6.0 GEOLOGY, GROUND CONDITIONS AND SOILS

Introduction

6.1 This section details the geological setting of the application site and discusses the present ground conditions. An outline of the geotechnical issues that would need to be taken into account for the proposed development is presented, together with a summary of the measures that would be implemented to mitigate the potential impacts relating to these geotechnical issues. Finally, this section provides a consideration of soil resources within the application site.

Methodology

6.2 The methodology applied in the assessment is a qualitative risk assessment methodology, in which the probability of an impact occurring and the magnitude of the impact, if it were to occur, are considered. This approach provides a mechanism for identifying the areas where mitigation measures are required, and for identifying mitigation measures appropriate to the risk presented by the development. This approach allows effort to be focused on reducing risk where the greatest benefit may result. The assessment of risk is outlined in Table 6/1.

Table 6/1
Matrix used to Estimate Risk

Probability of occurrence	Magnitude of potential Impacts			
	Severe	Moderate	Mild	Negligible
High	High	High	Medium	Low
Medium	High	Medium	Low	Near Zero
Low	Medium	Low	Low	Near Zero
Negligible	Low	Near Zero	Near Zero	Near Zero

Sources of Information

6.3 The following sources of information, which detail the geology of the site and the surrounding area, have been made available and consulted as part of this review:

- British Geological Survey Sheet 1:63,360 scale, No. 112 (Solid and Drift) – Chesterfield;
- British Geological Survey Sheet 1:50,000 scale, No 125 (Solid and Drift) – Derby;
- Planning Application, Bentinck Void, Terry Adams Limited, 1997;
- Addendum to Planning Application, Bentinck Void, Terry Adams Limited, August 1998;

- Assessment of Ground Conditions at the Former Bentinck Open Cast Site, Nottinghamshire, Marcus Hodges Environment Limited, May 1997; and
- Bentinck Tip Environmental Statement, MJ Carter Associates, September 1998.

Regional Geology

6.4 The available geological information for the Bentinck Tip and Void is presented in the following manner;

- Stratigraphical summary presented in Table 6/2;
- Drawing BC 6/1 presents the regional geology as an excerpt from the geological maps; and
- Drawing BC 6/2 presents the regional cross section which passes through the southern part of the application site.

Drift Geology

6.5 The geological maps detailed in paragraph 6.3 indicate that the western part of the application site (within the Bentinck Site) is underlain predominately by Boulder Clay. Small lenses of Glacial Sands and Gravels are present in the south of the application site, and a strip of Alluvium associated with the natural path of the Cuttail Brook is present trending approximately north-south through the centre of the application site. All drift deposits are of Pleistocene and Recent age.

6.6 The geological maps also show that drift deposits do not cover the application site in its entirety; solid geology outcrops on the eastern part of the application site.

Solid Geology

6.7 The majority of the application site is underlain by Middle Coal Measures of Carboniferous age.

6.8 The Middle Coal Measures comprise a number of marine bands, sandstone lenses, and coal bands with a total thickness of up to 450m.

6.9 Outcropping north-south along the eastern boundary of the application site is Permian bedrock comprising a lower mudstone facies (formerly termed the Lower Permian Marl) overlain by an upper carbonate facies (formerly termed the Lower Magnesian Limestone). The outcrop youngs towards the east, so that the mudstone facies outcrops along the eastern boundary of the application site and the upper carbonate facies outcrops to the east of the application site boundary.

6.10 A summary of the characteristics of the regional geological succession are shown in Table 6/2.

Table 6/2
Regional Geological Succession

Formation	Characteristics
Pleistocene to Recent Glacial Sand and Gravel and Boulder Clay	Up to 20m of unconsolidated sands, gravels and clays.
Permian	Up to 40m of Permian age deposits consisting of an upper carbonate facies (formerly termed the Lower Magnesian Limestone) deposited under marine conditions and comprising a silty dolomitic limestone. This passes downwards into lower mudstone facies (formerly known as the Lower Permian Marl) comprising calcarious shales, sandy mudstones and thin sandstones, deposited under a fluviatile regime
Lower Carboniferous Coal Measures	Predominantly Middle Coal Measures, greater than 100m of mudstones, siltstones, sandstones and occasional coal seams.

Local Geology

Superficial and Drift Geology

6.11 Superficial and drift deposits are present within the application site boundary and comprise Made Ground, Boulder Clay, Glacial Sands and Gravels and Alluvium.

6.12 Subsequent to the publication of the regional geological maps detailed in 6.3 opencasting has taken place at the application site, resulting in the majority of the natural drift deposits, and in particular Boulder Clay detailed on these maps, being excavated as part of the opencast process.

6.13 Boulder Clay is only present generally on ground above 115mAOD in the west of the application site. The boundary of the Boulder Clay runs approximately north-west to south-east and site investigation has proven these deposits to comprise approximately 1.5m of stiff clay with fine gravel, overlying 3.8m of sandy clay and gravel adjacent to the western site boundary.

6.14 Made Ground, comprising colliery spoil fill through to a clay with mudstone and sandstone blocks, is present over the majority of the application site with a range of thicknesses.

6.15 Made Ground in the southern part of the application site is up to 9m thick to the east and up to 30m thick in the west. The base of the void was reformed using Made Ground with approximately 17m of compacted colliery spoil. Up to 22m of Made Ground is present across the eastern side slopes of the reformed valley area.

6.16 Made Ground in the form of spoil tips covers natural ground over much of the northern part of the application site. The voids left by opencasting have also been infilled by colliery spoil.

6.17 Marcus Hodges Environment Limited states that an embankment of Made Ground, between 30m and 70m wide, was located at the old railways sidings running south from the northern boundary of the application site to the centre of the tip area in the northern half of the site. It is considered unlikely that the embankment was removed before tipping commenced in the northern void area, and it is therefore likely that it has also been overtipped with colliery spoil.

6.18 Glacial Sand and Gravel deposits are present in the southern half of the application site, with a maximum thickness of up to 21m in the west. The deposits thin eastwards to around 5 metres near the void in the southern part of the application site.

6.19 Prior to opencasting, Glacial Sands and Gravels were also present across the entire northern half of the application site.

6.20 Previous investigations including the M1 Motorway site investigation show that the Glacial Sands and Gravels extend westwards beneath the M1 Motorway and Selston Village, and comprise stiff clays interbedded with sands and gravels.

6.21 The Glacial Sands and Gravels directly overlie the residual undisturbed Coal Measures in the south western corner of the site.

6.22 Site investigations have proved Glacial Sand and Gravel deposits to the west of the application site, and four groundwater monitoring boreholes (91/97, 92/97, 94/97 and 95/97) have been completed within glacial strata. The Glacial Sands and Gravels are within a south-west to north-easterly trending glacial channel.

6.23 Alluvial deposits, which form a channel with a width of up to 45m, overlie the valley floor of the Cuttail Brook.

6.24 There are no superficial or drift deposits over most of the eastern side and centre of the application site.

Solid Geology

6.25 The site is located within the Middle Coal Measures strata, which have been subject to extensive previous opencast and underground coal mining.

6.26 A large number of boreholes have historically been drilled at the site to prove shallow coal seams, some of which were drilled in 1957 to assess the Rosedale Colliery south and east of the site.

6.27 The Middle Coal Measures comprise a cyclical sequence of predominantly mudstones with subordinate sandstones, siltstones, seat earths and coals. These strata dip to the south-east on the eastern side of the application site and to the north-east to the west of the site. The sandstone bands within the Coal Measures are considered to be laterally discontinuous.

6.28 Beneath the application site are mainly undifferentiated Coal Measures. However, particular marker horizons have been noted:

- The Mansfield Marine Band crops out beneath spoil near the eastern boundary in the north part of the application site.
- The Clown Coal subcrops the drift deposits immediately to the west of the application site boundary in the north, and is at an estimated depth of approximately 30m below ground level at the eastern edge of the site.
- There are small areas in the north-east of the application site, one stratigraphically above and one stratigraphically below the Mansfield Marine Band, where sandstone crops out beneath the spoil covering the northern part of the site.

6.29 The following Coal seams have been encountered during mining beneath the site:

- Clown, Mainbright, Two Foot, Lowbright, Brinsley Thin, High Hazles, Cinderhill, Dunsil, Second Waterloo, Top Hard, Top Soft, Deep Hard, Tupton and Blackshale.

6.30 The major productive coal seams are over 100m beneath the base of the application site. Mine workings are recorded at depths of between 130m and 580m below ground level.

6.31 The Coal Measures have been drilled to a maximum of 60m across the site to determine baseline conditions and install groundwater monitoring boreholes.

6.32 Younger Permian strata comprising marls, mudstones, limestones and sandstones unconformably overlie the Coal Measures along the eastern margins of the application site only.

6.33 The base of the Permian strata is marked by a unit previously termed the Lower Permian Marl. This is described as a grey sandy mudstone with calcareous shales, siltstone, limestone, thin reddish sandstones and dolomite bands, which weathers to a yellow brown colour.

6.34 The top of the Permian strata is marked by a unit previously termed the Lower Magnesian Limestone. This consists of a pale grey and yellow flaggy coarse granular crystalline dolomitic limestone with frequent silt horizons.

6.35 Transition between the marl and the limestone is gradational, and the strata dip regionally to the east with a shallow angle so that successively younger strata crop out from the west towards the east. The strata have a maximum thickness of about 40m.

6.36 The marl crops out along the eastern boundary of the application site and has been identified within several groundwater monitoring boreholes (86/97, 87/97 and 88/97) in the south-east of the application site. The marl increases in thickness to the east.

6.37 The limestone outcrops to the east of the application site outside the proposed development at a level above approximately 150mAOD, thereby forming the high ground on the eastern side of the Cuttail Brook Valley.

6.38 Further to the east of the application site, over the area of Annesley Woodhouse, the geological succession also includes Sherwood Sandstones.

Geological Structure

6.39 Regionally the Middle Coal Measures dip eastwards, beneath the Permian cover, at angles of about 5 to 8 degrees (1:12 and 1:8). Within the site these strata have undergone substantial disturbance due to irregular folding, faulting and fracturing.

6.40 Two major faults are identified on the published BGS geological maps. The first trends in a north-west to south-east direction, with a downthrow to the south-west of approximately 10m. This fault runs through the centre of the application site. The second fault trends north-north-west to south-south-east, and is downthrown to the west-north-west. This fault is present in the northern half of the application site only and is located in the east.

6.41 Two smaller faults have been proved at depth within the coal seams. Subsurface faults are recorded in the Top Hard seam with a downthrow of approximately 13.5m to the east, and in the Deep Hard seam with a downthrow of approximately 15.8m to the east. It is likely that the two faults recorded at depth and the faults shown at the surface crossing the centre of the site are the same structural feature.

6.42 Fault breccia present at site has been recorded in groundwater monitoring boreholes within the area of a mapped fault in the south-west part of the site.

Mining and Quarrying

6.43 The Bentinck Site has been subject to both opencast and underground coal mining in the past, both activities have now ceased within and below the site.

6.44 Former deep mining in the Top Hard and Lower Seams took place between 1822 and 1968 at depths of between 130m and 520m.

6.45 Portland Colliery shafts 1, 2, 4, 5, 6 and 7 previously existed for deep mining purposes within the application site boundary. Shaft 4 was located adjacent to the Cuttail Brook towards the north of the site, and shafts 5, 6 and 7 were also located in the north of the site. The main colliery shafts were located in the south of the site.

6.46 Shafts 4 and 5 were filled and capped in 1951 and 1974 prior to open cast workings. All shafts were capped by the end of the opencast operations in 1989 to a level between 101.4mAOD and 108mAOD.

6.47 Opencast workings were operational in the north of the application area between 1983 and 1986, and in the south of the application area between 1987 and 1989.

6.48 Opencasting in the south of the application site extended to a depth of 30m below ground level down to the Swinton Pottery Lower Seam.

6.49 In 1986 the northern part of the application site was consented for backfilling and restoration by colliery disposal and was used as a colliery spoil disposal site for the Annesley-Bentinck Colliery until its closure in the year 2000. However, in the southern part of the application site the backfilling of the opencast void ceased shortly after opencasting finished in 1989 and restoration work was never completed.

6.50 The Coal Authority state that the application site is not within the zone of influence, and that no ground movements have been recorded.

6.51 Both the Permian Strata (predominantly the Lower Magnesian Limestone) and the sand and gravel deposits have been quarried in the past, beyond the application site boundary to the west and south, respectively. Both these disused quarries are now nationally important sites for nature conservation (SSSIs).

Geotechnical Considerations

6.52 A number of issues relating to the geotechnical characteristics of the Bentinck site need to be taken into consideration for the proposed development. These issues are presented qualitatively in the "*Assessment of Potential Impacts*" (paragraph 6.55 *et seq*.) below. Outline mitigation measures are subsequently discussed in terms of the approach that would be adopted to ensure long term geotechnical stability and integrity of the proposed development. It is pointed out that mitigation measures can comprise detailed quantitative analyses that demonstrate acceptable levels of geotechnical stability and integrity without the need for physical mitigation. Such analyses are not within the scope of this assessment, but would be undertaken as part of standard regulatory requirements (see below).

6.53 The geotechnical issues and mitigation measures are presented in the context of the requirements of the PPC permit Application Stability Risk Assessment (SRA) that would need to be undertaken for the development proposals. The completion of the SRA would necessitate a detailed quantitative determination of the geotechnical stability and integrity of the development and would use all currently available geotechnical data, together with any additionally proposed data, in the analyses. The geotechnical stability and integrity of the site would only be accepted within the PPC process if the results of the quantitative assessment meet the strict requirements of the Environment Agency Guidance on such issues.

6.54 A landfill SRA is required to consider the following components of a development:

- Basal sub-grade;
- Side slope sub-grade;
- Basal lining system;
- Side slope lining system;
- Waste mass; and
- Capping system

Assessment of Potential Impacts

6.55 This section identifies all potential impacts of the development on the geological environment and assesses the potential impacts and the likelihood of occurrence as detailed in the Methodology section above. The results of this assessment are summarised in Table 6/3.

Summary of Proposed Development

6.56 The proposed development is described in detail in Section 3 of the ES. However, for ease of reference the main features are summarised here.

- Restoration of the void in the southern part of the application site by controlled infilling with non-hazardous waste ;
- Continued restoration of the tip in the northern part of the application site by inert wastes with a final blend of composting soils;
- Re-establishment and culverting of the Cuttail Brook; and
- Engineering of a site access road and site infrastructure from the A608 south of the application site

Impacts Associated with Proposed Development

6.57 The following paragraphs present a summary of the key geotechnical issues that could be encountered during both the development of the site and after closure of the site. The potential impacts are discussed in terms of the unmitigated situation.

6.58 Basal Sub-Grade: The development of the landfill in the south and the reclamation of the tip in the north of the application site lies in an area that has previously been mined by underground mining methods, with a number of capped shafts being present. Consideration must therefore be given to the possible effects of any underground workings and shafts on the proposed development, particularly in the long term, where ground movements could affect the integrity of the basal lining system. In determining the unmitigated potential impacts of these issues on the development, the current level of knowledge relating to the issues must be taken into account. The Coal Authority has stated that any movements relating to underground mining should now have stopped. In addition, it is understood that the shafts at the site were capped according to robust standards devised by the National Coal Board (NCB). In the absence of mitigation measures the likelihood of

occurrence is considered to be ‘low’, although the magnitude of potential impacts is considered to be ‘moderate’ to 'severe'. Hence, the overall risk is considered to be 'low' to ‘medium’.

6.59 Side Slope Sub-Grade: There are known areas of slope instability around the Void and it is understood that isolated incidences of instability have occurred within the fill materials to the north of the site. The latter were probably the result of tipping material with a high water content at a relatively rapid rate, leading to excess pore pressure generation and hence instability. The slips that have been noted in the void slopes are generally the result of over-steepened slope sections and localised groundwater seepages that tend to soften the tipped materials and in-situ mudstones. Careful consideration would be given to the excavation to formation levels of the Tip to the north of the void owing to the fact that old coal tailings deposits are present. Any instability within the side slope sub-grade would have an impact on the integrity of the side slope lining system and possibly the functioning of the proposed Cuttail Brook culvert extension. However, it is emphasised that side slope stability would be effectively eliminated once the slopes are buttressed by the placement of waste. This issue therefore relates to the period prior to waste filling. In the absence of mitigation, the likelihood of the occurrence of instability is considered to be ‘medium’, and the magnitude of the potential impact is considered to be ‘moderate’, such that the overall risk is considered to be 'medium'.

6.60 Basal Lining System: Where groundwater is artificially lowered prior to the construction of a low permeability lining system, a rise in the groundwater level can result in heave of the lining system. However, as the level of the basal liner has been designed to lie above the proposed groundwater rebound level, the likelihood of occurrence is considered to be ‘negligible’ and the magnitude of the potential impact is considered to be ‘severe’, such that the overall risk is considered to be ‘low'.

6.61 Side Slope Lining System: Damage to the lining system resulting from side slope sub-grade stability is assessed in the same manner as instability of the side slope sub-grade itself. Additional risks to the side slope sub-grade include:

i) the potential for instability to occur as a result of rising groundwater levels (similar to the impacts noted above for the basal lining system); and
ii) the settlement of the side slope sub-grade giving.

6.62 The former is assessed in the same manner as the basal lining ('severe'), while the latter could potentially occur on the slope formed on the former tip/lagoons to the north of the void. However, the magnitude of settlement of the slope under the weight of the new waste would be small given the degree of consolidation of softer materials that has already taken place and, more importantly, the potential for differential settlements to occur at the slope surface would be minimal owing to the ability of the materials overlying any soft deposits to disperse differences in consolidation settlement that occur in the sub-strata. The likelihood of occurrence of differential settlements up the

side slope is considered to be ‘low’ and the magnitude of the potential impact is considered to be ‘mild', such that the overall risk is considered to be ‘low'. In addition, the effects on the lining system of the settlement of the waste mass need to be considered in the same context *i.e.* long term integrity. Again, with appropriate design, the assessed overall risk is assessed as being 'low'.

6.63 Waste Mass: This aspect in the SRA relates to the stability of the waste mass which is essentially dictated by good design and operation of the landfill. Given that the detailed design and proposed phasing of the operation would be undertaken by experienced personnel, and also given that the site would be operated in accordance with strict corporate procedures, the likelihood of occurrence of waste mass instability is assessed as being 'low'. However, should waste mass instability occur, there is the potential that the side slope and/or basal lining systems could be damaged, although any damage could be repaired. The magnitude of potential impacts is therefore considered to be 'moderate', with the overall risk assessed as being 'low'.

6.64 Capping System: The capping system is required to provide a low permeability seal to minimise the infiltration of rainfall. Capping systems are subject to the influence of differential settlements within the underlying waste mass. However, while waste does settle significantly, the occurrence of *differential* settlements (*i.e.* those that could cause damage to the capping system) are rare. Furthermore, the impact on leachate levels for a limited area of damaged cap would be minor. Therefore, the likelihood of occurrence of differential settlements beneath the cap is assessed as 'low', with the magnitude of potential impacts being 'negligible', and the overall assessment of risk being 'near zero'. In terms of the stability of the capping system on the proposed pre-settlement slopes, again, appropriate design would ensure that the likelihood of occurrence of instability is 'low', and the overall assessed risk is therefore assessed as being 'near zero'.

6.65 Other Components: The current development also includes two other structures for which risk must be assessed; these being the extension to the Cuttail Brook culvert and the compost maturation facility. In terms of the former, this is to be founded on a bench cut into the in-situ ground on the eastern side of the void. Therefore, the risks associated with the potential to occur for both i) ground movements associated with former mining activities and ii) side slope instability would both apply here. Given the probability that ground movements associated with underground mining should now have stopped (according to the Coal Authority report), the likelihood of occurrence is assessed as being 'low'. The likelihood of side slope instability occurring is assessed, as before, as being 'medium'. However, any problems associated with the functionality of the culvert as a result of ground movements/instability would have serious implications in hydrological terms and the potential magnitude of impacts is assessed as being 'severe'. The overall risk is therefore assessed as being 'medium'.

6.66 The compost maturation facility is to be constructed at the toe of a slope forming the retaining wall of Lagoon 30/15. There is to be some degree of

excavation of the slope to accommodate the building. Although no clear evidence of historic instability is evident, seepage has been noted at the toe of the slope and there exists the potential for excavation works to disturb the current equilibrium. Therefore, the likelihood of occurrence of instability of the slope above the structure is assessed as being 'medium'. Should a slope failure occur, there would be a risk of loss of life, and so the magnitude of potential impacts are assessed as being 'severe', with the overall assessment of risk being 'high'.

6.67 A summary of all of the above potential impacts is presented in Table 6/3.

Table 6/3
Summary of Potential Impacts

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Magnitude of Impact	Significance of Impact	Mitigation Required ?
Ground movements in basal sub-grade	Local, long-term	Low	Moderate to Severe	Low to Medium	Yes
Side slope sub-grade instability	Local, short- to medium-term	Medium	Moderate	Medium	Yes
Basal lining system heave	Local/regional, short- to medium-term	Negligible	Severe	Low	No
Side slope lining system stability and integrity	Local, short- to medium-term	Low	Mild	Low	Yes
Waste mass stability	Local/regional, short- to medium-term	Low	Moderate	Low	Yes*
Capping system stability and integrity	Local, medium- to long-term	Low	Negligible	Near Zero	Yes*
Cuttail Brook functionality	Local/regional, short- to long-term	Low	Severe	Medium	Yes
Slope stability above compost facility	Local, short- to medium-term	Medium	Severe	High	Yes

*'Mitigation' constitutes appropriate design only

Identification of Appropriate Mitigation Measures

6.68 Table 6/3 identified the impacts that require mitigation measures to reduce the impacts of the development to acceptable levels. Mitigation measures are identified within this section can comprise:

i) further study (data gathering and/or analyses) that provides a high degree of confidence in the assessment of 'low' or 'negligible' likelihood or

ii) the implementation of works to reduce the likelihood of an event occurring or reduce the magnitude of the consequences if the event does occur.

6.69 It should be noted that several of the mitigation measures proposed below would have a positive effect on more than one potential impact, as identified in Table 6/3. Table 6/4 summarises the mitigation measures applied to each potential impact.

6.70 Basal Sub-Grade: The level of data available with respect to former coal mining activities (either through archive material, Coal Authority reports or site investigations that have been undertaken) is considered to provide a high degree of confidence in the assessed 'low' likelihood of mining-related ground movements occurring. Further study, either through assessment of currently available data, or supplementary data acquisition, would reduce the assessed likelihood to 'negligible'. This can be achieved by undertaking detailed analysis of the potential effects of ground movements on the development. The analyses would include the consideration of engineering measures such as grouting or use of geosynthetics to control the effects of potential ground movements should these be deemed to be required.

6.71 Side Slope Sub-Grade: Limit equilibrium slope stability analyses would be undertaken in order to determine the factors of safety for both current slopes and those that would exist once the engineering works associated with the formation of the required side slopes have been completed. The extent of current data for use in the analyses would be assessed and further data acquired if considered necessary. In particular, the analyses of the proposed cut slope to the north of the void would take into account the presence of buried lagoon deposits, with sensitivity analyses being undertaken on key variables, such as the presence of excess pore pressures/degree of consolidation of slurries and proximity of weak material to the excavated face. The analyses would be developed, where necessary, to incorporate appropriate ground engineering solutions where the assessed level of stability is considered inadequate. Such solutions could include the simple slackening of slope angles or use of ground improvement techniques such as soil reinforcement, buttressing, accelerated consolidation and soil strengthening. By adopting appropriate target factors of safety, the analyses would be able to ensure that all designed slopes will have a 'low' to 'negligible' likelihood of occurrence of instability. In the longer term, the actual filling of the site with waste would effectively stabilise the side slopes and can be considered a mitigation measure with respect to the stability of the existing side slopes. The long-term likelihood of side slope instability is therefore 'negligible' and the residual risk is assessed as being 'near zero'.

6.72 Basal Lining System: Although the significance of impact of groundwater rebound on the basal lining system has been determined to be low, it is proposed that a groundwater underdrainage system would be installed together with drainage grips on the sidewalls. The underdrainage would consist of slotted pipework in a gravel surround installed underneath the basal liner and around the boundaries of the excavation during landfill engineering.

In the highly unlikely event of groundwater rebound occurring to levels above 110mAOD this drainage system would allow groundwater beneath and adjacent to the site to be removed by pumping, thereby preventing the development of excessive pressures.

6.73 Side Slope Lining System: Potential damage to the side slope lining system resulting from instability and/or excessive underlying groundwater pressures would be reduced to 'negligible' levels by adopting the measures described above for the side slope sub-grade and basal lining system. While the assessed risk for differential settlements to impact the side slope lining system is 'low', detailed numerical analyses would, nonetheless, be undertaken to demonstrate this within the SRA. These analyses can be considered a mitigation measure that provides a high degree of confidence in the initial qualitative assessment ensuring that the residual risk would be 'low' to 'near zero'.

6.74 Waste Mass Stability: Here, the mitigation is considered to simply comprise the appropriate design of the landfill ensuring that temporary waste slopes exist at all times with suitable factors of safety against instability. The residual risk attained should therefore be 'low'.

6.75 Capping: As with waste mass stability, the mitigation is considered to simply comprise the appropriate design of the capping system. The residual risk attained should therefore be 'low' to 'near zero'.

6.76 Cuttial Brook Culvert: The mitigation measures proposed for the stabilisation of the side slopes adjacent to the route of the culvert reduce the likelihood of the occurrence of slope instability from 'medium' to 'near zero'. In terms of the ground conditions of the bench upon which the culvert will be founded, it is proposed that these be investigated by appropriate methods and be remediated using suitable methods (*e.g.* grouting) if the requirement to do so is indicated by the investigative works. The goal of the design assessment would be to achieve 'negligible' likelihood of occurrence of culvert problems, and the overall residual risk to the culvert is assessed as being 'low'.

6.77 Compost maturation facility: The mitigation measures for the potential slope instability above the facility are as described above for the side slope sub-grade (i.e. resulting in 'negligible' likelihood of occurrence). Hence, the residual risk is assessed as being 'low'.

Assessment of Residual Impacts

6.78 Table 6/4 summarises the identified mitigation measures and details the residual impacts at the Bentinck Site.

6.79 Examination of Table 6/4 confirms that there are no significant residual impacts with respect to geology/geotechnics.

Table 6/4
Summary of Mitigation and Residual Impacts

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Magnitude of Impact	Significance of Impact	Mitigation Required?	Mitigation Measures	Mitigated Probability of Occurrence	Mitigated Magnitude of Impact	Residual Magnitude of Impact
Ground movements in basal sub-grade	Local, long-term	Low	Moderate to Severe	Low to Medium	Yes	Additional study and numerical modelling	Negligible	Moderate to Severe	Low
Side slope sub-grade instability	Local, short- to medium-term	Medium	Moderate	Medium	Yes	Stability analyses and slope design	Negligible	Moderate	Near Zero
Basal lining system heave	Local/regional, short- to medium-term	Negigible	Severe	Low	No	N/A	N/A	N/A	N/A
Side slope lining system stability and integrity	Local, short- to medium-term	Low	Mild	Low	Yes	Underdrainage system, numerical analyses	Negligible	Moderate	Near Zero
Waste mass stability	Local/regional, short- to medium-term	Low	Moderate	Low	Yes	Appropriate design based upon stability modelling	Low	Moderate	Low
Capping system stability and integrity	Local, medium- to long-term	Low	Negligible	Near Zero	Yes	Appropriate design based upon stability and integrity modelling	Low	Negligible	Near Zero
Cuttail Brook	Local/regional,	Low	Severe	Medium	Yes	Site	Negligible	Severe	Low

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Magnitude of Impact	Significance of Impact	Mitigation Required?	Mitigation Measures	Mitigated Probability of Occurrence	Mitigated Magnitude of Impact	Residual Magnitude of Impact
functionality	short- to long-term					investigation, possible ground improvement measures			
Slope stability above composting facility	Local, short- to medium-term	Medium	Severe	High	Yes	Stability analyses and slope design	Negligible	Severe	Low

SOILS

Introduction

6.80 As set out in Section 2, the main body of the application site is largely devoid of any soil cover. Soils have been removed, coal extracted by opencast methods and colliery spoils has been tipped within the northern section.

6.81 A small area of essentially unworked farmland is situated in the south-west corner of the main site, now partly covered by a soil storage mound which has grassland over. It is understood that no soils are available within the Tip, however, a series of topsoil and subsoil storage mounds are scattered around the periphery of the Void, remaining from the opencast operations.

6.82 The line of the proposed access road on the other hand is currently in agricultural use.

6.83 There is no previously published detailed Agricultural Land Classification (ALC) data for either of the parts described above, although work carried out by ADAS as part of the 1997 Terry Adams application has demonstrated that land within the haul road corridor ranges from grades 3b to 2.

6.84 Soil resources for the reclamation of the Bentinck site are detailed in the Restoration part of Section 3. The remainder of this section assesses the soil resource along the line of the access road.

Agricultural Land and Farming Practices

6.85 The haul road corridor, as shown edged in red on the application plan (Drawing BC 2/2 and BC 3/14) occupies around 12.5 ha. In practice 7.7 ha of the corridor width would be taken out of agricultural use, with approximately 4.2 ha accommodating the highway works and the balance used to create new habitats.

6.86 In July and August 1997 ADAS carried out a survey on a substantially larger area of almost 40 ha in the vicinity of the access road. The purpose of the survey was to provide details on the physical characteristics of the soil to indicate the land quality and to enable an appropriate restoration scheme to be designed.

6.87 The soils were augured to a target depth of 100 cm at approximately 100 m intervals along the centre line of the proposed access road with additional borings on each side. A total of 34 auger borings and two pits were undertaken. As a result of this work 8 separate soil units were identified. The characteristics of these units are summarised below, whilst a copy of the ADAS report is included at Appendix 6/1.

Unit 1

6.88 These soils are the most extensive within the study area and have developed over fill. They consist typically of about 270 mm of medium clay loam topsoil overlaying clay loam upper subsoil to a depth of around 500 mm to 700 mm. Below this depth the lower subsoil varies from clay loam in the south to clay in the north. They are gleyed within 400 mm in most profiles and fall into Wetness Class IV and III.

Unit 2

6.89 These soils have developed in Coal Measure deposits. They consist typically of 250 mm of medium to heavy clay loam topsoil, overlying similarly textured upper subsoils to a depth of about 450-500 mm. They are slowly permeable and show signs of seasonal wetness in the subsoil. They fall into Wetness Class IV and III.

Unit 3

6.90 These include medium to heavy textured disturbed soils of Coal Measure and till origin. They consist typically of 230 mm of medium clay loam to sandy clay loam topsoil on clay loam subsoil to about 1000m. They are slightly compact, have some drainage impedance and fall into Wetness Class IV

Unit 4

6.91 This is of limited extent and occurs where previous cut and fill operations have taken place. It consists typically of about 500 mm of slightly stony unweathered red marl over stony fill.

Unit 5

6.92 This includes a small area of moderately to well drained sandy soils, typically consisting of 270 mm of sandy loam, or sandy clay loam topsoil on loamy sand or sand subsoil down to about 1000 mm.

Unit 6

6.93 This unit is mapped over old pasture partly colonised by scrub and woodland. The soils are similar to Unit 2 but contain more organic topsoil. There are some deep organic clay loams in the vicinity of a wet flash.

Unit 7

6.94 These are areas with no soil at the surface including hardcored or tarmaced area around the gas unit.

Unit 8

6.95 This unit is mapped over soil stores which consist predominantly of sandy clay loam topsoil in the top 400 mm.

6.96 The agricultural land quality (ALC) of the haul route study has been assessed by ADAS. In brief, the land quality ranges from Grade 2 to Sub-grade 3b, the distribution in percentage terms of these grades is shown in Table 6/5. The proposed location of the road itself does not impinge on the Grade 2 land.

Table 6/5
Distribution of Agricultural Land Grades in the Haul Road Corridor

Grade	Area (ha)	% Agricultural Land	% Total Area
1	-	-	-
2	0.6	1.8	1.5
3a	12.6	38.4	31.7
3b	19.6	59.8	49.4
4	-	-	-
5	-	-	-
Non-ag/Urban	6.9	-	17.4
Total	**39.7**	**100.0**	**100.0**

6.97 The study area land currently supports cereals, oil seed rape and grass which is grazed by horses. It is farmed from Two Dale Farm.

Predicted Operational Period Effects

6.98 The construction of the access road and its continued use, in connection with the landfilling of the Void and reclamation of the Tip, would remove some 7.7 ha of moderate to good agricultural land from productive use. However, this is a small percentage of the agricultural unit in question and it would not have a significant effect on the viability of the rest of the farm unit. Furthermore, as the proposed haul road would closely follow the boundary of the agricultural land with the M1 over most of its 1.6 km length it thus would not sever any substantial area of land from the unit which farms it.

Mitigation

6.99 The loss of land associated with the construction of the access road, and its immediate environs, is an unavoidable impact of the development on agriculture. The proposed mitigation would be to strip, store and replace the soils overlying the access road in such a way that the land can be restored to its original quality and thus there would be minimal long-term loss of agricultural quality or productivity. In order to do this the steps set out in paragraphs 6.100 to 6.104 would be taken. Allied to this, severed parcels of land would be managed for nature conservation enhancement, thereby enhancing its value to offset the loss of agricultural land. This would include broadleaved woodland planting, areas of species rich grassland associated

with roadside verges and bunding, new swales/drainage ditches and a number of small scale, fish-free ponds.

6.100 Soil stripping procedures would include:

- all excessive vegetation would be stripped and the grass would be cut or grazed down to a maximum of 50 mm.
- the soils would only be handled when in a dry and friable condition between April and September.
- soils would be handled using back-acters and dump trucks and all unnecessary trafficking across soils would be avoided.
- the soils would be separately stripped (and separately stored) in accordance with the stripping and storage recommendations made by ADAS and summarised in Table 6/6 below.

6.101 Whilst soil storage procedures would ensure that:

- the soil would be stored in separate mounds as identified in Table 6/6
- the mounds would be as shallow as practicable and in any event topsoil mounds would not exceed 3 metres in height. Subsoil mounds would not exceed 5 metres. Side slopes would not exceed 1 in 3.
- soils would be stored "like on like", so that topsoil is always stripped from under subsoil mounds.
- the mounds would be appropriately cultivated and grass/clover would be established in the earliest available sowing season on all storage mounds which are to be in place for more that 6 months.
- the sward would be maintained by cutting at least twice per annum and appropriate action would be taken (*e.g.* spraying) to prevent the establishment of broad leafed weeds.

Table 6/6
Summary of Soil Stripping and Storage Requirements

Unit	Horizon	Depth (mm)	Storage Mound
1	Topsoil Upper Subsoil Lower Subsoil	0 – 270 270 – 600 6050 – 1000	1a 1b 1c
2	Topsoil Subsoil Lower Subsoil	0 – 250 250 – 450 450 – 1000	2a 2b 2c
3	Topsoil Subsoil	0 – 230 230 – 1000	3a 3b
4	Soil Making Material (SMM) SMM/fill ?	0 – 500 500 +	4a 4b
5	Topsoil Subsoil	0 – 270 270 – 1000 or to sandstone	5a 5b
6	Topsoil Subsoil	0 – 200 200 – 1000	6a 6b
7	(Madeground)		discard
8	Topsoil (in store)	n/a	n/a

6.102 Soil Reinstatement

- unless there is any subsequent proposal to retain any part of the haul road as a farm track, it would be dug out to formation level, the construction materials removed from site, and the formation level ripped or deep-rooted to relieve compaction.
- soil horizons would be replaced in the correct sequence, *i.e.* lower subsoil, upper subsoil and topsoil.
- so far as practicable, the soils would be replaced in the same area from which they were removed to minimise trafficking and to ensure continuity with the surrounding areas.
- as each horizon is replaced it would be thoroughly subsoiled, in dry conditions, prior to spreading the next layer. The subsoiling would be carried out with a winged subsoiled and the spacing between the tines would not be more than 1.5 times the depth.
- topsoil samples would be analysed and lime fertilisers applied as necessary to correct and deficiencies.

6.103 Vegetation Establishment

- fixed and chain harrows would be used to prepare a fine filth as a seed bed.
- NPK 15:15:15 pre-seed fertiliser would be incorporated into the topsoil at a rate of 150 kg/ha.
- seeding with a suitable grass seeds mixture at a rate of 40 kg/ha would be carried out in dry calm weather when the soil is not wet or frozen.

6.104 Aftercare

- an aftercare scheme in accordance with the recommendations of MPG7 would be submitted to the minerals planning authority for its approval, and thereafter implemented to ensure that the grass sword is fully established without dieback or regression.
- all disturbed hedgerows would be re-established.

Predicted Residual and Long Term Effects

6.105 At the end of the operational life the landfill vehicular access would still be required to the Bentinck Site for maintenance operations, be it in connection with the aftercare, or the environmental management infrastructure. On completion of the restoration works, the access road would be downgraded to a single lane road with passing bays. Ultimately, once the landfill gas engines were removed from the site the access road would be removed. The substrate ripped to relieve compaction, a subsoil and topsoil would be replaced and the surface cultivated to bring the land back into agricultural use in accordance with the more detailed specifications set out above. The land would then enter a five year aftercare period to restore it back to its previous agricultural grade, or better. There would inevitably be some loss of

agricultural productivity during the aftercare period, where the emphasis is on re-establishing soil fertility rather than productivity but this would be marginal in the context of the agricultural units as a whole. After this period there would be no adverse long term impacts.

CONCLUSIONS

6.106 The geology, ground conditions and soil resources at the application site have been assessed with reference to all currently available relevant information.

6.107 The application site is situated within the Middle Coal Measures, which have previously been mined using both opencast and deep mining methods. The Coal Measures are overlain by Glacial Sands and Gravels in the south-west of the application area and by the Permian Marl in the east of the application site. There is a substantial thickness of Made Ground across the application site and in particular surrounding the southern void and the northern tip.

6.108 The site would be engineered to form a landfill in the south of the application site and restoration of a tip by infilling with inert soils in the north of the site.

6.109 The potential impacts of the proposed development upon the geological environment and soil resources have been identified and assessed, and where appropriate, mitigation measures have been accommodated into the design of the development.

6.110 Overall, it is concluded that, with respect to the geological environment, there are no significant residual impacts of the development after consideration of the identified mitigation measures.