7 GEOTECHNICAL AND GEO-ENVIRONMENTAL ISSUES

7.1 Introduction

7.1.1 The objective of this Section and the statements presented is to assess the existing site conditions to understand the geo-environmental and geo-technical constraints and sensitivities of the Island Farm site in relation to the proposed development. This section also addresses the points raised by the Environment Agency in their scoping consultation report ref. *"P/09/97/ESO Scoping Opinion for Proposed Leisure and Employment Development, 13th February 2009".*

7.1.2 In order to address the points raised by the EA in the scoping opinion a two stage geo-environmental and geo-technical investigation was carried out at the Island Farm site to support the statements and conclusions made in this Section.

7.1.3 The main objectives of the geo-environmental investigations were to:

- Identify the potential environmental liabilities at the site associated with any soil and groundwater contamination from past site uses.
- Provide a preliminary risk assessment based on the available desk study and site investigation reports.
- Provide recommendations with regard to likely geo-environmental aspects pertaining to the development, including radon protection measures.

7.1.4 The main objectives of the geo-technical investigation were to:

- Determine the likely type, strength and bearing characteristics of the shallow superficial and underlying solid geology based on available information.
- Anticipate a suitable and economic foundation/floor slab solution for the development.
- Provide recommendations with regard to any other geo-technical aspects pertaining to the development including potential natural and man-made cavities.
- Provide a detailed assessment of the risk to the controlled waters.
- Provide human health risk assessment associated with development.

7.1.5 A full summary of site history, current use and site conditions, geology, natural and manmade cavities, ground conditions and contamination is provided in the Stage 1 and Stage 2 site investigation Reports by Terra Firma ref. 10781, August 2009 which are included in Volume 3 Appendices 7.1 and 7.2.

7.2 Baseline Data and Assessment

Investigations Completed

7.2.1 A two stage geo-environmental and geo-technical site investigation was completed by Terra Firma (Wales) Ltd on behalf of HD Ltd in July and August 2009. Both reports are included in Appendix 7.1 and 7.2 respectively

Stage 1: Desk Study Report - Terra Firma ref. 10781, July 2009

- Site history
- Hydrogeology and hydrology
- Environment agency data
- Preliminary risk assessment
- Anticipated ground conditions
- Geological features
- Recommended site investigations
- Radon report
- Envirocheck report

7.2.2 In order to achieve the above objectives, Terra Firma carried out an assessment programme including a review of historical maps, British Geological Survey Radon Reports, and Landmark Information Group Envirocheck reports. The desk study set the scope of the intrusive investigation.

7.2.3 Following the desk study an intrusive investigation was performed using trial pits and windowless sampler boreholes. Selected soil samples were chemically and geo-technically tested.

Stage 2: Site Investigation Report: Terra Firma ref. 10781, August 2009

- Field investigations
- Chemical testing
- Risk assessment and evaluation of analytical results
- Site conceptual model
- Human health risk assessment
- Geological feature risk assessment
- Engineering recommendations
- Mineral assessment

7.2.4 The main objectives of the intrusive ground investigation were to:

- Determine the type, strength and bearing characteristics of the shallow superficial geology using hand and machine excavated trial pits and windowless sampler boreholes.
- Perform a Human Health Risk Assessment using site specific data.
- Determine chemical composition of soil samples taken across the site
- Determine the geo-technical properties of selected strata to design a strategy for the proposed cut and fill exercises and the building foundations.

7.2.5 A geo-technical and geo-environmental site investigation comprising 16 No. Machine Excavated Trial Pits, 3 No. Hand dug Trial Pits and 4 No. Mini percussive boreholes with in-situ soil strength testing (Standard/Cone Penetration (SPT/CPT) was carried out at the site. The number of testing locations is considered appropriate due to the low variation in ground conditions and historical and current use across the development site.

7.2.6 Refer to Drawing 09063-ES-100 in Appendix 7.3 for a plan of the testing locations.

7.2.7 Machine excavated trial pits were performed in the south of the site using a JCB 3CX. Due to restrictions imposed by the Countryside Council for Wales, only hand-dug trial pits were permitted in the former PoW camp.

7.2.8 Trial pits were spread across the site to provide a good degree of coverage. Selected trial pits were positioned to target specific proposed buildings and development areas. Windowless Sampler Boreholes were positioned to provide deeper geological information in proposed cut areas and within the proposed pool area and one was also positioned adjacent to a large swallow hole feature to determine the geological profile adjacent to it.

7.2.9 The hand dug trial pits were positioned close to the alignment of the proposed road in the north of the site and machine excavated trial pit 11 was located within a large depression which is suspected to represent a possible partially subsided solution feature.

Geo-Technical Summary

Site History

7.2.10 The history of the site has been traced using historic maps from an Envirocheck Report. Selected editions of the maps are presented in the site investigation report in Volume 3, Appendix 7.1. Key years are discussed below:

> *1885: The 1885 edition shows the site to comprise undeveloped field with the exception of two small buildings in the east of the site. Three small areas of woodland are positioned in the west of the site, where solution features were observed during the walkover survey. A further area of woodland is positioned near the centre of the site and this may also represent a solution feature although this would need to be confirmed. Ewenny pottery and associated clay pits are positioned approximately 200m southeast of the site. The site is bound on its south-western and western sides by a lane. Fields surround the site. The Ogmore River runs approximately 200m southwest of the site at its nearest point.*

1900: The 1900 edition shows the site to still comprise undeveloped fields. The Vale of Glamorgan Railway has been developed by this time and this runs along the south-eastern edge of the site. A rifle range is located to the northwest of the site.

1921: The 1921 edition shows those features mentioned previously.

1941: By 1941 buildings had been erected in the north of the site including an individual structure named crossways and a series of hostels. The A48 had been constructed by this time. Historic records reveal that the huts were initially constructed to house workers from the nearby Royal Ordnance Factory and was converted into a Prisoner of War Camp later in the Second World War. The remainder of the site was open fields.

1964: The 1964 edition shows the site to remain unchanged, with the huts and building in the north of the site and fields in the south of the site.

1992/93: The 1992/93 edition shows the huts to still be present in the north of the site. The Crossways building is identified as a Country Club. Between 1983 and 1993 factories were constructed at Technology Drive located immediately east of the study site.

1999: The 1999 edition shows that all the huts had been demolished by this time with the exception of one hut in the east of the site and a large building in the northwest of the site. Crossways country club is still present.

2006/2009:The 2006/2009 editions reveal that Crossways Country Club was demolished by 2006 and that only one hut remains of the former camp. The south of the site remains open fields.

7.2.11 It is proposed that the area to the north and west of the site is safeguarded and enhanced for nature conservation and is largely undeveloped save for road access. Drawing 09063-ES-102, included as Appendix 7.4 shows the split between the development zone and the safeguarded area. As these two areas are different in terms of past use and proposed use they are considered separately throughout this Section and are referred to as:

"North Site", proposed area safeguarded for nature conservation

"South Site", proposed development zone

Current Use and Site Conditions

7.2.12 The north of the site is accessed via a lay-by off the A48. The site contains areas of concrete and tarmac hard standing from the former camp. The location of many of the former huts is overgrown with dense vegetation.

7.2.13 Hut No. 9 is preserved and is surrounded by a tall steel fence. The hut is a prefabricated concrete construction.

7.2.14 Hard standing areas were also located at the site of the former Crossways Country Club. A large mound of crushed concrete and brick is positioned near the centre of the site. Subject to testing and environment agency approval, this material is suitable for re-use in construction following simple processing.

7.2.15 The majority of the northern site is bounded by hedgerows and trees.

7.2.16 The south of the site is seen to comprise large open fields bounded by hedgerows and trees. The fields are currently sown with barley.

7.2.17 A large high voltage pylon runs across the site from south-east to north-west and a smaller electricity pylon also crosses the south-west corner of the site.

7.2.18 Three large tree-filled depressions were located in the south of the site and further depressions were also noted.

Geology

7.2.19 The geological maps of the area show that the solid geology beneath the site is masked by a cover of “superficial” deposits, which in this case are gravelly silts and clays.

7.2.20 Based on the outcrop of the solid geology in the vicinity of the site it appears that the site is north of the boundary of the Carboniferous Limestone Series and rocks of the Lower Lias (Jurassic). The site is, therefore underlain by the Lower Lias

7.2.21 The Geological Map indicates that the study site is underlain by superficial deposits of Glacial Sand and Gravel in the west of the site with Boulder Clay in the east of the site.

7.2.22 A typical trial pit excavated during the intrusive works shows that topsoil depths range from 0.2m to 0.7m deep, a silty material from 0.2m to around 2m deep with increasing gravels and cobbles from 2.0m down. Boreholes showed that rock head is between 5m and 7m below existing ground level. Full trial pit and borehole logs are presented in the Stage 2 Terra Firma Site Investigation Report in Appendix 7.2. Across the development site the ground conditions show little variation.

7.2.23 The geology beneath the site is susceptible to natural cavity formations features, referred hereafter as “Karst” features. These cavity formations are often referred to as swallow holes and are naturally occurring voids within the ground. Specific investigations have been undertaken to assess this presence of such features across the site and such features have been observed in the south of the site. Areas affected by karst will require special consideration. This issue was raised in the Scoping Opinion of February 2009 and is covered in more detail in Section 7.6.

Site Clearance Summary

7.2.24 The existing grass and scrub vegetation, including roots and topsoil will be grubbed up and removed from beneath the proposed buildings, car parks and highways as the construction programme dictates. Topsoil will be set aside for reuse in the extensive landscaping areas where suitable. Any excavations that require filling as a result of root removal will be backfilled with suitable clean material under the cut and fill bulk earthworks operations. All materials will

be placed in accordance with the methodologies of Series 600 of the Specification for Highway Works.

7.2.25 A site waste management plan will be developed in accordance with the Site Waste Management Plans Regulations 2008 along with an earthworks management plan to address the issues with earthmoving and reuse associated with clearance operations. The plan will be developed with and approved by the Environment Agency

Earthworks Summary

7.2.26 Careful consideration has been given to minimising existing site disruption by setting development platform levels as close to the existing as possible. Several ground model options were developed and analysed to determine the optimum base development levels.

7.2.27 Ground modelling of the masterplan has shown that a cut and fill earthworks balance will be achieved within the site boundary without adversely affecting the finished heights of the proposed buildings or the interfaces with existing infrastructure at the site boundaries.

7.2.28 This will avoid importing fill material to achieve desired levels and remove the requirement for disposal of surplus material 'off site' with corresponding environmental benefits. Avoiding large numbers of vehicle movement to move cut/fill material benefits the construction programme, the local residents and the environment in general.

7.2.29 Through an iterative process the development platform levels were refined to find the optimum levels. This has informed the masterplan as a whole. Level changes between each platform can be achieved with landscaped batters rather that extensive retaining structures.

7.2.30 Appendix 7.5 contains the simplified development formation levels within the development zone, cut and fill summary and simplified earthworks contours.

Foundation Solutions

7.2.31 For simple low rise structures traditional mass concrete strip / trench fill / pad foundations, extended into the medium dense to dense sandy gravels or stiff clay will be applicable for the majority of the buildings.

7.2.32 For the given foundation solution and in-situ materials a safe allowable bearing pressure of 150 kN/m2 should be feasible.

7.2.33 Foundations for the more significant buildings such as the main stadium are likely to be large pad foundations or piled. Structures near any Karst feature or at risk from the formation of such a feature will be piled in such a way to avoid the structural risk (refer to Section 7.6).

7.2.34 The floor slabs may be designed as ground bearing provided they sit upon competent natural material or well placed compacted granular material placed in accordance with Series 600 of the Specifications for Highway Works. Alternatively they may be designed as suspended.

7.2.35 Following the completion of the geotechnical testing in August 2009 the outline foundation solutions for the various building are summarised below:

- Sports Centre – Traditional foundations
- Main Rugby League Stadium – Traditional or Piled foundations

- Rugby Union Stadium – Traditional or piled foundations
- Tennis Centre – Traditional or piled foundations
- Football Stand - Traditional or piled foundations
- Other Low Rise Structures - Traditional foundations

7.2.36 The foundation solutions above are based on current information, it is recognised that where Karst features exist under proposed footprints more detailed information will be obtained to determine exact foundation solution. It should be noted that once Karst features have been treated then the above foundation types are still applicable albeit adapted to suit the specific location. This may mean that in a piling scenario (if required) the piles are founded further into the limestone at a depth below identified Karst features.

7.2.37 In accordance with EA Guidance on pollution prevention 'Piling and Penetrative Ground Improvement methods on land affected by Contamination' where possible piled solutions will be avoided due to the presence of a major aquifer partially within the site boundary. If the detailed design loads require a piled solution then this would be assessed against the Guidance document.

7.2.38 Environmental risks to groundwater posed by foundation solutions are covered in Section 11.4.

7.3 Karst Features (Natural Cavity Formations)

7.3.1 As stated in Section 7.2 the geology beneath the site is susceptible to natural cavity formation or "Karst" features these are sometimes referred to as sink or swallow holes.

7.3.2 It has been theorised that natural cavities within the limestone were previously in communication with the surface and that these features were in-filled with superficial glacial deposits at the end of the ice age. Subsequent washing-out of the cavity backfill by groundwater has resulted in the creation of voids which eventually reach the surface.

7.3.3 These features have the potential to be direct pathways between ground surface and ground water and may pose a risk to controlled waters. It is demonstrated later in this section that the risk to controlled waters from site derived contamination is insignificant

7.3.4 As the intrusive investigations carried out in July/August investigations have concluded that the existing ground is classified as clean and poses minimal risk. It is however recognized that the scope and extent of these features has to be fully determined to assess not only the risk to the controlled waters that may arise from construction activities but the engineering implication of such features in respect of building footprints.

Identifying Extent of Karst Risk

7.3.5 Within the scope of the Stage 2 Site investigations 3 large well developed surface solutions were identified, along with several less developed features suggesting partially formed solutions across the site.

7.3.6 One large solution feature (K1) is present in the centre of the site, which sits in the vicinity of

the proposed Rugby League stadium. Two further smaller features have been observed in the South West of the site denoted K2 and K3. (See Appendix 7.8, Figure 1)

K1: 42 X 20 X 6.5m Deep Max

K2: 12 X 9 X 4.7m Deep Max

K3: 22 X 10 X 5.8m Deep Max

7.3.7 An Intrusive investigation was carried out alongside one of these features the results of which indicated that the rock head was approximately at the same depth of the base of the depression suggesting that the depression extends to rock-head and thus, a voids lies within the underlying bedrock, superficial material has been washed into these voids until the voids have become temporarily blocked and/or the overlying superficial materials have obtained their natural angle of repose.

7.3.8 The existing material in the base of the features which comprise reworked superficial deposits, is likely to be in a state of flux and, in addition, the depressions will serve to concentrate surface water flow. The subterranean voids may contain sub-surface water flow. The backfill in the base of these features is, therefore, likely to be very unstable and prone to further sudden subsidence.

7.3.9 Prior to detailed design further site investigation will need to be carried out to inform the detailed foundation design and remedial solutions and will include excavation and removal of vegetation and superficial material observed in existing features to determine the base of the known feature and associated hydrology. In addition across the development site Geological (geo-morphological) mapping of the vulnerable sections of the site will be undertaken to further identify surface subsidence features and abnormalities in the surface. It is conceivable that the three large features in the south of the site are in hydraulic conductivity due to their close proximity and may, therefore, be a surface expression of a larger single karstic system at depth.

7.3.10 In addition, areas of interest identified during the completed site investigations and future morphological mapping will be subject to a geo-physical (or similar) investigation, which is likely to comprise selected deep rotary core boreholes within the footprint of significant structures to assess geophysical anomalies and to assist with the calibration of the geophysical data that will inform the detailed foundation design.

7.3.11 Once the full extent of the natural cavity features have been identified detailed engineering solutions and management strategies for dealing with the risk to controlled waters will be prepared during consultation with the Environment Agency.

7.3.12 Following this consultation agreed management strategies will be incorporated into the construction package ensuring implementation during scheme development

Karst Treatment (Options)

7.3.13 The method of Karst treatment will depend not only on the size and extent of features identified in the more detailed investigation works but also the proposed land uses above

7.3.14 Appendix 7.6 identifies that of the three known solutions features K1 will have an impact on

the proposed Rugby League stadium whilst K2 is in a landscaping area and K3 partially under proposed sports pitches.

7.3.15 It is possible that more detailed investigation may identify further features which, depending on nature and extent would be subject to a number of engineering solutions.

7.3.16 A number of options are available for treatment of these features and may include the following

- If the affected area does not contain a structure or car park the treatment of the feature will be primarily concerned with the protection of end users. If the morphology of the feature and the location does not affect the proposed development, it may be sufficient to fence-off the features in a manner that prevents access. Alternatively the features could be backfilled in a non-engineered fashion and incorporated into landscaping arrangements, backfilling of these features would remove the risk to the end user.
- If a feature is backfilled, inert granular material should be used below the water table to maintain groundwater flow. Any backfilled feature should be monitored as settlement may occur over time and topping-up may be required.
- If potential features are identified in areas of proposed parks/playing fields a tensile geo-textile can be buried at shallow depth to prevent any catastrophic subsidence of the surface. The textile should be fastened to competent soil/rock beyond the edges of the feature.
- If an engineered treatment of a karstic feature is necessary to allow structural development, it is likely that the treatment will be performed using pressure grouting. Any subsidence would first be cleaned out then backfilled to ground level and a grillage erected to allow safe passage across the feature. Grouting would be performed in a grid extending beyond the perimeter of the feature and the pressure Vs depth profile of the treatment would be designed by a Geotechnical Consultant. Provision would be made for carrying out validation of grout treatment and there may be a requirement to maintain hydraulic conductivity beneath the water table.

7.3.17 Consultations with the Environment Agency would be undertaken to determine a suitable grout mixture for use within a Major Aquifer and also to establish a monitoring regime during the injection phase of the works.

7.3.18 Refer to appendix 7.6 (Drawing 09036-ES-104) for a schematic showing typical karst treatment.

7.3.19 Specialist foundations will be required if structures are to be erected above, or within the zone of influence of treated Karst features. Such designs would be based on individual assessments following treatment although typically raft or reinforced strip foundations, with a capacity to accommodate ground settlement and span depressions, may be employed. Where design dictates the requirement for higher loadings then piled solutions would be employed and would typically found on competent material below the base of the remediated Karst feature.

7.3.20 Detailed investigation as previously described will inform the foundation design.

7.3.21 The risk to groundwater posed by treatment of Karst features is assessed in Section 11.4

Radon

7.3.22 A Radon report has been obtained and is included in the Stage 2 geo-environmental and geo-technical site investigation report which is included in Appendix 7.2.

7.3.23 Basic radon protection measures are required for the site. This will be incorporated during the detailed design of the foundations.

7.4 Contamination Risk Assessment and Remediation

7.4.1 Environmental risk assessment evaluates the risk to receptors via an analysis of the 'source-pathway-receptor' linkage. In order for a risk to be present, there must be a contaminant source capable of causing a health risk, a vulnerable receptor, and a pathway linking the two.

7.4.2 The results obtained from the Stage 2 Site Investigation, were used to conduct an environmental risk assessment for the site. The objectives of the risk assessment are as follows:

- Identify sensitive receptors
- Determine pathways for contaminant migration to the receptors
- Estimate nature and extent contaminants and assess impact on receptors
- Establish whether remedial action is required
- Calculate remediation target levels if required

7.4.3 The future use of the site i.e. whether it is to be used for residential or commercial has an impact on any risk assessment. For the current assessment the ATRISK Guidelines for parks and playing fields, provided by Atkins Environmental, were used where appropriate. The parks and playing fields guidelines are more conservative than the corresponding guidelines for a commercial development and, therefore, are suitable as a screening tool for assessing the Human Health Risk posed by soils beneath either type of development.

7.4.4 For the Island Farm site it is necessary to consider the two main parts individually. The "Development Zone" to the south of the site, which is currently undeveloped agricultural land and the "Nature Area" to the north of the site. These two areas are shown on Drawing 09063-ES-102, included in Appendix 7.4

Risk Assessment Methodology

7.4.5 This sort of risk assessment is usually conducted using a tiered approach. Tier 1 consists of a comparison of the analytical results obtained from the site investigation with Soil Guideline Values (SGV's) specific to the type of development obtained from The Environment Agency Contaminated Land Exposure Assessment (CLEA) Guidelines.

- Should Tier 1 levels be exceeded, a choice is made either to remediate the site to conservative Tier 1 levels, or proceed to Tier 2.
- Tier 2 makes use of site-specific data to evaluate acceptable concentrations of

chemicals for the particular conditions present at the site.

- At each tier, the amount and detail of investigation work increases as more site-specific data are needed to refine the characterisation of the site. Conversely, as site conditions are better understood, a more site-specific remediation strategy can be determined.

Potential Sources of Contamination

7.4.6 The sources of contamination considered in the risk assessment are taken to be concentrations of chemicals beneath the site. The potential contamination beneath the site, whether in the matrix of the soil or groundwater will be related to the site's past use.

7.4.7 The historical map review has revealed that the south of the site has had an uneventful history, being agricultural land during its recorded history. The north of the site has previously been developed with accommodation which was later adopted as a PoW camp. Whilst we have not identified any industrial processes associated with the site historically, there may be impact from heating fuels, vehicular fuels and possible burning ground associated with the camp.

Potential Pollution Pathways

7.4.8 The various pathways considered in the risk assessment are:

- Direct contact/inhalation/ingestion of affected superficial soils, up to 1.0m
- in depth
- Wind born dust from affected superficial soils
- Leaching from soils to groundwater
- Groundwater transport
- Potential Receptors

7.4.9 Potential receptors include:

- Construction site workers
- Future staff based at the Island Farm development.
- Future visitors, end-users of the site
- Residents in the area surrounding the site
- Persons who may come into contact with water in the vicinity of the site
- The underlying major aquifer
- Nearby surface waters and aquatic life in these waters.

Conceptual Model

7.4.10 A conceptual model is a representation of environmental processes on the site and its immediate vicinity. Its purpose is to identify potential contaminants, pathways and receptors

with a view to identifying potential and significant pollution linkages.

7.4.11 Chemical testing has revealed that the determinants tested were present at concentrations below the relevant guidelines for a commercial/industrial development. The ground investigation encountered groundwater within at 3m below current ground level.

7.4.12 The Site Conceptual Model is presented in Appendix 7.8 Figures 2 and 3;

Evaluation of Analytical Results

7.4.13 For Tier 1, the site itself is considered to be the receptor. Therefore, attenuation of contaminants between the source and receptor is not considered.

7.4.14 The regulatory guidelines used to compare the concentration of the tested elements/compounds are in general The Environment Agency Contaminated Land Exposure Assessment (CLEA) Guidelines. Where guidance on tolerable concentrations of individual substances is not given in CLEA, reference has been made to the ATRISK Values calculated by Atkins Environmental Ltd.

7.4.15 For the purpose of human health risk assessment the site was divided into two areas for consideration. The northern area (i.e. the former PoW Camp) where no development is proposed except for new infrastructure was considered separately from the south of the site where development is proposed.

7.4.16 Refer to drawing 09063-ES-102, included in Appendix 7.4 for the north / south site split.

7.4.17 A summary of the chemical test results which include the regulatory trigger and action levels used in the Tier 1 assessment are given in Table 5.1 of the Stage 2 Site Investigation by Terra Firma in Appendix 7.2

Summary of determinants tested for at both North and South sites:

Arsenic	Cadmium	Chromium
Copper	Lead	Mercury
Nickel	Selenium	Zinc
Cyanide	MonoPhenol	Sulphate
pH	PAH (total)	Asbestos(silicates)

Northern Area only (PAH)

Naphthalene	Fluoranthene	Benzo(k)fluoranthene
Acenaphthylene	Pyrene	Benzo(a)pyrene
Acenaphthene	Benzo(a)anthracene	Dibenzo(ah)anthracene
Fluorene	Chrysene	Benzo(ghi)perylene
Phenanthrene	Benzo(b)fluoranthene	Indeno(123cd)pyrene
Anthracene		

Development Zone "Southern Area"

7.4.18 It can be seen from Table 5.1 that the determinants (chemicals) tested were all present at concentrations below the relevant Human Health guidelines for Parks and Playing Fields and, therefore, also for an Industrial/Commercial development.

7.4.19 One basis of these results the southern site can be deemed as suitable for its proposed end use in respect to Human Health Risk without modification in relation to contamination.

7.4.20 Whilst future site occupiers/users will not be exposed to significant levels of soil contamination, ground workers will be in more intimate contact with the soils during the construction phase and should, therefore, take standard personal measures to protect themselves. This practice is covered by current health and safety at work legislation.

7.4.21 The Environment Agency's *"Model Procedures for the Management of Land Contamination, Contaminated Land Report 11"* shows in Figure 1 that in the case of the development zone that following the risk assessment carried out in the Stage 2 site investigations that no further action is required as it is known that there are no potential risks to the receptors (above concern levels) as the pollutant linkage is not complete as the essential element "contamination" is not present despite clear pathways and receptors.

7.4.22 From the work completed in both the Stage 1 desk study and Stage 2 intrusive investigation it can be concluded that the ground within the development zone is uncontaminated and that a remediation strategy is not necessary.

7.4.23 Preventing risks to the identified receptors during the construction stage is covered in Section 11.4.

7.4.24 Preventing risk during the construction stage to construction works can be achieved through the use of standard personal protective equipment.

Nature zone "Northern Area"

7.4.25 Industrial processes are not associated with the site historically, it was anticipated that there may be impact from heating fuels, vehicular fuels and possible burning ground associated with the camp.

7.4.26 Within the northern site, all determinants tested were present at concentrations below the relevant soil guidelines with the exception of elevated levels of Total PAH in the made ground samples.

7.4.27 The highest recorded PAH result was split into its constituent parts to determine the composition of the total PAH value since the individual PAH species have differing toxicities and hence different soil guideline values.

7.4.28 The PAH data was compared to the ATRISK Generic Guideline Values for Open Spaces, which is the appropriate set of guideline values for potential Hut-9 visitors. The guideline values for the potential Hut-9 staff members are less onerous than that of the open space guidelines.

7.4.29 All of the recorded concentrations were below the generic guideline values and hence the tested soils can be considered to not pose a human health risk is relation to the sites proposed end use.

7.4.30 Asbestos was not detected during the testing of three made ground soil samples from the northern site.

Risks to Human Health

7.4.31 In respect to the sites proposed end use, significant levels of contamination were not encountered. However, during the construction phase

7.4.32 A Risk Assessment considers the following receptors/targets:

- Future Site Occupier
- Site Visitors, passers-by and neighbours during construction phase
- Construction workers

7.4.33 The potential routes of exposure (pathway) considered are:

- Ingestion of soil
- Ingestion of soil dust
- Dermal contact with soil
- Inhalation of fugitive soil
- Inhalation of volatile organic vapours

7.4.34 A Qualitative Risk Assessment is presented in the following table.

Table 6.1 – Human Health Risk Assessment

Source	**Pathway**	**Target**	**Risk Assessment**	**Mitigation Measures**
In-situ Made Ground	Dermal contact with soil/dust Inhalation of soil/dust Ingestion of soil/dust Inhalation of organic vapours	Construction workers	Low risk to site construction workers involved in excavation phase of development	COSHH assessment and good level of PPE/ hygiene by site workers/ staff; dust suppression measures if required
In-situ Made Ground	Dermal contact with soil/dust Inhalation of soil/dust Ingestion of soil/dust	Passers-by & neighbours during construction phase	Low risk during construction phase.	Dust suppression measures should be employed if required

In-situ Made Ground	Dermal contact with soil/dust Inhalation of soil/dust Ingestion of soil/dust Ingestion of vegetables Inhalation of organic vapours	Future site users	Negligible risk provide mitigating measures are employed	Source will then no longer be present.

7.4.35 The above concludes that due to the low risk nature of this site that the mitigation measures are simple and are part of standard construction working practices.

Risks to the Aquatic Environment

7.4.36 Leachate analysis has revealed that the made ground soils do not leach the determinants tested at concentrations exceeding the guidelines for environmental protection. The site can therefore be considered as not posing a risk to the aquatic environment.

7.4.37 This is covered in more depth in Section 11.3

7.5 Summary and Conclusions

7.5.1 Following a two stage geo-environmental and geo-technical investigation at the proposed site the following conclusions have been presented:

7.5.2 In the development zone the existing ground is uncontaminated so the risk to end-users, construction workers and the geological/hydrological environment is negligible. Minor contamination in the nature area is below the levels for its intended use. The site does not require remediation and an earthworks balance will be achieved on the site.

7.5.3 Karst features will be fully investigated and recorded before detailed design commences and appropriate engineering treatment carried out to remove risks associated with their presence. Risk to the aquatic environment is considered low following treatment.

7.5.4 It has been demonstrated that from a Geotechnical and Geo-environmental viewpoint that the residual effects of the development to both Human health and the aquatic Environment are considered negligible to minor.