7.0 HYDROLOGY AND HYDROGEOLOGY

Introduction

7.1 This section details the local hydrology and hydrogeology of the application site and surrounding area, identifies potential hydrogeological and hydrological impacts associated with the proposed development and discusses appropriate mitigation measures. The assessment is based on a detailed baseline description of the local geology (which is set out in the previous section) and the hydrological and hydrogeological regimes.

Methodology

7.2 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 focussed on reducing risk where the greatest benefit may result. The assessment of risk is outlined in Table 7/1.

Table 7/1
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

Information Sources

7.3 The following sources of information have been consulted in order to investigate the hydrogeology and hydrology of the area surrounding the application site:

- Ordnance Survey 1:25,000 scale Explorer Map No. 269, Chesterfield and Alfreton;
- Environment Agency Policy and Practice for the Protection of Groundwater Vulnerability 1:100,000 Map Series, Sheet 18 – Nottinghamshire;
- Environment Agency Policy and Practice for the Protection of Groundwater, 1998;

- Environment Agency Website (www.environment-agency.gov.uk) for details of groundwater source protection zones, indicative fluvial and tidal floodplains and river quality;
- Centre for Ecology and Hydrology and British Geological Survey Wallingford Hydrometric Register and Statistics 1996-2000;
- Institute of Hydrology Flood Estimation Handbook CD ROM (1999);
- Ministry of Agriculture, Fisheries and Food (MAFF) Technical Bulletin 34 Climate and Drainage (1975);
- Envirocheck Report based on a two kilometre envelope around the application site;
- Local Council for private water abstractions;
- Planning Application, Bentinck Void, Terry Adams Limited, 1997;
- Addendum to Planning Application, Bentinck Void, Terry Adams Limited, August 1998;
- Bentinck Tip Environmental Statement, MJ Carter Associates, September 1998; and
- Mine water rebound in South Nottinghamshire: risk evaluation using 3-D visualization and predictive modelling, Dumpleton et al, 2001, Quarterly Journal of Engineering Geology and Hydrogeology, Volume 34, Part 3, 307-319.

7.4 The hydrological regime at the application site and the surrounding area is considered in a number of sections: recharge mechanisms and aquifer characteristics; groundwater levels and flow; water abstractions and Source Protection Zones; and finally, groundwater quality. This is followed by a discussion of the local hydrology and surface water quality.

7.5 The hydrological data has been used to develop a conceptual site model that is used to assess potential impacts associated with the proposed development. The model has also been used to determine appropriate mitigation measures.

Recharge Mechanisms and Aquifer Characteristics

7.6 The Institute of Hydrology (FEH CD ROM, 1999) reports that the average annual rainfall at the application site is 721mm. This concurs with the MAFF Agroclimate Bulletin 34 (Area 16), which reports the average annual rainfall varies between 540mm/year to 800mm/year with an annual average total of 622mm/year. MAFF report total winter and summer potential transpiration values of 68mm and 442mm respectively.

7.7 The Meteorological Office record rainfall at Kirkby Sewage Works (NGR SK 484 548), where the average annual rainfall between 1941 and 1970 was 730mm. This, which is comparable with the Institute of Hydrology and slightly more than the average for the agroclimate region.

7.8 The geology of the application site is reported in Section 6. In summary the northern Tip area is partially filled with colliery spoil with the southern void area remaining open. Originally superficial deposits covered the entire application site comprising Glacial Sands and Gravels with Boulder Clay, with thicknesses up to 20m prior to opencast mining. The glacial deposits thin towards the east and are present with a thickness of approximately 5m towards the void. A considerable thickness (up to 40m) of Made Ground is present within the application site. The superficial deposits overlie Permian strata in the east of the site which comprises a lower mudstone facies (formerly termed the Lower Permian Marl) overlain by an upper carbonate facies (formerly termed the Lower Magnesian Limestone), of which only the lower mudstone facies is present beneath the site. The Permian deposits overlie Middle Coal Measures of Carboniferous age.

7.9 The Environment Agency's Groundwater Vulnerability Map Sheet 18 Nottinghamshire (see Drawing BC7/1) shows the application site is situated on a 'minor aquifer'.

7.10 Table 7/2 presents a more detailed description and hydrogeological classification of the individual materials found at the application site.

7.11 Rainfall onto the low permeability fill deposits would form surface water runoff preferentially. Rainfall onto the Sands and Gravels would potentially recharge the groundwater within the Sands and Gravel unit and, where in continuity, would provide recharge to the more permeable sandstone units within the Middle Coal Measures.

7.12 The Environment Agency's Groundwater Vulnerability Map, Sheet 18, Nottinghamshire (see Drawing BC7/1) reports that the soils within the application site have a vulnerability class (soil leaching potential) of 'Low'. Soils with vulnerability class Low are those in which pollutants are unlikely to penetrate the soil layer because water movement is largely horizontal, or they have the ability to attenuate diffuse pollutants. Lateral flow from these soils may contribute to groundwater recharge elsewhere in the catchment.

Table 7/2
Hydrogeological Classification of Materials Found at Site

Period	Geological Unit	Description	Hydrogeological Classification[1]
Pleistocene to Recent	Glacial Sand and Gravel and Boulder Clay	Variably permeable unconsolidated deposits of Glacial Sand and Gravel with bands of low permeability clays.	Minor Aquifer
Permian	Upper carbonate facies (formerly termed the Lower Magnesian Limestone)	Outcrops entirely to the east of the site outside the application site boundary, comprising silty dolomitic limestone. Highly permeable, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes.	Major Aquifer
	Lower mudstone facies (formerly termed the Lower Permian Marl)	Generally regarded as containing insignificant quantities of groundwater. However, groundwater flow through such rocks, although imperceptible, does take place and needs to be considered in assessing the risk associated with persistent pollutants. Some Non-Aquifers can yield water in sufficient quantities for domestic use and provide base flows to rivers.	Non-Aquifer
Carboniferous	Coal Measures	Fractured or potentially fractured rocks. Characteristically low primary permeability, but a variable secondary permeability. Although these aquifers would seldom produce large quantities of water for abstraction, they are important both for local supplies and in supplying base flow to rivers.	Minor Aquifer

[1] After Environment Agency, Policy and Practice for the Protection of Groundwater

Groundwater Levels and Flow

7.13 The Envirocheck report does not detail the presence of any groundwater elevation monitoring points within 2km of the application site.

7.14 Groundwater has been encountered in 27 boreholes around the Void, installed during 1997 to provide a groundwater and gas monitoring network. Locations are shown within Appendix 7/1 which contains the Terry Adams Limited reports. Only small quantities of groundwater were encountered during drilling within the Made Ground, Glacial soils and bedrock materials. A summary of the installations is shown in Table 7/3. Review of the borehole installation details and initial rest water levels indicates the following:

Made Ground

Nine boreholes encountered fill. Made Ground was found in the lower central part of the southern half of the application site around the void. Monitoring installations were installed to monitor groundwater in the fill deposits in seven of the nine boreholes. Rest water levels show that two of the boreholes were found to be dry, and in the others groundwater ranged from approximately 102mAOD in BH98/97 adjacent to the western slope of the void to 118mAOD in BH96/97 towards the west of the application site.

Sand and Gravel

Sand and gravel was encountered in a total of thirteen boreholes located in the south-west of the application site, to the west of the void area. A total of eleven boreholes have been instrumented to enable monitoring of groundwater within these horizons. Of these monitoring installations two boreholes were dry. In the remainder of the boreholes the rest water levels range from approximately 118mAOD in BH89/97, the borehole closest to the void, to approximately 149mAOD in BH110/97, which is located to the west of the void on the edge of Bogs Wood SSSI.

Permian

Permian deposits (considered to be the lower mudstone facies), were encountered in three boreholes situated on the eastern boundary of the application site. Of these boreholes, one was installed to solely monitor groundwater within these deposits. This borehole encountered groundwater at a rest level of approximately 122mAOD.

Coal Measures

Coal Measures strata were encountered in twenty of the twenty seven boreholes across the entire southern part of the application site. A total of eight monitoring installations were installed to monitor the groundwater encountered in the Coal Measures only. The majority of these boreholes are located to the west of the void. All of the Coal Measures boreholes have recorded a rest water level. Rest water levels indicate that groundwater ranges from 97mAOD in BH90/97 located to the west of the void, to 134mAOD in BH108/97 in the south-western corner of the application site.

7.15 Within the Made Ground deposits groundwater is associated with discrete perched horizons, overlying lower permeability clays within the colliery spoil. Groundwater levels within the Made Ground are not comparable with groundwater levels within the Sands and Gravels, therefore suggesting that they are not in hydraulic continuity.

7.16 Groundwater, where present, within the Sand and Gravel deposits is primarily at the base of the strata where directly overlying low permeability Coal Measure Mudstone. It is probable that there are also minor perched bodies of groundwater higher in the sequence supported by clay bands or lenses. Groundwater occurs at elevations of up to 22m above those in the Coal Measures.

7.17 Bogs Farm Quarry SSSI is situated within the Sand and Gravel deposits and has been designated on account of its plant communities, which are supported by acid-loam marsh conditions with flushes and open water. The SSSI is supported by recharge from shallow groundwater in the Sands and Gravels and runoff derived from farmland to the west. This area includes up to 30% of the surface water and groundwater catchment of the SSSI. Further consideration of the potential impacts upon the SSSI are set out in paragraphs 7.101 below and in Section 13)

7.18 The lower mudstone facies (formerly termed the Lower Permian Marl) comprises silty clays and does not contain any permeable units. It is therefore considered not to be in hydraulic continuity with the overlying upper carbonate facies (formerly termed the Lower Magnesian Limestone) located to the east of the eastern boundary of the application site.

7.19 Marcus Hodges Environment (1997)[2] state that permeability tests conducted within the Coal Measures strata have indicated a permeability of between 10^{-5} and 10^{-7}m/s. Laboratory tests on undisturbed mudstone bedrock indicate a permeability of between 10^{-10} to 10^{-11} m/s.

7.20 MJ Carter (1998) note that in the northern part of the application site there are groundwater springs beneath the Tip. They conclude that this is evidence of perched groundwater within the Coal Measures.

7.21 Groundwater in the Middle Coal Measures beneath the void ranges from c.110mAOD on the eastern edge through to c.102mAOD on the western edge. Groundwater is at c.105mAOD beneath the void itself.

7.22 Analysis of the initial groundwater rest levels within the boreholes installed within and around the Void (see Table 7/3, below) has shown that in general the direction of flow reflects topography; flow onto the site from the east, south and west is radially towards borehole 90/97, located to the west of the void.

[2] Assessment of Ground Conditions at the Former Bentinck OCCS, Nottinghamshire. Marcus Hodges Ltd, September 1997

7.23 Terry Adams Limited (August 1998) states the hydraulic gradient ranges from 0.08 to 0.15 across the western and eastern valley to a shallow gradient of 0.03 beneath the base of the void.

Table 7/3
Summary of Borehole Installations around the Void in the Southern Part of the Application Site.

Location (Drawing BC7/1) Drilled Ref	Monitoring Ref	Anticipated Geology	Drilled Depth (m)	Strata	Borehole Installation Length of Screen	Filter screen	Completion	Initial Rest Water Levels After Completion (mbgl)	Plumbed depth (mbdl)
085/97	1	Coal Measures	40	CM	30	9.7-39.7	slotted	6.59	39.7
086/97	2	Fill/Permian	10	Fill	3	6.66-9.66	wrapped	Dry	9.66
087/97	3	Fill/Permian	18.2	Permian	3	14.3-17.3	wrapped	16	17.3
088/97	4	Fill/Permian/Coal Measures	60	CM	40	19-59	slotted	17.39	59
089/97	5	Sand and Gravel	10.5	SG	6	4.38-10.38	wrapped	7.26	10.38
090/97	6	Sand and Gravel/Coal Measures	50.2	CM	30	20.1-50.1	wrapped	30.13	50.1
091/97	7	Sand and Gravel	12	SG	6	5.8-11.8	wrapped	9.2	11.8
092/97	8	Sand and Gravel	19.5	SG	15	3.38-18.38	wrapped	18.3	18.38
093/97	9	Sand and Gravel/Coal Measures	45	CM	18	26.8-44.8	slotted	30.1	44.8
094/97	10	Sand and Gravel	18	SG	3	15.1-18.1	wrapped	17.81	18.1
095/97	11	Sand and Gravel	13.5	SG	3	7.66-10.66	wrapped	10.28	10.66
096/97	12	Soil/Fill/Coal Measures	33.2	Fill	20	13.15-33.15	wrapped	33.14	33.15
097/97	13	Fill/Coal Measures	27.2	Fill	1.5	18.78-20.28	wrapped	19.3	20.28
098/97	14	Fill/Coal Measures	10.5	Fill	1.5	8.5-10	wrapped	10.43	10
099/97	15	Fill/Coal Measures	22.3	Fill	12	8.15-20.15	wrapped	10.32	20.15
100/97	16	Fill/Coal Measures	19.8	Fill	1.5	15.78-20.28	wrapped	Dry	17.28
104/97	20	Fill/Coal Measures	6	Fill	3	2.8-5.8	wrapped	5.88	5.8
101/97	17	Coal Measures	20	CM	10	4.0-14.0	Cass. Piez	4.93	14
102/97	18	Coal Measures	35.8	CM	30	3.62-33.62	slotted	1.74	33.62
103/97	19	Coal Measures	35	CM	10	4.13-14.13	Cass. piez	6.7	14.13
108/97	24	Coal Measures	20.5	CM	6	14.5-20.5	slotted	16.3	20.5
105/97	21	Sand and gravel/Coal Measures	6	SG	4.8	1-5.8	Cass.Piez	Dry	5.8
106/97	22	Sand and gravel/Coal Measures	6.5	SG	4.9	1-5.9	Cass.Piez	5.8	5.9
107/97	23	Sand and gravel/Coal Measures	7	SG	4.9	1-5.9	Cass.Piez	Dry	5.9
109/97	25	Sand and gravel/Coal Measures	6.4	SG	5.4	1-6.4	Cass.Piez	1.74	6.4
110/97	26	Sand and gravel/Coal Measures	5.2	SG	4.2	1-5.2	Cass.Piez	1.01	5.2
111/97	27	Sand and gravel/Coal Measures	3	SG	2	1.0-3.0	Cass.Piez	2	3

7.24 It is considered likely that local groundwater flow and elevations may be influenced by a fault crossing the site (refer to Section 6). Marcus Hodges Environment (1997) suggested that this fault may act as an impermeable boundary to groundwater flow, resulting in higher groundwater elevations upgradient of the fault in the west of the site.

7.25 Groundwater flow at the site may also be influenced by pumping which is systematically undertaken over the entire South Nottinghamshire Coalfield to artificially lower the water table to the deepest working levels.

7.26 Groundwater from the mined areas of Bentinck, Newstead and Annesley collieries flow to Annesley, where it is pumped from the level of the active workings in the Blackshale Coal. The water is abstracted at a rate of approximately 6.5 mega litres pre day (Ml/d) or 75 l/s. Water is not discharged locally due to elevated chloride levels and is piped 18 miles to the south, discharging to the River Trent.

7.27 Dumpleton *et. al*. (2001) report that in 1996 the Annesley-Bentinck pumping station north of the application site had an average pumping rate of 3.79 Ml/d. Upstream from Annesley-Bentinck are pumping stations 'A' Winning (3.81 Ml/d) and Woodside (12.48 Ml/d). When these two pumping stations cease the mine waters would flow towards Annesley-Bentinck. When pumping operations at Annesley-Bentinck cease water flow would be downdip towards Calverton Colliery and to the point of lowest working at 670mBOD (Top Hard) prior to commencement of final flooding and rebound of water levels. It is suggested that there is an interconnected drainage system through the current and old workings and that pumping would continue for at least as long as the reserves at Calverton are worked.

7.28 Once pits close and pumps are switched off, iron-rich and possibly acid mine waters are expected to flood the workings and ultimately to rebound to a level which may allow discharge to surface in the exposed coalfield.

7.29 Previous reports (Marcus Hodges Environment, 1997[3]) considered a worst case groundwater rebound to the level of the Cuttail Brook at 110mAOD.

Water Abstractions and Groundwater Source Protection Zones

Water Abstractions

7.30 The Envirocheck report details two current licensed abstractions within 2km of application site. Summary details are presented in Table 7/4, and their locations are shown on Drawing BC7/2. This information indicates the following:

- Both of the abstractions are from surface water;
- The abstractions approximately 300m north-east of the application site is from the River Erewash; and

[3] Bentinck Void Outline Landfill Design. Marcus Hodges Ltd, November 1997 (Report No. 50842/R2)

- The abstraction approximately 1km to the south-east of the application site is from the Cuttail Brook.

Table 7/4
Licensed Abstractions within 2km of Application Site

Ref No	Licence No.	Owner	Purpose	Type	Source	National Grid Ref
1	03/28/61/0066	Annesley Bentinck Mine Limited	Extractive: Process Water	Water abstracted from a single point: Surface Water	River Erewash	SK 486 548
2	03/28/61/0054,1	Kodak Ltd	Impounding	Surface Water	Cuttail Brook	SK 499 528

7.31 Formerly British Coal Corporation had a license (03/28/61/0017) to abstract surface water from the River Erewash for industrial processing at the Bentinck Colliery. The license allowed up to 1,309m^3 per day or 454,600 m^3 per year to be abstracted at SK 485 548. The license has now either been revoked, cancelled or lapsed.

7.32 Ashfield District Council Environmental Health Department have confirmed that there are no private water supplies within 2km of the application site.

7.33 The Ordnance Survey 1:25,000 map (Explorer 269) shows the location of a well within the vicinity of the application site. The well is located at SK 493 552 some 1.2km to the north-east, adjacent to the River Erewash. It is not known if this well is still active.

Groundwater Source Protection Zones

7.34 The Environment Agency has confirmed that part of the application site (namely the access onto the A608) lies within Zone III of a Source Protection Zone. Zone III is described as the Total Catchment area needed to support the abstraction of discharge from the protected groundwater source. The Groundwater Source Protection Zone is shown on Drawing BC 7/2.

7.35 The Inner Catchment Zone is located towards the north-east of the application site. This suggests that groundwater reserves are drawn from the highly permeable Lower Magnesian Limestone major aquifer, which outcrops to the east of the application site.

Groundwater Quality

7.36 Groundwater has been analysed from ten of the available monitoring locations on site: three monitoring groundwater in the Made Ground deposits; two monitoring groundwater in the Sand and Gravel deposits and five monitoring the groundwater within the Coal Measures strata.

7.37 A summary of groundwater quality from this initial characterisation analysis is shown in Table 7/5.

7.38 Groundwater within the Made Ground deposits is of a poorer quality than the Coal Measures with the Drinking Waster Standard (DWS) exceeded for magnesium, ammonia, manganese, iron and potassium.

7.39 Groundwater within the Sands and Gravels is of better quality than the Coal Measures, only exceeding the DWS for manganese and iron.

7.40 Groundwater quality within the Coal Measures strata generally exceeded the Drinking Water Standards (DWS) for the following determinands :

- Ammonia - 1.5mg/l in BH90/97 and 0.6mg/l BH102/97 (DWS of 0.39mg/l)
- Magnesium - 51mg/l in BH88/97 (DWS of 50mg/l)
- Manganese - 0.47mg/l in BH87/97, 0.45mg/l in BH088/97, 0.34mg/l in BH90/97, 1.86mg/l in BH93/97 and 0.079mg/l in BH102/97 (DWS of 0.05mg/l); and
- Iron - 0.23mg/l in BH88/97 and 0.36mg/l in BH90/97 (DWS of 0.2mg/l)

Table 7/5
Summary of Initial Groundwater Quality Characterisation Analysis

Borehole	Monitored Strata	Conductivity uS/cm	Magnesium(diss) mg/l	Alkalinity mg/l (HC03)	Ammonia mg/l (N)	TON mg/l (N)	Nitrate mg/l (N)	Nitrite mg/l (N)	Chloride mg/l	Ammonium mg/l (NH4)
098/97	Fill	3070	250	763	1.8	<1.0	<0.99	0.009	66	2.3
099/97	Fill	1450	88	430	1.3	<1.0	<0.98	0.015	28	1.6
104/97	Fill	1520	80	625	0.059	1.7	1.7	<0.006	74	0.074
89/97	Sand and Gravel	1081	50	337	0.013	3.2	3.1	0.015	206	0.016
91/97	Sand and Gravel	893	49	446	<0.008	4.9	4.8	0.015	44	<0.01
085/97	Coal Measures	354	20	243	0.127	<1.0	<0.92	0.076	14	0.16
088/97	Coal Measures	680	51	423	0.041	<1.0	<1.0	<0.006	37	0.052
090/97	Coal Measures	688	42	416	1.5	<1.0	<0.96	0.033	56	0.66
093/97	Coal Measures	798		456	0.326	2.2	2.1	0.064	15	0.41
102/97	Coal Measures	1152	35	165	0.6	<1.0	<1.0	<0.006	213	

Table 7/5 (Continued)
Summary of Initial Groundwater Quality Characterisation Analysis

Borehole	Monitored Strata	Copper (diss) mg/l	Zinc (diss) mg/l	Cadmium (diss) mg/l	Lead (diss) mg/l	Chromium (diss) mg/l	Manganese (diss) mg/l	Iron (diss) mg/l	Nickel (diss) mg/l	Sulphur mg/l
098/97	Fill	<0.01	<0.01	<0.003	<0.06	<0.01	2.18	<0.03	0.06	1670
099/97	Fill	<0.01		<0.003	<0.06	<0.01	0.8	<0.03	0.024	475
104/97	Fill	<0.01	<0.01	<0.003	<0.06	<0.01	0.21	0.88	0.021	539
89/97	Sand and Gravel	<0.01	<0.01	<0.003	<0.06	<0.01	0.079	0.07	<0.02	133
91/97	Sand and Gravel	<0.01	<0.01	<0.003	<0.06	<0.01	0.17	0.29	<0.02	102
085/97	Coal Measures	<0.01	<0.01	<0.003	<0.06	<0.01	0.47	0.055	<0.02	59
088/97	Coal Measures	<0.01	<0.01	<0.003	<0.06	<0.01	0.45	0.23	<0.02	87
090/97	Coal Measures	<0.01	<0.01	<0.003	<0.06	<0.01	0.34	0.36	<0.02	245
093/97	Coal Measures	<0.01		<0.003	<0.06	<0.01		0.12	<0.02	63
102/97	Coal Measures	<0.01	<0.01	<0.003	<0.06	<0.01	1.86	0.12	0.023	169

Table 7/5 (Continued)
Summary of Initial Groundwater Quality Characterisation Analysis

Borehole	Monitored Strata	Nitrite (NO2) mg/l (NO2)	Phosphate Total mg/l	Sodium (diss) mg/l	BOD mg/l	COD mg/l	pH	Calcium (diss) mg/l	Potassium (diss) mg/l
098/97	Fill	0.03	<0.15	27	<5	908	6.5	441	15
099/97	Fill	0.05	0.26	17	21		6.9	124	18
104/97	Fill	<0.02	0.16	21			6.9	231	12.7
89/97	Sand and Gravel	0.05	23.6		22	506	7.4	86	3.1
91/97	Sand and Gravel	0.05	3.2		15	1050	7.2	89	8.7
085/97	Coal Measures	0.25	6.2	9.9	5	1755	7	44	3
088/97	Coal Measures	<0.02	1.4	13	<5	178	7.1	88	2.7
090/97	Coal Measures	0.11	23.8	12	21		7.5		8.8
093/97	Coal Measures	0.21	<0.15		<5	531	7.2	80	3.4
102/97	Coal Measures	<0.02	<0.15	116	<3	<20	6.8	59	6.5

Review Of Local Hydrology and Flooding History

Local Hydrology

7.41 The application site lies within the catchment area of the River Erewash, which is located approximately 250m to the north. The River Erewash has a catchment area of approximately 182km^2 and rises in the vicinity of Kirkby-in-Ashfield. The river flows initially to the west before changing direction and flowing southwards to the west of Nottingham.

7.42 A gauging station is located at Sandiacre (NGR SK482 364) some 17km south of the application site, which records a mean flow of 2.03m^3/s.

7.43 The River Erewash has been augmented by mine water discharges from pumping stations in the vicinity. However, it has been reported that the discharge of deep minewater to the Erewash catchment has ceased at present due to the high chloride concentration in the minewater (refer to paragraph 7.26).

7.44 The River Erewash is the subject of the River Erewash Catchment Management Plan (NRA, 1995), which describes the river as generally of poor quality consisting largely of sewage effluent.

7.45 The Environment Agency has recorded the quality of the River Erewash at SK 485 546, some 400m north-west of the application site. The River Erewash has achieved a River Ecosystem (RE) Grade 4 (with Grade 1 being the cleanest and Grade 5 being the most polluted). This was mainly based on the 'very high' levels of nitrates found in 2002. However, the River Erewash achieved a Chemical General Quality Assessment (GQA) grade of 'Good' in 2002 and a Biological GQA grade of 'Fairly Good' in 2000.

7.46 A tributary of the River Erewash, the Cuttail Brook, flows in a northerly direction through the application site. The Cuttail Brook arises from springs in the Magnesian Limestone and exposed Coal Measures south of Annesley Woodhouse.

7.47 Within the application site the former course of the Cuttail Brook has been affected by opencast mining and the channel has been diverted onto a bench in the sidewall of the excavation. Instability on the sidewall has blocked the channel, thereby diverting the flow into the bottom of the void, and resulting in a water depth of up to 9m in the void base.

7.48 This flood water discharges through a 1.8m diameter reinforced concrete culvert at the northern end of the excavation. The culvert, which was designed to accept a 1 in 100 year storm event and to sustain the loading of the tipped spoil, extends below the spoil tip in the northern part of the application site to discharge directly into the River Erewash (c.1100m in length). A walk through survey is made annually to evaluate its integrity, and in 1998 was found to be in good condition with no leakages observed.

7.49 MJ Carter (1998) state that before spoil was tipped in the northern part of the site, a system of stone drains, pipes and culverts was installed to collect surface water. A 0.9m diameter and a 0.6m diameter culvert drains ground below the west side of the tip and discharges to the 1.8m diameter culvert.

7.50 Water flow and quality of the Cuttail Brook is monitored upstream at SK 485 547 by the Environment Agency. The Environment Agency has calculated theoretical flows, which indicate that the 95 percentile (Q95) low flow is 0.5-0.9Ml/d and the mean flow is 2-3.4Ml/d. A comparison of gauged flow by the Clean River Trust (CRT) in 1997 implies that, in the real case, peak flows were higher and low flows were lower than predicted.

7.51 The CRT flow assessment also assessed water quality finding it to be generally good on both entering and leaving the site, but found Biological Oxygen Demand (BOD) to be exceeding the accepted level for an RE2 watercourse.

7.52 In 1995 the National Rivers Authority classified the Cuttail Brook as having a GQA Class A. In 2002 the Environment Agency classified the Cuttail Brook upstream of the application site as having an RE Grade 2, with a chemical GQA of 'Very good' (2002), a nitrate GQA of 'low' (2002), a phosphate GQA of 'low' (2002) and a biological GQA of 'Good' (2000).

7.53 In 1997 Terry Adams Limited monitored the water quality within the Cuttail Brook and within the mine drainage ponds. A summary of the results are detailed within Table 7/6. These indicate the following:

- The quality limits of the Cuttail Brook fall within those outlined by the Environment Agency for an RE2 level water course;
- Only iron exceeds the DWS (0.2mg/l) in the Cuttail Brook;
- The water within the mining drainage ponds was of a poorer quality than the Cuttail Brook, with generally higher concentrations of all determinands recorded and an increased pH; and
- The DWS was exceeded for manganese (0.05mg/l) and iron (0.2mg/l) within the mine drainage ponds.

Table 7/6
Summary of surface water quality monitoring taken by Terry Adams Limited (1997)

Determinand	Units	Location	
		Cuttail Brook	Mining Drainage Ponds
Conductivity	uS/cm	711	1035
Magnesium (total)	mg/l	34	41
Calcium (total)	mg/l	70	86
Alkalinity	mg/l HC03	236	317
Ammonia	mg/l (N)	0.191	0.036
TON	mg/l (N)	2.6	3.1
Nitrate	mg/l (N)	2.4	3.1
Nitrite	mg/l (N)	0.113	<0.006
Chloride	mg/l	144	209
Ammonium	mg/l (NH4)	0.4	0.045
Nitrite (NO2)	mg/l (NO2)	0.37	<0.02
Phosphate (total)	mg/l	<0.15	<0.15
Sodium (total)	mg/l	84	103
Potassium (total)	mg/l	5	7.5
Copper (total)	mg/l	<0.01	<0.01
Zinc (total)	mg/l	0.011	<0.01
Cadmium (total)	mg/l	<0.003	<0.003
Lead (total)	mg/l	<0.06	<0.06
Chromium (total)	mg/l	<0.01	<0.01
Manganese (total)	mg/l	0.039	0.053
Iron (total)	mg/l	0.37	0.22
Nickel (total)	mg/l	<0.02	<0.02
Sulpher	mg/l	88	131
BOD	mg/l	<3	<3
COD	mg/l	23	<20
Dissolved Organic Carbon	mg/l	5.5	<3
pH		7.9	8.2

7.54 The Envirocheck report details a total of nine discharge consents within the vicinity of the application site, as shown on Drawing BC7/2, and summarised in Table 7/7. Examination of this information indicates that:

- Seven of the discharges fall under Consent No. T/61/22153/T and allow trade effluent, site drainage, and minewaters to discharge to the Cuttail Brook;
- Four of the discharges (1a to 1d) under Consent No. T/61/22153/T fall with the boundary of the application site. Discharges 1e, 1f and 1g are to the north of the application site boundary;
- One of the discharges is owned by British Coal (Consent No. T/61/01455/T) and also discharges to the Cuttail Brook 300m north of the site; and

- One of the discharges (Consent No. T/61/45171/R) is to the River Erewash from the Kirkby Sewage Treatment Works 300m north-east of the application area.

7.55 The Environment Agency has set discharge consent limits for all discharges relating to Consent No. T/61/22153/T, which are as follows:

- Hydrocarbon Oils 5mg/l;
- pH 9;
- Suspended Solids 50mg/l; and
- No presence of oil and grease.

7.56 The consent to discharge pumped minewater (Consent No. T/61/01455/T) also has constraints placed on the iron concentration (max of 5mg/l) and a volume constraint of 800m^3/d.

7.57 The Environment Agency monitor the discharge for compliance with the limits: in July 2004 and October 2004 it found that all determinands fell well below the limits set. In July both hydrocarbon oils and suspended solids fell below the laboratory reporting limits and a pH of 7.6 was recorded, whilst in October hydrocarbon oils were <0.2 mg/l and suspended solids were < 3mg/l, with a pH of 8.1.

Table 7/7
Discharge Consents within 2km of the Application Site

Drawing Ref. No.	Operator	Location	Discharge Consent No.	Discharge Type	Discharge Environment	Receiving Water	Grid Ref (SK)
1a	The following operators have been issued the same discharge consent: Annesley Bentinck Mine Ltd Carl Wright Reclamations Ltd Midlands Mining Ltd Viridor Waste Management Ltd Walker and Son (Hauliers) Ltd	Bentinck Colliery	T/61/22153/T	Trade Discharges- Site Drainage (Contam. Surface Water, Not Tips)	Freshwater Stream/River	Cuttail Bk R Erewash	486 538
1b				Trade Discharges- Site Drainage (Contam. Surface Water, Not Tips)			485 545
1c				Trade Discharges- Site Drainage (Contam. Surface Water, Not Tips) and Mineral Workings			480 545
1d				Trade Discharges - Site Drainage (Contam. Surface Water, Not Tips)			488 534
1e				Drainage of Other Matter- Minewater			485 547
1f				Trade Discharge- Mineral Workings			485 548
1g				Trade Discharges- Site Drainage (Contam. Surface Water, Not Tips)			481 549
2	British Coal Corporation	Lower Portland Coal Stocking Ground	T/61/01455/T	Discharge of Other Matter- Surface Water	Freshwater Stream/River	River Erewash (Tributary)	479 548
3	Severn Trent Water	Kikby in Ashfield Sewage Treatment Works	T/61/45171/R	Sewage Discharges- Stw Storm Overflow/Storm Tank- Water Company	Freshwater Stream/River	R Erewash	484 549

7.58 MJ Carter (1998) describes the current surface water drainage in the tip area in the north of the application site (Drawing BC7/3) as follows:

- Surface water has been divided into four catchments based on location; the north-eastern, north-western, south-eastern and south-western parts of the tipping area;
- Generally, surface water drains into a series of surface water drains, including a French drain along the north-eastern boundary, along the perimeter of the tipping area and then flow to a number of surface water settlement lagoons;
- Water from the lagoons flows into a ditch before discharging to the Cuttail Brook; and
- Reed beds have been developed in one of the lagoons to enhance the attenuation of suspended and dissolved solids in the runoff and seepage from the tipping area.

7.59 Previously, cleaned water from the series of slurry lagoons where slurry from the coal preparation plant was pumped, overflowed to the ditch on the northern boundary of the site and was pumped to discharge to a culverted section of the Cuttail Brook. The maximum consented rate of discharge was 1440m^3/d, which is equivalent to 280% of the Q95 low flow of the Cuttail Brook and 43% of the mean flow. It should be noted that these slurry lagoons are no longer required and under this application are to be infilled with inert wastes to permit restoration of the area.

Assessment of Potential Impacts

7.60 This part of the section identifies all potential impacts of the proposed development on the hydrological and hydrogeological environments and assesses their potential impact and the likelihood of occurrence as detailed in paragraph 7.2. The results of this assessment are summarised in Table 7/8.

Summary of Proposed Development

7.61 The proposed development is described in detail in Section 3 of the Environmental Statement. However, for ease of reference the main features are summarised below.

- the restoration of the Void in the south of the application site by infilling with non-hazardous waste;
- the reclamation of the Tip in the north of the application site by infilling with inert soils and an upper compost layer,
- building a compost maturation facility;
- the engineering of a culvert and reinstatement of the path for the Cuttail Brook;
- additional drainage for the northern tip part of the application site; and

- Installation and engineering of site infrastructure, including a new access road from the A608.

7.62 Following the submission of additional assessments in August 1998, the Environment Agency withdrew their objection to the culverting of the Cuttail Brook through the site. Engineering details produced by Montgomery Watson are contained in Appendix 7/2 and are summarised below:

- The initial scheme involves the construction of a bund from on-site material (opencast backfill and colliery spoil) along the western side of the Cuttail Brook to a minimum height of 120mAOD. The eastern facing slope of the bund would be formed to the final restoration contours;
- The culvert portal and first 65m of culvert would be installed to carry the brook beneath the northern face of the bund. An access manhole to the culvert would be provided at a level of around 122.5mAOD, and a sluice gate would be installed in the structure to enable the culvert to be sealed off in an emergency, creating an emergency water storage facility within the newly created valley of some 84,000 m^3, to a height of 120mAOD, sufficient to accommodate a 1 in 10 year flood;
- A temporary access track along the top of the bund and a hardstanding for pumps would enable the flooded valley to be pumped out (northwards across the Bentinck spoil disposal site) to the River Erewash pending repair of the culvert;
- In addition, the east facing flank would be completed to 125mAOD plus, emergency access track would be relocated to 122.5mAOD along the eastern flank, a new 30mx10m hardstanding for emergency pumps at 122.5mAOD immediately south of the culvert portal, installation of a permanent, buried 500mm diameter pumping main from the hardstanding to the high point of the existing landform; and
- This facility would be capable of storing some 140,000 m^3 of water and would accommodate a 1 in 100 year flood.

7.63 The proposed surface water management in the northern tip part of the application site is as follows:

- Existing perimeter ditches would be converted to shallow-sided grassed ditches (swales) with check weirs and an adjacent filter strip to provide additional filtration during restoration works;
- Additional swales and retention ponds would be developed to provide adequate storage in the event of heavy rain and thus protect the compost maturation building;
- Outfall from the retention ponds would be to an extension of a pre-existing ditch;
- Run-off in the vicinity of hardstanding and the compost maturation building and the site access road would pass through a filter strip of coarse grass to retain suspended matter and reduce the risk of hydrocarbons reaching the perimeter swale;
- A retention pond would be provided in the vicinity of the compost maturation facility such that the swale and the pond provide adequate

storage for a flood event with a 100-year return period and would have mechanism to contain liquid in case of a fuel spillage;

- Run-off from the roof of the compost maturation building would be directed via a segregated system to an isolated retention pond where outfall would be restricted to the greenfield rate of run-off; and
- The concrete pads would have a positive drainage system to ensure no uncontrolled releases from the area and suspended materials would be trapped in engineered gully pots. The drainage system would include a series of pools containing reed beds linked by small cascades to encourage oxygenation of the water and reduce BOD and ammonium content of the water before joining the western pond.

Hydrology

7.64 Potential impacts on the surface water environment can be considered as two distinct groups; impact on water quality and impacts on the hydraulic regime in the area. Accordingly, this assessment considers these two areas in turn.

Surface Water Quality

7.65 The proposed development would require construction of the landfill cells, which would involve the use of diesel powered plant. Construction is also required for the culverting of the Cuttail Brook, and the building of the compost maturation facility which may also involve the use of diesel powered plant. Such operations present a risk to surface water as any spillages of fuels or other potentially contaminating liquids could migrate to surface waters, either directly in the event of spillages on the haul roads and/or compound areas, or whilst constructing the culvert and pathway or via sump pumps if the spill occurred within the void itself. It is considered that there is a 'medium' probability of such a spill occurring, and that the magnitude of impact could be 'moderate' unless appropriate mitigation measures are implemented. The specific unmitigated impact of such a spill would be on the water quality of Cuttail Brook, and/or the water quality of the surface water management scheme that discharges to the Cuttail Brook.

7.66 The construction of the landfill facility within the Void would require dewatering of ponded surface waters within the Void. The ponded water therefore has the potential to be contaminated with suspended solids (clay and colliery spoil). There is also potential for surface waters to become contaminated with suspended solids during the construction of the landfill cells, construction of the bund for the culverting of the Cuttail Brook and construction of the compost maturation building due to surface runoff from working areas and soil stockpiles.

7.67 Unless appropriate mitigation measures are employed, it is considered that the likelihood of occurrence of these discharge waters containing an unacceptable suspended solids loading is 'high', and that the magnitude of impact could be 'moderate' such that the overall risk is considered to be 'high'.

7.68 It is noted that under the present discharge consent limits for all discharges to the Cuttail Brook the suspended solids must remain below 50mg/l. It is therefore considered likely that any controlled dewatering and discharge of the water within the void would need to be managed to fall within these limits.

7.69 The infiltration of water through wastes leads to the generation of leachate that contains high concentrations of contaminating substances and therefore presents a risk to surface water quality. Unless appropriate mitigation measures are included within the landfill design and operational procedures, leachate could potentially migrate to surface water pathways in one of three ways :

- Migration through the subsurface;
- Leachate breakout due to leachate overtopping the containment engineering of the site and flowing across the ground surface; or
- Leakage from any leachate management, extraction or storage facilities at the site.

7.70 The risk of leachate migration through the sub-surface is addressed within the groundwater section. It is considered that, in the absence of any mitigation measures, it is likely that leachate overtopping would eventually occur and therefore the unmitigated probability of occurrence is considered 'high'. The magnitude of impact may be 'severe' and therefore the risk is estimated to be 'high'. It is considered that in the absence of mitigation the likelihood of a release of leachate from the management system is 'medium' and the consequences could be 'severe' such that the overall risk is considered to be 'high'. It is considered that the specific impact of such an event would be confined to the surface water management systems and local water courses and the temporal impact would be short term due to the rapid flow rates within streams and rivers.

7.71 During operation of the compost maturation facility and the concrete yard there is a potential for uncontrolled release of liquors which may migrate to surface waters. Unless appropriate mitigation measures are employed it is considered that the likelihood of occurrence is 'high', the magnitude of impact is 'moderate' and therefore the overall risk is considered to be 'high'.

Surface Water Flow Regime

7.72 The development of the site has the potential to alter the local hydrological regime including rainfall – runoff characteristics. This may lead to increased surface water runoff, possibly increasing the risk of downstream flooding unless appropriate mitigation measures are employed. The comprehensive surface water management scheme present already at the site together with the proposed incorporated additions detailed in paragraph 7.63 would provide appropriate mitigation.

Flood Storage Assessment

7.73 Previous works (see Engineering details produced by Montgomery Watson in Appendix 7/2), with regard to the culverting proposals, have indicated that a volume of flood storage would be required, in order to provide attenuation in the very unlikely event that the culvert collapses. This sub-section reviews the previous calculations which were carried out using the Flood Studies Report (FSR) methodology. This method was superseded in 1999 by the publication of the Flood Estimation Handbook (FEH). Therefore comparative calculations have been undertaken using the FEH method, to ensure the original proposals remain valid.

7.74 The original FSR calculations indicated that a storage volume, to attenuate the whole 100yr design storm event upstream of the culvert would be 140,000m^3, the volume required to attenuate the 10yr design storm event was stated as 84,000m^3.

7.75 Comparative calculations carried out using the FEH Rainfall-Runoff method, indicate that the volumes required are less and, for the 100yr design storm event 91,000m^3, and for the 10yr design storm event 47,000m^3.

7.76 Although the simulated FEH storm attenuation volumes are lower, the original proposals allow a significant freeboard and safety margin. Therefore the original FSR higher values have been used in this assessment, adopting the precautionary principal as recommended in PPG25 *“Development and Flood Risk”.* The larger volumes would also be capable of providing enough storage to allow for the possible increase in peak flood flows due to climate change.

7.77 The reason for the difference in the two calculations, is primarily due to the change in the method, and improved rainfall depth duration frequency data which was created as part of the FEH project. Table 7/8 below indicates the parameters adopted in both calculation methods.

7.78 It is worthy of note that the calculations carried out here and those previously undertaken, only consider the design storm event i.e 4.5 or 5.5 hrs. A 10 or 100 year storm event of a greater duration could occur within the lifetime of the project. Should such an event occur it is proposed that pumps would be used to ensure the attenuation area upstream of the culvert is not overtopped. The pumps would discharge water to the watercourse downstream of the culvert. It is proposed that the sizing and location of the pumps and discharge pipework would be considered in further detail as part of the site surface water management plan.

Table 7/8
Summary of Parameters Adopted in the Hydrological Calculations

Parameter	FEH	FSR	Comments
Catchment Area (Km^2)	4.24	4.59	The digital catchment area from the FEH CD Rom is more accurate that the hand measured area used for the FSR. A larger catchment area will increase the peak flow.
Time to Peak	2.56	2.94	The time to peak calculation is derived from the catchment characteristics and was amended as part of the FEH project. A shorter time to peak shortens the hydrograph and delivers the flood peak quicker than a longer time to peak.
Design Storm Duration	4.5	5.5	The calculation of the design storm duration is derived form the Time to Peak and SAAR, therefore the longer Time to Peak and different SAAR will effect the two values. The result of a longer storm duration is to produce more overall volume within a flood event, in comparison to the same return period, and a shorter duration storm.
Rainfall Return Period	17	17	The 17year rainfall is used to produce a 10year flood event in a rural catchment.
Rainfall Depth	37.1	41.5	The FEH rainfall depth, takes into account data from more rainfall stations and from the period 1961-90, whereas the FSR method used fewer rainfall stations and was based on a time period of 1941-70. Therefore the reduction in the 17year 5.5hr rainfall is a factor of using more data and the change in rainfall patterns since 1941-70.
Design Storm Depth	35.6	40.03	This is calculated from the rainfall depth, by applying an areal reduction factor (ARF). The source of the difference between the two methods is the rainfall depth, since the same ARF has been adopted.
Catchment Wetness Index	106.25	106.25	This parameter is used in calculating the baseflow from the catchment; it is derived from an empirical relationship between the size of the catchment and the SAAR.

Parameter	FEH	FSR	Comments
Standard Percentage Runoff	32.6	44.01	The SPR from the FEH is based on the Institute of Hydrology's Hydrology of Soil Type (HOST) classification. This is more accurate than the previous FSR classification which only included 5 soil types. Reducing the SPR results in a lower flood peak and volume.
SAAR	730	720	The difference between the SAAR values is a factor of the FSR value being derived from data between 1941 and 1970, where as the FEH data is derived from the time period 1961-90.
Q_p Peak Flow ($m^3.s^{-1}$)	2.84	4.68	The FEH peak flow is lower primarily due to the storm duration being shorter, a lower SPR and 17yr rainfall depth.
Total Volume (m^3)	46,631	84,000	See above.
B_F Base Flow	0.07	0.07	No change due to the Baseflow being derived from the CWI which hasn't changed between the methods.

7.79 It is therefore concluded that the current design provides adequate flood storage to accommodate the 10 and 100 year events. The proposed pumping arrangement would also cater for storm durations in excess of the design duration.

7.80 The provision of this storage and pumping arrangement affords a greater level of protection than is currently available in this location. It also provides an engineering method of preventing flow from entering the culvert should a collapse occur, thereby providing time for remedial works to be carried out.

Culverting Policy

7.81 The Environment Agency has a national policy[4] against the culverting of watercourses due to the adverse ecological, flood defence and other effects which are caused by culverting.

7.82 It is recommended that culverting should not be considered until other options have been thoroughly explored. Where culverting is unavoidable, and the Agency considers that there are no reasonable practicable alternatives the length should be restricted to the minimum necessary; and appropriate enhancements should also be included in the proposal.

[4] Environment Agency (1999) 'Environment Agency Policy Regarding Culverts: Policy Statement'

7.83 It is also stated that the culvert should be larger than needed for the flow considerations alone to incorporate environmental requirements. In general the Environment Agency require that the proposed culvert should be no smaller than any adjacent culverts downstream.

7.84 Therefore, the culverting policy, advises against culverting of watercourses, unless there is no practicable alternative. However, where this occurs the culverting would be allowed provided a number of safeguards are put in place.

Proposed Culverting – Alternative Options

7.85 As part of the proposed scheme a series of alternative options were considered including whether the watercourse could be diverted in an environmentally sympathetic channel and corridor.

7.86 The proposed working and restoration scheme incorporates an extension to the existing Cuttail Brook culvert, at the south east side of the site. Extensive GIS 3D analysis of the site topography has been carried out to determine the alternative flow paths of water in and around the Cuttail Brook.

7.87 Drawing BC7/4 illustrates the flow direction analysis, this clearly shows any incident rainfall would flow towards the existing Cuttail Brook Culvert since the topography of this area dictates flow directions. It would not be possible to realign the Cuttail Brook around the site, with out a form of pumping.

7.88 Alternative site working schemes would result in the Bentinck reclamation scheme being unviable since there would not be sufficient void space.

7.89 Irrespective of the development proposals, the existing culvert would ultimately fail at some point in the future. The failure mode of the current Cuttail Brook culvert would be to fill the valley bottom into a lake, which would then overtop southwards over Salmon Lane. Hence the proposals would safeguard the culvert and protect third parties from the risk of flooding, caused by the failure of the culvert.

7.90 Therefore, the proposals are in accordance with the Environment Agency's policy on culverting. Since there are no reasonable alternative practicable solutions in this instance. Suitable mitigation measures and safeguards have also been identified to ensure long term maintenance and a fail safe scenario should the culvert fail.

Potential Impacts on Groundwater

7.91 The development of the landfill within the void and the continued restoration of the Tip have the potential to impact on groundwater in terms of both groundwater quality and flow regime. These two topics are considered separately below.

Groundwater Quality

7.92 During the development of the landfill the use of diesel or petrol powered plant has the potential to cause pollution with fuels or with other potentially polluting liquids. However, at the application site the potential for occurrence is limited by the underlying geology, given that the Made Ground surrounding and underlying the Void area typically comprises low permeability materials, containing only occasional localised perched groundwater horizons. The likelihood of groundwater contamination due to a leak or spill of pollutants is therefore considered to be ‘low’ due to the short time period during which there is a risk, together with the proposed mitigation measures to be employed at the site. The magnitude of impact is assessed as being ‘moderate’ to ‘severe’, as the Groundwater Regulations 1998 could be breached.

7.93 Leachate generated by the percolation of rainfall through waste within a landfill has the potential to be highly polluting if it is able to migrate to groundwater within the underlying Coal Measures bedrock aquifer over the long term. In the absence of any mitigation, it is concluded that the likelihood of occurrence would be ‘high’ and the magnitude of impact would be ‘moderate’ to ‘severe’ due to the potential to breach the Groundwater Regulations, 1998. Therefore, the overall unmitigated risk is assessed as being ‘high’.

Groundwater Flow Regime

7.94 Given the site setting it is considered that the proposed development would not have any significant impacts on the groundwater flow regime, for the following reasons:

- The continuing presence of a substantial thickness of low permeability Made Ground underlying and adjacent to the majority of the void area to be developed as the landfill;
- The depth of the groundwater within the Coal Measures bedrock aquifer below the site;
- The lack of groundwater seepages into the void from the limited exposed Coal Measures Bedrock and
- The lack of any deep excavations or groundwater dewatering within the Glacial Sand and Gravel.

7.95 It is therefore concluded that the likelihood of occurrence would be ‘negligible’ and the magnitude of impact would be ‘negligible’, with a corresponding ‘near zero’ level of overall risk.

Assessment of the potential impact of Groundwater Rebound on the Proposed Development

7.96 The cessation of pumping of groundwater within the Coal Measures strata would result in groundwater rebound. It has been postulated that a worse case groundwater rebound would be to a level of 110mAOD. It is also postulated that this may occur in approximately 20 years and therefore within the life (*i.e.* until the landfill has stabilised) of the landfill site.

7.97 This part of the section identifies the potential impacts of groundwater rebound on the proposed development, and assesses the potential impact and the likelihood of occurrence as detailed in the paragraph 7.2. The results of this assessment are summarised in Table 7/9.

7.98 The anticipated groundwater rebound is considered to have no effect on the shallow groundwater levels within the Sand and Gravel deposits as the maximum postulated rebound level (110mAOD) is lower than the base of the deposits, which has been determined by site investigation to be in the region of 125mAOD in the area surrounding the Bogs Farm Quarry SSSI.

7.99 Groundwater rebound to 110mAOD has the potential for basal instability of the landfill lining system. However, as the proposed landfill has been designed so that the basal level is above the predicted groundwater rebound level it is considered that the likelihood of occurrence of basal instability leading to liner damage is considered to be ‘negligible’. The magnitude of impact would be ‘severe’ due to the potential to breach the Groundwater Regulations, 1998. Therefore, the overall risk is assessed as being ‘low’, and so does not require mitigation.

7.100 Rebound of groundwater levels may rise to a level that would cause a greater interaction with the surface water flow regime of the surface water management system and the Cuttail Brook across the entire application site. There would be a potential for increased flows and therefore an increase in the likelihood of flooding and contamination from acid or iron rich mine waters. It can be considered that the likelihood of occurrence is ‘low’ to ‘medium’ as the rebound levels would need to be particularly high to interact with surface waters. The magnitude of potential impacts should contaminated mine waters influence the surface water regime would be ‘moderate to severe’ and therefore the overall risk would be low to medium.

Assessment of the Potential Impact of the Proposed Development on Bogs Farm SSSI

7.101 Following submission of the original planning application for Bentinck Void in 1997 (Terry Adams Limited), English Nature expressed concerns about the potential hydrological/hydrogeological impact of the development on Bogs Farm Quarry SSSI. Subsequently, the addendum to the planning application submitted in August 1998 resulted in the withdrawal of English

Nature's holding objection on these issues. A summary of the potential impacts expressed by English Nature and the agreed and accepted mitigation measures proposed by Terry Adams Limited are described below:

Groundwater Flow Regime

The Void lies down hydraulic gradient of the SSSI and therefore cannot affect the groundwater input into the SSSI. Drainage from the Void would not interact with groundwater in the SSSI. It was shown that the road cutting lies to the east of a bedrock ridge which forms a sub-surface groundwater divide and would not have a significant effect on groundwater to the west of the ridge, towards the SSSI. A section of the road cutting is also within the low permeability fill and therefore cannot have an effect on the groundwater flow regime in the sands and gravels. The residual risk is therefore negligible. As part of the internal road design, drainage would be directed via kerbing to an interceptor and then to the leachate treatment facilities, if required.

Surface Water Flow Regime

The restoration profile was altered to increase the area of catchment from that described in the original planning application submitted in 1997 (2.9ha) so that the catchment remains unchanged from the present catchment (3.2ha), therefore any risk associated with loss of surface water catchment to the SSSI has been eliminated and is therefore negligible. Potential changes to the surface/subsurface outflow from the SSSI as a result of the emplacement of the low permeability landfill liner was shown not to have an impact as the outflow regime from the SSSI would be retained and controlled in a reprofiled channel whereas landfill operations lie to the east of the channel and would have no influence or impact.

Groundwater Rebound

English Nature expressed concerns over the potential impact of groundwater rebound following cessation of mine dewatering on the SSSI. This has been assessed within the groundwater rebound section of this section.

7.102 In addition it is proposed that the concrete slab located to the north of the SSSI would be positively drained to the north to include a cut-off drain so that both the surface and groundwater flow regime and quality would not be compromised or impacted.

Table 7/9
Summary of Unmitigated Potential Impacts

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Magnitude of Impact	Significance of Impact	Mitigation Required ?
Surface Water Quality					
Spillage of fuels etc	Local, Short term	Medium	Moderate	Medium	Yes
Release of suspended solids	Local, Short term	High	Moderate	High	Yes
Migration of landfill leachate	Local, short to medium term	High	Moderate to Severe	High	Yes
Migration of compost liquors	Local, medium term	High	Moderate	High	Yes
Groundwater Quality					
Spillage of fuels etc	Local, Short to medium term	Low	Moderate to Severe	Low to Medium	Yes
Migration of landfill leachate	Local/Regional Medium to Long term	High	Moderate to Severe	High	Yes
Surface Water Flow and Flooding					
Reduction in flow	Local/Regional Medium term	Negligible	Negligible	Near Zero	No
Flooding	Local/Regional, permanent	Medium	Moderate to severe	Medium to High	Yes
Groundwater Flow					
Reduction in groundwater flow	Local, Permanent	Low to Negligible	Mild	Near Zero	No
Groundwater Rebound					
Heave on base of liner	Local, Long term	Negligible	Severe	Low	No
Increased surface water flow/flooding	Local, Medium to Long term	Low to Medium	Moderate to Severe	Low to Medium	Yes
Contamination of surface water	Local, Long term	Low to Medium	Moderate to Severe	Low to Medium	Yes

Identification of Appropriate Mitigation Measures

7.103 Table 7/9, above, identifies the potential impacts of the proposed development. It also identifies whether mitigation measures are required to reduce these potential impacts to acceptable levels.

7.104 Proposed mitigation measures are identified below. These measures either reduce the likelihood of an event occurring, or reduce the magnitude of the consequences if the event does occur. 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 7/9.

7.105 Table 7/10 summarises the mitigation measures applied to each potential impact.

Water Quality

7.106 In order to mitigate against the risk of surface or ground water pollution occurring during the engineering of the landfill, restoration of the tip, construction of the compost maturation facility, construction of the Cuttail Brook culvert and construction of the site access road, the following management measures would be included:

- Wherever possible a traffic management system would be put in place to reduce the potential conflicts between vehicles and thereby reduce the risk of collision;
- A site speed limit would be strictly enforced to further reduce the likelihood and significance of any collisions;
- All plant would be regularly maintained and inspected daily for leaks of fuel, lubricating oil or other contaminating liquids;
- Refuelling of vehicles would be undertaken in a surfaced compound area from a fuel tank(s) that is bunded in compliance with the Control of Pollution (Oil Storage) (England) Regulations 2001;
- Maintenance of plant and machinery would be undertaken within the site compound or off-site, as appropriate, to minimise the risk of uncontrolled release of polluting liquids;
- Soil movements and excavations would be undertaken to minimise the generation of silt, and all soils would be stored in accordance with the relevant guidance. Where necessary, ditches would be cut to capture runoff from areas generating clay and silt to allow for settlement of fines (clay and silt fractions) prior to discharge; and
- Water pumped from the Void during construction, which may be contaminated with silt, would be directed into a settlement pond prior to discharge.

7.107 The above measures would significantly reduce the likelihood of polluting liquids being released during construction, such that the overall risk is reduced to ‘medium’ to ‘low’.

7.108 The site would be subject to engineering and management controls during construction and operation to minimise the generation of leachate, and to enable the extraction and treatment of leachate, such that pollution does not occur. It should be noted that the entire landfill area, including the presently licensed areas, would be brought into the Pollution Prevention and Control (PPC) Regulations 2000 (as amended) regime and a PPC permit application would be required prior to the acceptance of waste. As part of the PPC process the site must comply with the Landfill Regulations 2002 and, therefore, with the Groundwater Regulations 1998. In order to demonstrate compliance with these two regulations a detailed hydrogeological risk assessment (Prior Investigation under the Groundwater Regulations) would be undertaken as part of the PPC application. A permit would be issued and the site able to operate, only if the hydrogeological risk assessment has demonstrated that the installation would comply with the relevant regulations. Specifically, the hydrogeological risk assessment must demonstrate that the site would not result in the discernable discharge of List I substances (e.g. cadmium, mercury, hydrocarbons and organohalogen compounds) to groundwater, and would limit the discharge of List II substances to groundwater so as to prevent pollution. In order to ensure that this is the case engineering measures may be used.

7.109 The precise design would be dependent on the results of the hydrogeological risk assessment, but, based on experience, is likely to include the following elements as required by the Landfill Regulations:

- a 1m thick *geological barrier* with a permeability of less than $1x10^{-9}$m/s, or its hydraulic equivalent on the base and lower side slopes of the non-hazardous landfill cells;
- a basal *artificial sealing liner* comprising HDPE; and
- a *leachate collection system,* comprising a piped drainage system laid within a drainage blanket of at least 300mm thickness of coarse clean, non-calcareous aggregate, with leachate extraction risers.

7.110 In order to minimise the generation of leachate in the longer term, completed cells would be capped with low permeability materials.

7.111 Leachate management would be undertaken to ensure that the allowable head of leachate at the site is kept within the limits determined by the hydrogeological risk assessment so that there would not be an unacceptable risk of breach of the Groundwater Regulations 1998.

7.112 Groundwater quality would be monitored against standards of environmental protection from on-site and off-site monitoring boreholes, and appropriate remedial action would be taken if leachate migration was detected.

7.113 Impacts upon groundwater due to leachate migration are unlikely to be significant due to the attenuation and retardation afforded by the engineered lining system and underlying low permeability Made Ground and unsaturated bedrock. Dilution, attenuation and degradation can also be expected within the Coal Measures strata.

7.114 Surface water quality would be monitored across the application site within the Cuttail Brook, the site drainage channels, lagoons, and various attenuation ponds. This would provide an early warning system to identify decreases in quality and ensure that necessary and appropriate remedial actions are taken if required.

7.115 These measures would reduce the overall risk of potential impacts from 'medium and high' to 'low and near zero'.

7.116 In order to mitigate against the risk of surface water pollution during the operational period of the compost maturation facility and the concrete yard from uncontrolled release of liquors, a surface management scheme has been proposed, which is detailed in paragraph 7.63. In summary, mitigation for the compost maturation facility would be in the form of positive drainage, which would be directed towards leachate management facilities of the landfill and mitigation for the concrete yard area would be in the form of drainage in combination with oil interceptors, as required. These measures would reduce the overall risk of potential impacts from 'high' to 'near zero'.

Impacts of Groundwater Rebound

7.117 Although it is considered that the significance of the impact of groundwater rebound on lining system damage and basal instability is low due to the design of the landfill liner being above the anticipated groundwater rebound level of 110mAOD, it is proposed that a groundwater underdrainage system would be installed together with drainage grips on the sidewall of the landfill. 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. Should the highly unlikely event of groundwater rebound occurring to levels above 110maOD this drainage system would allow any groundwater accumulating beneath or adjacent to the site to be removed by pumping, thereby preventing the development of excessive pressure.

7.118 The Cuttail Brook culvert would incorporate materials resistant to acid mine water attack and would be constructed at an elevation greater than the predicted rebound. The Culvert would also be built with compliance to the Environment Agency Policy (1999). It can therefore be concluded that the overall risk of contamination of Cuttail Brook surface water from groundwater rebound would be reduced to 'negligible' levels.

7.119 Further mitigation measures such as monitoring groundwater levels within the Coal Measures strata to identify rising trends, which may indicate that groundwater is rebounding, would be incorporated into the management operations of the site.

Water Resources

7.120 In order to minimise the effects of the development on the surface water resources, and the potential for the development to have adverse effects of flooding downstream of the site, runoff at site would be managed using principles encompassed by Sustainable Drainage Systems (SuDS) and in accordance with PPG 25.

7.121 CIRIA Report C523, Sustainable Urban Drainage Systems – Best Practice Manual (2001), notes that sustainable drainage systems would satisfy the following basic requirements:

- Runoff from a developed area should be no greater than the runoff prior to development;
- Runoff from a developed area should not result in any downgrading of downstream watercourses or habitat;
- Pollution in the runoff generated by a development should be treated within the development area prior to discharge;
- Consideration should be given at the design stage to water resource management and control in the development area; and
- The wider needs of the community are considered in development of the design.

7.122 The Environment Agency promotes SuDS, which include long-term environmental and social factors in decisions about drainage. SuDS take account of the quantity and quality of runoff, the amenity value of surface water in the local environment, and are more sustainable than conventional drainage systems because they:

- manage runoff flow rates, reducing the impact of the development on flooding;
- protect or enhance water quality;
- are sympathetic to the environmental setting and the needs of the local community;
- provide a habitat for wildlife; and
- encourage natural groundwater recharge (where appropriate).

7.123 The principles of SUDs would be used to manage surface water at site, and in particular:

- Surface water runoff from areas of hardstanding (including the access road) would be positively drained and attenuated prior to discharge; and
- Water at site would be managed in accordance with Discharge Consents already issued and regulated by the Environment Agency.

7.124 SuDS are made up of one or more structures built to manage surface water runoff. They are used in conjunction with good management of the site to prevent flooding and pollution. There are four general methods of control:

- filter strips and swales;
- filter drains and permeable surfaces;
- infiltration devices; and
- basins and ponds

7.125 The design of the surface water management scheme would be in accordance with guidance given in PPG 25, which details the importance the Government attaches to the management and reduction of flood risk in the land-use planning process.

7.126 The surface water management system in place at site (detailed in section 7.58) together with the additional features detailed in paragraph 7.63, and the design for reinstatement of the Cuttail Brook (detailed in paragraph 7.62) already encompasses SuDS and PPG25. It has also been designed to limit discharge from the site to the 'greenfield rate of runoff' and, as such, reduces the potential impact of the site to 'near zero' levels.

7.127 During site development of the void any water inflows would be captured and would require pumping. This water would be pumped into the surface water management system and would be allowed to flow from the site at close to the 'greenfield rate of runoff'.

7.128 The management measures would ensure continued compliance with discharge constrictions set by the Environment Agency.

Assessment of Residual Impacts

7.129 Table 7/10 summarises the identified mitigation measures and details the residual impacts at the site.

7.130 Examination of Table 7/10 confirms that there are no significant residual impacts with respect to groundwater or surface water.

Table 7/10
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
Surface Water Quality									
Spillage of fuels etc	Local, Short term	Medium	Moderate	Medium	Yes	Inspections, maintenance and bunding of fuel tanks	Negligible	Moderate	Near Zero
Release of suspended solids	Local, Short term	High	Moderate	High	Yes	Minimisation and settlement measures	Negligible	Moderate	Near Zero
Migration of landfill leachate	Local, short to medium term	High	Moderate to Severe	High	Yes	Engineering, management and monitoring	Negligible	Moderate to Severe	Near Zero to Low
Migration of compost liquors	Local, medium term	High	Moderate	High	Yes	Positive drainage, oil interceptors	Negligible	Moderate	Near Zero
Groundwater Quality									
Spillage of fuels etc	Local, Short to medium term	Low	Moderate to Severe	Low to Medium	Yes	Inspections, maintenance and bunding of fuel tanks	Negligible	Moderate to Severe	Near zero to Low
Migration of landfill	Local/Regional Medium to	High	Moderate to Severe	High	Yes	Engineering, management	Negligible	Moderate to Severe	Near zero to 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
leachate	Long term					and monitoring			
Surface Water Flow and Flooding									
Reduction in flow	Local/Regional Medium term	Negligible	Negligible	Near Zero	No	N/A	N/A	N/A	N/A
Flooding	Local/Regional, permanent	Medium	Moderate to severe	Medium to High	Yes	SuDS system	Negligible	Moderate to Severe	Near Zero to Low
Groundwater Flow									
Reduction in groundwater flow	Local, Permanent	Low to Negligible	Mild	Near Zero	No	N/A	N/A	N/A	N/A
Groundwater Rebound									
Heave on base of liner	Local, Long term	Negigible	Severe	Low	No	N/A	N/A	N/A	N/A
Increased surface water flow/flooding	Local, Medium to Long term	Low to Medium	Moderate to Severe	Low to Medium	Yes	SuDS and management	Negligible	Moderate to Severe	Near Zero to Low
Contamination of surface water	Local, Long Term	Low to Medium	Moderate to severe	Low to Medium	Yes	Management and monitoring	Negligible	Moderate to Severe	Near Zero to Low

Conclusions

7.131 The surface and groundwater regimes at the site have been assessed with reference to information held by the Environment Agency, Local Authorities and others, and by the consideration of site specific investigation and monitoring data.

7.132 The application site is located on the Middle Coal Measures, which is considered a Minor Aquifer and the Permian Marl, which is a Non-Aquifer. There is a substantial thickness of low permeability Made Ground across the application site, in particular surrounding and underlying the southern void and the northern tip. Glacial Sand and Gravel is also located within the site boundary.

7.133 No licensed or unlicensed abstractions have been identified within close proximity to the site.

7.134 The Cuttail Brook runs through the site and requires engineering measures to reinstate its course so that it no longer floods the southern void. These measures have been designed to cause minimal impact to surface water flow, quality and potential for flooding in accordance with recommended guidance.

7.135 The potential impacts of the proposed development upon the water environment have been identified and assessed, and where appropriate, mitigation measures have been accommodated into the design of the development.

7.136 In order to ensure that the landfill does not result in groundwater pollution the site would be managed under engineered containment, with active management of leachate and groundwater levels. The deposition of waste would only take place once a PPC permit had been obtained. As part of this process the detailed specification of the landfill lining system would be agreed with the Environment Agency in order to ensure that the site complied with both the Landfill and the Groundwater Regulations.

7.137 The proposed development has the potential to impact on the surface water flow regime by affecting the runoff characteristics of the site. Mitigation, such as Sustainable Drainage Systems (SuDS) techniques, would be used to control discharges from the site.

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