APPENDIX 13.1 HUGGINSTOWN FEN HYDROGEOLOGICAL REPORT

A13.1.1 INTRODUCTION

A13.1.1.1 Background and Purpose

A study was undertaken to assess the potential impact(s) of the proposed road development on Hugginstown Fen, Co. Kilkenny, for inclusion in this Environmental Impact Statement (EIS).

A synopsis by the National Parks and Wildlife Service (NPWS, formerly Dúchas) in 2003 states that Hugginstown Fen is one of the most important and diverse fens in the country. It is a candidate Special Area of Conservation (cSAC) under the Habitats Directive 92/43/EEC (Ref. 1). The proposed scheme runs along the eastern boundary of the fen and involves road chainage 17,400 to 19,700. This study examines the hydrology / hydrogeology of the fen and the potential impact(s) of the proposed road development on the water balance and hydrogeology of the fen. The location and layout of Hugginstown Fen can be seen on EIS Figures 13.1 and 13.2 in Volume 2 – Book 2 of this EIS.

This work was carried out in two phases. The first was a preliminary assessment, which investigated the hydrology of Hugginstown Fen and the potential impact of proposed road on the fen. Following the results of this work and the recommendations from its report (Ref. 14 & 15), a second phase of additional works was undertaken. This report outlines the results of this second phase of investigations and combines all data acquired over the study period to assess the potential impact of the proposed road development (see Chapter 4 of this EIS) on Hugginstown Fen.

A13.1.1.2 Work Schedule

Fieldwork for the preliminary study was undertaken over a number of visits between February and October 2003. A preliminary site visit was undertaken on the 21/06/03 and involved a site walkover and preliminary hydrological assessments. The main investigation period took place between 23-26/06/03 and involved peat probing and monitoring point installations. This was followed by water level monitoring and sampling on 01-02/07/03. A final round of water levels was taken on the 01/10/03 to establish stabilised and equilibrated water levels for report interpretation.

Fieldwork for the second phase of works was undertaken between the 15th to 17th October 2003 (Percussion Window Sampling), 28th to 31st October 2003 (Rotary Percussion Drilling), 6th to 7th November (Differential GPS Surveying) and 14th to 17th November (Permeability testing, water levels and hydrochemistry). Reporting for the additional works was undertaken in December 2003.

A13.1.1.3 Report Structure

This report's structure follows a standard EIS format. Report content is provided under the following key headings:

- Introduction
- Methodology
- The Receiving Environment
- Predicted Impacts
- Mitigation Measures
- Residual Impacts

A13.1.2 METHODOLOGY

The methodology for the EIS assessment of Hugginstown Fen involved both a desk study and field investigations. These investigations are outlined below.

A13.1.2.1 Desk Study

The desk based work items involved the following:

- Acquire and compile all plan maps of the proposed road development.
- Study road plans and cross sections.

- Acquire and overlay aerial photographs of the site and relate to road plans.
- Identify main land-uses in relation to Hugginstown Fen and the proposed road development.
- Overlay Ordnance survey OS Discovery Series 1:50,000 (and OS 1:25,000, 1:10,560 (6”)) maps with AutoCAD plan drawings.
- Overlay GSI Geology maps (1:100,000) to determine site bedrock geology and the presence of any major faults or other anomalies.
- Determine land ownership details in advance of field investigations.
- Acquire and study borehole logs and geotechnical results of site investigations along the proposed road development in the context of overburden and bedrock types and their geometry and permeability relative to Hugginstown Fen.
- Consultation with the Geological Survey of Ireland (GSI) databases and publications in relation to geology and resources of Co. Kilkenny.
- Consultation with National Soils Survey of Ireland (An Foras Taluntais) on the ‘Soils in Kilkenny’.
- Consultation with Met Eireann for meteorological service records for the period 1961 to 1990 of the closest pertaining synoptic and rain gauge sites.

The equipment and materials used during this desk study consisted of:
- MicroStation
- Adobe Illustrator
- Microsoft Excel
- Microsoft Word
- Microsoft Powerpoint
- Rockware Piper

A13.1.2.2 Field Investigations

These investigations involved:
- Site walkover and assessment of drainage and likely groundwater flow characteristics.
- Hydrochemical measurements of main drains along their courses (electrical conductivity, pH and temperature).
- Flow measurements at critical points in main drains to determine baseline flow capacity, influent or effluent conditions, drain significance and hierarchy.
- Selection of suitable transect locations (cross sections) in consultation with the ecological consultants to coincide with ecological zones of significance and position perpendicular to groundwater flow.
- Peat depth probing along the three transects selected, T1, T2 and T3.
- Description and logging of sediments to BS 5930 (Ref. 2) and to Von Post Humification scale (Ref. 3) to determine subsoils texture and permeability characteristics.
- Shallow overburden drilling to install nested piezometers to measure water levels and hydraulic gradients in the bog and at its boundary with the proposed road development.
- Deep bedrock drilling along the eastern valley catchment to determine water levels, permeability and flow gradients.
- Installation of secure wellhead completions for the bedrock and deep overburden monitoring points on agricultural lands for future monitoring.
- Differential GPS surveying of all investigation points and monitoring installations for the purpose of characterising groundwater flow in plan and cross section within the fen and along the eastern catchment boundary.
- Permeability testing of the bedrock boreholes and newly installed overburden monitoring wells to determine bedrock aquifer permeability and the permeability of saturated overburden subsoils that contribute groundwater to the fen.
- Sampling of water from the groundwater and surface water monitoring network for field parameter testing and for laboratory analysis.

The equipment and materials used during field investigations consisted of:
- WTW 340i pH/EC meter for hydrochemical measurements
- Alkalinity Hach AL-DT kit for field measurements
- Peristaltic Pump and hosing for extracting groundwater for hydrochemical analysis
- Gouge Corer and Hand Auger for peat and overburden hand probing

- Percussion Window Sampler (PWS) for deep overburden installations
- Rotary percussion air flush drilling for bedrock installations
- OTT Impellor flow meter for flow measurements in the main drains
- Pentax AL-180 levelling equipment for obtaining reduced levels
- Dip-meter to take water level measurements
- Handheld Magellan 315/320 Global Positioning System (GPS)
- Differential GPS 500 for accurate elevation and co-ordinate surveying of topography and monitoring point installations
- Canon S40 Digital Camera for taking photographs of all items of reference

A13.1.2.3 Impact Assessment Methodology

From the desk and field data acquired, the following calculations and assessments were undertaken in order to evaluate the potential impact of the proposed development on Hugginstown Fen:

- Characterise the site’s existing hydrological / hydrogeological regime from the topographical, geological, geographical, hydraulic and hydrochemical data acquired.
- Determine the likelihood of any existing environmental trends / changes that are currently occurring at Hugginstown Fen.
- Determine the existing / baseline catchment size of Hugginstown Fen.
- Determine any change to this catchment size arising from the proposed road development and identify impact.
- Consider water quality changes as a result of the proposed road development and its design (See Chapter 4 of this EIS)..
- Following desk and field data acquired, draw schematic cross-section(s) along the monitoring transects installed (T1, T2, T3) showing groundwater flow patterns and the cross sectional geology through the proposed N9/N10 route and Hugginstown Fen.
- Assess the combined data acquired and evaluate any likely impacts on Hugginstown Fen.
- If impacts are identified, consider measures that would prevent, mitigate or reduce the identified impact.
- Identify any residual impacts that would remain or arise from the mitigation measures identified.
- Present and report these findings in a clear and logical format that complies with EIS reporting requirements.

A13.1.3 THE RECEIVING ENVIRONMENT

A13.1.3.1 Site location

Hugginstown Fen is located at Irish national grid co-ordinates 252400E 130400N, some 6.5km southwest of Knocktopher, and approximately 25km south of Kilkenny City. The fen occurs within an elongate drainage valley that drains southwards to the Derrylacky River, which in turn enters the River Suir north of Waterford city. The cSAC at Hugginstown Fen covers an area of c.62 hectares, of which fen, swamp and transition bog make up c.32 hectares. The proposed road development occurs along the eastern flank of the fen valley, running essentially parallel to it.

A13.1.3.2 Topography

The topography around the study site is one of hill ridge elevation highs of 290mOD to 250mOD to valley depressions of 120mOD to 70mOD. The ground rises gently in elevation as one progresses from Knocktopher (60mOD) south to Hugginstown Fen (120mOD). Locally, there is a north-south trend in topographic alignment, which is geologically controlled by the Upper Palaeozoic outlier rocks that occur in the area. Further south towards Waterford, a contrasting east-west trending topography occurs and reflects the greater influence of the Variscan Orogeny in the Munster Province (Section A13.1.3.3 of this Appendix 13.1).

A13.1.3.3 Geology

Soils and Subsoils

A detailed soil survey report is not available for Co. Kilkenny (per. comm. Teagasc). The General Soil Map of Ireland (Ref. 4) indicates that the principal soil type that occurs at the study site is Brown Podzolics with associated acid brown earths and gleys. Sandstone and Lower Avonian shale glacial till are the parent materials to brown podzolics and they form from intense leaching of the profile, with upper horizons being depleted of bases and other constituents. A characteristic feature of these soils is a sub-surface horizon of strong red-brown or yellowish-brown colour due to enrichment, principally by iron oxides leached from the upper horizons.

The peat soils at Hugginstown Fen are not identified on the General Soil Map of Ireland due to its large 1:575,000 scale. Peat soils however, clearly occur over the fen / transition bog / swamp areas in Hugginstown valley and make up at least 30 to 50 hectares in soil cover. Peat is characterised by a high content of organic matter (over 30%) and by being at least 30cm in depth. Fen peat occurs at this site and this type of peat forms under the influence of base-rich groundwater (minerotrophic conditions) and is composed mainly of the remains of reeds, sedges and other semi-aquatic or woody plants. Variations in concentration of the component plant remains depend on the topographic situation and nutrient content of the water supply. The peat profile is characterised by the upper living “acrotelm” peat layer which is generally 0.2-0.3m depth. This is the living biomass of the fen habitat. Peat deeper than 0.3m is called the “catotelm” peat and consists of the partially decayed vegetation biomass (Ref. 5).

The “Geology of South Wexford” (Ref. 6) describes the general Quaternary and subsoils geology of the subject site. During the Quaternary period, southwest Ireland including the study site was covered by ice that flowed from the midlands and the Irish Sea basin respectively. Most of the glacial deposits and erosional features are a legacy of the most recent of the Quaternary glacial events “The Midlandian”, which came to a close some 10,000 years ago. Ice from the midlands carried mainly Carboniferous limestone debris, but as it moved over the sandstones and shales of the Upper Palaeozoic outliers (such as the subject site), it deposited the limestone and picked up fragments of the underlying lithologies. Patches of limestone till extend southward across the high ground underlain by Devonian sandstones and lower Palaeozoic rocks between Knocktopher and Mullinavat and then across the low ground underlain by Carboniferous limestone to Mooncoin. Due to the strong positive topographic relief and greater resistance to erosion by the Upper Palaeozoic outliers, the glacial sediments deposited at the study area are relatively thin compared to glacial deposits that occur further east.

Bedrock Geology

The bedrock geology at the study site is discussed in the Geological Survey of Ireland (GSI) publication entitled “Geology of South Wexford” (Ref. 6). The 1:100,000 scale bedrock geology map of the area (Sheet 14) indicates that the study site is underlain by rocks belonging to the Kiltorcan Formation (KT). The Kiltorcan Formation is Upper Palaeozoic and Devonian in age (410-355 million years). The Kiltorcan Formation was at one time known as the “Yellow Sandstone” because of its distinctive rock types. It also contains micaceous sandstones of white and red hues as well as interbedded yellow to green silty mudstone and unbedded dark red to green mudstone and mudflake conglomerates. The formation is best known for its fossils found in an old quarry on Kiltorcan Hill, near Ballyhale. Here excellent examples of mussels, fish and plants are preserved.

The Carrigmaclea Formation (Cl) occurs to the south, east and west of the fen. It is an older formation and is succeeded by the Kiltorcan Formation to the north. The Carrigmaclea Formation rests unconformably on Lower Palaeozoic rocks. It comprises a sequence of quartz cobble conglomerates, pebbly sandstones and cross-stratified sandstones deposited by braided streams. All of the units are red, brown or pink in colour.

Towards the end of the Carboniferous, the formations described above were subjected to the Variscan Orogeny. The effects of this event are best seen in Munster where a thick sequence of Old Red Sandstone was uplifted, folded and faulted. Similar effects are seen to the south of the study site in the Carrick-on-Suir Syncline. At the study site within the Kiltorcan formation, a north-south Variscan aged syncline occurs along the eastern boundary of the fen. This syncline changes direction along its length from a north-south direction, to a northwest-southeast direction further south. From the bedrock outcrops mapped, the bedding is gently dipping into the syncline at 10 to 4 degree dip angles. Further to the east a north-south fault divides the Kiltorcan Formation from the Carrigmaclea Formation. Within the Carrigmaclea, east-west anticlines and synclines occur.

Site Investigations
A preliminary site investigation was carried out for the proposed road, as outlined in Chapter 13 of Volume 1 – Main Text of the EIS. These investigations provide site-specific information on the subsoils and bedrock geology at the site. The boreholes and trial pits that are relevant to this study are: T-17000, T-17250, T-17500, RC-17500, T-17750, B-ST27, T-18300, RC-18300, T18610, RC-18620, B-18990, RC-18990, B-19250, and RC-19250. From these intrusive investigations the subsoils generally consist of firm to stiff, sandy gravelly CLAY with many cobbles and boulders. Slightly gravelly or slightly clayey SAND with some rounded to sub-angular cobbles and boulders were recorded at chainage 18,610, while a sandy, clayey GRAVEL was recorded at chainage 18,990. Generally the overburden is thin to moderately thick with a maximum thickness of 4.3m at B-ST27. To the far north (B-19250) and to the south (T-17750 and T-17500) overburden thickness appears much thinner at c.1.5m. In the intrusive investigations where “possible boulder or bedrock” was encountered, bedrock seemed to occur between 1.5 to 4.2m depth. In the bedrock boreholes, competent rock without significant weathering was returned at depths of 2.0 to 3.2m.

Subsoil drilling took place in the second phase of works (Brief A3) using a Percussion Window Sampler (PWS) drilling system. This work resulted in the installation of 4 deep overburden (subsoils) monitoring points at OB15, OB16, OB17 and OB18. These were positioned along the immediate eastern edge of the fen and where access and vegetation permitted, within the fen at Transect 1. The purpose of this phase of drilling was to (a) provide more accurate values of subsoils depth and potential rockhead under the fen, and (b) obtain better sample return and thus representation of the subsoils lithology under and adjacent to the fen. Results of these investigations indicate that a sandy to gravelly CLAY is generally succeeded within 2m depth by a gravelly SAND. Horizons of sandy GRAVEL also occur in the lower subsoils profile. These subsoils are significant in depth with OB15 recording >7m of subsoils. The origin of these subsoils within immediate proximity of the fen is alkaline boulder clay. The sand and gravel deposits represent greater water sorting associated with fluvio-glacial deposition. These fluvioglacial deposits are likely to be related to the projections of mineral soil ridges into the fen valley along the eastern margin of the valley.

Direct investigations of the fen were also undertaken using a manual hand drilling mechanism suitable to peat substrates. This work involved 24 gouge cores to determine peat depths and the mineral subsoils beneath the fen. Gouge coring involves the manual insertion of a half-cylindrical 1m length sample chamber into the ground at 1m depth incrementals. The sample is retrieved, logged, emptied and re-inserted with an extension rod to the next 1m interval. This is undertaken until refusal is encountered at bedrock or stiff mineral subsoils. The subsoils were logged using British Standards Institution Code of Practice for Site Investigations (BS 5930) (Ref. 2) and the Von Post Humification scale (Ref. 3) was used as an indicator of the degree of decay of the catotelm peat. From these investigations the peat is described as a spongy, fibrous, dark brown fen peat with generally H4 “poorly humified plant remains; peaty substance does not escape from between fingers when squeezed” to H5 “Moderately humified plant remains; the structure is however still very clearly visible; the squeezed water is dark brown and very cloudy while some peat escapes through the fingers” in Von Post Classification (Ref. 3). Direct investigations of mineral subsoils beneath the fen indicate that it is a soft to firm with depth, brown to grey sandy and occasionally gravelly CLAY.

Following preliminary peat probing and site investigations, in consultation with the ecological consultants, three suitable transects for fen characterisation and impact assessment were identified. Piezometer nests were installed along Transect 1 (T1), Transect 2 (T2) and Transect 3 (T3) to determine hydraulic gradients, flow and hydrochemistry. These investigations and the results obtained are discussed in Section A13.1.3.4 of this Appendix 13.1.

From the preliminary site investigation boreholes, a shallow rock-head between 0.8 to 3.2m below ground level is recorded along the proposed road development. Weathered bedrock is recorded at 0.4 to 1.6m thickness below rock-head. The Kiltorcan Formation at the site is recorded as “a strong to very strong, medium bedded to locally thin bedded, pale green / grey / brown, fine to locally medium grained SANDSTONE that is fresh to locally slightly weathered, intersected by smooth, planar, tight to narrow, locally clay-infilled, locally moderately iron-oxide stained, locally quartz-filled fractures of 45^{o} and sub-horizontal dip” (RC-19250). Variations in this description involve coarsening upward units such as in RC17500, where fine to locally coarse grained sandstone overlies units of fine to locally medium grained sandstone. Variation in the dip and colour also occurs locally (e.g. fractures of irregular dip in RC-17500 and orange to locally purple units in RC-18300).

Bedrock drilling of 4 deep boreholes was carried out to define the geology and hydrogeology along the extent of the eastern catchment boundary to Hugginstown Fen. These boreholes were drilled using a Rotary Percussion Air Flush System and they were positioned to best extrapolate from existing installations to obtain maximum hydrogeological data for interpretation and impact assessment. Geological results of these investigations indicate that the lithological sequence is generally dominated by brown, grey and purple, medium grained Sandstone. BR2 contains a finer lithological sequence with fine sandstone and 10m of dark brown Mudstone occurring above the water table. This Mudstone unit is identified as a local aquitard. The irregularity of its distribution is likely to be a function of the origin of the Kiltorcan Formation, interpreted to have been deposited in shallow waters in a fluvial / freshwater lacustrine environment (Ref. 13). Fractures are identified in boreholes by percentage weathering associated with iron oxide discolouration. Generally the frequency and percentage of weathering in these fractures increase when the water table is approached, e.g. BR3 and BR4.

A13.1.3.4 Water

Surface water

<u>Site Investigations</u>
Surface water site investigations involved the following:

- Preliminary site walkover and assessment of site hydrology.
- Mapping of significant drain features.
- Hydrochemical measurements of main drains along their course (electrical conductivity, pH and temperature).
- Setting up of permanent surface water monitoring points for hydrochemistry and flow measurements.
- Flow measurements at critical points in main drains to determine baseline flow capacity, influent or effluent conditions, drain significance and hierarchy.
- Installation of staff gauges in main drains to couple adjacent piezometers and for potential stage-discharge curve generation (for future water balance assessments).

These site investigations combined with close examination of aerial photographs along the proposed road development corridor provided the following results and understanding of surface water characteristics at Hugginstown Fen.

<u>Drainage</u>
Four significant drains have been identified at and surrounding Hugginstown Fen. These are:

- D1 (main central, south drain)
- D2 (peripheral south drain)
- D3 (northern drain)
- D4 (spring discharge feature)

Of these four drains, D1 is by far the most significant in physical size, flow yield and location in the fen. It is a man-made central drain in the southern fen. This part of the cSAC has been degraded by bog cutting, drainage and grazing (see EIS Figure 13.3 in Volume 2 – Book 2). The dimensions of D1 are c.2.5m wide and c.1.5 bank depth. It is a linear consistent feature. At Transect 1, its flow was measured at 1,537m^3/day on the 23/06/03 at FG1. This flow is representative of baseflow conditions following sustained dry conditions. Some c.850m south along D1 below the cSAC boundary at the site, at FG2 a flow yield of 2,868m^3/day is recorded on the same day. This indicates an average increase of 1.6m^3 per metre along this stretch of D1. FG2 is where D1 starts to form a distinct stream tributary to the River Derrylacky.

D2 is a much smaller drain that has been enhanced from spring discharge in the south-eastern part of the fen. Its flow was not measured but is considered to be one order of magnitude lower than in D1. D2 joins D1 at the southern boundary of the site. D3 is second in significance to D1 and occurs in the opposite side of the site, to the extreme north. It arises from a natural spring discharge area in the north part of the fen, and winds its way to and under the existing third class road at SG3. Flows measured here on the 24/06/03 under similar weather conditions to D1 indicate a baseline flow of 656m^3/day. D4 is a spring discharge feature of significant length (c.300m) but is of indistinct form. It seems to be a natural feature that drains to an enhanced “soakaway” (per. comm. with a landowner). While drains, D1, D2 and D4 occur within the catchment of Hugginstown Fen, D3 occurs outside the boundary of this catchment and feeds a separate catchment. This drain discharges to an early feeder stream to the Little Arrigle River that passes by Knocktopher in the northeast.

Aside from the distinct drains / surface water flow features identified above, ponding of water arising from diffuse spring discharge is identified along most of the eastern side of the fen. This is clearly seen from examination of aerial photographs of the site, and is also evident from the site walkover. This water is diffusing slowly into the groundwater and contributes to standing water in the fen of between 0.2-0.3m above ground level. Where ponding of water was significant and where iron staining and the clear discharge of groundwater were noticed, a surface water monitoring point for hydrochemistry was created. These were labelled as the SP/SW1 to SP/SW5 series to represent spring discharge measurements and are discussed under water quality below.

Water Quality

Surface water quality was assessed in the field by measuring electrical conductivity, pH and temperature. Along each of the drains identified above, as well as for spring discharge and surface water ponding locations, these parameters were measured and geo-referenced for future monitoring. Monitoring IDs such as D2/SW2 for the drains and SP/SW3 for the spring discharge areas were given to measurement locations. The results of these measurements indicate a general pattern of highest electrical conductivity in the spring discharge points along the boundary of the fen, particularly in the active central fen area with values of 420mS/cm to 520mS/cm. Values within the drains were lower between 200mS/cm to 300mS/cm reflecting the more mixed baseflow waters draining from the fen. Surface water pH values were generally high, with the highest 7.56 pH at SP/SW5 and the lowest value of 7.00 pH at D3/SW1. These values indicate that higher alkalinity waters occur at and along the margins of the fen as a result of carbonate rich groundwater spring discharge, while less alkaline waters occur in the drains in the central and northern fen. Temperatures were moderate at the time of measurement with values of 18.5ºC to 11.9ºC. No pattern in the distribution of temperature values was identified.

Surface water samples were taken for analysis of major ions, nutrients and suspended solids. The results indicate the water was clear at the time of sampling (01/07/03) with no suspended solid content at a detection limit of 10mg/l. The waters have high calcium and magnesium ionic concentration indicating a likely origin from a limestone based system. Nutrients are low with the exception of D3/SW3 with 11.7mg/l of nitrate. A trace of dissolved orthophosphate was recorded in D1/SW2 at 0.16mg/l. In the case of D3/SW3 the nitrate recorded is likely to reflect agricultural influence from the adjacent grasslands fields. The trace of orthophosphate at D1/SW2 is curious but may reflect the proximity and origins of D1 near the western boundary of the fen (near agricultural grassland). Iron and manganese are low and are likely to have precipitated out in the oxidising surface water environment. The electrical conductivities recorded indicate low values of 205mS/cm to 209mS/cm with alkaline (7.45 at D1/SW2) to near neutral (7.09 at D3/SW3) pH. It should be noted that these physiochemical parameters are less accurate than the field measurements taken. This is due to their changeability once taken from the sampling environment.

Results from field and laboratory analysis indicate that the surface water at the site originates from groundwater discharge, is alkaline and of a calcium / magnesium bicarbonate water type with moderate electrical conductivity and of generally good water quality at the time of sampling.

Groundwater

Site Investigations

Groundwater investigations undertaken at Hugginstown Fen involved the installation of a groundwater monitoring network along three transects, T1, T2 and T3 which run perpendicular to the proposed new mainline. These installations consisted of 8 deep mineral subsoil piezometers labelled “P1’s”, 4 deep peat piezometers labelled “P2’s” and 11 water table monitoring phreatic tubes labelled “PH1’s”. Notwithstanding some stand-alone phreatic tubes, these installations were arranged in nests along the three transects to provided depth profiles in hydraulic gradients and hydrochemistry.

These installations were installed by hand using a gouge corer and by carefully hammering and physically driving in place deeper “P1” piezometers. This is a proven methodology once ground conditions are suitable and it avoids significant disturbance and damage to vegetation by hydraulic and motor operated drilling / installation devices. The materials installed consist of 27mm OD/18mm ID uPVC screw threaded casing. For the mineral soil P1's a 0.35m length of 27mm OD/18mm ID uPVC screw threaded, 1mm slotted screen was installed as the response zone. For the P2's the response zone is a 0.35m length x 27mm OD/18mm ID uPVC microporous polyethylene tip. The polyethylene tip is specifically designed for use in peat substrates with a high exposed filtered surface area to assist well recharge, while avoiding peat clogging of apertures. The PH1's have a similar microporous polyethylene tip but it is 0.75m long and straddles the ground surface to monitor open water table fluctuations. These installations were undertaken between the 24-25/06/03 and provide access to the groundwater for hydrometric and hydrochemical assessment, the results of which are outlined below.

Under the second phase of investigations, 4 deep overburden installations (OB15 to OB18) were drilled using a Percussion Window Sampler (PWS). This motor operated hydraulic unit allowed for deep penetration of mineral subsoils along the eastern periphery of the fen (OB15, OB16 and OB17) and where access allowed, at OB18 within the fen itself. Due to the degraded nature of this part of the fen, flora was not damaged during the drilling of OB18. These installations were undertaken between the 15-16/10/03. Four bedrock wells were also drilled, mainly upgradient and to the east of the proposed road development. These boreholes were drilled between the 28-31/10/03 acquiring depths of up to 54m to intercept a deep water table on the upper slopes of the catchment. Finally, the following preliminary site investigation boreholes RC-17500, B-ST27, RC-18300, RC-18620, RC-18990, RC-19250 were used for water levels and field hydrochemistry.

<u>Groundwater Flow</u>
Following groundwater network installation, the points were initially surveyed using standard Pentax AL-180 (dumpy) levelling equipment and a marked temporary benchmark (TBM). This provisional survey was undertaken for installations within the fen only, in order to provide immediate data on vertical head differences for hydraulic interpretation. Differential GPS surveying was undertaken between 6-7/11/03 using GPS 500 instrumentation. The survey consisted of both (a) topographic representation at a frequency of 5m intervals along Transects 1, 2 and 3 for accurate cross section representation, and (b) accurate elevation and grid co-ordinate measurements (accurate to 0.02m) of monitoring point installations for the purpose of reduced water level representation and groundwater contouring.

Water level monitoring has been undertaken at the site from the 01/07/03 following installation of the first phase of installation points.

Preliminary yield testing of the newly installed OB points and BR4 was undertaken to provide an estimate of the permeability of the subsoils and saturated bedrock aquifer adjacent to Hugginstown Fen. Yields >3l/min were obtained for OB15 in Transect 3 and also for OB16 along Transect 2. These yields were sustainable during pumping and suggest a permeability range of 10-6 or 10-7m/s with locally higher permeability horizons in the clayey GRAVELS for example. Air flush testing of BR1, 2 and 3 indicates unsustainable and low yields of <10l/min. Permeability is likely to be spatially irregular due to fractal flow and local aquitard units as evidenced by BR2. The bedrock may vary in permeability from 10-5 to 10-9 m/s pending on fracture development and lithological variability. BR4 provides a yield of >20l/min. However this is a function of hydraulic connection with the overlying and neighbouring sands and gravels overburden rather than being exclusively a representation of the weathered bedrock. Extensive permeability testing of the bedrock was not deemed appropriate for the study following air-flush results and the low water table along the eastern catchment.

<u>Vertical Flow Distribution</u>

- *Transect 1*
  The reduced water levels from the nested piezometers illustrate the impact of drainage on the site's hydrology. Groundwater contours indicate the control by D1 and associated bog cutting in the southern fen on water levels and vertical hydraulic gradients. The impact of this drainage and cutting has impacted almost at far north as Transect 2. It is noted that the distribution of impact is likely to fluctuate, being greater and possibly extending to Transect 2 in the dryer months of the year. The inferred pre-drainage water table is extrapolated to the east of D1. This is likely to be a conservative estimate based on current altered conditions at the site. For the majority of the nests monitored there is a downward gradient in vertical hydraulic flow at the margins of the fen and distal to D1, while near and at D1 a strong upward gradient exists due to higher potential arising from lower pressure and discharging groundwater to the drain (T1/C2). It is suggested from the monitoring data to date that

some piezometer nests show seasonal reversal in hydraulic gradient; however it is recommended that further monitoring be undertaken for at least one calendar year to determine if this pattern is repeated and is seasonal rather than post-installation re-adjustment of head pressures.

BR1 provides valuable data on the water table at BR1 and the likely water table at the position of the proposed new mainline by extrapolation. The water level in BR1 is c.10m into bedrock at 129.76mOD. At the proposed road development, the extrapolated water table is at c.119.6mOD (Ch. 17750).

- *Transect 2*
  Transect 2 illustrates only marginal evidence of being impacted by drainage from D1. Piezometric water levels are almost equal to the free water table. There is a minor downward gradient at the margins of the fen and a very slight upward gradient in the centre. This is the expected hydrological pattern of most valley and basin wetland environments due to the potential of groundwater flow. It is noted that from the charted hydrographs of the installations, a period of hydraulic stabilisation following monitoring point installation is required for the deeper piezometers. This is best illustrated by T1/C4/P1, which took 3.5 months to equilibrate (until mid October 2003). Another example is T2/C2/P1. Examination of the water levels in individual nested couples suggest seasonal reversal in hydraulic gradient, where from November 2003 onwards, the fen surface is inundated with water from discharging springs. This causes a seasonally higher water table that is higher than the deeper piezometric levels. It is noted that a strong increase in the water table is observed near the eastern margin of the fen (T2/C2 and T2/C3) than in the western margin of the fen (T2/C4). This highlights the importance of spring discharge along the eastern side of the fen to the habitat.

  RC-18300 provides water level data along the proposed road development. The water table occurs within the bedrock in this borehole at a depth of c.7mbgl at 118.14mOD. This is lower than what would be expected relative to the results of Transect 1. BR2 occurs c.340m upgradient of RC-18300 provides a very low water table, which is a function of the very fine lithology encountered in this borehole. A mudstone aquitard occurs between c.110 to 120mOD, below which the water table occurs at 99.42mOD. In cross section, this appears as an irregularity and indicates that BR2 has encountered a local aquitard that restricts recharge to the bedrock aquifer. The spatial distribution of this aquitard is unknown, but from the hydrometric results at RC-18300, it seems extensive enough to locally lower the water table in the region immediately upgradient of the fen.

- *Transect 3*
  At the most northern transect, Transect 3, a similar hydraulic pattern to Transect 2 occurs, where at the margins a minor downward hydraulic gradient occurs and towards the centre of the fen a minor upward gradient occurs at T3/C2. The peat is much deeper in the northern fen valley. This allows for better assessment of the hydraulic behaviour within and below the peat by means of two piezometer installations within the peat layer. On examination of the nested piezometer couples, there is some fluctuation in hydraulic heads within the peat as a function of seasonal variation in recharge, while for T3/C2 a consistent upward gradient is identified for the basal mineral soils piezometer. There is more changeability of head gradients at T3/C1 at the margin of the fen.

  Transect 3 intercepts a projection of mineral subsoils at T3/PH1 and T3/PH2 and OB15. This intersection is important in identifying the type of subsoils that make up these “land ridges” and their potential significance to the fen hydrology. The geological results from drilling OB15 and BR4 indicates that proximal to the fen a thick sequence of sandy CLAYS, gravelly SANDS and clayey GRAVELS occur within this land ridge. Site specific lithological, hydrochemical and permeability results indicate that these subsoils are an alkaline boulder clay with some fluvio-glacial (water sorted) horizons occurring at depths, potentially above rockhead. The thickness of these subsoils (c.7m at OB15) near the axial trend of the valley relative to the thin subsoils deposits upgradient of the valley at BR4 and along the proposed road development at T-18610 (c.3.7m) suggests the preferential deposition of these deposits near and under the fen valley (topographic low). Water levels in OB15 and BR4 are high and within 1-2m of the ground surface. This indicates that the aquifer is a saturated aquifer and from the permeability testing of both OB15 and BR4 is moderately permeable and conducive to sustainable throughflow of groundwater to discharge to the fen.

Water levels in RC-18620 c.110m upgradient of BR4 are low and there is just c.0.25m of water column in the piezometer / phreatic tube installed. This low water level within bedrock at 121.26mOD does not follow the topographic rise to the east. This low water table is further emphasised by BR3. This information indicates that the groundwater divide occurs somewhere between RC-18620 and BR3 and that the groundwater is impacted by the proximity of the Little Arrigle catchment to the northeast. Based on regional topography, there is a difference in the surface water and groundwater catchment at the boundary of the Hugginstown Fen and Little Arrigle Catchments. A potential second explanation for the low water table at BR3 is the secondary impact of a large tract of established forestry (reducing groundwater recharge) to the northeast of the study area (see EIS Figure 13.2 in Volume 2 – Book 2).

Spatial Flow Distribution

Spatially the groundwater flow gradients are controlled by the valley topography. The study indicates that groundwater flows to the fen and then to the south past Transect 1. This southern direction of groundwater flow is an important hydraulic characteristic of the fen and implies, particularly at depth in the mineral subsoils accompanied by the vertical flow distribution outlined above, that recharge waters are received by the fen from depth along the axis of the fen valley itself. The percentage of this recharge compared to the normal upland sourced recharge in the catchment is unknown. The main aquifer of throughflow is likely to be the base-rich subsoils and the upper weathered bedrock where it is saturated (i.e. within the valley). Groundwater reaches the surface of the fen by diffuse spring discharge at the eastern boundary mainly, with secondary spring discharge occurring in the west. Due to the relatively low permeability of the peat, this water ponds up and becomes standing water over most of the fen. This standing water or semi-aquatic conditions is highest (0.3m above ground level) in the northern part of the valley where swamp conditions and bulrush and horsetail flora grow (see EIS Figure 13.2 in Volume 2 – Book 2). Groundwater flow also occurs within the mineral subsoils and the weathered bedrock beneath the fen peat. This lateral flow meets in the lowest part – the centre of the fen. Here pressure builds up and an upward gradient of flow is created. This upward gradient does not necessary imply that groundwater flows upward into the peat, but some upward leakage is likely and is indicated by the hydrochemistry of the deeper peat. The upward hydraulic gradient itself is an indicator of the habitat health of the fen or bog as it is essential in maintaining moist / wet conditions in the fen environment for active fen flora growth.

Groundwater Quality

Groundwater field hydrochemistry was obtained on the 01/07/03 from all groundwater monitoring points installed. As for the surface water, the parameters measured include physiochemical indicators: electrical conductivity, pH and temperature. The results of field analysis indicate two distinct trends in groundwater conductivity. The first is that the phreatic "water table" conductivity decreases as one moves from the boundary to the centre of the fen. Transect 3 best illustrates this pattern in the north, with values of 634mS/cm at T3/PH1 decreasing to 366mS/cm by T3/C1/PH1 and to 298mS/cm by T3/C2/PH1 in the centre of the reed swamp. A generally similar pattern occurs for Transect 1 and 2. A second trend is an increase in groundwater conductivity with depth in the piezometers nests installed. Due to the greater depth of peat along Transects 2 and 3, this pattern is reflected by a depth profile range in conductivity values of 298 to 388mS/cm in the PH series (shallow peat), 388 to 511mS/cm in the P2 series (deep peat) and 368 to 541mS/cm in the P1 series (mineral subsoils). Some miscellaneous values that do not fit these trends are T1/C3/PH1 (870mS/cm), T2/C4/P2 (511mS/cm) and T3/C2/P2 (419mS/cm). These installations all have higher conductivities than its nested deeper P1 installation. This may be explained by either intrusion into or proximity to similar mineral subsoils as P1 or all of these points occur near the western boundary of the site (may reflect variable subsoils conditions).

A subtle depth and spatial trend in pH is also observed. The lowest pH values recorded in the field occur within the peat substrate, reflecting the slightly acidic conditions induced by the reducing anaerobic peat environment. An average 6.66 pH (6.93 max, 6.28 min) is recorded for the shallow peat PH series and an average 6.61 pH (6.70 max, 6.47 min) is recorded for the deeper peat P2 series. For the mineral soil P1 series, an average pH of 6.75 pH (7.11 max, 6.47 min) is recorded. Within the water table PH series, the highest pH values occur near the eastern boundary of the fen where the spring discharge occurs, e.g. 6.89 pH at T3/PH1. This is also the case for Transect 2, while at Transect 1, which has been altered by drainage, bog cutting and grazing, the western peripheral T1/C3/PH1 has a marginally higher pH of 6.69 than at T1/C1/PH1 (6.56 pH). Of the groundwaters analysed, only one piezometer, T1/C2/P1 records an alkaline pH of 7.11. No pattern in the distribution of temperature values was identified.

A domestic well near the eastern boundary of the fen and cSAC, occurs c.130m north of T2/C1/PH1 of Transect 2. This well has been labelled as Well 1 and is known locally as "Paddy's well". It is the domestic supply well to a local landowner's dwellings. It was audited on the 21/06/03 and is recorded to be 0.75m depth below ground level (the GSI well audit indicates a depth of 1.3mbgl), is 1.5m wide and likely to consist of 1 ringed concrete culvert. The well manipulates a spring that discharges to the fen. This discharge to the fen is maintained by a side perforation in the culvert wall. The water quality of the well was recorded at 497mS/cm, 7.14pH and 10.7ºC. Depth stratification was identified in the well with conductivity more than halving to 225mS with depth, pH dropping to 6.61pH and temperature rising to 11.9ºC near the base of the well. Strong iron oxide staining and iron precipitation was observed in the well and in its discharge to the fen. A strong flow was observed to discharge naturally from the well into the fen (estimated at 5l/s) when stagnant surface vegetation was cleared.

Following the installation of further monitoring points during the second phase of works, a selective programme of field hydrochemistry measurements was undertaken between the 14-17/11/03. Field parameters were again electrical conductivity, pH and temperature, and also alkalinity where possible. The following monitoring points were selected for measurement: T1/C1, T1/C2, T2/C3, T3/C2, OB15, OB16, OB17, OB18, BR2, BR3, BR4, RC-19250, RC-18300, B-ST27, RC-17500, D1/ SW2. This data provides additional hydrochemical information and is combined with the full hydrochemical monitoring event on the 01/07/03. These selected couples clearly illustrate the control of depth and associated lithology on the hydrochemistry of the groundwater with conductivity, alkalinity and pH all increasing in depth within the fen environment, as the mineral subsoils are encountered and are alkaline rich due to the limestone origin of the boulder clay. However it is noted that as one moves away from the fen valley up the flank of the eastern valley catchment, conductivity, pH and alkalinity all reduce to moderate values within the deeper groundwater of the Kiltorcan Sandstone Formation. This is relatively fresh recharged groundwater within an acid bedrock environment. The low conductivity values and in particular alkalinity and pH reflect the contrast of this acidic environment to the alkaline environment beneath and adjacent to the fen. Due to the high vegetation content of the fen itself and partial decomposition, the peat environment is also acidic in nature. Transect 2 best illustrates the hydrochemical environment variation as discussed.

Samples were taken for analysis of major ions and nutrients. Comparing deep peat and mineral subsoils values to shallow peat results, it is noted that the redox elements iron and manganese are high in the shallow peat due to active organic reduction. Calcium, bicarbonate and marginally, magnesium are higher in the deeper groundwater as would be expected. Traces of nitrate are recorded in T1/C3/P1 and T3/PH1. Both are proximal to agricultural land and may be slightly contaminated by this source. Sulphate is average in value with higher values for T2/C3/PH1 and T3/PH1. Aside from the minor differences outlined, all groundwater analysed has a calcium bicarbonate signature indicating an origin or significant influence by an alkaline substrate medium. This assessment highlights the significance of the peripheral subsoils to the site to impart this chemistry rather than the acidic sandstone bedrock that underlies and surrounds the site.

Aquifer Classification

A provisional aquifer classification by the Geological Survey of Ireland (Ref. 7) describes the Kiltorcan Formation as a regionally important fissured bedrock aquifer (Rf). The main criteria for classification as a regionally important aquifer is that it is >25km^2 in areal extent, spring low flow is >4,000m^3/d and well yields are >400m^3/d, as well as other secondary criteria (Ref. 8). The groundwater flow in these aquifers occur in the fissures and fractures, with the main body of flow occurring in the upper weathered bedrock, which is generally <10m below rockhead. Site specific descriptions of the Kiltorcan Formation indicate that it is a fine to medium grained limestone with local iron-oxide stained fissures and fractures. The local clay infilling and the tight nature of the fractures may reduce the aquifer's resource potential locally. Weathering is observed to extend between 0.4 to 1.6m below rockhead.

The GSI do not identify any local or extensive sand and gravel Quaternary aquifers in the study area. However such deposits are significant in the amount of recharge that is allowed to reach the bedrock aquifer. In terms of this study, the glacial subsoils present at the margins of the site and beneath it, play an important role in imparting base-rich hydrochemistry to the groundwater prior to discharge to the fen. This is discussed further in Section A13.1.3.5.

A Review of the "regionally important fissured bedrock aquifer" status of the Kiltorcan Formation has been undertaken following the results of the second phase of site investigations at Hugginstown. Three bedrock wells were drilled along the upper eastern flank of the fen valley to establish the yield returns, water levels and importance of the Kiltorcan Formation in supplying groundwater to Hugginstown Fen and whether the proposed road development would hydraulically impact on this groundwater supply. A final bedrock well (BR4) was drilled near the fen itself above an identified area of clayey sands and gravels to assess the saturated upper weathered bedrock at this location (the upper weathered bedrock was unsaturated in the other BR wells). The results of these site specific investigations highlight that the Kiltorcan Formation is classified incorrectly. Due to the fineness and irregularity of the lithology accompanied by low water levels below the upper weathered rockhead layer, Minerex identifies the Kiltorcan Formation along the eastern valley side of Hugginstown Fen as a "Poor Aquifer" of type "bedrock which is generally unproductive except for local zones (Pl)" (Ref. 9).

<u>Preliminary Well Audit</u>

Consultation with the Geological Survey of Ireland's national well database indicates that 15 wells are registered with the GSI within 2km of the centre of the subject site. Two of the wells registered occur within the Carrigmaclea Formation while two further wells manipulate the Quaternary sediments that overly the Kiltorcan sandstone bedrock. One of these wells is "Paddy's well" that supplies a local landowner on the eastern margin of the fen, north of Transect 2. A second well that utilises a spring occurs opposite and south-southwest of Paddy's well along the western margin of the fen (2313SEW126). This spring, which sustains the reed swamp in this area, is partially drained by D1.

Unfortunately the yield class for 11 out of the 15 wells is unknown. Three wells are considered poor in yield (wells: 2313SEW116, 2313SEW123 and 2311NEW009). This implies a yield <40m^3/d. One well's yield class is failure (2313SEW128). While the results of this database enquiry indicate that a significant number of wells occur in the catchment(s) around the fen, suggesting an important water supply source, it provides little information on the yields obtained from 73% of the wells identified. In addition the reasons for the poor yields at the 3 wells and failure at 1 well are not highlighted / explained. The majority of the wells are for domestic and agricultural use (80%). The maximum depth bored is 44.4m in 2313SEW129 and the shallowest wells occur at springs such as 2313SEW126 (1.0m) and 2311NEW009 (0.6m), which are natural groundwater discharge points. In general a depth range of 19 to 45m is identified for the bored wells in bedrock. Little data exists for depth to bedrock and DTB will be strongly determined by topographic location, whether the wells are located near the top of hills (<3m depth of overburden) or are located in the valleys, where up to 20m of overburden may be encountered.

Records of a conversation with the landowner indicates that prior to utilising and relying solely on his spring well that naturally discharges to the fen, known as "Paddy's Well", he contracted a driller to attempt to source groundwater near his farmstead. Three boreholes were drilled to depths of c.40m but were unsuccessful in supplying a sustainable water supply for the house and farmyard (required estimate of c.50m^3/d). Further to site investigations undertaken as part of this study in October 2003, very poor and unsustainable well yields (<14m^3/d) were recorded for BR1, 2 and 3 along the eastern flank of the recharge valley to the fen. This is due to poor yields and also depth of the water table. This poor aquifer status is likely to explain the large number of attempted boreholes in the immediate catchment of the fen. The aquifer is likely to be highly variable and may be significantly better to the north, south or west of the fen.

<u>Vulnerability Assessment</u>

The Geological Survey has produced guidelines on groundwater vulnerability mapping that aim to represent the intrinsic geological and hydrogeological characteristics that determine how easily groundwater may be contaminated by human activities. Vulnerability depends on the quantity of contaminants that can reach the groundwater, the time taken by water to infiltrate to the water table and the attenuating capacity of the geological deposits through which the water travels. These factors are controlled by the types of subsoils that overlie the groundwater, the way in which the contaminants recharge the geological deposits (whether point or diffuse) and the unsaturated thickness of geological deposits from the point of contaminant discharge (Ref. 9, 10).

For vulnerability assessments with regard to bedrock aquifers, the relevant geological layer is the subsoil between the release point of contaminants and the top of the bedrock. Any unsaturated bedrock layer is not considered as it is assumed that bedrock has little or no attenuation capacity due to its fissure flow characteristics. Groundwater encountered in low permeability tills or peats or other non-aquifer subsoils is not considered to be a target. Therefore, where low permeability subsoils overlie the bedrock it is the thickness of subsoil between the release point of contaminants and bedrock that is considered when assessing vulnerability of bedrock aquifers, regardless of whether the low permeability materials are saturated or not (Ref. 9).

The GSI vulnerability mapping guidelines allow for the assignment of vulnerability ratings from "extreme" to "low", depending upon the subsoil type and thickness. With regard to site specific assessments where low, moderate and high permeability subsoils are present, the following subsoil thicknesses and associated vulnerability categories are specified (Ref. 10).

Table A13.1.1: Groundwater Vulnerability Guidelines Applicable to Site Assessment – Subsoil Thickness

	High permeability (sand/gravel)	Moderate permeability (sandy till)	Low permeability (clayey till, clay, peat)
Extreme	0 - 2.0m	0 – 1.5m	0 – 1.0m
High	>2.0m	1.5 – 8.0m	1.0 – 3.0m
Moderate	N/A	>8.0m	3.0 – 8.0m
Low	N/A	N/A	>8.0m

Notes: (i) N/A=Not applicable
(ii) Precise permeability values are not known

The Geological Survey of Ireland has attributed provisional vulnerability ratings for the study area based on their current understanding of the hydrogeology of the area. From this desk assessment, the entire eastern side of the fen is of "extreme (rock near surface) vulnerability", which implies a depth of <1m to bedrock (Ref 10). The fen area itself and the area to the west of it, is given an "extreme" vulnerability. However the GSI state that these vulnerability ratings are provisional based on the data acquired and available to them, and that site specific data will take precedence in vulnerability ratings for the study site in question. Following site-specific investigations and using the guidelines in Table A13.1.1 above, a site-specific vulnerability map was produced. This map defines from field data the vulnerability ratings along the eastern catchment to the fen. In the absence of site specific data for the northern and western part of the catchment, the GSI aquifer classification and vulnerability ratings are used.

From site specific data, an extreme vulnerability (Pl/E) for the bedrock aquifer has been identified to occur in the northeastern fen catchment, from data acquired from boreholes B-19250, RC-19250 and B-18990, RC-18990 respectively. Extreme vulnerability (Pl/E) is also designated in the immediate area of T-17750 and T-17500 / RC-17500 in the southern proposed road mainline section between Ch. 17,400 and 17,800. This combined area of proven (site specific) extreme vulnerability makes up c.20hectares of the catchment and up to 0.9km of the proposed road development section proposed at Hugginstown. This is c. 50% of the proposed road development route and c.7% of the total catchment. High Vulnerability (Pl/H) has been identified along the remaining eastern side of the valley. Within the fen itself, at peat and overburden depths >3m, a moderate vulnerability (Pl/M) is identified. This occurs in the northern to central fen.

In the absence of site specific information in the northern and western parts of the catchment, the original GSI aquifer classification and vulnerability ratings are used. A provisional high vulnerability rating (Rf/H) makes up the majority of the Hugginstown catchment and occurs around the fen and to the west of it. A provisional extreme vulnerability rating (Rf/E) is allocated to the north of the site, extending from the proven extreme vulnerability identified between Ch. 18,600 and 19,300.

Of significance to this study is the vulnerability rating along the proposed road development at the eastern boundary of the fen. Within the catchment boundary to Hugginstown Fen, for c.50% of the proposed road development an extreme vulnerability is identified. The significance of these vulnerability ratings in relation to the proposed development is discussed in Section A13.1.3.5 and A13.1.4.

A13.1.3.5 Fen Hydrology

Recharge and Discharge Zones
Distinct groundwater recharge and discharge zones are identified in the Hugginstown Fen catchment. Groundwater recharge is occurring along the valley side on the agricultural land to the east, west and to a much lesser degree north of the fen. Of relevance to this study is the recharge along the eastern side of the valley to the fen. Spring discharge evidence, flow gradients and hydrochemical results indicate that the eastern boundary to the fen is more significant than the west in terms of groundwater supply to the fen. However, following advanced investigations of the bedrock aquifer along the eastern valley, it is identified to be a poor aquifer rather than the GSI classified 'regional aquifer'. The depth to the water table is also deeper in places than would be expected, such as Transects 1 and 3. While a groundwater supply from the bedrock aquifer is identified as a recharge source to the fen, the significance of the adjacent and underlying glacial subsoils has increased since reporting on phase 1 of investigations (Ref. 14 & 15). While previously, these subsoils were identified as being important in imparting chemical content to the waters that recharge the fen (originally thought to be mainly sourced from the bedrock aquifer), these subsoils are also now identified to supply a lot of the recharge waters directly, from both upgradient within the valley of the fen, i.e. from the northern fen, and from the immediate periphery of the fen such as the "land ridges" that extend into the fen. The hydrogeological model for the site has altered significantly for the fen with the significance of the bedrock reducing and the significance of the underlying and adjacent subsoils increasing in both hydraulic and hydrochemical importance.

Discharge from groundwater to surface water occurs along the immediate periphery of the fen in the form of spring discharge. Because the fen is a 'fen valley system', the regional water table is higher that the fen topography and naturally discharges into it on meeting the less permeable peat substrates at the fen margin. This is the most obvious form of discharged water in the fen. Groundwater is also being discharged from the peat and the subsoils to any drains or natural invert features. Natural drainage appears to occur at D4 as a result of strong spring discharge from the area to the east of the fen. Hard standing drainage in D1 and D2 has a major impact on fen hydrology and affects groundwater discharge by at least 10 times the depth of the drain invert (Ref. 11). Close examination of the 6" map series (1:10,560 scale) indicates that drainage was more extensive in the 1920's and 1930's with D1 extending the length of the fen valley. This drainage would have limited fen growth promoting drier conditions and agricultural use of the terrain, as evidenced by the fenced fields within the fen study area at the time. The infilling of this drain by vegetation over time has lead to the partial recovery of fen vegetation. This stagnation in drainage assisted fen growth and the ponding of surface water at the fen surface for fen and flush growth.

Fen Catchment
The fen catchment size is c.2.67km^2. It is defined by the two topographic high ridges (180 to 150mOD) on either side of the fen and by a watershed contributing to the Little Arrigle River catchment in the north. A complex array of catchments that drain to separate river systems occur in this area. A total of four catchments are identified within an area 2-3km upgradient of Hugginstown Fen. These are described as follows:

a) Hugginstown Fen the lower limit of which is defined by the southern margin of the cSAC boundary. D1 flows south from the fen and forms a stream tributary to the Derrylacky River that in turn joins the River Suir north of Waterford city.
b) Little Arrigle River catchment to the northeast, which drains the most northern part of the cSAC. Here D3 feeds one of the stream tributaries to the River Arrigle that flows north to join the River Nore.
c) Pollanassa River catchment to the west which runs parallel to Hugginstown Fen. This forms the Pollanassa River, which enters the Blackwater and joins the River Suir below Mullinavat.
d) Toberdangan River catchment to the northeast and drains northwards to join the River Glory and King's River consecutively before joining the River Nore in the northeast.

The Fen catchment identified for Hugginstown is used in water balance calculations below as well as overlaying with geology and vulnerability ratings along the proposed road development to determine impacts on the catchment and its hydrology. These potential impacts are discussed in Section A13.1.4.

The very northern part of the cSAC is in a separate catchment, that of the Little Arrigle Catchment. While the proposed road is within cut in this catchment, detailed assessment of this section of the cSAC was not required for the following reasons:

(a) This stream / drain (Drain 3) controls the immediate hydrology of the cSAC in this area. The proposed road development chainage 19,200 to 19,700 occurs within this catchment. Groundwater that would recharge from the terrain along the proposed road would flow to the north and northwest. The majority of this groundwater would not reach the cSAC area, but would instead discharge to Drain 3. The topography at Drain 3 is the lowest in the immediate area with ground rising on either side of it. Due to topography and interception by Drain 3, the proposed road at its current location would not impact on the cSAC.

(b) The proposed route is at a minimum distance of c.180m from the cSAC boundary in an area of scrub habitat. Directly due west of the proposed Cut 2 at Ch. 19,250, the road development is c. 325m away from the reed swamp habitat and is in a separate water catchment. Both the distances and the catchment divide protect the cSAC area due west and northwest of the road development from any impact of the development.

(c) From assessment of the groundwater table and its potential interception by Cut 2, calculations to date indicate that a >2m clearance is characteristic. This implies a non-direct hydraulic impact. Furthering monitoring will be undertaken to evaluate these predictions.

(d) The cSAC habitat vegetation in the northern section of the fen is not as ecologically significant as that of the “rich fen and flush (PF1)”, “bulrush swamp (FS1)” and “transition mire and quaking bog (PF3)” in the centre and southern part of the fen. The positions of the transects and site investigations and permanent monitoring structures were undertaken following consultation with the ecological consultants in order to focus the hydrological studies on the most important ecological areas in the fen. This resulted in the three selected transects, T1, T2 and T3, which formed the applied assessment in this study along with the boreholes along the propose road.

From assessment of the above ecological, hydrogeological and engineering design results no further investigations are required for the northern catchment.

Water Balance

A water balance analysis has been calculated for the Hugginstown Fen and the results are presented in Table A13.1.2 below. ‘Mullinavat’ rainfall gauge occurs at an approximate elevation 56mOD and 7.5km southeast of the study site. While this elevation is half that of the subject site, the rainfall data at this location illustrates a local high in precipitation that is not reflected in the nearest rain gauge of similar elevation to the study site at Johnstown (37km to the northwest). Due to the proximity of Mullinavat and the sensitivity of wetlands to rainfall, the Mullinavat station is considered more representative of site conditions and is used in the water balance calculations for Hugginstown Fen. Mullinavat rain gauge listed at Grid Ref. S564239, has recorded rainfall between 1946 and 1984, the records of which are listed within the “Meteorological Service Records for period 1961-1990 database” (Ref. 12). The nearest synoptic station is at Kilkenny with meteorological service records for the period 1961 to 1990. These meteorological records show that the highest average monthly rainfall and the lowest average evapotranspiration occur in the month of January. As these data represent the worst case scenario, they have been used to estimate a water balance for the subject site.

Table A13.1.2 Water Balance Analysis

Parameter	Value
Average January Rainfall (mm) Based on 38 years data from Mullinavat rain gauge	126
Average January Potential Evaporation (mm) Based on 29 years data from Kilkenny Station	2.4
Average January Actual Evaporation (mm) (PE x 0.92)	2.2
Effective Rainfall (mm)	124
Area of "Hugginstown Fen" catchment (m^2)	2,670,000
Water Budget Available (m^3)	331,080
Area of mineralised groundwater recharge catchment (minus fen and peatland areas)	*2,350,000*
Water Budget Available from Recharge catchment (m^3)	*291,400*
Approximate area to be developed – hard standing road surface (m^2)	43,750
Approximate **Total Water Runoff** from impermeable areas in January (m^3)	5,425

The road development will take away 1.6% of the total catchment and equivalent potential recharge to the fen. If one takes out the fen itself and highlights the "recharge catchment" which describes the recharge of mineralised groundwater from the fen valley sides, this percentage reduction in water budget arising from the development is 1.8%.

If the proposed development is implemented, approximately 43,750m^2 of the subject site would be built upon creating a hard standing catchment that will feed a hard standing drainage system prior to outfall to natural drainage. This catchment area would amount to a runoff from the developed areas of c.175m^3/day in January, the wettest month. This storm runoff would need to be controlled and attenuated before release to natural drainage. Measures to mitigate any potential negative impacts by storm runoff, associated drainage and its release to the natural hydrological system is discussed in Sections A13.1.5 of this Appendix 13.1.

A13.1.4 PREDICTED IMPACTS

Probable or likely impacts on Hugginstown Fen by the proposed road development are outlined below. For each impact, it's significance, magnitude, duration and whether it is positive, negative or neutral is identified.

1. Dewatering by Cuts along Proposed Road Development

Two cuts occur between Ch.17,400 and Ch.19,700. These cuts are shown as part of Chapter 4 of the EIS Volume 1 – Main Text.

Cut 1 occurs between Ch.18,975 and Ch.19,040. It is c.65m in length and at its nearest point is located c.200m from the cSAC boundary. It is located near the fen catchment boundary and is the only cut to occur within the fen catchment. The proposed maximum cut depth is c.-1.5m to top of proposed road surface at 138.5mOD. Taking the worse case scenario of an additional -2m to cover cross fall, road foundation materials and road drainage associated with the project, the maximum vertical depth of the cut (road foundation & drainage) is c -3.5m. This is 136.5mOD. RC-18990 occurs at the proposed cut and a water level of 134.44mOD was recorded on 17th November 2003. This water level value indicates a clearance of c.2.06m. Water levels rarely vary by more than 1-2m under normal 'steady state' aquifer conditions in Ireland (Ref. 8); therefore, allowing for seasonal fluctuation in water levels, there is a low probability that Cut 1 will intercept the water table. If the cut were to lower the water table locally, the distance of the cut from the cSAC (c.200m) and its location on the proposed mainline (approximate chainage 19+000), just within the boundary of the hydrological catchment, indicates that Cut 1 would have an insignificant impact on Hugginstown Fen. In addition this cut will be within bedrock, which is designated to be of poor aquifer status in this part of the study site.

Cut 2 occurs between Ch.19,235 and Ch.19,338, with a cut length of 103m. This cut occurs outside the catchment of Hugginstown Fen, however because it is within 100m of the catchment boundary, it is discussed here. This cut is nearest to the cSAC boundary at c.200m in the north, but at this location it is outside the main catchment of the fen (Little Arrigle River Catchment). At Ch.19,315, the proposed maximum depth of the cut is c.-0.5m to proposed road surface at 135mOD. Adding another -2m to cut depth for road foundation and drainage, this brings the maximum cut to c.133mOD. Water level measurements at RC-19250 on 17th November give reduced water levels of 130.6mOD. This gives a clearance of c.2.4m. This clearance including the fact that the cut is outside of the hydrological catchment and c.200m from the cSAC boundary indicates that Cut 2 will have an insignificant impact on Hugginstown Fen.

In addition to the mainline of the road development, there is a proposed local road realignment (including overbridge across the mainline) that maintains access to the existing local road network. This road occurs between the mainline and Hugginstown Fen between chainage 17,900 to 18,500. This road will have no cuts and the cSAC is buffered by the existing third class road that occurs between this road and the cSAC boundary. Once standard engineering controls are used in the construction of this road with no excessive stripping of grounds for its construction, and with standard shallow road drainage, this secondary road will have an insignificant impact on Hugginstown Fen.

It is noted that the very northern part of the cSAC is within a separate catchment, that of the Little Arrigle Catchment.

2. Reduction in Fen Catchment

The proposed road development will reduce Hugginstown hydrological catchment by 1.6%. In terms of water balance calculations the net loss may reach 1.8%. This percentage reduction in catchment is insignificant and is of low magnitude. Natural catchment loss at <2% will have an insignificant negative impact on Hugginstown Fen.

3. Reduction in Groundwater Recharge

The construction of the hard standing road surface will lead to a reduction in direct groundwater recharge by diverting precipitation from the road surface to storm run-off and to the surface water drainage system. On assessment of the importance of the bedrock aquifer, which occurs in the area of development, the aquifer is not as previously thought, to be "regional" in significance (Ref. 9) and is not the dominant aquifer in relation to the fen. The peripheral and basal mineral subsoils play a more important role in recharge and chemistry proximal to the fen. Because these subsoils are relatively thin and unsaturated along the development area, the reduction in groundwater recharge, even proximal to the cSAC between Ch.17,400 and 17,820 is considered to be an insignificant impact on Hugginstown Fen.

4. Construction Works - Soils, Subsoils and Bedrock Removal

During the construction phase of the project, earthworks activity involving the stripping and removal of soils, subsoils and in places bedrock, has the potential to have a significant negative impact on the fen. However, with appropriate environmental engineering controls and procedures (Section A13.1.5 of this Appendix 13.1), this impact can be negated and mitigated. With correct engineering controls, the impact by construction activities is considered to be an insignificant negative impact.

5. Storm Runoff from the Hard Standing Road Surface

Coincident with this reduction in groundwater recharge will be increased runoff from the hard surface of the road. Estimates of road catchment size at 43,750m^2 would give an average runoff of 5,425m^3 during the wettest month of January (Table A13.1.2). This increased runoff has the potential to be a negative impact if not carefully engineered. Correct environmental drainage, attenuation and disposal of increased surface runoff would have to be undertaken to avoid soil erosion (Section A13.1.5 of this Appendix 13.1), potential flooding and hydrochemical impacts on the existing environment.

6. Environmental Emergency Response to Accidental Road Spillages

Environmental risk arising from accidental road spillage during the life cycle of the development is identified as a potential impact on Hugginstown Fen. This risk while not likely or probable is outlined here due to the high sensitivity of wetlands to release of contaminants. It is important therefore to have an emergency response system in place to cater for such an incident, such as an oil tanker overturning and spilling its contents onto the road surface. An emergency clean-up team should be signed up to respond to such an occurrence and deal with a spillage in an environmentally sound and acceptable manner (to the Environmental Protection Agency (EPA) and Local Authority requirements). Of potential relevance to such a spill is the holding capacity of the attenuation areas before outfall.

A13.1.5 MITIGATION MEASURES

1. Cuts along the Proposed Road Development

The proposed road has been designed to avoid any significant cutting in the glacial tills and bedrock aquifer that recharges the fen. The vertical profile of the alignment involves only one marginal cut within the fen catchment (Cut 1) and a second cut north of the fen catchment (Cut 2). From data acquired to date on topography, geology and water levels, these cuts are identified as having an insignificant hydraulic impact on Hugginstown Fen. It is however noted that this assessment does not have the luxury of a full 12 months of water levels to illustrate the range of seasonal variability. It is strongly recommended that to validate these findings and interpretations, 24 months of baseline monitoring of water levels be undertaken. This baseline data should be analysed, assessed and reported upon by a hydrogeologist at the end of each year to monitor the comparability of the real data collected and the predicted impact assessment outlined in this report.

In relation to the slip road that occurs between chainage 17,900 to 18,500. It is recommended that this road will have no cuts or excessive stripping of soils. Standard shallow road drainage (<0.4m depth) should be used. Standard environmental protective measures as outlined in No. 4 below should also apply to the construction of the secondary slip road.

2. Reduction in Fen Catchment

In terms of water balance, the reduction in fen catchment at 1.8% is an insignificant impact. No mitigation measure is required for this net reduction in catchment size.

3. Reduced Groundwater Recharge

The construction of the hard standing road surface will lead to a reduction in direct groundwater recharge by diverting precipitation over the road surface to storm run-off and the surface water drainage system. Due to the hydrogeological characteristics of the site (as outlined in detail in previous sections), this will result in an insignificant impact on Hugginstown Fen and no mitigation measure is required.

The optimised road alignment design (outlined in Chapter 4 of the EIS) minimises the use of cuts for road profile construction. Fill embankments up to 7m above the existing ground level (Ch. 18,450) will be constructed to maintain the profile gradient of the proposed road surface. These embankments will extend from the sides of the proposed new mainline in a 1:2 slope gradient to the base level of the topography. It is recommended in the construction of these embankments, that as far as possible local subsoil materials be used to maintain the same recharge characteristics of the in-situ substrate.

4. Construction Works - Soils, Subsoils and Bedrock Removal

The removal of soils and subsoils is an inevitable consequence of road developments. In the case of Hugginstown Fen, it is recommended that topsoil stripping for embankments be minimised and where ground conditions are suitable (compressive strength), a geotextile should be used and placed directly on the existing topsoil. This will minimise excavation and stripping of soils / subsoils, and thus the potential for suspended solids release.

The ground along the proposed road development is undulating and gently sloping to the fen (natural discharge gradient). As a result, any significant water ingress and entrainment of sediment load needs to be intercepted and controlled, and not allowed to enter the fen environment. Surface runoff and transport of suspended solids during excavation and construction must be strictly controlled by settlement / attenuation ponds prior to outfall to existing drains. These drains should bypass Hugginstown Fen and should not be allowed in any place to enter the fen environment.

Supplementary to engineering controls on the release of natural by-products such as suspended solids to the environment; during the construction phase, plant and construction equipment introduces the risk of “artificial” contaminant release such as hydrocarbons. To mitigate this potentially very damaging risk, an environmental management plan is required during the construction phase of the proposed road development along chainage 17,400 to 19,700. This should involve regular checking by an environmental officer or similarly responsible person of on-site equipment and transfer areas. Transfer areas should have adequate protective measures such as bunds to guard against potential accidental spills or leakages. All equipment and machinery should have regular checking for leakages and quality of performance.

5. Storm Runoff from the Hard Standing Road Surface
Engineering controls and capacity calculations for storm runoff is required for the hard standing road catchment, and attenuation and release of this water to the existing drainage network. It is recommended due to the sensitivity of the fen habitat to any significant hydrochemical changes that a closed drainage system be installed along the length of the cSAC. This will prevent any leakage of potential contaminants into the groundwater that may eventually discharge to the fen. In relation to the storm runoff itself, attenuation / settlement ponds will be required for volume storage and attenuation prior to disposal to the surface water network. It is recommended that these ponds be positioned outside of the fen designation boundary at either end of chainage 17,400 to 19,700. If this is hydraulically difficult, a second option is to use the more natural medium of reed bed attenuation ponds. Consideration should be given to any changes to the surface water system and further impacting on the groundwater recharge to Hugginstown Fen.

6. Environmental Emergency Response to Accidental Road Spillages
Due to the sensitivity of wetlands to contaminants and also the sensitivity of the existing surface water drainage to pollutant exposure, it is important to have an emergency response system in place to cater for accidental spillage and release of artificial contaminants, such as an oil tanker overturning and spilling its contents onto the road surface. An emergency clean-up team should be signed up to respond to such an occurrence and deal with a spillage in an environmentally sound and acceptable manner (to the Environmental Protection Agency (EPA) and Local Authority requirements). Of potential relevance to such a spill is the holding capacity of the attenuation areas before outfall.

7. Monitoring of Groundwater and Surface Waters at Hugginstown Fen
In order to provide accurate baseline data prior to the development, during the construction phase of the development and post-development, a monitoring schedule of the groundwater and surface water network is recommended. This can be tied in with ecological monitoring at the site. The recommended monitoring is as follows:

(a) *Pre-Development – Baseline:*
24 months of monitoring involving monthly water levels, quarterly field hydrochemistry and biannual analytical chemistry of key parameters in fen water quality. Surface water flows should be auto-logged with coincident discharge data during baseline conditions for water balance calculation purposes. This will provide accurate data to calculate the water budget for Hugginstown Fen and will be useful in monitoring any potential changes to this budget, whether caused naturally or artificially. This would involve flume / weir installation with automated discharge and water level recorders at one to two key monitoring points.

(b) *During Construction Monitoring*
During the construction phase of the project, pre-construction monitoring should apply but with increased frequency in field hydrochemistry to monthly intervals, and analytical sampling to quarterly intervals for a reduced range in water quality indicator parameters.

(c) *Post Construction Monitoring*
24 months of monitoring involving the same frequency and parameters as pre-construction baseline monitoring post construction of the development.

A13.1.6 RESIDUAL IMPACTS

On following the mitigation measures identified, one residual impact of the development is likely to be a reduction in catchment size and associated groundwater recharge to Hugginstown Fen if the proposed road development remains within the boundary of the catchment. The maximum reduction in catchment and associated impact on groundwater recharge is 1.6 to 1.8%. This is considered to be an insignificant impact on Hugginstown Fen.

A13.1.7 REFERENCES

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