali salt concentrations have been recorded at this location during previous site investigations, which is associated with CKD waste (48). Anecdotal information from Mr Peter Coveney of CMS-Enviro indicates that this landfill operated as the works tip and as such is likely to have received a mix of waste materials including CKD as well as general wastes from the works. Wastes from the demolition of the works are also understood to have been deposited in this site with the potential to include some hazardous materials such as asbestos. See Section 6.2.13.1 for further details of Halcrow's 2004 site investigation.

In terms of off-site landfills, in the vicinity of Zone 3, there is a historical landfill located 679 m south-west, at Knockhall Chase in Swale, Kent. It was used to deposit inert, industrial, commercial and household waste and its licence expired on 30th March 1994. There is also a small landfill ("Craylands Lane") located approximately 250 m south of the zone, discussed in relation to Zone 5 in Section 8; the licence for which expired on 31st December 1977.

There is an Environment Agency licensed facility to the south-east of the former Swanscombe Cement Landfill, in the south-eastern corner of Zone 3A. This is a physical treatment facility called "Swanscombe Glass Recovery", operated by "Recresco Limited", with an annual tonnage of 220,000 (2).

The location of the licensed Swanscombe Glass Recovery facility is shown on Figure 002.

6.2.12. Potentially Contaminative Industrial Sites

Zone 3 currently comprises, and historically comprised, predominantly of marshland. As a result, there are only three features deemed as being "potentially contaminative" within the GroundSure EnviroInsight (2), as listed in Table 6-5 below.

Table 6-5 Potentially Contaminative Industrial Sites within Zone 3

Feature	Location within the Zone and Address (if Provided)	Activity	Category
Tip (believed to be Swanscombe Cement Landfill) (Zone 3B)	West	Refuse disposal facilities	Infrastructure and facilities
Works (Zone 3B)	South	Unspecified works or factories	Industrial features
Silos (Zone 3B)	South-central	Hoppers and silos	Farming

It is believed that Allied Piling Co Ltd (potentially currently under Arcelor Mittal) may operate from a portion of the southern area of the site, based on previous ground investigation reports (48) (51).

There are off-site industrial land uses within close proximity to the site, although none of these are deemed highly significant individually.

For all other significant off-zone entries relating to potentially contaminative industrial sites within other zones, see the pertinent sections relating to the other zones.

6.2.13. Information Gained from Public Records

6.2.13.1. Previous Ground Investigation (Halcrow - 2004)

Dartford Borough Council's planning website was consulted, and a significant amount of information related to this zone is publicly available, in association with a previous masterplan for the Swanscombe Peninsula from 2004. The majority of the entire zone, along with portions of Zones 2 and 5, had been recommended for a large-scale new development to include 1,750 mixed dwellings, general commercial and industrial developments including offices, warehousing, retail, financial and professional services, restaurants, primary schools and a number of other community facilities with associated infrastructure and services within the area.

As the site is vulnerable to flooding (as outlined in Section 6.2.8 above), it was proposed that the development site would undergo land raising of 2-6 m in order to construct a development platform.

An EIA was undertaken, along with the associated Environmental Statement (51). Through this process, a land contamination report was also produced subsequent to intrusive ground investigations undertaken across the zone (48).

The following works were undertaken within Zone 3:

- 10 No. BHs;
- 30 No. WSs; and
- 27 No. TPs.

In addition, a number of the intrusive locations were completed with groundwater and ground gas monitoring installations.

The investigation was undertaken in order to assess part of the Swanscombe site in terms of the proposed mixed-use development as was anticipated at the time. This area of the site (the western peninsula) was categorised as "Phase 1" and was therefore investigated first. The development planning application was later halted, with the application being disposed of in March 2013, and it appears that only this initial stage of investigation was completed.

"Phase 1" was segregated into five distinct areas; all of which, except Swanscombe Gas Works Perimeter (Area 2), fall at least partially within Zone 3, with Areas 1 and 3 covering Zone 3A and Areas 1, 4 and 5 covering Zone 3B:

- Swanscombe Cement Works and Whiting Works (Area 1);
- Swanscombe Gas Works Perimeter (Area 2);
- Lovers Lane Pit (known as Swanscombe Cement Landfill by the Environment Agency and referred to as such throughout this report) (Area 3);
- Black Duck Marsh (marked as Swanscombe Marshes on historical and current maps, and referred to as such throughout this report) (Area 4); and
- Sea Wall (Area 5).

The report is available on the Dartford Borough Council planning portal.

Risk assessments for human health and controlled waters were undertaken using legislation and best practice applicable at the time, including Contaminated Land Exposure Assessment (CLEA)-developed SGVs and developed SSAC. Controlled waters risk assessment was undertaken using the R&D20 tiered approach.

The identified sources of contamination were related to significant historical industrial uses of the zone including, but not limited to, infilling with CKD and other works waste from the cement industry, gasworks, fuel storage, solvent use, etc.

6.2.13.1.1. Soils Results (Human Health)

Swanscombe Cement Works and Whiting Works (Area 1)

Asbestos was found in three out of twelve samples (25 %) within the demolition materials.

The 95th% UCL for all metals in shallow soils were below the relevant SGVs.

Strong hydrocarbon odours were noted during the works in two locations – one beneath a concrete slab in an Allied Piling storage area in the south-central area of the zone, and one near the former whiting works, considered to be currently off-site using the 2014 site boundary. The area within the Allied Piling storage area showed highly elevated concentrations of petroleum hydrocarbons within the Made Ground, and higher concentrations in the underlying chalk.

Swanscombe Cement (Area 3)

Elevated pH levels were noted within this area. Arsenic concentrations were found at levels such that the 95th% UCL exceeded the SGV. A small number of other heavy metals exceedances were noted.

Swanscombe Marshes (Area 4)

Again, arsenic concentrations were found to be elevated within this area of Zone 3, while no other heavy metals exceeded their respective SGVs. The assessment model used by Halcrow has since been superseded by one with a less conservative arsenic screening value of 35 mg/kg for a residential without plant uptake land use, as opposed to the 20 mg/kg SSAC used during the Halcrow assessment. Hence if the results were screened using the current screening criterion, it is likely that fewer arsenic exceedances would have been identified. However, without the original laboratory data, this cannot be confirmed and so, for the purposes of this study; it has been assumed that the conclusions drawn surrounding elevated arsenic concentrations are accurate.

Sea Wall (Area 5)

A very small number of heavy metals exceedances were noted within the top 1 m of material within this area.

6.2.13.1.2. Controlled Waters

The report generally considered that groundwater within the zone would be unlikely to be highly sensitive to potential contamination, due to its brackish nature and being located beyond a SPZ. The screening criteria

utilised for the generic assessment were therefore freshwater Environmental Quality Standards (EQSs), to assess risks to the ditches within the marshland (as identified as the key potential receptor) and water within the River Thames. Surrogate compounds benzene and naphthalene were selected to assess for VOCs and SVOCs, respectively.

Swanscombe Cement Factory and Whiting Works (Area 1)

Exceedances of the EQS for copper, SVOC, VOC, TPHs, and cyanide were identified within the soil leachate and/or groundwater samples taken from within this area. After completing a tiered assessment as per the R&D20 methodology, risks to the controlled waters receptors were not found to be significant. Unidentified "oil" was sampled from TP94 from perched water within the Made Ground.

Swanscombe Cement Landfill (Area 3)

Concentrations of contaminants potentially associated with the CKD placed within this area were indicated in soil-leachate and groundwater samples, including potassium, calcium and sulphate, and an elevated pH was found in the leachate samples. The drainage ditches within the marshland were also sampled and elevated pH was not encountered within these samples.

However, dewatering was being undertaken during the investigation period at nearby Eastern Quarry. It was believed that water levels in the area would have the potential to rise, following the cessation of the dewatering, possibly leading to increased leaching of contamination into the groundwater and surface water in the area.

Swanscombe Marshes (Area 4)

Potassium, calcium, and sodium were found at elevated concentrations within Swanscombe Marshes in all leachate and groundwater samples. This report concluded that concentrations of these compounds were naturally occurring.

Sea Wall (Area 5)

Leachate and groundwater samples taken from the sea wall indicate that "pH, potassium, calcium, and sodium concentrations…are not representative of conditions associated with the presence of aggressive, highly alkaline, CKD leachate and are naturally occurring".

6.2.13.1.3. Ground Gas

Only one round of ground gas monitoring was undertaken. The maximum concentrations of ground gas within each of the areas outlined for the investigation are presented in Table 6-6. All have been included to account for the potential migration of ground gas from other zones.

Table 6-6 Ground Gas Concentrations per Area (2004)

Location	Maximum CH_4 (% v/v)	Maximum CO_2 (% v/v)	Minimum O_2 (% v/v)
Swanscombe Cement Factory and Whiting Works	14.2	14.8	< 0.1
Swanscombe Gas Works Perimeter	< 0.1	3.2	Unknown
Swanscombe Cement Landfill	2.9	< 0.1	0.5
Swanscombe Marshes	32.3	16.4	6.5
Sea Wall	73.1	23.2	2.3

While methane concentrations within the Sea Wall and Swanscombe Marshes areas were attributed to natural sources (bog land and anaerobic conditions within the Thames tidal reaches), the boreholes within the area of the former cement works also indicated elevated concentrations of methane and carbon dioxide. These were stated to be likely associated with possible fuel spills, the presence of alluvium, or the chalk below the zone.

6.2.13.1.4. Conclusions and Recommendations

The risk assessments undertaken within this Halcrow report indicate that no remedial action was required for the protection of human health from concentrations of contaminants within the soils at the zone. However, this is based on the assumption that the area would undergo a significant land raise, therefore breaking a number of the potential pathways for exposure.

Similarly, using the tiered assessment approach in R&D20, no significant potential pollutant linkages were found for the controlled waters receptors at the zone.

However, risks were identified due to the concentrations of ground gas found within a number of boreholes within the zone.

A hotspot of unidentified “oil” contamination was encountered near TP94 in the south-eastern corner of zone 3B, close to Manor Way and which was not delineated.

Ongoing monitoring and sampling during construction and demolition was recommended for soils, groundwater and surface water, as well as additional assessment of ground gas.

6.3. Preliminary Geo-environmental Conceptual Site Model

The approach used for the creation of the preliminary CSM is detailed in Section 2.2.1. Identified zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Table 6-7.

6.3.1. Potential Sources

6.3.1.1. Potential On-Zone Sources

The potential within zone sources identified from the background searches, data review and site walkover observations for the zone have been split in the CSM into the two different areas outlined in Section 6.1.2. These include the northern Zone 3A (Swanscombe Marshes) which has had a relatively undisturbed history and the southern Zone 3B (industrial area) which has included various historical land uses, as follows:

Zone 3A: Swanscombe Marshes

- alluvium and marshland present below significant portions of the site potentially contributing to ground gas generation.

Zone 3B: Industrial Areas

- current and historical industrial uses of the zone (within the Made Ground and the natural ground), including the cement works in the south-east, which extended onto the zone (also included as an off-zone source, for completeness), welding works (Basic Engineering Co Ltd in the southern part of the zone), the licensed Swanscombe Glass Recovery facility, whiting works (with tanks and silos), an electricity substation and conveyors;
- contamination arising from the former landfill and pits, namely Swanscombe Cement Landfill which may have been infilled with CKD and other wastes, possibly including asbestos waste; and
- alluvium and marshland present below significant portions of the site potentially contributing to ground gas generation.

Known contamination exists on the zone based on the findings of the previous ground investigation undertaken in 2004, including areas of “oil” in the south-eastern corner and asbestos within demolition materials (48).

6.3.1.2. Potential Off-Zone Sources

Potential off-zone sources of contamination are discussed earlier on in this chapter, but are not included within the CSM, as discussed in Section 2.2.1.

6.3.2. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres (indoors and outdoors);
- inhalation of soil or groundwater-derived vapours (indoors and outdoors);
- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- leaching from CKD/waste soils to groundwater;
- leaching/migration of contaminants from soils;
- direct surface water run-off and sub-surface flow to surface waters;
- lateral migration of contaminated groundwater;
- vertical migration of contaminated groundwater;
- contaminant migration into drinking water pipes/supply to buildings, followed by subsequent ingestion; and
- chemical attack on building structures

6.3.3. Potential Receptors

As stated in Section 2.2.1, the CSM for each Chapter only considers on-zone receptors. The identified potential receptors of possible contamination, split by identified source area, are listed below:

Zone 3A: Swanscombe Marshes

- the Secondary (undifferentiated) aquifer within the Alluvium and Head superficial deposits beneath the majority of the zone;
- the Principal aquifer within the undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation bedrock beneath the zone;
- the surface water channels across the zone;
- the River Thames; and
- zone visitors.

Zone 3B: Industrial Area

- the Secondary (undifferentiated) aquifer within the Alluvium and Head superficial deposits beneath the majority of the zone;
- the Principal aquifer within the undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation bedrock beneath the zone;
- the secondary and tertiary rivers across the zone;
- zone visitors; and
- trespassers.

A schematic CSM for Zone 3 is represented on Figure 012.

Table 6-7 Preliminary Conceptual Site Model for Zone 3

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
Zone 3A: **Potential contaminants in soil/groundwater on the zone, originating from the following sources, within the Swanscombe Marshes area of the zone:** • Alluvium/marshland present below large portions of the zone. *The main potential contaminant from this is ground gas.*	Humans (zone visitors).	Inhalation of ground gas and vapours in outdoor and indoor (non-confined space) air.	**Medium**	**Unlikely** Known ground gas exists at the zone, potentially related to the underlying alluvium and/or marshland. Despite these risks, the probability of inhalation of ground gas and vapours in non-confined spaces is low. The zone is mostly marshland, reducing the likelihood of trespassing.	**Low**
	Controlled waters – surface water receptors: the surface water channels across the zone.	Lateral migration of contaminated surface runoff and entrained dust within surface runoff.	**Medium**	**Unlikely** The surface water channels (land drains) across the zone may act as receptors of zone-derived contamination, but they have been deemed to act more as pathways of contamination. Surface water sampling undertaken in 2004 (see Section 6.2.13) did not indicate significant risks to surface water receptors, according to assessments undertaken at that time.	**Low**
	Controlled waters – the River Thames	Leaching from CKD/waste materials to groundwater followed by lateral migration of contamination within groundwater	**Medium**	**Unlikely** The relatively undeveloped history of the zone suggest there is limited potential for significant contamination to exist on the zone, and it is therefore deemed unlikely that significant risks are posed to the River Thames.	**Low**
		Lateral migration of contaminated groundwater	**Medium**		
		Direct surface water run-off and sub-surface flow to surface waters	**Medium**		
	Controlled waters – groundwater receptors: Principal (bedrock) aquifer and Secondary	Leaching from unsaturated soils to shallow groundwater within the Secondary (undifferentiated) aquifer	**Medium**	**Unlikely** The western part of the zone is thought to comprise Made Ground above the Principal aquifer bedrock. Therefore, any zone-derived contamination is likely to migrate into the Principal aquifer below.	**Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
	(undifferentiated) (superficial deposits) aquifer beneath the zone.	to possibly the Principal aquifer, then lateral and downward migration of dissolved or separated non-aqueous phase contamination within groundwater.		However, risk assessments undertaken in 2004 (see Section 6.2.13) did not indicate significant risks to controlled waters receptors.	
<u>Zone 3B:</u> **Potential contaminants in soil/groundwater on the zone, originating from the following sources, within the <u>industrial area</u>:** • Contamination in the Made Ground and natural ground in the zone, resulting from current and historical industrial uses of the zone. *Various potential contaminants, including asbestos.* • Presence of historic landfill site • Alluvium/marshland present below a portion of the zone. *The main potential contaminant from this is ground gas.*	Humans (users, visitors and trespassers).	Inhalation of ground gas and vapours in outdoor and indoor (non-confined space) air.	**Medium**	**Low likelihood** The gas generating potential of the former landfill/s is considered to be relatively low due to their ages, and the anticipated nature of the fill materials. However, known ground gas exists at the zone, potentially related to the underlying alluvium and/or marshland. Vapour generation may also be possible, resulting from the presence of former tanks, known "oil" contamination in the south-eastern corner of the zone and the presence of VOCs and SVOCs in the groundwater.	**Moderate/Low**
		Migration of ground gases and vapours to confined spaces, leading to accumulation followed by inhalation or ignition, causing asphyxiation and/or explosion.	**Severe**		**Moderate**
		Inhalation, ingestion and dermal contact with contaminants in soil and soil-derived dust/fibres from areas free from hardstanding.	**Medium**	**Likely** A large proportion of this part of the zone is covered in softstanding, meaning there is a potential for soil-derived dusts/fibres to be present, where they can easily be inhaled, ingested and come into contact with people. Contamination was known to have been present within the top metre of the zone in 2004 (see Section 6.2.13), and asbestos was encountered during previous ground investigations.	**Moderate**
		Contaminant migration into drinking water pipes/supply to buildings to buildings and subsequent ingestion.	**Medium**	**Unlikely** There is believed to be a drinking water supply on the zone, although the extent of drinking water supplies is unconfirmed at this point and could be limited in scale. However, heavy metals, inorganic compounds and VOCs/SVOCs were present at the zone in 2004 (see Section 6.2.13).	**Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
	Property and buildings/services.	Accumulation and ignition of gas.	**Severe**	**Low likelihood** The gas generating potential of the former landfill is considered to be relatively low due to their ages, and the anticipated nature of the fill materials. However, known ground gas exists at the zone, potentially related to the underlying alluvium and/or marshland.	**Moderate**
		Chemical attack on building structures.	**Mild**	**Low likelihood** Contamination was found on the zone which could impact upon underground structures, including sulphates. However, the extent of this contamination across this part of the zone is unconfirmed.	**Low**
	Controlled waters – surface water receptors: the secondary and tertiary rivers across the zone.	Lateral migration of contaminated surface runoff and entrained dust within surface runoff.	**Medium**	**Unlikely** The secondary and tertiary rivers (land drains) across the zone may act as receptors of zone-derived contamination, but they have been deemed to act more as pathways of contamination. Surface water sampling undertaken in 2004 (see Section 6.2.13) did not indicate significant risks to surface water receptors, according to assessments undertaken at that time.	**Low**
	Controlled waters – groundwater receptors: Principal (bedrock) aquifer and Secondary (undifferentiated) (superficial deposits) aquifer beneath the zone.	Leaching from unsaturated soils to shallow groundwater within the Secondary (undifferentiated) aquifer to possibly the Principal aquifer, then lateral migration of dissolved or separated non-aqueous phase contamination within groundwater.	**Medium**	**Likely** The western part of the zone is thought to comprise Made Ground above the Principal aquifer bedrock. Therefore, any zone-derived contamination is likely to migrate into the Principal aquifer below. Where superficial deposits are present, it is predicted that contamination will migrate into these as well, before vertically migrating into the Principal aquifer below. Despite risk assessments undertaken in 2004 (see Section 6.2.13) not indicating significant risks to controlled waters receptors, using a tiered assessment approach, the excavations and landfilling of this part of the zone increases risk.	**Moderate**
		Downward migration to the Principal and Secondary	**Medium**		**Moderate**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
		(undifferentiated) aquifers.			

6.4. Geotechnical Context

6.4.1. Geological and Geotechnical Hazards

Table 6-8 describes some of the geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 6-8 Potential Geological and Geotechnical Hazards in Zone 3

Hazard	Description	Comment
Aggressive ground conditions	The BRE Special Digest (44) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	Swanscombe Cement Works landfill is located in Zone 3B and may have been infilled with CKD. The pH of CKD is known to be highly alkaline and it is often caustic.
Buried foundations	Buried foundations can cause a delay to construction and incur additional costs.	A number of buildings and other major infrastructure are present on site in Zone 3B. There is a possibility of additional buried foundations being present, notably in the northern part of Zone 3A where buildings associated with Bell Wharf and the where the cricket pavilion used to stand. Foundations are visible in the eastern part of Zone 3B where the former gasworks and cement works were located.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	The presence of a number of buildings across Zone 3B implies that buried services will be present. There are likely to be services associated with the former cement works. Services along Manor Way are expected.
CKD	CKD is a significant by product of the cement manufacturing process. CKD is currently considered a hazardous product due to its high pH content.	Swanscombe Cement Works landfill is located in Zone 3B and no records of the type and quantity of waste are available, but it is likely to contain some CKD waste (48).
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	Quarrying occurred in Zone 3B along with a whiting works.
Perched/high water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking construction.	The trial pit logs show a high groundwater level. It is not clear over what area this level is present, due to the lack of data. It is not known whether this is a perched water table or a high water table, due to a lack of sufficient data.
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	According to the GroundSure report (1) there is a moderate chance of running sand along the coast, most probably associated with the Tidal River and Creek deposits, with low risk throughout the rest of the zone.
Saline groundwater	The presence of saline groundwater	The Swanscombe Peninsula is

Hazard	Description	Comment
	(commonly at coastal sites) may result in increased corrosion of steel. Appropriate control measures will need to be taken.	located in a brackish water zone of the Thames, meaning the groundwater is likely to be slightly saline. Ground water is likely to be controlled by tidal river processes therefore levels are variable throughout the day.
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying lengths of piles.	As well as quarrying, weathering from periglacial and fluvial processes will be a concern
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The superficial deposits in Zone 3, particularly the clay alluvium and peat will have low bearing capacity values. CKD has been recorded as being self-cementing in some cases, however the properties of it are known to vary significantly based on the exact composition and manufacturing process.
Weak compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Peat and alluvium are present in Zone 3. These soils appear to be weak and could deform and fail as a result of the loads imposed on them.

6.4.2. Geotechnical Risk Register

The Geotechnical Risk Register is presented as Table 4-8. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a Low ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be substantial are:

- buried foundations;
- buried services;
- variable rockhead;
- weak bearing materials; and
- weak compressible ground.

Most of the other risks are rated as “moderate” or “low”.

6.4.3. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the Substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in-situ* and laboratory testing;
- planned Methodology for the earthworks; and
- detailed design for the temporary construction roads.

6.4.3.1. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be “low”. However, it should be recognised that some residual risks remain, as described in Table 6-9.

Table 6-9 Preliminary Geotechnical Hazard Assessment for Zone 3

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
1	Aggressive ground conditions	2	3	3	1	6	6	2	M	Ground investigation to confirm extent and thickness of CKD. Use BRE Special Digest 1 (44) to determine the concrete class from sulphate and pH results. Use appropriate concrete protection.	3	2	2	1	6	6	3	M
2	Buried foundations	3	3	3	1	9	9	3	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	2	L
3	Buried services	3	3	3	3	9	9	9	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	CKD	2	3	3	1	6	6	2	M	Review historical records and licence areas to confirm CKD extent. Ground investigation to confirm extent and thickness of CKD. Classify and use appropriately.	2	2	2	1	4	4	2	L
5	Historical works	2	3	3	1	6	6	2	M	See buried foundation and buried services.	2	2	2	1	4	4	2	L
6	Perched/high groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	2	1	1	1	2	2	2	L
7	Running sand	2	3	3	1	6	6	2	M	Ground investigation to confirm geological succession and geotechnical properties across the site	1	2	2	2	2	2	2	L
8	Saline groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be	3	1	1	1	3	3	3	L

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
										taken into account.								
9	Variable rockhead	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
10	Weak bearing materials	4	3	3	1	12	12	4	S	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
11	Weak compressible ground	4	3	3	1	12	12	4	S	Ground investigation to confirm extent and thickness alluvium and Tidal River and Creek deposits. Where necessary consider appropriately in geotechnical design.	3	2	2	1	6	6	3	M

6.5. Zone 3 Summary

6.5.1. Geo-environmental Summary

Zone 3, located on the western side of the Swanscombe Peninsula, mainly comprises undeveloped marshland in the northern part of the zone (Zone 3A), whilst the smaller southern part (Zone 3B) has historically been used for cement manufacture, as a whiting works, chalk extraction and landfilling and currently supports a range of light industrial and waste recycling operations.

The landfilled area was used as a works tip for the adjacent Blue Circle/Lafarge Northfleet cement works and is understood to have accepted a range of waste materials including CKD and also demolition materials from the works possibly including asbestos. The landfill is understood to have operated between 1980 and 1993 and does not have a current WML/EP.

Within the undeveloped northern Zone 3A no significant potential sources of soil and groundwater contamination have been identified and hence risks to both environmental and human health receptors are considered to be low. Within the southern Zone 3B, risks to both controlled waters and current human health receptors are considered to be moderate.

6.5.2. Geo-technical Summary

In Zone 3, the geological stratigraphy generally consists of alluvium interbedded with peat, overlying River Terrace deposits and White Chalk bedrock. In the south, Head deposits are identified above the bedrock, and there is Made Ground present, infilling a historical quarry and associated with the glass recovery company and engineering/welding works present in Zone 3B.

Substantial risks within Zone 3 are associated primarily with the beds of peat and alluvium. These beds are highly weak and compressible, which can pose a risk of settlement leading to subsidence, in addition the bearing capacity of these geological units is also expected to be low. It is anticipated that buried services will be encountered within Zone 3, although locations are unknown. The historical maps have identified various buildings in Zone 3 which have now been demolished, but the foundations may remain.

Medium risk constraints include aggressive ground conditions created by the high sulphate content in the alluvium and peat as well as issues associated with the historical works in the sub-Zone 3B. Groundwater levels are undetermined in the zone, although considering the variable and shallow nature of levels in Zone 2, it is assumed that the groundwater regime in Zone 3 is very similar. As previously noted, the River Thames is brackish in this area.

7. Zone 4

7.1. Zone Characterisation

7.1.1. Location

Zone 4 is located in the eastern part of the wider Swanscombe Peninsula site. The approximate NGR for the centre of the zone is 560860 175505 (TQ 60860, 75505). The zone is located partially within the Gravesham Borough Council administrative area, on its eastern side, and partially within the Dartford Borough Council administrative area, on its western side.

7.1.2. Zone Description

For the purposes of this assessment, the zone has been subdivided into three areas. The entire Zone 4 has an approximate area of 41 ha. The northern part of the zone, termed Zone 4A, has an approximate area of 14.5 ha and is marshland and is currently used as agricultural land. There have been no other known uses of Zone 4A since the earliest map edition provided to Atkins and no potentially contaminative land uses have been identified. Zone 4A is accessed by an un-paved road with a vehicle barrier which separates Zone 4A, from Zone 4B below. The plots of agricultural land are separated by surface water drainage ditches.

Zone 4B has an approximate area of 22.5 ha and is dissected by the HS1 railway, which passes in a north-westerly to south-easterly direction through Zone 4B. Zone 4B comprises a series of industrial/commercial including Northfleet Industrial Estate, Kent Kraft Industrial Estate and the eastern part of Manor Way Business Park and includes many buildings, warehouses, local access roads and parking. The industrial/commercial area is currently occupied by businesses such as car parts and repairs, ventilation contractors, storage/distribution, electrical engineering, plastic moulding buildings, a car breakers, skip hire/storage units, waste transfer station, recycling station, marble and stone cutting/processing company, a transportation/haulage business, removals and storage company and an electricity sub-station. There is an infilled lagoon in Zone 4B, which was historically a chalk excavation which was partially infilled by 1907 and again by 1977, leaving an approximately circular lagoon (also referred to as a reservoir on historical maps). A WML/EP for the infilling of the remaining lagoon with clean, inert material was granted in 2011 and the infilling works have since been completed.

The zone has a distinct topography, with substantial chalk spines upon which the principal roads and rail links are located. The chalk spines are approximately 16 to 20 m above the intervening land in places at an approximate elevation of 28 m AOD.

To the south of Zone 4B is Zone 4C, which has an area of 4 ha. All Saints Church (a listed building), a few houses and a pub (The George and the Dragon) are situated between the south-westernmost part of Zone 4B and Zone 4C. Zone 4C comprises open ground known as the Sportsfield, which also contains a historical rifle range, now disused. There are a number of tunnels and associated roadways through the chalk spine upon which London Road is located. A further tunnel, now backfilled, was formerly present through the chalk spine on which the North Kent Line railway is located and which connected Zone 4C to the northern part of Zone 6 (Zone 6A).

The boundaries of Zones 4A, 4B and 4C are shown on Figure 001, permitted areas within Zone 4 are shown on Figure 002 and key features, both historical and current, are shown on Figure 013. Photographs of the zone from a site reconnaissance undertaken on 23 October 2014 can be found in Appendix B.

7.1.3. Zone-Specific Data Sources

The Environment Agency was contacted and responded to a request for information on incidents and permits; the information has been included herein. Information from the HS1 railway was still awaited at the time of writing. The following zone-specific data sources were available:

- Hydrock, Desk Study and Ground Investigation at Northfleet Industrial Estate. February 2008 (52);
- Atkins, Review of Bamber Pit & Sports Ground, Draft Technical Note, September 2012 (53);
- Atkins, Bamber Pit and Sportsfield Environmental and Geotechnical Liability Assessment, 5 December 2014 (54);
- GVA for PBH Properties Ltd, Environmental Due Diligence Report, Sports Ground Nr. Swanscombe, Northfleet, Kent, 01B072915, June 2011 (55);
- GVA, Former Sports Ground, Swanscombe, Report on Town Planning Issues, June 2011; and
- Information provided by the client includes the Geotechnical and Land Raise Strategy Report by Halcrow (42).

7.1.4. Surrounding Land Uses

The area adjacent to the east of Zone 4A appears to be agricultural or natural land with a number of mature trees. To the east of the agricultural/natural area is an industrial area (including a large Cemex plant). The River Thames is located beyond the industrial area. There are some residential properties adjacent to the south of Zone 4B. Zone 1 is located to the north of Zone 4A, Zone 2 is located to the west of Zone 4A, Zone 5 is located to the west of Zone 4B and Zone 6 is located on the opposite side of the North Kent Line, to the south of Zone 4C.

7.1.5. Historical Land Uses

Zones 1, 2 and 5 are located adjacent to Zone 4, with Zone 6 only separated from Zone 4 by the North Kent Line. For details of historical land uses in these zones, please consult their respective chapters. A summary of historical land uses within Zone 4 is presented in Table 7-1.

Table 7-1 Historical Land Use Relating to Zone 4

Dates and Scales	Within Zone 4	Within 1 km of the Zone
1865-1866 1:10,560 **1865-1872** 1:2,500	Zone 4A comprises fields (with individual numbers shown on the historical maps) with land drains, field boundaries and tracks across the area. Zone 4A is labelled as Botany Marshes and has remained the same until present day. Zone 4B comprises open ground with a sloping northern boundary, and contains a small building within the southern portion. The western part of Zone 4C comprises a small area of buildings called “Galley Hill Farm”. The North Kent Line is adjacent to the southern boundary of Zone 4C.	The majority of the surrounding area to the east of Zone 4A comprises marshes with surface water features. A meandering river, (River Ebbsfleet), is located to the south-east of the site. The River Thames is located 330 m to the east of Zone 4, at its closest point. Adjacent to the south-eastern corner of the site, there have been some excavations associated with a kiln.
1888 1:10,560 **1897** 1:2,500	Zones 4B and 4C are dominated by chalk pits. Zone 4B now includes a number of industrial activities and at a lower elevation than the road adjacent to the southern boundary of the zone. Britannia Cement Works and Northfleet Paper Works (with associated tanks and aqueduct) are located in Zone 4B, in the eastern and central portions respectively. Ponds are present towards the centre of Zone 4B, associated with the paper works in this area. Schools are present in the south-west of Zone 4B. Mineral railway/tramway tracks intersect Zones 4B and 4C, with a track extending out of the southern boundary of 4C, beneath the North Kent Line, and across the northern boundary of Zone 6 into a chalk pit.	Due to the coverage of the maps provided to Atkins, the River Ebbsfleet is not shown adjacent to the east of the site but is shown to the south-east of Zone 4. An old chalk pit and a gravel pit are located to the south-east of the site. Portland Cement Works (different to the Portland Cement Works referred to in the Zone 5 chapter, to the west of Zone 4) are shown approximately 350 m to the east of Zone 4A and comprise railways, wharfs and an area of infilling or refuse tipping adjacent to the north of the cement works. There has been development of residential properties within 1 km of the site.
1907-1923 1:10,560 **1907-1909** 1:2,500	The chalk pit in Zone 4B has been partially infilled, leaving an irregularly shaped lagoon in the eastern part of the zone. This is the site of the lagoon which was subsequently infilled in 2011. Some allotment gardens are located Zone 4C. Another chalk pit is shown in the western portion of Zone 4B.	No significant changes.
1932-1939 1:2,500	Zone 4B is occupied by “British Vegetable Parchment Mills”, parts of “New Northfleet Paper Mills” (instead of the existing Northfleet	Part of Portland Cement Works is now labelled as Britannia Lead Works and there are a number of circular structures within

Dates and Scales	Within Zone 4	Within 1 km of the Zone
1931-1948 1:10,560	Paper Mills), and "Kent Kraft Mills". The chalk pit in the southern part of Zone 4B appears to have been infilled and "Thames Tar Distilleries" is now shown on site with a number of tanks and tramways. There are fewer buildings associated with Britannia Cement Works located in Zone 4B. The south-western portion of the zone comprises joinery works and houses. Zone 4C is shown to be partly vegetated, before the majority of Zone 4C is labelled as a sports ground (referred to within this report as "sportsfield") and the tramway tracks have changed alignment.	the compound. The residential area to the south-east of Zone 4B now includes football grounds and allotments.
1952 1:2,500 **1952** 1:1,250	The area formerly labelled as Thames Tar Distilleries is now labelled "Thames Chemical Works".	No significant changes.
1955-1966 1:10,560	A rifle range shown to the west of the sports ground on the 1952 map, within Zone 4C. There are a number of tanks and small buildings associated with the paper mills, although the tanks are in different locations to those shown previously. The location of the former Thames Chemical Works, is now a small unidentified works, with two additional large circular structures. A pipeline is shown to run eastwards from the eastern portion of Zone 4C, although the map is unclear where it is going to (appears to be somewhere in Tower Wharf to the east).	An electricity substation is located adjacent to the south-western boundary of Zone 4. There has been much residential development within 1 km of the site. A factory is shown adjacent to the south-east of the site. The industrial area to the east of Zone 4B is now labelled as "Tower Wharf". A factory is present south of the eastern part Zone 4B, immediately adjacent to the tramway tracks in this area.
1971-2014 1:10,000 **1984-1995** 1:2,500 **1986-1991** 1:1,250	The north-western part of Zone 4B is shown as comprising the southern part of a refuse tip in 1970 (known as Pilgrim's Pit – see Section 7.2.10 for further details). The lagoon has been partially infilled again, leaving it as a circular shape. A number of large buildings have been constructed in Zone 4B. These comprise warehouses, factories, depots and works. An electricity substation is located near the centre of Zone 4B. The tramways/railways are no longer shown. The 1986-1990 map shows the south-western part of Zone 4B to be labelled as Kent Kraft Industrial Estate, and the mills within the eastern portion of Zone 4B have changed configuration.	A number of buildings have been constructed between the zone and the wharf to the south-east. A depot with a large number of tanks is shown to the south-east of the zone, adjacent to the new railways. Depots and wharfs have been constructed to the east north-east of the Zone 4A, near Zone 1.
2014 (site walkover)	The lagoon was noted to be completely infilled during the site walkover undertaken on 23 October 2014.	No significant changes.

7.1.5.1. Summary of Historical Land uses

Zone 4A is not believed to have been subject to any industrial development or mineral extraction activities. Zone 4C was excavated and then later used as a sports ground and rifle range. A significant number of industrial activities have taken place in Zone 4B. The industrial activities within Zone 4B include:

- chalk excavation and subsequent infilling;
- Pilgrim's Pit landfill (see Section 7.2.10 for further details);
- Britannia Cement Works;
- various paper mills including Northfleet Paper Works, British Vegetable Parchment Mills and Kent Kraft Mills;
- joinery works;
- Thames Tar Distilleries;
- Thames Chemical Works (later labelled only as works);
- warehouses;
- mineral railways/tramways;
- tanks;
- electricity substations; and
- a pipeline.

Zone 4B is currently occupied with a range of industrial businesses which also represent potential contamination sources.

After chalk excavation, a lagoon (referred to as a reservoir on a number of historical maps) was formed in the eastern part of Zone 4B. This lagoon was partially infilled by 1907 and then partially infilled again by 1977. The lagoon was infilled completely using clean, inert material in 2011 and is currently open ground covered in vegetation and a security bund.

The part of Kent Kraft Industrial Estate, in the western part of Zone 4B, occupies the south-eastern part of a quarry previously located in this area. Little infilling of land is known to have occurred in this area, aside from Pilgrims Pit, the former quarry located predominantly within Zone 5A, but extending into Zone 4B, and the predominant historical land uses relate to paper milling. Potential contaminants are therefore associated with the area's former use, namely paper milling and manufacture, including heavy metals, inorganic compounds including hypochlorite, chlorates, sulphides and sulphites, sulphuric acid, sodium hydroxide, solvents for pulp production, organic compounds from the production of paper, oils, and PCBs (56).

The majority of the off-site potentially contaminative land uses are associated with the area to the east of the Zone 4B and include Portland Cement Works, Britannia Lead Works, electricity substations, depots and railways. There have been a large number of tanks and circular structures associated with these industrial activities, which could indicate potential historic contamination sources. There are a number of landfills surrounding the zone; namely within the adjacent Zones 1 and 2 and the nearby Zone 6, on the other side of the North Kent Line railway, which could also represent potential off-site contamination sources. There were also a number of potential off-site contamination sources within the Kent Kraft Industrial Estate in Zone 5, which is located to the west of Zone 4B.

7.2. Environmental Context

7.2.1. Historical Borehole Records

Using the BGS borehole record viewer, records of the available historical exploratory holes have been collated and reviewed. In total 22 borehole logs with depths between 9.51 m and 25.01 m were identified. The majority of the boreholes were located in Northfleet Industrial Estate and Kent Kraft Industrial Estate; with three available for Botany Marshes, just outside of the zone. Trial pit logs are also available for Northfleet Industrial Estate and Kent Kraft Industrial Estate, with a depth of up to 6 m, and one to a depth of 1.9 m for Botany Marshes.

Of the boreholes identified; which were installed between 1995 and 1997; nine were categorised as Grade A, 13 were categorised as Grade B, and none were Grade C. The information of the Grade A and B logs has been used to verify the published geological mapping information and inform the findings of this report.

7.2.2. Geology

The 1:10,000 BGS geological map, sheet TQ67SW (Northfleet), Solid and Drift edition (1996) shows the local geological succession to be alluvium and RTD overlying undifferentiated White Chalk in the north. In Zone 4B, in the area of the two industrial estates, the geological succession consists of Made Ground over undifferentiated White Chalk. Head deposits overly the chalk in Zone 4C, where original ground remains (see Table 7-2).

Table 7-2 Expected Stratigraphy beneath Zone 4

Strata	Typical Thickness (m)	Description
Made Ground	3	Brown sandy flint, chalk and brick gravel with concrete and metal inclusions.
Head	1	Brown sandy silt with chalk and flint gravel. Sometimes containing clay.
Alluvium	6	Silty and sandy clays, with some flint and chalk gravel. Containing bands of peat, and large proportions of organic material.
RTD	10	Grey brown sand and fine gravel, underlain by dense flint and chalk gravel, with some sand.
Chalk	>10	White Chalk from the Seaford and Newhaven formations, moderately weathered near the top of the sequence. Contains beds of sheet flints.

Notes:(1) Typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. (2) See Section7.2.4 for further details

7.2.3. Geomorphology

Botany Marshes (Zone 4A) and Kent Kraft and Northfleet Industrial Estates (Zone 4B) have a mostly uniform topography of about 3 m AOD, although in the industrial estates it dips to between 1 m and 2 m AOD in the centre, and rises to about 5 m AOD at the eastern boundary. In the Sportsfield, the elevation is about 5-6 m AOD, mostly although it ranges between about 9 m AOD and 2 m AOD in localised areas. Elevation data have been taken from the BGS borehole logs and topographic maps.

In the Northfleet Industrial Estate, a vertical chalk spine runs along the southern boundary of Zone 4B (Galley Hill Road) which decreases in height towards to east. At its highest the Chalk face reaches an elevation of 19.2 m AOD. The chalk spine continues from Northfleet Industrial Estate to run along the southern border of Kent Kraft Industrial Estate. Another chalk spine runs parallel to the first, to the south, and carries the North Kent Line railway.

7.2.4. Ground Conditions

Descriptions and geotechnical parameters provided in the following sections have been obtained from the information sources detailed above. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 4, the information is provided for guidance only and it is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain site specific design parameters.

7.2.4.1. Made Ground

Made Ground is recorded in 12 BGS boreholes in this zone, predominantly along the HS1 line and infilling of the Sportsfield (Zone 4C). The Made Ground is described as being brown sandy gravel of flint, chalk and brick. In some areas reinforced concrete, metal and cloth are recorded. In Zone 4B, the made ground is typically 1-2 m thick, however in Zone 4C, the Made Ground is thicker, reaching around 3-4 m thick over most of the zone, and as thick as 8 m in some areas. There is no recorded Made Ground in Zone 4A.

7.2.4.2. Head

Head approximately 1.3 m thick is observed beneath Made Ground in five BGS exploratory borehole records (5). It is described as being brown sandy, sometimes clayey, silt with some chalk and flint gravel. All of these logs are located in the south-eastern part of Northfleet Industrial Estate.

7.2.4.3. Alluvium

The alluvium is described in BGS borehole logs as being a sequence of firm to soft brown often silty or sandy clays with some gravel of flint and chalk. In borehole TQ67NW560, it is described as having bands of peat, and in borehole TQ67NW558, a bed of firm brown peat 1.6 m thick, was observed. It was not observed in the other boreholes.

Although the data for Botany Marshes are very limited, it has been inferred that the superficial deposits of Zone 1 and 2, i.e. the alluvium and RTD, are uniform and extend into Zone 4. As the deposits are laterally extensive in Zones 1 and 2, it would suggest that two peat beds up to 4 m thick may also be present in Botany Marsh.

7.2.4.4. River Terrace Deposits

BGS Boreholes TQ67NW560 and TQ67NW561 observe RTD approximately 9 m thick overlying the Chalk bedrock. The deposits are described as being sequences of grey brown fine to medium sand with some fine gravel, and soft dark grey brown sandy clay with some gravel. Underlying the sand and clay is a bed of dense to very dense sandy chalk and flint gravel. This correlates with RTD described on the BGS website (5). CPT values in borehole TQ67NW560 show the strength of the RTD increasing with depth, likely due to the gravel beds at the base of the unit.

7.2.4.5. White Chalk

From BGS borehole logs and geological maps, it has been determined that underlying the superficial deposits is a weathered, weak, medium density White Chalk with bands of flint nodules, which is often structureless in its uppermost 6 m. The chalk outcrops at the surface in Northfleet Industrial Estate due to quarrying in this area, and multiple vertical faces are evident along the southern boundary Zone 4B (Galley Hill Road/A226). On average, only 10 m of chalk is proven in borehole records; however. as previously referred to in the geological overview, the White Chalk group is known to extend to some depth.

SPT results recorded in BGS boreholes TQ67NW546, TQ67NW547, TQ67NW558 and TQ67NW560, show the strength of the chalk increases with depth on average. There are, however, areas of stronger and weaker chalk throughout, likely as a result of the flint banding.

7.2.5. Hydrology and Hydrogeology

7.2.5.1. Surface Water

A number of land drains are present within the Zone 4A separating the fields into roughly rectangular areas. The land drains also surround the Botany Marshes area.

7.2.5.2. Groundwater

From the boreholes available for Zone 4, it has been concluded that groundwater was encountered on average at 2.75 m below ground level, with a minimum level of 2.3 m (TQ67NW533 and TQ67NW546), and a maximum of depth of 4 m (TQ67NW558). This corresponds to an elevation of -1 to 2 m AOD. The RTD are a Secondary (undifferentiated) aquifer and the Chalk is a Principal aquifer.

7.2.5.3. Groundwater Abstractions

No groundwater abstractions are located in this zone. However a medium size groundwater abstraction is located approximately 300 m outside Zone 4 to the north-east, currently licensed for mineral washing by Cemex UK Materials Ltd. and spray irrigation by Lafarge. The maximum annual abstraction is between 26,300 m^3 and 1,186,000 m^3. No other groundwater or surface water abstractions are located within 1 km of this zone.

7.2.5.4. Groundwater Vulnerability

Information provided by the Environment Agency (9) concludes that the majority of Zone 4 is located in a SPZ 3: total catchment area. However the south-eastern corner of this zone, in Northfleet industrial Estate, is SPZ 2: outer zone.

7.2.6. Flood Risk

Zone 4 is generally at high risk of flooding though benefits from flood defences. It is within an Environment Agency Zone 3 Flood Plain. There have been historic flood events in the area (47).

Further details regarding flood risk can be found in Buro Happold's Flood Risk Assessment (in preparation).

7.2.7. Mineral Abstractions

An 1895 OS map shows that the whole of the area currently known as Northfleet Industrial Estate was a chalk quarry relating to Britannia/Northfleet Cement Works, at least until up to 1907 (3).

7.2.8. Designated Environmentally Sensitive Sites

A small portion of the south-west corner of Zone 4 is within a NVZ. There are no designated environmentally sensitive sites within 1 km of Zone 4, excluding those found within other zones on the wider site. Zone 4 is within a SSSI IRZ. There are no scheduled monuments or listed buildings within the zone boundary, although there is a Grade II* listed building ("Church of All Saints"), located at the junction of London Road and Swanscombe High Street, between the south-eastern and south-western segments of Zone 4B. This building is located on an elevated section between the chalk spines of London Road and the North Kent Line railway. Grade II* buildings are particularly important buildings of more than special interest.

7.2.9. Environmental Permits, Incidents and Registers

There are number of LPPC (Part B) enforcements located within Zone 4 (2), summarised below in Table 7-3.

Table 7-3 Environmental Permits, Incidents and Registers Located within Zone 4

Location within the Zone	Address	Process	Status	Enforcement Details
West (Zone 4B)	Unit D, North East Industrial Estate, Lower Road, Northfleet, DA11 9SN	Unknown	Historical permit	Enforcement notified in 02/05/2002, for timber/combustion
West (Zone 4B)	DSR, Kent Kraft Industrial Estate, Lower Road, Northfleet, DA11 9SR	Waste oil burning process	Historical permit	No enforcements notified
West (Zone 4B)	Oakes, Kent Kraft Industrial Estate, Northfleet, Kent, DA11 9SN	Concrete and crushing process	Historical permit	No enforcements notified
West (Zone 4B)	Regent Furniture (Medway) Ltd, Northfleet Industrial Estate, DA11 9SN	Timber process	Historical permit	No enforcements notified
West (Zone 4B)	SE Recycling, Kent Kraft Industrial Estate, Northfleet, Kent, DA11 9SR	Concrete and crushing process	Historical permit	No enforcements notified
East (Zone 4B)	North Kent Commercials Unit A1, Northfleet Industrial Estate, Lower Road, Northfleet, DA11 9SN	Vehicle re-spray process	Historical permit	No enforcements notified
East (Zone 4B)	Kent Coachworks Ltd, Northfleet, Industrial Estate, Kent, DA11 9SN	Vehicle Re-spray process	Historical permit	No enforcements notified
East (Zone 4B)	Barnet Sands Ltd, Lower Road, Gravesend, DA11 9SN	Vehicle Re-spray process	Historical permit	No enforcements notified
East (Zone 4B)	Bamber Garage, Northfleet Industrial	Waste oil burning process	Historical permit	No enforcements notified

Location within the Zone	Address	Process	Status	Enforcement Details
	Estate, DA11 9SR			
East (Zone 4B)	VMC Limited, Units E1 & E3, Kent Kraft Industrial Estate, Lower Road, Northfleet	Cement batchers process	Current permit (the historical permit is also listed in the GroundSure report)	No enforcements notified

There are two licensed discharge consents related to the Zone 4 land area, as detailed in Table 7-4.

Table 7-4 Licensed Discharge Consents within Zone 4

Location within the Zone	Address	Effluent Type	Receiving Water	Status
West (Zone 4B)	P15, Kent Kraft Industrial Estate, Lower Road, Northfleet, Kent	Trade discharges – site drainage	Into land	New consent: issued and effective from 14/09/1999
West (Zone 4B)	P15, Kent Kraft Industrial Estate, Lower Road, Northfleet, Kent	Trade discharges – site drainage	Into land	Varied under EPR 2010 (superseded by the above)

There are a number of EPs, Incidents and Registers located within 500 m of Zone 4 (2), summarised in Table 7-5. Only current or active LPPC permits are shown.

Table 7-5 Active Environmental Permits, Incidents and Registers Located within 500 m of Zone 4

Distance and Orientation from Zone 4	Owner	Type of Permit, Incident and/or Register	Status	Additional Information
9 m east of Zone 4B	London Bus and Truck Ltd	LPPC (Part B)	Current	Re-spraying of road vehicles
61 m south of Zone 4B and east of Zone 4C	Shell Northfleet Service Station	LPPC (Part B)	Current	Petrol storage
262 m east of Zone 4A	Britannia Refined Metals Ltd.	IPPC	Effective as of 1 March 2007.	Permit Number: ZP3836LP Process: Non-ferrous metals melting with a capacity of >4 tonnes per day of lead/cadmium or >20 tonnes per day other metals
322 m east of Zone 4B	North Kent Roadstone Ltd.	LPPC (Part B)	Current	Roadstone Coating Process
322 m east of Zone 4B	CPI Mortars Ltd.	LPPC (Part B)	Current	Drying of sand and batching of ready mixed cement
322 m east of Zone 4B	Brett Concrete, Robins Wharf	LPPC (Part B)	Current	Batching of ready mixed cement
413 m east of Zone 4A	Britannia Refined Metals Ltd.	Discharge Consent (List 1)	Active	Authorised substances: mercury (other) and

Distance and Orientation from Zone 4	Owner	Type of Permit, Incident and/or Register	Status	Additional Information
				cadmium into the Thames Estuary
413 m east of Zone 4A	Britannia Refined Metals Ltd.	Discharge Consent (List 2)	Active	Authorised substances: arsenic, copper, lead, nickel, zinc
413 m east of Zone 4B	Northfleet Sewage Treatment Works	Discharge Consent	Active (six permits currently active, 10 in total)	Discharge of sewage
483 m north-east of Zone 4B	Site at Grove Road, Northfleet	Discharge consent	Current	Trade discharges

There have been a number of pollution incidents within Zone 4, summarised in Table 7-6.

Table 7-6 Pollution Incidents within Zone 4

Location within Zone	Incident Date	Pollutant	Impact
West (Zone 4B)	27 June 2001	Inert materials and wastes: construction and demolition materials and wastes	Land – Category 3 (minor) Air – Category 3 (minor)
South-east (Zone 4B)	18 August 2001	Contaminated water, firefighting run-off	Water – Category 3 (minor)
South-east (Zone 4B)	1 August 2002	Organic chemicals/products	Land – Category 1 (major) Air – Category 3 (minor)
Not provided	1 August 2002	Fly-tipping with construction and demolition materials and wastes	Land – Category 1 (major) Air – Category 3 (minor)
South-east (Zone 4B)	23 October 2002	General Biodegradable Materials and Wastes	Land – Category 3 (minor impact)
South-east (Zone 4B)	18 September 2003	Construction and demolition materials and wastes	Land – Category 3 (minor)
Not provided	10 December 2003	Fly-tipping	No impact
Not provided	6 January 2004	Burning of waste	Air – Category 3 (minor)
Not provided	17 April 2008	Unauthorised waste management activity	Water – Category 3 (minor) Air – Category 3 (minor)
Not provided	29 October 2009	Fly-tipping of construction and demolition materials	No impact
Not provided	23 September 2011	Fires, burning of waste	Air – Category 3 (minor)
Not provided	30 September 2012	Unauthorised waste management activity from an exempt spreading/recovery facility	Water – Category 3 (minor) Air – Category 3 (minor)
Not provided	8 November 2012	Fires, burning of waste	Air – Category 3 (minor)

There were three pollution incidents within 500 m of Zone 4, with a maximum impact classification of Category 3 (minor).

7.2.10. Landfills and Other Waste Sites

There were a number of WMLs within 1 km of Zone 4 (2), as summarised in Table 7-7.

Table 7-7 Landfill and Waste Management Permits within Zone 4

Permit Number	Landfill/Waste Facility Name and Location	Operator	Waste Type	Dates of Operation
WML AED003 EPR EA/EPR/NP3698 VM/A001	Northfleet Lake (eastern part of Zone 4B)	Greenfield Properties (UK) Ltd	Deposit of waste to land as a recovery operation to a maximum of 114,800 tonnes a year.	Licence issued 10 August 2011
WML WOO170 EPR EA/EPR/KB3435 AK/T001	Northfleet Lake (eastern part of Zone 4B)	Woodland Environmental Limited	Deposit of waste to land as a recovery operation to a maximum of 114,800 tonnes a year.	Licence issued 10 August 2011
WML CRO002 EPR EA/EPR/KP3698 HF/V002	Crossways Recycling (western part of Zone 4B)	Crossways Recycling Ltd.	Household, commercial and industrial waste transfer station to a maximum of 39,060 tonnes a year.	Licence issued 25 May 1993
WML SOU001	South Herts Waste Management Limited (western part of Zone 4B)	South Herts Waste Management Limited (in liquidation)	Household, commercial and industrial waste transfer station to a maximum of 39,060 tonnes a year.	Licence issued 25 May 1993
WML LAN123 EPR EA/EPR/GB3730 RW/A001	Lancebox Limited (western part of Zone 4B)	Lancebox Limited	Inert and excavation waste transfer station and treatment	Licence issued 18 June 2014
WML EPR/ZP3195HH/ V004	Ace Car Breakers (Zone 4B, and also extends into Zone 5)	Mr Robert Arnold, Mrs. Ruth Arnold and Mr. Henry Arnold	Metal recycling site (vehicle dismantler) up to 15,600 tonnes per year and end-of-life vehicle facility up to 4,999 tonnes per year.	Licence issued 24 November 2004
WML P/02/01	Botany Road (297 m east of Zone 4A)	Britannia Refined Metals	Inert, industrial, special.	Licence issued 14 June 1977 Licence surrendered 19 September 2000

The lagoon, referred to in the EP as ‘Northfleet Lake’ was infilled with clean, inert material as part of an engineered land recovery operation. Hence, it is considered that the fill material placed under this permit should not represent a potential source of contamination.

The Environment Agency website (9) incorrectly identifies a historical landfill within Zone 4C labelled as Bamber Pit, which is actually located to the south of the North Kent Line railway, within Zone 6. This area is referred to in a number of historical reports as “Sports Ground” and elsewhere in this report as “Sportsfield”. The Sportsfield comprises a disused, partially filled quarry with the northern, southern and western boundaries formed by the chalk faces (spines) of the old quarry, to an average height of approximately 10 m above the ground level of the Sportsfield (54). Further details regarding the infilling of this area can be found in Section 7.3.1.9.

There are also three records of Local Authority recorded historical landfills within the zone. These all relate to an area on the northern-central part of Zone 4B - a small, former refuse tip (2). It is likely that the former refuse tip is the same as the tip referred to as Pilgrims Pit within Aspinwall & Company Ltd’s HS1

Assessment of Land Contamination report (57). According to the report, Pilgrims Pit lies in the western part of a disused chalk quarry, which was infilled between approximately 1947 and 1974; most likely with cement works waste and demolition materials. The infilled materials are thought to be 10 m deep in this area and resting directly upon the Chalk bedrock. The small stream within the zone forms the eastern boundary of this tip, which then flows north to join the drainage channels in Botany Marshes (54)(54).

7.2.11. Potentially Contaminative Industrial Sites

There are 48 potentially contaminative industrial sites within the GroundSure EnviroInsight report (2), and these relate to a variety of industries. All of the industries fall into the following categories, with all of them except one (which is specified) relating to Zone 4B:

- hire services;
- repair and servicing;
- industrial products;
- infrastructure and facilities;
- engineering services;
- transport, storage and delivery;
- construction services;
- industrial features;
- sports complex (referring to the rifle range in Zone 4C);
- extractive industries;
- consumer products;
- motoring; and
- IT, advertising, marketing and media services.

7.3. Information Gained from Public Records

7.3.1. Northfleet Industrial Estate

7.3.1.1. Introduction

The lagoon located in Zone 4B formed as a result of historical chalk extraction originally occupied a larger area which was partially infilled by 1907, prior to the construction of the Thames Tar Distillery. A further area of the lagoon is shown on historical OS mapping to have been infilled by 1977 to form a smaller and approximately circular lagoon.

A proposal for a development comprising the infilling of the remaining area of the lagoon (referred to in the EPs as Northfleet Lake), construction of industrial/commercial units and the construction of associated roads and hardstanding was submitted to Dartford Borough Council in 2008. An EP was granted in 2011 for the infilling of the lagoon with clean inert material. Prior to the infilling, a site investigation and contaminated land assessment was undertaken by Hydrock.

The report, produced by Hydrock (52), focussed on a 0.98 ha area, and included the lagoon and part of the land surrounding it. The Hydrock report collated and assessed information from three ground investigations; two by Consultants 2020 which were undertaken in November 2002 and August 2003 and one by Hydrock in December 2008. Only the Hydrock report was available and no Consultants 2020 reports were directly available to Atkins for review as part of this study. A summary of the investigation findings is presented below together with a reassessment of the analytical data against current assessment criteria.

7.3.1.2. Ground Investigation

Made Ground was encountered in all exploratory holes between 0.1 m to >3.60 m bgl and comprised hardcore type material overlying dark grey and brown clayey sandy gravels with frequent concrete cobbles and boulders, whole bricks and pockets of clay. The gravel comprised flint, chalk, brick, concrete and ash. Within the deeper Made Ground, occasional chalk layers were noted with much chalk gravel, flint and occasional brick. The Made Ground was deepest in the south-eastern edge of the lagoon, which had been infilled by 1977.

Possible head deposits were identified in two locations, recorded as brown clayey silty gravelly sand with occasional weakly cemented sandstone. Gravel was subangular to subrounded fine to coarse chalk and flint.

Seaford Chalk Formation was identified between 0.25 m bgl and 2.20 m bgl and comprised structureless chalk, of slightly sandy, silty, angular to sub-angular, medium to coarse gravel with occasional chalk cobbles.

Risks to controlled waters were assessed according to the remedial targets methodology and there were no exceedances of the standards used at the time. The available data were compared directly with Generic Assessment Criteria (GACs) based on the type of water sample. Groundwater data were assessed using a Level 2 (groundwater below source) assessment where the results are directly compared against the GACs for the quality of Controlled Waters. The GACs were selected from Drinking Water Standards (DWSs), Surface Water Abstraction Directive standards and EQSs which apply to surface waters.

7.3.1.3. Soil and Groundwater GQRA undertaken by Atkins

Soil and groundwater data from the Hydrock report were available in the public domain. Atkins has undertaken an updated generic quantitative risk assessment (GQRA) using current industry good practice. Surface water samples from the now-infilled lagoon were also available, however these are no longer considered relevant as the lagoon has been infilled.

7.3.1.4. Soil Assessment

The Hydrock report included chemical data from a total of 21 soils. Total PAHs were recorded in all six soil samples taken from the Made Ground at a maximum of 28.2 mg/kg at TP3 (0.5 m bgl). PAHs in natural ground (within the Chalk) were considered by Hydrock to be ‘low’ and no TPH, benzene, toluene, ethylbenzene and xylene, SVOCs or phenols were recorded above the MDL. No asbestos was detected. The soils results were analysed through a GQRA, using the methodology available at the time. Hydrock concluded that there were no hotspots of contamination after undertaking a maximum value test and mean value test against Hydrock’s GACs.

Atkins has screened the soils from the both the Consultants 2020 and Hydrock ground investigations against Atkins-derived soil screening values (SSVs) for 1 % soil organic matter content and a sandy soil. The assessment follows the UK risk-based approach to human health risk assessment of land contamination, outlined in CLR 11. Atkins has derived SSVs using the Contaminated Land Exposure Assessment v1.04 and v1.06 software. The assessment was undertaken assuming a future commercial land use scenario.

There were no exceedances of the Atkins SSVs and so the conclusions of this separate assessment are broadly the same as those presented in the Hydrock report. A summary of the soil assessment is presented in Table 7-8 and full screening sheets are presented in Appendix D.

Table 7-8 Summary of Atkins Soil Screening

Constituents	No. of Samples	GAC (mg/kg)	Maximum (mg/kg)	Constituents	No. of Samples	GAC (mg/kg)	Maximum (mg/kg)
Boron	9	-	1.1	TPH Aromatic C8-C10	1	58600	<0.1
Sulphur	21	-	66	TPH Aromatic C10-C12	1	68300	<0.1
Cyanide	21	34	2.5	TPH Aromatic C12-C16	1	68400	0.7
Sulphide	9	-	1.2	TPH Aromatic C16-C21	1	28400	8
Arsenic	21	640	26.	TPH Aromatic C21-C35	1	28400	16
Beryllium	9	1010	2.1	Total Petroleum Hydrocarbons	1	-	24
Cadmium	21	230	3.1	Naphthalene	9	8180	0.36
Chromium	21	-	57	Acenaphthylene	9	-	0.57
Copper	21	109000	130	Acenaphthene	9	109000	0.26
Mercury	21	-	2.1	Fluorene	9	66800	0.24
Nickel	21	1800	34	Phenanthrene	9	-	1.8
Lead	21	6490	830	Anthracene	9	536000	0.45
Selenium	9	13000	0.42	Fluoranthene	9	72300	4.2
Vanadium	9	7530	54	Pyrene	9	54200	3.9
Zinc	21	1000000	670	Benzo(a)anthracene	9	131	2.1
Sulphate	12	-	<0.5	Chrysene	9	14000	2.6
Barium	12	22100	369.3	Benzo(b)fluoranthene	9	142	3.2
TPH Aliphatic C5-C6	1	1000000	<0.1	Benzo(k)fluoranthene	9	1430	1.6
TPH Aliphatic C6-C8	1	1000000	<0.1	Benzo(a)pyrene	9	14.3	3.9
TPH Aliphatic C8-C10	1	167000	<0.1	Dibenz(a,h)anthracene	9	14.3	0.01
TPH Aliphatic C10-C12	1	171000	<0.1	Indeno(1,2,3-c,d)pyrene	9	142	2
TPH Aliphatic C12-C16	1	171000	<0.1	Benzo(g,h,i)perylene	9	1440	2.2
TPH Aliphatic C16-C21	1	-	<0.1	Total of 16 PAHs	9	-	28.2
TPH Aliphatic C21-C35	1	-	<0.1	Phenols	9	-	0.15
TPH Aromatic C5-C7	1	13.11739	<0.1	Asbestos	9	Not detected	
TPH Aromatic C7-C8	1	414000	<0.1				

7.3.1.5. Groundwater Assessment

Atkins has undertaken an updated GQRA of the groundwater samples available in the Hydrock report. A total of 27 rounds of monitoring were taken from three boreholes installed as part of the Consultants 2020 works. The response zones of the three boreholes are located within the Chalk. The sampling was undertaken from September 2003 to October 2008. To assess potential risks to the identified controlled waters receptors, a comparison of constituents within groundwater against pertinent screening criteria has been undertaken. The samples were screened against both UK/EU DWS and EQS. Statutory values were used in the first instance, but where none were available then non-statutory screening criteria were used. There were a number of exceedances noted, summarised below in Table 7-9.

Table 7-9 Summary of Exceedances by Constituents within Groundwater

Constituent	Unit	Maximum Concentration	EQS	Number of Exceedances of the EQS	DWS	Number of Exceedances of the DWS	Total Number of Samples
Chloride	mg/l	688	250	25	250	25	82
Sulphate	mg/l	279	400	0	250	13	82
Sodium	mg/l	395	-	-	200	20	76
Selenium	µg/l	14	10	4	10	4	82
Manganese	µg/l	138	30	23	50	13	76
PAH	µg/l	0.2	0.1	15	0.1	15	76
Nickel	µg/l	50	200	0	20	10	81
Zinc	µg/l	120	75	3	3,000	0	82

There were exceedances of the EQS and/or DWS by chloride, sulphate, sodium, selenium, manganese, PAH, nickel and zinc. The exceedances were all within one order of magnitude of the screening criteria except manganese. TPH Criteria Working Group and speciated PAH were not analysed. Full screening sheets are presented in Appendix D.

7.3.1.6. Surface Water Assessment

The Hydrock assessment undertook surface water sampling from the lagoon. However, as the lagoon has since been infilled, the surface water samples are no longer relevant.

7.3.1.7. Ground Gas Assessment

Hydrock undertook ground gas monitoring in three boreholes over two rounds. The flow rate was recorded as <0.1 L/hr in all boreholes. The maximum concentration of carbon dioxide detected was 0.3 % v/v and the maximum concentration of methane detected was 0.1 % v/v. Hydrock assessed the ground gas data against guidance in CIRIA C655, which is the methodology still currently used. Hydrock used the modified Wilson & Card methodology to develop Gas Screening Values. The assessment indicated that the site was Characteristic Situation 1 with a risk classification of very low.

7.3.1.8. Summary

The lagoon area which was investigated by Hydrock, represents only a relatively small part of Zone 4. However there were no exceedances noted in the soils. There were exceedances noted within the groundwater which indicates a potential source of groundwater contamination within the soils. The response zones of the boreholes were located in the Chalk and therefore, there is evidence that the Principal aquifer within the Chalk may be impacted by contamination from within Zone 4.

7.3.1.9. Sportsfield

No chemical test data for soils have been made available for review for the area referred to as the “Sportsfield”, within Zone 4C, although this area does have good exploratory hole coverage. However, given the historical use it would be expected to contain elevated concentrations of a range of contaminants including inorganic compounds, heavy metals and organic compounds, based on the visual and olfactory observations previously recorded in a number of exploratory holes across this area of the zone (54).

Subsequent use of the western part of this area of the zone as a rifle range may also have resulted in at least localised shallow soil contamination by lead.

Groundwater monitoring relating to Bamber Pit within Zone 6, to the south of the Sportsfield, has included sampling of boreholes located on the northern up-gradient boundary and which is likely to be indicative of groundwater flowing south out of the Sportsfield site. Groundwater quality in these boreholes has shown the presence of elevated concentrations of a range of heavy metals including arsenic, copper, nickel, lead and zinc and some hydrocarbons in excess of relevant EQSs.

7.3.2. HS1 Information

A number of borehole logs for Zone 4B are available from the BGS and relate to ground investigations undertaken as part of the construction of HS1. The logs frequently indicate visual and olfactory evidence of contamination. The indicators of contamination identified in the borehole/trial pit logs include:

- a moderate sweet solvent odour and a thin layer of black ash was identified within the Made Ground of TP7841, located in the north-east of Zone 4B;
- fracture planes of the Chalk were possibly stained by contamination within AC919, located to the north of the former tar distillery;
- potential contamination described as “loose black silty fine to coarse ash and cinder sand with some angular to rounded fine clinker chalk” within the Made Ground of TP1925 in the western part of Zone 4B;
- black bituminous-smelling Made Ground with 20 % black tar oil in AC1918, located to the west of the former tar distillery;
- petrochemical odour and oily sheens within the Chalk in AC1918;
- black contamination lenses and a diesel oil odour within the Chalk in SA1769, located to the west of the former tar distillery;
- potential contamination described as black organic (tarry odour) pulverised fuel ash within the Made Ground in TP1922;
- cinder and ash sand within TP1937 and SA1927A to the west of the HS1 railway;
- localised streaks and lenses of black material with a petrochemical odour within the Chalk in SA1915; and
- a dark brown and black diesel oil with clinker within the Made Ground in AC1931, located within the former paper mills in the south of Zone 4B.

Further details on the ground investigations have been requested from the HS1 and are currently still awaited.

7.3.3. Water Abstraction Borehole Records

There are no current groundwater abstractions within Zone 4, however have been three boreholes within Zone 4B associated with the paper mills which were historically used for water abstractions. A 60.96 m deep borehole located in Kent Kraft Industrial Estate for Northfleet Paper Mills has a note on the log dated 22 November 1961, which states “output has been decreased due to contamination”, although this may be related to saline intrusion and poor water quality for paper making. The status of these boreholes is currently unknown, although at least one is recorded as ‘disused and filled in as a result of cliff fall’.

7.4. Preliminary Geo-environmental Conceptual Site Model

7.4.1. Introduction

The approach used for the creation of the preliminary CSM is detailed in Section 2.2.1. Identified zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Section 2. Only Zone 4 sources and receptors have been considered.

7.4.2. Potential Sources

There were no potential sources identified within Zone 4A.

The potential Zone 4B sources identified from the background searches, data review and site walkover observations are as follows:

- historical potentially contaminative land uses including the Thames Tar Distillery, paper mills, chemical works, tramways, electricity substations and a pipeline;
- current potentially contaminative land uses including industrial uses within Northfleet Industrial Estate; and
- partial infilling of the lagoon with unknown materials in two stages by 1907 and 1977.

There was a firing range noted in Zone 4C.

7.4.3. Potential Pathways

The primary exposure pathways that are considered applicable are:

- migration and accumulation of ground gases followed by inhalation or ignition, causing asphyxiation and/or explosion;
- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres;
- inhalation of soil-derived and/or groundwater-derived vapours;
- leaching from unsaturated soils and lateral migration to controlled waters receptors;
- direct surface water run-off and sub-surface flow to surface waters;
- leaching from unsaturated soils followed by migration in the groundwater; and
- vertical migration to the Secondary (undifferentiated) aquifer and Principal aquifer .

7.4.4. Potential Receptors

The identified receptors for Zone 4 are as follows:

Zone 4A

- the Secondary (undifferentiated) aquifer and Principal aquifer;
- the surface water channels across the zone;
- zone visitors; and
- trespassers.

Zone 4B

- the Secondary (undifferentiated) aquifer and Principal aquifer;
- zone visitors and workers; and
- trespassers.

Zone 4C

- the Principal aquifer; and
- zone visitors.

A schematic CSM for Zone 4 is presented as Figure 014.

Table 7-10 Preliminary Conceptual Site Model for Zone 4

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
Zone 4A: **Potential contaminants in soil/groundwater, originating from the following sources:** Contamination resulting from use as agricultural land. *Potential contamination includes metals and other contaminants.*	Human health – zone visitors and trespassers	Migration and accumulation of ground gases followed by inhalation or ignition, causing asphyxiation and/or explosion	**Medium**	**Unlikely** There is not considered to be significant potential for ground gas generation and there are no structures located on site to facilitate the accumulation of ground gas.	**Low Risk**
		Inhalation, ingestion and/or dermal contact with contaminants in soils and soil-derived dusts	**Medium**	**Unlikely** There are no significant sources of potential contamination within Zone 4A.	**Low Risk**
		Inhalation of soil-derived and groundwater-derived vapours	**Medium**		
	Controlled waters – Secondary (undifferentiated) and Principal aquifer beneath the zone	Leaching from unsaturated soils followed by migration in the groundwater	**Medium**		
		Vertical migration to the Principal aquifer beneath Zone 4.	**Medium**		
	Controlled waters – surface water receptors: the surface water channels across the zone	Lateral migration of contaminated surface runoff and entrained dust within surface runoff.	**Medium**	**Unlikely** The surface water channels (land drains) across the zone may act as receptors of zone-derived contamination, but they have been deemed to act more as pathways of contamination.	**Low Risk**
Zone 4B: **Potential contaminants in soil/groundwater, originating from the following sources:** Contamination resulting from	Human health – zone visitors, workers and trespassers	Migration and accumulation of ground gases followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** There is not considered to be significant potential for ground gas generation.	**Moderate Risk**
		Inhalation, ingestion and/or dermal contact with contaminants in soils and soil-derived dusts	**Medium**	**Low Likelihood** The majority of Zone 4B is covered with hardstanding, meaning there will be limited contact with soils and soil-derived dusts.	**Moderate/Low Risk**

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
historical land uses, current land uses and potential infilling. *Potential contamination includes metals, PAHs, TPH and other contaminants.*		Inhalation of soil-derived and groundwater-derived vapours	**Medium**	**Likely** There was a former tar distillery located in Zone 4. There is now an industrial estate in this area. It is not known whether the construction of these warehouses and other buildings included gas and vapour protection measures.	**Moderate Risk**
	Controlled waters – Secondary (undifferentiated) and Principal aquifer beneath the zone	Leaching from unsaturated soils followed by migration in the groundwater	**Medium**	**High Likelihood** The borehole logs in the area associated with HS1 have indicated potential contamination within the Chalk and groundwater samples from the area near the reservoir were also noted to have exceedances of the relevant screening criteria. The extent of the contamination within Zone 4B is unknown. There were a number of potentially contaminative features located within Zone 4B. It is not known what remediation measures, if any, were put in place following the demolition of the tar distillery, the chemical works, or the other potentially contaminative land uses. The former lagoon was infilled with unknown material in 1907 and in 1977. There are a large number of potential sources identified within Zone 4B and there are indicators of contamination within the Chalk, therefore the likelihood is considered to be high.	**High Risk**
		Vertical migration to the Principal aquifer beneath Zone 4	**Medium**		**High Risk**
Zone 4C: **Potential contaminants in soil/groundwater, originating from the following sources:** Contamination resulting from historical land uses as	Human health – zone visitors	Migration and accumulation of ground gases followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** There is not considered to be significant potential for ground gas generation.	**Moderate Risk**
		Inhalation, ingestion and/or dermal contact with contaminants in soils and soil-derived dusts	**Medium**	**Low Likelihood** The majority of Zone 4C is covered with soft standing; however, Zone 4C is relatively inaccessible and is un-occupied. Significant contact with soils is unlikely.	**Moderate/Low Risk**

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
a firing range. *Potential contamination includes metals, PAHs, TPH and other contaminants.*		Inhalation of soil-derived and groundwater-derived vapours	**Medium**	**Low Likelihood** There is not considered to be significant potential for vapour generation.	**Moderate/Low Risk**
	Controlled waters – Principal aquifer beneath the zone	Leaching from unsaturated soils followed by migration in the groundwater	**Medium**	**Low Likelihood** There is not considered to be significant sources of contamination which would leach into the aquifer beneath the zone.	**Moderate/Low Risk**
		Vertical migration to the Principal aquifer beneath Zone 4	**Medium**		**Moderate/Low Risk**

7.4.5. Geological and Geotechnical Hazards

Table 7-11 describes some of the geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 7-11 Potential Geological and Geotechnical Hazards in Zone 4

Hazard	Description	Comment
Aggressive ground conditions	The BRE Special Digest (44) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	Significant concentrations of sulphate can also be found in alluvium and peat.
Buried foundations	Buried foundations can cause a delay to construction and incur additional costs.	Large numbers of buildings are present in Zone 4B, and so there is a chance of encountering significant amounts of buried foundations.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	No buried services have been identified in Zone 4, however the large number of buildings within the Zone, in particular in the Northfleet and Kent Kraft Industrial Estates means that buried services will be present, and must be located before intrusive ground investigations take place.
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	Old OS maps show the whole of the area currently known as Northfleet Industrial Estate was a chalk quarry. Vertical rock faces are still present. The lagoon historically present in Zone 4B was noted to be completely infilled during the site reconnaissance visits undertaken in October 2014.
Perched water table/fluctuating groundwater flow	The presence of high groundwater levels /perched water tables needs to be considered when undertaking construction.	Groundwater likely controlled by tidal river processes; therefore levels are possibly variable throughout the day. From the BGS borehole logs, it is known that the groundwater levels are high in the zone, typically at depths of 2.75 m bgl, which corresponds to an elevation of approximately -2 to 1 m AOD.
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel. Appropriate control measures will need to be taken.	Swanscombe Peninsula is located in a brackish water zone of the River Thames, meaning the groundwater is likely to be slightly saline. Groundwater is likely controlled by tidal river processes therefore levels are variable throughout the day.
Slope instability	Significant risk of casualty, delay to works and increased costs if slope instability occurs, this includes landslides, flows and falls.	Vertical faces in the Chalk are evident in Zone 4, undercutting may be present; therefore rockfall is a significant hazard.
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of	Most of Zones 4B and 4C makes up a historical quarry area, with an artificially lowered ground level. Erosion and

Hazard	Description	Comment
	reduced bearing capacity or require additional excavation.	weathering from periglacial and fluvial processes could also pose a concern. Due to this, there is a high chance of encountering a variable rockhead.
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The superficial deposits in Botany Marsh, particularly the alluvium and peat are likely to have low bearing capacity. The Made Ground is highly variable in composition, so the bearing capacity is not known. However, it is likely to be low.
Weak compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Peat and alluvium are present in Zone 4A. These soils appear to be weak and could deform and fail as a result of the loads imposed on them. Head deposits are also present in the east of Zone 4B, which could deform under load.

7.4.6. Geotechnical Risk Register

The Geotechnical Risk Register is presented as Table 7-12. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a Low ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be “substantial” are:

- buried foundations;
- buried services;
- historical works;
- variable rockhead;
- weak bearing materials;
- weak compressive ground; and
- rockfall.

Most of the other risks are rated as “medium” to “low”.

7.4.7. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the substantial risks listed above include:

- further desk study (including a further detailed walkover);
- ground investigation including *in-situ* and laboratory testing;
- planned methodology for the earthworks; and
- detailed design for the temporary construction roads.

7.4.8. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be low. However, it should be recognised that some residual risks remain, as described below.

Table 7-12 Geotechnical Risk Register for Zone 4

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
1	Aggressive ground conditions	2	3	3	1	6	6	2	M	Use BRE Special Digest 1 (44) to determine the concrete class from sulphate and pH results. Use appropriate concrete protection.	2	2	2	1	4	4	2	L
2	Buried foundations	3	3	3	1	9	9	3	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	1	L
3	Buried Services	3	3	3	3	9	9	9	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	Historical works	3	3	3	1	9	9	3	S	(See buried foundations and buried services)	2	2	2	1	4	4	2	L
5	Perched/high groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	3	1	1	1	3	3	3	L
6	Saline groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	3	1	1	1	3	3	3	L
7	Variable rockhead	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
8	Weak bearing materials	4	3	3	1	12	12	4	S	Ground investigation to confirm geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
19	Weak compressible ground	4	3	3	1	12	12	4	S	Ground investigation to confirm extent	3	2	2	1	6	6	2	M

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
										and thickness of alluvium and Tidal River and Creek deposits. Where necessary consider appropriately in geotechnical design.								
10	Rockfall	3	3	3	3	9	9	9	S	Ground investigation to confirm geological succession and geotechnical properties across the site. Detailed visual inspection of all chalk faces. Where necessary consider appropriately in geotechnical design	3	2	2	2	6	6	6	M

7.5. Zone 4 Summary

7.5.1. Geo-environmental Summary

Zone 4 is located in the eastern section of the Swanscombe Peninsula site and is split into three distinct sections, a northern section (Zone 4A) which has historically and is currently marsh and agricultural land (also referred to as Botany Marshes), a central section (Zone 4B), formerly partially quarried, which comprises a series of commercial/industrial areas and a southern section (Zone 4C) which comprises an area of former quarried and partially in-filled open land, known as the Sportsfield. Zone 4B currently comprises the Northfleet and Kent Kraft Industrial Estates and the eastern section of Manor Way Business Park which are characterised by small to medium sized commercial and industrial units including a car breakers, skip hire/storage company and waste transfer station. The HS1 rail line runs in a north westerly to south easterly orientation, above ground, through the south-east corner of Zone 4A and middle of Zone 4B.

London Road (A226) is situated on a chalk spine which runs west to east and forms the boundary between Zones 4B and 4C. The North Kent Railway line is located on a further chalk spine on the southern boundary of Zone 4C with Zone 6. Interconnecting chalk spines are present on Pilgrim's Road which runs partially on the boundary between Zone 4B and Zone 5 and between Zone 4C and Zone 5 where All Saints Church (a listed building), a few houses and a pub (The George and the Dragon) are located. In places these spines are cut through with historical tunnels which provided access for previous land uses.

Whilst Zone 4A has not been subject to development and has remained marshland, Zone 4B has undergone substantial changes including development as a tar distillery, paper mills, a chemical works, various tramways and electricity substations. Part of an in-filled chalk pit (Pilgrims Pit) and in-filled former lagoon are also present in the north western/northern sections of Zone 4B. Part of Zone 4C was historically in-filled and a rifle range was previously present in the western section.

The principal potential sources of soil and groundwater contamination are considered to be the former tar distillery, paper mills and chemical works alongside current operations in the industrial estates, all within Zone 4B. Risks associated with these features are assessed as moderate in terms of human health receptors (which include site workers, visitors and trespassers) and high in terms of controlled waters receptors, primarily the Principal Chalk Aquifer. Risks to current human health and controlled waters receptors in Zone 4C are assessed as moderate and moderate/low with all risks associated with Zone 4A considered low.

7.5.2. Geotechnical Summary

The general geological stratigraphy of Zone 4 can be split by the sub-sections. In sub-Zone 4A, Alluvium interbedded with peat is found overlying RTD, all of which is underlain by White Chalk bedrock. In Zones 4B and 4C, Made Ground is found directly overlying the White Chalk, and towards the east of 4B, Head deposits are found below the Made Ground.

In Zone 4, the geology is variable, so the constraints vary between sub-Zones. In Zone 4A, substantial constraints include highly compressible beds of peat and alluvium, which can result in differential settlement; these geological units also have a low bearing capacity. In Zones 4B and 4C, rockfall from the Chalk spines is a major hazard, which is potentially being exacerbated by undercutting of the cliffs by local businesses. Dissolution features have also been identified in the spine that carries the A226, meaning there is a risk of subsidence damage or collapse. In Zone 4B, there is a recently infilled reservoir, and the Sportsfield quarry in Zone 4C has previously been infilled. As the infill material for these areas is either unknown or to be verified therefore there may be unidentified issues associated with variable composition or aggressive chemicals. Buried services are expected to cross the site, but are currently unidentified. Foundations associated with demolished buildings are also likely to be encountered.

The medium risk constraints in Zone 4 are mainly related to the groundwater regime, as levels are highly variable, especially in the sports field quarry, and the water is expected to be saline, leading to an increased rate of corrosion to foundations. The alluvium and peat in Zone 4A have a high sulphate content, which could create aggressive ground conditions for concrete.

8. Zone 5

8.1. Zone Characterisation

8.1.1. Location

Zone 5 has an area of approximately 18 ha and is located within the middle of the wider Swanscombe Peninsula site, immediately north of the North Kent Line railway and west of the HS1. The approximate NGR for the centre of the zone is TQ 60218 175034.

8.1.2. Zone Description

The zone is characterised by topography/geology which comprises substantial chalk spines upon which the principal roads and rail links are located with industrial/retail and open space land uses between, in areas of former chalk quarrying. The chalk spines are, in places, some 16 to 20 m above the intervening land at an approximate elevation of 28 m AOD in the eastern part of Zone 5 and as low as 6 m AOD at the entrance to Manor Way Business Park.

The northern half of the zone, termed Zone 5A, comprises an area of land north of London Road (A226) but south of Manor Way. It includes the western part of Manor Way Business Park, which consists of light/medium industrial units. A chalk spine is also present running in a north-south alignment, along Pilgrim's Road, across the central portion of the zone.

The southern portion of the zone, termed Zone 5B, comprises an open area which is a part in-filled former quarry off Crayland's Lane, to the south of London Road. In this section of the zone, there are a number of tunnels and associated roadways through the chalk spine upon which London Road is located.

The elevation of the zone generally increases from north to south, away from the River Thames, and ranges from 4 to 23 m AOD, from the northern part of Zone 5A (along Manor Way) having the lowest elevation, and the southern part of Zone 5B (upon the chalk spines that comprise the southern zone boundary). Zone 5A is within a depressed area of ground, with London Road, which separates Zones 5A and 5B, being constructed at a much higher elevation, upon a chalk spine. Zone 5B is also depressed from London Road, although the difference in elevation is more minor.

The zone boundary is shown on Figure 001, environmental permits within Zone 5 are shown on Figure 002, and key features within the zone, both historical and current, are shown on Figure 015. Photographs of the zone from site reconnaissance on 23 October 2014 can be found in Appendix B.

8.1.3. Zone-Specific Data Sources

A historical site investigation report was identified through the BGS for HS1 Preliminary Ground Investigation Stage II. At the time of writing this report, the HS1 site investigation report has not been made available.

8.1.4. Surrounding Land Uses

The Zone is bounded by the land uses listed below; please note; all distances given are approximate.

- **North –** Zones 2 and 3 border Zone 5 to the north and include Lafarge land holdings. Zone 2 is known as Swanscombe Marshes and comprises disused scrub land, with a derelict sewage works towards the centre of the zone. Zone 3 comprises a works premises operated by Basic Engineering Co Ltd and also Swanscombe Marshes. Zone 3 historically comprised Lovers Lane Pit (subsequently landfilled) and a chalk pit and its eastern portion had a history associated with a cement works which was located on the border between Zones 2, 3 and 5. Further details regarding the land uses in other zones can be found in the respective zone chapters.
- **East –** Zone 4 is located to the east of Zone 5 and includes Kent Kraft Industrial Estate and Northfleet Industrial Estate, the Tower Wharf industrial site including the Cemex works and the River Thames beyond.
- **South –** the North Kent Line railway runs in an east to west alignment along the zone's southern boundary. Beyond this is the town of Swanscombe.
- **West –** the north-western portion of the site is bordered by Zone 3, whilst some open ground, followed by the Greenhithe residential area, comprises the remaining land to the west.

8.1.5. Historical Land Uses

The historical summary has been compiled from the available historical mapping obtained from GroundSure (3), and is presented in Table 8-1.

Table 8-1 Historical Land Uses Relating to Zone 5

Dates and Scales	Within Zone 5	Within 1 km of the Zone
1865-1866 1:10,560 **1865-1872** 1:2,500	The north-western part of Zone 5A comprises "Portland Cement Works", whilst the north-eastern part comprises open ground. There are a significant number of buildings present on the western part of the zone. There are chalk pits located in Zone 5B.	A residential area, then called "Ingress Park", appears to be present 300 m west of the zone.
1888-1895 1:10,560 **1897** 1:2,500	"Whiting Works" are now present on the zone's western portion, whilst chalk pits are present on the eastern portion. Cement works are located in the eastern portion with a farm ("Manor Way Farm") immediately north. The former chalk pit in Zone 5B is now occupied by additional buildings associated with the cement works.	The surrounding area, to the south and west, is shown to comprise chalk pits and gravel pits, along with additional small buildings.
1907 1:2,500 **1907-1923** 1:10,560	Portland Cement Works, in Zone 5A, is shown to comprise numerous tanks, conveyors, mineral railway tracks and a couple of electricity substations. Tramways are shown to intersect the northern part of the zone, and a small gasworks is shown towards the zone's northern boundary, adjacent to Manor Way Farm. Tanks are shown across the mid-section of Zone 5A, with one small tank associated with the gasworks towards the zone's northern boundary. The chalk pits on the southern portion of the zone are no longer shown, and many small tanks are shown instead. The southernmost boundary of Zone 5B, comprises "Swanscombe Sidings".	No significant changes.
1932 1:2,500 **1952** 1:1,250 **1931-1966** 1:10,560	The gasworks along the northern zone boundary is no longer shown. Additional buildings are present on the western part of the zone. There are now a large number of tanks present in Zone 5A and Zone 5B, and the tramway in this area has increased its coverage. The chalk pit within the north-eastern portion of Zone 5A is shown as a large quarry from 1931, which starts reducing in scale, suggesting infilling, from 1946-1948. This infilled area is believed to be what is known as Pilgrim's Pit in Aspinwall and Company's 1994 report (57) – see Section 8.2.9 for further details.	The area to the south and west of the zone is substantially more developed. However, pits are still interspersed throughout the residential buildings. The 1961-1966 map shows that a Palaeolithic skull was found 600 m south of the Zone. A "petroleum depot", complete with four large tanks, is shown in 1952 immediately west of the southern portion of the zone, with allotment gardens comprising the remaining three boundaries of it, and chalk pits beyond.
1984-1989 1:2,500 **1971-1990** 1:10,000 **1971-1990** 1:1,250	Numerous rectangular warehouses have been built in Zone 5A. The number of tanks in Zone 5B has increased again, on the land immediately north of Swanscombe Sidings. One of the former tracks in Zone 5B, that used to lead to other pits within the area, is now labelled as a tunnel. By 1970, the quarry in the north-eastern portion of Zone 5A is marked as a refuse tip and by 1974, the quarry appears to be completely infilled.	The pits within the surrounding area (to the south and west) are now marked as disused. A station (Swanscombe Station) is shown immediately south of the zone, on the railway line separating the zone from Zone 6 to the south. Tanks were no longer shown at the petroleum depot, to the west

Dates and Scales	Within Zone 5	Within 1 km of the Zone
		of the zone, on the 1975-1979 map. On the 1989-1990 map, the area was just labelled “depot”, and comprised three unknown features.
1993-2002 1:10,000	Many of the buildings in Zone 5A have been cleared.	By 2002, a small sewage pumping station is shown, immediately north of the zone (north of Manor Way).
2010-2014 1:10,000	A number of the buildings in the eastern portion have largely changed configuration.	HS1 is shown to the east of the zone within Zone 4. The small sewage station to the north of the zone is no longer shown.

Notes: For land uses within the surrounding zones (Zone 3 to the north and Zone 4 to the east), see their respective chapters (Chapters 6 and 7, respectively).

8.1.5.1. Summary of Historical Land Uses

Historical land uses within Zone 5 have been fairly varied. On the earliest historical maps available, from 1885-1886, the north-western part of the zone comprised part of “Portland Cement Works”, whilst the north-eastern part comprised open ground. The south was mostly open space, although also included an unidentified pit and a small number of buildings.

Other identified historical land uses within Zone 5 that may have contributed to possible soil and groundwater contamination in the area, include:

- the “Whiting Works”;
- conveyors associated with Portland Cement Works; and
- gasworks along the northern boundary and tanks.

In terms of off-site land uses in the vicinity of Zone 5, very little has changed over time. On the earliest maps available (1865-1866), the North Kent Line railway was shown to the south of the zone, and Ingress Park was shown to the west. Since then, the surrounding area became scattered with chalk pits and the town of Swanscombe, to the south of the zone, has grown in size. Palaeolithic artefacts have been noted within the surrounding area, and these were probably discovered during its large scale excavation.

In terms of potentially contaminative off-site land uses, near to Zone 5, there was a petroleum depot identified during the early 1930s, to the west of the zone, complete with four large tanks. These tanks remained till 1989-1990. There was also a small sewage pumping station, to the north of the zone, and HS1 is present east of the zone.

8.2. Environmental Context

8.2.1. Historical Borehole Records

A small number of historical borehole records are available via the BGS, of which 4 borehole records have been identified with depths ranging between 15.10 m and 20.01 m for collation and review. All the exploratory holes were conducted between 1994 and 1997.

Of all the logs identified; all were categorised as Grade A. The information from the grade A logs has been used to verify the published geological maps and to inform the findings of this report.

8.2.2. Geology

The 1:10,000 BGS geological maps of the area, sheets TQ67NW (Grays) and TQ67SW (Northfleet) solid and drift edition (1994) show the geological succession within Zone 5 to be Made Ground underlain by undifferentiated White Chalk, with a small area of Boyn Hill Gravel recorded near the A226/High Street. No faults are recorded in or around Zone 5.

Table 8-2 Expected Stratigraphy Below Zone 5

Formation	Typical Thickness (m)	Description
Made Ground	5	Fine to coarse sand, with some gravel, chalk and clay
Head deposits	1	Pale brown, sandy silt, with some chalk and flint gravel
Alluvium	2	Soft to firm organic clay to silt, interbedded with peat
Chalk	>14	Moderately weak to hard White Chalk with beds of flint in the upper 5 m

Note: typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness is marked as unknown, the bed has not been proven, and is only expected, and so a value for the thickness is not known.

8.2.2.1. Geomorphology

Zone 5 occupies an area which exhibits a long history of anthropogenic influences. It is located on the gently dipping northern face of the chalk limb which forms the North Downs. The steep dipping (scarp) of the southern face of the North Downs is located approximately 12 miles to the south. To the south of Zone 5 the chalk outcrop has been removed quarrying and excavations have left a chalk spine upon which the A226 is located (at 21 m OD), approximately 15 m above the adjacent quarry floors (at 6.4 m AOD).

The northern boundary of the site corresponds to the edge of the alluvial plain, as the surface of the chalk dips below the alluvium.

Zone 5 was, and in part remains an area of intense industrial activity. The presence of old foundations and other below ground works is anticipated.

8.2.3. Ground Conditions

A general description of the all the geological units is presented in Section 3, along with geotechnical parameters reproduced from CIRIA guides and other technical papers.

Descriptions and geotechnical parameters of the following sections have been obtained from the sources above. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 5, the information is provided for guidance only and it is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain site-specific parameters.

8.2.3.1. Made Ground

The borehole logs record a highly variable layer of Made Ground across the majority of Zone 5. It can be divided into two parts. The first part is generally described as dark brown/grey occasionally black silty fine to coarse ash and cinder sand with much coarse ash and cinder gravel. Variable inclusion of man-made debris comprising red brick cobbles, oil drums, rubber, glass bottles and a rusty car door. This is then typically underlain by the second part, a reworked Chalk, described as ‘soft to firm very light grey to cream comminuted chalk silt’ or as ‘a fine to coarse chalk gravel with some medium and coarse flint gravel’.

The Made Ground within Zone 5B is expected to comprise chalk spoil from the construction of the HS1 Thames Tunnel. There are currently no exploratory hole records available to confirm the composition of the fill material.

8.2.3.2. Head Deposits

BH06 sunk as part of the Swanscombe Sewer Scheme records ‘stiff brown sandy clay with flints’ for a thickness of 2.60 m. Although not indicated on the geological map, this description is generally associated with head deposits which are indicated to be present immediately to the east of the zone.

8.2.3.3. White Chalk

The White Chalk is comprised of the Seaford Chalk Formation and the Newhaven Chalk Formation, which form part of the White Chalk group. It is typically slightly to moderately weathered, weak of medium density. It includes many layers of flint and marl within the sequence.

The borehole records typically describe the chalk as 'silty sand size comminuted chalk with angular to subangular fine to coarse gravel size very weak low density fragments, becoming weak medium density chalk, fractures very closely to closely spaced infilled with a trace of comminuted chalk and brown clay, with some flints'.

8.2.4. Hydrogeology

8.2.4.1. Surface Water

The Groundsure report **(2)** identifies a small surface water feature in Zone 5; however, this is not clearly visible on aerial photography.

8.2.4.2. Groundwater

From the borehole logs available from the BGS, groundwater is expected between 5 and 7 m bgl, which is equivalent to roughly 0 and -2 m AOD. Information provided by the Environment Agency concludes that the Chalk is a Principal aquifer and is an important aquifer in the region with water movement being primarily controlled by fractures in the rock (9).

8.2.4.3. Groundwater Abstractions

There is currently a groundwater abstraction licence in place about 800 m to the north-east of the zone, currently licensed for mineral washing by Cemex UK Materials Ltd and for spray irrigation by Lafarge. The maximum annual abstraction is between 26,300 m^3 and 1,186,000 m^3 from the Chalk. No other groundwater or surface water abstractions are located within 1 km of this zone.

8.2.4.4. Groundwater Vulnerability

The Environment Agency website shows that Zone 5 is not within an SPZ (9).

8.2.5. Mineral Abstractions

The GroundSure report (1) has identified multiple unspecified pits and chalk pits within the area of Zone 5 and this is clearly seen on aerial photography from Google Earth. The report has also identified multiple tunnels going through the chalk outcrop under the A226 London road, connecting the northern and southern sides. There are also tunnels going under the railway on the southern edge of Zone 5B, in the eastern corner.

8.2.6. Flood Risk

The "Environment Agency Flood Map for Planning (from rivers and the sea)" (4) shows that Zone 5A (above London Road) is predominantly within an area at risk of flooding (from both rivers and the sea, predominantly relating to tidal events). The majority of the zone is classified as having a "low" NaFRA rating, with the southern portion of the zone not shown as having any risk of flooding.

The zone itself does not include any flood defences, although the northern portion of the zone is currently benefitting from existing flood defences along the north of Swanscombe Peninsula (along the northern boundaries of Zones 1, 2 and 3).

In terms of historical flood events, the zone has been affected by two that have been recorded by the Environment Agency. A tiny portion of the eastern portion of the zone was affected by a fluvial flood from 14th September 1968, which resulted from the channel capacity of a river being exceeded (although this predominantly affected Zone 4). The north-eastern part of the zone was also affected by tidal flooding between 1st and 5th February 1953, due to the flood defences being overtopped (4; 58).

Patches of the zone are at risk of pluvial flooding, predominantly within the northern and eastern sections of the zone. The highest risk rating of these is "significant", although the majority are "low" or "low to moderate". Pluvial flooding is defined, in the GroundSure FloodInsight report (4), as flooding caused by rainfall-generated overland flow, and is therefore usually the result of extreme rainfall events.

The BGS has identified that the south-western and north-eastern portions of the zone have potential for groundwater flooding to occur at the surface, whilst these areas plus the south-eastern portion of the zone have the potential for groundwater flooding of property below ground level. These risks appear in a band-like formation running east to west across the zone. The remainder of the zone has been deemed to have limited potential for groundwater flooding.

Further details regarding flood risk can be found in Buro Happold's Flood Risk Assessment (in preparation).

8.2.7. Designated Environmentally Sensitive Sites

According to the GroundSure EnviroInsight report, the zone is mostly void of designated environmentally sensitive sites. However, the south-eastern portion of the zone is within a NVZ for groundwater. The zone is also within four SSSI IRZs. The 3.88 ha "Swanscombe Skull Site" SSSI is located approximately 453 m to the south of the zone, which currently has a "favourable" condition (10). There is an SSSI and a scheduled ancient monument at Baker's Hole within Zone 6 to the south-east of Zone 5 (refer to the Chapter for Zone 6).

8.2.8. Environmental Permits, Incidents and Registers

There is one record of a Part B enforcement within the boundary of Zone 5. The Part B enforcement within Zone 5 is detailed in Table 8-3 and relates to a historical permit.

Table 8-3 Records of Part B Enforcements within Zone 5

Location within the Zone	Address	Process	Status	Enforcement Details
North-west (Zone 5A)	Omya UK, Whiting Works, Manor Wat, Swanscombe, DA10 0LL	Lime slaking	Historical permit (Part B)	No enforcements notified

None of the off-site records of Part B (or Part A(2) activities and enforcements) are closer to Zone 5 than the other site-defined zones.

There are two off-site entries, within close proximity to Zone 5, for Category 3 or 4 Radioactive Substances Authorisations (RAS). These relate to the same area ("Sirs Navigation Ltd", located at 186a Milton Road in Swanscombe), 305 m south of Zone 5, for the disposal of radioactive waste. The licence appears to still be active, having last been updated on 1 July 2014.

There are two licensed discharge consents related to the Zone 5 land area, as detailed in Table 8-4. There are no off-site discharge consents, listed within the GroundSure EnviroInsight report as being with 500 m of the site, that are closest to Zone 5 (2).

Table 8-4 Licensed Discharge Consents Related to Zone 5

Location within the Zone	Address	Effluent Type	Receiving Water	Status
North (Zone 5A)	Northfleet Eastern/Western Quarry, A2 Watling Street, Bean, Dartford, Kent	Trade discharges – mineral	Unknown	Revoked on 16/04/2000
				Post NRA legislation

For all other on and off-site entries relating to EPs, incidents and registers, see the sections relating to the other zones.

8.2.9. Landfills and Other Waste Sites

There are three records of Local Authority recorded historical landfills within the zone. These all relate to a small refuse tip within the north-eastern part of Zone 5A (2). It is likely that this former refuse tip is the same

as the tip referred to as Pilgrims Pit within Aspinwall and Company Ltd's HS1 Assessment of Land Contamination report (57). According to the report, Pilgrim's Pit lies in the western part of a disused chalk quarry, which was infilled between approximately 1947 and 1974; most likely with cement works waste and demolition materials. The small stream within the zone forms the eastern boundary of this tip, which then flows north to join the drainage channels in Botany Marshes (54).

There is a processing/recycling unit on Manor Way, along the north-western boundary of Zone 5A. This unit comprises a change of use facility, for the processing and recycling of plastic materials (2). Within this same area is also an Environment Agency licensed waste site operated by Veka Recycling Limited. It is a household, commercial and industrial waste transfer station and treatment facility, with an annual allowance of 74,999 tonnes.

8.2.10. Potentially Contaminative Industrial Sites

There are 11 entries for current potentially contaminative industrial sites within the GroundSure EnviroInsight report (2), listed as being within the Zone 5 boundary, as detailed in Table 8-5. These relate predominantly to industrial land uses; namely tanks.

Table 8-5 Potentially Contaminative Industrial Sites within Zone 5

Company/Feature	Location within the Zone and Address (if Provided)	Activity	Category
Tank	North-west (5A)	Tanks (generic)	Industrial features
Conveyor	South (5B)	Conveyors	Industrial features
Electricity substation	North-western boundary (with Zone 3) (5A)	Electrical features	Infrastructure and facilities
Tank	South (5B)	Tanks (generic)	Industrial features
Electricity substation	North-western boundary (5A)	Electrical features	Infrastructure and facilities
Tank	South-central (5B)	Tanks (generic)	Industrial features
Veka Recycling	North-western boundary; Manor Way, Swanscombe, DA10 0LL (5A)	Recycling, reclamation and disposal	Recycling services
Tank	South-west (towards the boundary) (5B)	Tanks (generic)	Industrial features
Tank	South (5B)	Tanks (generic)	Industrial features
Tank	South (5B)	Tanks (generic)	Industrial features
Tank	South (5B)	Tanks (generic)	Industrial features

There are off-site industrial land uses within close proximity to the zone, although none of these are deemed highly significant individually.

8.3. Information Gained from Public Records

8.3.1. Previous Ground Investigation (Halcrow, 2004)

Dartford Borough Council's planning website was consulted, and information related to this zone was publicly available in association with a previous master plan for the Swanscombe Peninsula from 2004. The north-western portion of the zone, along with portions of Zone 2 and the majority of Zone 3, had been recommended for a large-scale new development to include 1,750 mixed dwellings, general commercial and industrial developments including offices, warehousing, retail, financial and professional services, restaurants, primary schools, and a number of other community facilities with associated infrastructure and services within the area.

As the zone is vulnerable to flooding, it was proposed that the development area would undergo land raising of 2-6 m in order to construct a development platform.

An EIA was undertaken, along with the associated Environmental Statement (51). Through this process, a land contamination report (48) was also produced subsequent to intrusive ground investigations undertaken across the zone.

Within Zone 5 intrusive works comprised completion of boreholes, window sample locations and trial pits, with a number of the intrusive locations completed as groundwater and ground gas monitoring installations.

The investigation area including Zone 5 (the western peninsula) was categorised as “Phase 1” and was investigated first. The development planning application was later halted, with the application withdrawn in March 2013.

“Phase 1” was segregated into five distinct Areas. Only the south-eastern part of Area 1 – Swanscombe Cement Works and Whiting Works – falls within Zone 5. The south-western portion of Area 1 (west of Zone 5) is not included within this Phase 1 zone boundary, and specific results from this area have, therefore, not been included.

Risk assessments for human health and controlled waters were undertaken using legislation and best practice applicable at the time, including CLEA-developed SGVs and developed SSAC, developed using the CLEA modelling software. Controlled waters risk assessment was undertaken using the R&D20 tiered approach.

The identified sources of contamination were:

- significant historical industrial use in the zone including, but not limited to, infilling with CKD and other works waste from the cement industry, gasworks, fuel storage, solvent use, etc.

The receptors identified were:

- human health – local and nearby residents;
- human health – construction workers during redevelopment;
- groundwater resources and aquifer water supply;
- surface water quality and resources;
- materials and structures on and off-zone;
- Black Duck Marsh (also known as Swanscombe Marshes);
- River Thames;
- chalk/gravel aquifers; and
- flora and fauna.

Due to the proposed land raise, it was considered that a number of potential pathways for exposure of human health receptors would be broken; only areas around Swanscombe Marshes and the Sea Wall would remain at their current levels. However, a generic risk assessment was still undertaken for these potential contaminant linkages to understand the current contamination regime in the zone.

8.3.1.1.1. Soils Results (Human Health)

The raw data were not available for review and, as such, it is unclear which might pertain to the portion within Zone 5. However, Halcrow report that; asbestos was found in three out of twelve samples within the demolition materials and the 95th% UCLs for all metals in shallow soils were below the relevant SGVs.

8.3.1.1.2. Controlled Waters

The assessments within the report generally considered that groundwater beneath the zone would be unlikely to be highly sensitive to potential contamination, due to its brackish nature and the majority of the zone being outside of a SPZ. However, the eastern portion of the zone is within a Zone III SPZ for groundwater, suggesting that all groundwater recharge is predicted to be discharged at the source (2). The screening criteria utilised for the generic assessment were freshwater EQS values, to assess risks to the ditches within the marshland (as identified as the key potential receptor) and water within the River Thames. Surrogate compounds benzene and naphthalene were selected to assess for VOCs and SVOCs, respectively.

Exceedances of the EQS were recorded for copper, SVOC, VOC, TPHs, and cyanide within the leachate and/or groundwater samples. After completing a tiered assessment as per the R&D20 methodology, risks to

the controlled waters receptors were not found to be significant. Unidentified “oil” was sampled from TP94 from perched water within the Made Ground, near to the north-western boundary of Zone 5.

8.3.1.1.3. Ground Gas

Only one round of ground gas monitoring was undertaken during these investigation works. Threshold values of 0.1 % v/v (by volume) for methane and 5 % v/v for carbon dioxide were chosen to represent significant concentrations of these gases. No flow rate measurements were undertaken.

The maximum concentrations of ground gas, within each of the areas outlined for the investigation, were as follows. All have been included to account for the potential migration of ground gas from other zones:

Table 8-6 Ground Gas Concentrations per Area (2004)

Location	Maximum CH_4 (% v/v)	Maximum CO_2 (% v/v)	Minimum O_2 (% v/v)
Swanscombe Cement Factory and Whiting Works (Zone 5)	14.2	14.8	< 0.1
Swanscombe Gas Works Perimeter (Zone 2)	< 0.1	3.2	Unknown
Lovers Lane Pit (Zone 3)	2.9	< 0.1	0.5
Black Duck Marsh (Zone 3)	32.3	16.4	6.5
Sea Wall (Zone 2 and 3)	73.1	23.2	2.3

Within Zone 5 the boreholes within the area of the former cement and whiting works indicated elevated concentrations of methane and carbon dioxide. These were stated to be likely associated with the presence of alluvium/marshland, possible fuel spills, and the Chalk bedrock beneath the site.

8.3.1.1.4. Conclusions and Recommendations

The risk assessments undertaken within the report indicate that no remedial action was required for the protection of human health from concentrations of contaminants within the soils at the zone. However, this is based on the assumption that the area would undergo a significant land raise, which could break a number of the potential contaminant exposure pathways.

Similarly, using the tiered assessment approach in R&D20, no significant potential pollutant linkages were found for the controlled waters receptors at the investigated site.

However, there were risks identified due to the concentrations of ground gas found within a number of boreholes within the zone. Additional monitoring was recommended, including additional sampling points installed after the proposed land raise had been completed.

A hotspot of unidentified “oil” contamination was encountered near TP94 in the south-eastern corner of Zone 3, very near to the north-western boundary of Zone 5. This contamination was not delineated within this assessment.

Ongoing monitoring and sampling during construction and demolition was recommended for soils, groundwater and surface water, as well as additional assessment of ground gas.

8.3.2. Preliminary Land Quality Risk Assessment (SLR, 2014)

A planning application for development of an aggregates recycling facility (Sheerness Recycling Ltd), on an approximately 2.4 ha site within the western section of Manor Way Business Park, was lodged in July 2014 and incorporated a preliminary land quality risk assessment, by SLR, dated September 2014. The preliminary land quality risk assessment concluded that the previous use of the area, as part of a cement works, would not likely give cause for significant ground contamination which would present a constraint to the proposed development. In addition, the site development, which comprises predominantly hardstanding, was considered to reduce risks to site users and the general environment. No further works were proposed as part of the assessment with the exception of a watching brief by a suitably experienced Environmental Consultant during the development work (59).

8.4. Preliminary Geo-environmental Conceptual Site Model

8.4.1. Introduction

The approach used for the creation of the preliminary CSM is detailed in Section 2.2. Identified zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Table 8-7. Off-zone sources and receptors have not been included herein.

8.4.2. Potential Sources

The potential on-zone sources identified are as follows:

Zone 5A

- historical, potentially contaminative land uses within the zone (namely cement works, whiting works, tramway tracks, conveyors, railway sidings etc.);
- the potentially contaminative industrial sites (tank and electricity substations);
- infilled land within Pilgrims Pit;
- the licensed waste sites within the zone, including a change of use facility for the processing and recycling of plastic materials and a waste transfer station and treatment facility; and
- Made Ground present beneath the zone, which can contribute to ground gas generation.

Zone 5B

- the potentially contaminative industrial sites (tanks and a conveyor); and
- infilled land within the former chalk quarry.

8.4.3. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres;
- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- migration and accumulation of ground gases into confined spaces, followed by ignition, causing explosion;
- inhalation of soil or groundwater-derived vapours;
- leaching from waste materials;
- leaching/migration of contaminants from soils;
- direct surface water run-off and sub-surface flow to surface waters;
- lateral migration of contaminated groundwater;
- vertical migration of contaminated groundwater;
- contaminant migration into drinking water pipes/supply to buildings; and
- chemical attack on buildings and structures.

8.4.4. Potential Receptors

The identified potential receptors of possible contamination are:

Zone 5A

- zone workers, visitors and trespassers;
- property; and
- the Principal aquifer within the Chalk.

Zone 5B

- zone workers, visitors and trespassers; and
- the Principal aquifer within the Chalk.

A schematic CSM for Zone 5 is presented as Figure 012.

Table 8-7 Preliminary Conceptual Site Model for Zone 5

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
Zone 5A: **Potential contaminants in soil/groundwater, originating from the following on-zone sources:** • Contamination in the Made Ground resulting from historical potentially contaminative land uses, the current potentially contaminative industrial sites, historical landfills and licensed waste sites. *Various potential contaminants possibly including heavy metals, sulphates and corrosives, SVOCs, landfill gas, leachate and asbestos.* • Contamination in the natural ground beneath the zone (Boyn Hill Gravel Member superficial deposits and undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation bedrock), resulting from the potential sources listed above. *Various potential contaminants.*	Humans within the zone (current users)	Inhalation of soil or groundwater-derived vapours	**Medium**	**Low likelihood** Historical landfills were present towards the north-central portion of the zone. Furthermore, the Made Ground across this part of Zone 5 may also contribute to ground gas build up. The resulting gas concentrations from both of these sources are predicted to be low. Vapours may be present associated with volatile hydrocarbons due to the presence of fuel storage tanks, both historically and currently present across the zone and the historical industrial land uses.	**Moderate/Low**
		Migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**		**Moderate**
		Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	**Likely** The majority of the zone is covered in softstanding, indicating there is potential for soil-derived dusts/fibres to be present, where they can easily be breathed in, ingested and come into contact with people working, using and visiting the zone and its surrounding area. Heavy metals and asbestos have historically been present within the north-western portion of the zone; however, the extent of this contamination is unconfirmed.	**Moderate**
		Contaminant migration into drinking water pipes/supply to buildings	**Medium**	**Unlikely** Drinking water supplies may be impacted by potential contamination related to the historical uses of the zone. Organic contamination associated with the former gasworks, historically present along the northern boundary of the zone and fuel storage tanks across the zone are the most likely land uses to affect drinking water supply. The severity is of this potential contamination is unknown this stage; however, heavy metals, inorganic compounds and	**Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
				VOCs/SVOCs have historically been identified at the zone. However, these are not contaminants thought to affect drinking water supplies, so the probability of the identified pathway occurring has been considered unlikely.	
	Property and buildings/services	Migration and accumulation of ground gases into confined spaces, followed by ignition, causing explosion	**Severe**	**Unlikely** Historical landfills were present towards the north-central portion of the zone. Furthermore, the Made Ground across this part of Zone 5 may also contribute to ground gas build up. The resulting gas concentrations from both of these sources are predicted to be low and the chances of the identified pathway occurring is considered unlikely.	**Moderate/Low**
		Chemical attack on building structures	**Mild**	**Low likelihood** Soil and groundwater contamination exists which could impact below ground structures upon the zone, including sulphates. Although the probability of this occurring has been deemed low, the potential pathway still needs to be considered.	**Low**
	Controlled waters – groundwater receptors: Principal aquifer.	Leaching/migration of contaminants from soils	**Medium**	**Likely** The majority of the zone does not comprise superficial deposits. The geological sequence is predominantly Made Ground above the Principal aquifer bedrock; so any zone-derived contamination is likely to migrate into the Principal aquifer below. Where patches of the Boyn Hill Gravel Member superficial deposits (Secondary 'A' aquifer) are present, these may also be impacted and/or act as a preferential migration pathway though this is considered to be more of an issue in the eastern section, where the zone falls within a SPZ. Land contamination assessment undertaken in 2004 within the north-western area of the zone	**Moderate**
		Vertical migration of contaminated groundwater	**Medium**		**Moderate**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
				did not indicate significant risks to controlled waters receptors (48). However, large portions of the zone were not investigated during these works.	
<u>Zone 5B:</u> **Potential contaminants in soil/groundwater in Zone 5B (south of London Road), originating from the following <u>on-zone</u> sources:** • Contamination in the Made Ground resulting from historical potentially contaminative land uses, the current potentially contaminative industrial sites and the historically infilled area. *Various potential contaminants.* • Contamination in the natural ground (Boyn Hill Gravel Member superficial deposits and undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation bedrock), resulting from the potential sources listed above. *Various potential contaminants.*	Humans within the zone (current users)	Inhalation of soil or groundwater-derived vapours	**Medium**	**Low likelihood** Zone 5B was historically a chalk pit that has since been infilled, potentiall with HS1 waste though this is to be confirmed. It does however remain at a much (approximately 10 m) lower elevation than its surroundings. It is considered that the ground gas generating potential and subsequent concentration of any ground gas would be low. Vapours may be present associated with volatile hydrocarbons due to the presence of fuel storage tanks, historically present across the south-western part of the zone and the historical industrial land uses. The number of human health receptors on this part of the zone is likely very few, due to its predominantly open land use, thus reducing the probability of the identified pathways occurring.	**Moderate/Low**
		Migration of ground gases and vapours to confined spaces, leading to accumulation followed by inhalation or ignition, causing asphyxiation and/or explosion.	**Severe**		**Moderate**
		Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	Zone 5B is situated directly on the Chalk, indicating there is potential for soil-derived dusts/fibres to be present, where they can easily be breathed in, ingested and come into contact with people working, using and visiting the zone and its surrounding area. Heavy metals and asbestos have historically been present within the north-western portion of the zone; although the extent of this contamination is unconfirmed. The nature of this part of the zone, however, suggests that most people coming into contact with it will be dressed suitably protectively, thus reducing any potential impact.	**Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
		Contaminant migration into drinking water pipes/supply to buildings	**Medium**	**Unlikely** Drinking water supplies may be impacted by potential contamination related to the historical uses of the zone. Organic contamination associated with the former gasworks, historically present along the northern boundary of the zone and fuel storage tanks across the zone are the most likely land uses to affect drinking water supply. The severity is of this potential contamination is unknown this stage; however, heavy metals, inorganic compounds and VOCs/SVOCs have historically been identified at the zone. However, these are not contaminants thought to affect drinking water supplies, so the probability of the identified pathway occurring has been considered unlikely.	**Low**
	Property and buildings/services	Migration and accumulation of ground gases into confined spaces, followed by ignition, causing explosion	**Severe**	**Unlikely** The south-western part of the zone was historically a chalk pit that has since been infilled [potentially with HS1 waste; note information from HS1 is awaited]. It does however remain at a much (approximately 10 m) lower elevation than its surroundings. It is considered that the ground gas generating potential and subsequent concentration of any ground gas would be low. The resulting gas concentrations from both of these sources are predicted to be low and the chances of the identified pathway occurring is considered unlikely.	**Moderate/Low**
		Chemical attack on building structures	**Mild**	**Low** Soil and groundwater contamination has been found to exist on the north-western part of the zone, including sulphates which could impact below ground structures, although the extent of this is unconfirmed. However, the historical quarrying within this area vastly reduces the	**Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
				probability of this occurring.	
	Controlled waters – groundwater receptors: Principal aquifer.	Leaching/migration of contaminants from soils	**Medium**	**Likely** The south-eastern part of the zone does not comprise superficial deposits, so any zone-derived contamination is likely to migrate into the Principal aquifer below. This part of the zone is also within a Zone 3 SPZ. Land contamination assessment undertaken in 2004 within the north-western area of the zone did not indicate significant risks to controlled waters receptors (48), although the south-eastern portion of the zone was not investigated during these works.	**Moderate**
		Vertical migration of contaminated groundwater	**Medium**		**Moderate**

8.5. Preliminary Geotechnical Risk Assessment

8.5.1. Geological and Geotechnical Hazards

The main hazards identified for Zone 5 are listed in the table below. The table is not a complete list and so does not contain every hazard. All the hazards are also only briefly summarised.

Table 8-9 Geological and Geotechnical Hazards in Zone 5

Hazard Identified on the Zone	Description	Comment
Aggressive ground conditions	The BRE Special Digest (44) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	The Made Ground is known to contain clinker in some areas, meaning waste from the cement manufacturing process has been dumped here in the past. This means that there is a chance aggressive chemicals will be present.
Buried foundations	Buried foundations from railways, buildings etc. can cause a delay to construction and incur additional costs.	There are a number of visible foundations within Zone 5A. Historical maps show many buildings within the zone which are no longer standing, notably in the centre of Zone 5A, and in the former chalk pits of Zone 5B. There is a high probability that buried foundations will be encountered. Railway lines have also been identified running across Zone 5.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	Existing services are likely to include electricity, gas, drinking water, foul water and telecommunications. Services are expected to run parallel with Manor Way and service Manor Way Business Park.
Chalk dissolution features	Dissolution features can cause instability of overlying material or structures, and could be filled with weaker material. Solution features may also be hidden from view by overlying material.	There are no recorded historic dissolution features within Zone 5 in the GroundSure report, although there is still a possibility of them forming due to the nature of the made ground over the Chalk bedrock. The GroundSure report has identified existing dissolution features within 100 m of the zone boundary. During a site visit possible dissolution features were identified in the chalk spine of the A226, however these are not recorded in the GroundSure Report (1).
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	Most of the zone has been quarried away in the past. The pit in the south-west of the zone (south of the A226) has been previously part backfilled with unknown spoil (assumed to be chalk) from the construction of HS1.
Perched water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking construction.	There is no evidence of perched groundwater within borehole logs or historical data. The stratigraphy below Zone 5 is generally very shallow chalk, which extends to a considerable depth. A lack of significant impermeable beds beneath the zone means a perched

Hazard Identified on the Zone	Description	Comment
		water table is unlikely, although groundwater can be trapped by the sheet flints observed within the chalk faces.
Rockfall	The failure of a rockface can be attributed to a variety of factors such as anthropogenic activities, erosion from acidic water or weathering. Any failure has the potential to result in loss of ground support.	A number of vertical chalk faces are present in Zone 5 with major infrastructure located at the top. The A226 spine specifically rises up to an average of 14 m above the normal ground level and is vertical. There is also a chalk spine carrying a railway to the south of Zone 4B. Both of these spines have man-made tunnels running beneath them, which could create a preferential water path, leading to solution features and subsidence.
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	The GroundSure report identifies only a few small areas with a low risk of running sand, with a negligible risk elsewhere (1).
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel. Appropriate control measures will need to be taken.	The River Thames is known to be brackish in this area, meaning the groundwater is likely to be slightly saline and depending on the groundwater regime may reach parts of Zone 5
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying length of piles.	Zone 5 has been historically quarried therefore the rockhead is believed to be variable across the zone.
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The Made Ground can be classed as a weak bearing material. Alluvium is present in Zone 5, albeit in only a small area to the north of the zone.
Weak compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Alluvium is present in Zone 5, albeit in only a small area to the north of the zone.

8.5.2. Risk Register

The Geotechnical Risk Register is presented as Table 8-8. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a “low” ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be substantial are:

- aggressive ground conditions
- buried foundations
- buried services
- chalk dissolution features;
- historical works;
- rockfall;
- variable rockhead/deep weathering profile;
- weak bearing materials; and
- weak compressible ground.

Most of the other risks are rated as “medium” to “low”.

8.5.3. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in-situ* and laboratory testing;
- planned methodology for the earthworks; and
- detailed design for the temporary construction roads.

8.5.4. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be “low”. However, it should be recognised that some residual risks remain, as described below.

Table 8-8 Geotechnical Risk Register for Zone 5

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
1	Aggressive ground conditions	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site. Use BRE Special Digest 1 (44) to determine the concrete class from sulphate and pH results.	2	2	2	1	4	4	2	L
2	Buried foundations	3	3	3	1	9	9	3	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	2	L
3	Buried services	3	3	3	3	9	9	9	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	Chalk dissolution features	3	3	3	3	9	9	9	S	Ground investigation to confirm geological succession and geotechnical properties across the site. Detailed visual inspection of all chalk faces. Where necessary consider appropriately in geotechnical design	3	2	2	1	6	6	3	M
5	Historical works	3	3	3	1	9	9	3	S	(see buried foundations and buried services)	2	2	2	1	4	4	2	L
6	Perched/high water table	2	2	2	1	4	4	2	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	2	1	1	1	2	2	2	L
7	Rockfall	3	3	3	3	9	9	9	S	Ground investigation to confirm geological succession and geotechnical properties across the site. Detailed visual inspection of all chalk faces. Where necessary consider appropriately in geotechnical design	3	2	2	2	6	6	6	M
8	Running sand	2	3	3	1	6	6	2	M	Ground investigation and monitoring to	1	2	2	2	2	2	2	L

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
										determine the geological succession and geotechnical properties across the site								
9	Saline groundwater	2	2	2	1	4	4	2	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	1	1	1	1	3	3	3	L
10	Variable rockhead/deep weathering profile	3	3	3	1	9	9	3	S	Ground investigation and monitoring to determine the geological succession and geotechnical properties across the site	3	2	2	1	6	6	2	M
11	Weak bearing materials	3	3	3	1	9	9	3	S	Ground investigation and monitoring to determine the geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
12	Weak compressible ground	3	3	3	1	9	9	3	S	Ground investigation and monitoring to determine the geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M

8.6. Zone 5 Summary

8.6.1. Geo-environmental Summary

Zone 5, located in the central section of the site/Swanscombe Peninsula, to the west of Zone 4, comprises industrial/commercial, retail and open space land uses on former chalk quarried land between the chalk spines of London Road, the North Kent Railway and Pilgrim's Road. Zone 5A, the northern section, comprises the western portion of Manor Way Business Park which consists of small to medium sized industrial units including a haulage company and electrical substation and commercial units and some retail outlets on London Road (A226). The southern portion of the zone, Zone 5B, comprises an open area which is a part in-filled former quarry off Crayland's Lane, to the south of London Road. In this section of the zone, there are a number of tunnels and associated roadways through the chalk spine upon which London Road is located.

Historically Zone 5A was part of the Portland Cement Works and also included railway tracks/tramways, an electricity substation, part of the former paper works and mills and part of the in-filled Pilgrim's Pit in the north eastern section. Zone 5B is understood to have been part in-filled by arisings from the HS1 development, which runs through the adjacent Zone 4.

Previous ground investigation and assessment associated with a former masterplan development for part of Zone 5A identified risks associated with asbestos containing materials in Made Ground, a hotspot of oil contamination in the north western section and elevated ground gas concentrations. Risks to controlled waters receptors were not deemed to be significant following risk assessment modelling.

The main potential sources of soil and groundwater contamination in the zone are the historical uses as a cement works and in-filled Pilgrim's Pit plus current industrial uses in Manor Way Business Park. Moderate risks have been assigned to current human health receptors via migration of ground gases into confined spaces and inhalation, ingestion and dermal contact with contaminated soils/dusts. Moderate risks were also assigned to controlled waters receptors via leaching and migration to the Principal Chalk aquifer.

8.6.2. Geotechnical Summary

Within Zone 5, the general geological stratigraphy consists of Made Ground over White Chalk bedrock. On the western zone boundary, Head deposits lie in-between the Made Ground and the Chalk, and on the northern boundary a thin bed of alluvium is recorded.

In Zone 5, significant development constraints have been identified relating to the chalk spines carrying the A226 and the railway. These spines pose a risk of rockfall, which may be being increased by undercutting of the cliffs by local businesses. Unidentified infill material in Zone 5B is expected to be partially supporting the spine, so removal of this material will increase the rockfall risk. The infill material may also pose risks, as the composition is unknown. It is expected to mainly consist of Chalk spoil from the construction of the HS1 Thames tunnel, but this is unconfirmed. Dissolution features have been identified in the spine, which can lead to subsidence. Man-made tunnels travel through the chalk as well. These tunnels can create a preferential water path, which will lead to increased weathering of the Chalk, and potential subsidence problems.

Constraints associated with high groundwater and saline groundwater have been assessed as low risk.

9. Zone 6

9.1. Zone Characterisation

9.1.1. Location

Zone 6 has an area of approximately 41 ha and is located in the southern part of the site, to the south of the Swanscombe Peninsula. The approximate NGR for the centre of the zone is TQ 61033 74282.

9.1.2. Zone Description

For the purposes of this assessment, Zone 6 has been subdived into two sub-zones: Zone 6A (which comprises the northern portion of the zone) and Zone 6B (which comprises the southern portion). Zone 6A comprises a former chalk pit, known as “Bamber Pit”, which was now partially landfilled and is now overgrown open land. There are two areas of Bamber Pit referred to in this report: one licenced landfill in the northern part (known as Bamber Pit North), and one unlicenced landfill in the southern section (known as Bamber Pit South) – see Section 9.2.10.2. Bamber Pit South was not completely infilled and contains a pond (known as Swanscombe Pond (11)) on its north-eastern portion. The southern part of the zone, Zone 6B, comprises an excavated chalk pit and landfilled area, known previously as Baker’s Hole and later as Northfleet Landfill. Zone 6B is separated from Bamber Pit by a pedestrian and cyclist-only roadway, that links Stanhope Road to the west of the zone to the residential area on the opposite side of HS1, to the east of the zone. There is a compound to the south of Northfleet Landfill which contains the gas management/control system for the landfill.

The elevation of Zone 6 generally slopes from west to east, with Zone 6B having slightly higher elevations than Zone 6A. The elevations of the southern part of Zone 6A and the northern part of Zone 6B are highest in the location of the elevated pedestrian and cyclist-only walkway. The elevation along the western boundary of the zone is approximately 28 m AOD in Zone 6A and 24 to 31 m AOD in Zone 6B (from the south-western boundary to the north-western boundary respectively). The elevations across the central p-parts of Zones 6A and 6B are approximately 12 and 20 m AOD respectively, whilst the elevations of the southern boundaries range from 11 to 28 m AOD in Zone 6A and 11 to 24 m AOD in Zone 6B.

Along the eastern boundary of the site is car parking and related infrastructure for Ebbsfleet International Station. Electricity pylons traverse the zone in a south-west to north-easterly alignment across Northfleet Landfill and the HS1 line. In the south-eastern section and to the south of the zone is the link road off the A2260 for Ebbsfleet International Station. Immediately to the west of the zone are Swanscombe High Street and Stanhope Road with associated residential properties beyond.

The location of the zone is shown on Figure 001, the permitted areas within the zone are shown on Figure 002, and key features, both historical and current, are shown on Figure 017. Photographs from the site walkover undertaken on 23 October 2014 can be found in Appendix B.

9.1.3. Zone-Specific Data Sources

A number of zone-specific data sources have been used. A Freedom of Information (FOI) request was submitted in August 2014 for records on Bamber Pit. The following information sources were available:

- Atkins, Review of Bamber Pit & Sports Ground, Draft Technical Note, September 2012 (53);
- Atkins, Bamber Pit and Sportsfield Environmental and Geotechnical Liability Assessment, 1 August 2014 (54)(54);
- Parsons Brinckerhoff UK Ltd., Bamber Quarry Landfill Site, Environmental Monitoring and Management Plan Permit No CP3735PB, Issue 3, April 2011 (60);
- Parsons Brinckerhoff UK Ltd., Bamber Quarry Landfill, Landfill Gas Appraisal, December 2010 (58);
- Parsons Brinckerhoff UK Ltd., Bamber Quarry Landfill, Hydrogeological Risk Assessment, Issue No. 2, January 2011 (61);
- Parsons Brinckerhoff UK Ltd., Bamber Quarry Landfill: 2011 FID Walkover Survey, July 2011 (62);
- Parsons Brinckerhoff UK Ltd., Bamber Quarry Landfill, Replacement of Landfill Gas Management System, January 2012 (63);
- Environmental Agency, Notice of variation with introductory note, Environmental Permitting (England & Wales) Regulations 2010. Variation application number: EPR/KP3598HT/V003, December 2011 (64);
- GVA for Parsons Brinckerhoff Properties Ltd, Environmental Due Diligence Report, Sports Ground Nr. Swanscombe, Northfleet, Kent, 01B072915, June 2011 (55);
- Environment Agency, EPR Compliance Assessment Report. Report ID: 19374/0215200. July 2007 (65);

- Parsons Brinckerhoff, Bamber Quarry Landfill Annual Report 2013, Issue 1, February 2014 (66); and
- additional various data as supplied by CMS-Enviro following a meeting held on 4 December 2014..

In addition to the above, Atkins also met with the Environment Agency on 24 October 2014 to discuss Bamber Pit.

9.1.4. Surrounding Land Uses

Zone 6 is bounded by the land uses listed below; please note, all distances given are approximate.

- **North –** the North Kent Line railway, which runs along a chalk spine, borders the zone to the north, with Zone 4 present to the north and the remainder of the wider site beyond. Please see the respective Chapters for further details of the other zones.
- **East –** HS1 runs along the eastern boundary of the zone with Ebbsfleet International Station and associated infrastructure and link roads to the east and south of the southern boundary. There are car hire companies and associated HS1 car parks beyond the railway. Further east towards the central portion of the zone's eastern boundary is Northfleet Station (approximately 380 m to the east), with the town of Northfleet and the Northfleet Industrial Estate beyond. The River Ebbsfleet is located approximately 140 m to the east of Zone 6.
- **South –** there is a large car park for Ebbsfleet International Station (Car Park D) located to the south of Zone 6 with the associated link road off the A2260. Beyond this is an area of open space, agricultural fields, small ponds/reservoirs, a dismantled railway and the town of Southfleet.
- **West –** Swanscombe High Street, Stanhope Road/Southfleet Road are located immediately to the west of the zone, along with associated residential and retail properties within the town of Swanscombe also located to the west of the zone. A large chalk pit, known as Eastern Quarry, is located to the south-west of Zone 6.

9.1.5. Historical Land Uses

The historical land uses in Zone 6 and the immediately surrounding area have been identified from historical mapping provided in the accompanying MapInsight (3) and are provided below in Table 9-1, with a summary highlighting the key findings provided in Section 9.1.5.1.

Table 9-1 Historical Land Uses Relating to Zone 6

Dates and Scales	Within Zone 6	Within 1 km of the Zone
1865 1:2,500 **1865-1866** 1:10,560	The zone comprises predominantly open space, intersected by a small road in its southern portion. The grounds of "Swanscombe Lodge" and an infant school are present along the Zone 6B's western boundary. A small area within present-day Northfleet Landfill, in the south-eastern portion of Zone 6B, is labelled as an "old chalk pit".	Immediately north of the zone is a railway (North Kent Line). This railway leads to Northfleet Station and a goods depot approximately 300 m east of the zone. The town of Swanscombe is present immediately west of the zone. Swanscombe Park is present approximately 500 m south-west of the zone. A waterway (the River Ebbsfleet) is present to the east and south of the zone, approximately 80 m east at its closest point. The area immediately east of the zone is consequently marked as "liable to floods".
1872-1897 1:2,500 **1888- 1895** 1:10,560	The northern part of the zone (Bamber Pit/Zone 6A) is intersected by railway tracks indicating the presence of a tunnel along the northern zone boundary, beneath the North Kent Line. It also comprises chalk pits and a smithy. Zone 6B (Northfleet Landfill) comprises an old gravel pit and is intersected by a road. The southern part of Zone 6B comprises a large quarry, a large gravel pit (which extends	The area to the east of the zone is more developed. The area to the south and west of the zone is shown to comprise old clay and chalk pits, known today as Eastern Quarry, and has two boilers (510 m south-west and 745 m south). An old gravel pit is located 400 m to the west of the zone.

Dates and Scales	Within Zone 6	Within 1 km of the Zone
	outside the zone boundary to the east) and an old chalk pit. Tramway tracks are shown to access the gravel pit and quarry.	
1907-1909 1:2,500 **1907-1923** 1:10,560	Within Zone 6A, the chalk pit in the northern portion of the zone now stretches the entire width, and extends beyond the zone's eastern boundary. An engine house is shown in the north-eastern part of the zone, immediately north of the tramway tracks. Allotment gardens are also present in the northern part of the zone. In Zone 6B, an army barracks is shown along the zone's western boundary, and a marl pit is shown in the southernmost part of the zone, immediately south of the now extended quarry, which has covered the formerly shown gravel pit.	No significant changes.
1932- 1939 1:2,500 **1931-1938** 1:10,560	The areas of the zone that were previously open spaces have now mostly been taken up by additional pits or quarries or new allotment gardens. The large quarry on the southern portion of Zone 6B is now called "Baker's Hole", and has a pumping station along the zone's southern boundary. There is also a rifle range towards the southern-central portion of the zone and a miniature rifle range is present along the zone's south-eastern boundary. The engine house on the north-eastern part of Zone 6A is no longer shown.	The tramways to the east of the zone have changed alignment and "Portland Cement Works (Wash Mills)" and associated tanks are shown approximately 150 m east of the zone. The area to the south of the zone is now shown as a large, old, chalk pit. Swanscombe, to the west of the zone, has substantially grown in size, although pits still remain. Tennis grounds, bowling greens and a sports ground are present to the east of the zone.
1946-1948 1:10,560	The rifle range is no longer shown.	No significant changes.
1952 1:1,250 **1952** 1:2,500 **1955** 1:10,560	A pipeline (possibly underground) is shown intersecting the northern portion of Zone 6A, extending from a mineral railway line/tramway which also intersects Zone 4 and Zone 5. This passes beneath the North Kent Line in the same location as the former rail tracks, indicating that the tunnel in this area is still present. Baker's Hole is no longer labelled as such, and the pumping station within it is no longer shown. Two pump houses are shown on Zone 6A's northern section, with the pipeline leading to them both. Allotment gardens are shown within Zone 6B.	The area immediately west of the railway to the east of the zone, is now called Ebbsfleet Pleasure Ground. The area to the west of the zone continues to be developed into residential properties. The area immediately south of the zone now comprises an additional very large pit, this time extending from the zone itself. A sports ground is shown to the east of the zone. A paper sack factory is located 500 m to the west of the zone.
1961-1966, 1:10,560 **1961-1969** 1:2,500	A long conveyor is shown within Zone 6B, and appears to be associated with Eastern Quarry, although this is unclear. The conveyor is located on an embankment just to the west of the zone. Palaeolithic flints were found within the former Baker's Hole quarry. A pond is shown towards the centre of Zone 6B's southern boundary.	Archaeological finds have been discovered within the surrounding area, including a Roman burial ground immediately west of the zone and a Palaeolithic skull 600 m west. "Northfleet West Grid Substation" is present within a large building, 750 south-west of the zone.
1970-1973 1:1,250	The pits across the zone are marked as disused, and the pipeline within Zone 6A no	The pits within the surrounding area are marked as disused.

Dates and Scales	Within Zone 6	Within 1 km of the Zone
1971-1974 1:10,000	longer extends to the southernmost pump house. Electricity pylons are shown running south-west to north-east through Zone 6 from the Northfleet West Grid Substation.	
1985-1995 1:2,500 **1977-1990** 1:10,000	Some of the former pits in the zone appear infilled. A small pond is present in Zone 6A, in place of one of the former pits. The pump houses within Zone 6A are no longer shown on the 1896-1990 map. Zone 6B is first shown to comprise a refuse tip on the 1985-1995 maps. The refuse tip takes the place of the former pond in this area of the site.	The former pits to the south of the zone appear infilled. There is a large pond immediately south of the zone boundary, extending slightly into the southern portion of the zone, shown between 1990 and 1992. A station is shown immediately north of the zone, along the railway track separating the zone from Zone 5 to the north. The conveyor extending out of the zone's western boundary to Eastern Quarry is now shorter, and Eastern Quarry itself is shown to have increased in scale; the boundaries of which are not clearly shown on the 1:10,000 scale map provided.
2002 1:10,000	No significant changes.	The large chalk pit, approximately 490 m to the west of the site is now marked as disused workings, and the corresponding conveyor to the west of the site has reduced in size again. Separate conveyors are present within a chalk pit that starts 750 m west of the site, associated with unidentified works complete with numerous pits.
2010-2014 1:10,000	The south-eastern portion of Zone 6B is labelled as a car park, whilst the south-western portion is labelled as workings.	HS1 is present along the zone's eastern boundary. Ebbsfleet International Station is present adjacent to the zone's south-eastern boundary.

Notes: For land uses to the north of the zone (Zone 4), see Chapter 7.

9.1.5.1. Summary of Historical Land uses

Zone 6 has historically comprised mainly chalk quarries with some excavation of gravels and subsequent infilling with domestic waste and waste from paper manufacturing (9). On the earliest available map (OS Map from 1865), the zone was shown to comprise predominantly open land, intersected by a small road in its southern portion. Only the south-eastern portion of the zone (Zone 6B) was labelled as an "old chalk pit" at this stage.

By 1895, the northern part of the zone (Zone 6A) was also used as chalk pits. The chalk and gravel quarries continued to increase in size over time and included associated infrastructure, such as an engine house, railway tracks and pumping stations associated with the excavations and infilling. Baker's Hole was an area of the chalk pit, within Zone 6B, that was first labelled as such during the 1930s. Palaeolithic flints were found within Baker's Hole, making it an important archaeological site (refer to Section 9.2.8).

Potentially contaminative land uses within the zone included two licenced landfills (Bamber Pit [North] in Zone 6A and Northfleet Landfill in Zone 6B), tramway tracks, rifle ranges, an engine house, a pumping station and a car park. The two licenced landfills were constructed under the 'dilute and disperse' principle, and hence have no engineered containment. Filling has also taken place in Bamber Pit South, although this is thought to contain inert waste and it was not licenced. The zone also historically included allotment gardens.

There have been potentially contaminative industries and land uses located off-site and within 1 km of the zone. Northfleet Station was shown on the earliest maps provided, approximately 300 m east of the zone. The town of Swanscombe is present to the west of the zone. Archaeological finds have also been discovered

within the area to the west of the zone. Northfleet West Grid Substation has been shown approximately 750 m south-west of the zone but has recently been demolished and outline planning permission has been granted to transform the area into a mixed use development. Much of the area to the south of the zone has been used as chalk pits and there have also been some gravel and clay pits in the area. Eastern Quarry is a large quarry to the south-west of Zone 6. HS1 and Ebbsfleet International Station were opened in 2007 and are located to the north and east of Zone 6.

9.2. Environmental Context

9.2.1. Historical Borehole Records

A large number of historical boreholes records are available via the BGS, of which 18 have been collated and reviewed. These were undertaken for a number of schemes including Northfleet Papermills, Swanscombe Sewer Scheme and HS1 and are to depths of between 10 m (TQ67SW732) and 37.5 m (TQ67SW50). They have been summarised in Appendix C.

The majority of the boreholes were installed between 1994 and 1997, with three in 1975 (TQ67SW732, TQ67SW733 and TQ67SW734) and one in 1977 (TQ67SW428). Of these logs; 13 were categorised as Grade A, 5 as Grade B, and none as Grade C. The information from Grade A and B logs has been used to verify the published geological mapping information and inform the findings of this report.

9.2.2. Geology

The 1:10,000 BGS geological map, sheet TQ67SW (Northfleet), Solid and Drift edition (1996) shows the geological succession over much of Zone 6 to be Made Ground underlain by the White Chalk group. To the west of the zone, west of Church Road, the Chalk is overlain by Thanet Sand Formation and skirting the eastern boundary of Zone 6 are variable head deposits. Boyn Hill Gravel is expected along the footpath between the excavations of Bamber Pit (North and South) and Northfleet Landfill.

Table 9-2 Expected Stratigraphy beneath Zone 6

Formation	Typical Thickness (m)	Description
Made Ground	8.5	Soft brown clay to sandy clay, some brick gravel. Abundant domestic and industrial waste, including wood, plastic, rubber, metal, cloth and paper.
Head deposits	2.5	Soft to firm brown sandy clay with gravel of flint and chalk.
RTD	2.0	Dense silty fine to medium sand with chalk gravel and lensed chalk and flint gravel.
Boyn Hill Gravel	Unknown	Sand and gravel, with possible lenses of clay, silt and peat.
Chalk	>6	Moderately weak to hard white CHALK with beds of flint in the upper 5m.

Note: (1) Typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness of the Boyn Hill Gravel is marked as unknown, it is known to be present but no data on its thickness is available. (2) See text in Section 9.2.4 for further details.

9.2.3. Geomorphology

Zone 6 occupies an area which exhibits a long history of anthropogenic influences. It is located on the gently dipping northern face of the Chalk limb which forms the North Downs, with the steeply dipping southern face being located approximately 12 miles to the south. Throughout Zone 6 the Chalk exposure has been removed in multiple excavations, and chalk spines have been left along the northern boundary of the zone, as well as on the boundary between sub-zones 6A and 6B. The northern spine carries a railway, and has a backfilled manmade tunnel running underneath it. The spine splitting up the sub-zones caries a footpath, and is formed of Boyn Hill Gravel overlying the Chalk.

A ridge bounds the southern boundary of Zone 6 and two large mounds approximately 25 m^2 are located 20 m west of Ebbsfleet International Station, in the South-east of the zone. Elevation is highest at approximately 27 m AOD, along Standhope Road in the west, and drops towards the east to 4 m AOD at Ebbsfleet International Station.

9.2.4. Ground Conditions

A general description of all the geological units is presented in Section 3.2, along with geotechnical parameters reproduced from CIRIA guides and other technical parameters.

Descriptions and geotechnical parameters provided in the following sections have been obtained from the site specific information sources detailed above. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 6, therefore the information is provided for guidance only and it is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain site specific design parameters.

9.2.4.1. Made Ground

The majority of the zone is overlain with landfill (Made Ground) up to 21.6 m thick. In the mid-1970's, Bamber Pit, located within Zone 6A, became a landfill, primarily for wastes linked to local paper production facilities until at least the mid-1980's, as well as Thanet Sand from local quarries. The landfill is directly overlying the Chalk and there is no evidence of a landfill cap, though the surface has a soil covering and is now heavily vegetated.

Borehole records in Zone 6A (across both the licenced and unlicenced landfill areas) describe the fill as comprising beds of soft brown clay to sandy clay with some brick gravel, and beds of soft to dense black, oily sandy clay with domestic waste, including polystyrene, metal refrigerator parts, glass, plastic sheeting and bottles, cardboard and paper. Some beds of loose sand and ash, as well as gravel are also noted.

Zone 6B is known as Northfleet Landfill. Only five trial pits logs are available for this part. These logs describe the Made Ground here as being predominantly soft to firm, brown to black sandy clay with beds of brick, chalk, flint and concrete gravel. There is much domestic and industrial waste referenced in the logs, including wood, plastic, rubber and metal. It is often described as oily with a strong butyric acid odour, likely due to the crushed oil containers mentioned in borehole TQ67SW631.

9.2.4.2. Head Deposits

Up to 9 m of head deposits are recorded along the eastern edge of Zone 6. It is described as 'soft to firm brown sandy clay with chalk and flint gravel'. In borehole TQ67SW900, a bed of medium dense brown very sandy flint gravel is observed, as well as firm, thinly laminated brown to grey sandy clay with sand laminae.

9.2.4.3. River Terrace Deposits

In borehole TQ67SW861 undertaken on behalf of HS1, the log records possible RTD described as 'dense yellow brown silty fine to medium sand with little to some subangular; fine to medium chalk gravel and discontinuous layers and lenses of chalk and silt'. This unit is recorded as 1.5 m in thickness.

9.2.4.4. Boyn Hill Gravel

The 1:10,000 BGS geological map, sheet TQ67SW (Northfleet), Solid and Drift edition (1996) shows a thin spine of Boyn Hill Gravel along the footpath between Bamber Pit and Northfleet Landfill. No borehole records are available for the narrow spine where the Boyn Hill Gravel is shown. The BGS Lexicon of Named Rock Units (8) describes this unit as 'comprising of sand and gravel, with possible lenses of silt, clay or peat'.

9.2.4.5. White Chalk Group

Chalk bedrock underlies Zone 6 and is recorded in a number of borehole records as a layer of structureless chalk overlying structured chalk. It is encountered at about 4 m bgl towards the west of Zone 6 and at about 9 m bgl toward the east of Zone 6.

The structureless Chalk is described as 'fine to coarse gravel size white moderately weathered very weak to weak; low to medium density fragments with some matrix of light brown silt size fragments'. The structured Chalk is generally described as 'weak, medium density. Factures are extremely to very closely spaced generally infilled with a trace of comminuted chalk stained orange brown, grey blue or grey locally speckled black'

SPT results from the borehole logs show an increase in strength with depth, with the results ranging from 4 to 49 with stronger and weaker beds throughout, likely due to the presence of flint bands.

9.2.5. Hydrology and Hydrogeology

9.2.5.1. Surface Water

There is a groundwater-fed pond (Swanscombe Pond) in the northern portion of the zone. To the east, outside the zone, runs the Ebbsfleet River, which runs from Springhead to the River Thames located north-east of Zone 6. Along the river, adjacent to Ebbsfleet International Station, are areas of wetland.

9.2.5.2. Groundwater

Groundwater is observed generally between 8 and 10 m AOD, although it appears to be highly variable, having a range of 21 m and it was not encountered in a number of boreholes. This is likely due to the varying nature of the Made Ground infill. The Chalk bedrock is classified by the Environment Agency as a Principal aquifer.

9.2.5.3. Groundwater Abstractions

No groundwater abstractions are located within Zone 6. However according to the Environment Agency (2014), two large and one medium extractions of groundwater are present around Sawyers Lake, approximately 300 m south-east of Zone 6. These have maximum annual extraction rates of up to 17,700,000 m^3, largely for public water supply. Consequently the groundwater levels in the Chalk are likely to be depressed because of this extraction.

9.2.5.4. Groundwater Vulnerability

Information provided by the Environment Agency (2014) concludes that the majority of Zone 6 is located in a Zone 3 SPZ: total catchment area. Along the eastern fringe of the zone, by Ebbsfleet International Station, it is Zone 2: outer zone.

9.2.6. Flood Risk

The Environment Agency Flood Map for Planning (from rivers and the sea), included within the FloodInsight report (4) shows that the zone is not within an area at risk of flooding. The zone does not have an Environment Agency NaFRA rating. The Environment Agency NaFRA database provides an indication of river and coastal flood risk at a national level, and considers the probability that the flood defences will overtop or breach (4).

According to the GroundSure FloodInsight report, the Environment Agency does not hold any records of historical flood events affecting the zone.

Patches of Zone 6 are at risk of pluvial flooding, predominantly across the zone's northern portion (Bamber Pit area, opposite Milton Road), and western (Stanhope Road), southern (Northfleet Landfill) and eastern (HS1) boundaries. The most significant risk rating of these is "highly significant". Pluvial flooding is defined, in the FloodInsight report (4), as flooding caused by rainfall-generated overland flow, and is therefore usually the result of extreme rainfall events.

The BGS has identified that the northern portion of the zone (Zone 6A) has potential for groundwater flooding to occur at the surface and groundwater flooding of property, below ground level, although the majority of the zone has been deemed to have limited potential for groundwater flooding.

Further details regarding flood risk can be found in Buro Happold's Flood Risk Assessment (in preparation).

9.2.7. Mineral Abstractions

Historical OS maps show the majority of Zone 6 was quarried for Chalk or gravel between 1895 and 1946, and disused pits are still visible over much of the zone. Table 9-3 summarises the quarries found in this zone.

Table 9-3 Historical Quarries in Zone 6

Name of Quarry	Coordinates (Centre)	Location within Zone	Abstracted Mineral
Bamber Pit	560869, 174586	North	Chalk and gravel
Baker's Hole	561101, 173786	South-west	Chalk
Northfleet Landfill	560829, 174300	Central (south of pedestrian/cyclist path)	Chalk

From historical OS maps, a tunnel is located under Galley Hill Road in the Chalk, at the northern boundary of Zone 6A (560922, 174735). This tunnel was used to transport material from the quarries to the cement factories previously located in Zones 4 and 5. This was done via tram, which is now no longer in use. No evidence of a tramline is currently apparent in Zone 6 and the tunnel is understood to have been backfilled.

Located approximately 1 km to the south-east of Zone 6, on Springhead Road, is a denehole, according to the Chelsea Spelaeological Society(67). This is believed to be a double-trefoil denehole with two small intact chambers off the main chamber. To the west of Springhead Road, another medieval denehole was discovered, this one being 8.5 m below ground level with four possible chambers.

9.2.8. Designated Environmentally Sensitive Sites

There are a number of designated environmentally sensitive sites located within Zone 6, according to the GroundSure EnviroInsight Report (2).

A 6.8 ha area in the south-east of Zone 6B, along the eastern boundary, is classified as an SSSI known as Baker's Hole. Baker's Hole was designated as an SSSI as it was considered a key Pleistocene site exposing a complex sequence of periglacial and temperate climate deposits. Baker's Hole has been assessed by Natural England in March 2012 and was considered as being in an unfavourable condition due to surviving sediments and exposures becoming heavily overgrown and damaged by animal burrowing. Zone 6B also contains a 2.37 ha Scheduled Monument; the Palaeolithic sites near Baker's Hole. The location of Baker's Hole is shown on Figure 003.

There is an SSSI located 500 m west of the zone called Swanscombe Skull Site. The site is 3.88 ha and is also considered a National Nature Reserve.

The MAGIC website (10) also indicates that the zone is within five SSSI IRZs. The SSSI IRZs are areas assessed by Natural England as where developments could either create a significant risk to a local SSSI. The zone is within a NVZ for groundwater.

There are no other designated environmentally sensitive areas within Zone 6.

9.2.9. Environmental Permits, Incidents and Registers

There are no IPPC activities within Zone 6. There is one recorded LPPC activities within 1 km of Zone 6 (2): Swanscombe Dry Cleaners, located 77 m west of Zone 6; and a small waste oil burner operated by Hidsons Ltd. on Oakwood Industrial Estate, 230 m east of Zone 6.

There are no discharge consents within Zone 6, although there are four current and historical consents listed within 1 km of Zone 6, as summarised in Table 9-4.

Table 9-4 Discharge Consents within 1 km of Zone 6

Distance and Orientation from Zone 6	Operator	Effluent Type	Details
325 m east	Lafarge	Trade discharge - Mineral workings	Active
326 m east	Baker's Hole Landfill	Trade discharge – Site drainage	Revoked 5 September 2003
327 m east	Hochtief Norwest Holst	Trade discharge – Site drainage	Revoked 1 August 2005
341 m east	Northfleet Eastern Quarry	Trade discharge – Mineral workings	Active

Five historical pollution incidents have been recorded within 500 m of Zone 6, as summarised in Table 9-5.

Table 9-5 Records of Pollution Incidents within 1 km of Zone 6

Distance and Orientation from Zone 6	Incident Date	Pollutant	Impact
337 m north-east	7 November 2003	Inert materials and wastes	Land: Category 3 (Minor)
378 m south-east	11 July 2002	Sewage materials	Water: Category 3 (Minor) Air: Category 3 (Minor)
381 m south-east	17 May 2001	Mineral materials and wastes	Water: Category 3 (Minor)
470 m-east	17 March 2003	Crude oil	Water: Category 3 (Minor) Air: Category 3 (Minor)
485 m south-east	27 January 2002	Firefighting run-off	Water: Category 3 (Minor) Air: Category 3 (Minor)

9.2.10. Landfills and Other Waste Sites

9.2.10.1. Introduction

There are two licenced landfills within Zone 6: Bamber Pit [North] and Northfleet Landfill, and one unlicenced landfill (referred to as Bamber Pit South). Northfleet Landfill is located within Zone 6B, whilst Bamber Pit (North and South) is located adjacent to the north of Northfleet Landfill, within Zone 6A, separated by only a pedestrian and cyclist-only roadway that links Stanhope Road to the west of the zone to the residential area on the opposite side of HS1, to the east of the zone.

9.2.10.2. Bamber Pit (Zone 6A)

Bamber Pit landfill is located off Standhope Road. Some reports refer to a "Bamber Pit North" and "Bamber Pit South", whilst others refer to an overall "Bamber Quarry Landfill". Bamber Pit North was originally operated by Kent Kraft Mills Ltd under WML P/1/16, from 1974 to the mid-1980s. During this period, it accepted an estimated 500,000 m^3 of waste classified at that time as inert, semi-inert, putrescible or difficult and non-special asbestos waste, which included hydropulper (paper rag waste). PBH took ownership of the site in 1992 and no waste disposal has taken place since. From liaison with the Environment Agency and the current owner's environmental consultant (see Section 9.1.3) waste materials within Bamber Pit (North) are understood to comprise an estimated 10-20 % by volume of biodegradable/domestic wastes.

An active gas extraction and monitoring system exists for Bamber Pit North (58), focused on its western boundary; predominantly in order to control off-site migration to the residential area to the west. This system meets the requirements of the current EP for the site (WML P/01/16) and has been shown to be effective in controlling off-site gas risks providing that the control system is properly inspected and maintained (58)(63)(62)(63).

Bamber Pit South was owned and managed by Blue Circle Industries and was licensed to receive inert and industrial waste between 31 December 1977 and 16 April 1993. Anecdotal information from obtained during meetings with the Environment Agency suggests that Bamber Pit south was infilled predominantly with Thanet Sands. There is still a void at Bamber Pit South where the chalk pit was not infilled to capacity.

9.2.10.2.1. Ground Conditions at Bamber Pit

The local geology of Bamber Pit has been established from several phases of ground investigation. These include an investigation for the proposed alignment of what is now the HS1 railway (1988 by DRG/Lawrence Hewitt and Partners); an investigation as part of the pre-construction works for HS1; and three phases of ground investigation (in 2002, 2005 and 2007), undertaken by Parsons Brinckerhoff, for the current owners. Further details of these investigations can be found in Parsons Brinckerhoff's 2011 Hydrogeological Risk Assessment for Bamber Pit (61), 2010 Landfill Gas Appraisal for Bamber Pit (58) and Landfill Annual Report 2013 (66) and GVA's Bamber Pit Environmental Summary (68). Overall, Parsons Brinckerhoff determined that Bamber Pit poses little, if any, environmental risk.

9.2.10.2.2. Aftercare Conditions at Bamber Pit

According to liaison with the Environment Agency (see Section 9.1.3), Bamber Pit is currently in the aftercare phase and there is a requirement on the EP holder to ensure that it is managed in such a way that potential environmental and health and safety risks continue to be monitored, and where necessary, mitigated. Further details regarding Bamber Pit can be found in Atkins' Bamber Pit and Sportsfield Environment and Geotechnical Liability Assessment (54).

9.2.10.3. Northfleet Landfill (Zone 6B)

Northfleet Landfill is operated by Lafarge Tarmac Cement and Lime Limited (WML BLU002 19375) and is currently also in the aftercare phase. Minor household waste tipping is believed to have occurred during the 1960s and 1970s in the north-western corner. The landfill was operated officially from 1984 to 1994 and received 782,000 tonnes of mixed industrial and commercial wastes, plus inert cover/road materials (36). The landfill surface was restored in 1996. A landfill gas extraction system was installed within Northfleet Landfill, with flaring and power generation through to 2000, and after August 2000, the range of permitted wastes that could be deposited within Northfleet Landfill was restricted to inert wastes and contaminated soils. Also in 2000, a revised permit was secured for an additional four million tonnes of inert/lightly contaminated soils.

Inert inputs were operated under Jayflex control until 2009, when the site was completed. This included extending the landfill gas collection system, moving and adding a flare and constructing a high-density polyethylene cap on the 1996 restored levels (36).

The site was deemed official closed in April 2012, following the closure report of March 2012. The most recent modification to the permit was on 22 November 2013 and two landfill gas flares continue to operate full-time on the southern boundary of Northfleet Landfill; each capable of burning 600 m^3/hour (36) (53). There is also weekly landfill gas migration monitoring, landfill gas control system sampling every four weeks and monthly groundwater and leachate monitoring, with some groundwater issues currently under review with the Environment Agency (64).

9.3. Preliminary Geo-environmental Conceptual Site Model

9.3.1. Introduction

The approach used for the creation of the preliminary CSM is detailed in Section 2.2.1. Identified zone-specific potential sources, pathways and receptors associated with contamination are listed below, with the corresponding risk rating detailed in Table 9-6.

9.3.2. Potential Sources

9.3.2.1. Potential On-Zone Sources

The potential on-zone sources identified from the background searches, data review and site walkover observations for Zone 6 have been split in the CSM into those predominantly relating to the Bamber Pit part of the zone (the section north of the pedestrian and cyclist roadway) and those relating to the Northfleet

Landfill area (the southern section, south of the pedestrian and cyclist roadway) (Zones 6A and 6B respectively), as follows:

9.3.2.1.1. Zone 6A: Bamber Pit (North and South)

- Bamber Pit (predominantly Bamber Pit North), which received waste from local paper manufacture and cement works, and included putrescible waste, and had an active gas extraction and monitoring system;
- historical railway usage of this part of the zone (northern section); and
- the former pump houses, engine house and pipeline.

9.3.2.1.2. Zone 6B: Northfleet Landfill

- Northfleet Landfill which received mixed household, industrial and commercial wastes, and is believed to have experienced minor household waste tipping during the 1960s and 1970s in its north-western corner;
- former rifle ranges on the zone, which may have caused localised lead contamination;
- former railway uses and conveyor (which lead to the Eastern Quarry);
- former pumping station;
- current car parking use; and
- former army barracks along the western boundary.

9.3.2.2. Potential Off-Zone Sources

Potential off-zone sources of contamination are discussed earlier on in this Chapter, but are not included within the CSM, as discussed in Section 2.2.

9.3.3. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres ;
- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- inhalation of soil- and/or groundwater-derived vapours;
- leaching/migration of contaminants from soils;
- direct surface water run-off and sub-surface flow to surface waters, possibly facilitated by the tunnel along the northern boundary of Zone 6A;
- lateral migration of contaminated groundwater; and
- vertical migration of contaminated groundwater.

9.3.4. Potential Receptors

As stated in Section 2.2, the CSM for each chapter only considers on-zone receptors. The identified potential current receptors to the identified potential contamination, split by identified source area, are listed below:

9.3.4.1. Zone 6A: Bamber Pit

- the Principal aquifer within the Chalk bedrock beneath the zone, the sensitivity of which is increased as the zone is within SPZs: the majority is within a Zone 3 SPZ, whilst the south-eastern part is within a Zone 2 SPZ;
- small areas of superficial deposits within the zone, classified as Secondary ‘A’ along the western boundary of the zone and Secondary (undifferentiated) aquifers along the eastern, within the Boyn Hill Gravel Member and head deposits respectively;
- zone workers and trespassers; and
- adjacent residential receptors in Swanscombe to the west.

9.3.4.2. Northfleet Landfill (Zone 6B)

- the Principal aquifer within the Chalk bedrock beneath the zone, the sensitivity of which is increased as the zone is within SPZs: the majority is within a Zone 3 SPZ, whilst the strip along the eastern boundary is within a Zone 2 SPZ;
- small areas of superficial deposits within the zone, classified as Secondary ‘A’ along the western boundary of the zone and Secondary (undifferentiated) aquifers along the eastern, within the Boyn Hill Gravel Member and head deposits respectively;

- Baker's Hole SSSI within the zone;
- zone workers and trespassers; and
- adjacent residential receptors in Swanscombe to the west.

A schematic CSM for Zone 6 is presented as Figure 016.

Table 9-6 Preliminary Conceptual Site Model for Zone 6

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
Zone 6A: **Potential contaminants in soil/groundwater within the zone, originating from the following sources:** • Contamination in the Made Ground, resulting from landfilling of waste including that from local paper manufacture and cement works, historical railway usage and former structures (notably the pump houses, engine house and pipeline). • Contamination in the natural ground beneath the zone (Boyn Hill Gravel Member and Head superficial deposits and Chalk bedrock), resulting from the potential sources listed above. *Various potential contaminants.*	Human health receptors (zone workers, trespassers and residents in the neighbouring town of Swanscombe)	Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	**Unlikely** Zone 6A is predominantly covered in softstanding, meaning there may be soil-derived dusts/fibres. However, the majority of the zone is heavily vegetated, and access to it is limited.	**Low**
		Inhalation of soil- and/or groundwater-derived vapours	**Medium**	**Unlikely** Zone 6A has an extensive history as an area of mineral extraction and subsequent infilling. Bamber Pit has an active gas control system which is considered by the Environment Agency to be sufficient, thereby mitigating the risks associated with vapours and gases. The risk rating would increase significantly if these mitigation measures were removed.	**Low**
		Migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** Zone 6A has an extensive history as an area of mineral extraction and subsequent infilling. There are not confined spaces within Zone 6A, as although the landfill could be considered one, the active gas control system will be mitigating risks. The risk rating would increase significantly if these mitigation measures were removed.	**Moderate/Low**
	Controlled waters – groundwater receptors: Principal (bedrock) aquifer and Secondary 'A' and Secondary (undifferentiated) (superficial deposits) aquifers	Leaching/migration of contaminants from soils	**Medium**	**Likely** Zone 6A is located directly on the Principal aquifer. Therefore, any leachable contaminants present in the zone are highly likely to migrate to the aquifers beneath. Contaminant movement will be further facilitated by the soft ground cover (allowing infiltration of precipitation), predominant groundwater flow direction, excavation works and Swanscombe Pond. However, during previous site investigations (not completed by Atkins) little visual or olfactory evidence of contamination was recorded from this	**Moderate**
		Vertical migration of contaminated groundwater	**Medium**		**Moderate**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
				part of Zone 6.	
		Direct surface water run-off and sub-surface flow to surface waters, possibly facilitated by the tunnel along the northern boundary of Zone 6A	**Medium**	**Low likelihood** Surface run off is deemed unlikely as Bamber Pit comprises predominantly of softstanding. However, the tunnel that connects the northern part of the zone to Zone 4C could facilitate surface water movement.	**Moderate/Low**
Zone 6B: **Potential contaminants in soil/groundwater on the zone, originating from the following sources:** • Potential contaminants in the Made Ground from landfilling of mixed industrial and commercial wastes, minor household waste tipping, historical rifle ranges, former railway use, former pumping station and current car parking. • Contamination in the natural ground beneath the zone (Boyn Hill Gravel Member and Head superficial deposits and	Human health receptors (zone workers, trespassers and residents in the neighbouring town of Swanscombe)	Dermal contact, ingestion or inhalation of contaminated soils/dusts.	**Medium**	**Low likelihood** Zone 6B is predominantly covered in softstanding, meaning there may be soil-derived dusts/fibres. However, it is predominantly covered by an engineered cap, and access to the sites is limited.	**Moderate/Low**
		Inhalation of soil- and/or groundwater-derived vapours	**Medium**	**Low likelihood** Zone 6B has an extensive history as an area of mineral extraction and subsequent infilling. Northfleet Landfill only stopped accepting waste in 2006 and has an active gas control system, involving two flares which operate full time, indicating the high gas generating potential of this part of the zone. These are, however, considered by the Environment Agency to be sufficient, thereby mitigating the risks associated with vapours and gases. The risk rating would increase significantly if these mitigation measures were removed.	**Moderate/Low**
		Migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** Zone 6b has an extensive history as an area of mineral extraction and subsequent infilling. Northfleet Landfill only stopped accepting waste in 2006 and has an active gas control system, involving two flares which operate full time, indicating the high gas generating potential of this part of the zone. These are, however, considered by the Environment Agency to be sufficient, thereby mitigating the risks associated with	**Moderate/Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation bedrock), resulting from the potential sources listed above. *Various potential contaminants.*				vapours and gases. There are not confined spaces within Zone 6B, as although the landfill could be considered one, the active gas control system will be mitigating risks. The risk rating would increase significantly if these mitigation measures were removed.	
	Controlled waters – groundwater receptors: Principal (bedrock) aquifer and Secondary 'A' and Secondary (undifferentiated) (superficial deposits) aquifers	Leaching/migration of contaminants from soils	**Medium**	**High likelihood** Northfleet Landfill is located directly on the Principal aquifer. Therefore, any leachable contaminants present in the zone are highly likely to migrate to the aquifers beneath. Contaminant movement will be further facilitated by the soft ground cover (allowing infiltration of precipitation), predominant groundwater flow direction and excavation works.	**High**
		Vertical migration of contaminated groundwater	**Medium**		**High**
		Direct surface water run-off and sub-surface flow to surface waters	**Medium**	**Low likelihood** Surface run off is deemed unlikely as it comprises predominantly of softstanding, although the engineered capping layer and domed nature of Northfleet Landfill may contribute to some surface runoff.	**Moderate/Low**
	Ecological receptors within the zone: Baker's Hole SSSI	Leaching/migration of contaminants from soils	**Medium**	**Low likelihood** Northfleet Landfill is located directly on the Principal aquifer. Therefore, any leachable contaminants present in the zone are highly likely to migrate to the aquifers beneath. Contaminant movement will be further facilitated by the soft ground cover (allowing infiltration of precipitation) and excavation works. Bakers Hole SSSI is located within the former quarry and has waste material placed on top and directly adjacent to it. It is highly likely to be impacted with contamination resulting from the zone, possibly explaining why it is classified as having an "unfavourable declining" condition. However, the SSSI designation relates to Baker's	**Moderate/Low**
		Lateral migration of contaminated groundwater	**Medium**		**Moderate/Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
				Hole as an archaeological site (due to its Palaeolithic significance), rather than its ecological site, thus reducing the likely impact on groundwater contamination on this part of the zone.	
		Direct surface water run-off and sub-surface flow to surface waters	**Medium**	**Low likelihood** Surface run off is deemed unlikely as it comprises predominantly of softstanding, although the engineered capping layer and domed nature of Northfleet Landfill may contribute to some surface runoff.	**Moderate/Low**

9.4. Geotechnical Context

9.4.1. Geological and Geotechnical Hazards

Table 9-7 describes some of the geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 9-7 Potential Geological and Geotechnical Hazards in Zone 6

Hazard	Description	Comment
Aggressive ground conditions	The BRE Special Digest (44) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	The Made Ground infill in Bamber Pit has been noted to include oily residue, refrigerator parts and polystyrene. In Northfleet Landfill, the Made Ground has been described as oily, with a strong odour of butyric acid. The presence of crushed oil containers has also been noted in one borehole.
Buried foundations	Buried foundations from railways, buildings etc. can cause a delay to construction and incur additional costs.	Tramlines were a common occurrence across Zone 6 during the early twentieth century, however due to the land filling of the majority of Zone 6 the exact location and status of the any remaining foundations/infrastructure is unknown. The historical tunnel through the northern Chalk spine is thought to have been for an old tramline, but no evidence of the line is still visible.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	No buried services have been identified in Zone 6, but the site history does not rule out their presence. All buried services must be located before intrusive ground investigations take place.
Chalk dissolution features	Dissolution features can cause instability of overlying material or structures, and could be filled with weaker material. Solution features may also be hidden from view by overlying material.	The presence of Boyn Hill Gravel overlying the Upper Chalk around the footpath between Bamber Pit and Northfleet Landfill is indicative of a high subsidence risk area (69) consequently the presence of chalk dissolution features cannot be discounted. There is also a man-made tunnel in the northernmost Chalk face, which could create a preferential water path, leading to increased weathering and subsidence effects.
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement.	Deneholes are present to the east of Zone 6 in Northfleet, and also to the South of the Zone boundary. Major quarrying and infilling has taken place across the zone, resulting in two licenced landfills (Bamber Pit North and Northfleet Landfill) and one unlicenced landfill (Bamber Pit South). The waste in these historical quarries takes up most of the zone.
Perched water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking	Groundwater levels generally range from 8 to 10 m AOD, although a variation of 21 m has been recorded.

Hazard	Description	Comment
	construction.	The groundwater levels are highly variable in the area, which is likely an effect of the variable nature of the Made Ground. Multiple instances of localised perched water tables are likely.
Rockfall	The failure of rockface can be attributed to a variety of factors such as anthropogenic activities, erosion from acidic water or weathering. Any failure has the potential to result in loss of ground support.	A number of vertical Chalk faces are present in Zone 6 with major infrastructure located at the top. Old chalk quarry faces are likely to degrade overtime, characterised by local falls of material. Currently due to the nature of infilling, the faces appear to be supported and thus unlikely to fall, however if the landfill is disturbed or removed, then the risk of rockfall will increase.
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	No indicators for running sand have been identified, confirmed by Groundsure Report (1). However it is a moderate risk at approximately 100 m west of Zone 6 where Thanet Sand Formation is present.
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel. Appropriate control measures will need to be taken.	The Swanscombe Peninsula is located in a brackish water zone of the Thames, meaning the groundwater is likely to be slightly saline and depending on the groundwater regime may reach parts of Zone 6.
Slope instability	Landslide (slope instability) can be divided into four categories: falls, topples, slides or flows. They rarely comprise a single movement but are a result of several. The downslope movement of material through landsliding may damage buildings or infrastructure though loss of support or direct impact.	According to the 2014 Groundsure Report (1), landslip deposits are recorded 157 m south-west of Zone 6 in the Thanet Sand. There is no evidence of any slope instability in Zone 6 (see above for rockfall).
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying length of piles.	Zone 6 has been highly quarried therefore the rockhead is believed to be variable across the zone.
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	Made Ground can be classed as a weak bearing material. Head deposits present across the eastern boundary of the zone are also likely to have a low bearing capacity.
Weak compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	No evidence of peat or alluvium. However much of the area is Made Ground and some pockets of compressible soil may be evident. The Groundsure Report (1) marks the area at moderate risk. Old landfills may be highly compressible.

9.4.2. Geotechnical Risk

9.4.3. Risk Register

The Geotechnical Risk Register is presented as Table 9-8 below. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a "low" ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be substantial are:

- aggressive ground conditions;
- buried services;
- historical works;
- variable rockhead/deep weathering profile;
- weak bearing materials; and
- weak compressible ground.

Most of the other risks are rated as "moderate" to "low".

9.4.4. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in situ* and laboratory testing;
- planned methodology for the earthworks; and
- detailed design for the temporary construction roads.

9.4.4.1. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be "low". However, it should be recognised that some residual risks remain, as described below.

Table 9-8 Geotechnical Risk Register for Zone 6

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk Number			Risk Ranking		Likelihood	Severity			Risk Number			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
1	Aggressive ground conditions	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site. Use BRE Special Digest 1 (44) to determine the concrete class from sulphate and pH results.	2	2	2	1	4	4	2	L
2	Buried foundations	2	3	3	1	6	6	2	M	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	2	L
3	Buried services	3	3	3	3	9	9	9	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	Chalk dissolution features	2	3	3	3	6	6	6	M	Ground investigation to confirm geological succession and geotechnical properties across the site. Detailed visual inspection of all chalk faces. Where necessary consider appropriately in geotechnical design	2	2	2	1	4	4	2	L
5	Historical works	3	3	3	1	9	9	3	S	(See buried foundations and buried services)	2	2	2	1	4	4	2	L
6	Perched/high water table	2	2	2	1	4	4	2	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	2	1	1	1	2	2	2	L
7	Rockfall	2	3	3	3	6	6	6	M	Ground investigation to confirm geological succession and geotechnical properties across the site. Detailed visual inspection of all chalk faces. Where necessary consider appropriately in geotechnical	2	2	2	2	4	4	4	L

Category Risk No.	Constraint	Prior to mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk Number			Risk Ranking		Likelihood	Severity			Risk Number			Risk Ranking
			Capital cost	Programme	Safety	Capital cost	Programme	Safety				Capital cost	Programme	Safety	Capital cost	Programme	Safety	
										design								
8	Running sand	2	3	3	1	6	6	2	M	Ground investigation and monitoring to determine the geological succession and geotechnical properties across the site	1	2	2	2	2	2	2	L
9	Saline groundwater	2	2	2	1	4	4	2	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	1	1	1	1	3	3	3	L
10	Slope instability	2	3	3	1	6	6	2	M	Ground investigation to confirm geological succession and geotechnical properties across the site. Where necessary consider appropriately in geotechnical design	1	2	2	1	4	4	1	L
11	Variable rockhead/deep weathering profile	3	3	3	1	9	9	3	S	Ground investigation and monitoring to determine the geological succession and geotechnical properties across the site	3	2	2	1	6	6	2	M
12	Weak bearing materials	3	3	3	1	9	9	3	S	Ground investigation and monitoring to determine the geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M
13	Weak, compressible ground	3	3	3	1	9	9	3	S	Ground investigation and monitoring to determine the geological succession and geotechnical properties across the site	3	2	2	1	6	6	3	M

9.5. Zone 6 Summary

9.5.1. Geo-environmental Summary

Zone 6, located in the southern section of the site, comprises predominantly in-filled former chalk pits bordered to the east by the HS1 railway and to the west by Swanscombe town and High Street. The northern part of Zone 6 (Zone 6A) is known as Bamber Pit and is a permitted landfill (ref. WML P/01/16) within a former chalk quarry, now in the aftercare period. Bamber Pit received mixed wastes, predominantly associated with the adjacent paper industries, from 1974 until the mid 1980s. An active landfill gas extraction system is present in the western section of the landfill which manages the landfill gas risks associated with the adjacent properties in Swanscombe.

To the south of Bamber Pit is a further partially in-filled, non permitted, quarry (referred to as Bamber Pit South and also known as Baker's Hole) which includes a small pond in the north eastern section (Swanscombe Pond). It is understood this area received only inert natural deposits and that in-filling only took place over part of the site. A footpath/cycleway is present running west to east on the southern boundary of Bamber Pit South between here and a further in-filled quarry, Northfleet Landfill, to the south. The path/cycleway provides access from Swanscombe town across the HS1 rail lines to the residential area to the east.

The southern part of the zone (Zone 6B) comprises Northfleet Landfill, a further permitted landfill (ref. WML BLU002 19375) in the aftercare period, operated by Lafarge. Northfleet Landfill was active between 1984 and 2006 and received mixed household, industrial and commercial wastes, latterly restricted to inert wastes. An active gas extraction and flaring system is present and operates full-time on site with the plant located in the southern section of the landfill. There is an easement along the boundary of Northfleet Landfill with the HS1 land. A car park, an access roadway and related infrastructure for Ebbsfleet International Station are located in the eastern section of Zone 6B. Ebbsfleet International Station is located immediately east of the site with the access link road off the A2260 present in the south eastern section. A SSSI, known as Baker's Hole, is located in the eastern section of Zone 6B. This is an important local archaeological site dating back to Palaeolithic times. Electricity pylons also traverse the landfill in a south westerly to north easterly alignment.

The principal sources of contamination in Zone 6 relate to the Bamber Pit and Northfleet Landfills and include landfill gas and leachate generation and contact with the waste materials themselves, though recognising both sites are secure from the general public. As such current risks to human health from both sites have been assessed as low to moderate/low whilst risks to controlled waters receptors via leaching/migration of contamination from the waste into the aquifers and lateral migration of contaminated groundwater are considered moderate for Bamber Pit and high for Northfleet Landfill. Risks to the Baker's Hole SSSI are assessed as moderate/low.

9.5.2. Geotechnical Summary

Zone 6 is largely covered by Made Ground, consisting of landfill. Along the eastern boundary, Head deposits are found, and a few boreholes in Northfleet Landfill have identified possible River Terrace deposits. The entire zone is underlain by White Chalk bedrock. Along the small Chalk spine on the partition between Zones 6A and 6B, Boyn Hill Gravel has been recorded.

Substantial constraints within Zone 6 have been identified as relating to the historical landfilling activity which has taken place in Bamber Pit and Northfleet Landfill. Oily residue and butyric acid have been identified in the landfills, meaning there is a high chance that the ground will act aggressively towards concrete. The landfills are also highly variable in composition, meaning compression and differential settlement under load is expected. Buried services are anticipated to be found within the Zone possibly associated with the infrastructure for Ebbsfleet International Station, in the South-west of the Zone. The landfills should also have a leachate and gas collection system in place, posing another risk of buried services. The Head deposits in the east are likely to have a low bearing capacity.

Medium constraints are likely to include chalk dissolution features within the chalk spines. There is also at least one tunnel present underneath the railway spine, which as previously noted could create a preferential water path leading to more dissolution features. The spines also pose a risk of rockfall, although they are currently being supported by the infill material and should the material be removed the risk will increase.

10. References

1. **GroundSure.** *GeoInsight Plus.* 10 October 2014. GS-1708817.

2. —. *EnviroInsight.* 10 October 2014. GS-1708815.

3. —. *MapInsight.* 13 October 2014. GS-1708814.

4. —. *FloodInsight.* 10 October 2014. GS-1708816.

5. **British Geological Survey.** *GeoIndex.* [Online] 2014. [Cited: 19 November 2014.] http://mapapps2.bgs.ac.uk/geoindex/home.html.

6. —. *Geology of Britain Viewer.* [Online] 2014. [Cited: 19 November 2014.] http://mapapps.bgs.ac.uk/geologyofbritain/home.html.

7. —. *Hydrogeological Map of the Dartford (Kent) District (1:63,360) - 1968, Sheet 15.* 1968.

8. —. *Lexicon of Named Rock Units.* [Online] 2014. [Cited: 19 November 2014.] http://www.bgs.ac.uk/lexicon.

9. **Environment Agency.** What's In Your Backyard? [Online] 19 November 2014. http://apps.environment-agency.go.uk/wiyby.

10. **Defra.** Multi-Agency Geographic Information for the Countryside. [Online] 2014. [Cited: 19 November 2014.] http://magic.defra.gov.uk/home.htm.

11. **Google.** Google Maps. [Online] 2014. [Cited: 26 November 2014.]

12. **6 Alpha Associates.** *Detailed Unexploded Ordnance (UXO) Risk Assessment for Paramount Resort, Kent.* 2014.

13. **Environment Agency.** *Model Procedures for the Management of Land Contamination (Contaminated Land Report 11).* 2004.

14. **British Standards Institute.** *Code of Practice for Investigation of Potentially Contaminative Sites.* March 2011. BS 10175:2011.

15. **Department for Communities and Local Government.** *National Planning Policy Framework.* March 2012.

16. **Defra and Cranefield University.** *Guidelines for Environmental Risk Assessment and Management.* November 2011.

17. **Environment Agency.** *Human Health Toxicology Assessment of Contaminants in Soils.* 2009. SC050021/SR2.

18. **CIRIA.** *Contaminated Land Risk Assessment: A guide to good practice (C552).* 2001.

19. **British Standards Institute.** *Eurocode 7. Geotechnical Design. Ground Investigation and Testing (BS-EN1997-2:2007).* 2007.

20. —. *A Code of Practice for Site Investigations.* August 2010. BS5930:2010+A2.

21. **Clayton, C.R.I.** *Managing Geotechnical Risk - Improving Productivity in UK Building and Construction.* s.l. : Institution of Civil Engineers, 2001.

22. **Highways Agency.** *Design Manual for Roads and Bridges.* 2008.

23. **CIRIA.** *UXO - A Guide for the Construction Industry (C681).* 2009.

24. *Beneficial Uses of Cement Kiln Dust.* **Adaska, Wayne S and Taubert, Donald H.** 2008.

25. *Cement Kiln Dust.* **Corish, A and Coleman, T.** 1995, Concrete.

26. *Use of cement kiln dust in cement concrete and its leachate characteristics.* **Kunal, Siddique and Rajor.** 2012, Resources, Conservation and Recycling.

27. **Ellison, R.A.** *Geology of London. Special Memoir for 1:50,000 Geological sheets 256 (North London), 257 (Romford), 270 (South London) and 271 (Dartford) (England and Wales).* Keyworth, Nottingham : British Geological Survey, 2004.

28. *Benthic foraminiferal evidence for the formation of the Holocene mud-belt and bathymetrical evolution in the central Adriatic Sea.* **Morigi, C. et al.** 2005.

29. *Clay Materials Used in Construction.* **Reeves, G.M., Sims, I. and Cripps, J.C.** 2006.

30. *Chalk: Its stratigraphy, structure and engineering geology in east London and the Thames Gateway.* **Mortimore, R., et al.** s.l. : Quarterly Journal of Engineering Geology and Hydrogeology, 2011, Vol. 44.4.

31. **Hopson, P M.** *A stratigraphical framework for the Upper Cretaceous Chalk of England and Scotland with statements on the Chalk of Northern Ireland and UK Offshore Sector.* Keyworth, Nottingham : British Geological Survey, 2005.

32. *Chalk engineering geology - Channel tunnel rail link and North Downs Tunnel.* **Warren, C.D and Mortimore, R.N.** 1, s.l. : Quarterly journal of engineering geology and hydrogeology, 2003, Vol. 36.

33. **CIRIA.** *Engineering in Chalk (C574).* 2002.

34. *Influence of large-scale inhomogeneities on a construction dewatering system in Chalk.* **Bevan, M.A., Powrie, W. and Roberts, T.O.** 8, s.l. : Geotechnique, 2010, Vol. 60.

35. **SLR.** *Broadness Marsh Leachate/Percoalte Treatment Plan, Swanscombe, Kent. Section 73 Application to Amend Condition 2 of Planning Permission DA/06/200. Planning Supporting Statement.* 402.01288.00020 : s.n., October 2014.

36. **Lafarge Tarmac.** *Lafarge Tarmac Swanscombe Broadness and South Pit Landfill; Northfleet Landfill - Environmental Overview.* October 2014.

37. **AMEC.** *Percolate Treatment Discharge Review, Broadness Marsh.* January 2011.

38. —. *Percolate Treatment Discharge Review, Broadness Marsh.* February 2009.

39. —. *Percolate Treatment Discharge Review Broadness Marsh November & December 2009.* December 2009.

40. *The flood plain deposits of the Lower Thames.* **Marsland, A.** 3, s.l. : Quarterly Journal of Engineering Geology and Hydrogeology, 1986, Vol. 19.

41. **CMS Enviro.** *RP3039SZ South Pit Phase 3 Landfill Environmental Performance Annual Report January-December 2011.* January 2012.

42. *Swanscombe Peninsula West Geotechnical and Land Raise Strategy Report.* **Halcrow Group Limited.** 2004.

43. *Soil Investigations at Broadness Marsh, Swanscombe.* **Weeks, A.G. and partners.** 1974.

44. **BRE Construction Division.** *Concrete in Aggressive Ground (Special Digest 1).* s.l. : BREPress, 2005. ISBN 1-86081-754-8.

45. **CMS-Enviro.** *PPC Permit Application: EAWML19373 South Pit Phase 3 Landfill Applicant: Lafarge Cement UK.* 2004.

46. *Flandrian sea level changes and vegetational history of the lower Thames estuary.* **Devoy, R.J.N.** 1979, Philosophical Transactions of the Royal Society of London. Series B, Biological Science, pp. 355-407.

47. **GroundSure.** *FloodInsight.* 10 October 2014. GS-1708816.

48. **Halcrow Group Limited.** *Swanscombe Peninsula West Phase 1 Contamination Interpretive Report.* January 2004.

49. **SLR.** *Planning Support Statement South Pit (Phase 3) Leachate Disposal Plant.* September 2014.

50. **Sugg, Nicola.** *South Pit Phase 3 Landfill - Enforcement Notice Condition 2.9.1 Leachate Level Management.* 2014.

51. **Halcrow Group Limited.** *Swanscombe Peninsula West Environmental Statement - Volume 1.* 2004.

52. **Hydrock.** *Desk Study and Ground Investigation at Northfleet Industrial Estate.* 2008.

53. **Atkins.** *Review of Bamber Pit and Sports Ground, Draft Technical Note.* September 2012.

54. —. *Bamber Pit and Sportsfield Environmental and Geotechnical Liability Assessment.* December 2014.

55. **GVA (for PBH Properties Ltd).** *Environmental Due Diligence Reports, Sports Ground Nr. Swanscombe, Northfleet, Kent.* June 2011. 01B072915.

56. **Department of Environment.** *Industry Profile: Pulp and paper manufacturing works.* 1996.

57. **Aspinwalls and Company.** *Channel Tunnel Rail Link Assessment of Land Contamination Effects Volume 1 of 2.* November 1994.

58. **Parsons Brinckerhoff UK Limited.** *Bamber Quarry Landfill, Landfill Gas Appraisal.* 2010.

59. **SLR.** *Preliminary Land Quality Risk Assessment, Sheerness Recycling, Manor Way, Swanscombe, Kent (Ref. 416.04308.00005).* September 2014.

60. **Parsons Brinckerhoff UK Limited.** *Bamber Quarry Landfill Site Environmental Monitoring and Management Plan Permit No. CP3735PB, Issue 3.* April 2011.

61. —. *Bamber Quarry Landfill, Hydrogeological Risk Assessment, Issue No. 2.* January 2011.

62. —. *Bamber Quarry Landfill: 2011 FID Walkover Survey.* July 2011.

63. —. *Bamber Quarry Landfill, Replacement of Landfill Gas Management System.* January 2012.

64. **Environment Agency.** *Notice of Variation with Introductory Note. Environmental Permitting (England and Wales) Regulations 2010. Variation Application number EPR/KP3598HT/V003.* December 2011.

65. —. *EPR Compliance Assessment Report. Report ID: 19374/0215200.* July 2007.

66. **Parsons Brinckerhoff UK Limited.** *Bamber Quarry Landfill Annual Report 2013.* February 2014.

67. **Pearman, H.** *Deneholes.* s.l. : Chelsea Speleological Society, 2010.

68. **GVA.** *Bamber Pit Environmental Summary.*

69. *Subsidence hazard in Berkshire in areas underlain by chalk karst.* **Edmonds, C. N.** 2001.

70. *Engineering Stratigraphy and Paleaogeography for the Chalk of the Anglo-Paris basin.* **Mortimore, R., Pomerol, B. and Foord, R.** 1, 1990, Chalk: Proceedings of the International Chalk Symposium, Vol. 1, pp. 47-62.

Figures

Figure 001 **Site Layout Plan**

Figure 002 **Environmental Permit Boundaries**

Figure 003 **Geo-Environmental Hazards and Constraints Plan**

Figure 004 **Geotechnical Hazards and Constraints Plan**

Figure 005 **Borehole Grade Map**

Figure 006 **Borehole Depth Map**

Figure 007 **Geological Section A-A'**

Figure 008 **Zone 1: Key Features**

Figure 009 **Zones 1 & 2: Schematic Conceptual Site Model**

Figure 010 **Zone 2: Key Features**

Figure 011 **Zone 3: Key Features**

Figure 012 **Zones 3 & 5: Schematic Conceptual Site Model**

Figure 013 **Zone 4: Key Features**

Figure 014 **Zone 4: Schematic Conceptual Site Model**

Figure 015 **Zone 5: Key Features**

Figure 016 **Zone 6: Schematic Conceptual Site Model**

Figure 017 **Zone 6: Key Features**

DO NOT SCALE

N

ZONE 1

ZONE 2

ZONE 3

ZONE 4

ZONE 5

ZONE 6

3A

3B

4A

4B

4C

5A

5B

6A

6B

KEY:

ZONE BOUNDARY

SITE BOUNDARY

SUB-ZONE BOUNDARY

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00		–
	Purpose of issue	Rev	Date		Authorised

ATKINS

Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, KT18 5BW

Fax (01372) 740055
Tel. (01372) 726140

©

Client

LONDON RESORT COMPANY HOLDINGS

Project

PARAMOUNT PARK
ENTERTAINMENT RESORT

Title

SITE LAYOUT PLAN

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 18.12.14	Date 18.12.14	Date 18.12.14	

Drawing Number: 5134008-PHASE1-FIGURE 001 — Rev: A

Job Dept. Sub Unique No.

Drawing Number 5134008-PHASE1-FIGURE 001 Rev. A

DO NOT SCALE

WR3237 and CATM.3237

EPR/RP3039SZ

EPR/KP3998HW (previously P/1/11A)

ZONE 1

ZONE 2

3A

3B

4A

4B

4C

5A

5B

6A

6B

Recresco Ltd. Swanscombe Glass Recovery Facility: EPR/AB3103KR

Veka Recycling Ltd.: EPR/BB3033CH

Ace Car Breakers: EPR/ZP3195HH

Crossway Recycling Ltd.: WPR/KP3698HF

Lancebox Recycling Facility: EPR/GB3730RW

Greenfield Properties (UK) Ltd.: EPR/NP3698VM later Woodland Environmental Ltd.: EPR/KB3435AK

EPR/KP3598HT

EPR/KP3898HE

N

ATKINS

KEY:

- ZONE BOUNDARY
- SITE BOUNDARY
- SUB-ZONE BOUNDARY
- SOUTH PIT AND SURGE PILE PHASES 1, 2 AND 3
- SOUTH PIT AND SURGE PILE PHASE 3
- BAMBER PIT LANDFILL
- NORTHFLEET LANDFILL
- X OTHER ENVIRONMENTAL PERMITS

NOTE: Environmental Permit boundaries are not equivalent to land ownership boundaries.

Drawing Number 5134008-PHASE1-FIGURE 002 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00		–
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

©

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: ENVIRONMENTAL PERMIT BOUNDARIES

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 18.12.14	Date 18.12.14	Date 18.12.14	

Drawing Number: 5134008-PHASE1-FIGURE 002 Rev: A

Job Dept. Sub Unique No.

1 Broadness Landfill

- Cement Kiln Dust (CKD) deposited across entire zone
- Leachate collection system in place
- Under monitoring programme
- Pre-licensing needs and without land-based permits

2A North Pit, South Pit & Surge Pile Landfills

North Pit - CKD deposited
- Licence WML P/1/11 (handed back)

South Pit & Surge Pile - CKD deposited
- Phase 1 CKD deposited under WML P/1/11A
- Phase 2 not used for infilling
- Phase 3 re-permitted as RP3039SZ
- Disused sewage works

2B Cement Works

- Historical cement works
- Associated railways, gasworks and tanks
- Current use: old building foundations

3A Swanscombe Marshes

- No significant risk
- Historically and presently predominantly marshland

3B Former Whiting Works

- Chalk pits (possible infilling)
- Later whiting works with associated tanks
- Currently used as a welding works (operated by Basic Engineering Co Ltd)

4A Botany Marshes

- No significant risk
- Historically and presently marshland/agricultural land

4B Northfleet Industrial Estate

- Historically quarried and contained paper mills, chemical works, tar distilleries, tanks and a reservoir for industrial discharge
- Currently Kent Kraft Industrial Estate with potential contaminative activities

4C Former quarry

- A historical quarry that used to contain a rifle range
- Now overgrown and disused

5A Cement Works

- Historically a cement works
- Currently an industrial estate with commercial/industrial warehouses

5B HS1 Infilled Area

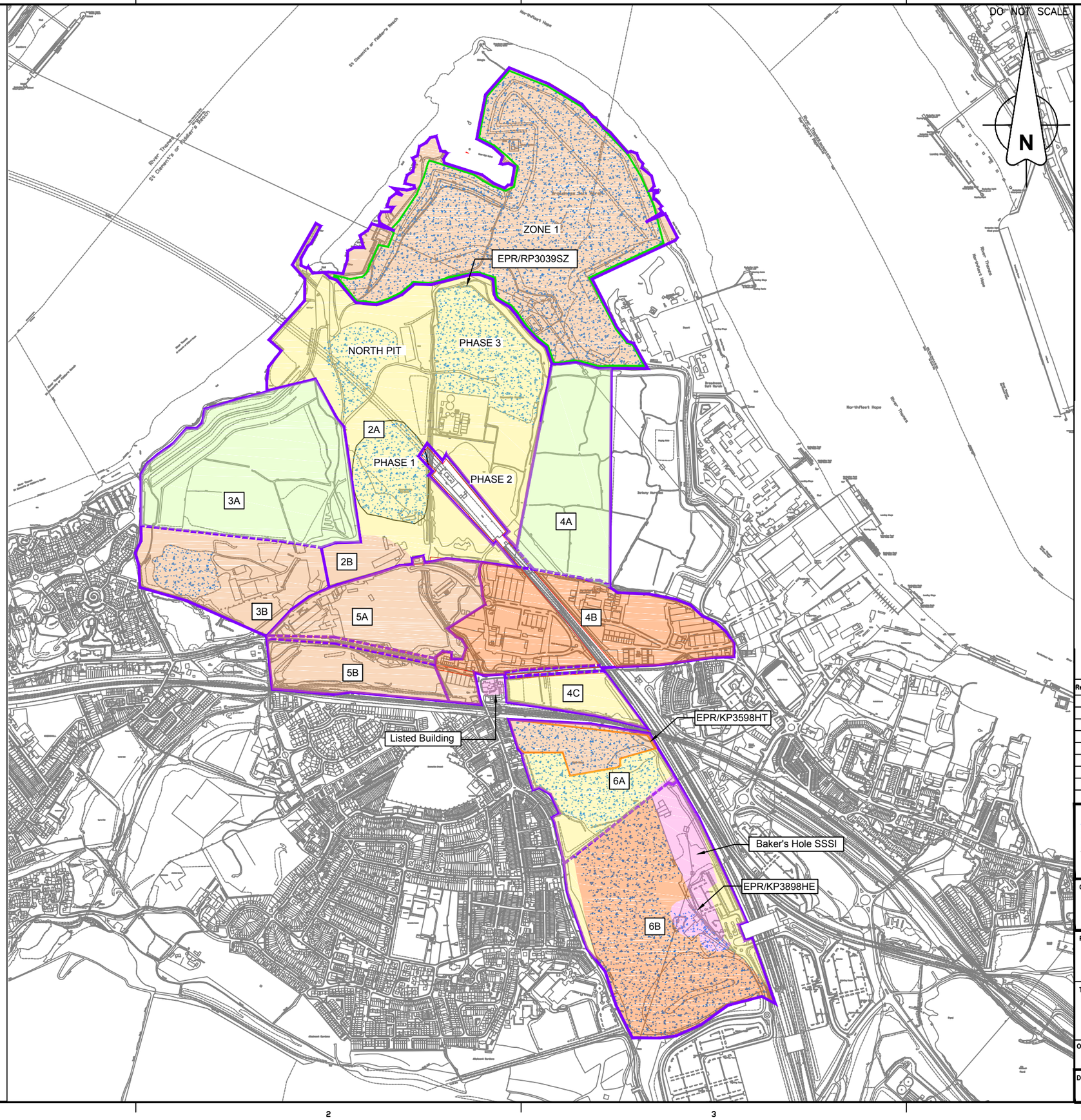
- Historically a quarry
- Infilled with High Speed 1 material

6A Bamber Pit Landfill

- Commercial waste from paper mills & cement works
- Also received domestic wastes
- Under a current monitoring programme
- WML 1937Y

6B Northfleet Landfill

- Received domestic, industrial and commercial waste
- Under monitoring programme including landfill gas extraction
- Closed to new waste
- WML1937S



KEY:

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- BROADNESS LANDFILL
- BAMBER PIT LANDFILL
- NORTHFLEET LANDFILL
- SITE BOUNDARY
- LOW
- MODERATE/LOW
- MODERATE
- HIGH
- SPECIAL CONSIDERATION
- INFILLED LAND

NOTE: THE HIGHEST RISK IDENTIFIED FOR EACH ZONE IS SHOWN ON THIS FIGURE. DETAILED ASSESSMENTS HAVE BEEN UNDERTAKEN AND CAN BE FOUND IN THE RESPECTIVE CHAPTER FOR EACH ZONE.

Drawing Number 5134008-PHASE1-FIGURE 003 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00		–
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England,
KT18 5BW
Fax (01372) 740055
Tel. (01372) 726140

©

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: GEO-ENVIRONMENTAL HAZARDS AND CONSTRAINTS PLAN

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 18.12.14	Date 18.12.14	Date 18.12.14	

Drawing Number: 5134008-PHASE1-FIGURE 003 Rev: A

Job Dept. Sub Unique No.

DO NOT SCALE

1 Broadness Marsh/Landfill

- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- CKD (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- HISTORICAL WORKS (M)
- HIGH GROUNDWATER (M)
- RUNNING SAND (M)
- SALINE GROUNDWATER (M)
- VARIABLE ROCKHEAD (M)

2A North Pit, South Pit and Surge Pile Landfills

- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- CKD (S)
- HISTORICAL WORKS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- HIGH GROUNDWATER (M)
- RUNNING SAND (M)
- SALINE GROUNDWATER (M)

2B Cement Works

- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- HISTORICAL WORKS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- HIGH GROUNDWATER (M)
- SALINE GROUNDWATER (M)

3A Swanscombe Marsh

- BURIED SERVICES AND FOUNDATIONS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- CKD (M)
- HISTORICAL WORKS (M)
- HIGH GROUNDWATER (M)
- RUNNING SAND (M)
- SALINE GROUNDWATER (M)

4A Botany Marshes

- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- HIGH GROUNDWATER (M)
- SALINE GROUNDWATER (M)

4B & 4C Northfleet Industrial Estate and Sports field

- BURIED SERVICES AND FOUNDATIONS (S)
- HISTORICAL WORKS (S)
- ROCKFALL (S)
- VARIABLE ROCKHEAD (S)
- WEAK BEARING MATERIALS (M)
- WEAK COMPRESSIBLE GROUND (M)

5A Whitecliff Park and Manor Way

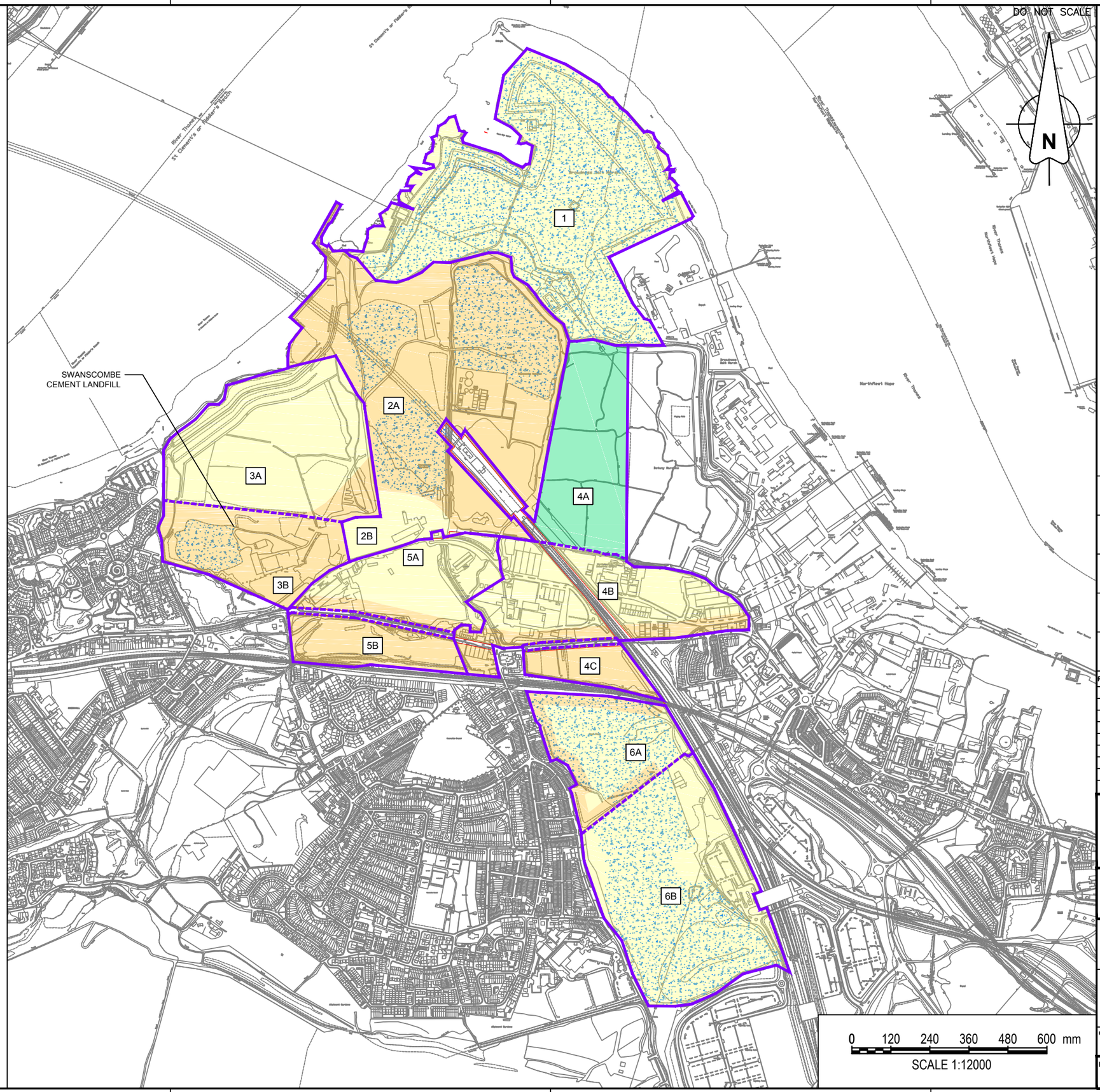
- BURIED SERVICES AND FOUNDATIONS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- CHALK DISSOLUTION FEATURES (S)
- HISTORICAL WORKS (S)
- ROCKFALL (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- RUNNING SAND (M)

5B CTRL Infilled Area

- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- CHALK DISSOLUTION FEATURES (S)
- HISTORICAL WORKS (S)
- ROCKFALL (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- BURIED SERVICES AND FOUNDATIONS (M)
- RUNNING SAND (M)

6A & 6B Northfleet and Bamber Pit Landfills

- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- HISTORICAL WORKS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- CHALK DISSOLUTION FEATURES (M)
- ROCKFALL (M)
- RUNNING SAND (M)
- SLOPE INSTABILITY (M)



0 120 240 360 480 600 mm

SCALE 1:12000

ATKINS

KEY:

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- SITE BOUNDARY
- LOW RISK
- MEDIUM RISK
- SUBSTANTIAL RISK
- INFILLED GROUND

NOTE:

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE REPORT PHASE 1 GEO-ENVIRONMENTAL AND GEOTECHNICAL RISK ASSESSMENT 5134008/PHASE1/FINAL3.0.

CONSTRAINTS HAVE BEEN IDENTIFIED USING READILY AVAILABLE SOURCES OF DATA AND RISK CATEGORIES APPLIED USING ATKINS' ENGINEERING JUDGEMENT.

THE SUBSTANTIAL (S) AND MEDIUM (M) GEOLOGICAL OR GEOTECHNICAL RISKS FOR EACH ZONE ARE LISTED AND THE LEVEL INDICATED BY THE SUFFIXED LETTER. FURTHER, ZONE-SPECIFIC DETAILS ON EACH RISK IS GIVEN IN THE REPORT.

Drawing Number 5134008-PHASE1-FIGURE 004 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00		–
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England,
KT18 5BW
Fax (01372) 740055
Tel. (01372) 726140

©

Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK ENTERTAINMENT RESORT

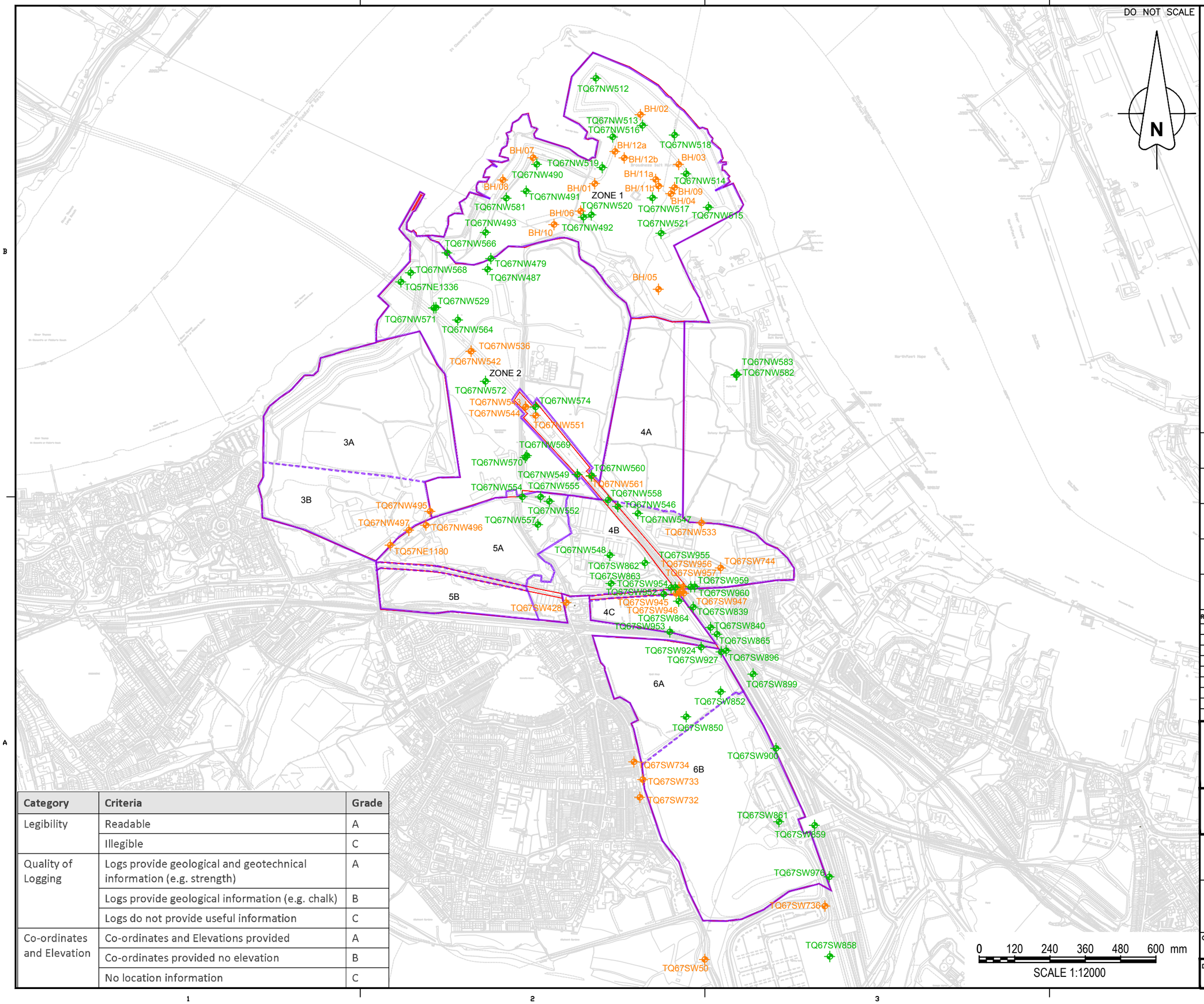
Title
GEO-TECHNICAL HAZARDS AND CONSTRAINTS PLAN

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 18.12.14	Date 18.12.14	Date 18.12.14	

Drawing Number 5134008-PHASE1-FIGURE 004 Rev A

Job Dept. Sub Unique No.

DO NOT SCALE



Category	Criteria	Grade
Legibility	Readable	A
	Illegible	C
Quality of Logging	Logs provide geological and geotechnical information (e.g. strength)	A
	Logs provide geological information (e.g. chalk)	B
	Logs do not provide useful information	C
Co-ordinates and Elevation	Co-ordinates and Elevations provided	A
	Co-ordinates provided no elevation	B
	No location information	C

ATKINS

KEY:

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- SITE BOUNDARY
- GRADE A EXPLORATORY HOLE
- GRADE B EXPLORATORY HOLE
- GRADE C EXPLORATORY HOLE

NOTE:

1. THIS DRAWING TO BE READ CONJUNCTION WITH ATKINS REPORT (REF.'5134008/PHASE1/FINAL 3.0/' DATED '19.12.2014')

2. LOCATION OF EXPLORATORY HOLES HAVE BEEN TAKEN FROM THE BGS GEOINDEX. NO INDEPENDENT VERIFICATION OF THE LOCATIONS HAVE BEEN UNDERTAKEN BY ATKINS

Drawing Number 5134008-PHASE1-FIGURE 005 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
–	FOR INFORMATION / COMMENT	–	00.00		–
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140
©

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

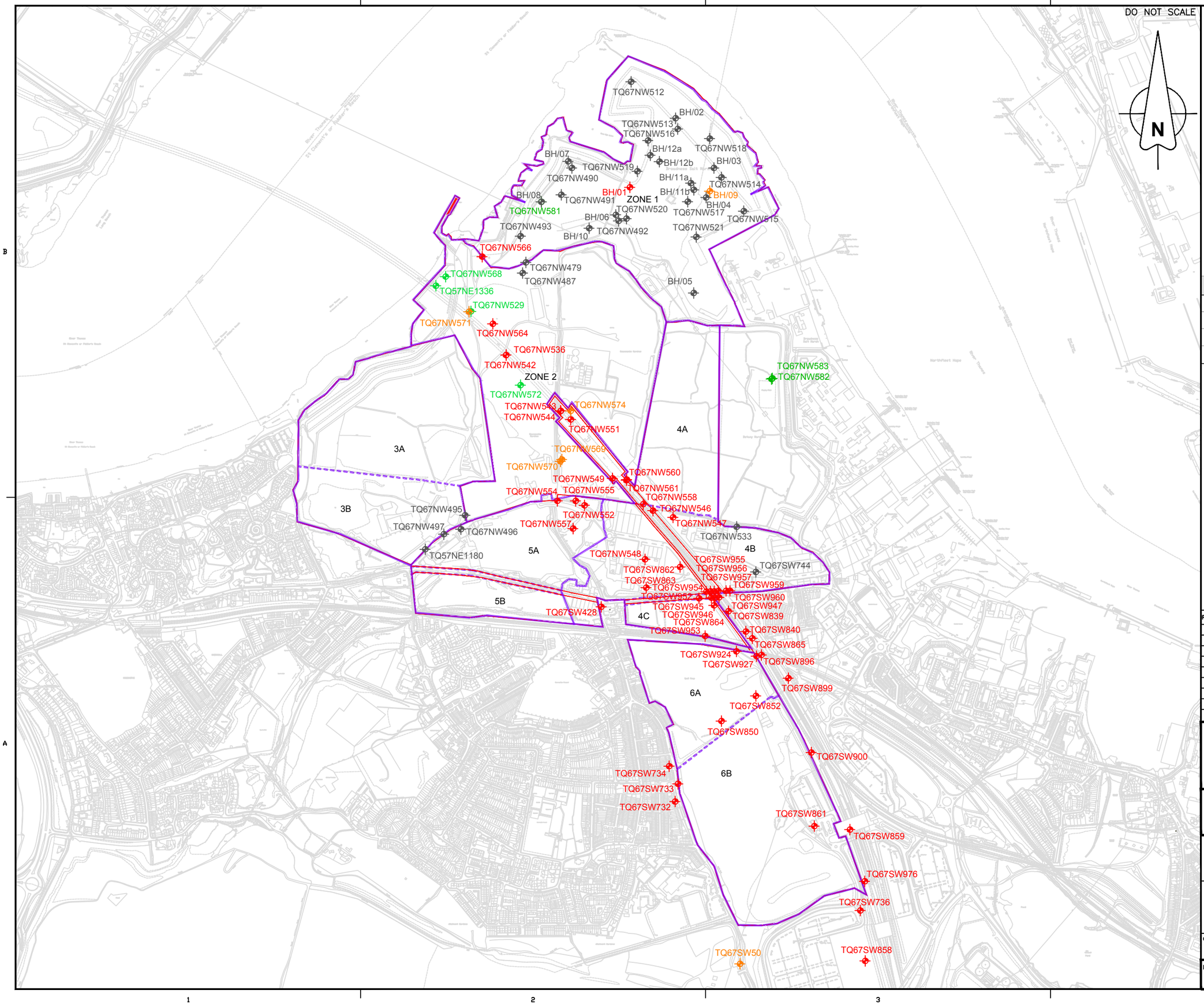
Title: BOREHOLE GRADE MAP

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 18.12.14	Date 18.12.14	Date 18.12.14	

Drawing Number: 5134008-PHASE1-FIGURE 005 Rev A

Job Dept. Sub Unique No.

DO NOT SCALE



KEY:

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- SITE BOUNDARY
- Depth A Exploratory Hole
- Depth B Exploratory Hole
- Depth C Exploratory Hole
- Depth D Exploratory Hole

Depth (m)	Depth Category
0-9.99	D
10-29.99	C
30-49.99	B
50+	A

NOTE:

1. THIS DRAWING TO BE READ IN CONJUNCTION WITH ATKINS REPORT (REF.'5134008/PHASE1/FINAL 030/' DATED '19.12.2014')

2. LOCATION OF EXPLORATORY HOLES HAVE BEEN TAKEN FROM THE BGS GEOINDEX. NO INDEPENDENT VERIFICATION OF THE LOCATIONS HAVE BEEN UNDERTAKEN BY ATKINS.

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00		–
	Purpose of issue	Rev	Date		Authorised

ATKINS ©
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: BOREHOLE DEPTH MAP

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 17812.14	Date 18.12.14	Date 18.12.14	

Drawing Number: 5134008-PHASE1-FIGURE 006 Rev: A

Job Dept. Sub Unique No.

Drawing Number 5134008-PHASE1-FIGURE 006 Rev. A

DO NOT SCALE

Millimetres 0 10 100

ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
3A
3B
4A
4B
4C
5A
5B
6A
6B

SR1232
PR1231
SA6409
SR2158
SR1261
SA2160
SA792
AC1916
AC1917
SA1926
SL757
SA7934
SA1857
SA1899
SR7848

A
A'

PLAN
SCALE 1:5000

OS map data reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown copyright. All rights reserved. Ordnance Survey licence number 0100040692.)

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

MAINTENANCE/CLEANING

DECOMMISSIONING/DEMOLITION

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

NOTES

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE REPORT PHASE 1 GEO-ENVIRONMENTAL AND GEOTECHNICAL RISK ASSESSMENT 5134008/PHASE 1/DRAFT
2. THE GEOLOGICAL INTERPRETATION IS BASED ON THE BGS1:50,000 MAPS SHEETS (270/271).
3. A SELECTION OF RECORDS FROM THE ONLINE BGS BOREHOLE DATABASE HAVE BEEN USED TO FURTHER DEFINE THE GEOLOGICAL BOUNDARIES.
4. THE SURFACE EXPRESSION AND DIP OF STRATA (WHERE AVAILABLE) HAVE BEEN USED TO DEVISE SCHEMATIC SECTIONS OF INDICATE STRATA SUCCESSION WITH DEPTH.
5. GIVEN THE ANTHROPOGENIC HISTORY OF THE SITE OTHER FEATURES MAY BE PRESENT.
6. THE GEOLOGICAL PROFILE IS INDICATIVE AND REPRESENTS ONLY ONE POSSIBLE INTERPRETATION OF THE GEOLOGICAL UNITS, OTHER INTERPRETATIONS MAY BE POSSIBLE.
7. THE EXTENT OF THE MADE GROUND HAS NOT BEEN VERIFIED AND IS EXPECTED TO BE PRESENT OVER MUCH OF THE SITE.
8. NO TOPOGRAPHIC PROFILE WAS AVAILABLE. THE PROFILE PRESENTED IS BASED ON LINEAR EXTRAPOLATION BETWEEN BOREHOLES AND OUR KNOWLEDGE OF LOCAL TOPOGRAPHIC FEATURES FROM SITE VISITS AND ORDNANCE SURVEY MAPS.
9. THE CHALK IS WELL DOCUMENTED TO EXTEND TO DEPTH GREATER THAN THOSE PROVEN BY THE BOREHOLES AND IS SHOWN AS SUCH.

KEY

AC1917 GI LOCATION

INFERRED GEOLOGICAL BOUNDARY

- MADE GROUND/FILL
- ALLUVIUM
- PEAT
- FLOOD PLAIN GRAVELS / RIVER TERRACE
- HEAD
- CHALK

ZONE 2 | ZONE 5 | ZONE 6

CTRL SR1232 (OFFSET 41m NE)
CTRL PR1231 (OFFSET 12m NE)
CTRL SA6409 (OFFSET 78m NE)
CTRL SR2158 (OFFSET 34m NE)
CTRL SR1261 (OFFSET 6m SW)
CTRL SA2160 (OFFSET 103m NE)
CTRL SA7921 (OFFSET 114m NE)
CTRL AC1916 (OFFSET 99m NE)
CTRL AC1917 (OFFSET 51m NE)
CTRL SA1926 (OFFSET 34m NE)
CTRL SA7978 (OFFSET 106m NE)
SPORTS GROUND
CTRL SA7934 (OFFSET 105m NE)
BAMBER PIT
CTRL SA1857 (OFFSET 73m SW)
CTRL SA1899 (OFFSET 24m SW)
CTRL SR7848 (OFFSET 7m NE)

ELEVATION 30 20 10 0 -10 -20 -30 -40 -50 -60 -70

GEOLOGICAL SECTION A-A'

SCALE 1:5000(H) 1:500(V)

100m 0m 100m 200m 300m
Scale 1:5000 HORIZONTAL

10m 0m 10m 20m 30m
Scale 1:500 VERTICAL

Rev.	Date	Description	By	Chk'd	App'd
A	09/12/14	FOR INFORMATION / COMMENT	DH	TR	

Drawing Status: FOR INFORMATION
Suitability: S0

ATKINS
Woodcote Grove
Ashley Road
Epsom
Surrey
KT18 5BW
Tel: +44 (0)1372 726140
Fax: +44 (0)1372 740055
www.atkinsglobal.com

Copyright © Atkins Limited (2014)

Client: LONDON RESORT COMPANY HOLDINGS

Project Title: PARAMOUNT PARK ENTERTAINMENT RESORT

Drawing Title: GEOLOGICAL SECTION A-A'

Scale	Designed	Drawn	Checked	Authorised
SHOWN	TR	DH	TR	--
Original Size	Date	Date	Date	Date
A1	09/12/14	09/12/14	09/12/14	--/--/--

Drawing Number: 5134008-Phase1-Figure007
Revision: A

Drawing file: Z:\GB\SALEGE\LEGEAF\0064_Leeds_Geotech\Projects\DH TEMP CAD FILES\39_Lauren Dombowsky\5134008-Phase1-Figure007_RevA.dwg

DO NOT SCALE

River Thames

Northfleet Hope

St Clement's or Fiddler's Reach

PORT OF LONDON AUTHORITY RADAR STATION

CKD WAS DEPOSITED ACROSS ALL OF ZONE 1

BOAT COMMUNITY

LEACHATE TREATMENT SYSTEM

ELECTRICITY PYLONS AND ABOVE GROUND CABLES TRAVERSE THIS SITE

GROUNDWATER ABSTRACTION FOR MINERAL WASHING AND SPRAY IRRIGATION

ZONE 1

Broadness Salt Marsh

Swanscombe Marshes

Broadness Salt Marsh

Depot

Playing Field

N

KEY:

ZONE BOUNDARY

Drawing Number 5134008-PHASE1-FIGURE 008 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00	–	
	Purpose of issue	Rev	Date	Authorised	

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

©

Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK ENTERTAINMENT RESORT

Title
ZONE 1: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
NTS	HS Date 17.12.14	ND Date 17.12.14	JS Date 17.12.14	A3

Drawing Number 5134008-PHASE1-FIGURE 008 Rev A

Job Dept. Sub Unique No.

Key

- MADE GROUND
- HEAD
- ALLUVIUM
- RIVER TERRACE DEPOSITS
- WHITE CHALK GROUP
- INFILLED LAND
- WATER TABLE

Sources

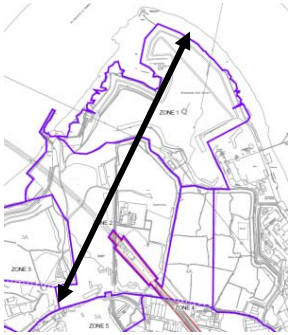
- S1 BROADNESS LANDFILL INFILLED WITH CKD AND OTHER DEPOSITS
- S2 NORTH PIT LANDFILL
- S3 SOUTH PIT & SURGE PILE PHASE 1, INFILLED WITH CKD
- S4 SOUTH PIT & SURGE PILE PHASE 3, INFILLED WITH CKD
- S5 BELL WHARF AND STORAGE TANKS
- S6 FORMER CEMENT WORKS AND ASSOCIATED INFRASTRUCTURE
- S7 FORMER GASWORKS
- S8 DERELICT SEWAGE WORKS AND OPERATIONAL PUMPING STATION

Pathways

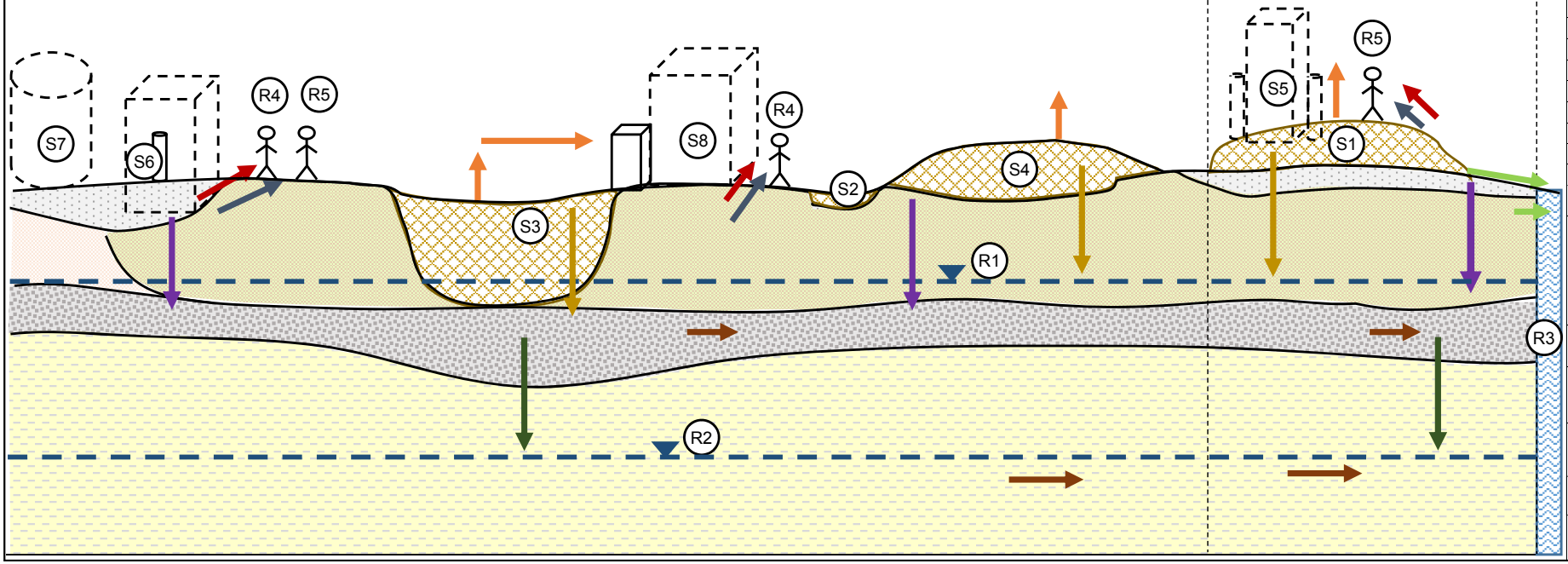
- INHALATION, INGESTION AND/OR DERMAL CONTACT WITH CONTAMINANTS IN SOIL AND SOIL-DERIVED DUST/FIBRES
- INHALATION OF SOIL- OR GROUNDWATER-DERIVED VAPOURS
- MIGRATION AND ACCUMULATION OF GROUND GASES
- LEACHING FROM CKD/WASTE MATERIALS
- LEACHING/MIGRATION OF CONTAMINANTS FROM SOILS
- DIRECT SURFACE WATER RUN-OFF AND SUB-SURFACE FLOW TO SURFACE WATERS
- LATERAL MIGRATION OF CONTAMINATED GROUNDWATER
- VERTICAL MIGRATION OF CONTAMINATED GROUNDWATER

Receptors

- R1 SECONDARY (UNDIFFERENTIATED) AQUIFER
- R2 PRINCIPAL AQUIFER
- R3 RIVER THAMES
- R4 ZONE VISITORS & WORKERS
- R5 TRESPASSERS



South-west — Zone 2 — Zone 1 — **North-east**



Drawing Number 5134008-PHASE1-FIGURE009 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	-			
	Purpose of Issue	Rev	Date	Authorised	

ATKINS
Consulting Engineers
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England,
KT18 5BW
Fax (01372) 740055
Tel. (01372) 726140

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: ZONES 1 & 2: SCHEMATIC CONCEPTUAL SITE MODEL

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A4
	Date 19.12.14	Date 19.12.14	Date 19.12.14	

Drawing Number: 5134008-PHASE1-FIGURE009 Rev A

DO NOT SCALE

NORTHPIT LANDFILL

SOUTHPIT PHASE 3 LANDFILL

ZONE 2

DISUSED SEWAGE WORKS

SOUTHPIT PHASE 1 LANDFILL

FORMER CEMENT WORKS AND
ASSOCIATED GAS WORKS

Broadness Salt Marsh

Swanscombe Marshes

Botany Marshes

Northfleet Industrial Estate

KEY:

ZONE BOUNDARY

N

Drawing Number 5134008-PHASE1-FIGURE 010 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00	–	
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

©

Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ZONE 2: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 17.12.14	Date 17.12.14	Date 17.12.14	

Drawing Number 5134008-PHASE1-FIGURE 010 Rev A

Job Dept. Sub Unique No.

DO NOT SCALE

N

3A

3B

SWANSCOMBE CEMENT WORKS LANDFILL

FORMER CEMENT WORKS AND ASSOCIATED GAS WORKS

FORMER WHITING WORK

River Thames
St Clement's or Fiddler's Reach

Swanscombe Marshes

SWANSCOMBE

KEY:

ZONE BOUNDARY

SUB-ZONE BOUNDARY

Drawing Number 5134008-PHASE1-FIGURE 011 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00	–	
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

©

Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ZONE 3: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
NTS	HS Date 17.12.14	ND Date 17.12.14	JS Date 17.12.14	A3

Drawing Number 5134008-PHASE1-FIGURE 011 Rev A

Job Dept. Sub Unique No.

Key

- MADE GROUND
- HEAD
- ALLUVIUM
- RIVER TERRACE DEPOSITS
- WHITE CHALK GROUP
- INFILLED LAND
- WATER TABLE

Sources

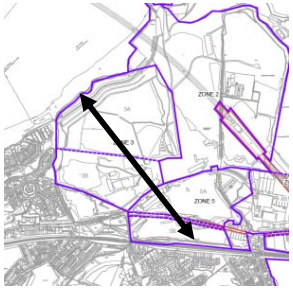
- S1 ALLUVIUM & MARSHLAND
- S2 FORMER CEMENT WORKS AND ASSOCIATED INFRASTRUCTURE
- S3 WELDING WORKS
- S4 SWANSCOMBE GLASS RECOVERY FACILITY
- S5 FORMER LANDFILLS AND PITS
- S6 HISTORICAL INDUSTRIAL LAND USES
- S7 MADE GROUND

Pathways

- INHALATION, INGESTION AND/OR DERMAL CONTACT WITH CONTAMINANTS IN SOIL AND SOIL-DERIVED DUST/FIBRES
- INHALATION OF SOIL- OR GROUNDWATER-DERIVED VAPOURS
- MIGRATION AND ACCUMULATION OF GROUND GASES
- LEACHING FROM CKD/WASTE MATERIALS
- LEACHING/MIGRATION OF CONTAMINANTS FROM SOILS
- DIRECT SURFACE WATER RUN-OFF AND SUB-SURFACE FLOW TO SURFACE WATERS
- LATERAL MIGRATION OF CONTAMINATED GROUNDWATER
- VERTICAL MIGRATION OF CONTAMINATED GROUNDWATER
- CONTAMINANT MIGRATION INTO DRINKING WATER PIPES/SUPPLY TO BUILDINGS
- CHEMICAL ATTACK ON BUILDINGS AND STRUCTURES

Receptors

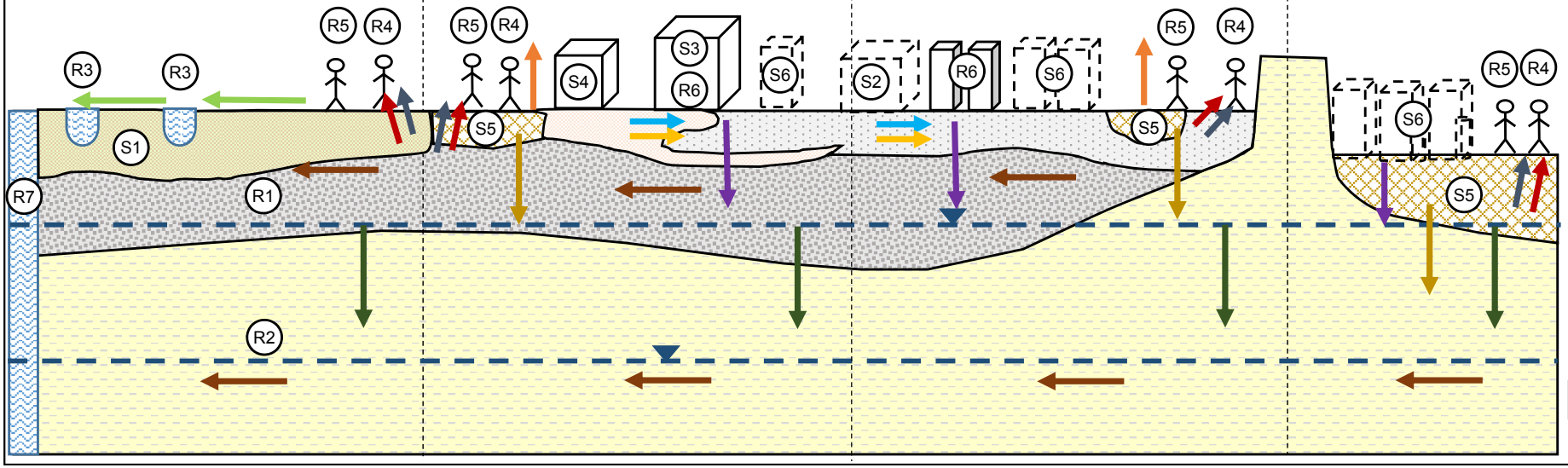
- R1 SECONDARY (UNDIFFERENTIATED) AQUIFER
- R2 PRINCIPAL AQUIFER
- R3 SURFACE WATER CHANNELS
- R4 ZONE VISITORS & WORKERS
- R5 TRESPASSERS
- R6 PROPERTY
- R7 RIVER THAMES



North-west — **South-east**

Zone 3 | Zone 5

Zone 3A | Zone 3B | Zone 5A | Zone 5B



ATKINS

Drawing Number 5134008-PHASE1-FIGURE012 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	-			

Purpose of Issue	Rev	Date	Authorised

ATKINS
Consulting Engineers
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England,
KT18 5BW
Fax (01372) 740055
Tel. (01372) 726140

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: ZONES 3 & 5: SCHEMATIC CONCEPTUAL SITE MODEL

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A4
	Date 19.12.14	Date 19.12.14	Date 19.12.14	

Drawing Number: 5134008-PHASE1-FIGURE012 Rev A

DO NOT SCALE

N

4A

4B

4C

PILGRIMS PIT LANDFILL

FORMER TAR DISTILLERY,
PAPER MILLS AND CHEMICAL WORKS

INFILLED LAGOON

FORMER RIFLE RANGE

FORMER RIFLE RANGE

Swanscombe Marshes

Swanscombe Marshes

Botany Marshes

Broadness Salt Marsh

Depot

Playing Field

Northfleet Industrial Estate

Spoil Heap

Recreation Ground

Tower Wharf

KEY:

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- SITE BOUNDARY

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00	–	
	Purpose of issue	Rev	Date		Authorised

ATKINS ©
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ZONE 4: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 17.12.14	Date 17.12.14	Date 17.12.14	

Drawing Number
5134008-PHASE1-FIGURE 013

Rev
A

Job Dept. Sub Unique No.

Drawing Number 5134008-PHASE1-FIGURE 013 Rev. A

Key

- MADE GROUND
- ALLUVIUM
- RIVER TERRACE DEPOSITS
- WHITE CHALK GROUP
- INFILLED LAND
- WATER TABLE

Sources

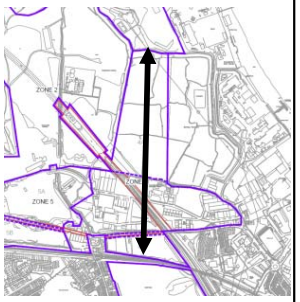
- S1 ALLUVIUM & MARSHLAND
- S2 FORMER THAMES TAR DISTILLERY
- S3 FORMER PAPER MILLS AND CHEMICAL WORKS
- S4 FORMER TRAMWAYS, ELECTRICITY SUBSTATIONS AND A PIPELINE
- S5 MISCELLANEOUS HISTORICAL LAND USES
- S6 NORTHFLEET INDUSTRIAL ESTATE
- S7 PARTIAL INFILLING OF THE LAGOON
- S8 PARTIALLY INFILLED SPORTSFIELD

Pathways

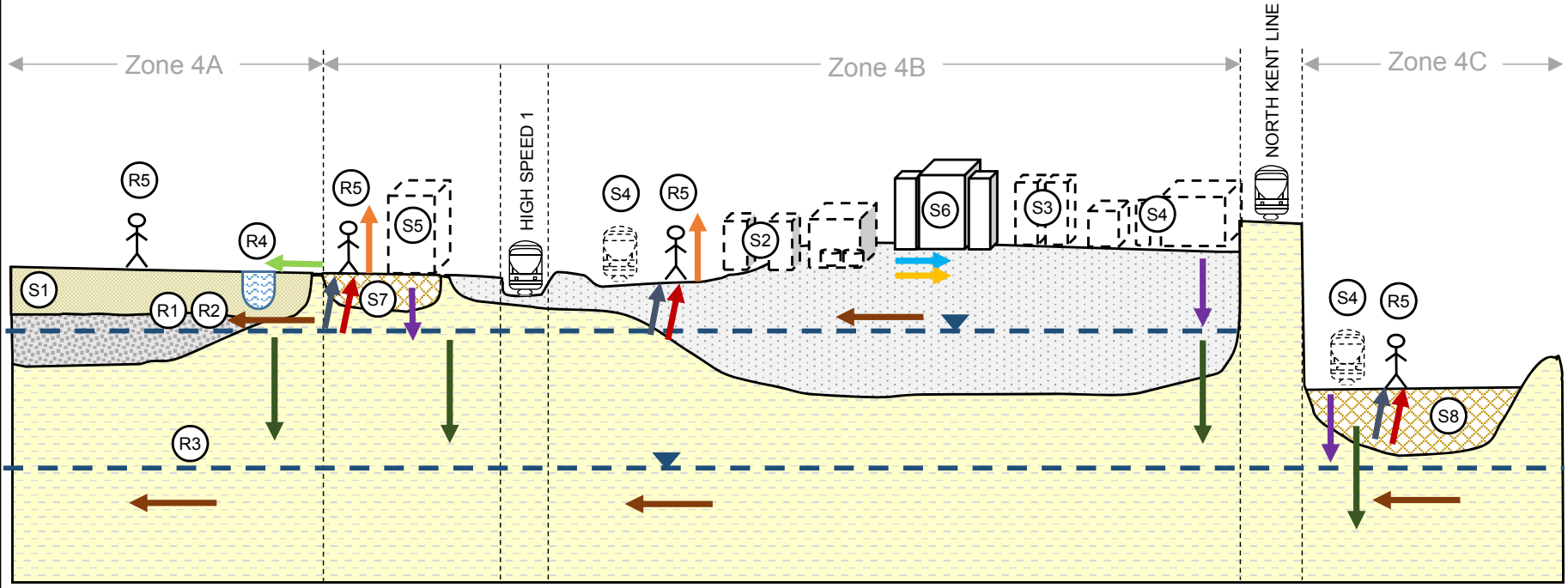
- INHALATION, INGESTION AND/OR DERMAL CONTACT WITH CONTAMINANTS IN SOIL AND SOIL-DERIVED DUST/FIBRES
- INHALATION OF SOIL- OR GROUNDWATER-DERIVED VAPOURS
- MIGRATION AND ACCUMULATION OF GROUND GASES
- LEACHING/MIGRATION OF CONTAMINANTS FROM SOILS
- DIRECT SURFACE WATER RUN-OFF AND SUB-SURFACE FLOW TO SURFACE WATERS
- LATERAL MIGRATION OF CONTAMINATED GROUNDWATER
- VERTICAL MIGRATION OF CONTAMINATED GROUNDWATER
- CONTAMINANT MIGRATION INTO DRINKING WATER PIPES/SUPPLY TO BUILDINGS
- CHEMICAL ATTACK ON BUILDINGS AND STRUCTURES

Receptors

- R1 SECONDARY (UNDIFFERENTIATED) AQUIFER
- R2 SECONDARY 'A' AQUIFER
- R3 PRINCIPAL AQUIFER
- R4 SURFACE WATER CHANNELS
- R5 ZONE WORKERS AND TRESPASSERS



North — Zone 4 — **South**



Rev.	Description	By	Date	Chk'd	Auth

Purpose of Issue	Rev	Date	Authorised
FOR INFORMATION / COMMENT	-		

ATKINS
Consulting Engineers
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England,
KT18 5BW
Fax (01372) 740055
Tel. (01372) 726140

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: ZONE 4: SCHEMATIC CONCEPTUAL SITE MODEL

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A4
	Date 19.12.14	Date 19.12.14	Date 19.12.14	

Drawing Number: 5134008-PHASE1-FIGURE014 — Rev A

Drawing Number 5134008-PHASE1-FIGURE014 — Rev. A

DO NOT SCALE

N

FORMER CEMENT WORK
AND ASSOCIATED GAS WORKS

PILGRIMS PIT LANDFILL

5A

5B

POSSIBLE HSI INFILLING

SWANSCOMBE

Swanscombe Marshes

Northfleet Industrial Estate

Spoil Heap

Recreation Ground

KEY:

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- SITE BOUNDARY

Drawing Number 5134008-PHASE1-FIGURE 015 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00		–
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England,
KT18 5BW
Fax (01372) 740055
Tel. (01372) 726140

©

Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ZONE 5: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A3
	Date 17.12.14	Date 17.12.14	Date 17.12.14	

Drawing Number 5134008-PHASE1-FIGURE 015 Rev A

Job Dept. Sub Unique No.

Key

- WHITE CHALK GROUP
- INFILLED LAND
- WATER TABLE

Sources

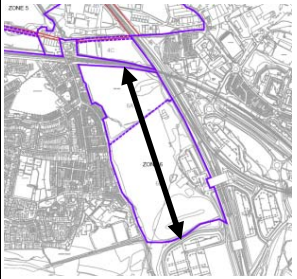
- S1 BAMBER PIT LANDFILL
- S2 NORTHFLEET LANDFILL
- S3 HISTORICAL RAILWAY/CONVEYOR USAGE
- S4 FORMER PUMP HOUSES, ENGINE HOUSE AND PIPELINE
- S5 FORMER PUMPING STATION
- S6 CAR PARKING
- S7 FORMER ARMY BARRACKS

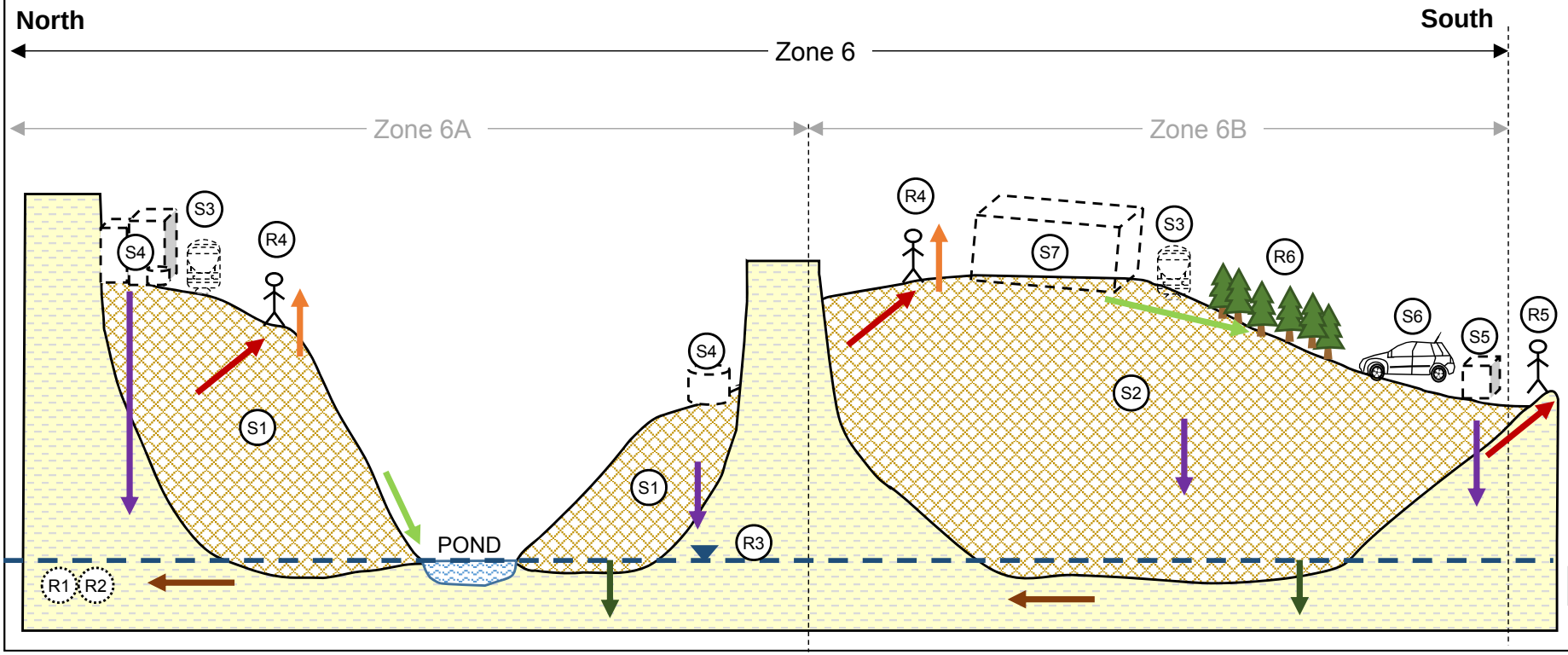
Pathways

- INHALATION, INGESTION AND/OR DERMAL CONTACT WITH CONTAMINANTS IN SOIL AND SOIL-DERIVED DUST/FIBRES
- MIGRATION AND ACCUMULATION OF GROUND GASES
- LEACHING/MIGRATION OF CONTAMINANTS FROM SOILS
- DIRECT SURFACE WATER RUN-OFF
- LATERAL MIGRATION OF CONTAMINATED GROUNDWATER
- VERTICAL MIGRATION OF CONTAMINATED GROUNDWATER

Receptors

- R1 SECONDARY (UNDIFFERENTIATED) AQUIFER (may not be present throughout the zone)
- R2 SECONDARY 'A' AQUIFER (may not be present throughout the zone)
- R3 PRINCIPAL AQUIFER
- R4 ZONE WORKERS AND TRESPASSERS
- R5 ADJACENT RESIDENTIAL RECEPTORS IN SWANSCOMBE
- R6 BAKER'S HOLE SSSI





Rev.	Description	By	Date	Chk'd	Auth

Purpose of Issue	Rev	Date	Authorised
FOR INFORMATION / COMMENT	-		

ATKINS
Consulting Engineers
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England,
KT18 5BW
Fax (01372) 740055
Tel. (01372) 726140

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: ZONE 6: SCHEMATIC CONCEPTUAL SITE MODEL

Original Scale	Drawn	Checked	Authorised	
NTS	HS	ND	JS	A4
	Date 19.12.14	Date 19.12.14	Date 19.12.14	

Drawing Number: 5134008-PHASE1-FIGURE016

Rev: A

Drawing Number 5134008-PHASE1-FIGURE016 Rev. A

DO NOT SCALE

N

BAMBER PIT LANDFILL

6A

6B

BAKER'S HOLE SSSI

NORTH FLEET LANDFILL

LANDFILL GAS FLARE/PLANT

KEY:

ZONE BOUNDARY

SUB-ZONE BOUNDARY

Drawing Number 5134008-PHASE1-FIGURE 018

Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	–	00.00	–	
	Purpose of issue	Rev	Date		Authorised

ATKINS
Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

©

Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ZONE 6: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
NTS	HS Date 18.12.14	ND Date 18.12.14	JS Date 18.12.14	A3

Drawing Number 5134008-PHASE1-FIGURE 017 Rev A

Job Dept. Sub Unique No.

Appendices

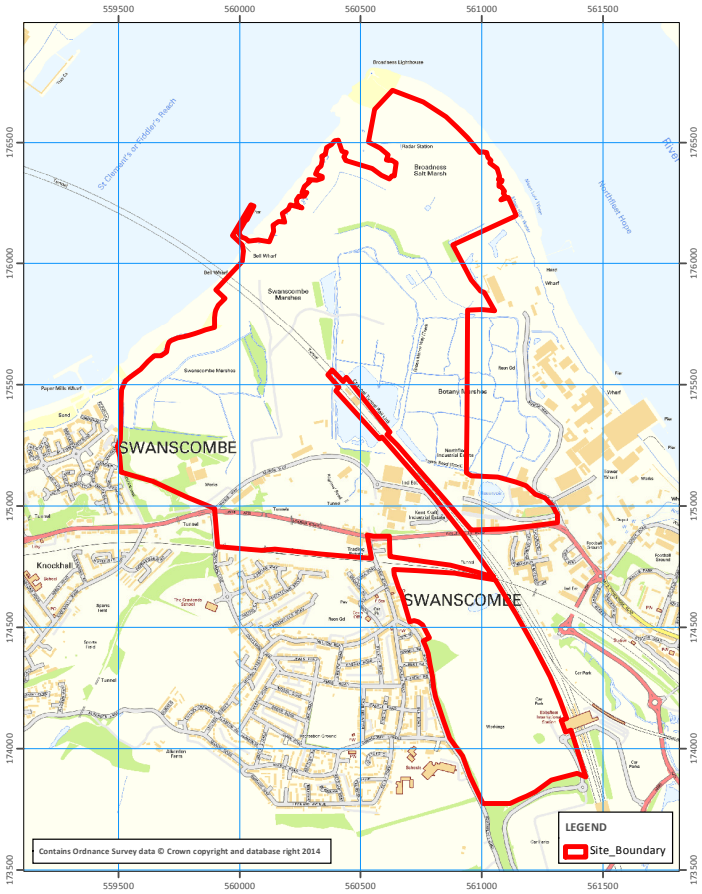
Appendix A. Unexploded Ordnance Report

6 Alpha Associates Limited
Quatro House, Frimley Road
Camberley, Surrey
GU16 7ER

T: +44(0) 203 371 3900
W: www.6alpha.com

Detailed Unexploded Ordnance (UXO) Risk Assessment

Meeting the requirements of CIRIA C681 "Unexploded Ordnance (UXO) – A guide for the Construction Industry" Risk Management Framework



6 Alpha Project Number: P4181

Client: Atkins

Site: Paramount Resort, Kent

Originator: Jennifer Russell (19th November 2014)

Technical Review: Robin Rickard (27th November 2014)

Released By: Lisa Askham (3rd December 2014)

Delivered by

alpha ASSOCIATES
special risks consultancy

Contents

Contents 1

Executive Summary 2

Assessment Methodology 4

Stage One – Site Location & Description 5

Stage Two – Review of Historical Datasets 6

Stage Three – Data Analysis 9

Stage Four – Risk Assessment 11

Stage Five – Risk Mitigation Measures 13

Figures

Figure One – Site Location

Figure Two – Site Boundary

Figure Three – Aerial Photography (Current)

Figure Four – WWII Luftwaffe Bombing Targets

Figure Five – WWII Bombing Activity

Figure Six – Former Rifle Ranges

Figure Seven – WWII High Explosive Bomb Density

EXECUTIVE SUMMARY	
Study Site	The Client has described the Study Site as "Paramount Resort, Kent". The Site is located at National Grid Reference (NGR) 560415, 175584.
Key Findings	During WWII, the Study Site was situated within both the *Swanscombe Urban District* and *Northfleet Urban District,* which recorded 81 and 86 High Explosive (HE) bomb strikes per 1000 acres, a moderate level of bombing. *Luftwaffe* aerial reconnaissance photography associated with the Site could not be found. Nonetheless, *Portland Cement Works, New Northfleet Paper Mills,* and other smaller works (all located on-Site), and mills and stores (located within the immediate vicinity), may have been considered secondary bombing targets. *Air Raid Precaution* (ARP) HE bomb strike mapping and bomb damage mapping associated with the Site could not be found. Nonetheless, using a combination of historical records, and *County Series* (CS) and *Ordnance Survey* (OS) mapping, a number of bomb strikes were identified on and within the vicinity of the Site, such as missing buildings and 'ruins'. The Site was predominantly undeveloped during WWII, although there were industrial facilities. Given the lack of development within large areas of the Site, it is considered likely that Unexploded Bomb (UXB) entry holes would have gone unnoticed. Similarly, whilst it is more likely that UXB entry holes would have been noticed in developed areas, some may well have been missed. An analysis of the post-WWII mapping associated with the Site shows that various areas of the Site have been subjected to post-WWII development. It is possible that the development of the Site's post-WWII features and structures may have removed items of UXO within the scale and depth of their foundations, although evidence to support this supposition could not be found. Nevertheless, despite the post-WWII development, many parts of the Site have remained undeveloped since WWII therefore; the probability of UXO encounter is increased within those extents.
Potential Threat Items	The most probable UXO threat items at this Site are *German* HE bombs, Incendiary Bombs (IBs) and *British* Anti-Aircraft Artillery (AAA) projectiles, with a minor threat from Small Arms Ammunition (SAA) in former rifle ranges. The consequences of initiating *German* HE bombs are more severe than initiating IBs or AAA projectiles, and thus they pose the greatest prospective risk to intrusive works.

EXECUTIVE SUMMARY (…continued)	
Risk Pathway	Given the types of UXO that might be present on Site, all types of aggressive intrusive engineering activities may generate a significant risk pathway.
Risk Level	**HIGH**
Recommended Risk Mitigation	**All Ground Works in all Areas:** **1. Operational UXO Risk Management Plan;** appropriate Site management documentation should be held on Site to plan for and guide upon the actions to be undertaken in the event of a suspected or real UXO discovery, (6 Alpha can supply this plan); **2. UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a general briefing concerning the identification of a UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Posters and information concerning the general nature of the UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The safety and awareness briefing is an essential part of the Health and Safety Plan for the Site and helps to evidence conformity with the principles laid down in the CDM regulations 2007, (6 Alpha can supply this brief).
	All Shallow Excavations and Trial Pits, and within former Rifle Ranges **3. On Call EOD Engineer;** all shallow excavations in undeveloped areas should be supported by an 'On Call' EOD Engineer, who will be able to identify and/or advise on the appropriate course of action in the event of any suspicious and/or real UXO finds, (6 Alpha can provide this service).
	All Bulk Excavations, Window Sampling and Deep Foundations **4. EOD Banksman Support;** EOD Engineer(s) to survey and/or supervise the excavations and/or geotechnical investigations ≥1m bgl in all areas for UXO and to identify any suspicious items as the work proceeds in the EOD Banksman role, (6 Alpha can provide this service).
	All Boreholes and Piling **5. Intrusive Magnetometer Survey;** an intrusive survey (employing down-hole magnetometer or MagCone techniques) ahead of piling and boreholing is strongly recommended. Such a survey should extend to the maximum bomb penetration depth or to the maximum depth of the works, whichever is encountered first, (6 Alpha can provide this service).

ASSESSMENT METHODOLOGY	
Approach	6 Alpha Associates is an independent, specialist risk management consultancy practice, which has assessed the risk of encountering UXO (as well as buried bulk high explosives) at this site, by employing a process advocated for this purpose by the Construction Industry Research & Information Association (CIRIA). The CIRIA guide for managing UXO risks (C681) not only represents best practice but has also been endorsed by the Health and Safety Executive (HSE). Therefore, any risk levels identified in this assessment are considered objective and quantifiable. Any risk mitigation solution is recommended *only* because it delivers the Client a risk reduced to As Low As Reasonably Practicable (ALARP). Potential UXO hazards have been identified through investigation of Local and National archives associated with the Site, Ministry of Defence (MoD) archives, local historical sources, historical mapping as well as contemporaneous aerial photography (where available). Potential hazards have only been recorded if there is specific information that could reasonably place them within the boundaries of the Site. Key source material is referenced within this document, whilst data of lesser relevance (which may have been properly considered and discounted by 6 Alpha), may be made available upon request. The assessment of UXO risk is a measure of ***probability*** *of encounter* and ***consequence*** *of encounter*; the former being a function of the identified hazard and proposed development methodology; the latter being a function of the type of hazard and the proximity of personnel (and/or other sensitive receptors), to the hazard at the moment of encounter. If UXO risks are identified, the methods of mitigation we have recommended are considered reasonably and sufficiently robust to reduce them to ALARP. We advocate the adoption of the legal ALARP principal because it is a key factor in efficiently and effectively ameliorating UXO risks. It also provides a ready means for assessing the Client's tolerability of UXO risk. In essence the principle states that if the cost of reducing a risk significantly outweighs the benefit, then the risk may be considered tolerable. Clearly this does not mean that there is never a requirement for UXO risk mitigation, but that any mitigation must demonstrate that it is beneficial. Any additional mitigation that delivers diminishing benefits and that consumes disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle, UXB and UXO risks will rarely be reduced to zero (nor need they be).
Important Notes	Although this report is up to date and accurate, our databases are continually being populated, as and when additional information becomes available. Nonetheless, 6 Alpha have exercised all reasonable care, skill and diligence in providing this service and producing this report. The assessment levels are based upon our professional opinion and have been supported by our interpretation of historical records and by third party data sources. Wherever possible, 6 Alpha has sought to corroborate and to verify the accuracy of all of the data we have employed, but we are not accountable for any inherent errors that may be contained in third party data sets (e.g. National Archive or other library sources), and over which 6 Alpha cannot reasonably exercise control.

STAGE ONE – SITE LOCATION AND DESCRIPTION	
Study Site	The Client has described the Study Site as "Paramount Resort, Kent". The Site is located at NGR 560415, 175584. The Site location and Site boundary (including the section designation) are presented at *Figures 1* and *2* respectively.
Location Description	The Study Site is located within the county of *Kent,* immediately south of the *River Thames,* and within the town of *Swanscombe.* The Study Site covers an area of approximately 237 hectares (ha), and is irregular in shape. The Site currently comprises undeveloped land (consisting of brownfields) and areas of industrial buildings and associated access roads, along with a portion of the A226 and a railway line. An aerial view of the Study Site is presented at *Figure 3*.
Proposed Works	The Client has not provided any proposed works. 6 Alpha have assumed a number of ground investigation and construction methods; including, trial pits, window sampling, boreholes, piling, bulk excavations and deep foundations.
Ground Conditions	6 Alpha has referred to *British Geological Survey* (BGS) borehole logs (provided by the Client) from across the Site and have summarised the findings below (depths beds will vary): North: • 0m to 6-12m - Made ground – Cement fragments, ash progressing into silty sandy flint and chalk gravel; • 6-12m to 20m - Alluvium – Varies: Clay, underlain by areas of sand and gravel (Terrace Gravel); • 20m to 50m – Chalk Central: • 0m to 1-10m – Made ground / Alluvium (thickness of varies across central area becoming shallower towards the south); • 4-8m to 50m – Chalk South: • 0m to 4m – Made ground • 4m to 7-10m – Alluvium – Terrace Gravel • 7-10m to 50m - Chalk

STAGE TWO – REVIEW OF HISTORICAL DATASETS	
Sources of Information Consulted	The following primary information sources have been used in order to establish the background UXO threat: 1. Home Office WWII Bomb Census Maps; 2. WWII and post-WWII Aerial Photography; 3. Official Abandoned Bomb Register; 4. 6 Alpha Database; 5. Information gathered from the National Archives at Kew; 6. Historic UXO information provided by 33 Engineer Regiment (Explosive Ordnance Disposal) at Carver Barracks, Wimbish.
Site History	For ease of analysis, the Site's history has been described across three separate time frames, namely, pre-WWII, WWII and post-WWII. From an analysis of the published *County Series* (CS) and *Ordnance Survey* (OS) historical mapping associated with the Site, the following generalised overview can be deduced: Pre-WWII – The Site was comprised undeveloped marshes, identified as *Swanscombe Marshes* and *Broadness Salt Marshes.* Some areas of the Site included industrial facilities such as cement works, gas works, paper works and chalk pits/quarries, as well as small piers into the *Thames River,* a few farm buildings, a school, *All Saints Church* and a few residential properties. During WWII – The area saw minor expansion of some of the works, and the disuse of some of the quarries. Tramways were implemented in the vicinity of works for transport, and small areas of marshland were dedicated to recreation or allotments. Post-WWII – There were some areas of the residential housing in the south of the Site that show missing buildings and there are areas within the industrial facilities identified as 'ruins', presumably related to bomb damage. The industrial facilities underwent expansion and some were redeveloped, with additional railways passing through the industrial facilities to a wharf. Several areas have been dedicated to recreation, including two small rifle ranges (Figure 6).
WWII Site Use	CS mapping prior to WWII shows that the Site was largely undeveloped, with areas of industry, namely, cement works, quarries/chalk pits and paper works, along with small areas of residential use.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)

WWII Bombing of Swanscombe	*Swanscombe* was subjected to numerous air raids given it was situated under the flight path to *London.* It is estimated that as a result of air raids and '*V*'1 and '*V*'2 rockets attacks, 62 people died, 250 people were injured and almost 500 buildings were damaged. In addition, there were 211 HE bombs recorded to have landed within the *Swanscombe* area, as well as 5000 incendiary bombs (IBs) and 10 flying bombs ('*V*'1 and '*V*'2 rockets).
WWII Luftwaffe Bombing Targets (*Figure 4*)	Prior to WWII, the *Luftwaffe* conducted numerous aerial photographic reconnaissance missions over *Britain*, recording key military, industrial and commercial targets for attack, in the event of war. Although, *Luftwaffe* aerial reconnaissance photography associated with the Site could not be found, photography adjacent (to the east) identified a port installation (located 680m to the northeast) as a primary bombing target. In addition, *Portland Cement Works, New Northfleet Paper Mills,* and other smaller works (all located on-site), and mills and store (located within the immediate vicinity), may have been considered secondary bombing targets.
WWII Bombing Activity (*Figure 5*)	*Air Raid Precaution* (ARP) HE bomb strike records associated with the Site could not be found. Nonetheless, anecdotal historical evidence indicates the area was heavily bombed during WWII, with up to 211 HE bombs landing within the *Swanscombe* area. The following bombing activity was recorded within *Swanscombe,* which can be seen in figure 5: • One HE bomb fell within the Site boundary on housing *London Road/Galley Hall Road* in October 1940; • One HE bomb feel near to *All Saints Close* (located 40m to the south); • One HE bomb struck the *Morning Star Pub* on the corner of *Vernon Road* and *Church Road* (located 150m to the southwest); • One HE bomb fell on the junction of *Trebble Road* and *Ames Road* on November 1944 (located 490m to the south); • One HE bomb fell on *Broad Road* (located 670m to the south) in August 1944; • One HE bomb impacted on housing on *Knockhall Chase* (located 810m to the southwest). Furthermore, whilst IBs were likely to have fallen within the Site's boundary (and/or within it's immediate vicinity), they fell in such high numbers they were considered ubiquitous and accurate record keeping was not often maintained. Nonetheless, it was estimated that up to 5,000 IBs were dropped across the area of *Swanscombe.* In addition to IBs and HE bomb strikes, during the latter part of the war when aerial bombing had significantly declined, *'V'* type weapons posed a residual threat. Records indicate that a '*V*'1 rocket landed on *Taunton Road* (located 10m to the south) on 30th July 1944, in which 13 people were killed. In addition, '*V*'2 rockets impacted *Eagles Road* (located 900m to the west) on 12th November 1944, a small river (located 340m to the south) on 30th December 1944, and *Milton Street* (650m to the south) on 27th February 1945. *(Please note, the points marked on figure 5 are not precise locations of HE bomb strikes, but the vicinity of where a HE bomb strike is suspected to have impacted).*

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)	
WWII Bomb Damage	Bomb damage mapping associated with the Site could not be obtained. Nonetheless, an analysis of the pre and post-WWII mapping and anecdotal historical evidence determined the following: • Housing (located on-Site) on *London Road/Galley Hall Road* were destroyed in October 1940; • *All Saints Church* on *All Saints Close* (located 40m to the south) was suffered blast damage; • The *Morning Star Pub* on the corner of *Vernon Road* and *Church Road* was demolished and several houses surrounding the pub sustained blast damage (located 150m to the southwest) on 10th November 1940. Several people were killed and many more injured; • Housing was damage around the junction of *Trebble Road* and *Ames Road* on November 1944 (located 490m to the south) along with several of the surrounding roads sustaining blown out windows; • Housing sustained damage on *Broad Road* (located 670m to the south) in August 1944; • Housing on *Knockhall Chase* was destroyed (located 810m to the southwest) in October 1940; • Housing was destroyed on *Taunton Road* by a '*V*'1 rocket (located 10m to the south) on 30th July 1944. Several people were killed and several more injured; • Housing was destroyed on *Milton Road* by a '*V*'2 rocket (located 650m to the southwest). • A number of ruins have been identified to buildings within the various works located on-Site. It is possible that these ruins are the result of bomb damage
WWII HE Bomb Density (*Figure 7*)	During WWII, the Study Site was situated within both *Swanscombe Urban District* and *Northfleet Urban District,* which recorded 81 and 86 HE bomb strikes per 1000 acres, a moderate level of bombing.
Abandoned Bombs	An examination of the official abandoned bomb records has not identified any abandoned bombs within 4,000m of the Site's boundary.
Post-WWII Bomb Disposal Officer (BDO) Tasks	Records of post-WWII BDO tasks conducted within the area during WWII could not be located.

STAGE THREE – DATA ANALYSIS	
Was the ground undeveloped during WWII?	Yes; Pre-WWII CS mapping shows that the Site was largely undeveloped although there were areas of industry, namely, a cement works and paper works.
Is there a reason to suspect that the immediate area was a bombing target during WWII?	No; *Luftwaffe* aerial reconnaissance photography associated with the Site could not be found. While the industry on-Site was not vital in the war effort, they may have been considered secondary bombing targets. The Site was situated within the *Kentish Industrial Belt* along the *River Thames.* In addition, as WWII progressed, major towns and cities were targeted. The *Luftwaffe* switched from specifically targeting individual military and industrial facilities to a more general method of bombing *('carpet-bombing'*), and as a result, suburban and residential areas were bombed (as witnessed in *London).*
Is there firm evidence that ordnance landed on Site?	Yes; Although official ARP HE bomb strike mapping could not be found, an analysis of the pre and post WWII mapping has identified a number of buildings that were missing or marked as 'ruins' post-WWII, which could be attributed to bomb damage. These correspond with historical records, which noted bomb strikes within the vicinity of the missing buildings. Furthermore, whilst IBs may have fallen within the Site's boundary, they were deployed in such large numbers they were considered ubiquitous and their numbers and locations were rarely accurately recorded.
Is there evidence of bomb damage on Site?	Yes; Although bomb damage mapping associated with the Site could not be obtained, an analysis of the pre and post-WWII mapping associated with the Site identified several 'ruins' within the Site. It is likely that the 'ruins' could be attributed to bombing, however, the scale and severity of the identified damage could not be ascertained.
Would Post Air Raid Inspections have been conducted on Site?	Unlikely; Given that the majority of the Site was undeveloped (marshland) during WWII, it is considered improbable that post-air raid inspections would have been undertaken across large areas of the Site. However, where the Site comprised industrial development, it is likely that inspections would have been carried out although it is not known how comprehensive such inspections would have been.
Would a UXB entry hole have been observed and reported during WWII?	Unlikely; Since large areas of the Site were undeveloped (marshland) during WWII, it is likely that UXB entry holes would have gone unnoticed. Conversely, whilst it is more likely that UXB entry holes would have been noticed in developed areas, it is possible that rubble from damaged buildings could have obscured UXB entry holes.
Is there any reason to suspect that Live Firing or military training may have occurred at this location?	Yes; There are two small rifle ranges identified from pre and post WWII mapping (*figure 6*).

STAGE THREE – DATA ANALYSIS (…continued)	
What is the expected UXO contamination?	The most probable UXO threat items at this Site are *German* HE bombs, IBs and *British* AAA projectiles, with a minor threat from Small Arms Ammunition (SAA) within the former rifle ranges (figure 6).
Would previous earthwork have removed the potential for UXO to be present?	Possibly; It is evident from the post-WWII mapping that various areas of the Site have been subjected to post-WWII development. It is possible that the development of the Site's post-WWII features and structures may have removed items of UXO within the scale and depth of their foundations, although evidence to support this supposition could not be found. Nevertheless, the potential for UXO to be present within unworked pre-WWII ground remains extant.
Does the probability of a UXO discovery vary across the Site?	No; The probability of a UXO discovery is considered to be slightly elevated within undeveloped areas and decreased within the scale and depth of the post-WWII features and structures foundations across the Site. However, given that many of the structures were present during WWII, it cannot be ruled out that a UXO could be found beneath the buildings foundations, thus the Site as a whole is considered high risk.

STAGE FOUR – RISK ASSESSMENT	
Threat Items	The threat is posed predominately by WWII *German* HE bombs, IBs and *British* AAA projectiles (the latter were used to defend against *German* bombing raids), with a minor threat from SAA within the former rifle ranges.
Maximum Penetration	Considering the ground conditions (assumed in Stage 1), the average Bomb Penetration Depth (BPD) may vary across the Site. North: For a 250kg bomb, the average BPD is assessed to be approximately 5m below ground level (bgl) and the maximum BPD is assessed to be approximately 14m bgl in extreme cases. Central: For a 250kg bomb, the average BPD is assessed to be approximately 5.5m below ground level (bgl) and the maximum BPD is assessed to be approximately 13m bgl in extreme cases. South: For a 250kg bomb, the average BPD is assessed to be approximately 5m below ground level (bgl) and the maximum BPD is assessed to be approximately 14m bgl in extreme cases. However, this figures assumes that ground conditions were homogenous throughout the Site and does not take into account the presence of made ground and/or hard standing on-Site during WWII, which could retard a UXBs penetration capability. Whilst the *Luftwaffe* did employ larger bombs during WWII, their deployment was both target-specific and infrequent, and to use such larger (or the largest) bombs for BPD calculations are not justifiable on either technical or risk management grounds.
Risk Pathway	Given the types of UXO that might be present on Site, all types of aggressive intrusive engineering activities (i.e. ground works) may generate a significant risk pathway. Whilst not all munitions encountered aggressively will initiate upon contact, such a discovery could lead to serious impact on the project especially in terms of critical injuries and project delay.
Consequence	Consequences of UXO initiation include: 1. Kill and/or critically injure personnel; 2. Severe damage to plant and equipment; 3. Deliver blast and fragmentation damage to nearby buildings; 4. Rupture and damage underground utilities/services. Consequences of UXO initiation include: 1. Delay to the project and blight; 2. Disruption to local community/infrastructure; 3. The expenditure of additional risk mitigation resources and Explosive Ordnance Disposal (EOD) clearance; 4. Incurring additional time and cost.

UXO RISK CALCULATION	
Site Activities	Although there is some variation in the probability of encountering and initiating items of UXO when conducting different types of intrusive activities, several intrusive methodologies have been described for analysis at this Site. The consequences of initiating UXO vary greatly, depending upon, *inter alia* the mass of HE in the UXO and how aggressively it might be encountered. For this reason, 6 Alpha has conducted separate risk rating calculations for each construction methodology that might be employed.
Threat Items	The most probable UXO threat items for this Site are *German* HE bombs, IBs and *British* AAA projectiles, with a minor threat from SAA within the former rifle ranges. The consequences of initiating *German* HE bombs are more severe than initiating IBs or AAA projectiles, and thus they pose the greatest prospective risk to intrusive works.
Risk Rating Calculation	6 Alpha's Semi-Quantitative Risk Assessment assesses and rates the risks posed by the most probable threat items when conducting a number of different activities on the Site. Risk Rating is determined by calculating the probability of encountering UXO and the consequences of initiating it.

STAGE FOUR - RISK ASSESSMENT (…continued)				
UXO RISK CALCULATION TABLE – ALL AREAS				
Activity	**Threat Item**	**Probability** (SHxEM=P)	**Consequence** (DxPSR=C)	**Risk Rating** (PxC=RR)
Trial Pits	HE Bombs	3x1=3	1x3=3	3x3=9
	IBs	1x1=1	3x2=6	1x6=6
	AAA Projectiles	1x1=1	3x2=6	1x6=6
Window Sampling	HE Bombs	3x1=3	1x3=3	3x3=9
	IBs	1x1=1	3x2=6	1x6=6
	AAA Projectiles	1x1=1	3x2=6	1x6=6
Boreholes	HE Bombs	3x3=9	2x3=6	9x6=36
	IBs	1x3=3	3x1=3	3x3=9
	AAA Projectiles	1x3=3	3x1=3	3x3=9
Piling	HE Bombs	3x3=9	2x3=6	9x6=36
	IBs	1x3=3	3x1=3	3x3=9
	AAA Projectiles	1x3=3	3x1=3	3x3=9
Bulk Excavations	HE Bombs	3x3=9	2x3=6	9x6=36
	IBs	1x3=3	3x2=6	3x6=12
	AAA Projectiles	1x3=3	3x2=6	3x6=12
Deep Foundations	HE Bombs	3x3=9	2x3=6	9x6=36
	IBs	1x3=3	3x2=6	3x6=12
	AAA Projectiles	1x3=3	3x2=6	3x6=12
Abbreviations – Site History (SH), Engineering Methodology (EM), Probability (P), Depth (D), Consequence (C), Proximity to Sensitive Receptors (PSR) and Risk Rating (RR).				

STAGE FIVE – RECOMMENDED RISK MITIGATION MEASURES WITH RESULTING RISK RATING		
If a geophysical survey is required are the ground conditions an issue?	**Non-Intrusive/Intrusive Methods of Mitigation** – This type of survey is likely be effective within undeveloped areas of the Site, although magnetometer results are highly likely to be affected by ferro-magnetic contamination in any old foundations/made ground.	
MITIGATION MEASURES TO REDUCE RISK TO 'ALARP'		
Activity/Area	**Risk Mitigation Measures**	**Final Risk Rating**
All Ground Works in All Areas	**1. Operational UXO Risk Management Plan;** appropriate Site management documentation should be held on Site to plan for and guide upon the actions to be undertaken in the event of a suspected or real UXO discovery, (6 Alpha can supply this plan). **2. UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a general briefing concerning the identification of a UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Posters and information concerning the general nature of the UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The safety and awareness briefing is an essential part of the Health and Safety Plan for the Site and helps to evidence conformity with the principles laid down in the CDM regulations 2007, (6 Alpha can supply this brief).	ALARP
All Shallow Excavations and Trial Pits, and within former Rifle Ranges	**3. On Call EOD Engineer;** all shallow excavations in undeveloped areas should be supported by an 'On Call' EOD Engineer, who will be able to identify and/or advise on the appropriate course of action in the event of any suspicious and/or real UXO finds, (6 Alpha can provide this service).	
All Bulk Excavations, Window Sampling and Deep Foundations	**4. EOD Banksman Support;** EOD Engineer(s) to survey and/or supervise the excavations and/or geotechnical investigations ≥1m bgl in all areas for UXO and to identify any suspicious items as the work proceeds in the EOD Banksman role, (6 Alpha can provide this service).	
All Boreholes and Piling	**5. Intrusive Magnetometer Survey;** an intrusive survey (employing down-hole magnetometer or MagCone techniques) ahead of piling and boreholing is strongly recommended. Such a survey should extend to the maximum bomb penetration depth or to the maximum depth of the works, whichever is encountered first, (6 Alpha can provide this service).	
This assessment has been conducted based on the information provided by the Client, should the proposed works change then 6 Alpha should be re-engaged to refine this risk assessment.		

Report Figures

-

Figure One

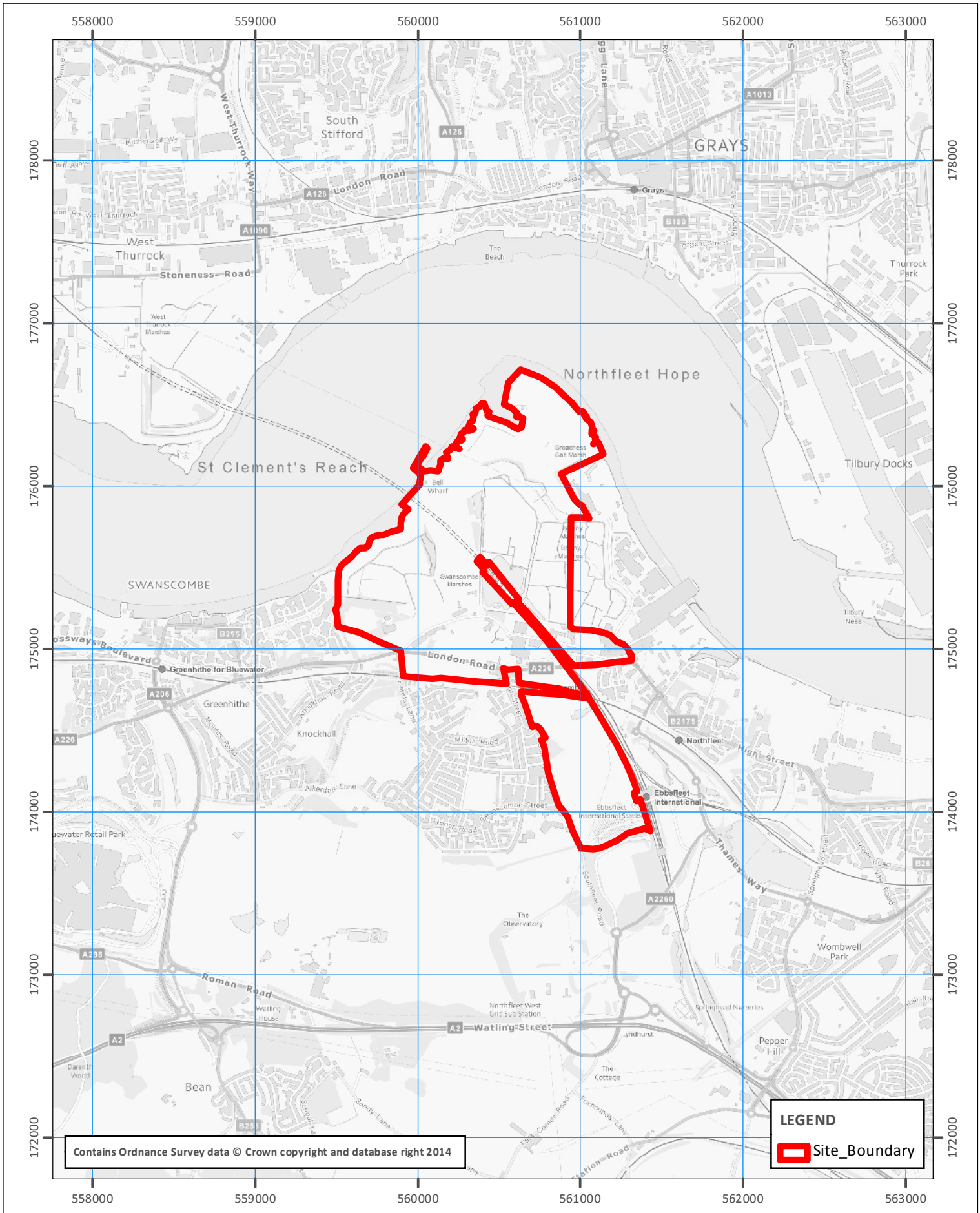
Site Location

PARAMOUNT RESORT, KENT

Site Location

BRITISH NATIONAL GRID

Figure 1



BOMB SEARCH
WWW.6ALPHA.COM

0 250 500 1,000 1,500 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.

PROJECT NO.	P4181
DRAWN BY	DR
CHECKED BY	RR
DATE	18 November 2014

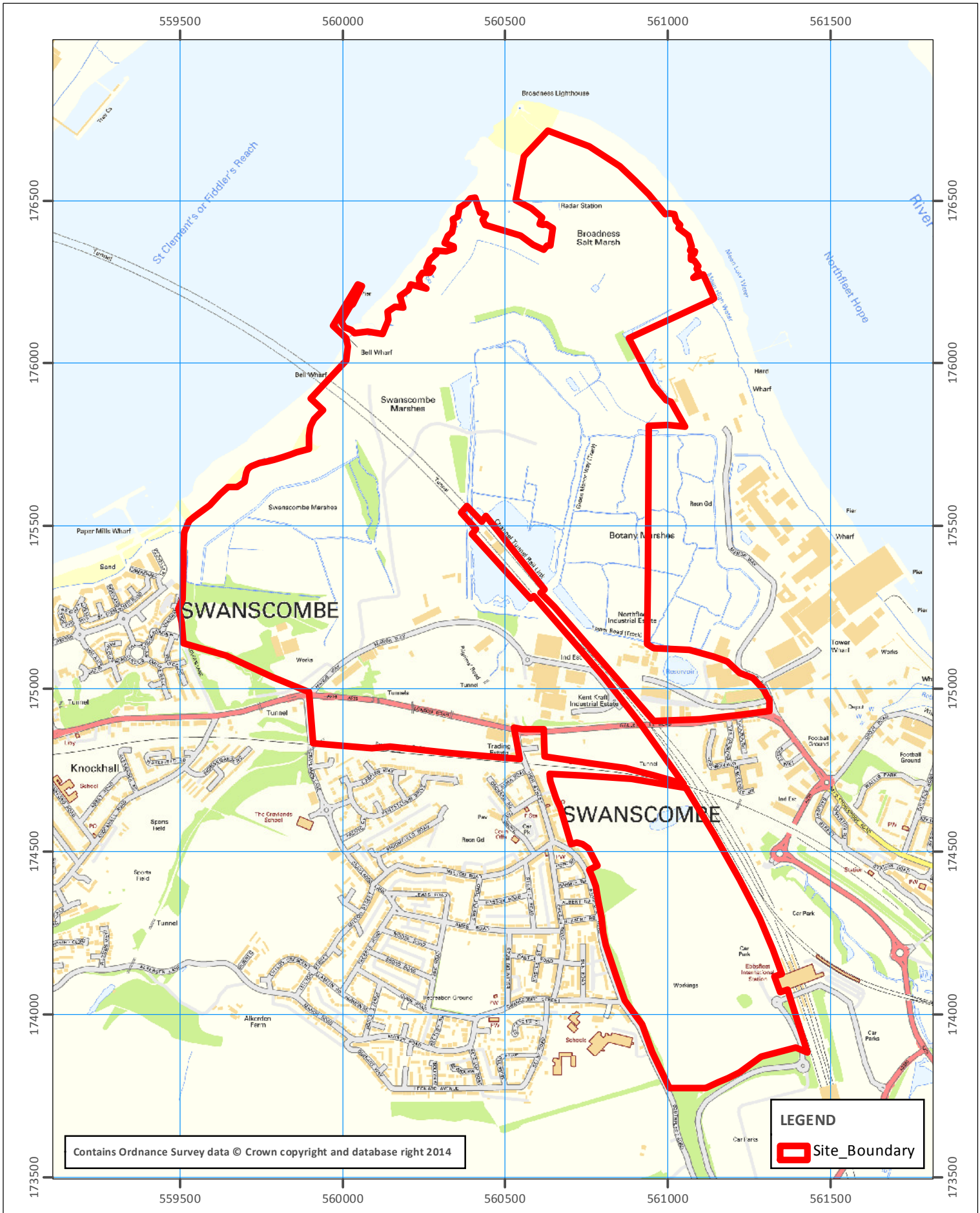
Figure Two

Site Boundary

PARAMOUNT RESORT, KENT
Site Boundary

BRITISH NATIONAL GRID

Figure 2



BOMB SEARCH
WWW.6ALPHA.COM

0 50 100 200 300 400 500 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.

PROJECT NO.	P4181
DRAWN BY	DR
CHECKED BY	RR
DATE	18 November 2014

Figure Three

Aerial Photography (Current)

PARAMOUNT RESORT, KENT
Aerial Photography (Current)

BRITISH NATIONAL GRID

Figure 3

BOMB SEARCH
WWW.6ALPHA.COM

0 50 100 200 300 400 500
Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.

PROJECT NO.	P4181
DRAWN BY	DR
CHECKED BY	RR
DATE	18 November 2014

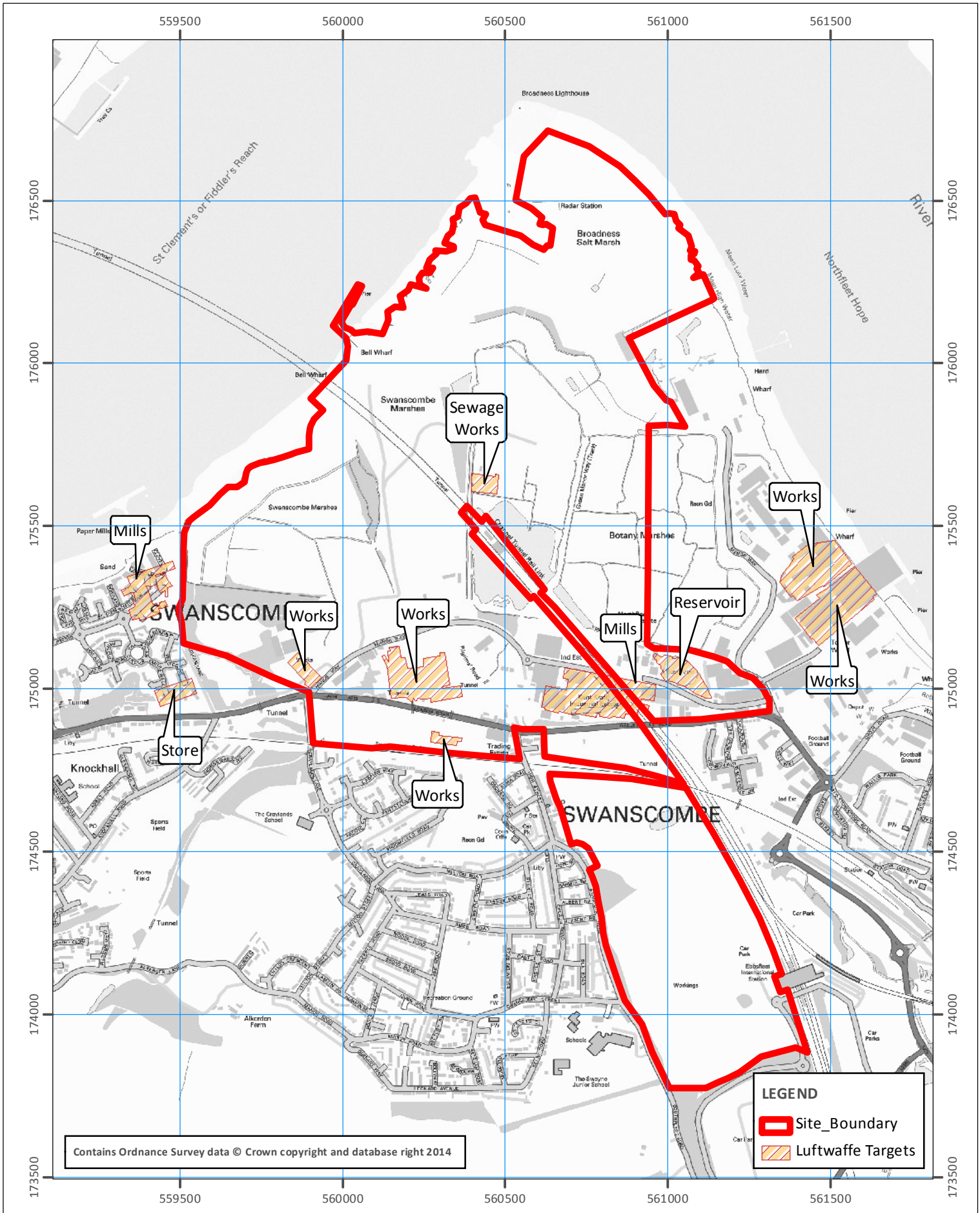
Figure Four

WWII Luftwaffe Bombing Targets

PARAMOUNT RESORT, KENT
WWII Luftwaffe Bombing Targets

BRITISH NATIONAL GRID

Figure 4



BOMB SEARCH
WWW.6ALPHA.COM

0 50 100 200 300 400 500 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.

PROJECT NO.	P4181
DRAWN BY	DR
CHECKED BY	RR
DATE	18 November 2014

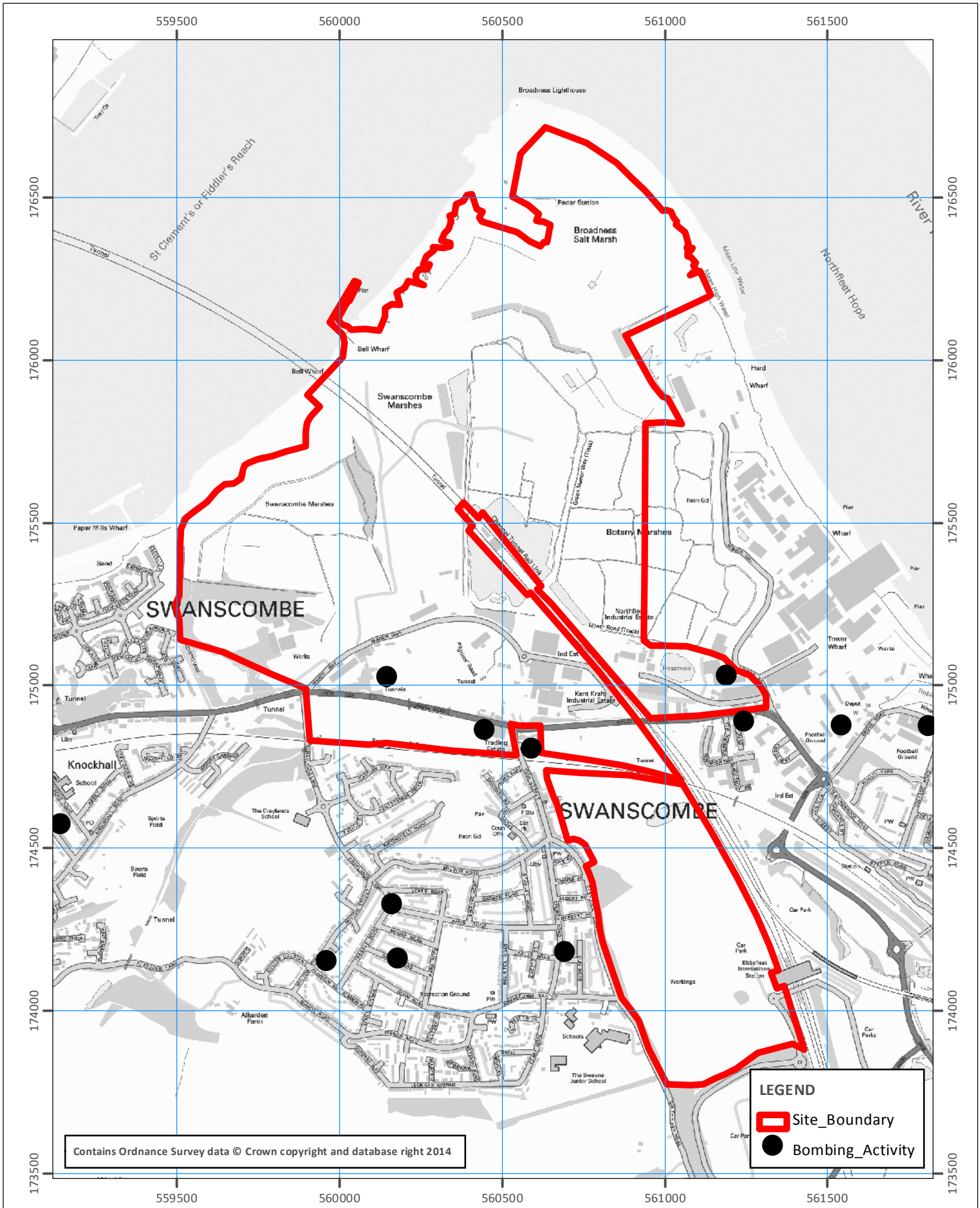
Figure Five

WWII Bombing Activity

PARAMOUNT RESORT, KENT
Areas of WWII Bombing Activity

BRITISH NATIONAL GRID

Figure 5



BOMB SEARCH
WWW.6ALPHA.COM

0 50 100 200 300 400 500
Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.

PROJECT NO.	P4181
DRAWN BY	DR
CHECKED BY	RR
DATE	26 November 2014

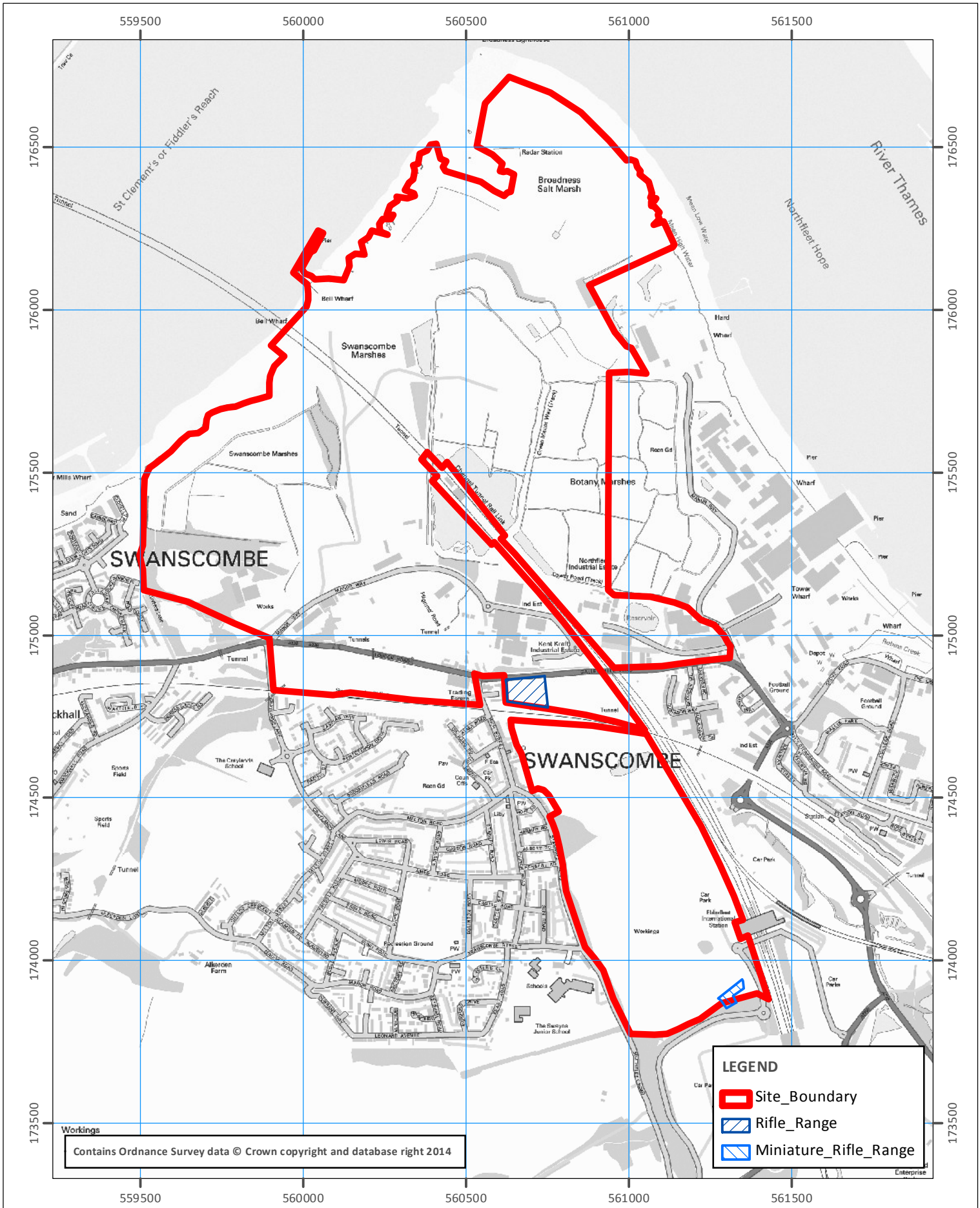
Figure Six

Former Rifle Ranges

PARAMOUNT RESORT, KENT
Former Rifle Ranges

BRITISH NATIONAL GRID

Figure 6



BOMB SEARCH
WWW.6ALPHA.COM

0 50 100 200 300 400 500 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.

PROJECT NO.	P4181
DRAWN BY	DR
CHECKED BY	RR
DATE	01 December 2014

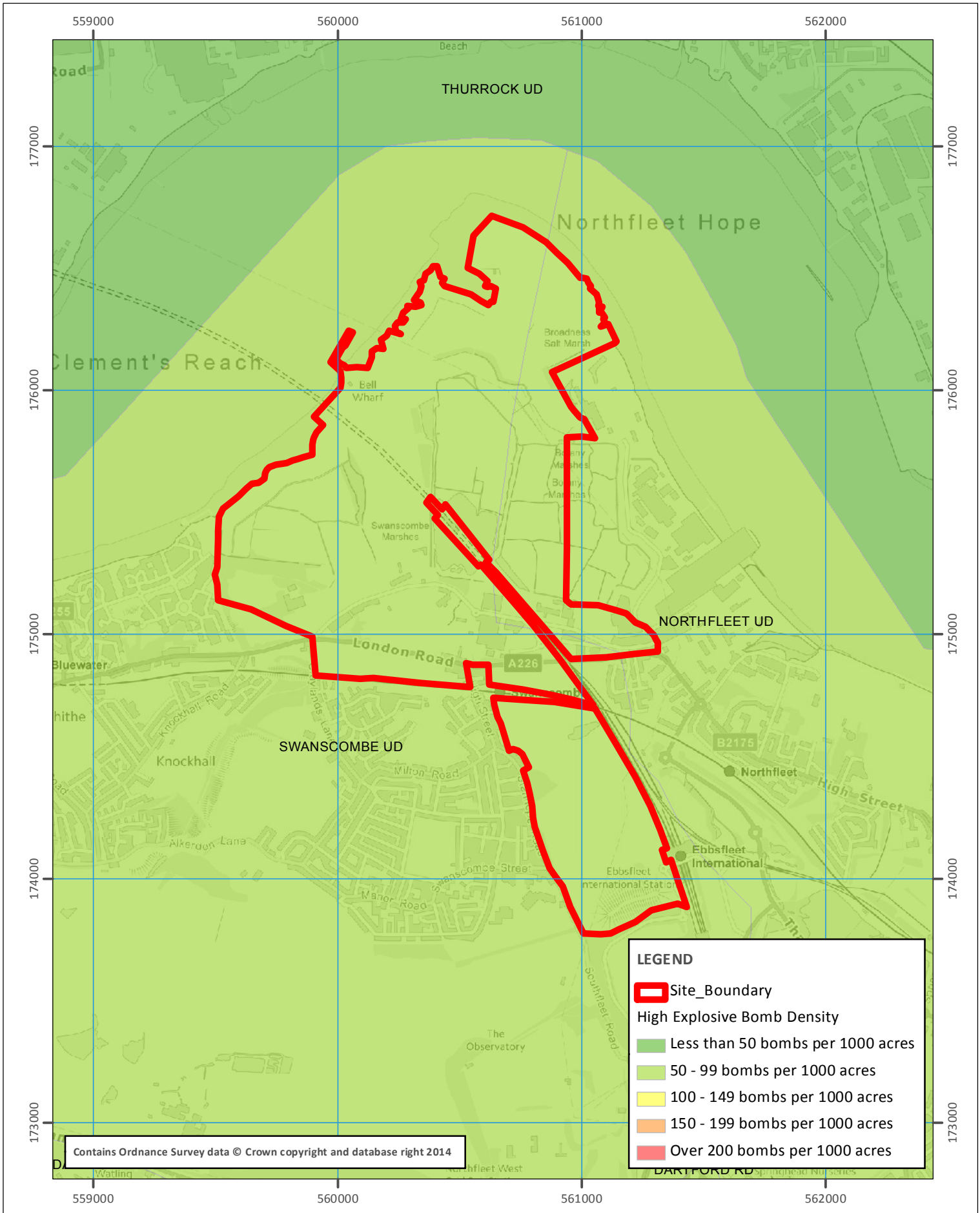
Figure Six

WWII High Explosive Bomb Density

PARAMOUNT RESORT, KENT
WWII High Explosive Bomb Density

BRITISH NATIONAL GRID

Figure 7



BOMB SEARCH
WWW.6ALPHA.COM

0 100 200 400 600 800 1,000 Meters

N

Produced by and Copyright to 6 Alpha Associates Ltd.
Users noting any errors please forward to 6 Alpha.

PROJECT NO.	P4181
DRAWN BY	DR
CHECKED BY	RR
DATE	01 December 2014

Appendix B. Site Walkover Photographs

Appendix B: Site Walkover Photos

Zone 1

Photo 1. Looking at the surface water pumping station on the southern boundary of Zone 1. The large electricity pylon can be seen in the background.

Photo 2. Looking directly between the boundary of Zone 1 and 2, eastwards towards Bell Wharf.

Appendix B: Site Walkover Photos

Photo 3. Looking towards the large electricity pylon located on the western boundary of Zone 1.

Appendix B: Site Walkover Photos

Photo 4. Looking toward the excised area of boats within an inlet on teh western edge of Zone 1. The boats can be seen in the distance. The lighthouse / radar station can be seen on the right.

Photo 5. From within Zone 1, looking north towards the boat community. The boats and lighthouse are visible in the distance.

Appendix B: Site Walkover Photos

Photo 6. Looking at Broadness Lighthouse and radar station at the very northern part of the site. Surface water ponding is evident.

Appendix B: Site Walkover Photos

Photo 7. Looking towards the centre of the site from the northern part of Zone 1. Surface water ponding is evident in the 'soakaway' created in the CKD.

Photo 8. Visible ponding water on the surface near the northern part of the Zone 1, the 'soakway', by Broadness Lighthouse.

Appendix B: Site Walkover Photos

Photo 9. The leachate treatment 'reed bed' within Zone 1.

Photo 10. Zone 1 looking east towards the leachate treatment facility and 'reed bed'.

Appendix B: Site Walkover Photos

Photo 11. The leachate treatment lagoons in Zone 1.

Photo 12. Portable cabins near the leachate treatment area in Zone 1.

Appendix B: Site Walkover Photos

Photo 13. Leachate Treatment Lagoon in Zone 1.

Photo 14. Boundary between Zone 1 and Zone 2 looking north towards the large electricity pylon.

Appendix B: Site Walkover Photos

Photo 15. At the boundary between Zone 1 and Zone looking north towards the large electricity pylon.

Appendix B: Site Walkover Photos

Zone 2

Photo 1. Looking south towards London Road and the Chalk Spines. Zone 5 visible in the distance. The Grade II-listed building, the Church of All Saints, is visible in the distance at a higher elevation than the site.

Photo 2. Looking east near the western boundary of Zone 1. The large electricity pylons are located within Zone 1 and a drainage ditch culvert can be seen in the foreground.

Appendix B: Site Walkover Photos

Photo 3. Looking south towards the chalk spines of London Road. Agricultural land comprising Phase 2 of the South Pit and Surge Pile landfill can be seen.

Photo 4. Looking south-east towards the chalk spines of London Road. CTRL can be seen in the distance.

Appendix B: Site Walkover Photos

Appendix B: Site Walkover Photos

Zone 3

Photo 1. Looking towards Zone 3 from the boundary between Zone 2 and Zone 3.

Photo 2. Looking towards Zone 3 from the boundary between Zone 2 and Zone 3.

Appendix B: Site Walkover Photos

Photo 3. Zone 3 looking south. The chalk spines of London Road can be seen in the distance. Zone 3 generally comprises marshes.

Appendix B: Site Walkover Photos

Zone 4

Photo 1. Part of Northfleet Industrial Estates. Development has occurred up to the near-vertical chalk spines.

Photo 2. Part of the industrial and commercial land uses within Northfleet Industrial Estate.

Appendix B: Site Walkover Photos

Photo 3. Looking westward from within Northfleet Industrial Estate. London Road/Galley Hill Road can be seen in the distance.

Photo 4. Part of the warehouses within Northfleet Industrial Estate.

Appendix B: Site Walkover Photos

Photo 5. Part of the industrial and commercial land uses within Northfleet Industrial Estate.

Photo 6. Part of the industrial and commercial land uses within Northfleet Industrial Estate.

Appendix B: Site Walkover Photos

Photo 7. Part of Kent Kraft Industrial Estate, Zone 4

Photo 8. Part of Kent Kraft Industrial Estate

Appendix B: Site Walkover Photos

Photo 9. A recycling plant within Kent Kraft Industrial Estate, Zone 4.

Photo 10. A recycling plant within Kent Kraft Industrial Estate, Zone 4.

Appendix B: Site Walkover Photos

Photo 11. A removal and storage company within Kent Kraft Industrial Estate.

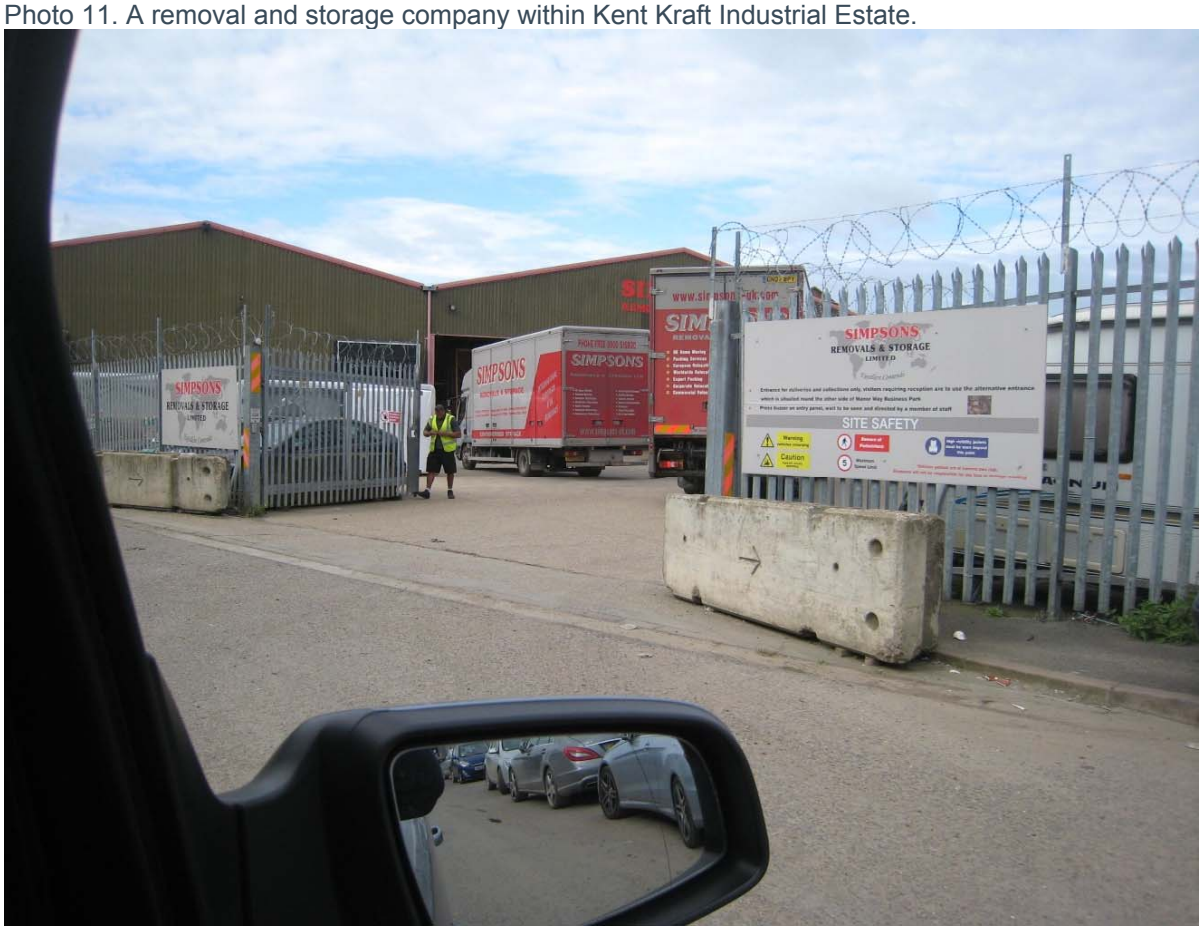


Photo 12. The Chalk spine and part of the industrial activities at Kent Kraft Industrial Estate.

Appendix B: Site Walkover Photos

Photo 13. Part of Kent Kraft Industrial Estate, Zone 5.

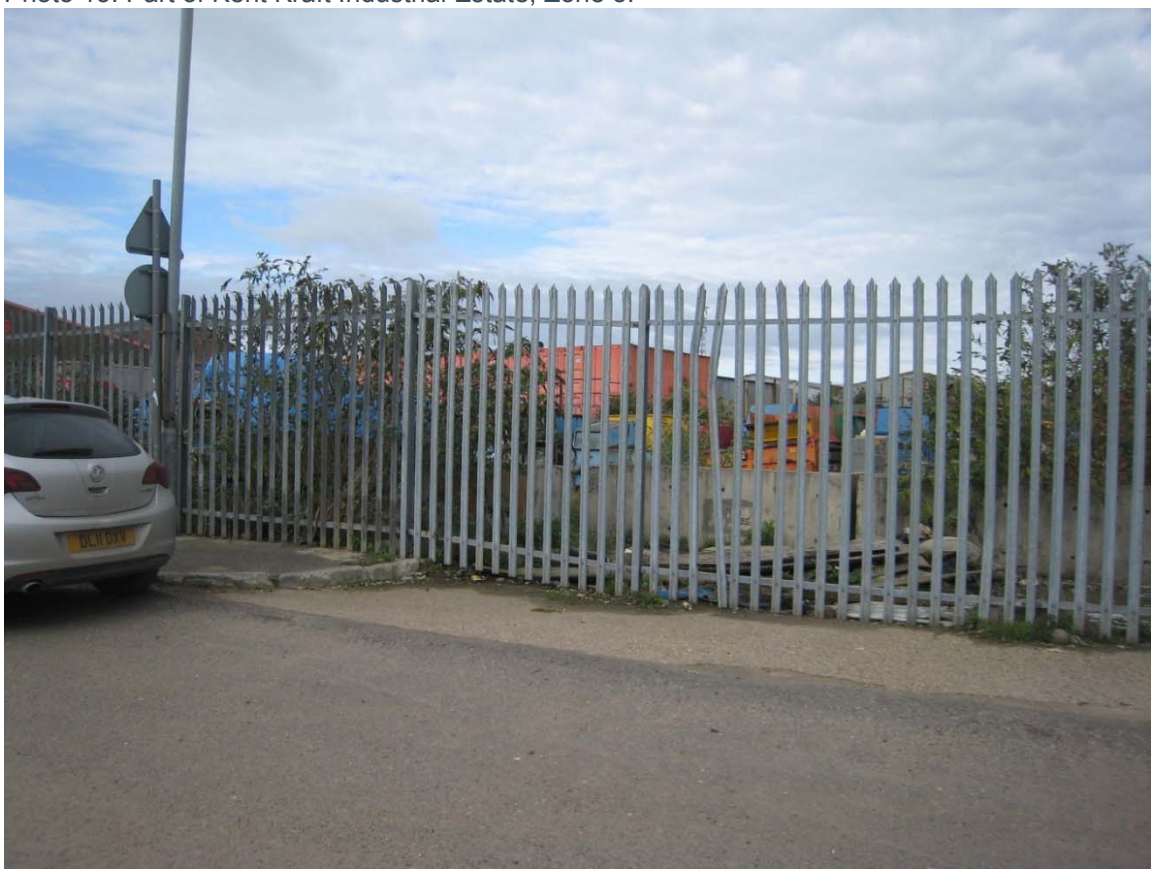


Photo 14. Part of Kent Kraft Industrial Estate, Zone 5.

Appendix B: Site Walkover Photos

Zone 5

Photo 1. Part of Manor Way Business Park, Zone 5

Photo 2. Located towards the centre of Zone 5, north of London Road, looking eastwards.

Appendix B: Site Walkover Photos

Photo 3. A possible tunnel running through the chalk spine of London Road to the southern part of Zone 5. A solution features in the Chalk can be seen on the right.

Photo 4. Chalk spines within Zone 5. London Road is visible on the right.

Appendix B: Site Walkover Photos

Photo 5. A dissolution feature in the Chalk at London Road.

Appendix A: Site Walkover Photos

Zone 6

Photo 1. Bamber Pit, Zone 6.

Photo 2. Bamber Pit, Zone 6.

Appendix A: Site Walkover Photos

Photo 3. Bamber Pit, Zone 6

Photo 4. Looking towards Northfleet Landfill from the northern edge of the landfill, near the centre of Zone 6.

Appendix A: Site Walkover Photos

Photo 5. Looking into Bamber Pit from the path between Northfleet Landfill and Bamber Pit Landfill.

Photo 6. Looking into Bamber Pit, the area is heavily overgrown.

Appendix A: Site Walkover Photos

Photo 7. Looking at the boundary of the site at Zone 6, looking towards Northfleet Landfill.

Photo 8. Looking into Bamber Pit.

Appendix A: Site Walkover Photos

Photo 9. Looking toward Ebbsfleet International Station from the site.

Photo 10. Looking towards Ebbsfleet International Station from the site.

Appendix A: Site Walkover Photos

Photo 11. Looking towards Ebbsfleet International Station from the site.

Appendix C. Summary of Borehole Records

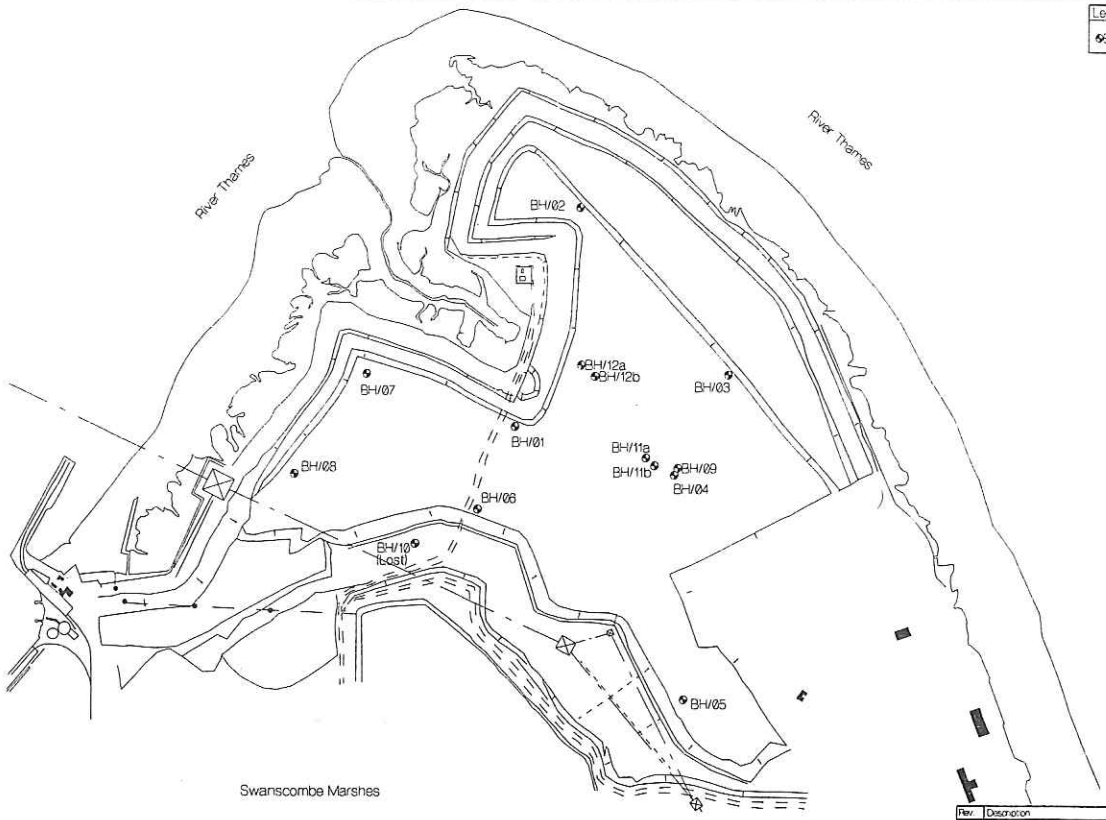
C.1. List of Borehole Records

London Paramount Entertainment Resort Borehole Locations							
Zone	Borehole ID	National Grid Reference (NGR)		Depth (m)	Depth Category	Grade	Source
		Easting	Northing				
1	TQ67NW512	560641	176629	2.50	D	A	BGS
	TQ67NW513	560799	176469	2.50	D	A	
	TQ67NW516	560698	176430	2.50	D	A	
	TQ67NW518	560917	176418	2.50	D	A	
	TQ67NW514	560947	176305	2.50	D	A	
	TQ67NW519	560662	176326	2.65	D	A	
	TQ67NW490	560440	176337	4.00	D	A	
	TQ67NW491	560404	176246	3.30	D	A	
	TQ67NW517	560833	176223	2.50	D	A	
	TQ67NW515	561023	176191	2.60	D	A	
	TQ67NW493	560266	176106	4.60	D	A	
	TQ67NW492	560591	176165	4.20	D	A	
	TQ67NW520	560673	176155	2.45	D	A	
	TQ67NW521	560853	176107	2.50	D	A	
	TQ67NW479	560264	176038	6.01	D	A	
	TQ67NW487	560273	175981	5.81	D	A	
	TQ67NW581	560325	176284	16.00	C	B	
	BH/01	See 'Appendix C.2'		12.50	C	B	Halcrow Report
	BH/02			9.00	D	B	
	BH/03			9.30	D	B	
	BH/04			6.50	D	B	
	BH/05			9.50	D	B	
	BH/06			8.80	D	B	
	BH/07			8.50	D	B	
	BH/08			7.80	D	B	
	BH/09			32.50	B	B	
	BH/10			1.90	D	B	
	BH/11a			6.80	D	B	
	BH/11b			4.50	D	B	
	BH/12a			8.00	D	B	
	BH/12b			5.50	D	B	
	BH/13			32.50	B	B	
2	TQ57NE1336	559979	175938	60.86	A	A	BGS
	TQ67NW529	560098	175851	50.31	A	A	
	TQ67NW536	560217	175703	15.01	C	B	
	TQ67NW542	560217	175703	16.41	C	B	
	TQ67NW543	560402	175514	12.11	C	B	
	TQ67NW544	560402	175514	17.31	C	B	
	TQ67NW549	560578	175285	25.01	C	A	
	TQ67NW551	560436	175485	19.01	C	B	
	TQ67NW560	560626	175281	25.01	C	A	
	TQ67NW561	560625	175279	18.01	C	B	
	TQ67NW564	560172	175809	25.06	C	A	
	TQ67NW566	560142	176040	15.01	C	A	
	TQ67NW568	560012	175969	60.01	A	A	
	TQ67NW569	560406	175349	39.96	B	A	
	TQ67NW570	560401	175343	40.01	B	A	
	TQ67NW571	560091	175850	50.11	B	A	
	TQ67NW572	560266	175601	51.21	A	A	
	TQ67NW574	560436	175514	41.21	B	A	
3	TQ57NE1180	559943	175045	3.60	D	B	
	TQ67NW495	560078	175160	4.00	D	B	
	TQ67NW496	560064	175113	4.00	D	B	
	TQ67NW497	560006	175096	4.00	D	B	
4	TQ67NW533	560999	175121	9.51	D	B	
	TQ67NW546	560715	175176	10.51	C	A	
	TQ67NW547	560783	175153	15.01	C	A	
	TQ67NW558	560682	175198	25.01	C	A	
	TQ67NW548	560688	175011	10.31	C	A	
	TQ67NW583	561120	175624	11.30	C	B	
	TQ67SW428	560540	174850	13.00	C	B	
	TQ67SW744	561064	174968	9.81	D	B	
	TQ67SW862	560807	174985	10.36	C	A	
	TQ67SW864	560922	174855	10.01	C	A	
	TQ67SW865	561052	174743	10.01	C	A	
	TQ67SW945	560913	174881	14.60	C	B	
	TQ67SW946	560926	174881	13.30	C	B	
	TQ67SW947	560939	174882	12.80	C	B	
	TQ67SW952	560871	174879	16.00	C	B	
	TQ67SW953	560892	174751	10.10	C	B	

Depth (m)	Depth Category
0-9.99	D
10-29.99	C
30-49.99	B
50+	A

	TQ67SW954	560896	174901	18.30	C	B	
	TQ67SW955	560910	174902	17.30	C	B	
	TQ67SW956	560923	174902	17.60	C	B	
	TQ67SW957	560936	174903	17.60	C	B	
	TQ67SW959	560963	174904	16.30	C	A	
	TQ67SW960	560976	174904	15.30	C	A	
5	TQ67NW552	560483	175194	20.01	C	A	
	TQ67NW554	560391	175209	20.01	C	A	
	TQ67NW555	560453	175209	15.01	C	A	
	TQ67NW557	560444	175115	18.06	C	A	
6	TQ67SW50	561010	173640	37.50	B	B	
	TQ67SW732	560790	174190	10.00	C	B	
	TQ67SW733	560800	174250	10.00	C	B	
	TQ67SW734	560770	174310	10.00	C	B	
	TQ67SW736	561418	173821	10.71	C	B	
	TQ67SW839	560971	174835	10.01	C	A	
	TQ67SW840	561030	174766	10.01	C	A	
	TQ67SW850	560947	174463	26.61	C	A	
	TQ67SW852	561064	174548	18.51	C	A	
	TQ67SW858	561435	173650	24.97	C	A	
	TQ67SW859	561383	174095	12.55	C	A	
	TQ67SW861	561262	174107	11.75	C	A	
	TQ67SW896	561083	174687	15.85	C	A	
	TQ67SW899	561174	174608	10.35	C	A	
	TQ67SW900	561252	174356	25.45	C	A	
	TQ67SW924	560998	174699	20.00	C	A	
	TQ67SW927	561066	174683	25.71	C	A	
	TQ67SW976	561433	173920	35.00	B	A	

C.2. Borehole Map for Zone 1



Rev.	Description	Date/File Ref.
-	Based upon digital Promap data	F:\PMS_01\FCW 02/12/05

Applied Environmental Research Centre Ltd
AERC
Tey Grove, Elm Lane, Fearing, Colchester, Essex, CO5 9ES
www.aerc.co.uk
Telephone : 01376 572592 Facsimile : 01376 572769 E-mail : aerc@aerc.co.uk

Project: Broadness Marsh CKD Tip

Title: Borehole Location Plan

Scale	Date
N.T.S.	December 2005

Drawn	Checked	Approved
DR		

Drawing Number	Revision	
B2116/PMS/01	-	A3 297 x 420

Appendix D. Screening Sheets

Assessment Criteria	Commercial - 1% SOM

Constituents	Method Detection Limit (mg/kg)	Generic Assessment Criteria (mg/kg)	No. Samples	Minimum Value	Maximum Value	No. Exceedences	Locations of Exceedences	TP1	TP2	TP2	TP3	TP4	HTP1	HTP2
								0.3 m m	0.3 m m	0.9 m m	0.5 m m	0.5 m m	0.6 m m	0.4 m m
Boron		-	9	0.20	1.10	0		0.2	1.1	0.2	1	0.5	0.2	0.7
Sulphur		-	21	0.50	66.00	0		1	2	0.5	7	0.5	0.5	12
Cyanide		34.00000	21	0.25	2.50	0		0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sulphide		-	9	0.25	1.20	0		0.5	0.25	0.5	0.8	0.8	0.25	1.1
Sulphide		-	12	0.01	0.01	0								
Arsenic		640.00000	21	2.50	26.00	0		12	13	7.9	17	20	6.9	24
Beryllium		1010.00000	9	0.50	2.10	0		0.5	0.5	0.5	1.1	0.5	0.5	2.1
Cadmium		230.00000	21	0.05	3.10	0		0.05	0.51	0.14	3.1	0.61	0.23	0.38
Chromium		-	21	2.50	57.00	0		33	21	2.5	41	22	20	27
Copper		109000.00000	21	2.50	130.00	0		11	32	2.5	110	69	6.1	120
Mercury		-	21	0.05	2.10	0		0.05	0.35	0.05	2	0.26	0.05	2.1
Nickel		1800.00000	21	2.50	34.00	0		26	18	2.5	30	22	22	30
Lead		6490.00000	21	9.90	830.00	0		14	17	12	830	430	9.9	400
Selenium		13000.00000	9	0.10	0.42	0		0.1	0.39	0.1	0.1	0.24	0.1	0.42
Vanadium		7530.00000	9	2.50	54.00	0		44	33	2.5	40	29	27	43
Zinc		1000000.00000	21	15.00	670.00	0		49	160	19	670	140	38	250
Fraction of Organic Carbon		-	9	0.00	0.05	0		0.001	0.03	0.05	0.038	0.046	0.006	0.04
Sulphate		-	12	0.25	0.25	0								
Barium		22100.00000	12	10.50	369.30	0								
		-		0.05	0.05							0.05		
TPH Aliphatic C5-C6		1000000.00000	1	0.05	0.05	0						0.05		
TPH Aliphatic C6-C8		1000000.00000	1	0.05	0.05	0						0.05		
TPH Aliphatic C8-C10		167000.00000	1	0.05	0.05	0						0.05		
TPH Aliphatic C10-C12		171000.00000	1	0.05	0.05	0						0.05		
TPH Aliphatic C12-C16		171000.00000	1	0.05	0.05	0						0.05		
TPH Aliphatic C16-C21		-	1	0.05	0.05	0						0.05		
TPH Aliphatic C21-C35		-	1	0.05	0.05	0						0.05		
TPH Aromatic C5-C7		13.11739	1	0.05	0.05	0						0.05		
TPH Aromatic C7-C8		414000.00000	1	0.05	0.05	0						0.05		
TPH Aromatic C8-C10		58600.00000	1	0.05	0.05	0						0.05		
TPH Aromatic C10-C12		68300.00000	1	0.05	0.05	0						0.05		
TPH Aromatic C12-C16		68400.00000	1	0.70	0.70	0						0.7		
TPH Aromatic C16-C21		28400.00000	1	8.00	8.00	0						8		
TPH Aromatic C21-C35		28400.00000	1	16.00	16.00	0						16		
Total Petroleum Hydrocarbons		-	1	24.00	24.00	0						24		
		-												
Naphthalene		8180.00000	9	0.02	0.36	0		0.22	0.14	0.02	0.36	0.3	0.13	0.3
Acenaphthylene		-	9	0.01	0.57	0		0.07	0.1	0.005	0.57	0.17	0.005	0.005
Acenphthene		-	9	0.01	0.26	0		0.005	0.09	0.14	0.26	0.13	0.14	0.13
Fluorene		66800.00000	9	0.01	0.24	0		0.1	0.09	0.005	0.24	0.2	0.07	0.14
Phenanthrene		-	9	0.08	1.80	0		0.08	0.8	0.09	1.3	0.71	0.1	1.1
Anthracene		536000.00000	9	0.01	0.45	0		0.005	0.16	0.005	0.32	0.14	0.005	0.27
Fluoranthene		72300.00000	9	0.48	4.20	0		0.5	2.6	0.55	4	1.5	0.48	2.3
Pyrene		54200.00000	9	0.19	3.90	0		0.19	2.2	0.34	3.9	1.2	0.24	2.1

Assessment Criteria	Commercial - 1% SOM

Constituents	Method Detection Limit (mg/kg)	Generic Assessment Criteria (mg/kg)	No. Samples	Minimum Value	Maximum Value	No. Exceedences	Locations of Exceedences	TP1	TP2	TP2	TP3	TP4	HTP1	HTP2
								0.3 m m	0.3 m m	0.9 m m	0.5 m m	0.5 m m	0.6 m m	0.4 m m
Benzo(a)anthracene		131.00000	9	0.01	2.10	0		0.005	1.2	0.02	2.1	0.75	0.09	1
Chrysene		14000.00000	9	0.01	2.60	0		0.005	1.5	0.005	2.6	0.86	0.005	1.4
Benzo(b)fluoranthene		142.00000	9	0.01	3.20	0		0.005	1.2	0.01	3.2	1.2	0.005	1.4
Benzo(k)fluoranthene		1430.00000	9	0.01	1.60	0		0.005	0.68	0.005	1.4	0.47	0.005	0.65
Benzo(a)pyrene		14.30000	9	0.01	3.90	0		0.005	0.73	0.05	3.9	1.1	0.005	2
Dibenz(a,h)anthracene		14.30000	9	0.01	0.01	0		0.005	0.005	0.005	0.005	0.005	0.005	0.005
Indeno(1,2,3-c,d)pyrene		142.00000	9	0.01	2.00	0		0.005	2	0.005	1.8	0.51	0.005	1.1
Benzo(g,h,i)perylene		1440.00000	9	0.01	2.20	0		0.005	0.83	0.005	2.2	0.69	0.005	0.89
Total of 16 PAHs		-	9	1.15	28.20	0		1.15	14.3	1.22	28.2	9.93	1.24	14.8
Phenols		-	9	0.15	0.15	0		0.15	0.15	0.15	0.15	0.15	0.15	0.15
pH		-	20	7.90	10.30	0		8	8	8.3	8.1	8.5	8.1	8.1
Asbestos		-	9			9		non-detect	non-detect	non-detect	non-detect	non-detect	non-detect	non-detect

Assessment Criteria	Commercial - 1% SOM

Constituents	Method Detection Limit (mg/kg)	Generic Assessment Criteria (mg/kg)	HTP3	HTP4	2AED7	2AED8	2AED9	2AED10	2AED11	2AED12	2AED13	2AED14	2AED15	2AED16	2AED17	2AED18
			0.5 m m	0.4 m m												
Boron		-	0.2	0.5												
Sulphur		-	1	5	25	25	25	25	25	25	25	25	66	25	25	25
Cyanide		34.00000	0.25	0.25	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sulphide		-	1.2	1.1												
Sulphide		-			0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Arsenic		640.00000	14	14	24	26	2.5	14	5.4	2.5	7.1	10	2.5	5	2.5	2.5
Beryllium		1010.00000	1.8	1												
Cadmium		230.00000	0.4	0.59	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5
Chromium		-	57	49	15	15	15	15	15	15	15	15	15	15	15	15
Copper		109000.00000	26	59	130	100	14	37	26	15	12	14	5	25	5	5
Mercury		-	0.26	0.58	1.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Nickel		1800.00000	34	27	31	33	10	26	10	10	23	27	10	10	10	10
Lead		6490.00000	120	190	690	110	15	760	260	52	15	15	15	69	15	15
Selenium		13000.00000	0.1	0.1												
Vanadium		7530.00000	54	43												
Zinc		1000000.00000	110	180	340	180	41	160	51	37	38	49	19	73	19	15
Fraction of Organic Carbon		-	0.013	0.025												
Sulphate		-			0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Barium		22100.00000			369.3	88	16.4	92.5	28.1	29.4	40.7	43.3	15.2	62.2	12.5	10.5
		-														
TPH Aliphatic C5-C6		1000000.00000														
TPH Aliphatic C6-C8		1000000.00000														
TPH Aliphatic C8-C10		167000.00000														
TPH Aliphatic C10-C12		171000.00000														
TPH Aliphatic C12-C16		171000.00000														
TPH Aliphatic C16-C21		-														
TPH Aliphatic C21-C35		-														
TPH Aromatic C5-C7		13.11739														
TPH Aromatic C7-C8		414000.00000														
TPH Aromatic C8-C10		58600.00000														
TPH Aromatic C10-C12		68300.00000														
TPH Aromatic C12-C16		68400.00000														
TPH Aromatic C16-C21		28400.00000														
TPH Aromatic C21-C35		28400.00000														
Total Petroleum Hydrocarbons		-														
		-														
Naphthalene		8180.00000	0.1	0.28												
Acenaphthylene		-	0.21	0.17												
Acenphthene		-	0.06	0.17												
Fluorene		66800.00000	0.12	0.2												
Phenanthrene		-	0.76	1.8												
Anthracene		536000.00000	0.21	0.45												
Fluoranthene		72300.00000	2.1	4.2												
Pyrene		54200.00000	1.8	3.8												

Assessment Criteria	Commercial - 1% SOM

Constituents	Method Detection Limit (mg/kg)	Generic Assessment Criteria (mg/kg)	HTP3	HTP4	2AED7	2AED8	2AED9	2AED10	2AED11	2AED12	2AED13	2AED14	2AED15	2AED16	2AED17	2AED18
			0.5 m m	0.4 m m												
Benzo(a)anthracene		131.00000	0.98	2												
Chrysene		14000.00000	1.1	2.5												
Benzo(b)fluoranthene		142.00000	1	2.6												
Benzo(k)fluoranthene		1430.00000	0.71	1.6												
Benzo(a)pyrene		14.30000	1.3	3.1												
Dibenz(a,h)anthracene		14.30000	0.005	0.005												
Indeno(1,2,3-c,d)pyrene		142.00000	0.58	1.3												
Benzo(g,h,i)perylene		1440.00000	0.58	2												
Total of 16 PAHs		-	11.6	26.2												
Phenols		-	0.15	0.15												
pH		-	10.3	8.4	7.9	8.2	8.5	8.1	8.2	8.3	8.3	8.2	8.8	8.3	8.7	
Asbestos		-	non-detect	non-detect												

Zone 4 - Screening of Available Hydrock & Consultants 2020

Borehole 1 water chemical testing

Sample				Sep-03	Oct-03	Nov-03	Mar-04	May-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Jan-05	Apr-05	Jul-05	Oct-05
																Lab ID	1288B	1931B
Test																Anal ID	7170	1477
																Retest	Fluoride	F/PO4
	Units	Tests	LOD															
Ammonium	µg/l	1	0.1	0.17	0.18	0.19	0.02	0.16	0.46	0.09	0.15	0.23	0.2	0.12	0.21	0.2	0.2	0.2
Chloride	mg/l	1	1	655	627	583	554	688	602	625	638	605	594	588	587	450	424	329
Orthophosphate	µg/l	1	0.1	10	10	10	10	10	10	10	10	10	10	10	10	10	38	10
Sulphate	mg/l	1	1	271	271	253	219	249	272	279	253	260	267	272	275	220	237	230
TON	mg/l	1	0.1	15.5	13.3	17.8	N/T	26.2	6.6	9.5	13.2	18.9	18.5	16.2	17.1	N/T	4.8	3.2
Sodium	mg/l	1		319	395	288	N/T	330	325	317	299	313	326	304	315	N/T	253.4	244.7
Magnesium	mg/l	1	50	41.8	45.3	39.2	N/T	49.7	40.5	15.2	30.4	42.6	41.5	39.2	40.6	N/T	33.1	26.4
BOD	µg/l	1		2	2	2	N/T	2	2	2	2	2	2	2	2	N/T	2	6
COD	µg/l	1		23	60	25	N/T	47.7	53.3	19	29	37	33	30	30	N/T	36	16
Conductivity	µs/cm	1		2716	2732	2655	2497	2662	2602	2550	2632	2704	2744	2629	2831	Site	tests	Site
Potassium	µg/l	1		32.6	33.2	28.8	N/T	40.5	34.7	12.2	20.9	20.9	19.5	16.7	18.4	N/T	37.8	33.2
Calcium	mg/l	1		204	183	167	N/T	193	247	211	231	199	204	199	201	N/T	126.1	180.9
Chromium	µg/l	1		13	1	13	16	15	14	16	13	14	16	12	14	N/T	8	7
Nickel	µg/l	1		18	13		11	10	11	18	16	12	10	13	12	10	16	9
Copper	µg/l	1		20	20	20	10	10	10	10	10	10	10	10	10	10	9	6
Zinc	µg/l	1		42	60	20	29	36	43	86	59	37	33	30	38	14	55	23
Arsenic	µg/l	1		7	4	6	5	9.2	6	1	1	1	1	1	1	1	7	4
Selenium	µg/l	1		9	7	7	10	11	7	4	6	10	14	10	12	14	7.4	5.7
Cadmium	µg/l	1		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Antimony	µg/l	1		4	2.6	2.3	3.5	3.9	2.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mercury	µg/l	1		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lead	µg/l	1		1	1	1	1	24	17	1	1	1	1	1	1	1	1	1
pH	Units	1		7.1	7.2	7.2	7.1	7.2	7.4	7	7.2	7.2	7.1	7.1	7	Site	tests	Site
Iron	µg/l	1		13	27	14	13	18	14	24	15	17	14	18	17	8	5	5
Manganese	µg/l	1		46	39	37	N/T	4	81	16	37	30	31	28	29	N/T	5	95
Alkalinity	mg/l	1		289	290	290	307	292	270	184	236	271	278	259	274	N/T	210	330
Cyanide	µg/l	1		0.005	0.005	0.005	N/T	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	N/T	0.005	0.005
Fluoride	µg/l	1		284	684	370	534	251	513	361	454	398	390	978	400	320	301	308
Nitrate	mg/l	1		15.2	13.1	17.4	24	26.2	6.5	10.1	15.8	22.4	22.6	20.4	20.5	1	3.8	3.2
TOC	µg/l	1		2	1.8	2	N/T	1.5	1.4	5.8	2.9	2	2.1	2.5	2	N/T	3.4	2.8
DOC	µg/l	1		1.7	1.2	1.5	2	1.3	1.2	3.1	2	1.4	1.3	1.4	1	4	2.7	2.2
Phenols	µg/l	6		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
SVOC	µg/l	10		10	10	10	N/T	10	10	10	10	10	10	10	10	N/T	10	10
Tributyl-tins	µg/l	1		0.05	0.05	0.05	N/T	0.005	0.05	0.05	0.02	0.02	0.02	0.02	0.02	Yearly	Yearly	Yearly
Triphenyl-tins	µg/l	1		0.01	0.01	0.01	N/T	0.005	0.01	0.01	0.02	0.02	0.02	0.02	0.02	Yearly	Yearly	Yearly
PCBs	µg/l	7		0.005	0.005	0.005	N/T	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Pesticides-P	µg/l	27		0.1	0.1	0.1	N/T	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	Yearly	Yearly	Yearly
Pesticides-Cl	µg/l	34		0.05	0.05	0.05	N/T	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	Yearly	Yearly	Yearly
TPH	µg/l	8		30	20	40	N/T	25	20	10	10	10	10	10	10	N/T	10	10
PAH	µg/l	16		0.2	0.2	0.2	N/T	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	N/T	0.1	0.1
Molybdenum	µg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	2	5	5
Solids	µg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	1300	1444	1280
Barium	µg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	30	50	27
Nitrite	mg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	0.01	0.01
Sulphide	µg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	1	1
Sulphur	mg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	1	1
BTEX	µg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	1	1
Boron	µg/l			N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	247	173
Ion Balance	5%																17.2	4.79

EQS DWS

1,000 - 500
250 - 250
400 - 250
— 200
50 - 50
200 - 20
20 - 2000
75 - 5000
23 - 10
10 - 10
— 5
0.05 - 1
50 - 10
300 - 200
30 - 50
1 - 50
1000 - 1500
50 - 50
7.7 —
0.1 - 0.1
— 70
— 700
0.01 - 0.50
1000 - 1000

Where analysis is below minimum detection level, value shown is minimum detection level.

Data written up by Hydrock from hard copy provided by client from Consultants 2020 report.

Borehole 1 water chemical testing

Sample				Jan-06	Apr-06	Jul-06	Oct-06	Jan-07	Apr-07	Jul-07	Oct-07	Jan-08	Apr-08	Jul-08	Oct-08
				2580	3366A	4318A	5502	6479	7877	9416	10894	12347	13979	15752	17337
Test				5611	10243	15628	22949	28435	37247	46852	57116	66882	76829	88800	99031
						B									Very
		Tests	LOD							Raining					Windy
	Units														
Ammonium	µg/l	1	0.1	0.1	0.12	0.1	0.2	0.08	0.06	0.1	0.13	0.18	0.09	0.09	0.1
Chloride	mg/l	1	1	279	433	450	304	322	327	259	193	211	344	331	277
Orthophosphate	µg/l	1	0.1	10	10	10	10	10	10	10	10	10	10	10	10
Sulphate	mg/l	1	1	205	232	259	197	175	164	156	147	161	199	214	163
TON	mg/l	1	0.1	2.3	0.6	0.1	5	0.1	0.1	1.4	2	3	0.1	1.7	0.1
Sodium	mg/l	1		199.3	259.5	267.6	203	203	208	164.5	137.2	161.2	222.8	216	166.4
Magnesium	mg/l	1	50	26.4	21.9	35.4	23	28	27	22.6	20	26.9	30.9	32.6	22.3
BOD	µg/l	1		2	2	2	2	2	2	2	2	2	2	2	2
COD	µg/l	1		18	42	35	29	15	16	5	24	5	23	5	21
Conductivity	µs/cm	1		Site	Site	Site	Site	Site	Site	Site	Site	Site	Site	Site	Site
Potassium	µg/l	1		33.5	32.9	37.6	33	37	29	31.4	30.9	41.4	39.2	38.3	34.5
Calcium	mg/l	1		170	172.9	163.4	153	135	118	100	125.8	126.5	123.2	141.2	108.9
Chromium	µg/l	1		6	5	5	5	5	5	5	5	5	5	5	5
Nickel	µg/l	1		8	9	11	13	7	5	5	5	13	13	5	4
Copper	µg/l	1		6	6	9	5	5	5	5	5	5	5	5	3
Zinc	µg/l	1		21	21	29	14	10	10	11	12	11	8	10	10
Arsenic	µg/l	1		1	2	1	2	8	3.9	1	2	1	1	1	7
Selenium	µg/l	1		5	5	8.7	7	5	5	4	1.1	1	1	3	1
Cadmium	µg/l	1		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Antimony	µg/l	1		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mercury	µg/l	1		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lead	µg/l	1		1	1	1	1	1	1	1	1	1	1	1	1
pH	Units	1		Site	Site	Site	Site	Site	Site	Site	Site	Site	Site	Site	Site
Iron	µg/l	1		5	5	13	14	76	211	5	12	5	25	5	12
Manganese	µg/l	1		5	5	42	59	21	138	76	44	7	7	6	36
Alkalinity	mg/l	1		320	320	325	280	380	330	230	270	320	335	260	280
Cyanide	µg/l	1		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Fluoride	µg/l	1		245	344	325	465	300	296	263	359	321	385	382	302
Nitrate	mg/l	1		2.3	0.6	0.1	5	0.1	0.1	1.4	2	3	0.1	1.7	0.1
TOC	µg/l	1		4.8	5	5	5.1	3.8	2.9	2.8	4.5	5	3.7	5	4
DOC	µg/l	1		2.2	3.2	4.1	4.2	3.2	2.3	2.1	2.3	2.1	2.7	4.3	3.7
Phenols	µg/l	6		2	2	2	2	2	2	2	2	2	2	2	2
SVOC	µg/l	10		10	10	10	10	10	10	10	10	10	10	10	10
Tributyl-tins	µg/l	1		0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly
Triphenyl-tins	µg/l	1		0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly
PCBs	µg/l	7		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Pesticides-P	µg/l	27		0.5	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
Pesticides-Cl	µg/l	34		0.5	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
TPH	µg/l	8		10	10	10	10	10	10	10	10	10	10	10	10
PAH	µg/l	16		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Molybdenum	µg/l			2	2	5	6	2	2	2	5	12	9	8	2
Solids	µg/l			1180	1128	1258	1090	1698	1576	1084	1200	1072	1120	1239	1072
Barium	µg/l			28	35	50	27	45	54	40	31	34	53	47	53
Nitrite	mg/l			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sulphide	µg/l			1	1	1	1	1	1	1	1	1	1	1	1
Sulphur	mg/l			1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BTEX	µg/l			1	1	1	1	1	1	1	1	1	1	1	1
Boron	µg/l			247	187	323	274	253	262	292	293	266	259	263	186
Ion Balance	5%			4.43	-1.74	-1.69	2.47	-3.55	-3.25	-1.65	2.92	2.93	-2.63	3.01	-4.21

EQS DWS

Ammonium: 1,000 — 50
Chloride: 250 — 250
Orthophosphate:
Sulphate: 400 — 250
TON:
Sodium: — 200
Magnesium:
BOD:
COD:
Conductivity:
Potassium:
Calcium:
Chromium: 50 — 50
Nickel: 200 — 20
Copper: 20 — 2000
Zinc: 75 — 3000
Arsenic: 25 — 10
Selenium: 10 — 10
Cadmium:
Antimony:
Mercury: — 5
Lead: 0.03 — 1
pH:
Iron: 50 — 10
Manganese: 300 — 200
Alkalinity: 30 — 50
Cyanide:
Fluoride: 1 — 50
Nitrate: 1000 — 1500
TOC: 50 — 50
DOC:
Phenols: 7.7 —
SVOC:
Tributyl-tins:
Triphenyl-tins:
PCBs:
Pesticides-P:
Pesticides-Cl:
TPH:
PAH:
Molybdenum: 0.1 — 0.1
Solids: — 70
Barium: — 700
Nitrite:
Sulphide: 0.01 — 0.50
Sulphur:
BTEX:
Boron: 1000 — 1000
Ion Balance:

Where analysis is below minimum detection level, value shown is minimum detection level.

Data written up by Hydrock from hard copy provided by client from Consultants 2020 report.

Borehole 2 water chemical testing

Sample				Jan-06	Apr-06	Jul-06	Oct-06	Jan-07	Apr-07	Jul-07	Oct-07	Jan-08	Apr-08	Jul-08	Oct-08
Test				Fe/Mn											
		Tests		5612	10243	15629	22950	28436	37248	46853	57117	66883	76830	88802	99032
			MDO	2580 A	3366	4318 A	5502	6479	7877 A	9410	10894	12347	13979	15752	17337
Ammonium	µg/l	1		0.2	0.24	0.22	0.18	0.12	0.12	0.09	0.16	0.12	0.16	0.12	0.2
Chloride	mg/l	1		200	182	164	141	150	165	157	156	162	200	195	187
Orthophosphate	µg/l	1	10	10	60	10	10	10	10	10	10	10	10	10	10
Sulphate	mg/l	1		210	186	177	150	164	174	175	162	176	183	207	189
TON	mg/l	1		13.9	13.9	21.8	26.4	31.8	21.4	16.5	10.4	12	6	10.2	8
Sodium	mg/l	1		127.8	131.2	107.5	99	96	90	97.6	112.6	131.6	133.4	115.5	114.3
Magnesium	mg/l	1		21.3	19.7	20.5	16	20	16	18.1	17.8	20.7	20	21.1	17.1
BOD	µg/l	1	10	2	2	2	2	2	2	2	2	2	2	2	2
COD	µg/l	1	15	14	20	22	24	24	18	24	7	1	15	3	26
Conductivity	µs/cm	1		Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test
Potassium	µg/l	1		39.4	35.3	30.4	27	27	26	29.5	31.4	42.9	42.7	40.1	36.2
Calcium	mg/l	1		187.6	177	149	157	139	138	123.2	138.1	121.8	140.9	153	126
Chromium	µg/l	1		5	5	5	5	5	5	5	5	5	5	5	5
Nickel	µg/l	1		6	8	7	5	7	6	5	5	5	5	6	5
Copper	µg/l	1	20	5	5	3	3	5	3	2	2	2	2	2	2
Zinc	µg/l	1	20	16	16	8	10	20	17	11	10	7	14	14	9
Arsenic	µg/l	1		1	1	1	1	1	1	1	1	1	1	1	1
Selenium	µg/l	1		1	1	1	1	1	1	1	2.1	1	1	3	3
Cadmium	µg/l	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Antimony	µg/l	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mercury	µg/l	1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lead	µg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1
pH	Units	1		Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test
Iron	µg/l	1	13	5	5	7	5	5	5	5	5	5	5	5	9
Manganese	µg/l	1		2	2	11	8	13	11	9	7	6	5	5	7
Alkalinity	mg/l	1		340	390	310	330	340	260	280	290	270	330	290	280
Cyanide	µg/l	1	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Fluoride	µg/l	1		255	373	305	239	203	333	312	321	310	322	366	320
Nitrate	mg/l	1		13.9	13.9	21.8	26.4	31.8	21.4	16.5	10.4	12	6	10.2	8
TOC	µg/l			3.2	4.8	3.8	4.4	4.6	3.2	3.4	4.7	4.8	4.8	4.6	4.3
DOC	µg/l	1		2.7	3.9	2.8	3.7	3.9	2.2	2.8	2.4	2.2	2.5	3.9	2.8
Phenols	µg/l		2	2	2	2	2	2	2	2	2	2	2	2	2
SVOC	µg/l	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Tributyl-tins	µg/l	1	0.05	0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly
Triphenyl-tins	µg/l	1	0.05	0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly	0.02	Yearly	Yearly	Yearly
PCBs	µg/l	7	0.005	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Pesticides-P	µg/l	27	0.1	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
Pesticides-Cl	µg/l	34	0.05	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
TPH	µg/l	8	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
PAH	µg/l	16	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Molybdenum	µg/l			2	2	2	2	2	2	2	4	2	2	2	2
Solids	µg/l			912	1256	1090	890	944	1280	996	1200	1132	1300	1023	888
Barium	µg/l			30	35	34	34	36	35	36	32	31	30	29	32
Nitrite	mg/l			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sulphide	µg/l			1	1	1	1	1	1	1	1	1	1	1	1
Sulphur	mg/l	4		1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BTEX	µg/l			1	1	1	1	1	1	1	1	1	1	1	1
Boron	µg/l			210	177	268	245	242	220	283	268	241	251	232	165
Ion Balance				2.15	0.47	-0.63	0.15	-4.94	-3.85	-4.57	1.48	3.06	-1.46	-0.81	-4.28

EQS DWS

1,000 — 500
250 — 250
400 — 250
200
50 — 50
200 — 20
20 — 2000
75 — 3,000
25 — 10
10 — 10
0.05 — 1
50 — 10
300 — 200
30 — 50
1 — 50
1000 — 1500
50 — 50
7.7 —
0.1 — 0.1
70
700
0.01 — 0.50
1000 — 1000

Where analysis is below minimum detection level, value shown is minimum detection level.

Data written up by Hydrock from hard copy provided by client from Consultants 2020 report.

Borehole 2 water chemical testing

Sample				Sep-03	Oct-03	Nov-03	Mar-04	May-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Jan-05	Apr-05	Jul-05	Oct-05
Test																Retest		F/PO4
		Tests														Lab ID	7108	1478
			MDO													Test ID	1288 B	1931 B
Ammonium	µg/l	1		0.38	0.02	0.02	0.02	0.14	0.79	0.23	0.02	0.24	0.22	0.2	0.18		0.2	0.2
Chloride	mg/l	1		148	142	134	150	140	140	135	146	132	128	122	130	190	205	241
Orthophosphate	µg/l	1	10	10	13	18	10	10	10	10	10	10	10	10	10	10	24	10
Sulphate	mg/l	1		159	145	143	141	165	159	231	184	189	179	170	184	220	229	248
TON	mg/l	1		19.4	25.9	19.8		20.2	25	21.3	24.6	21.9	20.4	21.6	19.1		9.1	18.9
Sodium	mg/l	1		69	63	51		83	85	70	61	69	60	64	65		120.8	166
Magnesium	mg/l	1		12.9	12.1	10		15	16.5	13.6	12.2	13.1	12.7	11.9	13.1		18.9	22.6
BOD	µg/l	1	10	2	2	2		2	2	2	2	2	2	2	2		2	3
COD	µg/l	1	15	15	15	17		25.5	19.5	18	20.9	18.6	18.4	17.8	20.2		22	20
Conductivity	µs/cm	1		1292	1216	1216	1262	1267	1229	1270	1294	1277	1258	1269	1306	Site test	Site test	Site test
Potassium	µg/l	1		104.8	105.4	102		106.3	71.7	10.3	54.9	66.7	64.6	58.9	61.9		66.9	40.1
Calcium	mg/l	1		141	149	135		150	174	145	151	163	174	163	180		130.7	187.6
Chromium	µg/l	1		12	1	9	19	15	13	10	8	9	10	9	13	5	5	6
Nickel	µg/l	1		11	11	38	9	6	4	25	19	14	12	15	10	12	11	8
Copper	µg/l	1	20	20	20	20	10	10	10	10	10	10	10	10	10	10	7	6
Zinc	µg/l	1	20	20	120	20	10	18	12	104	73	56	49	55	47	13	25	20
Arsenic	µg/l	1		2	1	1	1	1.5	2	1	1	1	1	1	1	1	1	1
Selenium	µg/l	1		4	4	3	5	5	5	8	6	5	8	4	10	10	1	1
Cadmium	µg/l	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Antimony	µg/l	1	0.5	1	0.7	0.7	0.9	0.6	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mercury	µg/l	1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lead	µg/l	1	1	1	3	2	3	8	4	1	1	1	1	1	1	1	1	1
pH	Units	1		7.2	7.1	7.1	7.1	7.2	7.3	7	7.2	7.2	7.1	7.1	7	Site test	Site test	Site test
Iron	µg/l	1	13	13	18	13	13	14	14	38	24	16	17	11	19	9	5	21
Manganese	µg/l	1		39	17	20		2	38	15	22	27	28	20	27		2	6
Alkalinity	mg/l	1		305	330	360	318	308	278	216	244	294	287	261	271		230	300
Cyanide	µg/l	1	0.005	0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		0.005	0.005
Fluoride	µg/l	1		306	378	270	657	245	492	347	316	393	388	375	394	270	171	296
Nitrate	mg/l	1		19.3	25.8	19.8	19.8	20.2	25	20	22.4	23.8	23	22.1	22.8	12	8.2	18.9
TOC	µg/l			1.7	1.3	1.5	1.8	1.8	1.6	5	3.6	3.2	3.3	3.6	3.2		2	3.2
DOC	µg/l	1		1.3	0.7	1	1.6	1	1.1	2.7	2.1	2	2.1	2.2	2	3.6	1.3	1.4
Phenols	µg/l		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
SVOC	µg/l	10	10	10	10	10		10	10	10	10	10	10	10	10		10	10
Tributyl-tins	µg/l	1	0.05	0.05	0.05	0.05		0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.02	Yearly	Yearly	Yearly
Triphenyl-tins	µg/l	1	0.05	0.01	0.01	0.01		0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	Yearly	Yearly	Yearly
PCBs	µg/l	7	0.005	0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		0.05	0.05
Pesticides-P	µg/l	27	0.1	0.1	0.1	0.1		0.1	0.1	0.005	0.005	0.005	0.005	0.005	0.005	Yearly	Yearly	Yearly
Pesticides-Cl	µg/l	34	0.05	0.05	0.05	0.05		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	Yearly	Yearly	Yearly
TPH	µg/l	8	0.02	0.02	0.02	0.03		0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01
PAH	µg/l	16	0.2	0.2	0.2	0.2		0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1		0.1	0.1
Molybdenum	µg/l															2	2	2
Solids	µg/l															950	1880	1805
Barium	µg/l															30	39	32
Nitrite	mg/l																0.01	0.01
Sulphide	µg/l																1	1
Sulphur	mg/l	4															1	1
BTEX	µg/l																1	1
Boron	µg/l																216	145
Ion Balance																	-1.92	3.41

EQS DWS

1000 – 500
250 – 250
400 – 250
200
50 – 50
200 – 20
20 – 2000
75 – 3000
25 – 10
10 – 10
5
0.05 – 1
50 – 10
300 – 200
50 – 50
1 – 50
1000 – 1500
50 – 50
7.7
0.1 – 0.1
70
700
0.01 – 0.50
1000 – 1000

Where analysis is below minimum detection level, value shown is minimum detection level.

Data written up by Hydrock from hard copy provided by client from Consultants 2020 report.

Borehole 3 water chemical testing

Sample				Sep-03	Oct-03	Nov-03	Mar-04	May-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Jan-05	Apr-05	Jul-05	Oct-05
																Retest	F/Ca	F/PO4
Test	Units	Tests	MDO													Test ID	7109	1479
																Lab Data	1288B	1931A
Ammonium	µg/l	1		0.02	0.02	0.02	0.02	0.14	0.41	0.2	0.18	0.21	0.2	0.22	0.16		0.2	0.1
Chloride	mg/l	1		150	148	148	140	135	149	147	151	160	168	175	172	190	203	212
Orthophosphate	µg/l	1	10	10	17	19	10	10	10	10	10	10	10	10	10	10	19	10
Sulphate	mg/l	1		157	131	147	149	169	151	211	174	183	174	168	169	260	272	240
TON	mg/l	. 1		31.8	35.1	27.3		27.3	31.4	29.4	27.6	25..8	25.5	27.3	23.8		11.5	19.5
Sodium	mg/l	1		74	63	58		74	76	65	54	51	55	60	67		121.1	142.4
Magnesium	mg/l	1		13.4	11.4	10.6		12.3	13.1	10	13.7	14.4	16.2	15.4	14.1		24.1	22.1
BOD	µg/l	1	10	2	2	2		2	2	2	2	2	2	2	2		2	2
COD	µg/l	1	15	15	15	15		26.8	16.8	23	20	22	21	19	23		24	18
Conductivity	µs/cm	1		1310	1215	1270	1307	1229	1328	1314	1324	1330	1309	1300	1311	Site test	Site test	Site test
Potassium	µg/l	1		125.7	95.5	108.2		100.7	69.9	14.6	53.2	54.7	50	48.6	53.5		50.2	38.3
Calcium	mg/l	1		165	160	143		128	180	168	159	163	168	180	173		135.6	184.8
Chromium	µg/l	1		12	11	6	17	14	12	9	13	11	16	12	14	6	1	1
Nickel	µg/l	1		7	50	24	5	4	3	30	14	26	29	26	27	14	19	16
Copper	µg/l	1	20	20	20	20	10	10	10	10	10	10	10	10	10	10	8	6
Zinc	µg/l	1	20	20	32	20	10	20	22	85	52	67	58	70	55	21	23	20
Arsenic	µg/l	1		2	1	1	1	1.5	3	1	1	1	1	1	1	1	1	1
Selenium	µg/l	1		5	4	4	6	6	7	5	4	3	7	6	8	9	1	1
Cadmium	µg/l	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Antimony	µg/l	1	0.5	1	1	1.8	1.2	1	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mercury	µg/l	1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lead	µg/l	1	1	1	1	1	1	1.5	3	1	1	1	1	1	1	1	1	1
pH	Units	1		7.1	7	7.1	7.2	7.2	7.3	7.1	7.1	7.2	7.1	7	7	Site test	Site test	Site test
Iron	µg/l	1	13	15	30	16	31	106	22	47	33	39	35	40	58	7	1	31
Manganese	µg/l	1		7	11	9		178	56	32	50	54	58	51	50		7	27
Alkalinity	mg/l	1		322	330	290	311	264	254	236	251	249	237	230	251		210	310
Cyanide	µg/l	1	0.005	0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		0.005	0.005
Fluoride	µg/l	1		255	780	244	450	241	292	294	313	320	317	322	324	230	173	235
Nitrate	mg/l	1		31.8	35.1	27.3	29	27.3	31.4	30.6	28.1	27.2	27.7	28.5	26.6	8.4	11.5	19.5
TOC	µg/l	1		1.3	1.1	1.4		0.7	1.7	3.8	2.6	2.4	2.5	2.7	2.6		2.5	2.3
DOC	µg/l	1		1.1	0.8	0.9	1.6	0.6	1.2	1.8	1.7	1.6	1.8	1.9	1.7	4.3	1.8	1.6
Phenols	µg/l	10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
SVOC	µg/l	10	10	10	10	10		10	10	10	10	10	10	10	10		10	10
Tributyl-tins	µg/l	1	0.05	0.05	0.05	0.05		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	Yearly	Yearly	Yearly
Triphenyl-tins	µg/l	1	0.05	0.01	0.01	0.01		0.01	0.01	0.05	0.05	0.05	0.05	0.05	0.05	Yearly	Yearly	Yearly
PCBs	µg/l	7	0.005	0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Pesticides-P	µg/l	27	0.1	0.1	0.1	0.1		0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	Yearly	Yearly	Yearly
Pesticides-Cl	µg/l	34	0.05	0.05	0.05	0.05		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	Yearly	Yearly	Yearly
TPH	µg/l	8	0.02	0.07	0.02	0.03		0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01
PAH	µg/l	16	0.2	0.2	0.2	0.2		0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1		0.1	0.1
Molybdenum	µg/l															2	2	2
Solids	µg/l															980	1248	1350
Barium	µg/l															40	49	35
Nitrite	mg/l																0.01	0.01
Sulphide	µg/l																1	1
Sulphur	mg/l																1	1
BTEX	µg/l																1	1
Boron	µg/l																227	142
Ion Balance																	-0.97	2.31

EQS DWS

1,000 — 500
250 — 250
400 — 250
200
50 — 50
200 — 20
20 — 2000
75 — 3000
25 — 10
10 — 10
5
0.05 — 1
50 — 10
300 — 200
30 — 50
1 — 50
1000 — 1500
50 — 50
7.7
0.1 — 0.1
70
700
0.01 — 0.5
1000 — 1000

Where analysis is below minimum detection level, value shown is minimum detection level.

Data written up by Hydrock from hard copy provided by client from Consultants 2020 report.

Borehole 3 water chemical testing

Sample				Jan-06	Apr-06	Jul-06	Oct-06	Jan-07	Apr-07	Jul-07	Oct-07	Jan-08	Apr-08	Jul-08	Oct-08
				Fe/Mn		B		Ba	Broken						
Test	Units	Tests		5613	10245	15630	22951	28437	40154	46854	57118	66884	76831	88802	99033
			MDO	2580A	3366	4318A	5502	6479	7877A	9410	10894	12347	13979	15752	17337
Ammonium	µg/l	1		0.1	0.26	0.32	0.32	0.12	0.12	0.16	0.17	0.09	0.14	0.12	0.2
Chloride	mg/l	1		182	151	141	128	133	154	152	132	140	180	194	191
Orthophosphate	µg/l	1	10	10	115	10	10	10	10	10	10	10	10	10	10
Sulphate	mg/l	1		209	165	167	150	157	236	175	162	172	204	227	213
TON	mg/l	1		14	13.2	20.3	23.8	25.5	12.6	9.2	6.8	5.1	1	3	2
Sodium	mg/l	1		114.9	128.2	95.5	88	86	95	89.5	97.9	117.9	121.8	120.2	117.9
Magnesium	mg/l	1		20.5	19.1	19.4	15	19	18	16.9	18.4	22.9	21.6	21	16.7
BOD	µg/l	1	10	2	2	2	2	2	2	2	2	2	2	2	2
COD	µg/l	1	15	14	20	23	20	28	20	25	12	1	22	1	22
Conductivity	µs/cm	1		Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test
Potassium	µg/l	1		36.7	31	29	26	26	29	27.8	29.4	37.2	37.9	35.4	33.4
Calcium	mg/l	1		176.2	183.2	144.5	151	134	141	120.6	156.6	153.4	159	121.5	127.3
Chromium	µg/l	1		1	1	1	1	1	1	1	1	1	1	1	1
Nickel	µg/l	1		14	13	13	12	7	35	6	14	6	6	6	10
Copper	µg/l	1	20	5	5	4	4	7	4	3	3	3	3	3	6
Zinc	µg/l	1	20	23	15	11	14	23	25	14	17	11	11	13	10
Arsenic	µg/l	1		1	1	1	1	1	1	1	1	1	1	1	1
Selenium	µg/l	1		1	1	1	1	1	1	1	1	1	1	3	1
Cadmium	µg/l	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Antimony	µg/l	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mercury	µg/l	1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lead	µg/l	1	1	1	1	1	1	1	1	1	1	1	1	1	1
pH	Units	1		7	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test	Site test
Iron	µg/l	1	13	1	1	14	1	1	41	1	1	1	1	1	6
Manganese	µg/l	1		5	6	11	13	14	12	22	5	8	8	6	7
Alkalinity	mg/l	1		350	395	300	330	320	270	260	340	340	380	260	260
Cyanide	µg/l	1	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Fluoride	µg/l	1		206	367	321	300	267	338	296	299	285	359	350	306
Nitrate	mg/l	1		14	13.2	20.3	23.8	25.5	12.6	9.2	6.8	5.1	1	3	2
TOC	µg/l	1		3.1	3.3	3.6	4	3.8	2.9	3.2	5	4.2	3.5	3.1	3.7
DOC	µg/l	1		2.6	2.1	2	3	3.1	1.9	2.6	2.8	2.1	2.2	2.6	3.6
Phenols	µg/l	10	2	2	2	2	2	2	2	2	2	2	2	2	2
SVOC	µg/l	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Tributyl-tins	µg/l	1	0.05	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
Triphenyl-tins	µg/l	1	0.05	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
PCBs	µg/l	7	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Pesticides-P	µg/l	27	0.1	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
Pesticides-Cl	µg/l	34	0.05	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly	0.05	Yearly	Yearly	Yearly
TPH	µg/l	8	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
PAH	µg/l	16	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Molybdenum	µg/l			2	2	2	2	2	2	2	5	2	2	5	5
Solids	µg/l			900	1200	1210	770	892	1105	908	800	1072	1260	1117	968
Barium	µg/l			32	33	34	33	33	36	35	38	36	35	28	31
Nitrite	mg/l			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sulphide	µg/l			1	1	1	1	1	1	1	1	1	1	1	1
Sulphur	mg/l			1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
BTEX	µg/l			1	1	1	1	1	1	1	1	1	1	1	1
Boron	µg/l			194	166	212	241	220	268	287	290	251	262	171	203
Ion Balance				-0.5	4.23	0.07	-1.03	-4.06	-4.93	-4.69	1.57	4.41	-2.48	-4.94	-4.39

EQS DWS

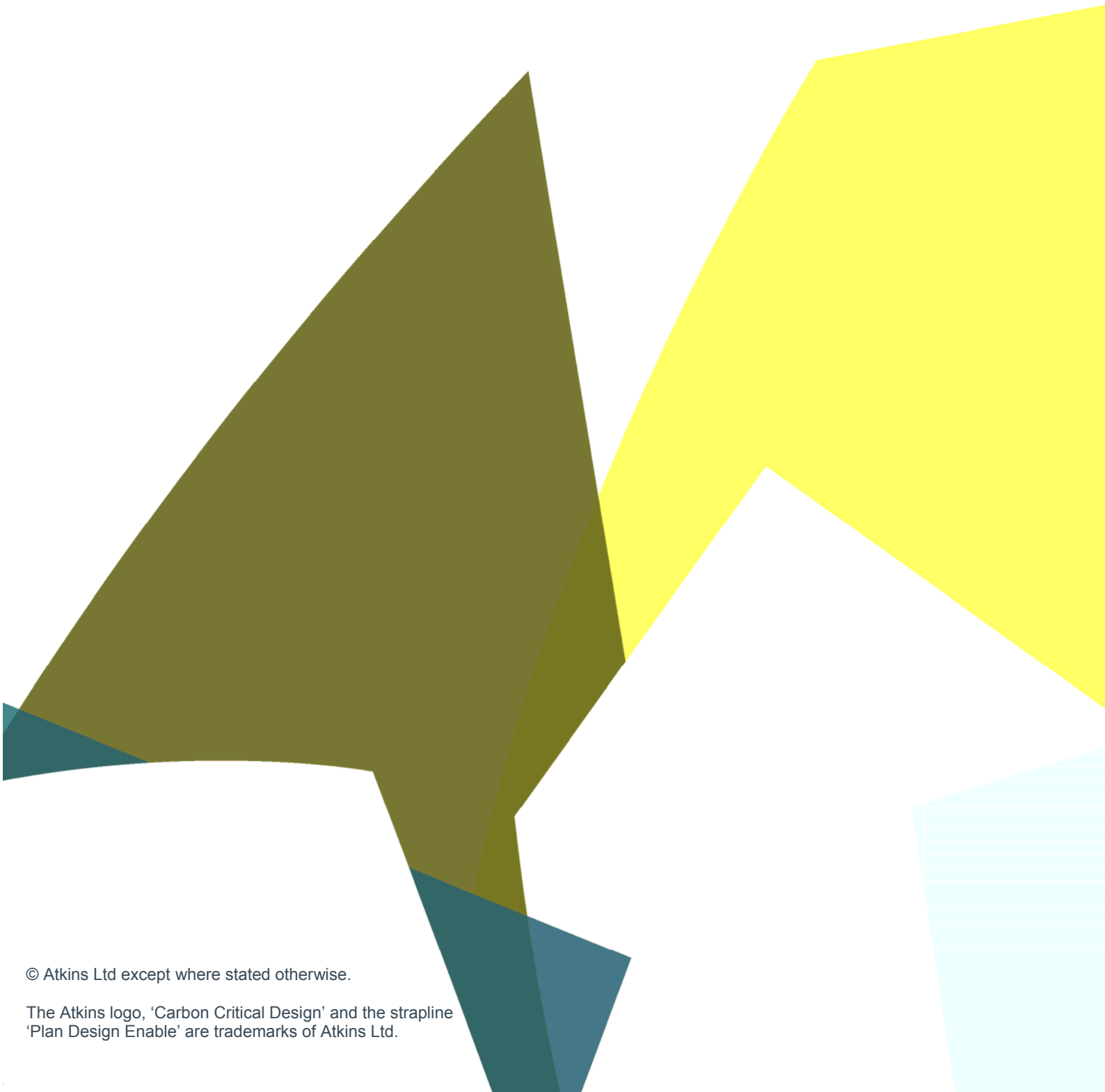
1,000 — 500
250 — 250
400 — 250
200
50 — 50
200 — 20
20 — 2000
75 — 3,000
25 — 10
10 — 10
0.05 — 1
50 — 10
300 — 200
30 — 50
1 — 50
1000 — 1500
50 — 50
7.7 —
0.1 — 0.1
70
700
0.01 — 050
1000 — 1080

Where analysis is below minimum detection level, value shown is minimum detection level.

Data written up by Hydrock from hard copy provided by client from Consultants 2020 report.

Jonathan Steeds
Atkins Limited
Epsom Gateway
Epsom
United Kingdom

Jonathan.Steeds@atkinsglobal.com



© Atkins Ltd except where stated otherwise.

The Atkins logo, ‘Carbon Critical Design’ and the strapline ‘Plan Design Enable’ are trademarks of Atkins Ltd.