APPENDIX 13.2 DANGANBEG WETLAND HYDROGEOLOGICAL REPORT

A13.2.1 INTRODUCTION

A13.2.1.1 Scope and Purpose

A detailed hydrogeological assessment was undertaken of Danganbeg wetland, Co. Kilkenny, to determine the likely impact of the proposed road development on the hydrology and hydrogeology of Danganbeg wetland. The scope and focus of this hydrogeological assessment was agreed to include the following:

- Produce a conceptual hydrogeological model for Danganbeg wetland from desk and field based investigations.
- Clearly outline the potential impacts of the proposed road scheme on Danganbeg Wetland and recommend appropriate mitigation measures, residual impacts and recommendations where they apply.
- Provide ground-specific data to support and validate preliminary findings.
- Incorporate the acquired data into a detailed report for Danganbeg wetland for the purpose of presenting to NPWS and for the input to this EIS.

This study and all calculations and assessments within, is undertaken on the preliminary design alignment outlined in Chapter 4 of this EIS.

A13.2.1.2 Work Schedule

Further to preliminary assessments undertaken in April and May 2004, the following work schedule has been completed for this detailed report.

- 24th to 27th August 2004 – Management and supervision of cable percussion (shell and auger) drilling, standpipe and piezometer nest installations and dynamic probing (macintosh probes) at 25m intervals along the proposed alignment.
- 30th August to 1st September 2004 – Gouge coring and installation of piezometer and phreatic tube couples along two transects across Danganbeg Wetland for the purposed of monitoring and detailed hydrogeological cross section production.
- 9th to 10th September - Measurement of water levels and field chemistry of all groundwater and surface water monitoring points (full monitoring network). Monitoring results for July to September 2004 quarterly report. Under cover of a separate study, but key results are referred to in this report for impact assessment.
- 14th and 17th September 2004 – Installation of staff gauges, flow measurement dams and gauging stations, 3 max-min water level recorders at two surface water locations and one groundwater location.
- 14th and 15th September 2004 – detailed topographical survey along hydrogeological cross section transects including all installations and monitoring upstand points using Differential Global Positioning System (D-GPS) and total station where satellite cover was not sufficient for D-GPS.
- 14th and 15th October 2004 - Permeability testing in the form of SLUG tests (rising or falling tests) - undertaken in selected standpipes within and along the boundary of the wetland.
- 8th and 10th November – Measurement of water levels, field hydrochemistry and sampling of waters for laboratory analysis for October to December 2004 quarterly monitoring report. Under cover of separate study, but key results are referred to in this report for impact assessment.

This programme indicates that an extensive fieldwork programme was executed to acquire all key data needed to undertake a full impact assessment for the site. Field results were typed up or processed (e.g. elevation data) after each field event into standard templates, databases, maps and cross sections. Annual sampling results are reported separately and are also referred to in this EIA report in order to support findings and conclusions.

A13.2.2. METHODOLOGY

A13.2.2.1 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 relative to Danganbeg wetland.
- Overlay Ordnance survey OS Discovery Series 1:50,000 and 1:10,560 (6”)) maps with AutoCAD plan drawings.
- Overlay Geological Survey of Ireland (GSI) Geology maps (1:100,000) to determine site bedrock geology and the presence of any major faults or other anomalies.
- Acquire and study borehole logs and geotechnical results of site investigations along the proposed road development in the context of overburden and bedrock types, geometry and permeability.
- Determine land ownership details and secure site access in advance of field investigations.
- 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
- Selection of transect locations (cross sections) in consultation with the specialist ecologists (see Chapter 11 of the main EIS) and the National Parks and Wildlife Services (NPWS) in order to determine impact on ecological zones of significance.
- Liase with and manage the selected drilling contractor to install overburden boreholes (OB Series).
- Update and / or modify existing graphics with new layers of information arising from the results of this additional work.
- Draw detailed hydrogeological cross sections for the site along the site investigation and monitoring transects installed.
- Further to the preliminary report, use all newly acquired data to provide a detailed report for presentation to NPWS and for the scheme’s EIS.

The equipment and materials used during this desk study consisted of:

- Adobe Illustrator
- Microsoft Excel
- Microsoft Word
- Microsoft Powerpoint

A13.2.2.2 Field Investigations

These investigations involved:

- Site walkover and assessment of drainage, spring discharge zones and likely groundwater flow characteristics.
- Hydrochemical measurements of drain and spring discharge (electrical conductivity, pH and temperature).
- Peat depth probing transverse to axis of wetland to determine range of peat depths and the nature of subsoils beneath the wetland.
- 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.
- Installation of wetland piezometers and phreatic tubes to monitor water levels, piezometric pressures, field chemistry, sampling for laboratory analysis and permeability testing of substrate.
- Flow measurements at spring discharges and at critical points in main drains to determine baseline flow capacity, drain and spring contribution to the water balance.
- Sampling of water from the groundwater and surface water monitoring network for field parameter testing and for laboratory analysis.
- Shallow overburden drilling using a shell and auger (cable percussion) rig to install nested piezometers and single standpipes to measure water levels, hydraulic gradients and chemistry in the recharge margins of the wetland.

- Installation of secure wellhead completions for the shell and auger installations on agricultural lands for future monitoring.
- Differential GPS and Total Station surveying of all investigation points and monitoring installations for the purpose of characterising groundwater flow in plan and cross section.
- Permeability testing of mineral subsoils and peat installations to determine vertical and lateral permeability characteristics.
- Digital photographs of all items of significance.

The equipment and materials used during field investigations consisted of:
- Wheel Mounted Cable Percussive Boring (Shell and Auger) Rig
- Gouge Corer and Hand Auger for peat and overburden hand probing
- GPS 500 and R125N Pentax Total Station for surveying
- WTW 340i pH/EC meter for hydrochemical measurements
- Handheld Magellan 315/320 Global Positioning System (GPS) for navigation.
- Olympus Digital Camera C-220 for taking photographs of all items of reference
- OTT C2 Impellor flow meter for drain and spring flow measurements

A13.2.2.3 Impact Assessment Methodology

This is a detailed impact assessment report involving extensive site investigations. From the desk and field data acquired, the following calculations and assessments were undertaken in order to evaluate the potential impact of the proposed road development on Danganbeg wetland:
- 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 Danganbeg Wetland.
- Determine the existing / baseline catchment size of Danganbeg Wetland.
- 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.
- Produce a clear graphical conceptual hydrogeological model for Danganbeg to convey understanding of the site's hydrogeology based on site investigations
- Following desk and field data acquired, draw schematic cross-section(s) along the monitoring transects installed, showing groundwater flow patterns and the cross sectional geology through the proposed route and Danganbeg Wetland.
- Assess the combined data acquired and evaluate the likely impacts on Danganbeg Wetland.
- 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.

A13.2.3 SCHEME DESCRIPTION

The section of the Kilcullen to Waterford Scheme: Waterford to Powerstown relevant to this study is from chainage 24,600 to 27,450 as captured within the water catchment that contributes and feeds Danganbeg wetland. This section of the proposed road development is described in terms of proposed cut, fill, excavation depths, local road realignments and reference is made to the preliminary design outlined in Chapter 4 of the EIS Volume 1 – Main Text, throughout.

The proposed road passes from the south through the townland of "Glebe" north via intersection at R699, northwards flanking the western boundary of Danganbeg wetland before wrapping around the western edge of high ground at Knockadrina Wood. Along this section of alignment, the main route intersects three local roads (one regional road and two third class roads), requiring realignment to maintain access following the construction of the proposed new mainline.

The main components of the road scheme that are of significance to the hydrogeology of Danganbeg wetland and that occur within its hydrological catchment are:

1. FILL 1 – Ch. 24,600 to 25,535 (c.535m)

This centres on Knocktopher junction with significant fill and structure piling to accommodate access roads and roundabouts. Maximum difference in height between existing ground level and road surface is approximately +8.5m at the centre of the Knocktopher junction (Ch. 25,125) with proposed road elevation of c.69mOD at maximum fill point. Road design south of Ch. 25,125 continues in fill beyond the Danganbeg catchment. The fill temporally shallows to meet required road surface elevation at Ch. 25,425 before returning to fill by Ch. 25,535. This fill occurs south of Danganbeg wetland and downstream of the wetland within its catchment.

2. CUT 1 – Ch. 25,535 to 25,910 (c.375m)

The northern part of this cut touches on the south-western boundary of the wetland, west of the existing D6 and D9 and improved grasslands. Maximum cut depth to sealed road surface is –3.5m with proposed road elevation of c.64mOD at maximum cut point. This is a relatively short cut with relatively consistent cut requirements of 2.5-3.5m.

3. FILL 2 – Ch. 25,010 to 26,610 (c.600m)

Fill 2 extends over the remainder of the western boundary to Danganbeg wetland, approaching the third class road that borders the site to the north. This fill flanks the wetland with a maximum fill of +2m in the north-western boundary of the wetland to proposed road surface of c.65.5mOD at maximum fill point. It is Fill 2 that intercepts the immediate wetland area as shown in Chapter 4 of the EIS Volume 1 – Main Text, running up the western boundary of the site. It is an elongate fill of relatively low elevation (1-2m) that gradually rises to the north.

4. CUT 2 – Ch. 26,610 to 27,145 (c.535m)

Cut 2 starts at the tertiary road north of Danganbeg and runs northwards until it intercepts the north-south tertiary road to the east of the site. This cut increases gradually in depth as one progresses north, with a maximum cut of –3m to proposed road surface of c.76mOD at Ch. 27,8250.

5. FILL 3 – Ch.27,145 to 27,450 (c.305m)

This fill reaches the northern boundary of the water catchment for Danganbeg. It is a short fill with concave base and reaches a maximum fill depth of +3m to bring ground surface to proposed road elevation of c.80.5mOD. Maximum fill occurs in the centre of Fill 3 near Ch. 27,300, reflecting the concave depression that requires infilling.

In summary the section of proposed road (Ch. 24,600 to 27,450) that has relevance to this study has two cuts and three fills with maximum cut depth of -3.5m to proposed road surface and maximum fill increase of +8.5m to proposed road surface. These maxima occur in the southern part of the scheme, south and southwest of the wetland and downstream within its recharge catchment. Cuts and fills that border and occur upstream of the wetland are –3m to +2m respectively in extent (to road surface), with an elongate fill flanking the wetland along its western boundary.

A13.2.4 SITE DESCRIPTION

A13.2.4.1 Location

Danganbeg wetland is located at Irish national grid co-ordinates 251700E 138400N, less than 2km northwest of Knocktopher, and approximately 18km south of Kilkenny city. The wetland occurs within a broad topographic depression between 70 to 60mOD Malin and is c.800m at its longest extent and c.400m wide. The main wetland area, as identified by marsh and fen habitats is approximately 400m by 300m at the centre of the site (Ref. 7). Spatially the site covers approximately 17 hectares, of which fen and swamp makes up c.10.5 hectares. Danganbeg drains to the south and contributes to the Little Arrigle River, which in turn is a tributary to the River Nore near Thomastown in the northeast. For site location and layout plans, see EIS Figures 13.1 and 13.3 in Volume 2 – Book 2 of this EIS.

A13.2.4.2 Topography

Maximum catchment topography is c. 140mOD at Knockadrina Wood northeast of the wetland. Elsewhere catchment threshold is c.90mOD. Aside from Knockadrina, which is locally the highest ground for 4km, topographic contours are of low gradient indicating relatively flat and rolling hill conditions around the wetland. The fall of land is to the south with a coalescence of contours at Danganbeg, hence the formation of a valley wetland feature.

A13.2.4.3 Geology

Soils and Subsoils

The General Soil Map of Ireland (Ref. 4) indicates that the principal soil type at and around the study site is "Minimal Grey Brown Podzolics" with associated gleys and brown earths. Limestone glacial till is identified as the parent material. The "Geology of South Wexford" (Ref. 5) outlines that lowlands at and around the study site is covered by moderately thick accumulations of limestone till and gravel on the limestone bedrock of this region. These accumulations resulted from rapid melting of the midland ice sheet as it retreated north from the higher ground in the south at the end of the "Midlandian" period close to 10,000 years ago.

Direct site investigations indicate that aside from the wetland itself, the covering soils and subsoils at the site are generally characterised by:

- SOUTH: Ch.25,390 to 25,750 - a silty to sandy gravelly CLAY with cobbles and boulders is evidenced from site investigations.
- WETLAND: Ch. 25,850 to 26,300 - a firm, slightly sandy to sandy, gravelly CLAY occurs to a depth of c.2.2 to 5.7m, which is succeeded where depth allows by a medium to coarse SAND OR silty or sandy GRAVEL. At BH 25850, a second unit of stiff silty, sandy, gravelly CLAY occurs.
- NORTH: Ch. 26,400 to 26,620 - thick deposits (>5m) of SAND, GRAVEL and COBBLES are found in BH 26,400 and BH 26,620. Underneath the alignment at OB1, interlayers of gravelly CLAY and sandy GRAVEL occur. The gravel horizons are characteristically 0.5m in thickness.

As one progresses to the north and with depth, the subsoils increase in coarseness and co-incident permeability. In particular this is the case just north of the wetland habitat and is likely to be significant in terms of groundwater supply. Following results of the preliminary investigations (Ref. 10), OB 5 was drilled on the eastern fringe of the wetland in order to determine the nature of the subsoils geology immediately upgradient of the source of the tufa springs complex and adjacent to the non-tufa springs (see EIS Figure 13.3 in Volume 2 – Book 2). OB5 illustrates that a soft to firm sandy, gravelly CLAY occurs to 3.0m depth and is followed by silty, clayey GRAVEL with cobbles and boulders. The return on chiselling of angular argillaceous limestone fragments from 3.5m depth indicates that bedrock is proximal. The main source of water was observed to arise from the gravel and is likely to be in hydraulic continuum with the bedrock.

Two phases of probing were undertaken at Danganbeg wetland. The first phase was for the preliminary study and was undertaken along two lines of investigations (SI-Line 1 and SI-Line 2) across the centre of the wetland and perpendicular to the proposed alignment and involved 11 gouge cores (hand augers for bogs) (Ref. 10). The second phase was undertaken in tandem with peat piezometer couple installations for water level and hydrochemistry monitoring. This involved an additional 11 gouge cores. The results indicate that peat depths are generally shallow with 55% of values less than 0.5m. The deepest peat was recorded at GC9 at 0.92m. The PEAT is generally described as fibrous to very fibrous, brown to dark brown of generally H3-H4 von post humification (Ref. 3). Underneath the peat a grey to light brown, sandy, gravelly CLAY with occasional angular to subangular gravel occurs. At GC2 a coarser, brown sandy SILT occurs, while at GC19 and GC21 a wet, medium grained incohesive SAND was identified beneath a thin layer of clay. The higher permeability silts, sands and with depth gravel that occur under the thin veneer of sandy, gravelly clay provides the main source of groundwater to the young wetland, which is still groundwater dependent in terms of nutrient supply.

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. 5). The 1:100,000 scale bedrock geology map of the area (Sheet 14) indicates that the study site is underlain by the Lower Carboniferous Ballysteen Formation (BA). This formation is a limestone deposited under marine conditions, consisting of well-bedded relatively clean calcarenitic (sand grade) limestone in the lower part of the formation. This passes up to finer grained and muddy limestones. This dark grey, argillaceous limestone occurs at the study site, as evidenced by outcrop at a disused quarry at the foot of Knockadrina Wood. Here it is characterised by subhorizontal bedding. Direct site investigation of this limestone is recorded at RCST34 where it is logged as "strong, medium bedded to locally thinly laminated, pale green-blue, fine grained LIMESTONE (slightly dolomitised), fresh to locally moderately weathered, intersected by smooth, planar, tight to narrow, locally clay filled, moderately iron oxide stained fractures of sub-horizontal and very locally sub-vertical dip."

The Variscan Orogeny at the end of the Carboniferous Period is responsible for the structural geology of the region. At Danganbeg, the geology is bound to the east by an anticlinal fold axis and to the west by a synclinal fold axis. Both axes are in a northwest-southeast alignment. Danganbeg appears to be more proximal to the synclinal axis and thus is likely to occur on a concave geological structure. This would have controlled geological evolution at the site. A significant fault occurs to the east of the site in a northwest-southeast direction. West of this fault a distinct zone of dolomitisation is recorded. Dolomitisation also occurs to the northwest of the site.

A13.2.4.4 Hydrology

Drainage

From initial investigations by the ecological consultants (Ref. 7) and design consultants (Ref. 8), two significant drains were identified. Following the site investigations on the 29th-30th April 2004, eleven drains were identified, of which five are primary drains and six are secondary short transverse drains (see EIS Figure 13.3 in Volume 2 – Book 2). Aside from these short transverse drains that mainly connect D6 to D1 from west to east, the five primary drains all drain south. These primary drains are outlined in order of significance (i.e. flow capacity) as follows:

- D1 (main spine / axial drain)
- D2 (northeastern boundary)
- D6 (southwestern boundary)
- D9 (agricultural land drain in south-west)
- D10 (offshoot from D6 in south)

Of these five drains, D1 and D6 are most significant in physical size, flow yield and location in the wetland. The central drain has been enhanced and modified for drainage from D4 intersection southwards. North of this, D1 may originate as a natural discharge feature along the axis of the wetland. The dimensions of the modified drains range from c. 1.5m wide, 1.5m deep with c.0.4m baseflow (D1) to 0.5m wide, 0.3m depth with 0.15m baseflow (D6 near Spring A / SP5). D1, D6 and D10 have been the most effective drains in modifying wetland conditions. In the case of D6, it has successfully captured spring discharge from Spring A / SP5 (see EIS Figure 13.3 in Volume 2 – Book 2) and is the main factor in the cultivation and management of grasslands in the three fields east of the proposed mainline between Ch. 25,780 and 25,990. D1 has also had a very significant impact on wetland hydrology and is likely to be an important factor in the transition from wet grassland in the south under enhanced drainage, passing to poor fen and flush in the centre of the wetland where the drain is less defined.

Springs

Danganbeg is rich in spring discharge, indicating young groundwater fed wetland conditions. At least 9 distinct springs were identified at the site on the 29th April 2004. The chemistry of these springs and their descriptions are outlined in Monitoring Reports (Ref. 11, 12 and 13). In terms of spring discharge contribution, the most significant of these springs occur on the eastern flank of the wetland in a cluster just south of the farm dwelling and yard. Springs 8 and 9 have estimated discharge rates of c.1litres/second at time of observation. They coalesce with other springs to form dendritic, overland flow to the wetland via point D9/SW1. West of this point, the ground is dangerous to walk on and is essentially floating bog conditions and is impassable by foot. Immediately south of these springs, a complex of high pH, calcareous "tufa" Springs occur. Calcium carbonate precipitates accompanied by high pH values (>8) are the main distinctive feature of these springs. It is noted however, that these springs are not preserved or managed at present and that grazing cattle are causing damage to the calcareous precipitates. In fact, there are no restrictions to grazing cattle on this part of the wetland, which is unusual due to dangerous ground conditions in places. Another spring occurs in the very northeast of the site at SP1/SW1. This is a local break of slope diffuse spring discharge point at the start of wetland vegetation. It is noted that spring potential is likely to have been captured and / or negated by the intercepting D2 along the more northern part of the eastern boundary of the wetland. The eastern springs in terms of volumetric discharge and alkaline chemistry are significant springs in Danganbeg, and it from flow measurements undertaken in September 2004, they have been calculated to make up c.50% of the spring discharge to the site. This accounts for spring discharge only and not groundwater contributions at depth.

A number of springs also occur on the west of the site. Springs A and B that were identified in early April 2004 (Ref. 8) were confirmed and labelled SP3 and SP5. In addition, another two springs were clearly identified at SP's 2 and 4. The springs on the western boundary are controlled by topography and the transition from mineral subsoils to the softer peat grounds of the wetland. As the groundwater approaches the surface, these springs emerge in weakness zones and discharge along an approximate linear line boundary to the wetland. Two of these springs have been managed to some degree with transverse drains D3 and D4 dug to intercept the central axial D1. In the case of SP5, this spring has been efficiently captured and manipulated with some of its discharge entering D4, but most of its discharge being canalised away from the wetland via D6. The chemistry and details of these springs are detailed in Reports Ref. 11, 12 and 13 and above. In the case of SP2 and SP4, the discharges from these springs are overgrown and marked by bright green vegetation. On clearing away this vegetation, it is evident that groundwater is upwelling at these points. SP4 is a diffuse spring discharge zone parallel to slope and marks a clear transition from dry to wet ground. More springs are likely to be found, but the most significant ones relevant to this study have been identified. In terms of significance, these springs are responsible for wetland recharge to the west of the axial D1. D1 is a no flow boundary and may be viewed as the central axis of the site with separate recharge regimes on either side. In terms of volumetric recharge to the wetland, these springs appear to be equivalent in contribution (Ref. 12 and 13) as the eastern springs. Comparisons in chemistry are outlined in the next section.

Water Chemistry

Following the preliminary assessment of the hydrology at Danganbeg (Ref. 10), a 12 month monitoring programme has been commissioned to undertake to provide baseline data on water levels and chemistry for groundwater and surface water, discharge flows for the springs and drains, and annual laboratory analysis of water samples taken from representative groundwater and surface water points at the site. This work was initiated in April 2004 and quarterly reports on monitoring results are being produced. At the time of completion of this detailed report, the hydrological assessment is based on results obtained from 8 months of the baseline monitoring programme.

<u>Surface Water</u>

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 D1/SW2 for the drains and SP2/SW1 for the spring discharges were given to measurement locations. An annual suite of laboratory testing was also undertaken on selected surface water monitoring points, the results and interpretation of which are detailed below.

The results of these measurements to date (Ref. 11, 12 and 13) indicate that high electrical conductivity is characteristic of both spring discharges and drainage flow with values ranging from 514 to 787mS/cm. The highest values in conductivity are recorded in SP5 in the west (787mS/cm) and SP9 in the east (770mS/cm). Aside from these springs, there is no significant contrast in the distribution of electrical conductivity readings throughout the site. This is the result of shallow peat cover and ubiquitous occurrence of ion rich water conditions. These high electrical conductivity values indicate a highly mineralised and mineratrophic wetland environment with groundwater dominating hydrological conditions.

All pH values at Danganbeg range from 6.70pH (SP4/SW1) to 8.03pH (SP7/SW1). Only 3 measurements to date indicate slightly acidic conditions; these were recorded at SP4, SP5 and D5. The majority (80%) of pH measurements indicate slightly alkaline conditions with strong alkaline conditions recorded at the tufa springs such as SP7/SW1 at 8.03pH. In the same pattern as electrical conductivity results, there is little spatial variability in the distribution of pH values across the site. The vast majority of values recorded hover around 7.7pH indicating a consistency in slightly alkaline wetland conditions.

Surface water samples were taken for laboratory analysis in November 2004 as part of further work. The results of this analysis are outlined in detail in a separate report (Ref. 13). In terms of surface water chemistry, the analytical results clearly indicate and confirm a strong calcium bicarbonate source of water. Calcium in particular, has high concentrations suggesting a high saturation of this parameter, while magnesium is also high and connected to calcium and bicarbonate species. There are positive but low values of nitrate in the surface water system with values ranging from 8 to 17mg/l. None of these values exceed nitrate regulations. Phosphate (as orthophosphate) was not detected, but total phosphorus was recorded in most places and at D1/SW2b, has the highest value of 6.3mg/l. All surface water samples analysed with the exception of SP5/SW1 are in exceedence of Phosphorus Regulations (S.I. 258 of 1998; Ref. 14). Some nutrient enrichment is expected at the site due the small size of wetland, its groundwater fed hydrology and the largely dairy agricultural lands that surrounds the wetland.

In summary the spring and drain chemistry recorded at Danganbeg is characterised by high electrical conductivity and slightly alkaline to alkaline pH conditions with waters that are strongly calcium with secondary magnesium bicarbonate in origin. Some nutrient loading is occurring from the peripheral managed lands. These parameters confirm that the wetland is strongly controlled and fed by groundwater discharge, primarily in the from of springs but also by groundwater beneath the wetland, as evidenced by vertical profiles in chemistry and analytical results in both surface water and groundwater at the site (Ref. 13).

Groundwater

Groundwater chemistry was assessed in the field by extracting water from the boreholes and piezometer nests / couples installed and measuring indicator parameters electrical conductivity, pH and temperature. An annual suite of laboratory testing was also undertaken on selected groundwater points to tie in with detailed impact assessment report.

Electrical conductivity measurements for groundwater ranged from 860 to 453mS/cm. This wide range in values is indicative of several subsurface geo-units that have been monitored, from bedrock to gravels to sand to clay and peat. The highest electrical conductivity values have been recorded in wetland couples, that is underneath the peat wetland itself, in T2-C5-PH1, T1-C6-P1 and T1-C7-P1 with values >800mS/cm. All three installations have response zones in subsoils, which consist of sandy, gravelly CLAY and in the case of T1-C7-P1 and possibly T1-C5-PH1 these intercept wet, incohesive, medium grained SAND. Lowest values of electrical conductivity appear to occur in boreholes that monitor GRAVELS, BH 26620 (453mS/cm) and BH26950 (501mS/cm). Most peaty CLAY and gravelly CLAY substrates are characterised by electrical conductivity values of 600-800mS/cm. Only one borehole BH-ST33 exclusively monitors BEDROCK within the Danganbeg catchment. The electrical conductivity values for BH-ST33 range from 655 to 781mS/cm to date. Unfortunately, little electrical conductivity results are available for PEAT, due to the summer months as there has often been insufficient water in the standpipes that monitor this shallow unit. However monitoring over the winter and spring period should provide better baseline data for peat.

Groundwater pH values range from 8.11 to 6.65pH units. The highest values of 8.11pH (BH 26620) and 7.88pH (OB1-P2) occur in a GRAVEL substrate. pH values that are less than 7.00 generally occur within the wetland in a PEAT and CLAY or PEAT-CLAY environment, hence indicating slightly acidic and anaerobic conditions. Intermediate pH values of between 7.0 to 7.6pH occur in all types of substrate environments including bedrock, gravel, sand, clay and peat. An average pH for the site is 7.24pH. The majority of measurements indicate a slightly alkaline pH groundwater environment with >85% of values greater than 7.00. This is in tandem with the surface water chemistry results.

Groundwater samples were taken for laboratory analysis in November 2004 as part of further work. Water typing results indicates that the groundwater is strongly calcium bicarbonate in origin. Magnesium is also high in concentration. It is noted that highest concentrations of calcium occur in OB5 near the tufa spring complex on the eastern margin of the wetland. Interestingly, nitrate is also high in OB5-P1 (22.3mg/l) and OB5-P2 (19.9mg/l) but is relatively low elsewhere. Phosphorus (orthophosphate) is below detection for all groundwater points with the exception of a trace result in OB5-PH1 (0.05mg/l). Total phosphorus is quite high in some standpipe installations in the wetland such as T1-C6-PH1 (6.3mg/l) and T1-C6-P1 (12.8mg/l) and at T2-C5-PH1 (5.5mg/l), which is located near OB5. An explanation for these high concentrations is the location of these points relative to D9 and D2, which carry runoff from the springs that arise from agricultural lands, into the wetland and towards D1.

Water Levels

Further to the preliminary assessment of hydrometrics at Danganbeg, which was based on limited water level data from six standpipes, an extensive groundwater monitoring network has been installed (24 additional points) at Danganbeg in order to provide better evaluation of the water levels distribution and the piezometric pressures that occur at the site. The main results of these levels are summarised below:

- Highest fluctuation in water levels is recorded at BH-26950 (4.87m variation) and BH-ST35/1 (3.27m variation). These boreholes monitor high permeability gravels and occur north of the wetland near Cut 2.
- The range of water levels between boreholes to date is 56.69mOD Malin (BH-ST33) in the south and adjacent to a tributary to the Little Arrigle River, and 68.74mOD Malin (BH-ST35/1) to the north of the wetland. This distribution in water levels is topographically controlled.
- The phreatic surface in and near the wetland is strongly controlled by topography (valley profile) and by drainage.
- The piezometric surface is less affected by drainage and is characterised by a more uniform profile that is controlled by topography and the distribution of geological substrates at the site.
- A pattern of seasonality in the monitored water levels is beginning to appear in the data set, providing data of expected levels in winter and summer months and with time, environmental trends in levels. Excluding a peaking in water levels on 14/06/04 which followed a period of heavy rainfall in late May 2004, water levels are lowest between the months of July and September and start to rise to winter and spring levels from October to a likely period of April / May.
- Spatial comparison of September 2004 water levels with those of November 2004 (full monitoring network) indicates that recharge to the system has resulted in a net gain of c.0.5m in the contoured phreatic water table. This is less emphasised in the east and more pronounced in the west where groundwater contours are closer in distribution. Further monitoring over the winter period will identify annual gains in water levels across the site, allowing projection during the construction phase of the project.
- The piezometric contours do not fluctuate as much as the phreatic surface due to their protection from immediate meteorological and surface hydrological changes. Spatially, the eastern side of the wetland illustrates minor change in levels, while the western part of the site illustrates an net gain of c.0.5 to 1m in contoured piezometric levels between September 2004 and November 2004.
- Lands peripheral to the wetland are characterised by greater water level fluctuation than within the wetland due to the difference in recharge and discharge regimes, and dampening of variation by the peat substrate within the wetland.
- Focusing on hydraulic gradients on the periphery (OB Series) and within the wetland (C Series), there is generally a downward “recharge gradient” from the OB Series into the wetland. The wetland is characterised by moderate upward gradients from mineral subsoils vertically upwards into the wetland peat where depth distribution of piezometer nests allow. This upward gradient changes into a slight downward gradient in close proximity to the central drain D1, illustrating the significance of this drain is capturing groundwater from the system.

The results of the water level monitoring to date confirms the preliminary assessment conclusions with regards to the hydrogeological regime at Danganbeg (Ref. 10). The hydrometric data obtained confirms the hydrogeological model for the site (Section A13.2.5) and provides useful data in designing appropriate mitigation measures for the proposed alignment at the site.

Permeability Results

A summary of the results of permeability testing undertaken between the 14th and 15th October 2004 are shown as results per geological unit, indicated below (Table A13.2.1).

Table A13.2.1 Permeability Results

Geo Unit	Max	Min	Average
PEAT	9.067E-06	1.701E-06	5.487E-06
CLAY	6.914E-03	2.055E-06	8.526E-04
SAND	3.398E-06	4.765E-06	4.082E-06*
GRAVEL	4.591E-03	8.271E-05	1.229E-03

** Little data points for SAND geo-unit. Result is provisional.*

The main result from this permeability testing is the identification of the sandy, gravelly "CLAY" as a relatively permeable unit with significant variability in permeability based on composition and location. This moderate permeability clay allows water to move from more permeable gravels and sands below it, through the clay unit and discharge these mineratrophic waters to the peat environment. The PEAT is as expected of low permeability, while the gravel is clearly the main subsoils aquifer in the area. Limited data is available for the occasional sands that occur at the site.

Catchment Calculations

Danganbeg wetland catchment is approximately c.6210 hectares (6.21km^2). The catchment is subtlety defined by topographic hills no higher than 90mOD, with the single exception of Knockadrina Wood in the northeastern corner, where this isolated hill reaches c.140mOD. A broad "pan" catchment is created as a result, with likely low spatial hydraulic gradients of groundwater flow. In terms of catchment size, the wetland makes up a very small percentage of the total catchment at 17 hectares (0.17km^2), of which fen and swamp makes up c.10.5 hectares (0.011km^2). This is 2.7% and 1.7% respectively. Therefore a large surface area provides the recharge to this small wetland.

A calculation of the reduction in this catchment arising from the proposed road development is that the road hard standing area will be approximately 48,840m^2 (2,220m length x 22m wide) or 0.5km^2. The reduction in catchment is minimum at 0.7%. It is noted that this calculation does not take into account realignment of local access roads or the spatial proximity of the road to the wetland, nor does it take into account potential reduction in groundwater throughflow. It does, however, illustrate in simple catchment arithmetic that the proposed road development will take up less than 1% of the total water catchment for Danganbeg. This is a minimal value and once direct impacts are avoided, it suggests that the contributing catchment is large enough to absorb the reduction in vertical recharge (from rainfall) to Danganbeg wetland.

A13.2.5 CONCEPTUAL HYDROGEOLOGICAL MODEL

Arising from the preliminary and detailed hydrogeological investigations, the following hydrogeological model for Danganbeg is understood to characterise the site.

Danganbeg is a young wetland / fen environment that is groundwater fed by highly mineralised water in terms of electrical conductivity (ion content) and alkaline pH (>7 neutral). These provides for poor to rich fen and flush habitats. The methodology in which this groundwater is fed is by a combination of spring and groundwater discharge. Spring discharge is concentrated at the eastern and western boundaries of the wetland. These springs discharge either directly to the wetland in the form of seepage through vegetation (northwest), by overland flow (east) or have been captured by drainage such as D6 (southwest). As groundwater approaches the surface near the eastern and western boundaries of the wetland, groundwater emerges under pressure at weak points in mineral subsoils cover and / or at some locations diffuse spring discharge occurs at the contact line between mineral subsoils and peat. This produces a peripheral phenomenon of spring discharge near topographic break of slope concentrated at c.63mOD.

Spring discharge is the most visually obvious means of "water" contribution to the wetland, but groundwater at depth that passes under the springs and discharges under the wetland is also very important and sustains the central wetland environment. This groundwater discharges mainly along the central axis of the wetland to D1 and sustains the flow in the drains as baseflow. The drains at the site are extensive and have drained the wetland considerably, degrading it ecologically. In particular the manipulation of spring discharge by capturing these high mineral content waters and carrying it away to discharge to the south of the wetland has lead to de-mineralisation of the western wetland. Drainage has diverted the highly mineralised water (highest conductivity values) in the western margin of the wetland from the ecology by this mechanism.

In terms of spatial flow, as outlined above under catchments, groundwater and surface water is moving from north to south generally with local topography determining local flow directions. The catchment is a broad "pan" valley with flow from the north, east and west coalescing within the wetland and discharging via D1 south to the Little Arrigle River and ultimately to the River Nore.

A13.2.6 PREDICTED IMPACTS

Probable or likely impacts on Danganbeg wetland by the proposed road development as outlined in the preliminary design drawings (see Chapter 4 of the EIS) are outlined in this section.

1. Groundwater Dewatering by Cuts

Two cuts have been identified along the proposed scheme within the catchment of Danganbeg wetland. These are cuts 1 and 2 as detailed in Section A13.2.3 and occur to the southwest of the wetland (Cut 1) and to the north of the wetland (Cut 2). From hydrogeological data acquired to date, Cut 1 is not likely have a significant direct hydrogeological impact on the wetland because:

(a) It is in the southwest of the wetland, with the main body of the cut downstream in terms of groundwater flow to the wetland.

(b) Three significant drains occur between the proposed road and the wetland in the form of D10, D9 and D6, as well as the transverse drain D7. Under baseline conditions, these drains intercept groundwater by means of baseflow contribution and will continue to do so in the future once their invert levels are not exceeded by excavation along the road. Invert levels (from topographical map) currently appear to be at c.60mOD, which are approximately 4m lower than the proposed road surface along the cut at c.64mOD.

(c) No springs were observed to occur along the road section allocated to Cut 1.

(d) The part of the wetland that Cut 1 potentially intercepts is well degraded compared to the main wetland and is currently managed agricultural lands, thus the Cut is not likely to have a greater impacts on the hydrology than what is currently occurring in terms of extensive drainage and farmland management.

(e) The area of maximum cut is >200m from the habitats area designated as poor fen and flush, on the eastern side of D1. This distance and the interception of D1 would protect this habitat from Cut 1 at its current proposed depth, including the allowance of an additional –2m to bring cut depth to c.62mOD for road foundation excavation and associated drainage.

(f) Fen and flush wetland vegetation on the eastern side of D1 is recharged by groundwater from the eastern flank of the catchment.

(g) D1 operates as a no flow barrier to impacts from the west on the wetland vegetation in the east (once invert limits are not exceeded).

(h) Subsequent to the preliminary investigations, the detailed site investigations involved the drilling of OB4 at maximum cut depth of –3.5m to 64mOD in Cut 1. The result of these site investigations indicates that OB4 was dry to a drilled depth of -5.5m depth, that is to 62mOD. This borehole was left overnight to ensure no water entered the hole before backfilling it. This data provides factual evidence that the extensive drainage by D9, D6 and D10 downslope of OB4 and the proposed alignment, has already significantly lowered the water table in this region. The proposed alignment will not intercept the water table at this location.

Taking these points into account, Cut 1 will not have a hydraulic impact on Danganbeg wetland in terms of dewatering of the wetland ecology.

Cut 2 occurs c.150m north of the provisional boundary of the wetland between Ch. 26,610 to 27,145. It increases gently in cut depth from –1m in the south to a maximum of –3m in the north at Ch. 27,065. Water level data is available from boreholes installed adjacent to this cut at BH 26,950 and at BH-ST35/1 near the top of the cut at Ch. 27,150. Both boreholes monitor gravel subsoils. Monitoring to date indicates a range of water levels of 62.79mOD (-6.95mbRef) to 67.66mOD (-11.82mbRef) in BH 26,950. This borehole does not occur directly on the revised alignment but at c.1 to 2m lower elevation. Using similar depth profiles, this would suggest a water level depth of 63mOD to 58.5mOD underneath the proposed road alignment. The proposed cut level at Ch. 26,950 is 68.5mOD, which is 10m higher than maximum water levels projected to date. With this data therefore, it is very unlikely that Cut 2 will intercept the water table in this region.

Using monitored water level data in the north of Cut 2 near Ch. 27,600 where a proposed maximum cut of –3m to 76mOD is projected, BH-ST35/1 indicates a water level range of –10.03mbRef (65.47mOD) to 6.76mbRef (68.74mOD). BH-ST35/2 is located at c.3-4m lower elevation and to the northeast of the maximum cut location in the proposed alignment. Extrapolating these water levels to directly under the alignment indicates that water levels are likely to be 69mOD to 72mOD. These projected water levels are 7m to 4m below the maximum cut level and suggests adequate clearance of the water table in this part of the cut. It is unlikely that the maximum cut level in Cut 2 of –3m to 76mOD at Ch. 27,600 will intercept the local water table, and at a distance of c.575m from the boundary of Danganbeg wetland will have not have a negative impact on the hydrology of this wetland.

To the south at BH 26620, the water level is near the surface (as one approximates the wetland basin) between –2.06mRef (64.28mOD) and –1.59mbRef (64.75mOD). The lower topographic sections of Cut 2 from Ch. 26,610 to 26,800 are more likely to intersect the water table or approach it than the deeper cut in the north. However, cut depth to proposed road surface is at –1m by this point. Allowing for road foundation and associated drainage, maximum cut impact is likely to approach to –3m. Assessment of this information suggests that Cut 2 may cause a minor hydraulic impact on the wetland in terms of dewatering of groundwater recharge in the north. The extent of this impact is likely to be local due to topographic control (isolated to a small area in the southern part of the Cut 2) and with adequate engineering measures should be sufficiently mitigated to make the impact insignificant. These mitigation measures are outlined in Section A13.2.7.

2. Groundwater Dewatering / Diversion by Fills

One elongate fill, Fill 2 is relevant to this study. It occurs along the western edge of the main body of the wetland, reaching an elevation of +2m greater than existing topography at its maximum point (Ch. 26,370). Engineering fills have an equal and on occasion, a greater capacity to cause hydraulic dewatering when excavation of poor grounds is required prior to raising the ground profile. This is required where clay or peat or other unsuitable bearing materials are present. These unsuitable materials are replaced with suitable bearing materials such as Clause 804 with non-plastic fines (Ref. 9). This implies two things, the first is (a) that excavation below ground level to a pre-determined depth is required, which may cause dewatering of the water table, and (b) that the original material which is of low permeability and high plasticity is replaced by a higher permeability material of low plasticity. This causes a change in groundwater potential at and around the fill foundation, causing the road to become a preferential pathway for groundwater flow. This would lead to diversion of groundwater throughflow and spring discharge.

Data from the Design Consultants (Ref. 8) indicate a typical excavation depth of –1.0m from ground level to construct the foundation for the embankment structure along this section of road. Where the water table is high, temporary local sumps to a depth of -1.5m below ground level will be used to dewater the immediate area around the embankment during a construction period of c.9 months. Detailed site investigation works have been undertaken targeting Fill 2 in the north at Ch. 26,410 near maximum fill level at Ch. 26,370 and north of SP2, half way along Fill 2 at Ch. 26,290 and near Spring B / SP3, and also in the south of Fill 2 at Ch. 26,120 and just south of Spring A / SP5. The results of this work have provided both phreatic and piezometric water level data to work on and project the interception of the water table along Fill 2. This data indicates that the phreatic surface is likely to be impacted during all but the summer months of the year, and if intercepted would cause a temporary moderate negative impact. The piezometric surface should not be affected by the proposed alignment due to the significant depths of CLAY subsoils (>5m) that overlie the gravel aquifer horizons and restoration of levels after excavation and fill is completed. Both the excavation and replacement of materials in close proximity to the wetland along Fill 2 have been identified as a potential significant negative impact on the hydrology of the wetland east of Fill 2. This impact however, can be mitigated by modification of engineering design along the length of Fill 2 to prevent a negative hydraulic impact on the wetland in its vicinity. Measures to mitigate this impact are outlined in Section A13.2.7.

Secondly, four distinct springs occur under the proposed road route, namely Springs 2, 3, 4 and 5. Springs 2, 3 and 4, along with groundwater throughflow are essential in recharging the western wetland and in maintaining high water levels and suitable hydrochemical conditions for fen and wetland ecology.

Discharge from Spring 5 has been canalised by D6, making it less significant in terms of direct contribution to the wetland. Spring 5 does maintain surface water hydraulic heads in D6, which indirectly avoids enhanced drainage of the surrounding wetland. The proposed road currently has the potential to significantly impact these springs and groundwater throughflow in the aquifer, thereby shutting off the water source to the wetland along the western part of the wetland. A significant negative impact is identified by the existing road location and its design in terms of standard fill construction methodology, on the wetland hydrological system along the western part of Danganbeg. This impact is highlighted here, but can be mitigated by careful engineering design by a number of options, which are outlined in Section A13.2.7.

3. Aquifer Compression and Reduction in Storage / Permeability

Little data is available on the depth to bedrock in the immediate vicinity of Danganbeg wetland. BH-ST34 gives some information further south of c.10m to rockhead. BH-ST34 occurs along the synclinal axis indicated in the GSI's 1:100,000 geological map for the region, and therefore pending on relevance and accuracy of data may indicate highest depths to bedrock locally. More immediate site investigations along the proposed alignment indicates that a stiff sandy, gravelly CLAY occurs along that part of the alignment that runs parallel to Danganbeg wetland. In the near Ch. 26,400 this clay is interlayered with clayey, gravelly SAND and clayey, sandy GRAVEL (0.5m thick units). In the south between Ch. 25,800 to 26,300, this clay occurs to significant depths (c.5.7m) and is underlain by either angular GRAVEL or is proximal to BEDROCK. The average permeability value for this clay is 8.5 x 10-4 m/s. This combined with ubiquitous presence of gravels in the clay along with interlayering with sands and gravels in the north where maximum loading will occur along Fill 2 suggests that the proposed road will not lead to aquifer compression and reduction in horizontal permeability along the western fringe of the wetland. Measures to mitigate this potential impact and that of dewatering and diversion of groundwater are outlined in the next section.

4. Groundwater Hydrochemical Changes by Cuts and Fills

Hydrochemical changes in groundwater can arise from road construction with and independent of hydraulic changes. Road construction in Cut 1 and Cut 2 should not affect the groundwater hydrochemistry as they do not significantly affect the hydrogeology of the wetland (Item 1 in Section A13.2.6). The use of road materials in cuts and fills that are not of similar chemistry to that of in-situ ground can lead to chemical changes that can impact wetland environments. In the case of this site, the details of sub-base and sub-grade materials have not been determined at this stage of the project. In order to avoid adverse hydrochemical impacts on the wetland, in particular to the sensitive parameter of pH, recommendations / mitigation measures for this potential impact are outlined in Section A13.2.7.

5. Local Road Realignments

In addition to the mainline of the proposed road development, there are three local road realignments proposed (Section A13.2.3). Of relevance to this study is the local road realignment complex to the north of the wetland between Ch. 26,600 and 27,220. The existing tertiary road running north south to the east of the wetland will be re-engineered with the provision of an overbridge over the mainline at Ch. 27.170. The road will remain on its existing path with minimum horizontal realignment form it current route. The modified sections will remain in fill. Taking these factors into account and its distance from the wetland, no significant impact is identified from this feature of the scheme.

On the western side of the overbridge outlined above, a new local road realignment is proposed to tie into the proposed local road crossing of the mainline, to the west of the dual carriageway and north of the wetland. The proposed replacement road is in fill for the first 200m as one progresses southwards and then goes into cut until it reaches the existing road north of Danganbeg wetland. This second road runs parallel and adjacent to Cut 2. The detailed design of this road requires consideration and recommendations on this road design are outlined in Section A13.2.7 of this Appendix 13.2.

6. Reduction in Wetland Catchment and Groundwater Recharge

The proposed road development will reduce the Danganbeg hydrological catchment by <1%. This percentage reduction in catchment is insignificant in terms of water balance the potential to impact net water levels in Danganbeg.

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. However, due to the overall low percentage of the road development surface relative to the full catchment, any reduction in groundwater recharge, even proximal to the wetland can be buffered by the remaining catchment, once the mitigation measures outlined for impacts 1 and 2 above are incorporated into the road design.

7. 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. 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 (Section A13.2.7) would have to be undertaken to avoid soil erosion, potential flooding and hydrochemical impacts on the existing environment.

8. Construction Works - Soils, Subsoils and Bedrock Removal

During the construction phase of the project, earthworks activity involving the stripping and removal of soils, and subsoils has the potential to have a significant negative impact on the wetland. There is no bedrock excavation on the proposed road between chainage 24,600 to 27,450 that is, within the Danganbeg catchment. However, with appropriate environmental engineering controls and procedures (Section A13.2.7), this impact can be negated and mitigated. With correct engineering controls, the impact by construction activities is considered to be an insignificant negative impact.

9. 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 Danganbeg wetland due to the proximity of the proposed road to the wetland. 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.

A13.2.7 MITIGATION MEASURES

1. Groundwater Dewatering by Cuts

Preliminary assessment of Cut 2 indicates that it may have a minor hydraulic impact on the wetland in terms of dewatering of groundwater recharge from the north. The extent of this impact is likely to be local and with adequate engineering measures should be sufficiently mitigated to make the impact insignificant.

Recommended mitigation measures to minimise dewatering by cuts are:

(a) The road and its foundation should not act as a conduit to preferential groundwater flow as likened to a tube of higher permeability installed in a lower permeability environment. This would enhance the potential impacts of dewatering by re-diversion of groundwater. To inhibit and mitigate preferential flow along the proposed road structure, periodic transverse and vertical hydraulic barriers made of either impermeable geotextile membrane or very low permeability natural materials (c.10^{-9}m/s) should be installed every 50-100m along the mainline within the catchment of the wetland (Ch. 24,600 to 27,450). This will force any groundwater entering the foundation of the road structure to pass through it and emerge on the opposite side to natural ground conditions, rather than flow along the axis of the proposed road.

(b) During excavation and construction, groundwater intercepted should be pumped to soakaway structures downstream and away from the mainline in order to replenish dewatered waters at least during construction phase.

These mitigation measures are provisional and required further research, assessment and discussion to reach desired objectives.

2. Groundwater Dewatering / Diversion by Fills

In the absence of site-specific excavation estimates at the time of this study, both the excavation and replacement of materials in close proximity to the wetland along Fill 2 have been identified as potential significant negative impact on the hydrology both in terms of groundwater and spring supply to the wetland east of Fill 2. This impact, however, can be mitigated by modification of engineering design along the length of Fill 2 to prevent a negative hydraulic impact on the wetland in its vicinity. Proposed measures to mitigate the impact of Fill 2 on the wetland hydrology, in particular groundwater and springs sources to the wetland along the western boundary of the wetland are:

(a) Use either an inert lightweight fill (e.g. polystyrene blocks) to minimise sub-grade compaction or a "free draining granular fill" (Ref. 9) to keep permeability high. This will maintain groundwater throughflow under the proposed road and transmit groundwater and springs to the wetland. The use of an inert polystyrene granular fill is the preferred hydrological option in order to minimise compaction of sub-grade materials and minimise any change to groundwater chemistry. This granular fill will ensure that spring discharge is diffuse and not canalised to isolated point-discharge locations. This will benefit the hydro-ecology of the wetland in terms of water saturation and nutrient supply.

(b) Where possible the construction of the embankment should occur during the dryer months from April to September to avoid interception of the higher phreatic surface as evidenced from monitoring to date. Aside from the mainline, any sumps used should be filled and returned to or above pre-construction ground level conditions.

(c) The insertion of vertical hydraulic barriers transverse to the road axis, made of either impermeable geotextile membrane or very low permeability natural materials (c.10^{-9}m/s) should be undertaken at 50-100m frequency to counteract the tendency for along road preferential groundwater flow due the emplacement of a linear high permeability substrate. These barriers will force the groundwater to cross the road and flow into the wetland.

3. Aquifer Compression and Reduction in Storage / Permeability

The aquifer materials likely to occur along the existing proposed road and in particular along Fill 2 are c.2.5m to 5.7m of sandy, gravelly CLAY overlying clayey, sandy GRAVEL and in places (near Ch. 26,400) this clay is interlayered with 0.5m thick units of clayey SAND and GRAVEL (Section A13.2.4.3). While some compaction is likely to occur, these lithological descriptions suggest that the subsoils aquifer is relatively robust in terms of compression loading. In addition, the upper layers of sandy CLAY or equivalent of the in-situ subsoils will be replaced for road foundation and construction. The incorporation of the mitigation measure (a) for impact no. 2 will mitigate for aquifer compression. Aside from this, no dedicated mitigation measure is required.

4. Groundwater Hydrochemical Changes by Cuts and Fills

The replacement of in-situ ground materials with introduced new materials during road construction has the potential to impact on groundwater chemistry. In order to avoid adverse hydrochemical impacts on the wetland, the following mitigation measures are recommended:

(a) Use of local excavated materials along the road scheme where possible.

(b) In cases where introduced materials are required to meet other impact mitigation measures, then the introduced material should be composed of similar baseline chemistry. In the case of Danganbeg, the clause materials used should be alkaline based and sourced from limestone quarries and limestone till sand and gravel pits. An alkaline chemistry must be maintained for wetland ecology at pH >7.

(c) In the case where synthesised geotextiles or polystyrene fill are used, these materials must be inert and do not impart or absorb chemistry to / from passing groundwater.

(d) All materials used must be sourced from greenfield sites with no history of contamination.

(e) Use of other construction materials that have the potential to change groundwater chemistry (e.g. cement, bentonite) should be reviewed with respect to throughflow of sensitive groundwater to the wetland. Mitigation measures such as using alternative materials or sleeving of items in sensitive areas is recommended.

5. Local Road Realignments

The potential impacts of the realignment of tertiary roads are discussed in the previous section. In the case of the replacement access road that runs west and parallel to the mainline from Ch. 26,600 to 27,200, the detailed design of this road should be reviewed by a hydrogeologist to minimise potential hydraulic impact. In specifics, this proposed access road is parallel to Cut 2 and it is recommended that:

(a) Where possible, to keep the road out of cut.
(b) Where cut is a necessity, it should be minimised to <1m depth and be less than the mainline Cut 2.
(c) Mitigation measures for hydraulic hydrochemical impacts as detailed in this report should apply to all tertiary road construction / realignment within the catchment of Danganbeg wetland.

6. Reduction in WetlandCatchment and Groundwater Recharge

In terms of water balance, the reduction in wetland catchment at <1% is an insignificant impact. No mitigation measure is required for this net reduction in catchment size.

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. However, due to the overall low percentage of the road development surface relative to the full catchment, any reduction in groundwater recharge, even proximal to the wetland can be buffered by the remaining catchment, once the mitigation measures outlined under 1 and 2 above are incorporated into the road design.

7. 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 wetland habitat to any significant hydrochemical changes that a closed drainage system be installed along the length of wetland between Ch. 25,540 (base of Cut 1) to 26,620 (top of Fill 2). This will prevent any leakage of potential contaminants into the groundwater that may discharge to the wetland.

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. The location of the proposed attenuation pond for this section of road has been assessed in terms of potential hydraulic and hyrochemical impact on contributing waters to the wetland. The proposed pond occurs parallel to the mainline between chainage 25,750 and 26,400. The position of this pond is acceptable pending on the following mitigation measures:
(a) The pond is fully lined and divorced hydraulically form any groundwater interaction.
(b) Pollution control measures are employed to maintain outflow water quality to existing baseline standards.
(c) Constructed reed bed attenuation is recommended as the preferred methodology of attenuation prior to outfall to existing drainage.
(d) Outfall to D10 rather than locally to D6 is preferred as it occurs downstream of the wetland. Also this allows flexibility in restoration of the fields immediately to the east of the attenuation pond as recommended the specialist ecologists (see Chapter 11 of the main EIS).

8. Construction Works - Soils, Subsoils and Bedrock Removal

The removal of soils and subsoils is an inevitable consequence of road developments. In the case of Danganbeg, 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 wetland (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 wetland 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 Danganbeg wetland and should not be allowed in any place to enter the wetland 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 Ch. 24,600 to 27,450 (within the catchment of the wetland), with particular care required between Ch. 25,700 to 26,500 where the road flanks the wetland. 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.

9. 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.

A13.2.8 RESIDUAL IMPACTS

On imposition of the mitigation measures as detailed in this report and based on preliminary site assessments, two residual impacts are identified:

(a) There will be a reduction in recharge catchment to Danganbeg of c.0.7%. This is considered to be an insignificant in terms of wetland hydrology.

(b) The permeability of subground conditions along the western flank of the wetland will be changed. With the mitigation measures outlined, it will be improved in places such as in Fill 2. This change is a residual impact and is not necessarily a negative one. In fact with the mitigation measures proposed, it is likely to lead to a positive impact on the wetland by manipulating construction design to improve recharge to the wetland.

(c) Some local dewatering may occur in the southern part of Cut 2, but the hydraulic impact is likely to be of low magnitude and of insignificance to Danganbeg wetland based on data acquired in this assessment.

A13.2.9 RECOMMENDATIONS

All of the recommendations listed in the preliminary impact assessment report (Ref. 10) have been acted upon and completed, the results of which have been used to provide valuable baseline data in order to complete this detailed EIA report. The conclusions, interpretations and mitigation measures proposed in the preliminary impact assessment have been validated by the additional factual data acquired at Danganbeg.

Further to the “Pre-Development Baseline Monitoring” which is now up and running at Danganbeg since April 2004, consideration should be given to monitoring during and post construction with the following recommended schedules.

(a) *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.

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

A13.2.10 CONCLUSIONS

It has been recommended that the proposed road development go ahead in its current position and elevation as there is confidence based on the extensive site investigations completed that the potential negative impacts posed by the scheme on Danganbeg can be mitigated by careful engineering design to a level that will not significantly impact the wetland as an integral hydrological unit.

In addition, it is also highlighted that the potential impact zone is the northwestern part of the wetland. This area may be viewed a quadrant defined by bounding drains D1 to the east and D4 to the south. This area of wetland consists of wet grassland to the north and marsh to the south. Habitats that have links with Annex 1 habitats (under the EU Habitats Directive (92/43/EEC) are alkaline fen and petrifying “tufa” springs at this site (Ref. 1). These habitats occur on the opposite side of the wetland in the east. Because the eastern “half” of the wetland is separated hydrologically from the west by D1 and by natural catchment flow patterns, these Annex habitats will not be impacted by the proposed road scheme.

With reference to the proposed ecological mitigation measure of habitat compensation proposed by the ecological consultants in their ecological report for Danganbeg (Appendix 11.2 of this EIS and Ref. 7), the two fields identified between D1 and D6 have been heavily drained by a network of drains in this area. In order for this compensation to work and restore or bring the fields back to wetland conditions, a programme of drain blocking will be required. This will involve D6, D4, D5 and D9. Careful management of the design of this programme and its potential relationship with the proposed road scheme design between chainage 25,600 to 26,000 is recommended, particularly in relation to road drainage, balancing ponds, outfall attenuation, and spring occurrence.

A13.2.11 REFERENCES

1. **The European Commission (1992)** “The Habitats Directive (92/43/EEC)”.
2. **British Standards Institution (1981)** “Code of Practice for Site Investigations - BS 5930”.
3. **Von Post, L. (1922)** “SGU (Seriges Geologiska Undersoknings) peat inventory and some preliminary results”. In Dann. Geol. Unders. IV Series. Vol. 3 (10).
4. **An Foras Taluntais (1980)** “General Soil Map of Ireland”.
5. **Tietzsch-Tyler, J and Sleeman, A.G., (1994)** “Geology of South Wexford”, Geological Survey of Ireland Publication.
6. **Feehan, J. and O’Donovan, G., (1996)** “The Bogs of Ireland”, Environmental Institute, UCD.
7. **Natura Environmental Consultants (NEC) (2003)** “Danaganbeg Ecological Report (DRAFT)”.
8. **Arup Consulting Engineers (Arup) (2004)** “Technical Paper TP 318 Danganbeg Wetland”
9. **Department of the Environment and Local Government (2000)** “Specification for Road Works”. Vol. 1, Series 400.
10. **Minerex Environmental Ltd (MEL) (May 2004)** “Hydrogeological Impact Assessment of the Proposed N9/N10 Kilcullen to Waterford Scheme: Waterford to Powerstown on Danganbeg Wetland - Preliminary Impact Assessment Report” (MEL Doc. Ref. 1557-241.doc).
11. **Minerex Environmental Ltd (MEL) (June 2004)** “Groundwater and Surface Water Monitoring Report: Quarter 1 (April to June) 2004” (MEL Doc. Ref. 1557-296.doc).
12. **Minerex Environmental Ltd (MEL) (October 2004)** “Groundwater and Surface Water Monitoring Report: Quarter 1 (July to September) 2004” (MEL Doc. Ref. 1557-391.doc).
13. **Minerex Environmental Ltd (MEL) (December 2004)** “Groundwater and Surface Water Monitoring Report: Quarter 1 (October to December) 2004” (MEL Doc. Ref. 1557-392.doc).
14. **Local Government (Water pollution) Act, 1977** (Water Quality Standards for Phosphorus) Regulations, 1998. SI No.258 of 1998.
15. **Minerex Environmental Ltd (MEL) (November 2004)** “Hydrogeological Impact Assessment of the Proposed N9/N10 Kilcullen to Waterford Scheme: Waterford to Powerstown on Danganbeg Wetland – Environmental Impact Assessment Report”. (MEL Doc. Ref. 1557-362.doc).