Appendix 4A

Geophysical Survey

Mott MacDonald

Cork Lower Harbour Main Drainage Scheme
Water Treatment Plant, Shanbally, County Cork

Geophysical Survey

Report Status: Draft

MGX Project Number: 5213

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14th November 2007

Confidential Report To:

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Geophysical Services

EXECUTIVE SUMMARY

1. Minerex Geophysics Ltd. (MGX) carried out a geophysical survey consisting of EM31 Ground Conductivity, 2D-Resistivity and Seismic Refraction measurements for a proposed water treatment works development at a Cork County Council site in Shanbally, Co. Cork.
2. The main objectives of the survey were to determine ground conditions, the depth to rock, the existence of karst features and to reduce the risk of encountering difficult subsurface conditions and possible subsidence for proposed developments on the site.
3. The results of the geophysical survey show a thick overburden and possible fractured rock layer overlying clean strong limestone at a depth between 8 and in excess of 20m below ground level. Where the top of strong bedrock is approx. 20m and more deep it is at the penetration limit of the seismic setup.
4. The data describes a four layer earth model. The top three layers represent a transition from topsoil to stiff to very dense overburden and possible broken/fractured mudstone to clean limestone. The limestone bedrock has a typical depth of > 20m below ground level.
5. Overburden conductivities are quite low (unless influenced by metal objects) and indicate gravelly soil and sub soil types. There are no indications for soft ground layers on the site.
6. The overburden is interpreted as gravelly clay, sand and gravel and is expected to be well drained.
7. The shallowest rock is in the SE corner of the site (at R1) and the rock head dips to the north at the centre of the profile R1.
8. Generally the top of rock is so deep that no indicating for karstification of the bedrock can be found.
9. In the south east corner of the site where limestone bedrock is interpreted a 25m wide zone of possible faulting, fracturing or karstification is present and a borehole is recommended at this location.
10. Borehole locations for a possible drilling programme are recommended to further investigate areas of possible thickening of the overburden and shallowing bedrock as they may be related to the proposed constructions on the site.

CONTENTS

List of Tables, Maps and Figures:

1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out a geophysical survey for a proposed development by Cork County Council at a site in Shanbally, Co. Cork. The survey consisted of mapping the site with EM31 Ground Conductivity Measurements followed by 2D-Resistivity and Seismic Refraction Profiles.

1.2 Objectives

The main objectives of the geophysical survey were:

- To determine the ground conditions under the site
- To determine the depth to rock
- To estimate the strength/stiffness/quality of overburden and rock
- To detect lateral changes within the geological layers
- To determine the presence of possible faults, fracture zones and karstified rock
- To reduce the risk of encountering difficult subsurface conditions during construction
- To reduce the risk of possible subsidence of future buildings and structures

1.3 Site Description

The site has a size of approximately 12 ha and consists of two open fields of pastureland. There is an elevation difference of about 2m from the northern to southern side of the site. An ESB station lies 200m to the west of the area and a number of pylons and high powered overhead cables are present. There is a BGE installation in the southwest. Underground pipelines (possible foul sewer and surface water drain) run west – east across the southern part of the site.

1.4 Geology

The site is underlain by Carboniferous lithologies, Waulsortian limestones and rocks of the latest Devonian and Carboniferous Cork Group, the Kinsale Formation. The Waulsortian Limestones consist of massive unbedded fine grained limestone. To the north near Cloyne the Waulsortian is known to be over 400m thick. The Kinsale Formation consists of grey mudstone with sandstone. South Cork consists of a series of west – east trending synclines and anticlines. The site lies between the Ringaskiddy Anticline and the more southerly Church Bay Anticline. These fold belts are cross-cut by a series of NNW – SSE trending faults (GSI, 1995).

1.5 Report

This report includes the draft results and interpretation of the geophysical survey. Maps, figures and tables are included to illustrate the survey and the results. More detailed descriptions of geophysical methods and measurements can be found in GSEG (2002), Milsom (1989) and Reynolds (1997).

The client provided a digital map of the site and ground investigation data from boreholes and trial pits in an area just north of the survey site. The map was used as the background for the maps in this report.

The interpretative nature and the non-intrusive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practice to execute, interpret and present the data give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The methodology consisted of using EM31 Ground Conductivity measurements to map the whole accessible area within the site. The results were reviewed and followed by 2D-Resistivity profiles and seismic refraction profiles.

The conductivity survey was carried out on lines nominally 10 m apart using a Geonics EM31. Along each line a reading of ground conductivity was taken every second, thereby resulting in a survey grid of about 10 x 2 m. Base station readings were taken and no instrument drift was noted. The ground conductivity contour map is shown on Map 2. The locations were measured with a DGPS system attached to the EM31 and all data was jointly stored in a data logger for later office based processing and analysis.

The 2D-Resistivity profiles were located to give good coverage of the site. The specifications for the 2D-Resistivity survey were: Multi-electrode switching system Tigre Resistivity Meter, laptop computer, power supply, 32 electrodes under computer control per array, 5 m electrode spacing, profile length of 155m, Imager 5 cable, stainless steel electrodes, contact resistances < 2000 Ωm, Wenner electrode configuration and 3 cycles per reading to reduce background noise. A total of 8 locations were surveyed (R1 – R8, see Map1).

Along each 2D-Resistivity profile a seismic profile with 12 geophones and 5 m geophone spacing, resulting in a profile length of 55m, was surveyed. The recording equipment was 6 DMT Summit 2in1 remote units with 10 Hz vertical geophones. The seismic energy source was a hammer and plate. A zero delay trigger was used to start the recording.

The resolution of the geophysical methods used depends on a large number of factors, but the following can be used to estimate the performance and detection ability of layers and features:

The EM31 method determines bulk ground conductivities to an approximate depth of 6m below ground level.

2D-Resistivity profiles determine the subsurface resistivity on a cross section. With a five meter electrode spacing and profile length of 155m as used in this project it is possible to detect lateral changes with an extent of 3-5 m and more and get depth penetration of 30m.

Seismic Refraction generally determines the depth to layers where the compaction/strength/rock quality changes with an accuracy of 10 – 20% of depth to that layer. The depth of penetration for the setup used on this site is approx. 20m.

The field observers ensured that good data quality was gathered and recognised on site if sudden changes in ground conditions occurred.

2.2 Site Work

The geophysical survey was carried out between the 5th and 7th of November 2007 in good weather conditions. The locations are indicated on the following table.

Table 1: Geophysical Survey Locations.

Profile Name	ING Northing Start	ING Easting Start	ING Northing End	ING Easting End
R1	175299	63630	175313	63784
R2	175140	63709	175295	63704
R3	175003	63853	175157	63838
R4	175092	63637	175122	63789
R5	175003	63723	175034	63875
R6	174856	63706	175007	63672
R7	174870	63645	174899	63797
R8	174916	63782	175068	63754
S1	175305	63679	175310	63734
S2	175200	63706	175255	63704
S3	175080	63843	175134	63839
S4	175103	63686	175114	63740
S5	175014	63772	175025	63826
S6	174905	63694	174958	63682
S7	174881	63694	174891	63748
S8	174965	63772	175019	63762

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was carried out utilising the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site and the experience of the authors.

3.1 EM31 Ground Conductivity

The EM31 ground conductivity values were merged into one data file and contoured and gridded with the SURFER contouring package. The colour contour map with ground conductivities is displayed on Map 2 overlaid over the site base map. The contours are created by gridding and interpolation and care must be taken when using the data. The values in milliSiemens/metre (mS/m) are colour coded and the colour scale is shown on the map.

Low (blue contours) conductivities would indicate shallow bedrock and higher (green to red contours) conductivities would indicate deeper bedrock and thicker overburden. Very high conductivities (orange) indicate noise from man made metal objects. High interference occurs along the route of the pipelines in the south of the area as indicated by the long linear and bulls eye anomalies. The pipelines show as a different pattern in the EM31 data as the walking direction differed between the two fields. In some parts of the site small scale interference from a number of fences can be seen in the conductivity data. Such anomalies are seen close to the north – south field boundary running down the middle of the site and also in the western field boundary.

The ground conductivity values are generally quite small (where not disturbed by metal objects). This would indicate soils and subsoil with a gravelly nature. The range of values would indicate gravely clay and sand and gravel. The values would also indicate a well drained overburden. The conductivities do not show strong geological anomalies within the depth range of 6m. More detail within the overburden will be shown below by the other methods.

3.2 2D-Resistivity and Seismic Refraction

The 2D-Resistivity data was inverted with the RES2DINV inversion package. The programme uses a smoothness constrained least-squares inversion method to produce a 2D model of the subsurface model resistivities from the recorded apparent resistivity values. Three variations of the least squares method are available but it was determined that for this project the Jacobian Matrix would be recalculated for the first two iterations then a Quasi-Newton approximation would be used for subsequent iterations. This is deemed sufficient for this project as the largest changes in the Jacobian matrix normally occur in the early iterations, where a more robust Gauss – Newton method was used, and as large resistivity contrasts over small areas are not significant here. Each dataset was inverted using five iterations resulting in a maximum RMS error of < 2.5%. The resulting models are displayed as colour contoured sections in Figures 1 - 3 (left hand section) in the report. Interpretations of the data are shown on the right hand sections in Figures 1 - 3. The colour scale is the same for all profiles.

The seismic refraction data was processed with the SEISIMAGER software package to give a layered model of the subsurface. The number of layers has been determined by analysing the seismic traces and 4 layers were used in the models. All seismic profiles have been ray-traced, and residual deviations of typically 0.6 to 2.8 msec RMS have been obtained for each profile. The resulting layer boundaries are shown as thick lines on the cross sections (Fig. 1 – 3).

The interpretations for the site were based on all available geophysical data and supplied ground investigation data for a nearby site. The layer boundaries were determined by the seismic velocities and interpretation of lateral variation within the layers was based on the 2D-Resistivity datasets.

Table 2 summarises the interpretation of the geophysical data. The compaction/strength/rock quality has been estimated from the seismic velocity. An estimation of the excavatability for the bedrock has been made according to the caterpillar chart published in Reynolds (1997). A full estimation of excavatability should take borehole data and core descriptions into account.

Table 2: Summary of Results and Interpretation

Layer	**General Seismic Velocity Range (km/sec)**	**General Resistivity Range (Ohmm)**	**Compaction/ Strength/ Rock Quality**	**Interpretation**	**Estimated Excavation Method**
1	0.3	any	Loose/Soft	**Overburden/Topsoil**	Diggable
2a	0.9	< 566	Loose/Soft	**Gravelly Clay Overburden**	Diggable
2b	0.9	> 566	Loose	**Sand and Gravel Overburden**	Diggable
3a	1.9 – 2.0	< 566	Stiff – Very Stiff	**Gravelly Clay** (Or Fractured Rock/Mudstone)	Diggable
3b	1.9 – 2.0	> 566	Very Dense	**Sand and Gravel** (Or fractured Rock/Limestone)	Diggable
4	2.7 – 2.8	> 400	Good Rock	**Clean Limestone**	Breaking/Blasting

3.3 Summary Interpretation

The combined geophysical datasets collected at Shanbally describe a four layered earth model below the site with very thick overburden overlying clean limestone and mudstone bedrock lithologies. Layer 1 consists of a thin loose/soft overburden/topsoil deposit which is no more than about 3m thick.

Layer 2, which is < 3m - ~22m thick, has seismic velocities of 0.9 Km/S and is interpreted as overburden rather than rock. This layer has a very wide range of model resistivity values, 200 Ωm - > 1600 Ωm, and this variation is used to subdivide the layer into two. Layer 2a which has resistivity values < 566 Ωm is described as a gravelly clay. Resistivity values between 200 and 566 Ohmm are typical for gravelly clay. There are no model resistivity values less than 200 Ohmm recorded under the site. Such smaller values would be typical for soft clay and cohesive soils with high water content. Therefore it is concluded that there are no soft clays or organic mud in the overburden layer under the site. No soft ground conditions are likely to exist under the site. Layer 2b has model resistivity values > 566 Ωm, suggesting a decrease in clay content and an increase in sand and gravel. Within this layer there are pockets of very high values > 1131 Ωm. It is likely that these areas, mainly found in the eastern part of the site, are unsaturated sand and gravel deposits. These areas are seen at the north end of profile R1, the eastern end of R2 and R3 and centred around 60m on R4 (Figures 1 & 2). In the east of the site, at a distance of ~ 40 m – 80 m on R1, very high resistivity values suggest the gravel here may be rock derived in nature. It is possible that weathering, fracturing and breaking of the bedrock created a gravel deposit close to the surface and at the top of the strong rock.

The boundary between Layer 2 and Layer 3 is at a maximum depth of ~ 24m. It is important to note that given such significant depth values an accurate depth estimation of the deeper boundaries is difficult with small scale seismic refraction methodologies. Layer 3 has a significant seismic velocity of 1.9 – 2.0 Km/s and is therefore described as a very dense/very stiff lithology. This layer is also subdivided based on model resistivity values and is similar to layer 2 but is more indurated. It has a thickness range of < 2.0m - ~15m and reaches its maximum in the far west. It is likely this layer is made up of gravelly clay and sand and gravel deposits but given the determined velocity it may in places be a fractured or broken mudstone or limestone.

Layer 4 which has high seismic velocities and model resistivity values is a clean limestone. The top of this layer is at depths > 8m but is normally > 20m. In the SE corner of the site the rock is shallowest with values of 8m at the start of S1. Generally the strong rock is deep and at the depth penetration limit of the seismic refraction setup.

In addition to the above descriptions it should be noted that strong lateral variation in the model resistivity values on Profile R1 (see Figure 1) at depths of over 15 – 20 m may be due to faulting or fracturing of the rock. It is also possible that this zone represents karstification of the Waulsortian Limestone.

4. Conclusions and Recommendations

The following conclusions and recommendations are made:

- A geophysical survey consisting of EM31 Ground Conductivity, 2D-Resistivity and Seismic Refraction measurements was undertaken at the site of a proposed water treatment works at a site in Shanbally County Cork.

- The results of each of the geophysical methodologies indicated thick overburden overlying limestone and mudstone geology at a depth of 20m and more below ground level.

- The data describes a four layer earth model. Layer 1 is about 3m thick and is overburden and topsoil.

- Layer 2 is 3 – 22m of thick overburden. This layer shows significant lateral variation and consists mainly of gravelly clay (low resistivities) and sand and gravel (high resistivities). In places, particularly in the east, the gravels are likely unsaturated to depths of 10 – 15m bgl.

- Layer 3 is subdivided into stiff – very stiff gravelly clay and very dense sand and gravel. This layer is more consolidated than layer 2 and may in places contain fractured mudstone or limestone. This layer is ~2m - ~15m thick.

- Layer 4 is a clean limestone and has a depth which is normally 20m b.g.l. This layer is shallowest in the southeast corner of the site with a depth to the top of rock of 8m.

- In the east of the area there is a small area at the centre of R1 which may represent faulting/fracturing of the rock or karstification of the limestone (see Figure 1).

- In general ground conductivities are low and resistivities are larger than 200Ohmm. This would indicate gravelly and very gravelly clay as well as Sand and Gravel. This overburden type would provide for good drainage on the site and would indicate an absence of ground water to within 10 – 15 m under the site.

- For a possible drilling programme a number of boreholes are recommended at the following locations (Map 1). These target possible thickening of the overburden and areas of shallower bedrock. These should be considered based on the design of proposed constructions:

Borehole Number	ING Northing Coordinate	ING Easting Coordinate
BH1	175304	63689
BH2	175309	63723
BH3	175136	63840
BH4	175105	63707
BH5	174930	63689
BH6	174884	63719

5. REFERENCES

1. **CIRIA 2002.** Geophysics in Engineering Investigations, 2002. Geological Society Engineering Geology Special Publication 19, London, 2002.

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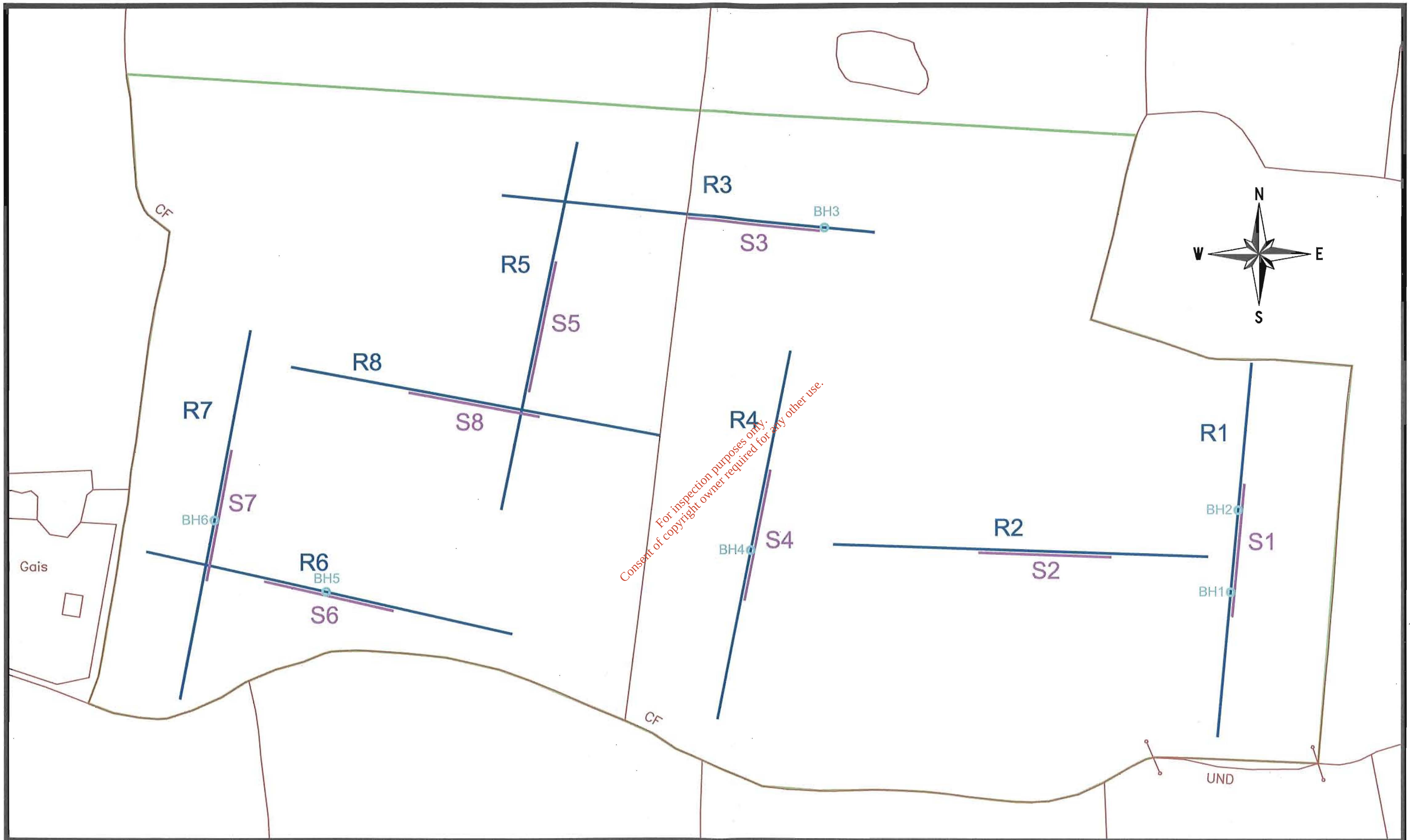

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CLIENT	Mott MacDonald Pettit Cork County Council
PROJECT	Water Treatment Plant, Shanbally, Co. Cork, Geophysical Survey
TITLE	Map 1: Location Map of Geophysical Survey

SCALE:	1:1500 at A3
PROJECT:	5213
DRAWN:	TL
DATE:	13/11/07
MGX FILE:	5213d_Maps.dwg
STATUS:	Draft

LEGEND: (Refer to Report)

- Site and EM31 Survey Boundary
- 2D-Resistivity Profile
- Seismic Profile
- BH1 Proposed Borehole Location

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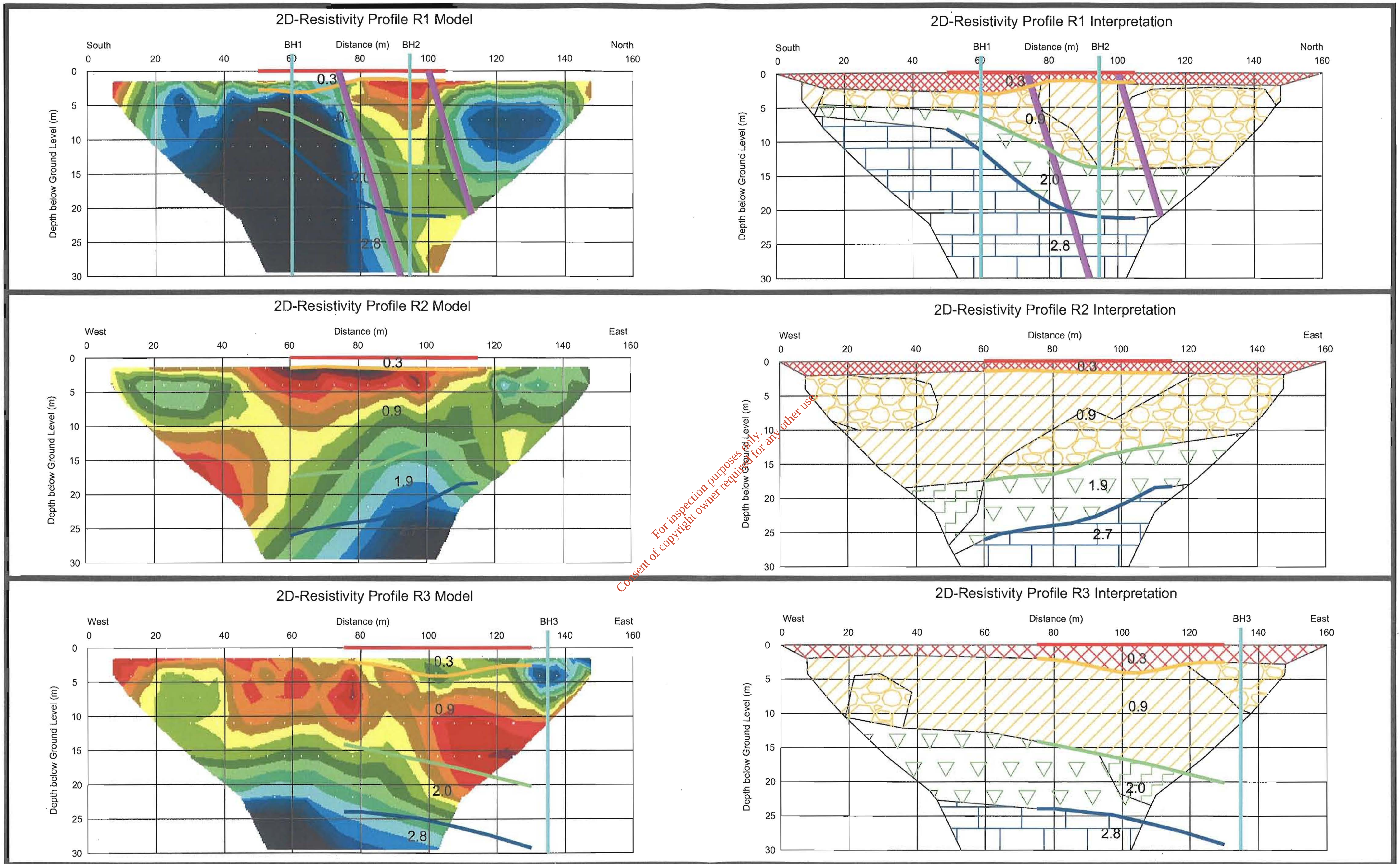
PROJECT	Water Treatment Plant, Shanbally, Co. Cork, Geophysical Survey	PROJECT:	5213
		DRAWN:	TL
		DATE:	13/11/07
TITLE	Map 2: EM31 Ground Conductivity Contour Map	MGX FILE:	5213d_Maps.dwg
		STATUS:	Draft

LEGEND: (Refer to Report)

- Site and EM31 Survey Boundary
- 2D-Resistivity Profile
- Seismic Profile
- Colour Contours show conductivities in mS/m
- BH1 Proposed Borehole Location



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CLIENT: Mott MacDonald Pettit, Cork County Council

PROJECT: Water Treatment Plant, Shanbally, Co. Cork Geophysical Survey

TITLE: Figure 1: Results and Interpretation of 2D-Resistivity & Seismic Profiles R1 - R3

SCALE:	NTS, 2 x VE
PROJECT:	5213
DRAWN:	TL
DATE:	13/11/07
MGX FILE:	5213d_Figs.dwg
STATUS:	Draft

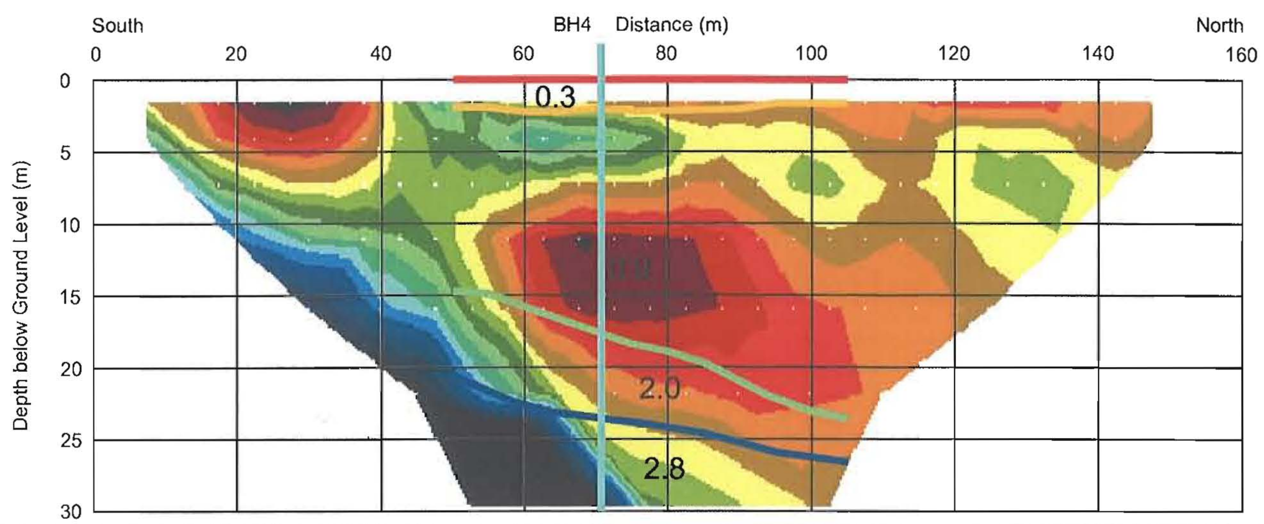
LEGEND: Integrated Interpretation

- Top of Layer 1 from Seismic Data
- Top of Layer 2 from Seismic Data
- Top of Layer 3 from Seismic Data
- Top of Layer 4 from Seismic Data
- 0.9 Seismic Velocity in Km/S
- 1 - Overburden/Soil
- 2A - Gravelly Clay
- 2B - Sand and Gravel
- 3A - Stiff -Very Stiff Gravelly Clay or Fractured Mudstone
- 3B - Very Dense Sand and Gravel or Fractured Limestone
- 4 - Clean Limestone
- Possible Fault, Fracture or Karst Zone
- BH1 Recommended Borehole Location

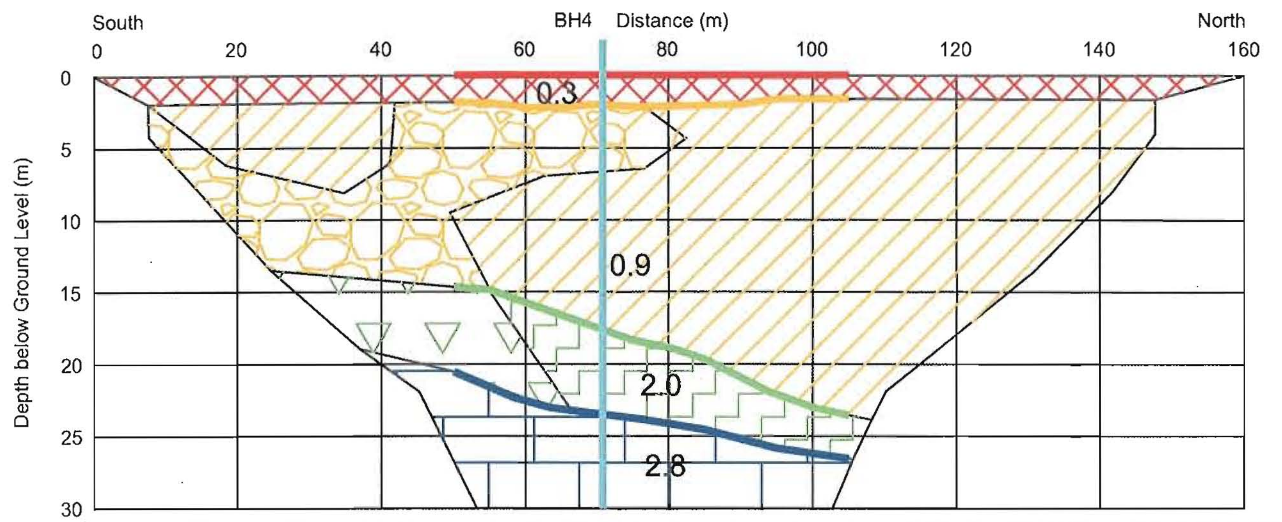
Model Resistivities Ohm.m

200 283 400 566 800 1131 1600 2263

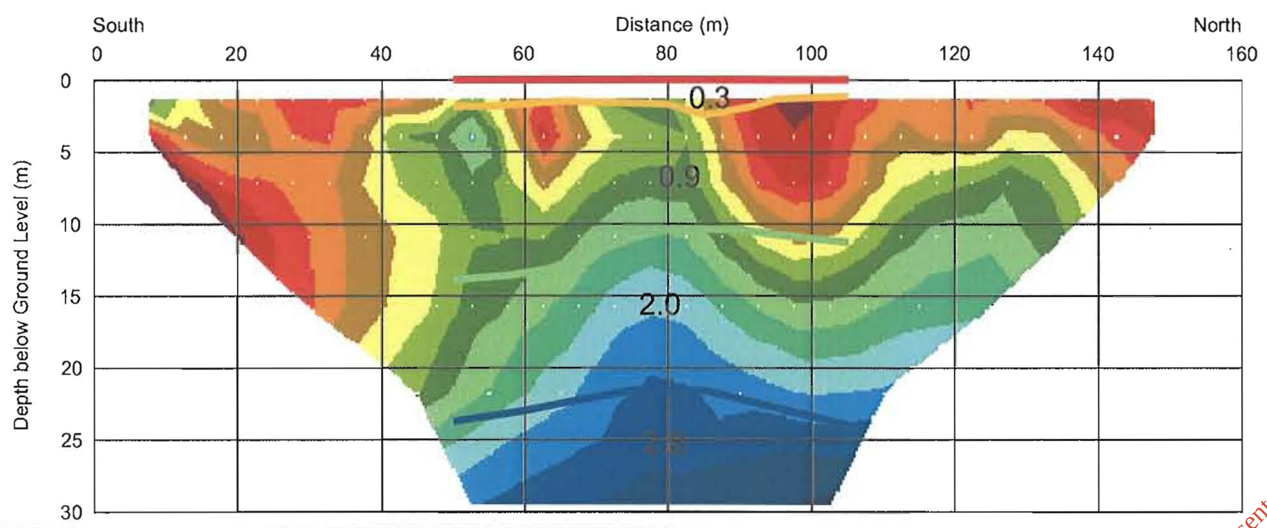
2D-Resistivity Profile R4 Model



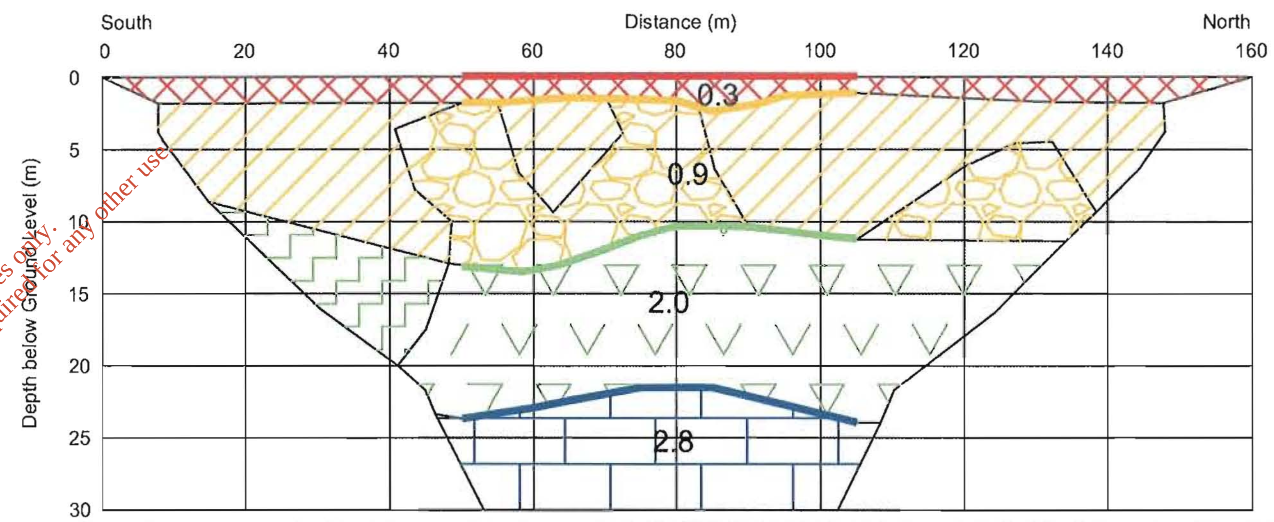
2D-Resistivity Profile R4 Interpretation



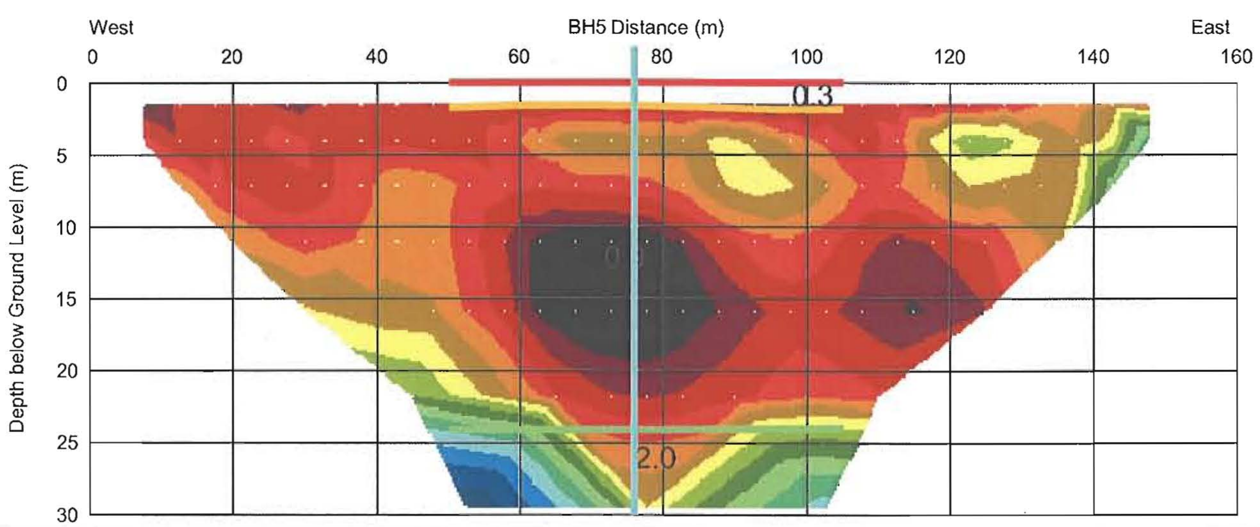
2D-Resistivity Profile R5 Model



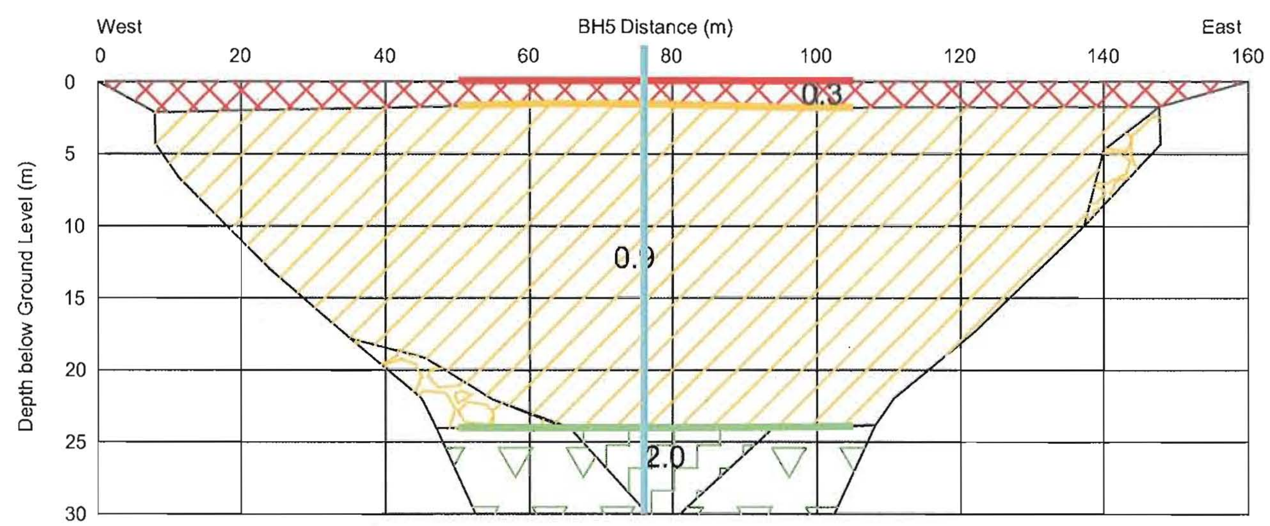
2D-Resistivity Profile R5 Interpretation



2D-Resistivity Profile R6 Model



2D-Resistivity Profile R6 Interpretation



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CLIENT	Mott MacDonald Pettit Cork County Council
PROJECT	Water Treatment Plant, Shanbally, Co. Cork Geophysical Survey
TITLE	Figure 2: Results and Interpretation of 2D-Resistivity & Seismic Profiles R4 - R6

SCALE:	NTS, 2 x VE
PROJECT:	5213
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DATE:	13/11/07
MGX FILE:	5213d_Figs.dwg
STATUS:	Draft

LEGEND: Integrated Interpretation

Model Resistivities Ohm.m

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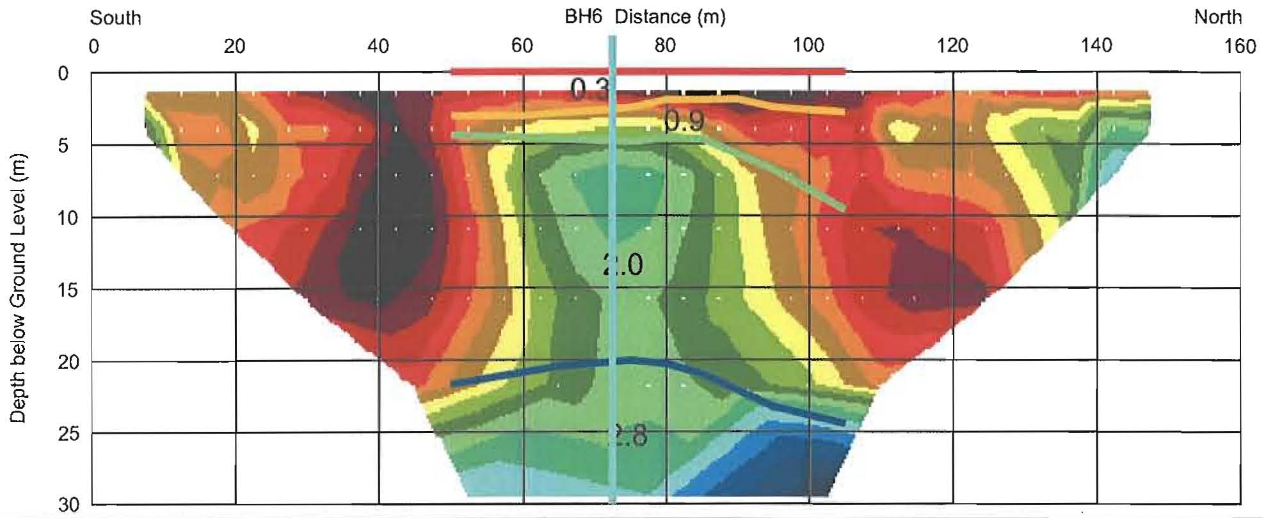
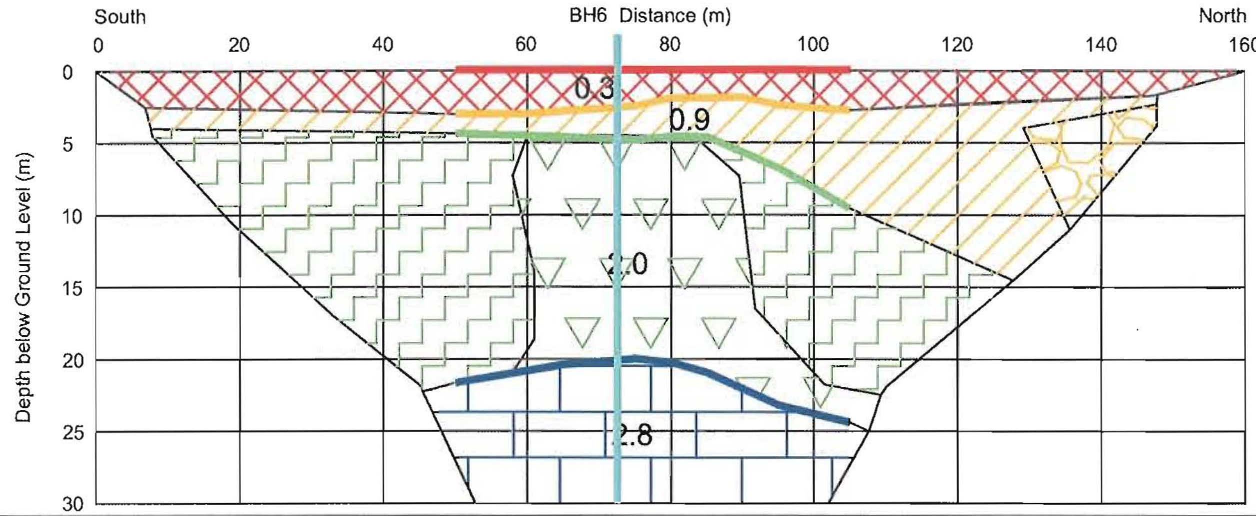
- 3B - Very Dense Sand and Gravel or Fractured Limestone
- 4 - Clean Limestone
- Possible Fault, Fracture or Karst Zone
- BH1 Recommended Borehole Location

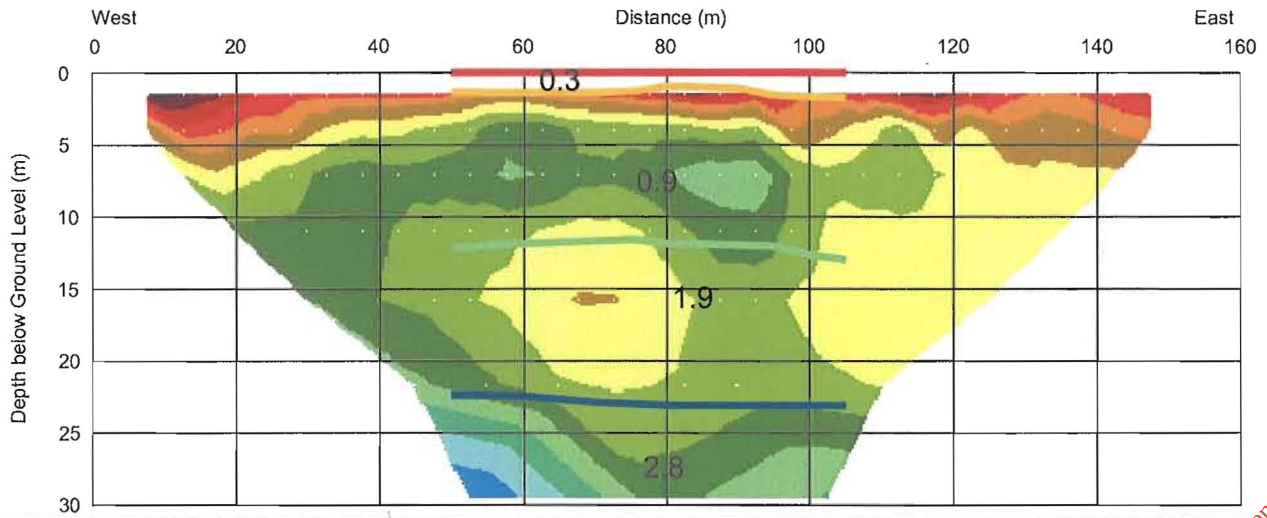
2D-Resistivity Profile R7 Model



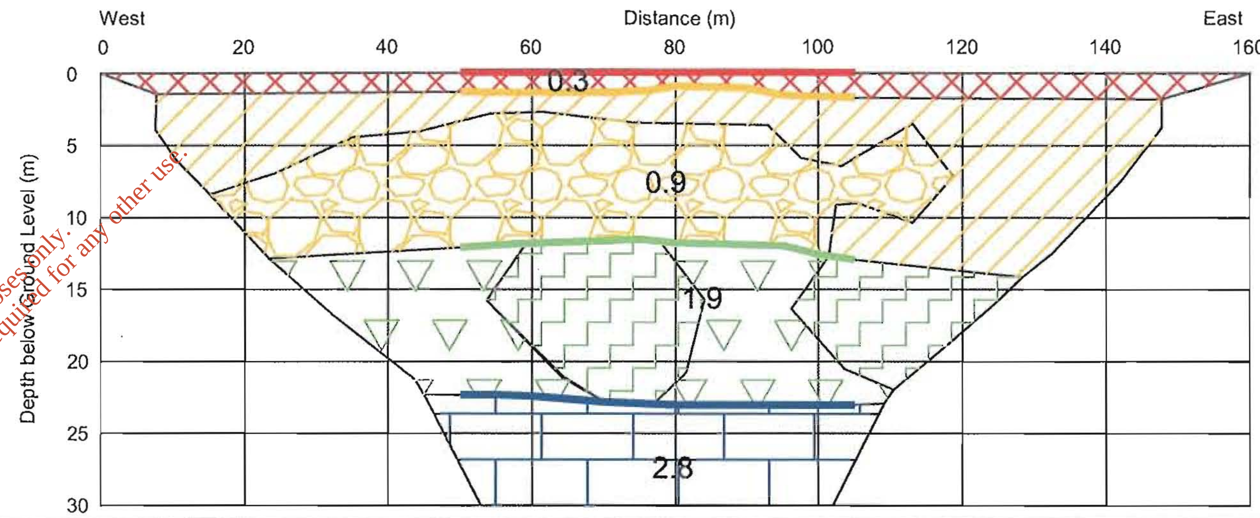
2D-Resistivity Profile R7 Interpretation



2D-Resistivity Profile R8 Model



2D-Resistivity Profile R8 Interpretation



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CLIENT: Mott MacDonald Pettit
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PROJECT: Water Treatment Plant, Shanbally, Co. Cork
Geophysical Survey

TITLE: Figure 3: Results and Interpretation of 2D-Resistivity & Seismic Profiles R7 - R8

SCALE:	NTS, 2 x VE
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MGX FILE:	5213d_Figs.dwg
STATUS:	Draft

LEGEND: Integrated Interpretation

- Top of Layer 1 from Seismic Data
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- BH1 Recommended Borehole Location

Model Resistivities Ohm.m

200 283 400 566 800 1131 1600 2263

Appendix 4B

Bedrock Geology Summary

Mott MacDonald

GEOLOGY OF SOUTH CORK

A GEOLOGICAL DESCRIPTION OF SOUTH CORK
AND ADJOINING PARTS OF WATERFORD
TO ACCOMPANY THE BEDROCK GEOLOGY
1:100,000 SCALE MAP SERIES, SHEET 25, SOUTH CORK.

A.G. Sleeman, M. Pracht

E. P. Daly, A.M. Flegg,
P. J. O'Connor, and W.P. Warren.

Published under the authority of the
Director of the Geological Survey of Ireland.

The lack of heterolithic lithologies and bipolar current structures suggest that the environment was fluviatile. The succession is interpreted to be the deposit of meandering rivers with **levees** in a coastal plain environment. There is a total absence of marine faunas.

THE DEVONIAN STRATIGRAPHY IN THE CENTRAL AND EASTERN PART OF THE MUNSTER BASIN

Apart from the Gortanimill Fm. which extends into East Cork (to the south of Ballynoe at grid ref. 19500 08700), no other formations recognised in West Cork have been mapped. In general, only the higher parts of the Old Red Sandstone facies are exposed in East Cork.

Ballytrasna Formation

The type section of the Ballytrasna Formation (MacCarthy *et al.* 1978, here raised to formation status) is at Ballytrasna near Ballycotton (grid ref. 19830 06320). The thickness ranges from 360m up to 1500m. In the type area some 90% of the formation is composed of dusky-red mudstone while the remainder comprises pale-red fine-medium grained sandstone. The sandstones are occasionally large scale trough cross-laminated with planar or irregular lower surfaces (MacCarthy *et al.* 1978). Correlation of the Ballytrasna Formation with the Caha Mountain, Gun Point and Castlehaven Formations on broad lithological grounds is possible.

The Gyleen Formation

The Gyleen Formation (Gyleen Member, MacCarthy 1974; raised to formation status by Sleeman 1991) is characterised by alternating mudstones and sandstones. The type section is situated to the northwest of Cotters Point (grid ref. 18480 06030).

At the type section the Gyleen Formation comprises about 20% of medium-grained sandstone with large and small-scale cross lamination and about 80% mudstones. Fining up sequences are characteristic throughout the formation. Intraformational breccias, where present, occur in the basal parts of the sandstone units (MacCarthy *et al.* 1978).

The formation shows various colours from green to grey and purple but there is a general decrease of the purple colouration in relation to the underlying units. The base of the formation is at the lowermost thick (greater than 1.5m) sandstone unit, the top at the incoming of the first heterolithic sediments. Stratigraphically it has a similar transitional position as the Toe Head Formation further to the southwest.

Ballyknock Member

The type section is north west of Cotters Point, Co. Cork(grid Ref: 18500 06020). The member varies from 0-365m thick and comprises rapidly alternating thin green siltstone and sandstones with red mudstones. Thick fining upwards sequences, as found in the rest of the Gyleen Formation are rare. The red mudstones (2-30m thick) occur as sheets separated by thin red sandstones. The green siltstones and sandstones (2-20m thick) contain ubiquitous small-scale cross- lamination. About 50% of these sandstones are cross-stratified and arranged in lenticular units. Thin pale green and grey mudstones occur towards the top of the member (MacCarthy *et al.* 1978).

Ballyquinn Member

The type section is in the cliffs at Ballyquinn, Co. Waterford (grid Ref: 22130 08020) where it is approximately 390m thick. The base of the member is transitional from the Ballytrasna Formation and the top passes up transitionall to the Ardmore Member. The member comprises, alternating thick, grey and red medium-grained sandstones with thick red mudstones. The sandstones erosively cut into earlier mudstones and are large-scale, tabular and trough cross-stratified and parallel laminated. They frequently show **epsilon cross-stratification** and **fining upwards cycles**. Intraformational mudstone-flake conglomerates occur at several levels (MacCarthy *et al.* 1978).

Ardmore Member

The type section is located on the coast to the north of Ardmore Village, Co.Waterford (grid Ref: 21970 07740) where it is approximately 107-154m thick. It overlies the Ballyquinn Member conformably and passes up to the Castle Slate Member of the Kinsale Formation at the type section. The member is distinguished by regular alternations of grey and pale red sandstones (2-9m thick) (38%), with grey-yellow siltstones up to 6m thick (62%) (MacCarthy *et al.* 1978). Red beds are isolated and discontinuous where present.

The formations of the Cork Group are defined at the Old Head of Kinsale where they form a sequence more than 2km thick (Naylor 1966; Naylor *et al.* 1985; Kuijpers 1972). This Old Head sequence compares with a thickness near the geographical centre of the South Munster Basin (George *et al.* 1976) of 2.5km recorded in the Ringabella area (Naylor 1969). Further to the north, however, in Cork Harbour, the succession thins markedly (Sleeman et al 1978; Naylor *et al.* 1989) as the North Munster shelf is reached[6]. Further northeast at Ardmore, in County Waterford, the Cork Group is only represented by the 8m thick (MacCarthy et al 1978) Castle Slate Member of the Kinsale Formation.

OLD HEAD SANDSTONE FORMATION

The Old Head Sandstone Formation comprises a thick succession of grey sandstones and heterolithic bedded sandstones and mudstones. The type section is at the Old Head of Kinsale where the sequence has been divided into two members, the Bream Rock Member (550m thick) and the overlying Holeopen Bay Member (290m thick) (Naylor 1966; Kuijpers 1972). Individual members within the formation have generally only been recognised on well exposed coastal sections, so these are not distinguished separately on this mapsheet. The base of the formation is not seen at the type section, but where it can be seen (e.g. Curraghbinny to the north of Crosshaven), it is generally taken "at the entry of significant amounts of lens bedding and flaser bedding into the sequence" (Naylor 1975; Sleeman *et al.* 1978).

The lowest 60m of the Bream Rock Member are mud dominant and bioturbated heterolithic beds (Kuijpers 1972). Above this the heterolithic beds are less bioturbated and the sand dominant heterolithic beds are more common though still subordinate. From 170m above the lowest bed, sand dominant heterolithics predominate. From 355m - 410m above the base the section is inaccessible, but above this sandstone facies constitutes 40% of the succession and the remainder are sand dominant heterolithics (Kuijpers 1972).

The lowest 100m of the Holeopen Bay Member is dominated by sandstone facies. In the remainder of the member, sandstone bodies and mudstone complexes are both common whereas heterolithic facies rocks are less common (Kuijpers 1972).

Kuijpers (1972) interprets the Old Head Sandstone Formation as a tidally influenced depositional environment. The base of the Bream Rock Formation he interprets partly as intertidal mudflat deposits while the remainder of the member is considered to represent a sub tidal environment governed by low energy tidal currents. The Holeopen Bay Member Kuijpers interprets as a tidally influenced environment in which high energy tidal currents prevailed with some strata presumably deposited in a shallow lagoon or (interdistributary) bay lacking evidence of appreciable tidal current action.

The formation is well exposed (in part) at Coolmain (southwest of Ballinspittle) and further west at Seven Heads where Naylor (1964) recognised both the Bream Rock and Holeopen Bay Members. Here the succession is thinner (450m - Kuijpers 1972).Eastwards the formation is well exposed along the coastline from the Old Head of Kinsale, through Reanies Bay, Flat Head to Man of War Cove and Carrigada Bay and on to Cork Harbour (Naylor and Higgs 1980). In the latter area it is well exposed north of Roches Point at Whitebay (MacCarthy *et al.* 1978 - as the Coomhola Formation, Whitebay and Glanagow Members) and is also well exposed at Curraghbinny, Ringaskiddy, Cuskinny (Grid. Ref. 18097 06657) and Marino Point (Grid. Ref. 17716 06955) (Sleeman *et al.* 1978). The latter exposures in Cork Harbour are much thinner (92m - 42m) than further south into the main basin (Sleeman *et al.* 1978).

Inland, the formation is generally rather poorly exposed. Further thinning has been demonstrated northwards (Sleeman *et al.* 1978, Sleeman 1991) into the Cork Syncline where a 10m thick exposure can be seen at the entrance to St. Joseph's Hospital (grid ref: 16295 07201), beyond Sundays Wells, Cork City (MacCarthy 1987). East of Midleton the formation feathers out and is replaced **diachronously** by the topmost red beds of the Gyleen Formation (Sleeman 1991). The formation is also well exposed in Killeady Quarry (Crossbarry, north of Inishannon, grid ref: 15675 06170), where the apparent outcrop width is increased by subsidiary folding (Sleeman 1991).

[6] The top of the "Old Red Sandstone facies", on which the Cork Group rests conformably, is, however, diachronous. This has been demonstrated within the confines of this map sheet (Sleeman et al 1978).

The age of the formation, based on miospores is summarised by Higgs *et al.* (1988) who show that the formation encompases the LL, LE and LN miospore Biozones and is thus of Strunian age. The northward thinning of the formation is paralleled by the later age of the base of the formation demonstrated by the presence of LN Biozone miospores at or near the base of the formation at various localities between North Ringabella and Marino Point (Higgs 1975; Higgs *et al.* 1988; Sleeman *et al.* 1978).

KINSALE FORMATION

The Kinsale Formation, 762m thick at the Old Head of Kinsale (Naylor 1966), is defined, overall, as a mud-dominant succession. The formation is divided into three members on the Old Head: the Castle Slate, Narrow Cove and Pig's Cove Members

Plate 3. The topmost beds of the Uppermost Devonian Old Head Sandstone Formation on the right pass up to the dark-grey mudstones of the Carboniferous Kinsale Formation (Castle Slate Member) at the Old Head of Kinsale. This locality is the Courceyan Stratotype and approximates to the international Devonian-Carboniferous boundary (photo. by A.G.Sleeman).

(Naylor 1966; see also Naylor *et al.* 1977). They are not always shown separately on the mapsheet because inland, west of Kinsale, it has not yet proved possible to map them out in detail, for the most part. The individual members however are mapped out in the Cork City and Harbour district as shown here and on the recent Geological Survey 1:25,000 maps (Sleeman 1991). Approximately east and north of Belgooly and the Carrigada Fault, the overall mud dominant but sandy Narrow Cove Member, is represented by the sand dominant Cuskinny Member (MacCarthy *et al.* 1978; *Sleeman 1987*).

The Old Head of Kinsale is the stratotype for the base of the Courceyan Stage, the lowest of six regional stages in the Dinantian proposed for Great Britain and Ireland (George *et al.* 1976). It is named after the local Barony of de Courceys. The base of the stage corresponds to the Old Head Sandstone/ Kinsale Formation boundary located in Holeopen Bay West (plate 3). The base of the Courceyan Stage corresponds with the boundary between the LN and VI miospore Zones, (Clayton *et al.* 1974; George *et al.* 1976), which, in the absence of **goniatites** of the *Gattendorfia subinvoluta* Zone of Germany, approximates to the Devonian/ Carboniferous boundary.

The formation spans the VI, HD and BP miospore Biozones. Higgs *et al.* (1988) summarise the available data for localities within the mapsheet. The Castle Slate Member contains miospores of the VI Biozone. The Narrow Cove and Cuskinny Members contain VI Biozone miospores near the base but most of the sequence is in the HD Biozone. The base of the Pig's Cove Member contains upper HD biozone miospores and the top generally contains BP miospores[7]. These miospores show that the formation is of earliest to mid Courceyan age (Tn1b - Tn2b/c in Belgian terms).

Other stratigraphically useful fossils are scarce. Matthews and Naylor (1973), however, have recorded **conodonts** from the Castle Slate Member at the Old Head and Matthews (1983), has recorded an interesting goniatite fauna from the same member at Nohaval Cove (east of Kinsale).

Castle Slate Member

The Castle Slate Member, as defined in Holeopen Bay West, is 61.5m thick. The base of the member

[7] At one locality PC Biozone miospores were obtained from the topmost few metres suggesting that elsewhere the top of the member was eroded before deposition of the overlying Courtmacsherry Formation.

is the base of the Courceyan Stage as described above. The member consists of uniform, dark-grey, well cleaved massive mudstones (Naylor 1966) and is in marked contrast to the sandstones of the underlying Old Head Formation. Phosphatic **cryptocrystalline** quartz nodules are common, and especially near the base of the member, comminuted crinoid debris is found, sometimes in bioclastic lenses which also contain **ostracods** and small indeterminate bivalves (Naylor 1966).

The member is an excellent marker horizon across the whole South Munster Basin. It is found as far west as the Beara Peninsula (Gardiner and Horne 1976) and as far east as Ardmore (MacCarthy *et al.* 1978; Clayton *et al.* 1982). Within the area of Sheet 25 it can be seen in many other coastal sites including Dunnycove Bay (Galley Head), Lions Cove (Dunworly Bay) (Graham and Reilly 1976; Naylor and Reilly 1981, MacCarthy 1987), Nohaval Cove and Flat Head (Naylor and Higgs 1980), Ringabella Bay (Naylor 1969), Curraghbinny, Marino Point and Cuskinny, (Sleeman *et al.* 1978; MacCarthy *et al.* 1978), Whitebay, Inch, Ballycotton and Knockadoon (MacCarthy *et al.* 1978).

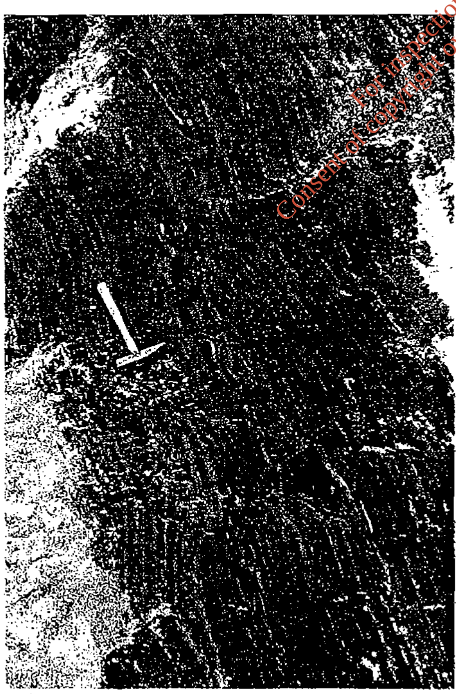

Plate 4. Vertically bedded sand-lensed (linsen) and sand-streaked mudstones of the Courceyan (Lower Carboniferous) Kinsale Formation (Narrow Cove Member) at Duneen Bay near Clonakilty (photo by A.G. Sleeman).

The member is found in many stream sections and quarries inland (the latter often worked in the past for roofing slate), but is difficult to map inland west of Belgooly.

The base of the member represents a sudden but slight deepening of the sea (Naylor *et al.* 1983), immediately succeeding the topmost sandstones of the Old Head Formation which, in some places, are probably shore face deposits (Graham 1975a).

Narrow Cove Member

The type section at Narrow Cove, on the west coast of the Old Head is 303m thick (Naylor 1966). The dominant lithology is sand-lensed (linsen) mudstone (plate 4); although a wide range of lithologies are found including parallel and cross-bedded sandstone, flaser-bedded sandstones and laminated mudstones. There is a general increase in the proportion of sand up sequence so that the top few metres are sand-dominant (Naylor 1966).

The member is well exposed between the Old Head of Kinsale and Kinsale Harbour (de Raaf *et al.* 1977; Naylor and Higgs 1980). Further east the cliff sections are inaccessible. Westwards, there is a good section at Dunworly Bay (Graham and Reilly 1976) and the member thins towards Galley Head (Keegan 1977). Inland it is exposed along the Cork - Bandon road west of Inishannon, where it is very sandy. However, at present it has not been mapped out inland west of Belgooly.

The member, while mudstone dominant, is relatively sandy. The proportion of sandstone gradually increases north and east from the Old Head until north of the Carrigada Fault at Robert's Cove (Robert's Cove Sandstone Formation of Naylor 1969) its equivalent is sandstone dominant (Van Gelder and Clayton 1978). In consequence Sleeman (1987) proposed that the name Cuskinny Member (MacCarthy *et al.* 1978) should be used north of the Carrigada Fault.

De Raaf *et al* . (1977) concluded that the depositional environment was a muddy shallow marine platform on which sandy shoals were formed under the influence of wave action and, overall, represents a regressive phase.

Cuskinny Member

The Cuskinny Member (MacCarthy *et al.* 1978) is the lateral equivalent of the Narrow Cove Member, north and east of the Carrigada Fault (Sleeman 1987). The type section at Cuskinny, east of Cobh (Grid. Ref. 18097 06651), is more than 235m thick wheras the section at South Ringabella (the Robert's Cove Sandstone Formation of Naylor *et al.* 1969; Naylor 1969), records 243m in total.

The Cuskinny Member is distinguished from the equivalent Narrow Cove Member in the higher proportion of sandstone and sand-dominant heterolithic bedded facies. MacCarthy *et al.* (1978) describe the member as composed of relatively thick (0 - 2.65m) sometimes conglomeratic sandstone units (54%), alternating with thin sandstone laminated mudstones (3%), massive claystone (8%) and heterolithic sediments (35%).

North and east of the type section it is difficult to map due to poor outcrop. The member dies out in the region of Knockadoon Head north of which it is laterally replaced by the Crows Point Formation.

MacCarthy *et al.* (1978) and Cotter (1985) describe the member as a regressional phase representing a shallow coastal marine environment with storm generated offshore gravel-topped barrier bar and beach facies.

Pig's Cove Member

The member is distinguished from the underlying Narrow Cove Member by a general lack of sandstones. At the type section (397m thick, Grid Ref. 16200 04005) the lowermost 66m are characterised by silt and fine sand lenses (linsen) within a parallel laminated mud-siltstone sequence. The next 68m of the member consists of undifferentiated highly cleaved massive mudstones and the following 70m are similar to the basal 66m (Naylor 1966). The uppermost 195m, originally designated as the Coosduff Member (Naylor 1966), is sandier than the underlying beds. There is a high proportion of sand-lensed mudstones and thin (less than 0.15m) sandstone beds with rare thick sandstones. Small discoid silicophosphatic nodules are common throughout the mudstones (Naylor 1966; Naylor and Reilly 1981).

The member reaches a maximum thickness in the Kinsale - Ringabella area where Naylor (1969) recorded 709m (Doonavanig Formation) and Sleeman (1987) recorded a similar thickness in Tracton Wood. Further north, however, the member rapidly thins (340m - Paulgorm Formation of Naylor (1969) at North Ringabella) and is probably laterally replaced by the upper part of the Cuskinny Member north of the Cloyne Syncline (Sleeman 1987). In the Cork Harbour area the member is recorded by MacCarthy *et al.* (1978) from the core of the syncline at Whitebay and from the Inch and Ballyshane (east of Gyleen) area (see also MacCarthy 1988 -map). A section at Halfway (between Cork and Bandon), at the western end of the Cloyne Syncline, exposes about 200m through the member, but this sequence appears to thin rapidly eastwards towards Ballea Gorge (north of Carrigaline), where only 75m is recorded (Sleeman 1987). At Raffeen, where the member is no more than 50m thick, it is seen to pass up to the Courtmacsherry Formation. The member has not been found further north and east of Raffeen. While available evidence points to eastward thinning of the member, post Kinsale Formation erosion, suggested by the absence of the BP Miospore Biozone in the Ballea area (Sleeman *et al.* 1986), and strike parallel faulting may both have contributed to the apparent thinning and absence of the member through much of the Cloyne Syncline (Sleeman 1987).

MacCarthy and Gardiner (1987) suggest that the member represents deposition on an offshore wave influenced muddy shelf.

Courtmacsherry Formation

Naylor (1966) recorded a thickness of about 343m from the type section on the west side of the Old Head of Kinsale, between Ringalurisky Point and Well Cove. The formation is informally divided into four units at the type section (Naylor 1966; Matthews and Naylor 1973; Naylor *et al.* 1985), the base of which is taken at the incoming of the first calcareous mudstone. The first unit is characterised by crinoidal debris in beds and lenses inserted into a sequence of calcareous and non-calcareous grey nodular mudstones. Above this the second member is composed of non calcareous siltstones with fine-sand cross-laminae. The third unit comprises interbedded calcareous and non-calcareous mudstones with fewer thicklimestone beds than the basal unit. The topmost unit contains dark-grey mudstones with up to 20% ferroan carbonate as rhombs or concretions[8].

While this description suffices for the formation in the Old Head - Seven Heads area, at Ringabella and Inishannon there is a significant increase in limestone incorporated into the formation (equivalent to member 2).

[8] Away from the Old Head, the boundary between the Courtmacsherry and Lispatrick Formations is rather difficult to define (Naylor *et al* 1987 - Seven Heads).

Elsewhere only member 1 appears to be present. The formation on the basin margin is much less calcareous and less fossiliferous than the equivalent formation on the North Munster Shelf, at Whiting Bay and Mallow for instance (i.e. the Ringmoylan Formation - Campbell 1988; Sevastopulo and Sleeman, unpublished).

The most notable locality is Ringabella Bay where the lower part of the formation (The Fountainstown Member) is succeeded by the limestone rich Ringabella Limestone Member (Naylor 1969; Sleeman 1987). Here the member comprises alternations of 0.1-0.2m thick crinoidal biomicritic limestones and black siliceous and in some cases calcareous, and commonly phosphatic, mudstones. The limestones also contain quartz sand whose origin is difficult to establish. The presence of reworked conodonts in these limestones, however, lends support to the argument that the carbonates found in the Ringabella Limestone Member are derived by removal of material from an intrabasinal uplifted fault block to the north as a result of local intra Courceyan slumping and erosion (Naylor *et al.* 1983).

The Ringabella Limestone Member cannot be mapped away from the coast. Inland adjacent to the old National School at Minane Bridge the Geological Survey drilled a short hole which encountered calcareous mudstones (Sleeman 1987).

The second area where limestones are a significant proportion of the Courtmacsherry sequence is at Rag Bridge east of Inishannon. Here boreholes drilled by Riofinex penetrated a succession comparable to that at Ringabella, but about 1/10th the thickness: the succession is still poorly known and is referred to here informally as the "Inishannon Limestone" (Naylor *et al.* 1983). Again, thin limestones present in the sequence contain quartz sand and reworked conodonts.

The Courtmacsherry Formation has been mapped by one of us (AGS) recently in the area between Upton, Kilpatrick and to the west of Mishells House. A particularly interesting section has been noted in the old Bandon and South Coast Railway cutting at Rockfort House, Brinny (see Key Localities), where the formation as measured is about 200m thick (true thickness) and passes up to the Lispatrick Formation. The section exposes silty and variably calcareous mudstones with thin crinoidal **bioclastic** limestones and dolomitised calcisiltites. The upper part of the sequence is dominated by blocky, nodular, cherty, dolomitised, calcisiltites and **argillaceous** decalcified and cleaved mudstones (Sleeman unpublished). This passes up gradationally to bedded cherts assigned here to the Lispatrick Formation (cf the Minane Chert Member - Naylor 1969; Sleeman 1987).

Further east in the Cloyne Syncline, the formation thins rapidly and passes northwards laterally into the Ringmoylan Formation. The 24m thick sequence exposed between faults at Golden Rock, Ringaskiddy (Sleeman *et al.* 1978, 1986) is transitional to the Ringmoylan Formation; it resembles the Fountainstown Member at Ringabella but is considerably more fossiliferous and was probably more calcareous originally (the mudstones are all weathered and decalcified). At Ballygarvan and Kilnahone Mill the formation is only 3 - 5m thick.

At Broadstrand (Seven Heads), the formation can be divided into four members as at the Old Head but is only 208m thick. The basal beds contain conodonts of the *Siphonodella* Biozone while in member 4 specimens of *Gnathodus cuneiformis*, similar to those recovered from the Ringabella Limestone, have been found. At Ringabella these are known to be of earliest *Polygnathus communis carina* Biozonal age (Naylor *et al.* 1988). Thus the Courceyan age for the top of the Courtmacsherry Formation, as at Ringabella is confirmed at Seven Heads.

At Ballinglanna, on the west side of Seven Heads, the formation is only 7 - 17m thick and lithologically is only slightly different from the underlying Kinsale Formation. It comprises silty mudstones with thin linsen laminae and siliceous and pyritic bullions up to 0.5m across (Naylor *et al.* 1988). The formation here is of early Courceyan (PC Biozone) age.

At Galley Head, only 10km further west, the Courtmacsherry Formation is equivalent to, at most, 8.25m of chert and mudstone (but assigned by Naylor *et al.* (1985) to the Lispatrick Formation). Alternatively and more probably, equivalents of the Courtmacsherry are not present, or are to be found within the 2.15m of cherty mudstone just above the Kinsale Formation (Naylor *et al.* 1985).

Lispatrick Formation

The Lispatrick Formation, 67m thick at the Old Head (Naylor *et al.* 1985), comprises a sequence of fissile and blocky dark-grey to black mudstones, often extremely pyritic, with interbedded bands of ferroan dolomite. The mudstones often weather to a pale ash-grey colour. Bands of black chert are common.

The distinction between the upper part of the Courtmacsherry Formation and the Lispatrick Formation is subtle; while the base of the Lispatrick Formation in Well Cove (Old Head of Kinsale) is satisfactory, the overall nature of the transition between the two formations presents problems in regional correlation (Naylor *et al.* 1985).

The Brigantian bivalve *Posidonia becheri* is found between 13 - 21m above the base of the formation and goniatites of the Brigantian P1d Subzone occur higher up (Naylor *et al.* 1985). However, conodonts (Naylor *et al.* 1985) suggest a late Courceyan to Arundian age for the base of the formation, although reworking from older levels (as for example is known from the Ringabella Limestone Member) cannot be discounted yet.

At Seven Heads the formation is exposed in a small cove east of Meelmane (Naylor *et al.* 1988) where it is 40m thick. At Ballinglanna it is 32.8m thick and **palynological** data (VF Biozone) and conodont data (*Gnathodus girtyi*) confirm the Brigantian age here (Naylor *et al.* 1988). At Galley Head the base of the formation rests on the Kinsale Formation. Here a 2.15m thick sequence of cherty mudstone is present. Its basal 0.2m contains abundant, angular granules and moulds of crinoid ossicles. It is lithologically distinct from typical mudstone of the Lispatrick but is included in the formation by Naylor *et al.* (1988) to avoid introducing another stratigraphical term unique to the locality. Mudstones containing P1c subzonal goniatites (Brigantian) occur 8.25m above the base.

In the Cloyne Syncline the formation is poorly exposed. It has been recorded, however, in boreholes at Meadstown House (Grid. Ref. 16781 06280, Sleeman 1987). Here the sequence comprises very dark-grey pyritic mudstones interdigitating with brecciated **calcilutites** and dolomitised **calcarenites** of Asbian age (Little Island Formation). This is considered to reflect a position on the basin slope margin. Elsewhere the formation appears to pass up to the Namurian White Strand Formation.

Further south, in the Ringabella Syncline, bedded cherts and dark-grey phosphatic and pyritic mudstones at Minane Bridge (plate 5) are assigned to the formation (Minane Chert Member - Naylor 1969; Sleeman 1987). The discovery of a goniatite (*Ammonellipsites*) from Minane Quarry (Naylor *et al.* 1983) suggest a Courceyan age for the base of the Lispatrick Formation here. The possibility of a similar age for the base of the formation at the Old Head has already been noted.

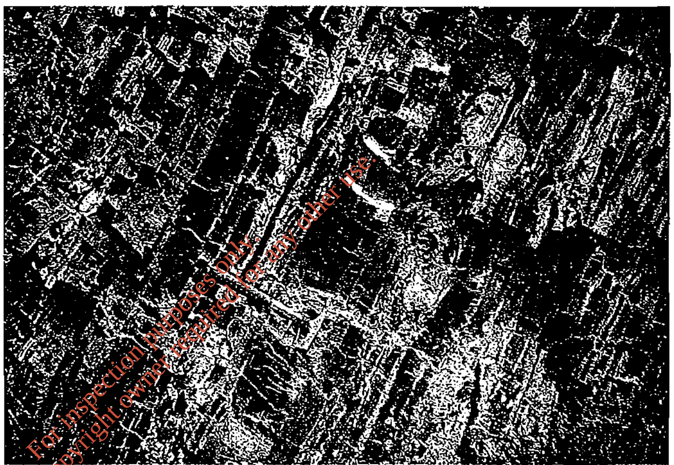

Plate 5. Bedded cherts from Minane Quarry (at Minane Bridge), Lispatrick Formation. These rocks are the basinal down-slope equivalents of the cherty Loughbeg Formation on the shelf edge (photo by A.G. Sleeman).

At Rag Bridge, southeast of Innishannon, the Lispatrick Formation has been drilled fairly extensively by Riofinex. Here black cherty shales interbedded with limestone breccias (similar to those at Meadstown) rest on limestones and calcareous shales of the "Innishannon Limestones" (Courtmacsherry Formation)[9]. Only about 4km further eastwards, however, the Lispatrick Formation mudstones are in juxtaposition with the Kinsale Formation due to strike parallel faulting.

White Strand Formation

The Namurian White Strand Formation is 44m thick at the Old Head of Kinsale, where the top is not reached. At Ballinglanna, however, Naylor *et al.* (1988) record a thickness of 346m. The outcrop of

[9] Work in progress (Naylor, Sevastopulo and Sleeman). Northwest of Inishannon itself, in the Kilpatrick Syncline, the Lispatrick Formation may occupy the centre of the syncline (Sleeman unpublished).

the formation in the Cloyne Syncline (between Meadstown and Inishannon) is probably of the same order of thickness.

This formation is the youngest formation present on the South Cork mapsheet and is of Pendleian or Arnsbergian age (E1 - ?H goniatite subzone).

At the type section the formation consists of sandstones up to 0.7m thick, interbedded with brittle, commonly pyritic, grey mudstones. The ratio of sandstone to mudstone is approximately 1:3. Much of the lower part of the formation is strongly slumped. Its base istaken at the abrupt entry of sandstones on the southern side of White Strand Point.

In the Cloyne Syncline, the formation is poorly exposed, but comprises a mixed sequence of grey silty mudstones and dark-grey to khaki or greeny-grey medium to coarse grained sandstones; it is easily mistaken in the field for the Cuskinny Member of the Kinsale Formation (Sleeman 1987). Outcrops at Ballyheady Church west of Ballinhassig have yielded Namurian miospores of the NC Biozone (Sleeman 1987) and Coelacanth fish remains (Huxley 1866).

At Ballinglanna miospores belonging to the NC Biozone have been found 41m above the base and miospores of the SO Biozone at the top of the formation as exposed (Naylor *et al.* 1988).

Carboniferous Limestones

"THE LOWER LIMESTONE SHALE"

The standard succession through the "Lower Limestone Shales" on the North Munster Shelf to the north of this mapsheet comprises the Mellon House, Ringmoylan and Ballyvergin Shale Formations respectively (table 2). The northern half of mapsheet 25 is geographically in a transitional position between the basinal succession of the South Munster Basin and the shallow water North Munster Shelf succession outlined above. Consequently aspects of both sequences can be seen in juxtaposition in the Cork, Riverstown, Ardmore and Clashmore Synclines. The shelf succession is also laterally very variable, so a series of laterally equivalent units have been proposed in different areas (e.g. Sleeman *et al.* 1978; MacCarthy *et al.* 1978; Campbell 1988; Tietzsch-Tyler *et al.* 1994).

Crows Point Formation

The Crows Point Formation, restricted to the Youghal, Ardmore and Helvick Head areas of East Cork and Waterford, is the lateral equivalent on the southern edge of the North Munster Shelf of the Cuskinny and Pig's Cove Members (Kinsale Formation) further south. The formation differs from the Kinsale Formation in being sandstone dominant (92% at the type section - MacCarthy *et al.* 1978). It probably equates with part of the Mellon House Formation further north on the shelf.

At the type section, at Helvick Head just northeast of this mapsheet, the formation is 73m thick (although the bottom contact is faulted and the top is not seen). The formation here comprises mainly thick, parallel-sided, massive and epsilon cross-stratified grey sandstones, interbedded with minor thin cross-stratified grey sandstones, grey mudstones and heterolithic lithologies (MacCarthy *et al.* 1978; MacCarthy 1979).

Plate 6. Megaripples developed on a bedding surface of grey sandstones in the Crows Point Formation, Whiting Bay, Co. Waterford (photo by A.G. Sleeman).

At Crushea (Ballyquinn, north of Ardmore) and Whiting Bay, however, where only the presumed top of the formation is exposed, sandstones with interbedded burrowed weathered mudstones and decalcified sandstones occur. These sequences also contain appreciable quantities of quartz-pebble conglomerates lining the bases of sandstones

Appendix 4C

Geological Heritage Correspondence

Mott MacDonald

From: Sarah Gatley [Sarah.Gatley@gsi.ie]
Sent: 09 July 2007 15:34
To: Freyne, Orla
Subject: RE: 234541 (A5670 Cork Lower Harbour WWTP EIS) - Geological Heritage

Dear Orla,

With reference to your enquiry on geological heritage sites in the Cork Harbour region, I have attached an xls. showing 3 sites of geological heritage interest in the area. I do not see any potential impacts from your proposed Waste Water Treatment Plant development; this is mostly for your information. As you can see from the 'Cork Harbour' entry, details of the extent of the raised beach feature have not been resolved, but I see that few of your proposed pipes are mapped for the foreshore areas.

I am sure that you are already aware of the biodiversity NHAs in this area; namely Loughbeg, Monkstown Creek and Owenboy River (?proposed foreshore pipe runs along the north bank).

If development does proceed (all other factors considered), GSI would much appreciate a copy of reports detailing site investigations undertaken. The data would be added to GSI's national database of site investigation boreholes, implemented to provide a better service to the civil engineering sector.

We would also appreciate notification of any ground excavations etc. carried out that might provide good geological exposures for our examination and enhance our understanding of the area. This would allow recording, fossil or rock sample collecting and gathering of new data.

Should any significant bedrock cuttings be created, we would request that they be designed to remain available as rock exposure rather than covered with soil and vegetated.

I hope that these comments will be of assistance, and if the GSI can be of any further help, please contact me.

Kind regards

Sarah

Dr Sarah Gatley
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Website: www.gsi.ie
Latest GSI Newsletter: www.gsi.ie/newsletters/

Theme Site No.	Site Name	County	Sheet No. 6 Inch	Sheet No. 1:50,000	Easting	Northing	Principal characteristics Critical feature(s) key words	Townland(s)/district	Grid Ref.	Nominated by or ex-ASI site?	Summary description	definite NHA	NHA?	Definite CGS	Key references	IGH Theme - Primary	IGH Theme - Secondary	IGH Theme- Tertiary	Comments	Possible site report author bold red means agreed to do it	Age/Type	Colour Code
IGH8	Lough Beg Section	Cork		87	178000	063000		Loughbeg, Curraghbinny	W 78 63		Coastal section. Armour stone		NHA?		Sleeman, A.G., Thornbury, B. and Sevastopulo, G.D. The Stratigraphy of the Courceyan (Carboniferous; Dinantian) Rocks of the Cloyne Syncline, West of Cork Harbour. *Irish Jnl. Earth Sci.* 8, 1986, 21-40.	IGH8 Lower Carboniferous					Carboniferous	
IGH8	Ringaskiddy, Golden Rock	Cork	87	87	179000	064000		Ringaskiddy	W 79 64					CGS		IGH8 Lower Carboniferous					Carboniferous	
IGH13	Cork Harbour	Cork		87, 81	181000	061000	ORS, structural features, raised beaches		N/A		On the western side of Cork Harbour is the Crosshaven Peninsula, where the Old Red Sandstone comes up in a Southern Anticline trending east-west, exposed on Weaver's Point, flanked by Carboniferous Limestone to the north. An emerged ("raised") beach can be traced around the shores of Cork Harbour, but there are discrepancies in the levels of Late Quaternary sediment sequence levels on either side of the harbour which could result from Holocene warping (Devoy). Near Rostellan on the eastern side of the bay a dolmen (megalithic tomb) a dolmen built 3000-4000 years ago is submerged at high tide.				Farrington, A. 1966 The early glacial raised beach in County Cork. Sci Proc Roy Dublin Soc A, 2: 197-219.	IGH13 Coastal Geomorphology			grs refer to Weaver's Point, W.Cork harbour -sg			

Appendix 4D

Well Search Results

Mott MacDonald

GEOLOGICAL SURVEY OF IRELAND

GROUNDWATER DATABASE

List of abbreviations

GSIHolename. 1:25,000 sheet Number and number of the well on that sheet

EASTING (E) & NORTHING (N) Grid Reference of the well

Grid Acc or Acc Accuracy level, refers to the accuracy of the grid reference.

1 = 10m	5 = 200m	9 = 5km
2 = 20m	6 = 500m	10 = 10km
3 = 50m	7 = 1km	
4 = 100m	8 = 2km	

Schemename Name of the person or organisation who own the well.

Townland Name of the area where the well is located

Co. County i.e. DO = County Donegal

Six or Six" 1:10,560 sheet number (6" sheet number)

InvType Well Type:

WD = Dug Well	WB = Bored Well
WS = Spring	WU = Unknown

U Usage:

A = Agricultural use only	B = Agricultural & Domestic use
D = Domestic use only	G = Group Scheme
I = Industrial use	P = Public Supply
O = Other	

Y or Yield Class Yield:

F = Failure	P = Poor (<40m^3/d)
M = Moderate (40 – 100m^3/d)	G = Good (100 – 400m^3/d)
E = Excellent (>400m^3/d)	U = Unknown

Depth Total depth of the well in metres

DTB Depth to bedrock in metres

Yield Usually yield obtained during initial well testing in m^3/day

SpeCap_Abstract Discharge/ Drawdown m^3/day/ m (from yield test or abstraction data)

MainAquifer Lith. General description of the geological unit supplying water to the well.

AveDailyAbstract m^3/day

WaterStrike Metres below dipping reference – ground level unless stated otherwise

GSIHOLENAME	EASTING	NORTHING	GRID_ACCURACY	TOWNLAND	TOWN	SIXINCH	INVTYPE	USAGE	STARTDATE	DTB	DEPTH	DTB_CONFID	COMPANYHOLENAME	SCHEMENAME	CASING1DIAMETER	YIELD	YIELDCLASS
5SWW047	17393	6305	8	BALLINDEASIG		113	WB	U	01/04/1963	3.7	15.2	Bedrock Met				28	P
1705NWW077	17627	6468	3	BALLINTAGGART		87	WB	U	01/10/1995	17	25	Bedrock Met	C2				
1705NWW078	17628	6463	3	BALLINTAGGART		87	WB	M	01/10/1995	14	23	Bedrock Met	C1				
1705NWW079	17629	6459	3	BALLINTAGGART		87	WB	M	01/10/1995	18.5	23.5	Bedrock Met	C3				
1705NWW006	18213	6835	8	BALLYDANIEL MORE		74	WB	U	01/07/1967	3.7	30.5	Bedrock Met		WTB/CK 2372		32.7	P
1705NWW017	18106	6819	6	BALLYDULEA		87	WB	U	01/06/1973	4.3	30.5	Bedrock Met				32.7	P
1705NWW100	17924	6817	1	BALLYLEARY		87	WB		28/08/2001	6	6	Bedrock Met	1705NW D12				
1705NWW021	18238	6763	7	BALLYMORE		88	WB	U	01/06/1970	3	23.5	Bedrock Met		WTB/CK 5971		32.7	P
1705NWW018	18238	6769	7	BALLYMORE		87	WB	U	01/10/1971	5.5	27.4	Bedrock Met				32.7	P
1705NWW116	18264	6791	3	BALLYMORE	Cobh	87	WB	B		3.7	56.4	Bedrock Met	DWG 1918		165	16.4	P
1705NWW005	18002	6880	7	BALLYNACRUSHA		74	WB	U	01/04/1971	3.7	24.7	Bedrock Met				38.2	P
1705NWW040	18032	6855	2	BALLYNACRUSHA		87	WB	D	03/07/1998	4.3	46.6	Bedrock Met				43.6	M
1705NWW115	18231	6273	4	CARLISLE FORT	Whitegate	87	WB	B	03/08/2001	6	44.2	Bedrock Met	DWG 2653		165	43.6	M
1705NWW020	17345	6321	9	CARRIGALINE		87	WB	U	01/01/1966	3.1	45.7	Bedrock Met				28	P
1705NWW032	17532	6328	3	CARRIGALINE EAST		87	WB	B	01/11/1983		45.7	Bedrock Not Met				300	G
1705NWW029	17380	6170	7	COMMEEN		99	WB	U	01/05/1971	3.4	25.6	Bedrock Met				32.7	P
1705NWW028	17382	6169	7	COMMEEN		99	WB	U	01/05/1971	3.7	19.5	Bedrock Met				32.7	P
1705NWW087	17740	6257	5	CURRAGHBINNY		87	WB	I	12/12/1999	1	20	Bedrock Met	1979/TW-2		150	272.5	G
1705NWW086	17846	6261	5	CURRAGHBINNY		87	WB	I	09/12/2000	1.5	15	Bedrock Met	1979/TW-1		150		
1705NWW016	18155	6743	6	CUSKINNY		87	WB	U	01/05/1971	2.1	22.9	Bedrock Met				32.7	P
1705NWW004	18063	6902	7	FANICK		74	WB	U	01/07/1961	1.8	19.2	Bedrock Met				10.9	P
705NWW007	17827	6935	8	MARINO		74	WB	U	01/05/1970		27.4	DTB Unknown				21.8	P
5NWW019	17356	6793	7	OLD COURT		87	WB	U	01/10/1970	2.4	35.1	Bedrock Met				43.6	M
05NWW068	17431	6552	4	RAFFEEN		87	WB	D	19/05/1998	6.1	50.3	Bedrock Met				49.1	M
1705NWW082	17442	6472	8	RAFFEEN		87	WB	O	22/05/1986	10	30	Bedrock Met	BH3	CORK CO CO			
1705NWW083	17442	6477	8	RAFFEEN		87	WB	O	20/05/1986	0	13.5	Bedrock Met	BH2	CORK CO CO			
1705NWW081	17443	6482	8	RAFFEEN		87	WB	O	19/05/1986	1	10	Bedrock Met	BH1	CORK CO CO			
1705NWW080	17443	6485	8	RAFFEEN		87	WB	O	01/05/1986	2	36.5	Bedrock Met	BH4	CORK CO CO			
1705NWW015	17444	6490	7	RAFFEEN		87	WB	U	01/08/1973	2.4	54.9	Bedrock Met				43.6	M
1705NWW098	17453	6367	1	RAFFEEN		87	WB		03/09/2001	5	5	Bedrock Met	1705NW D10				
1705NWW036	17521	6542	3	RAFFEEN		87	WB	O	21/11/1997	0	26	Bedrock Met	B3	CORK CO CO	150		
1705NWW038	17522	6539	3	RAFFEEN		87	WB	O	20/01/1998	0	13.9	Bedrock Met	F3	CORK CO CO			
1705NWW037	17527	6529	3	RAFFEEN		87	WB	O	20/11/1997	0	26	Bedrock Met	B4	CORK CO CO	150		
1705NWW039	17538	6526	3	RAFFEEN		87	WB	O	23/01/1998	0	18	Bedrock Met	F4	CORK CO CO			
1705NWW072	17670	6310	4	RAHEENS EAST		87	WB	O	01/11/1985	2.5	91	Bedrock Met		WHEAT INDUSTRIES			U
1705NWW092	17617	6732	1	RATHANKER		87	WB		08/08/2001	2	2	Bedrock Met	1705NW D4				
1705NWW048	17877	6305	5	RINGASKIDDY		87	WB	O	01/07/1997	11.8	15.3	Bedrock Met		G/T WARNER LAMBERT			
1705NWW047	17877	6312	5	RINGASKIDDY		87	WB	O	01/02/1998	7.3	10.5	Bedrock Met	WD3A	G/T WARNER LAMBERT			
1705NWW049	17879	6302	5	RINGASKIDDY		87	WB	O	01/07/1997	9.5	14.5	Bedrock Met		G/T WARNER LAMBERT			
1705NWW045	17879	6303	2	RINGASKIDDY		87	WB	O	01/02/1998	1.5	7	Bedrock Met	WD1	G/T WARNER LAMBERT			
1705NWW046	17880	6316	5	RINGASKIDDY		87	WB	O	01/02/1998	2	6	Bedrock Met	WD2	G/T WARNER LAMBERT			
1705NWW050	17883	6298	5	RINGASKIDDY		87	WB	O	01/07/1997	6	9	Bedrock Met	WD3	G/T WARNER LAMBERT			
705NWW041	17883	6304	2	RINGASKIDDY		87	WB	O	01/07/1997	15	21	Bedrock Met	RC1	G/T WARNER LAMBERT			
5NWW042	17883	6306	2	RINGASKIDDY		87	WB	O	01/07/1997	4	10.5	Bedrock Met	RC2	G/T WARNER LAMBERT			
05NWW051	17885	6293	5	RINGASKIDDY		87	WB	O	01/07/1997	1.5	4.5	Bedrock Met	WD11	G/T WARNER LAMBERT			
1705NWW044	17888	6315	2	RINGASKIDDY		87	WB	O	01/07/1997	12.5	17.5	Bedrock Met	RC9	G/T WARNER LAMBERT			
1705NWW052	17889	6319	5	RINGASKIDDY		87	WB	O	01/07/1997	4.5	7.5	Bedrock Met	WD34	G/T WARNER LAMBERT			
1705NWW053	17892	6315	5	RINGASKIDDY		87	WB	O	01/07/1997	1.5	5	Bedrock Met	WD35	G/T WARNER LAMBERT			
1705NWW056	17893	6303	5	RINGASKIDDY		87	WB	O	01/07/1997	12.3	15.5	Bedrock Met	WD41	G/T WARNER LAMBERT			
1705NWW055	17894	6306	5	RINGASKIDDY		87	WB	O	01/07/1997	4.5	8	Bedrock Met	WD40	G/T WARNER LAMBERT			
1705NWW054	17894	6311	5	RINGASKIDDY		87	WB	O	01/07/1997		19	Bedrock Not Met	WD39	G/T WARNER LAMBERT			
1705NWW043	17895	6305	2	RINGASKIDDY		87	WB	O	01/07/1997	5.1	11	Bedrock Met	RC5	G/T WARNER LAMBERT			
1705NWW058	17897	6296	5	RINGASKIDDY		87	WB	O	01/07/1997	4.5	7.5	Bedrock Met		G/T WARNER LAMBERT			
1705NWW057	17898	6299	5	RINGASKIDDY		87	WB	O	01/07/1997	5.5	10	Bedrock Met	WD42	G/T WARNER LAMBERT			
1705NWW113	17528	6938	3	ROCHESTOWN	Passage West	75	WB	B		1.5	68.6	Bedrock Met	DWG 2498		162.5	10.9	P
1705NWW097	18095	6978	1	ROSSLAGUE		75	WB		16/08/2001		10.3	Bedrock Not Met	1705NW D9				
1705NWW096	18121	6991	1	ROSSLAGUE		75	WB		16/08/2001		10	Bedrock Not Met	1705NW D8				
1705NWW095	18126	6913	1	ROSSLAGUE		75	WB		16/08/2001	0.5	0.5	Bedrock Met	1705NW D7				
1705NWW111	18126	6965	3	ROSSLAGUE	Cobh	75	WB	B			13.1	Bedrock Not Met	DWG 2385		165	65.5	M
1705NWW076	17493	6458	3	SHANBALLY		87	WB	I	01/01/1973	6.1	61	Bedrock Met		PFIZERS CHEMICALS (WELL 5A)		802	E
1705NWW067	17530	6390	5	SHANBALLY		87	WB	O	01/10/1997		12.8	Bedrock Not Met	BH8	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW066	17530	6396	5	SHANBALLY		87	WB	O	01/10/1997		9.7	Bedrock Not Met	BH7	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW065	17530	6402	5	SHANBALLY		87	WB	O	01/10/1997	6.5	6.5	Bedrock Presumed	BH6	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW060	17530	6418	5	SHANBALLY		87	WB	O	01/10/1997	14	14.1	Bedrock Met	BH1	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW061	17530	6423	5	SHANBALLY		87	WB	O	01/10/1997		7.2	Bedrock Not Met	BH2	IDA NEPTUNE PROJECT (SEAGATE)			
5NWW062	17530	6428	5	SHANBALLY		87	WB	O	01/10/1997		14.3	Bedrock Not Met	BH3	IDA NEPTUNE PROJECT (SEAGATE			
5NWW064	17531	6406	5	SHANBALLY		87	WB	O	01/10/1997		7.6	Bedrock Not Met	BH5	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW063	17531	6412	5	SHANBALLY		87	WB	O	01/10/1997		14.1	Bedrock Not Met	BH4	IDA NEPTUNE PROJECT (SEAGATE)			
1705NWW075	17535	6450	3	SHANBALLY		87	WB	I	01/01/1973	7	56.4	Bedrock Met		PFIZERS CHEMICALS (WELL 14A)		632	E
1705NWW014	17548	6458	3	SHANBALLY		87	WB	I	01/03/1980	5.5	49.7	Bedrock Met	Well 15B	PFIZER LTD		1374.7	E

GSIHOLENAME	PROD_CLASS	ABSTRACTDDOWN	WATERSTRIKE_1	MAINAQUIFER_MLITH	WATERSTRIKE_2	WATERSTRIKE_3	SPECAP_ABSTRACTION	COMMENTS	COMMENTS	CWCOMMENTS
1705SWW047				ORS				w/ck 7209		
1705NWW077								b/hole c2		
1705NWW078				GRAVEL/SILT/LIMESTONE				b/hole c1		
1705NWW079								b/hole c3		
1705NWW006				RED SANDSTONE						
1705NWW017				BROWN SANDSTONE				wtb/ck 10487		
1705NWW100										
1705NWW021				BROWN SANDSTONE						
1705NWW018				BROWN SANDSTONE				wtb/ck 9644		
1705NWW116	V	45.7	9.1	SANDSTONE	19.8	45.7	0.36	Drilled by Southern Pumps Ltd□□Chemical data available	Rotary.□□Location from site r	Clear and good quality
1705NWW005										
1705NWW040								Drilled by Dominick Harte		
1705NWW115	IV	11.3	13.7		36.6		3.87	DtB inferred from casing□□Drilled by Southern Pumps Ltd	Rotary.□□Location from site r	Clear
1705NWW020								wtb/ck 3394		
1705NWW032				SAND				another well on site drilled to 27m, no other info		
1705NWW029				BROWN SANDSTONE						
1705NWW028				SANDSTONE				wtb/ck 8997		
1705NWW087			18	LIMESTONE	26					
1705NWW086			12	LIMESTONE						
1705NWW016				BROWN SANDSTONE				wtb/ck 9337		
1705NWW004				ORS				w/ck 1668		
1705NWW007				SANDSTONE				lined 9.14m		
1705NWW019								wtb/ck 8696		
1705NWW068								Drilled by Southern Pumps Ltd		
1705NWW082								drilled by dunnes/bhole no3		
1705NWW083				MUDSTONE				drilled by dunnes/b/hole no 2		
1705NWW081								drilled by dunnes b/hole no1		
1705NWW080				MUD & SANDSTONE				drilled by dunnes/b/hole no.4		
1705NWW015				BROWN SANDSTONE				wtb/ck 10271		
1705NWW098										
1705NWW036								site invest & monitoring @ raffeen landfill bh-b3	Raffeen Landfill Site	casing surrounded by pea gravel from 2.5 to 26m□
1705NWW038				SHALE				site invest & monit @ raffeen landfill bh-f3	Raffeen Landfill Site	
1705NWW037								site invest & monitor @ raffeen landfill Site bh-b4	Raffeen Landfill Site	Pea gravel 2.5 to 26m
1705NWW039				SHALE				site invest & monit @raffeen landfill bh-f4	Raffeen Landfill Site	
1705NWW072			5.5	LIMESTONE				see file 3.1.4 v. little water		
1705NWW092										
1705NWW048				LIMESTONE				site invest petits rotary percussive bhole wd1		
1705NWW047								site invest petits rotary percussive bhole wd3a (bh3 on map)		
1705NWW049				LIMESTONE				site invest petits rotary percussive bhole wd2		
1705NWW045				LIMESTONE				site invest by Pettits rotary percussive b/hole wd1 (bh1)		
1705NWW046				LIMESTONE				site invest by petits rotary percussive b/hole wd2 (bh2)		
1705NWW050				LIMESTONE				site invest by petits rotary percussive bhole wd3		
1705NWW041				LIMESTONE				site invest report by Pettits rotary coring b/hole c1		
1705NWW042				LIMESTONE				site invest by Pettits rotary coring- bhole c2		
1705NWW051				LIMESTONE				site invest by petits rotary percussive bhole wd11		
1705NWW044				LIMESTONE				site investigation by Pettits rotary coring b-hole c9		
1705NWW052				LIMESTONE				site invest by petits rotary percussive bhole wd34		
1705NWW053								site invest by petits rotary percussive bhole wd35		
1705NWW056								site invest by petits rotary percussive bhole wd41		
1705NWW055								site invest by petits rotary percussive bhole wd40		
1705NWW054								site invest by petits rotary percussive bhole wd39 (skipped 38)		
1705NWW043				LIMESTONE				site invest by Pettits rotary coring b/hole c5		
1705NWW058				LIMESTONE				site invest by petits rotary percussive bhole wd_		
1705NWW057								site invest by petit's rotary percussive b/hole wd42		
1705NWW113	V		48.77	MUDSTONE	60.96		0.22	unknown□□Drilled in Sept 2001□□Chemical data available	Rotary.□□Location from site r	Ok quality
1705NWW097										
1705NWW096										
1705NWW095										
1705NWW111			13.1	GRAVEL				Chemical data available	Rotary.□□Location from site r	OK quality; 72 hr test
1705NWW076	I	8.5		LIMESTONE			94.35	from files in Core room -log and Q and ddwn		
1705NWW067								SITE INVEST BY GEOTECH SHELL & AUGER BH8		
1705NWW066								SITE INVEST BY GEOTECH SHELL & AUGER BH7		
1705NWW065								SITE INVEST BY GEOTECH SHELL & AUGER BH6		
1705NWW060								site invest by geotech shell & auger BH-1		
1705NWW061								site investigation by geotech shell & auger bh2		
1705NWW062								site invest by geotech shell & auger bh3		
1705NWW064								SITE INVEST BY GEOTECH SHELL & AUGER BH5		
1705NWW063								site invest by geotech shell & auger bh4		
1705NWW075	II	13.7		LIMESTONE			46.13	from files in Core room-logs including Q and ddwn		
1705NWW014	I	7.3					188.32	new" well located on map from reg of abs AB/9/81"		