Fingal County Council Comhairle Contae Fhine Gall

ENVIRONMENTAL PROTECTION AGENCY
30 JAN 2007

Environment Department
P.O. Box 174,
County Hall,
Swords,
Fingal,
Co. Dublin

An Roinn Seirbhísí Comshaoil
Bosca 174,
Áras an Chontae,
Sord,
Fine Gall,
Contae Átha Cliath

Telephone
01 890 5601
Facsimile
01 890 6299
Email
envserv@fingalcoco.ie
www.fingalcoco.ie

Dr. Ian Marnane
Office of Licensing and Guidance
Environmental Protection Agency
P.O. Box 3000
Johnstown Castle Estate
County Wexford

26th January 2007

Re: W231-01, Proposed Fingal Landfill

Dear Dr. Marnane

I enclose for your information 3 no. hard copies and 2 CD's of the following:

1. Letter from the EPA to Tobins, dated 18th December 2006.
2. Letter from Tobins to Fingal County Council, dated 8th January 2007.
3. TES Bog of the Ring Report, re-issued January 2007.

The documentation is self explanatory. Copies have also been sent to the GSI and the Nevitt Lusk Action Group.

Yours sincerely

Gilbert Power
Director of Services
Environment Department

TOBIN
Patrick J. Tobin & Co. Ltd.

Consulting Engineers

www.tobin.ie

Block 10-3, Blanchardstown Corporate Park, Dublin 15, Ireland. Tel: +353 (0)1 8030401/6 Fax: +353 (0)1 8030409/10
Fairgreen House, Fairgreen Road, Galway, Ireland. Tel: +353 (0)91 565211 Fax: +353 (0)91 565398
Northpoint House, New Mallow Road, Cork, Ireland. Tel: +353 (0)21 4308624 Fax: +353 (0)21 4308625
Bedford Place, Howleys Quay, Lower Shannon Street, Limerick, Ireland. Tel: +353 (0)61 415757 Fax: +353 (0)61 409378
Market Square, Castlebar, Co. Mayo, Ireland. Tel: +353 (0)94 9021401 Fax: +353 (0)94 9021534
Eimear Court, Market Square, Dundalk, Co. Louth, Ireland. Tel: +353 (0)42 9335107 Fax: +353 (0)42 9331715

Our Ref: 1207/BOTR/080107

Date: 8th January 2007

Fingal County Council
Water Services
1st Floor
Grove Road
Blanchardstown
Dublin 15

Attn of: Mr Lar Spain, Senior Engineer

Re: Re-issue (January 2007) of Final Hydrogeological Assessment Report on the Bog of the Ring Scheme

Dear Lar,

In a letter from Mr Donal Daly (Senior Scientific Officer, Hydrometric and Groundwater Section, EPA), on the 18th December 2006, it was suggested that specific terminology used in the Final Hydrogeological Assessment Report (October 2006) had the potential to cause confusion. A copy of the letter issued from the EPA is attached.

The specific terminology referred to was the use of the term '*groundwater catchment boundary*', as defined by TES Consulting Engineers. The *groundwater catchment boundary* (as defined by TES) is the induced catchment area referred to sustain supplies from the Bog of the Ring Abstraction Scheme. As pointed out by the EPA, this should be more appropriately referred to as the '*cone of depression*' or the '*zone of influence*'. The alteration of the terminology has no material change to the overall report findings and conclusions. The EPA also concur that such a change is not a major issue in the context of the report

In order to eliminate any confusion the Final Hydrogeological Assessment Report, dated October 2006, is being re-issued (Re-issue January 2006). A full schedule of text amendments in the report re-issue is included at the front of the report for clarity.

Directors: D.A. Downes (Chairman) L.E. Waldron (Managing Director) M.F. Garrick R.F. Tobin J. Colleran B.J. Downes S. Finlay P.J. Fogarty D. Grehan J.P. Kelly B.M. Mulligan B. Murray C. O'Keeffe F. Renkema E.J. Harrigan (Company Secretary)

Associates: T. Cannon P. Cloonan T. Curran D. Downes B. Gaffney B. Gallagher B. Heaney B. Hutchinson D. Kennedy J. McCrea C. McGovern E. McPartlin

We again re-iterate that the amendment of terminology is not considered to have resulted in any material change to the overall report findings or conclusions. The amendments are made purely to avoid any potential confusion in the future. There is no alteration to the Appendices Report, therefore this has not been re-issued.

If you require any further clarification on this issue, please do not hesitate to contact me.

Yours faithfully,

Mark Conroy
Senior Hydrogeologist

Encl: Letter from EPA, dated 18/12/2006

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Regional Inspectorate, McCumiskey House
Richview, Clonskeagh Road, Dublin 14, Ireland
Cigireacht Réigiúnach, Teach Mhic Chumascaigh
Dea-Radharc, Bóthar Cluain Sceach
Baile Átha Cliath 14, Éire

T: +353 1 268 0100
F: +353 1 268 0199
E: info@epa.ie
W: www.epa.ie

Lo Call: 1890 33 55 99

Mr. Mark Conroy,
Tobin Consulting Engineers,
Block 10/3,
Blanchardstown Corporate Park,
Dublin 15

18th December 2006

Re: Report "Groundwater Monitoring of the Bog of the Ring" for Fingal County Council

Dear Mark,

I recently received a copy of the above report, which deals comprehensively with water level monitoring in the vicinity of the Bog of the Ring wells. I have a query about Figure No. 3, which shows the 'groundwater catchment boundary'. The 'catchment area' is also referred to in the 4th bulleted point on page 95. My impression is that this is meant to be the boundary of the 'zone of influence' or 'cone of depression' rather than the 'zone of contribution' or 'catchment boundary'. In the context of the objectives of the report, this is not a major issue. However, I would appreciate it if you would consider amending the figure and the text in case it causes confusion.

Yours sincerely,

Donal Daly,
Senior Scientific Officer
Hydrometric and Groundwater Section

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Regional Inspectorate, McCumiskey House
Richview, Clonskeagh Road, Dublin 14, Ireland
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Senior Scientific Officer
Hydrometric and Groundwater Section

Fingal County Council
Comhairle Contae Fhine Gall

Fingal County Council
Comhairle Contae Fhine Gall

FINGAL COUNTY COUNCIL
BOG OF THE RING

GROUNDWATER MONITORING OF THE BOG OF THE RING

FINAL HYDROGEOLOGICAL ASSESSMENT REPORT

October 2006

(Re-issued January 2007)

TES
CONSULTING ENGINEERS

Document Amendment Record

Client: Fingal County Council

Project: Bog of the Ring

Title: Final Hydrogeological Assessment Report

Project Number: 1207			**Document Ref:**		
5	Revision to Published Report	MC	MB	DG	05-01-2007
4	Issued to Client	MC	ST	DG	09/10/06
3 (Draft)	Amended/Client Review	MC	ST	DG	06/10/06
2 (Draft)	Amended/Client Review	MC	ST	DG	26/09/06
1(Draft)	Draft for Client Review	MC			19/09/06
Revision	**Purpose / Description**	**Originated**	**Checked**	**Authorised**	**Date**
		TES CONSULTING ENGINEERS			

TES CONSULTING ENGINEERS

SCHEDULE OF TEXT AMENDMENTS IN FINAL HYDROGEOLOGICAL ASSESSMENT REPORT (RE-ISSUE JANUARY 2007)

Item	Report Locator	Original Text	Amended Text
1	Page 88, 3rd Para	The land required to provide recharge to the aquifer……….	The land required (i.e. referred to as the ‘Cone of Depression’ or ‘Zone of Influence’) to provide recharge to the aquifer…….
2	Page 88, 3rd Para	The catchment area delineated by TES……….	The cone of depression delineated by TES…………
3	Page 88, 5th Para	However, the water level monitoring programme has determined a conflict in the catchment area delineated by the GSI.	However, the water level monitoring programme has determined a conflict in the catchment area delineated by the GSI and the cone of depression delineated by TES.
4	Page 88, 5th Para	The main difference in the catchment area delineated by TES and GSI results in the …...	The main difference in the cone of depression delineated by TES and the catchment area delineated by the GSI results in the ………
5	Page 88, 5th Para	Therefore the catchment boundary is somewhere in between these points.	Therefore the cone of depression boundary is somewhere in between these points.
6	Page 89, 1st Para	Therefore, it is submitted that the area to the east of the M1 should not be included in the catchment area of the abstraction scheme.	Therefore, it is submitted that the area to the east of the M1 should not be included in the cone of depression of the abstraction scheme.
7	Page 89, 3rd Para	The catchment area delineated by TES is generally consistent…..	The cone of depression delineated by TES is generally consistent…………
8	Page 89, 3rd Para	The catchment boundary to the north, south and west is generally consistent with the GSI boundaries.	The cone of depression boundary to the north, south and west is generally consistent with the GSI catchment boundaries.
9	Page 94, 4th Bullet Point	The catchment area delineated from the water level monitoring data…….	The extent of the cone of depression delineated from the water level monitoring data……
10	Page 94, 4th Bullet Point	The catchment area extends across the surface water catchment……	The cone of depression extends across a surface water catchment… .

11	Page 94, 4th Bullet Point	The catchment divide to the north and south are generally consistent……	The boundary of the cone of depression to the north and south are generally consistent……
12	Page 94, 5th Bullet Point	It is concluded that there is no significant scope for increasing abstraction from the Bog of the Ring aquifer without an unsustainable enlargement of the catchment area.	It is concluded that there is no significant scope for increasing abstraction from the Bog of the Ring aquifer without an unsustainable enlargement of the cone of depression.
13	Page 95, 3rd Bullet Point	The water level monitoring programme indicates that a sustainable supply is available from the Bog of the Ring aquifer (4,00cu.m/day +/- 15%)…….	The water level monitoring programme indicates that a sustainable supply is available from the Bog of the Ring aquifer (4,000cu.m/day +/- 15%)…..
14	Page 95, 4th Bullet Point	The catchment area delineated from the water level monitoring programme	The extent of the cone of depression delineated from the water level monitoring programme
15	Figure 3, Figure Title	DELINEATION OF CATCHMENT AREA	DELIENATION OF CONE OF DEPRESSION

Table of Contents

1 INTRODUCTION

TES Consulting Engineers were engaged by Fingal County Council in August 2004 to act as hydrogeological consultants for the Bog of the Ring Groundwater Abstraction Scheme.

Hydrogeological monitoring is required as the Bog of the Ring site has been designated as a proposed Natural Heritage Area by the National Parks and Wildlife Service (Department of Environment, Heritage and Local Government).

The terms of appointment for the hydrogeological monitoring are detailed below:

- The measurement of groundwater levels from the monitoring network within and adjacent to the Bog of the Ring on a fortnightly basis for a 2 year period.

- Assess the necessity for installing replacement and/or additional standpipes in the Bog area to ensure adequate coverage of monitoring, to allow determination of water levels.

- Based on the monitoring data, assess the impact of groundwater abstraction on the Bog.

- Based on the monitoring data and abstraction volumes from the scheme, assess the maximum sustainable yield of the aquifer. The maximum sustainable yield of the aquifer is both a factor of the geological ground conditions and the ecological sensitivity of the Bog of the Ring.

- Previous hydrogeological surveys of the monitoring network were to be used with recent surveys (i.e. from August 2004 to August 2006) for comparison purposes and to determine any trends.

- Details of meteorological conditions over the course of monitoring were be used to determine trends in rainfall over the monitoring period and provide data for possible explanation of possible reasons for water level fluctuations.

- Reporting of results, which comprised two separate aspects, namely;
  (a) A written quarterly report on the monitoring surveys (8 No. quarterly reports in total); and

  (b) A final hydrogeological assessment report to assess the maximum sustainable yield of the aquifer, without having detrimental effect on the bog.

To date, TES Consulting Engineers have adhered to the consultancy brief, by carrying out the following:

(a) Fortnightly monitoring has been conducted from mid-August 2004 through to mid-August 2006;

(b) The monitoring network has been assessed and 1 No. shallow standpipe has been replaced (Standpipe S7) and 3 No. shallow standpipes have been newly installed to augment the monitoring network to improve coverage across the designated area of the Bog (Standpipes S18, S19 and S20);

(c) Daily meteorological data has been collected over the two year period from Met Eireann from their synoptic climate station at Dublin Airport;

(d) Ecological surveys were undertaken in January and August 2006 and compared to previous ecological surveys of the Bog of the Ring to determine any changes in habitats, etc;

(e) 8 No. quarterly monitoring report have been submitted to Fingal County Council, as per appointment reporting criteria; and

(f) An interim hydrogeological assessment report was submitted to Fingal County Council in May 2006 to address the overall findings of the initial 15 months of monitoring data.

This report is prepared at the termination of the monitoring surveys and forms the final hydrogeological assessment report, as per appointment reporting criteria.

This report has been compiled to collate and address the following aspects pertaining the Bog of the Ring Groundwater Abstraction Scheme:

I. Site location, topography and natural setting;

II. Ecological assessment and impact assessment on the status of Bog of the Ring due to groundwater abstractions from the scheme;

III. Operation of the Bog of the Ring Groundwater Abstraction Scheme;

IV. Development, testing and current performance of the Bog of the Ring production boreholes;

V. Overview of meteorological conditions during the course of monitoring programme;

VI. Overview of existing groundwater monitoring dataset;

VII. Review of GSI Groundwater Protection Zones report, with specific reference to the geological and hydrogeological setting of the production boreholes;

VIII. Assessment of sustainability of supply from existing production borehole sources and assessment of the maximum sustainable yield from the overall aquifer; and

IX. Conclusions.

2 SITE LOCATION, TOPOGRAPHY AND NATURAL SETTING

The Bog of the Ring is located in north County Dublin. The Bog of the Ring, in relation to the surrounding environment, is shown on Figure 1. The site area is approximately 4km to the east of Naul and 5km to the southwest of Balbriggan. The M1 motorway carriageway encroaches on the eastern extremity of the designated area.

Bog of the Ring is the only freshwater marsh in the Dublin area and was considered in the 1970's to be of first rate importance as an educational area.

The topography of the area is dominated by hilly terrain and low lying valleys. Bog of the Ring is a freshwater marsh, covering approximately 56hectares. Ring Commons is situated in a low elevation, flat-lying valley, trending west-northwest to east-southeast, to an elevation within the range of 37m OD to 34m OD.

The land rises in elevation to the northeast and southwest of the valley, with maximum elevation to the southwest of 176m OD (Knockbrack Hill) and 73m OD to the northeast (Dermotstown).

The drainage pattern in this region is dominated by the topographic landform and the underlying glacial deposits. The topographic maps for the area show many streams emerging on the flanks of Knockbrack Hill (i.e. southwest of Bog of the Ring) and draining into the Bog of the Ring valley. The fall of the land within the Bog of the Ring is at very low gradient. The surface water channels draining through Bog of the Ring continue westwards towards the Matt River. Drainage channels from the northeast flank of the valley are noticeably lower. All such water channels drain to a main surface water channel flowing west to east through the centre of the Bog of the Ring and ultimately converging with the main Matt River.

The Bog of the Ring water supply scheme is operated by abstraction of groundwater from 4 No. production boreholes, which are located to the west of the M1 motorway. The 4 No. production boreholes are located within the townlands of Ring Commons and Killougher on the county road, which provides a link between the N1 (Dublin-Belfast National Primary road) to the R122 (Naul-Balbriggan Regional road). A collector main is aligned along this road to transmit the raw groundwater to a Water Treatment Plant situated immediately to the east of the M1 motorway at Decoy Bridge.

The position of the production boreholes and other monitoring locations are shown on Figure 2. Production boreholes PW2, PW3 and PW4 are located within or on the verge of the designated area. Production borehole PW5 is located approximately 1,050m to the northwest of the designated area, on slightly more elevated and freer draining ground conditions.

Bog of the Ring has been considered as an ecologically sensitive area since the 1970's as it was one of the few marshes remaining in County Dublin. An artificial drainage programme has been undertaken by the OPW across the surface water channels flowing through Bog of the Ring. This artificial drainage has significantly impacted the natural hydrology of the site. The construction of the M1 motorway has encroached onto the eastern verge of the designated area. Drainage along the motorway may impact on the hydrology of the designated area.

Land-use in this area is dominated by low intensity agricultural activity, principally dominated by grassland grazing. Grazing has been noted within the designated Bog of the Ring area during summer months. Residential ribbon development occurs along many of the country roads in the area. It is considered probable that, owing to the relative remoteness of the area, each of these houses is serviced by individual effluent treatment plants, ranging from old septic tanks and soakaways (for older residences) to proprietary treatment plants (for new domestic builds).

3 ECOLOGICAL STATUS OF BOG OF THE RING

The ecological importance of Bog of the Ring was noted in the 1970's, when the area was designated as an Area of Scientific Interest. At that time it was considered to be of regional importance on the basis that it was the only freshwater marsh in the Dublin area and was considered to be of first rate importance as an educational area. The Bog of the Ring is currently designated as a proposed Natural Heritage Area by the National Parks and Wildlife Service of the Department of Environment, Heritage and Local Government.

The current designation of Bog of the Ring is a proposed Natural Heritage Area (pNHA), under Wildlife (Amendment) Act 2000. Protection of such sites is a function of the relevant Local Authority. Each Local Authority must recognise the ecological value of such sites with respect to planning and licensing activities.

The site synopsis for Bog of the Ring (Site Code 1204) indicates that the site receives ecological status due to its wetland nature. The designated area is a flat, low-lying area with impeded drainage, showing signs of peat development in its upper horizons.

It should be noted that all site investigations undertaken, by TES and others, within the designated area of Bog of the Ring indicate the occurrence of an organic rich clay, with no peat material recorded.

The main watercourse flowing through Bog of the Ring is periodically dredged by the OPW. The dredging of the watercourse and the increased flow rates in the watercourse are considered to have significantly altered the natural hydrological setting of the designated site. In essence the hydrology has been impacted by improving the drainage of the land and thereby reducing the waterlogged ground conditions.

A detailed ecological survey was conducted in 1999 by Natural Environmental Consultants. This assessment was conducted to ascertain the ecological status of the wetland and to provide a baseline of the site prior to the commencement of groundwater abstraction from the Bog of the Ring well-field.

The ecological survey described the Bog of the Ring site as a linear depression with impeded drainage, which extends over 2km in length (east-west approx) and approximately 0.3km at its widest point. The substrate is an organic rich soil, which is waterlogged in places, but quite dry over much of the site.

Bog of the Ring comprises two blocks of waterlogged ground separated by slightly elevated ground. The adjacent land is predominantly agricultural and is comprised mainly of grassland with some tillage. Residential development has occurred in a ribbon fashion along the public road network on naturally or artificially raised platforms.

The ecological survey of the site (1999) undertook a study of vegetation types to evaluate the ecological significance of the site in 1999 relative to its status when designated in the 1970's. The ecological evaluation determined that the Bog of the Ring has been drying out in recent decades and was characterised as a marshy grassland rather than a marsh.

Many of the wetland plants indicated in the Site Synopsis (Ref.: 1204) have not been recorded at this site since the 1950's. The decline in rare plants was considered to be associated with artificial drainage and intensification of agricultural practices. The bird community is typical of farmland and marshy grassland. The natural hydrological regime of the area has been much disturbed by repeated dredging and drainage.

The ecological survey of 1999 concluded that the significance of the Bog of the Ring has declined as a result of drying out of the habitat and loss of rare wetland plant species. Bog of the Ring was evaluated as local significance in terms of ecological value.

In August 2004, Natura Environmental Consultants carried out a second habitat assessment and repeated the vegetation monitoring set up in 1999. The report concluded that the site had further dried out but that this could be down to a number of factors; short/long term climate change, local drainage and/or water abstraction. The report also stated that more positive management of the site would be required to maintain its local ecological importance (Natura Environmental Consultants, 2004).

The National Parks and Wildlife Service (previously Dúchas) has indicated that they are not opposed to the development of the aquifer for potable supply, subject to certain mitigation measures and monitoring being implemented. This hydrogeological monitoring programme is designed to ascertain if, and to what extent, the groundwater abstractions are impacting on the ecological status and significance of the Bog of the Ring area.

TES Consulting Engineers (2006) concluded that there was very little difference in the ecological status of the designated area from studies undertake in 1999 (pre abstraction) and 2006 (3 year after commencement of abstraction.)

There is very little difference in the types of habitat classification and their extent between the study carried out by Natural Environmental Consultants in 1999 and TES in 2006. The extent of 'Wet Grassland (GS4)' has remained relatively constant; on this basis the ecological status of the site is unchanged.

The hedgerow surveys indicate the findings of 1999 and 2006 are consistent, however it is noted that the hedgerows have received no management in the intervening years;

The detailed vegetation monitoring recorded a marginal change in some areas of the designated site from the 1999 survey to the 2006 survey. The change is attributed to lack of site management (i.e. lack of grazing and cutting) and some drying of land.

As the water level monitoring has concluded that the soil environment is rewetted rapidly following rainfall, it is concluded that the marginal drying is attributable to a very dry summer and/or the drainage improvement works undertaken by the OPW.

The full ecological report is included in Appendix A herein.

4 OPERATION OF BOG OF THE RING GROUNDWATER ABSTRACTION SCHEME

Fingal County Council operate the Bog of the Ring Groundwater Abstraction Scheme as a pilot scheme. Groundwater abstractions for the scheme commenced in July 2003. In order for the scheme to be permitted on a full time basis, a long-term assessment needs to be conducted to assess the impact of groundwater abstractions on the proposed Natural Heritage Area.

The operation of the Bog of the Ring groundwater abstraction scheme is required to augment the potable water supply to the north of County Dublin from the main source at Leixlip Water Treatment Works, operated by Fingal County Council.

Hydrogeological studies undertaken periodically from 1984 to 2000 within and in the environs of Bog of the Ring indicated that hydrogeological potential existed for the development of a groundwater abstraction scheme.

The studies indicated that the development of an abstraction scheme for approximately 4,500cu.m/day was feasible in the short term. The longer term viability of the scheme was dependent on interpretation of hydrogeological data to determine that no significant impacts on the ecological status of the designated area occurred.

The installation of the existing monitoring network of trial boreholes, observation borehole, standpipes and production boreholes has been progressive since studies began in the Bog of the Ring area in 1984. The function of the monitoring network was to determine the hydrogeological productivity of the aquifer underlying Bog of the Ring and also ascertain potential impacts on water levels within the designated area due to groundwater abstraction.

EPS Ltd. designed and constructed the scheme in accordance with specifications. As detailed, the pilot scheme commenced operation in July 2003.The plant was taken in charge by Fingal County Council in November 2004.

Groundwater is abstracted from 4 No. production boreholes and is conveyed to the treatment worksite, which is located immediately adjacent to the M1 motorway at Decoy Bridge. The current capacity of the treatment plant is approximately 4,080cu.m/day (4.08 Mega litres per day).

The raw groundwater is generally of a high natural quality, however levels of Iron and Manganese are in excess of statutory limits for potable water, in line with S.I. 439 of

2000 (Drinking Water Regulation).

Upon transmittal to the treatment plant, the raw groundwater is initially aerated and chlorinated within the treatment works, to oxidise the dissolved metals out of solution. The water is then passed though pressure filters, which captures the oxidised metal particles. The water is then suitably chlorinated and fluoridated to ensure sterilisation before being pumped to Jordanstown Reservoir for supply to the water main distribution network.

The plant is operated by two on-site personnel using a SCADA (Supervisory Control and Data Acquisition) system. The SCADA system controls the pumping regime within the plant. Abstraction rates and water levels in the Production Boreholes are continuously monitored and recorded. Water levels in the clear water tank are monitored and relayed to the SCADA system. This SCADA system then increases or decreases the pumping regime, based on the head of water in the clearwater tank. The plant is continuously monitored, to ensure the quality of water leaving the plant meets the requirements of the drinking water regulations.

The operation of the groundwater abstraction scheme from July 2003 to the present (August 2006) can be viewed as a sustained pump test and presents a more complete hydrogeological dataset to assess the sustainability of supplies from the scheme. The sustainability assessment is directed at establishing the steady state (equilibrium) conditions and to confirm, or otherwise amend, the preliminary findings reached during the initial testing of the production boreholes in 2000.

The combined groundwater abstraction from the 4 No. operational production boreholes are shown on Figure 4.1 below. The data presented is based on average daily abstraction rates from the 4 No. individual Production Boreholes. The abstraction rates are recorded on the SCADA system as abstraction in cubic metres per hour. This has been converted to abstraction in cubic metres per day for ease of representation. Abstraction data from the scheme is available from mid October 2003 onwards. The abstraction volume of the scheme has varied since the commencement of operations.

The Water Treatment Works are designed for a maximum capacity of 4,080cu.m/day of treated water to the distribution network. A maximum of approximately 4,100-4,200cu.m/day of raw water is required to output 4,080cu.m/day of treated water.

The combined abstraction during the initial operational period was variable from October 2003 through to December 2003, as commissioning and adjustments were being made. The total daily abstraction during this period was generally 3,500-4,250cu.m/day.

From 19/11/03 to 23/03/04 the pumping rates were maintained relatively constant. The average daily groundwater abstraction volume of approximately 2,500cu.m/day.

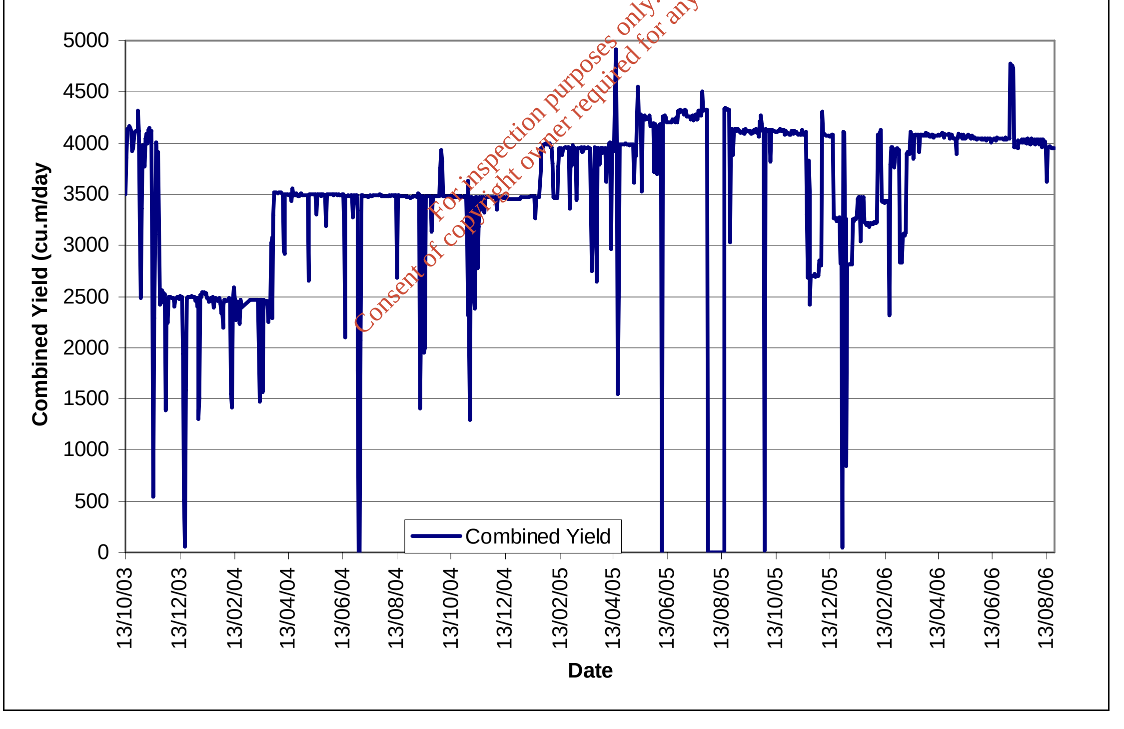
From 23/03/04 to 20/01/05 the pump rate was increased and maintained relatively constant, at an abstraction rate of 3,500cu.m/day.

From 20/01/05 to 10/05/05 the pump rate was again increased and maintained relatively constant, at an abstraction rate of 4,000cu.m/day.

From 10/05/05 to 21/08/05 the pump rate was increased slightly to an abstraction rate within the range 4,100-4,250cu.m/day.

From 21/08/05 to 15/11/05 the pump rate was maintained at a relatively steady abstraction rate of 4,100cu.m/day.

Figure 4.1: Combined Groundwater Abstraction from Bog of the Ring Scheme



From 15/11/05 to 15/03/06 the pump rate varied significantly. The variation during this period is reportedly largely dependent on temporary reductions in abstraction due to a variety of reasons, including reduced demand and operational problems/failures within the treatment plant and production boreholes.

From 15/03/06 to present (end August 2006) the abstraction volume has been maintained at a relatively constant abstraction rate of 4,000-4,100cu.m/day.

The Bog of the Ring Groundwater Abstraction Scheme has reached occasions of operating at the maximum design capacity of the treatment works. The existing 4 No. production boreholes have been capable of abstracting sufficient volumes of raw groundwater to facilitate the treatment plant to operate at maximum design capacity.

The volume of groundwater abstracted from each individual production borehole varies. The maximum sustainable abstraction from individual production boreholes is assessed within this report, using available data.

All available production boreholes (i.e. PW2, PW3, PW4 and PW5) are currently in operation.

5 HYDROGEOLOGICAL DEVELOPMENT AND CHARACTERISTICS OF BOG OF THE RING GROUNDWATER ABSTRACTION BOREHOLES

5.1 Introduction

Hydrogeological investigations in the North Dublin area commenced in 1984.

The initial stage of investigation in 1984 was based on a desk study of available hydrogeological information and a limited programme of trial well drilling (5 No. boreholes drilled, boreholes TW1 to TW5 inclusive). This preliminary investigation identified two important aquifer units in the region, namely:

- The Balbriggan Volcanics; and
- The Bog of the Ring Limestones.

A second stage of the hydrogeological investigation was undertaken in 1993 and was directed at delineating the productivity of the limestone unit at Bog of the Ring. The investigation was focused on establishing the extent of the productive limestone aquifer and whether this high aquifer productivity was related to a major east-west fault zone or the geology of the Carboniferous syncline. In this phase of investigation 9 No. trial boreholes were drilled (TW6 to TW14 inclusive). Hydraulic testing was conducted on a number of the boreholes to determine the hydrogeological characteristics and productivity of the aquifer.

The third stage of the hydrogeological investigation was undertaken in 2000 and focused on the drilling and testing of production boreholes. The aim of this investigation was to drill production boreholes at, or close to, trial boreholes of proven aquifer potential, in order to source high quality groundwater to augment potable water supplies in North Dublin. In total, 5 No. production boreholes were drilled (PW1 to PW5 inclusive). The pump test programme for each of the production boreholes was designed to provide hydraulic data to enable specification of submersible pump capacities. This hydraulic data was required for inclusion on the tender documents for the 'Design and Build' Contract for the pilot treatment plant and ancillary infrastructure. The yields at which the pump tests were conducted is not an estimation of the sustainable yields available at each abstraction point, as longer term pumping is required to establish such rates.

The geological and hydrogeological data provided below for each of the Production Boreholes was obtained from reports available from Fingal County Council, relating to the various phases of investigation. Appendix B contains logs for all production boreholes and available trial boreholes.

The data collected by TES Consulting Engineers, together with data from the Bog of the Ring SCADA system, was also assessed. The purpose of this assessment was to address a number of aspects relating to the scheme, to include:

1. To determine the current hydraulic performance and efficiency of each individual borehole;
2. To compare the current efficiency to the initial estimations of the 2000 testing project;
3. To assess the trends in the abstraction rates and water levels for each Production Borehole from available data;
4. To estimate the maximum sustainable yield for each of the Production Boreholes; and
5. To examine the potential of the Bog of the Ring Aquifer and assess the possibility of expanding the scheme.

5.2 Rectification of Water Level Data

The SCADA system installed within the Bog of the Ring treatment plant has been an important aspect is monitoring programme. The water level response relative to the abstraction volume is required to assess the current performance of the scheme and to investigate any trends in the aquifer condition over time.

The SCADA system has provided an almost continuous recording of the abstraction rate from each of the operational borehole from 13th October 2003 to the end of the monitoring programme in mid August 2006. Probes in the production borehole have also provided almost continuous record on the water level in each production borehole from 1st May 2004 to the end of monitoring in mid August 2006.

A malfunction was noted in recording on the SCADA system for PW2 from the 28th August 2005 to 3rd December 2005. The malfunction related to the water level monitoring probe. During the programme of remediation an anomaly was detected in the water level recordings of the SCADA system. The SCADA system was supposed to record the water levels as the level relative to mOD. However, during the investigation this was found not to be the case. The probes record the height of water above the level of the probe.

In order to rectify the levels to a fixed level, the water level was physically measured in each of the production boreholes on the 14th August 2006 (PW2, PW3 and PW4) and 28th August 2006 (PW5) and reduced to Ordnance Datum (Malin Head). Also, the water levels for each of the production boreholes at the exact date and time of the physical readings were noted from the SCADA system. Thereafter, all SCADA readings for the production boreholes were rectified to record the water level relative to Ordnance Datum.

The following table indicates the difference between the physical readings recorded on the 14th and 28th August 2006.

Table 5.1: Rectification of SCADA Readings to Ordnance Datum (mOD Malin Head)

Borehole I.D.	Ground Level (Malin Head) at Well-Head	Water Level (m bgl)	Reduced Water Level (Malin Head)	SCADA Recording	Correction factor to rectify SCADA to mOD (Malin Head)
PW2*	34.26mOD	21.58m bgl	12.68m OD	40.05	-27.37m
PW3	35.61mOD	25.86m bgl	9.75m OD	13.2	-3.45m
PW4	37.19mOD	25.48m bgl	11.71m OD	9.35	+2.36m
PW5	55.08mOD	35.36m bgl	19.72m OD	20.11	-0.39m

Note: Not possible to rectify levels prior to 4th December 2005 as the probe height was changed and there are no physical measurements to calibrate these earlier readings.

The probe level is at a fixed height in PW3, PW4 and PW5 throughout the monitoring period. However the corrective measures undertaken on PW2 to fix the water level probe changed the level in November 2005. It is not possible to establish the corrected water level in PW2 from 1st May 2004 through to 3rd December 2005, however from 4th December 2005 onwards the water level in PW2 can be established relative to Ordnance Datum Malin Head.

All assessments undertaken on Bog of the Ring since the commencement of operation of the treatment plant have assumed that the SCADA system was displaying the water relative to Ordnance Datum, as this is what the output indicated. Had it not been for the failure of the probe in PW2, this assumption would have continued. The correction factor has been applied to all water levels discussed further herein (where possible).

It should be noted that while the water levels have been rectified to Ordnance Datum, the SCADA system has recorded the water level to metres above the fixed probe, therefore all trends are considered reliable and usable data can be interpreted from this information.

5.3 Production Borehole PW1

Background Geological and Hydrogeological Setting

A production borehole (PW1) was drilled in the environs of Decoy Bridge (National Grid Ref: E318635, N260140), based on favourable aquifer conditions encountered during the drilling of trial borehole TW8, drilled in 1993.

Available information indicates that borehole TW8 encountered silty stoney clay from the surface to a depth of 13.5m bgl. Coarse sand and gravel was encountered from 13.5m bgl to 20m bgl. Bedrock comprised a limestone conglomerate, which was significantly fractured and fissured. In order to support the boreholes walls during overburden drilling, 250mm diameter steel casing was installed to a depth of 21m bgl. Owing to the broken and unstable nature of the upper bedrock zone, 200mm diameter steel casing was placed to a depth of 24m bgl. Drilling then continued 'open-hole' to a depth of 38m bgl. Drilling terminated at 38m bgl due to the unstable nature of the bedrock and the ingress of material from a fissure at 30m bgl.

Groundwater encountered in trial borehole TW8 was artesian and was overflowing at a rate of approximately 50cu.m/day. The confining pressure (i.e. artesian head) of this borehole was not ascertained.

A 72 hour pump test was conducted on trial borehole TW8 (1994). The abstraction volume during the test was set initially at 1,080cu.m/day, which reduced to 979cu.m/day at the end of the test, due to the increased hydraulic head. The final drawdown at the termination of the test was measured as 27.74m. The specific capacity of this borehole, based on the pump test data, was calculated as 35.3cu.m/day/m, indicating that the borehole would be rated as a Class II (second highest rating) borehole, as per GSI well productivity classification system (Ref. Appendix C).

It was not possible to drill production borehole PW1 at the exact location of trial borehole TW8, as this borehole was positioned along the alignment of the M1 motorway. Trial borehole TW8 was decommissioned during its construction. The position of production PW1 was as close as practicable to the original location of TW8.

During the 2000 drilling programme, a borehole was drilled within the compound of the Water Treatment Plant, close to the stream at Decoy Bridge. However, records indicate that the geological material encountered in this borehole was significantly different to the strata recorded in TW8. Drilling records indicate that potential yield from the borehole drilled within the compound was considerably less than anticipated, therefore the decision was reached to drill a borehole closer to the original location of trial borehole TW8.

Production Borehole PW1 was drilled approximately 30m to the south of the Water Treatment Plant. During drilling approximately 9.1m of undefined fill material was encountered. Black boulder clay was recorded from 9.1m to 15.25m bgl. A clayey gravel was recorded from 15.25m to 36.6m bgl. Soft, brown discoloured, weathered bedrock was noted from 36.6m to 42.7m bgl. Solid grey limestone was recorded from 42.7m to 75m bgl, at which point drilling was terminated.

Major groundwater inflows were recorded during the drilling within the intervals 17m to 19m bgl and from 38m to 39.5m bgl.

The production borehole was retrofitted with 46m (73m to 27m bgl) of 250mm diameter Johnson stainless steel well screen (3mm slot size), with 27m (29m to 0m bgl) of 250mm Demco casing riser. The annulus between the wellscreen and the borehole wall was filled with silica gravel. The 400mm borehole steel lining was pulled back from 43m to 27m bgl to allow ingress of groundwater from the clayey gravel. The yield from production borehole PW1 was estimated at 654cu.m/day. A visible evidence of sand was noted in the groundwater expelled from the borehole, during development works. Although groundwater within TW8 was artesian, the static water level in PW1 was 5.74m bgl. The water level within production borehole PW1 may have been influenced by excavations during the construction of the M1 motorway.

Initial Hydraulic Testing Programme (2000)

Following the drilling of PW1, a hydraulic testing programme was undertaken. Initially a 24 hour individual pump test was undertaken. The test was undertaken at a constant abstraction rate of 1,057cu.m/day, which resulted in a drawdown of 33.59m bgl. Steady state (equilibrium) conditions were not achieved by the end of the 24 hour test. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 31.5cu.m/day/m.

A 7 day continuous pump test was undertaken on PW1, PW2 and PW3 simultaneously. The abstraction rate from PW1 was 1,218cu.m/day for the duration of the test. Again records indicate that steady state conditions were not achieved by the end of the 7 day pump test. However, the rate of drawdown was increasing at very small increments by the end of the test. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 32.4cu.m/day/m.

Based on the hydraulic information gathered from the pump tests, production borehole PW1 would be rated as a Class II (mid range) productive borehole, which is the second highest borehole productivity rating as per the GSI classification system (Ref.: Appendix C). It was recommended that this borehole have a submersible pump installed to the base of the borehole and should be capable of a sustained surface output of 1,000cu.m/day.

Operational Difficulties with PW1

Owing to continual ingress of sand and gravel into the production borehole standpipe during the early stages of abstraction scheme, it was deemed that continued pumping was not sustainable. No further pumping or remedial works have been undertaken since 2000.

A literature review was undertaken to examine the problems arising in PW1, with respect to possible explanations for the ingress of sand and gravel. Production Borehole PW1 was drilled though a series of boulder clays and clayey gravel prior to encountering bedrock. Drilling was terminated at approximately 75m bgl, (i.e. 38.4m into rock). The estimated groundwater yield in the bedrock was approximately 650cu.m/day. In an attempt to maximise the yield from this borehole, the steel casing was pulled-back to expose the clayey gravel subsoil. While additional groundwater inflows were enabled by this action, it is probably that the ingress of sand and gravel resulted due to the exposure of the subsoil. The quality of the raw groundwater from PW1 was significantly impacted by the ingress of material and precluded further usage of this borehole as an abstraction source for the scheme.

Summary

Production Borehole PW1 was drilled in 2000, as a result of encountering favourable aquifer conditions in borehole TW8 during the 1993 investigation programme.

The site investigations in the vicinity of PW1 suggest a difference in the geology in this area compared to conditions encountered further to the west (i.e. in the Bog of the Ring area).

Hydraulic testing of PW1 in 2000 indicated that an abstraction rate of 1,218cu.m/day was capable for a 7 day period. Based on the data retrieved during the hydraulic testing programme, PW1 would be rated as a Class II (mid range) Productive Borehole.

Continual ingress of sand and gravel was noted into the PW1 during the early stages of operation of the Bog of the Ring Abstraction Scheme. Pumping from this borehole was ceased in order to maintain the high quality of the raw groundwater from the other production borehole sources.

Table 5.2 below provides a summary of the hydrogeological characteristics of the aquifer in the environs of Production Borehole PW1.

Table 5.2: Hydrogeological Characteristics of Aquifer in environs of PW1

BH I.D.	Geological Strata	Hydraulic Test Duration	Abstraction Rate	Specific Capacity	GSI Borehole Productivity Classification
TW8	0-13.5m Silty, stoney clay 13.5-20m Sand and gravel 20-38m Limestone	72 hour (1993)	1080cu.m/day reducing to 979cu.m/day	35.3 cu.m/day/m	Class II
PW1	0-9.1m Undefined fill 9.1-15.25m Boulder clay 15.25-36.6m Clayey gravel 36.6-42.7m Weathered Limestone 42.7-75m Grey Limestone	24 hour (2000)	1057cu.m/day	31.5 cu.m/day/m	Class II
PW1	As above	7-day (2000)	1218 cu.m/day	32.4 cu.m/day/m	Class II

5.4 Production Borehole PW2

Background Geological and Hydrogeological Setting

It was decided to drill a production borehole on the road verge at the junction with road to Balrickard, within the designated pNHA area. The location of this production borehole was based on favourable aquifer conditions encountered during the drilling of trial borehole TW4.

Available information indicates that borehole TW4 was drilled and lined through the overburden (Boulder Clay) to a depth of 15.5m bgl, i.e. socketed into rock to a depth of 1.5m. The borehole was drilled 'open-hole' through bedrock. Groundwater inflows were recorded at depths of 27m bgl and 65m bgl. Drilling was terminated at 65m bgl.

Trial borehole TW4 was pump tested for 72 hours (1994) at a yield of 1,080cu.m/day. The safe yield from borehole TW4 was estimated as 2,000cu.m/day.

Production borehole PW2 was drilled in the summer of 2000 close to the site of trial borehole TW4. Blue sticky boulder clay was recorded from 0m to 9.1m bgl, which is underlain by clayey gravel from 9.1m to 13.4m bgl. Drilling continued through bedrock from 13.4m to the termination depth of the borehole at 79.3m bgl. Bedrock is described as dark grey limestone, with shaley limestone at certain intervals. Some weathered cavernous limestone horizons were noted during drilling at intervals from 42.7m to 54m bgl and from 66m to 67.5m bgl.

Significant groundwater inflows were associated with these weathered zones. Groundwater encountered in production borehole PW2 is artesian and was overflowing at the surface. The confining pressure of this borehole was not ascertained.

Following drilling, the PW2 borehole wall collapsed and infilled from 79.3m to 52m bgl, due to unstable rock conditions in the borehole wall. The borehole was retrofitted with 36m (52m to 16m bgl) of 250mm diameter Johnson stainless steel well screen (3mm slot size), with 16m (16m to 0m bgl) of 250mm Deco casing riser. The annulus between the well screen and the borehole wall was filled with silica gravel.

Initial Hydraulic Testing Programme (2000)

Following the drilling of PW2, a hydraulic testing programme was undertaken. Initially a 24-hour individual pump test was undertaken. The test was undertaken at a constant abstraction rate of 2,631cu.m/day, which resulted in a drawdown of 9.42m bgl. Steady state (equilibrium) conditions were not achieved by the end of the test. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 284.6cu.m/day/m.

A 7 day continuous pump test was undertaken on PW1, PW2 and PW3 simultaneously. The abstraction rate from PW2 was approximately 2720cu.m/day for the duration of the test. Steady state (equilibrium) conditions were not achieved by the end of the 7 day pump test. Based on the hydraulic information gathered, the specific capacity of this borehole is calculated as 155.6cu.m/day/m.

Based on the hydraulic information gathered from the pump tests, production borehole PW2 would be rated as a Class I (lower range) productive borehole, which is the highest borehole productivity rating as per the GSI classification system (Ref.: Appendix C). It was recommended that this borehole have a submersible pump installed to the base of the borehole and should be capable of a sustained surface output of 2500cu.m/day.

Operational Pumping from July 2003 to August 2006

Pumping from production borehole PW2 has been ongoing from July 2003 to the present.

Figure 5.1 and Figure 5.2 below shows the abstraction rate and water level in the production borehole. Figure 5.1 shows the abstraction rate and the water level based on telemetric data collected by Fingal County Council at the Water Treatment Plant from 1st May 2004 through to November 2005. It is not possible to rectify this data to the corrected Ordnance Datum, as it is not possible to establish the level of the probe prior to corrective action was undertaken. Figure 5.2 shows the abstraction rate and the rectified water level relative to Ordnance Datum Malin Head from November 2005 to the end of monitoring in August 2006.

Figure 5.1: Water Abstraction and Water Level from PW2 based on SCADA Records

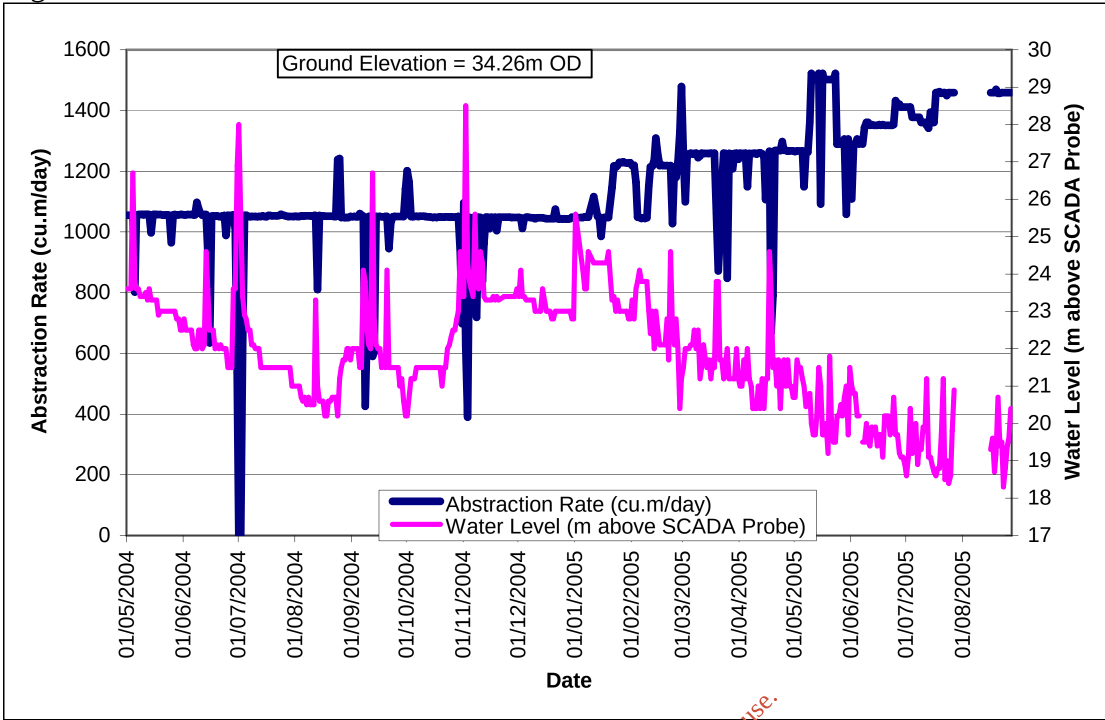
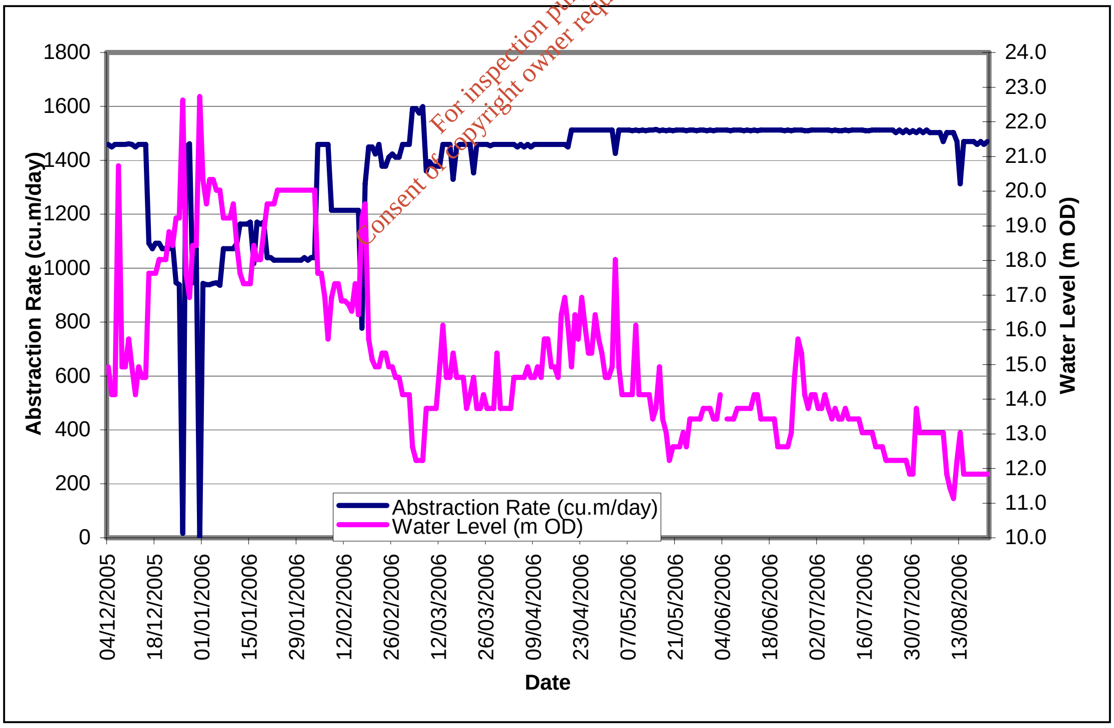


Figure 5.2: Water Abstraction and Water Level from PW2 (Water Level corrected to mOD Malin Head)



It is acknowledged that there are some isolated deviations from the norm, however if these isolated deviations are discounted, the normal trends are more apparent.

From 1st May 2004 to 19th January 2005, the abstraction rate from PW2 was maintained at a relatively constant rate of 1,055cu.m/day. The water level during this period varied, with a recession observed during summer months and a recovery in water levels through the winter period. The water level in January 2005 was at, or above the water level in May 2004.

From 19th January to 9th May 2005, the abstraction rate was increased from 1,055cu.m/day to 1,227cu.m/day (up to 27th February) and then up to 1,258cu.m/day. The water level in the borehole fell to compensate for the increased abstraction, however the rate of fall was quite small. A recession in water levels would have occurred during this period in any event, due to reduction in recharge.

From 9th May to 7th June 2005, TES varied abstraction rates on a weekly basis to test the potential of each of the boreholes. The variation in abstraction rates during this period resulted in compensatory variations in the water level during this period.

From the 8th June to 24th July 2005, the abstraction rate from PW2 was maintained at 1,351cu.m/day. The abstraction rate was then increased from 25th July 2005 to the 15th December 2005 (with exception from 16th November-2nd December when the borehole was not operational) to 1,459cu.m/day.

The abstraction rate varied significantly from the 16th December 2005 through to 3rd February 2006, with the average daily abstraction rate varying between 936-1165cu.m/day.

The abstraction rate was increased to an almost steady rate of 1,459cu.m/day from 3rd February 2006 to mid August 2006.

The water level in PW2 declines during summer months and recovers during winter months.. There are a number of periods with interruptions in the dataset, which are detailed below:

- From the 28th July to 15th August 2005 (inclusive), the Bog of the Ring was operational however due to a fault with the SCADA information relating to abstractions and water level was not recorded;
- From the 28th August to 16th November 2005 (inclusive), abstractions from PW2 were recorded by the SCADA system, however the water level in PW2 was not recorded owing to a fault in a probe; and

- From the 16th November to 2nd December 2005 (inclusive), PW2 was not operational when remedial works were undertaken.

Figure 5.1 shows the water level (relative to the standing water above the level of the probe from May 2004 through to end August 2005). The water levels data shows a decline in water levels from May 2004 through to August 2004. There is a recovery in water levels from September 2004 through to February 2005. The data shows a progressive decline in water level from February 2005 to end of August 2005. This decline is attributed to seasonal factors and also compensation for increasing abstraction rates.

The corrected water levels relative to Ordnance Datum Malin Head are shown on Figure 5.2. The abstraction rate has been maintained at a relative steady abstraction rate of 1460cu.m/day from mid-February to August 2006. While there was an initial fall in water levels when the abstraction rate was increased in February 2006, the water levels recovered through to late April/early May, coinciding with periods of high rainfall and low evapotranspiration. Thereafter, during the summer months, the water level has declined by approximately 4m due to low recharge to the aquifer.

Overall, the available water level data indicates that on an annual cycle the aquifer in the environs of PW2 is recharged during winter months, with recovery in water levels noted during winter months and recessions in water levels during summer months. Over the two year monitoring period the water levels shows a very minor progressive decline. The change in the water level probe in November 2005 has resulted in an alteration in the datum, however this has been rectified as much as possible by obtaining actual water level readings from the production boreholes.

The slight progressive decline in water levels is attributed to two main factors. The progressive increase in abstraction rate has resulted in a compensatory increase in water level decline. With each increase in abstraction rate the cone of depression increases until equilibrium conditions are achieved, whereby cone of depression expands to provide adequate catchment area to replenish the volume of groundwater abstracted. The second main factor in the slight progressive drawdown is considered to result from a slight fall in the hydraulic efficiency of the borehole. Over time the slot intake in the production borehole casing can become encrusted due to mineralization.

The submersible pump in production borehole PW2 has been installed to a depth of approximately 60m bgl. The current water level (August 2006) in the production borehole is recorded at approximately 22m bgl. Therefore there is no threat to the continued viability of this production borehole in the short to medium term.

Hydraulic Testing Programme (2005)

A hydraulic testing programme was undertaken between 9th May 2005 and 7th June 2005. During this 4 week period, 4 No. different abstraction arrangements were programmed, as detailed in Table 5.3 below. The abstraction rate variations were made during normal operation of the Bog of the Ring Scheme and at all times the combined abstraction volume to the treatment works was maintained.

Table 5.3: Abstraction rates maintained during hydraulic testing programme 2005

Date	**Abstraction Rate PW2**	Abstraction Rate PW3	Abstraction Rate PW4	Abstraction Rate PW5
Pre 09th May 2005	**1356cu.m/day**	1356cu.m/day	240cu.m/day	1226cu.m/day
09th to 16th May 2005	**1512cu.m/day**	1512cu.m/day	336cu.m/day	900cu.m/day
16th to 23rd May 2005	**1512cu.m/day**	1512cu.m/day	240cu.m/day	996cu.m/day
23rd to 30th May 2005	**1344cu.m/day**	1344cu.m/day	240cu.m/day	1344cu.m/day
30th May to 07th June 2005	**1260cu.m/day**	1260cu.m/day	240cu.m/day	1500cu.m/day
Post 07th June 2005	**1356cu.m/day**	1356cu.m/day	240cu.m/day	1308cu.m/day

The purpose of this testing programme was as follows:

- to re-evaluate the aquifer characteristics and compare to the initial results determined in 2000;
- to ascertain the sustainability of supplies and to determine if there is any spare capacity available to augment supplies;
- to evaluate if abstraction rates could be increased in the short term to compensate for temporary deficiencies in the overall supply (i.e. in the event of failure of any of the other in-service Production Boreholes.

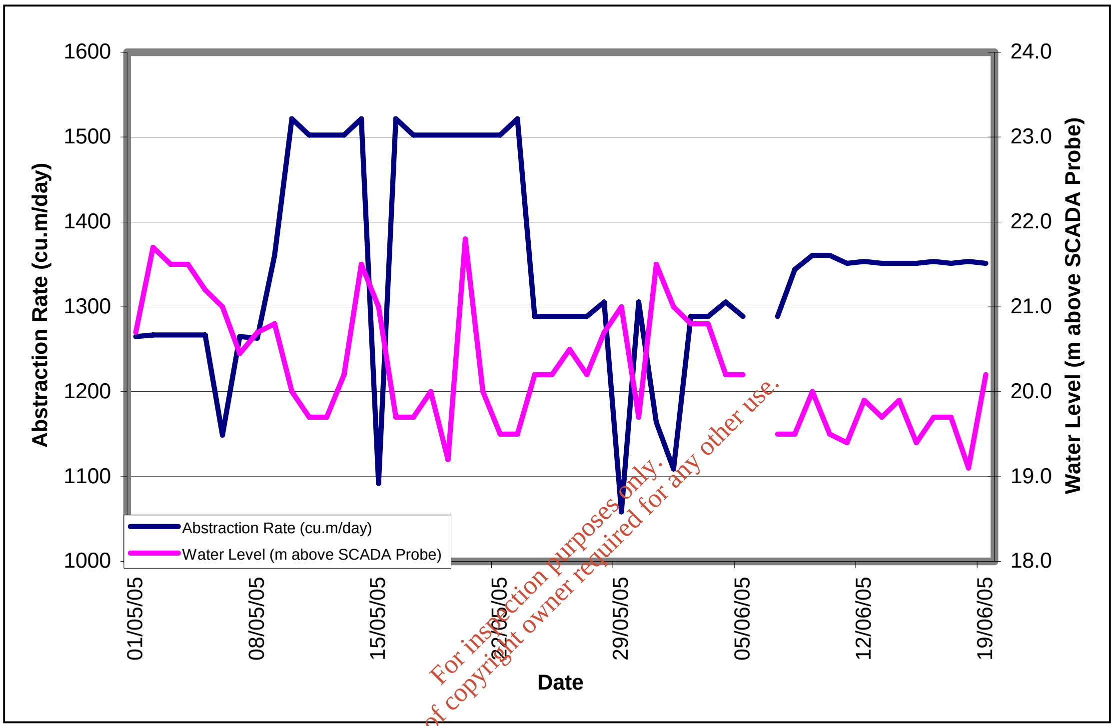
The protocol for the test was to vary abstraction rates for a period of 7-day, to determine the impact of such variations on water levels, etc.

With specific reference to Production Borehole PW2, the following relates to the pumping regime prior to, during and after the hydraulic test programme.

The abstraction rate prior to the commencement of the test was maintained at approximately 1356cu.m/day (56.5cu.m/hour). The water level fluctuated within the range of 1m (20.6 to 21.6m OD) during this period. When the abstraction rate was increased to 1512cu.m/day from the 9th May to the 23rd May 2005 the water level decreased to a consistent water level.

When the abstraction rate was reduced to 1344cu.m/day (23rd May to 30th May) and then to 1260cu.m/day (30th May to 7th June), the water level recovered, however it did not recover to pre-test levels. Upon completion of the test the abstraction rate was reset to 1356cu.m/day.

Figure 5.3: Abstraction rate and water level during testing programme of PW2



During summer months, the recharge to the aquifer can be considered to be practically zero, therefore the consistency in the water levels suggest that the bedrock aquifer is being replenished from the overlying saturated gravel deposit.

Current Hydraulic Efficiency of PW2

In order to evaluate the operating efficiency of borehole PW2, water yield and water levels have been obtained for August 2006. It is not possible to use the data for summer 2004 or 2005 as it is not possible to estimate the drawdown in the well as the exact level of the water level probe is unknown during this period. The data for August 2006 is compared to the data obtained from the original hydraulic test programme undertaken in 2000. This data is provided in Table 5.4 below.

Table 5.4: Hydraulic Efficiency of PW2

Date	Yield	Drawdown	Specific Capacity	Efficiency
2000	2720cu.m/day	17.5m	155.6cu.m/day/m	100%
Aug 2006	1512cu.m/day	21.23	71.22cu.m/day/m	45.8%

Based on the hydraulic information obtained for 1st August 2006, production borehole PW2 is rated as a Class I (lower range)/Class II (upper range) productive borehole (i.e. highest to second highest borehole productivity rating as per the GSI classification system, Ref.: Appendix C).

Comparison of the specific capacity determined in 2000, following the 7 day pump test and the specific capacity determined from data collected in August 2006, following 3 years of almost continuous pumping, indicates a reduction in the operating hydraulic efficiency. The operating hydraulic efficiency, based on calculated specific capacities, has reduced by approximately 54.2%, when compared to the original hydraulic data.

It can reasonably be expected that the hydraulic characteristics estimated from a pump test of relatively short duration (2000) overestimated the potential yield from the aquifer. The reduction in efficiency is mainly attributed to the reduction on the volume of groundwater stored in the aquifer. During the 2000 pump tests, the aquifer storage would have provided water to the borehole. With continued pumping from the scheme the aquifer storage has been gradually depleted and the cone of depression has increased in extent.

Recharge to the aquifer in this area is considered to be practically zero during summer months, therefore the performance of this borehole during the test and the relative consistency of the water levels suggests that the bedrock aquifer is replenished from the saturated gravels during summer months.

The current yield from the aquifer is largely dictated by available recharge from the catchment area.

The results of the hydraulic testing programme and the longer term data indicate that the sustainable yield of PW2 is 1,500cu.m/day.

Summary

Production Borehole PW2 was drilled in 2000, as a result of encountering favourable aquifer conditions in borehole TW4 during the 1993 investigation programme.

Hydraulic testing of PW2 in 2000 indicated that an abstraction rate of 2,720cu.m/day was capable for a 7 day period. Based on the data retrieved during the hydraulic testing programme, PW1 would be rated as a Class I (lower range) Productive Borehole.

Pumping from PW2 has been ongoing from 2003 to present. Abstraction rates have been progressively increased to a current abstraction rate of approximately 1,500cu.m/day. Available data to date indicate that Production Borehole PW2 is capable of a yield of 1,500cu.m/day.

Table 5.5 below provides a summary of the hydrogeological characteristics of the aquifer in the environs of Production Borehole PW2.

Table 5.5: Hydrogeological Characteristics of Aquifer in environs of PW2

BH I.D.	Geological Strata	Hydraulic Test Duration	Abstraction Rate	Specific Capacity	GSI Borehole Productivity Classificatio
TW4	0-15.5m Overburden 15.5-65m Limestone	72 hour (1993)	1080cu.m/day		
PW2	0-9.1m Boulder clay 9.1-13.4m Clayey gravel 13.4-79.3m Limestone	24 hour (2000)	2631cu.m/day	284.6 cu.m/day/m	Class I
PW2	As above	7-day (2000)	2720cu.m/day	155.6 cu.m/day/m	Class I
PW2		Aug (2006)	1512cu.m/day	71.22 cu.m/day/m	Class I/ ClassII

The data indicates that the operating hydraulic efficiency of the borehole has declined by approximately 54.2%. The borehole is still classified as a Class I/Class II productive borehole.

The sustainable yield from Production borehole PW2 is estimated to be 1,500cu.m/day.

5.4 Production Borehole PW3

Background Geological and Hydrogeological Setting

A production borehole was drilled on the road verge at the junction with road to Curragh Bridge, within the designated pNHA area. The location of this production borehole was based on favourable aquifer conditions encountered during the drilling of trial borehole TW11.

Available information indicates that borehole TW11 was drilled and lined (with 250mm diameter steel casing) through the overburden. The overburden comprised of organic rich clay and grey clay to a depth of 10m bgl, with sand and gravel recorded from 10m bgl to 17m bgl. The borehole was drilled 'open-hole' through bedrock, which comprised of black shaley limestone, to a finished depth of 61m bgl. Groundwater inflows were recorded at depth with the interval of 10m bgl to 17m bgl (within the sand and gravel) and at 32.5m bgl, 45m bgl and at 51m bgl. Drilling was terminated at 61m bgl due to the volume of groundwater inflowing to the borehole, which prevented further penetration.

No hydraulic test was conducted on this trial borehole during the 1994 investigation programme. The yield from trial borehole TW11 was estimated during development of the borehole to be approximately 2,000cu.m/day.

Production borehole PW3 was drilled close to the site of trial borehole TW11. Gravelly boulder clay was recorded from the surface to 12.2m bgl. Sandy clayey gravel was recorded from 12.2m to 18.3m bgl. Soft, black, shaley limestone was recorded from 18.3m to the base of the borehole, which terminated at 53m bgl. Some weathered cavernous limestone horizons were noted during drilling from 45m to 47m bgl. Drilling was terminated at 53m bgl due to loss of air pressure, possibly due to caverns in the bedrock.

Significant groundwater inflows were recorded during drilling at intervals from 16 to 17.5m bgl and from 45 to 47m bgl. The static water level in this production borehole was recorded at 0.37m bgl. The borehole was retrofitted with 39m (53 to 14m bgl) of 250mm diameter Johnson stainless steel well screen (3mm slot size), with 14m (14m to 0m bgl) of 250mm Demco casing riser. The annulus between the wellscreen and the borehole wall was filled with silica gravel.

Initial Hydraulic Testing Programme (2000)

Following the drilling of PW3, a hydraulic testing programme was undertaken. Initially a 24 hour individual pump test was undertaken. The test was undertaken at a constant abstraction rate of 2714cu.m/day, which resulted in a drawdown of 13.63m bgl. Steady state (equilibrium) conditions were not achieved by the end of the test. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 199.1cu.m/day/m.

A 7 day continuous pump test was undertaken on PW1, PW2 and PW3 simultaneously. The abstraction rate from PW3 was approximately 2780cu.m/day for the duration of the test, which resulted in a final drawdown of 20.96m. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 132.6cu.m/day/m.

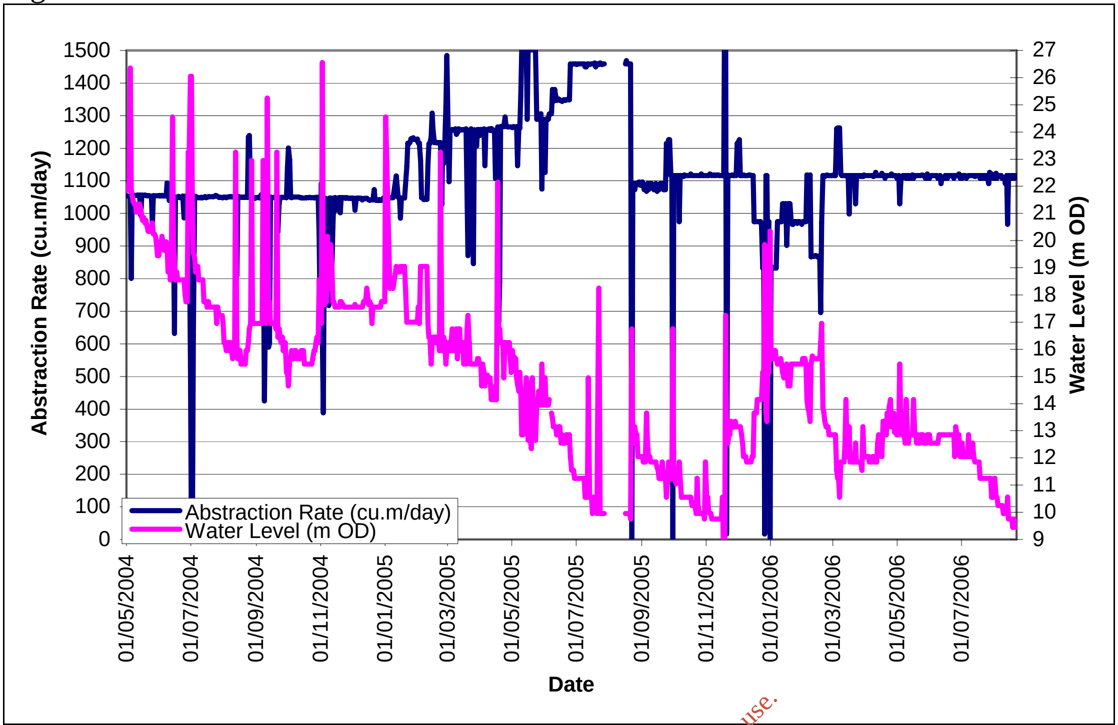
Based on the hydraulic information gathered from the pump tests, production borehole PW3 would be rated as a Class I (lower range) productive borehole, which is the highest borehole productivity rating as per the GSI classification system (Ref. Appendix C). It was recommended that the submersible pump be installed to the base of the borehole and should be capable of a sustained surface output of 2500cu.m/day.

Operation Pumping from July 2003 to August 2006

Pumping from production borehole PW3 has been ongoing from July 2003 to the present.

Figure 5.4 below shows the abstraction rate and water level in the production borehole from May 2004 through to mid August 2006 (water level data available from May onwards) based on rectified data collected by Fingal County Council at the Water Treatment Plant. The telemetric data has been rectified to show water levels as metres above Ordnance Datum, based on actual recording of water level in the production borehole.

Figure 5.4: Water Abstraction and Water Level from PW3



The water monitoring data provides some important data, with respect to abstraction rates and water levels.

From 1st May 2004 to 19th January 2005 the abstraction rate from PW3 was maintained at a relatively constant rate of 1,055cu.m/day. The water levels during this timeframe show a recession in water levels from May through to September, and thereafter a gradual (while interrupted) recovery is noted.

From the 19th January to 9th May 2005, the abstraction rate was increased to approximately 1,260cu.m/day. This increase in abstraction rates induced a further decline in water level, to compensate for the increase abstraction.

From the 9th May to the 7th June 2005, a series of hydraulic tests were conducted on the production boreholes, with the abstraction rate varied for 7 day durations. The results of this hydraulic testing is detailed below.

From the 7th June to the 24th June 2005, the abstraction rate was maintained at approximately 1,350cu.m/day and then increased to 1,460cu.m/day from 24th June to 21st August 2005. The water level continued to decline to compensate for this increased abstraction.

From the 21st August to 15th December 2005, the abstraction rate was decreased to 1090-1,116cu.m/day. While an initial recovery in water level was observed with the reduction in abstraction, a continued mild recession in water levels was observed up to mid November 2005. Thereafter over the early winter a recovery in water levels was observed.

From the 16th December 2005 through to 18th February 2006, the abstraction rate was decreased at rates generally varying from 860cu.m/day to 1,030cu.m/day (average approximately 974cu.m/day). The reduction in abstraction rate corresponded with the annual recovery in water levels, therefore it is difficult to distinguish the natural recovery from the impact of the abstraction reduction.

From the 18th February through to mid August 2006 the abstraction rate has been maintained at a relatively constant rate of 1116cu.m/day. A significant reduction in water level is observed during January /early February 2006, which coincides with the increase in abstraction rate, but also a very dry climate period. From mid February to late June 2006 the water levels held relatively steady. From late June/early July onwards the water levels declined again, corresponding with a very dry summer.

The water level data indicates that generally during summer months the water levels decline, with recovery in water levels occurring from mid to late October and continuing to recovery over the winter/spring months.

The water levels from May 2004 through to May 2005 are significantly different than the water levels from May 2005 through to August 2006. The water level on 1st May 2004 is approximately 13.76m bgl, however this drops to 19.66m bgl on 1st May 2005 and further to 22.76mbgl on 1st May 2006. The most recent data shows a steadying out of conditions. Annual recovery in water levels occurs very late, suggesting the recharge to the aquifer is impeded by the low permeability overburden. However, the recovery in water levels does occur and is evident each winter period

Hydraulic Testing Programme (2005)

A hydraulic testing programme was undertaken between 9th May 2005 and 7th June 2005. During this 4 week period, 4 No. different abstraction arrangements were programmed, as detailed in Table 5.6 below. The abstraction rate variations were made during normal operation of the Bog of the Ring Scheme and at all times the combined abstraction volume to the treatment works was maintained.

Table 5.6: Abstraction rates maintained during hydraulic testing programme 2005

Date	Abstraction Rate PW2	**Abstraction Rate PW3**	Abstraction Rate PW4	Abstraction Rate PW5
Pre 09th May 2005	1356cu.m/day	**1356cu.m/day**	240cu.m/day	1226cu.m/day
09th to 16th May 2005	1512cu.m/day	**1512cu.m/day**	336cu.m/day	900cu.m/day
16th to 23rd May 2005	1512cu.m/day	**1512cu.m/day**	240cu.m/day	996cu.m/day
23rd to 30th May 2005	1344cu.m/day	**1344cu.m/day**	240cu.m/day	1344cu.m/day
30th May to 07th June 2005	1260cu.m/day	**1260cu.m/day**	240cu.m/day	1500cu.m/day
Post 07th June 2005	1356cu.m/day	**1356cu.m/day**	240cu.m/day	1308cu.m/day

The purpose of this testing programme was as follows:

- to re-evaluate the aquifer characteristics and compare to the initial results determined in 2000;
- to ascertain the sustainability of supplies and to determine if there is any spare capacity available to augment supplies;
- to evaluate if abstraction rates could be increased in the short term to compensate for temporary deficiencies in the overall supply (i.e. in the event of failure of any of the other in-service Production Boreholes.

The protocol for the test was to vary abstraction rates for a period of 7-day, to determine the impact of such variations on water levels, etc.

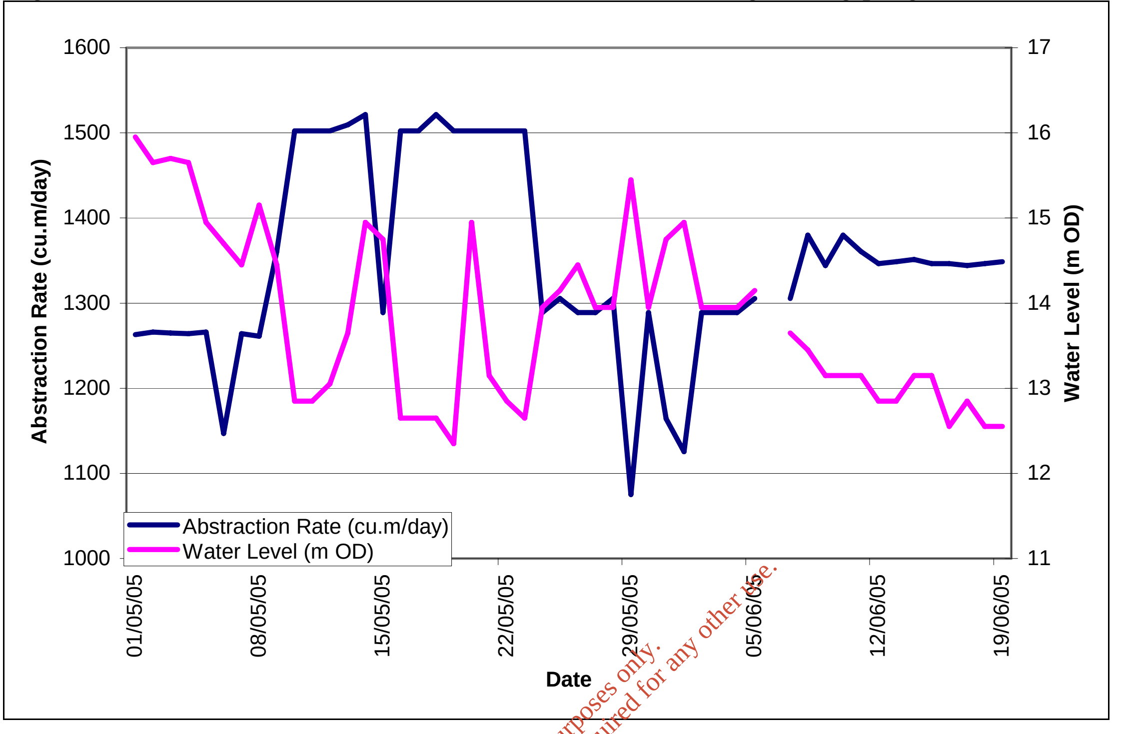
With specific reference to Production Borehole PW3, the following relates to the pumping regime prior to, during and after the hydraulic test programme.

The abstraction rate from borehole PW3 prior to the commencement of the test was approximately1356cu.m/day. The water levels prior to this period varied within the range 20.46m to 21.16m bgl in the days preceding the test.

The abstraction rate was increased to 1512cu.m/day from 9th May to 23rd May, which resulted in the water level decreasing to a relatively consistent level within the range 22.5 to 23m bgl. The consistency of the water level suggested that this borehole was capable of yielding a higher abstraction rate over this relatively short timeframe.

The abstraction rate in PW3 was decreased to 1344cu.m/day (23rd to 30th May) and then to 1260cu.m/day (30th May to 7th June), which resulted in a water level recovery to 21.75m bgl, which is lower than pre-test levels. Following completion of the testing programme, the abstraction rate was returned to 1350cu.m/day. The water levels declined following the test, however this is attributed to a seasonal recession in water levels during summer months.

Figure 5.5: Abstraction rate and induced water level during testing programme



Current Hydraulic Efficiency of PW3

In order to evaluate the efficiency of borehole PW3, abstraction rates and water levels have been taken for 1st August for the years 2004, 2005 and 2006. This data is then compared to the data obtained from the original hydraulic test programme undertaken in 2000. This data is provided in Table 5.7 below.

Table 5.7: Hydraulic Efficiency of PW3

Date	Yield	Drawdown	Specific Capacity	Efficiency
2000	2780cu.m/day	20.96m	132.63cu.m/day/m	100%
Aug 2004	1050cu.m/day	18.99m	55.29cu.m/day/m	41.69%
Aug 2005	1459cu.m/day	25.5m	57.22cu.m/day/m	43.14%
Aug 2006	1109cu.m/day	24m	46.21cu.m/day/m	34.84%

Based on the 2004-2006 data, Production borehole PW3 is rated as a Class II (upper range) productive borehole, which is the second highest productivity rating as per GSI classification system (Ref.: Appendix C).

Based on comparison of hydraulic data, production borehole PW3 has decreased from a Class I to a Class II productive borehole. The specific capacity has reduced from 132.6cu.m/day/m (7 day pump test data in 2000) to 46.21cu.m/day/m (data from August 2006). The operating efficiency has reduced by up to 65.16%, when compared to the original hydraulic data.

It can reasonably be expected that the hydraulic characteristics estimated from a pump test of relatively short duration (2000) overestimated the potential yield from the aquifer. The reduction in the efficiency of the borehole is mainly attributed to the reduction in the volume of groundwater stored in the aquifer. With continued pumping from the Bog of the Ring aquifer, the aquifer storage has been depleted and therefore, the cone of hydraulic depression has increased in extent. This cone of depression is essentially the catchment area required to replenish the aquifer for the volume abstracted from PW3. The specific capacity of PW3 does not vary significantly between 2004, 2005 and 2006, thereby supporting the suggestion that the initial testing programme overestimated the borehole potential.

Recharge to the underlying aquifer during the summer months is practically zero, therefore the performance of this borehole during the test and the consistency of the water levels suggest that the bedrock aquifer is being replenished from the overlying saturated gravel overburden.

Based on the results of the hydraulic testing programme and the longer term data, it is estimated that the sustainable yield of PW3 is 1,100cu.m/day.

It should be noted that this borehole was finished at a depth of 53m bgl and the submersible is fitted at a level of approximately 42m bgl (-3m OD). In the foreseeable future (i.e. short to medium term), there is no significant risk of a sudden fall in water levels. However, periodic monitoring should be taken to ensure that the water level is maintained above this level.

Summary

Production Borehole PW3 was drilled in 2000, as a result of encountering favourable aquifer conditions in borehole TW11 during the 1993 investigation programme.

Hydraulic testing of PW3 in 2000 indicated that an abstraction rate of 2,780cu.m/day was capable for a 7 day period. Based on the data retrieved during the hydraulic testing programme, PW3 would be rated as a Class I (lower range) Productive Borehole.

Table 5.8 below provide a summary of the hydrogeological characteristics of the aquifer in the environs of Production Borehole PW3.

Table 5.8: Hydrogeological Characteristics of Aquifer in environs of PW3

BH I.D.	Geological Strata	Hydraulic Test Duration	Abstraction Rate	Specific Capacity	GSI Borehole Productivity Classificatio
TW11	0-10m Peat and grey clay 10-17m Sand and gravel 17-61m Limestone	No Test			
PW3	0-12.2m Gravelly boulder clay 12.2-18.3m Sand and gravel 18.3-53m Limestone	24 hour (2000)	2714cu.m/day	199.1 cu.m/day/m	Class I
PW3	As above	7-day(2000)	2780cu.m/day	132.6cu.m/day/m	Class I
PW3	As above	August 2004 August 2005 August 2006	1090cu.m/day 1459cu.m/day 1109cu.m/day	55.29cu.m/day/m 57.22 cu.m/day/m 46.21 cu.m/day/m	Class II Class II Class II

The data indicates that the operating hydraulic efficiency of the borehole has declined by a maximum of 65.16%. The borehole is classified as a Class II productive borehole.

The available data set indicates that this borehole is capable of a sustainable yield of approximately 1,100cu.m/day.

5.5 Production Borehole PW4

Background Geological and Hydrogeological Setting

The location of this production borehole was based on favourable aquifer conditions encountered during the drilling of trial borehole TW13.

Available information indicates that borehole TW13 was drilled and lined (with 175mm diameter steel casing) through the overburden. The overburden comprised gravelly clay, with a lens of limestone gravel, to a depth of 36m bgl. Owing to the degree of bedrock weathering and instability the steel lining was continued to a depth of 68m bgl. The borehole was drilled 'open-hole' through bedrock, which comprised white weathered cavernous limestone, to a finished depth of 80m bgl. Groundwater inflows were recorded at depth of 25m bgl (within gravel lens) and in bedrock at 45m bgl, 52.5m bgl and 69m bgl.

A series of hydraulic tests were undertaken on borehole TW13 in 1994. The step tests undertaken on the borehole determined specific capacities for various abstraction rates. Based on the calculated specific capacities, the productivity of borehole TW13 was classed as a Class II (lower limits) to Class III (upper limits), as defined by the GSI well productivity classification system (Ref.: Appendix C). A 48 hour continuous abstraction test was undertaken on this borehole. The abstraction rate for the test was maintained at 969cu.m/day, which induced a drawdown in the water level of 39.08m. Equilibrium conditions were not achieved during this test. Based on the results of the test, the safe yield from borehole TW13 was estimated as 900cu.m/day.

Production borehole PW4 was drilled close to the site of trial borehole TW13. Brown boulder clay was recorded from the surface to 9.1m bgl. Sandy clayey gravel was recorded from 9.1m to 24.4m bgl. Drilling through bedrock continued from 24.4m to 91.4m bgl. Bedrock comprises grey limestone.

Groundwater inflows were noted during drilling at intervals from 10 to 12m bgl in the gravel horizon and at intervals from 28m to 29.5m bgl and from 44m to 46m bgl in the bedrock. The static water level at the completion of the borehole was noted at 2.45m bgl.

The borehole was retrofitted with 53m (89 to 36m bgl) of 250mm diameter Johnson stainless steel well screen (3mm slot size), with 36m (36m to 0m bgl) of 250mm Demco casing riser. The annulus between the well screen and the borehole wall was filled with silica gravel

Initial Hydraulic Testing Programme (2000)

Following the drilling of PW4, a hydraulic testing programme was undertaken. Initially a 24 hour individual pump test was undertaken. The test was undertaken at an initial abstraction rate of approximately 850cu.m/day, however this was reduced during the initial quarter of the test to 670cu.m/day for the remainder of the test. Steady state (equilibrium) conditions were not achieved by the end of the test. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 18.5cu.m/day/m.

A 7 day continuous pump test was undertaken on PW4 and PW5 simultaneously. The abstraction rate from PW4 was approximately 594cu.m/day for the duration of the test, which resulted in a final drawdown of 30.28m. Steady state conditions were achieved in PW4 during the 7 day test. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 19.6cu.m/day/m.

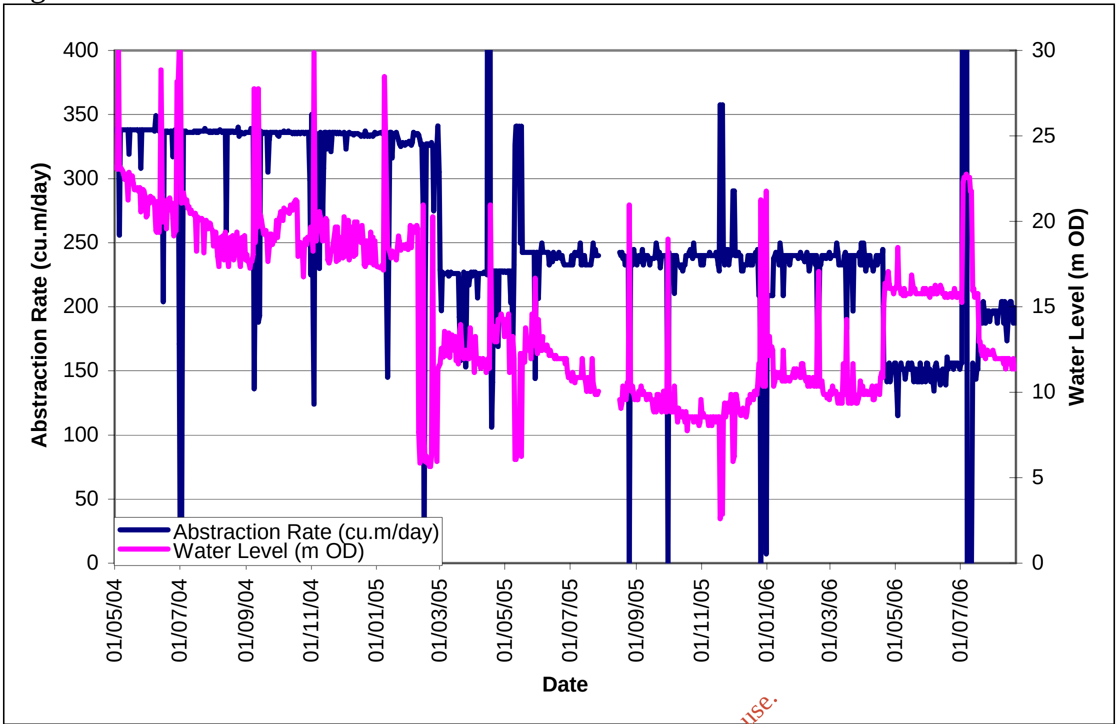
Based on the hydraulic information gathered from the pump tests, production borehole PW4 would be rated as a Class III (upper range) productive borehole, which is the third highest borehole productivity rating as per the GSI classification system (Ref. Appendix C). It was recommended that a submersible pump be installed to the base of the borehole and should be capable of a sustained surface output of 500cu.m/day.

Operational Pumping from July 2003 to August 2006

Pumping from production borehole PW4 has been ongoing from July 2003 to the present.

Figure 5.6 below shows the abstraction rate and water level in the production borehole from May 2004 through to mid August 2006 (water level data available from May 2004 onwards) based on telemetric data collected by Fingal County Council at the Water Treatment Plant. The telemetric data has been rectified to show water levels as metres above Ordnance Datum (m OD), based on actual recording of the water level in the production borehole.

Figure 5.6: Water Abstraction and Water Level from PW4



From May 2004 to the end of February 2005, the abstraction rate from the borehole was maintained at an almost constant rate of 336cu.m/day. The water level data showed a summer recession during 2004, with a levelling to minor recovery during the winter period of 2005.

The telemetric data shows a rapid water level decline (11.9m fall) between the 8th and 9th February 2005, which is not attributable to any increases or fluctuations in abstraction rates. In order to mitigate for this rapid fall, the abstraction rate from PW4 was reduced to 226-240cu.m/day from end of February 2005 to end of March 2006. While this reduction initially resulted in an increase in water levels, the water levels gradually fell during the summer months, with very little recovery during the winter period.

The abstraction rate was reduced to approximately 150cu.m/day from start of April to end of June 2006. During this period the water level was very steady and no appreciable recessing in water levels was noted. From mid July onwards the abstraction rate has been increased to approximately 200cu.m/day. This increase has resulted in a corresponding increase in the drawdown, with a gradual recession in water levels.

Based on the information available, the sudden fall in water level in mid February

2006 is not considered to result from a sudden deterioration in the aquifer potential, rather it is suggested that either the gravel pack or the borehole screen intake has become blocked with fine sediment, leading to a deterioration in the performance of the borehole. The productivity of this borehole is considered low in any event. Based on the available telemetric data, the sustainable yield is low.

Hydraulic Testing Programme (2005)

A hydraulic testing programme was undertaken between 9th May 2005 and 7th June 2005. During this 4 week period, 4 No. different abstraction arrangements were programmed, as detailed in Table 5.9 below. The abstraction rate variations were made during normal operation of the Bog of the Ring Scheme and at all times the combined abstraction volume to the treatment works was maintained.

Table 5.9: Abstraction rates maintained during hydraulic testing programme 2005

Date	Abstraction Rate PW2	Abstraction Rate PW3	**Abstraction Rate PW4**	Abstraction Rate PW5
Pre 09th May 2005	1356cu.m/day	1356cu.m/day	**240cu.m/day**	1226cu.m/day
09th to 16th May 2005	1512cu.m/day	1512cu.m/day	**336cu.m/day**	900cu.m/day
16th to 23rd May 2005	1512cu.m/day	1512cu.m/day	**240cu.m/day**	996cu.m/day
23rd to 30th May 2005	1344cu.m/day	1344cu.m/day	**240cu.m/day**	1344cu.m/day
30th May to 07th June 2005	1260cu.m/day	1260cu.m/day	**240cu.m/day**	1500cu.m/day
Post 07th June 2005	1356cu.m/day	1356cu.m/day	**240cu.m/day**	1308cu.m/day

The purpose of this testing programme was as follows:

- to re-evaluate the aquifer characteristics and compare to the initial results determined in 2000;
- to ascertain the sustainability of supplies and to determine if there is any spare capacity available to augment supplies;
- to evaluate if abstraction rates could be increased in the short term to compensate for temporary deficiencies in the overall supply (i.e. in the event of failure of any of the other in-service Production Boreholes.

The protocol for the test was to vary abstraction rates for a period of 7-days, to determine the impact of such variations on water levels, etc.

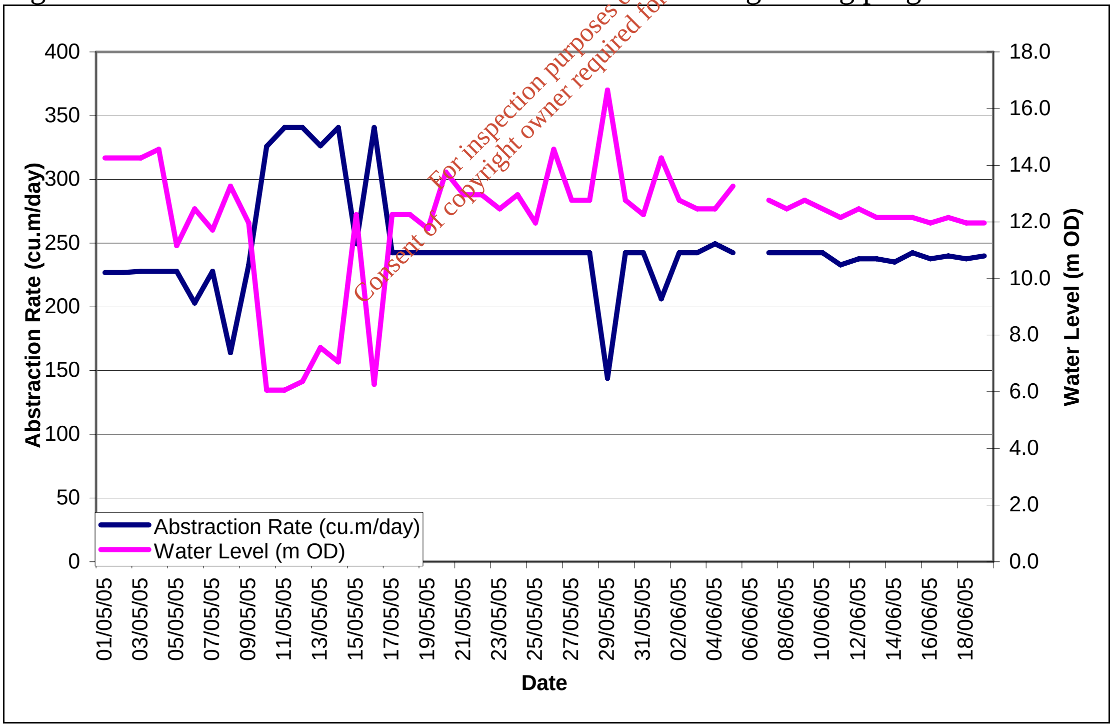
With specific reference to Production Borehole PW2, the following relates to the pumping regime prior to, during and after the hydraulic test programme.

The abstraction rate from PW4 prior to commencement of the test (i.e. pre-9th May 2005) was maintained, as close as possible, to 240cu.m/day, which resulted in a relatively consistent water level of 11.6m OD.

On the 09th to the 16th May 2005 the abstraction rate was increased to 336cu.m/day. The water level decreased dramatically to 31m bgl during this period. Owing to the fall in water levels, it was concluded that the pumping had exceeded the maximum sustainable yield of this borehole and the rate was throttled back to 240cu.m/day for the remainder of the test. The water levels recovered to approximately 24.5mbgl when the abstraction rate was decreased. Over the detailed monitoring period, at a constant abstraction rate of 240cu.m/day, the water level continued to fall. The rate of fall was considered too high to attribute purely to summer recession. It is estimated that pumping at rates of 240cu.m/day is above the maximum sustainable yield of the PW3.

During the pump test period, the water level recorded for an abstraction rate of 240cu.m/day is relatively consistent, however a different pattern is observed when the water levels are observed on the full dataset. The data observes a consistent reduction in water level with no significant changes in abstraction rate.

Figure 5.7: Abstraction rate and induced water level during testing programme



Current Hydraulic Efficiency of PW4

In order to evaluate the efficiency of borehole PW4, water yields and water levels have been taken for 1st August for the years 2004, 2005 and 2006. This data is then compared to the data obtained from the original hydraulic test programme undertaken in 2000. This data is provided in Table 5.10 below.

Table 5.10: Hydraulic Efficiency of PW4

Date	Yield	Drawdown	Specific Capacity	Efficiency
2000	594cu.m/day	30.28m	19.6cu.m/day/m	100%
Aug 2004	337cu.m/day	16.18m	20.83cu.m/day/m	106.28%
Aug 2005	233cu.m/day	24.68m	9.44cu.m/day/m	48.16%%
Aug 2006	197cu.m/day	22.58m	8.72cu.m/day/m	44.49%

Based on the hydraulic information production borehole PW4 is rated as a Class III, (lower range) productive borehole (i.e. third highest borehole productivity rating as per the GSI classification system, Ref.: Appendix C).

Although the productivity class of borehole PW4 was rated as a Class III borehole in 2000 and is still rated as Class III at the current time, the operating efficiency of the borehole has decreased significantly in February 2005. Comparison of specific capacity for production borehole PW4, with respect to 7 day pump test in 2000 and data from August 2005, indicates a reduction in the operating hydraulic efficiency by approximately 55.51%.

The hydraulic characteristics estimated from the original pump test were maintained during the operation of this borehole up to mid February 2005. However the sharp and sudden decrease in the operating efficiency over the space of one day, suggests that the decrease in the operating efficiency of the borehole is not a factor of the surrounding aquifer, rather the loss in performance is due to clogging of the gravel pack or the screen intake, which has impeded the inflow of groundwater to the borehole.

The available data set indicates that this borehole is capable of a sustainable yield of approximately 150cu.m/day. Pumping at rates exceeding this rate could lead to further deterioration of the efficiency of the borehole by inducing further mobilisation of fine material, leading to further clogging of the gravel pack and screen intake.

Summary

Production Borehole PW4 was drilled in 2000, as a result of encountering favourable aquifer conditions in borehole TW13 during the 1993 investigation programme.

Hydraulic testing of PW4 in 2000 indicated that an abstraction rate of 594cu.m/day was capable for a 7 day period. Based on the data retrieved during the hydraulic testing programme, PW4 would be rated as a Class III (upper range) Productive Borehole.

Pumping from PW4 has been ongoing from 2003 to present. Abstraction rates have been progressively decreased to an abstraction rate of 150cu.m/day.

The data indicates that the operating hydraulic efficiency of the borehole has declined by approximately 55.51%.

The available data set indicates that this borehole is capable of a sustainable yield of approximately 150cu.m/day. It would appear from the data that this borehole is not capable of sustaining higher yields without inducing significant drawdowns.

Table 5.11 below provides a summary of the hydrogeological characteristics of the aquifer in the environs of Production Borehole PW4.

Table 5.11: Hydrogeological Characteristics of Aquifer in environs of PW4

BH I.D.	Geological Strata	Hydraulic Test Duration	Abstraction Rate	Specific Capacity	GSI Borehole Productivity Classification
TW13	0-36m Gravelly clay and gravel 36-69m Limestone	48 hours	969 cu.m/day	24.8 cu.m/day/m	Class II to Class III
PW4	0-9.1m Boulder clay 9.1-24.4m Sandy, gravelly clay 24.4-91.4m Limestone	24 hour (2000)	670cu.m/day	18.5 cu.m/day/m	Class III
PW4	As above	7-day (2000)	594cu.m/day	19.6 cu.m/day/m	Class III
PW4	As above	August 2004 August 2005 August 2006	337cu.m/day 233cu.m/day 197cu.m/day	20.83cu.m/day/m 9.44cu.m/day/m 8.72cu.m/day/m	Class III Class III Class III

The available data set indicates that this borehole is capable of a sustainable yield of approximately 150cu.m/day.

5.6 Production Borehole PW5

Background Geological and Hydrogeological Setting

Production borehole PW5 was drilled on the road verge at Killougher, approximately 1,050m from the designated pNHA area. The location of this production borehole was based on favourable aquifer conditions encountered during the drilling of trial borehole TW12.

Available information indicates that borehole TW12 was drilled and lined (with 200mm diameter steel casing) through the overburden. The overburden comprised black boulder clay to a depth of 31m bgl. Highly fissured/fractured bedrock was encountered from 31m to 43m bgl, with cavernous sections infilled, or partially infilled, with coarse gravel. The borehole was completed 'open-hole' from 43m to 54m bgl.

A 48 hour continuous abstraction test was undertaken on this borehole in 1994. The abstraction rate for the test was initially set at 2,468cu.m/day, which fluctuated slightly between 2,400 to 2,541cu.m/day during the course of the test. Near steady state (equilibrium) conditions were reached after 1440 minutes, with drawdown varying between 8.5m and 8.6m. Based on the pump test measurement, at an abstraction rate of 2,468cu.m/day, the specific capacity of this borehole was calculated as 287cu.m/day/m. This borehole is classified as a Class I productivity borehole, in accordance with the GSI classification system (Ref.: Appendix C).

Production borehole PW5 was drilled immediately adjacent to trial borehole TW12. Blue boulder clay was noted from the surface to 12.1m bgl. Grey-blue gravelly clay was noted form 12.1m to 18.3m bgl. Blue boulder clay was again recorded from 18.3m to 24m bgl. Soft, weathered grey limestone extended from 24m to 42m bgl, with soft black shaley limestone noted from 42m to 79.3m bgl, where drilling terminated.

A major groundwater inflow was noted in the bedrock during drilling from 34 to 36m bgl. The static water level at the completion of the borehole was noted at 7.68m bgl.

The borehole was retrofitted with 43m (75 to 32m bgl) of 250mm diameter Johnson stainless steel well screen (3mm slot size), with 32m (32m to 0m bgl) of 250mm Demco casing riser. The annulus between the well screen and the borehole wall was filled with silica gravel.

Initial Hydraulic Testing Programme (2000)

Following the drilling of PW5, a hydraulic testing programme was undertaken. Firstly a 24 hour individual pump test was undertaken. The test was undertaken at an initial rate of approximately 1938cu.m/day, which induced a drawdown of 7.7m at the end of the test. Steady state (equilibrium) conditions were not achieved by the end of the test. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 251.7cu.m/day/m.

A 7 day continuous pump test was undertaken on PW4 and PW5 simultaneously. The abstraction rate from PW5 was approximately 2654cu.m/day for the duration of the test, which resulted in a final drawdown of 13.16m. Steady state conditions were not achieved in PW5 during the 7 day test. While the borehole sustained the abstraction rate for the duration of the test, subsequent monitoring of water levels indicated a very slow rate of recovery. The slow rate of recovery was attributed at the time to particularly dry weather or difficulties of sustained yield to the borehole from the aquifer. Based on the hydraulic information gathered, the specific capacity of this borehole was calculated as 201.7cu.m/day/m.

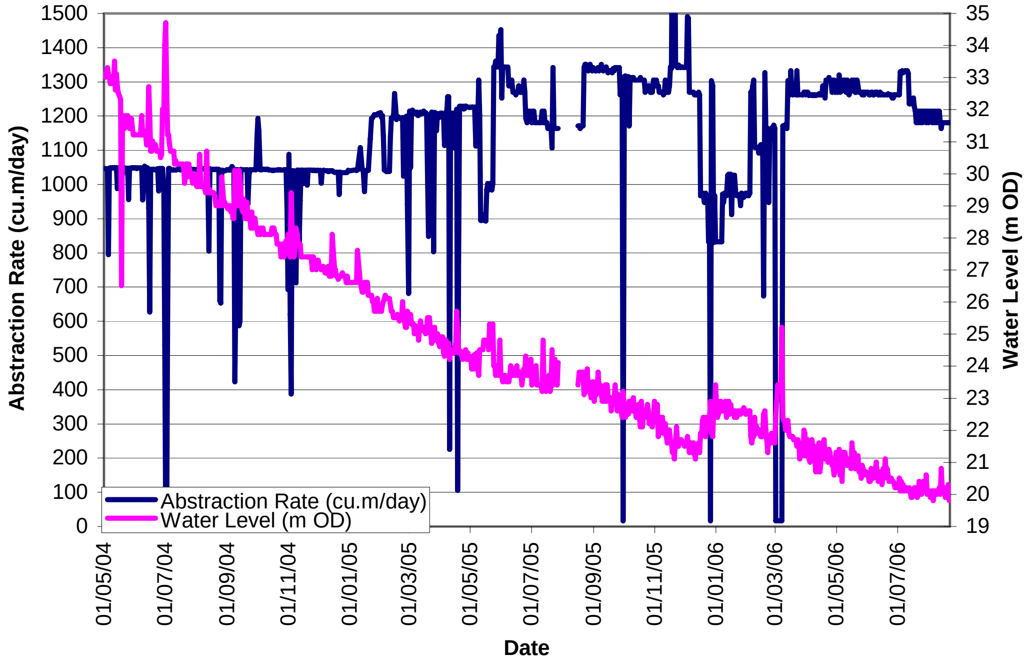
Based on the hydraulic information gathered from the pump tests, production borehole PW5 would be rated as a Class I productive borehole, which is the highest borehole productivity rating as per the GSI classification system (Ref.: Appendix C). It was recommended that a submersible pump be installed to the base of the borehole and should be capable of a sustained surface output of 2500cu.m/day.

Operational Pumping from July 2003 to August 2006

Pumping from production borehole PW5 has been ongoing from July 2003 to the present.

Figure 5.8 below shows the abstraction rate and water level in the production borehole based on telemetric data collected by Fingal County Council at the Water Treatment Plant. The telemetric data has been rectified to show water levels as metres below ground level, based on actual recording of water level in the production borehole.

Figure 5.8: Water Abstraction and Water Level from PW5



The abstraction rates and water level measurement from the telemetric data record an apparent trend. It is acknowledged that there are some isolated deviations from the norm, however if these isolated deviations are discounted, the normal pumping conditions are more apparent.

From 1st May 2004 to 19th January 2005 the abstraction rate from PW5 was maintained at a relatively constant rate of 1,040cu.m/day. The water level during this period showed a relatively constant rate of fall, with no recovery in water level during the winter period.

From 19th January 2005 to 9th May 2005 the abstraction rate was increased to 1200-1225cu.m/day (decreased from 2nd Feb to 9th Feb to 1040 cu.m/day). Again, the water level data shows a progressive water level decline during this period.

From the 9th May to the 07th June 2005, a hydraulic test programme was undertaken which involved significant changes to the abstraction rates from each of the production boreholes.

When normal operations were resumed on the 9th June 2005 to end July 2005, the abstraction rate from PW5 was maintained within the range 1225-1330cu.m/day. The water level data for this period shows that the rate of water level decline has decreased and the water level appears to be reaching pseudo-equilibrium conditions.

From early August to end November 2005 the abstraction rate was maintained within the range of 1270-1340cu.m/day. While a fall in water level was again recorded, the rate of decline continued to decrease, again suggesting that pseudo-equilibrium conditions were being approached.

The abstraction rate was decreased from the end of November 2005 to mid January 2006 to an average rate of approximately 970cu.m/day. A small recovery in water level was recorded during this period. From mid January to the end of the monitoring period in mid August 2006 the abstraction rate has varied between 1100cu.m/day and 1350cu.m/day. During this period no recovery in water level was noted over the late winter or early spring, nor was any significant decline noted during the summer months. The rate of drawdown in the borehole continues at a relatively steady rate, although at a significantly lower rate than previously observed in 2004/early 2005.

Overall, the early data indicated that, owing to the rate of water level decline in this production borehole, the abstraction rate was exceeding the maximum sustainable yield. The more recent data shows a levelling of water levels which suggests that equilibrium conditions are being approached, whereby the zone of contribution has extended to achieve sufficient recharge area. However, even allowing for the extensive monitoring of this borehole, equilibrium conditions have not been achieved. The lack of seasonal influence suggests that recharge to the underlying bedrock aquifer is slow and the cone of depression induced by pumping is large.

Hydraulic Testing Programme 2005

A hydraulic testing programme was undertaken between 9th May 2005 and 7th June 2005. During this 4 week period, 4 No. different abstraction arrangements were programmed, as detailed in Table 5.12 below. The abstraction rate variations were made during normal operation of the Bog of the Ring Scheme and at all times the combined abstraction volume to the treatment works was maintained.

Table 5.12: Abstraction rates maintained during hydraulic testing programme 2005

Date	Abstraction Rate PW2	Abstraction Rate PW3	Abstraction Rate PW4	**Abstraction Rate PW5**
Pre 09th May 2005	1356cu.m/day	1356cu.m/day	240cu.m/day	**1226cu.m/day**
09th to 16th May 2005	1512cu.m/day	1512cu.m/day	336cu.m/day	**900cu.m/day**
16th to 23rd May 2005	1512cu.m/day	1512cu.m/day	240cu.m/day	**996cu.m/day**
23rd to 30th May 2005	1344cu.m/day	1344cu.m/day	240cu.m/day	**1344cu.m/day**
30th May to 07th June 2005	1260cu.m/day	1260cu.m/day	240cu.m/day	**1308cu.m/day**
Post 07th June 2005	1356cu.m/day	1356cu.m/day	240cu.m/day	**1308cu.m/day**

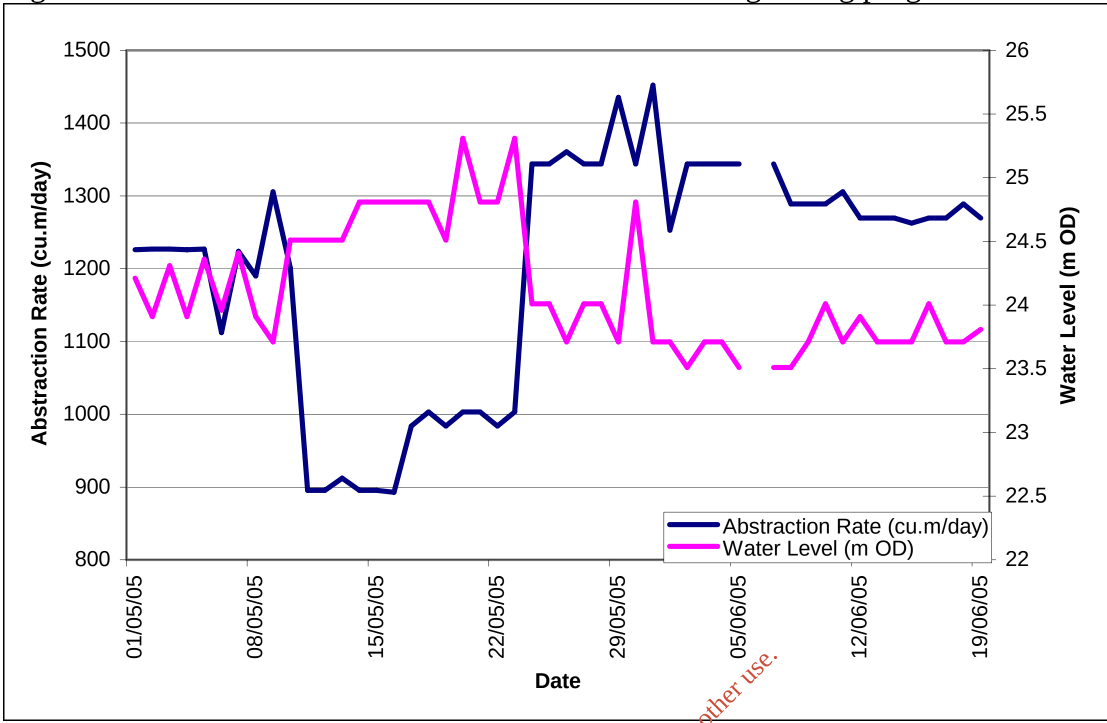
The purpose of this testing programme was as follows:

- to re-evaluate the aquifer characteristics and compare to the initial results determined in 2000;
- to ascertain the sustainability of supplies and to determine if there is any spare capacity available to augment supplies;
- to evaluate if abstraction rates could be increased in the short term to compensate for temporary deficiencies in the overall supply (i.e. in the event of failure of any of the other in-service Production Boreholes.

The protocol for the test was to vary abstraction rates for a period of 7-days, to determine the impact of such variations on water levels, etc.

With specific reference to Production Borehole PW5, the following relates to the pumping regime prior to, during and after the hydraulic test programme.

Figure 5.9: Abstraction rate and induced water level during testing programme



Prior to commencement of testing (i.e. pre-9th May 2005), this borehole operated at an abstraction rate of approximately 1226cu.m/day, which resulted in a recorded water level of 31m bgl. This water level was recorded immediately prior to the test, however as detailed earlier a progressive water level decline has been observed since pumping commenced.

The abstraction rate from the 9th to the 16th May 2005 was reduced to 900cu.m/day, which resulted in a water level recovery to approximately 30.25m bgl. From the 16th May to 23rd May 2005, the abstraction rate was increased to 996cu.m/day, which resulted in negligible change in the water level (i.e. water level recorded at 30m bgl).

The telemetric data indicates that from 23rd May to 30th May 2005, the abstraction rate was maintained at 1,344cu.m/day and resulted in a water level decrease of 31.25m bgl.

From 30th May to 07th June 2005, the abstraction rate was set at 1500cu.m/day, however in actuality the maximum abstraction rate recorded was 1450cu.m/day for a short duration. The maximum sustained yiled achieved during this period was approximately 1308 cu.m/day. The water level varied by a negligible margin during this period (i.e. maintained within the range of 31.25m bgl.

Following completion of the test, the abstraction rate from PW5 was maintained at 1,308cu.m/day. The water level was maintained within the range of 31.25-31.5m bgl following the test.

Current Hydraulic Efficiency of PW5

In order to evaluate the efficiency of the borehole PW5, abstraction rates and water levels have been taken for 1st August 2004, 2005 and 2006. This data is then compared to the data obtained from the original hydraulic test programme undertaken in 2000. This data is provided in Table 5.13 below.

Table 5.13: Hydraulic Efficiency of PW5

Date	Yield	Drawdown	Specific Capacity	Efficiency
2000	2654cu.m/day	13.16m	201.67cu.m/day/m	100%
Aug 2004	1044cu.m/day	17.79m	58.68cu.m/day/m	29.10%
Aug 2005	1171cu.m/day	23.59m	49.63cu.m/day/m	24.61%%
Aug 2006	1214cu.m/day	27.29m	44.49cu.m/day/m	22.06%

Based on the 2004-2006 data, Production Borehole PW5 is rated as a Class II (upper range) productive borehole, which is the second highest productivity rating as per the GSI classification system (Ref.: Appendix C). This is a decrease from the original hydraulic test, where the borehole would have been rated as a Class I productive borehole.

The current operating efficiency of PW5 has reduced by 77.94%, when compared to the original hydraulic data.

It can reasonably be expected that the hydraulic characteristics estimated from a pump test of relatively short duration (2000) over-estimated the potential yield from the aquifer. The observed reduction in the efficiency of the borehole is mainly attributed to the reduction in the volume of groundwater stored in the aquifer. With continued pumping from the Bog of the Ring, the aquifer storage has been depleted. The thick clay overburden is impeding recharge of the underlying bedrock aquifer, therefore the cone of depression induced by pumping is continuing to expand. This is evident from the progressive decline in the water level in this production borehole. This cone of depression will extend until a sufficient catchment area is available to replenish the volume of groundwater abstracted.

The hydraulic data, coupled with monitoring data collected from observation borehole TW12 and OW7, indicate recoveries in water levels when the abstraction rate is at or below 1,000cu.m/day. The gradual decline in water levels in this borehole is attributed to the thick low permeability clay overburden recorded in the vicinity of PW5.

When the water levels in this borehole are viewed over an extended period (Ref.: Figure 5.7), the water levels have declined from 21.97m bgl (early May 2004), to 35.27m bgl (mid August 2006). No winter recovery in water levels of significance have been noted, although occasional levelling of water levels have been recorded.

There is no immediate threat of failure of this borehole, owing to the fact that the submersible pump has been installed to 60m bgl depth and the water level is presently approximately 35m bgl. Also the rate of drawdown appears to be decreasing. Monitoring of the water level should be maintained to ensure that the water level is maintained above the submersible pump intake.

Owing to the continued progressive decline in water levels in this boreholes, albeit at gradually reducing rates, it is concluded that the recharge to the borehole is not adequate to replenish the borehole. It is estimated that the maximum sustainable yield of this borehole at 1,100cu.m/day.

Summary

Production Borehole PW5 was drilled in 2000, as a result of encountering favourable aquifer conditions in borehole TW12 during the 1993 investigation programme.

Hydraulic testing of PW5 in 2000 indicated that an abstraction rate of 2,654cu.m/day was capable for a 7 day period. Based on the data retrieved during the hydraulic testing programme, PW5 would be rated as a Class I Productive Borehole.

The hydraulic characteristics of this borehole have declined significantly since pumping commenced in 2003. The low permeability of the overburden coupled with the depletion of the aquifer storage is considered to have affected the hydraulic performance of the aquifer system. However the recent characteristics are considered to be more reflective of the true hydraulic performance of the system.

Table 5.14 below provide a summary of the hydrogeological characteristics of the aquifer in the environs of Production Borehole PW5.

Table 5.14: Hydrogeological Characteristics of Aquifer in environs of PW5

BH I.D.	Geological Strata	Hydraulic Test Duration	Abstraction Rate	Specific Capacity	GSI Borehole Productivity Classification
TW12	0-31m Boulder clay 31-54m Limestone	48 hour (1993)	2468cu.m/day	287 cu.m/day/m	Class I
PW5	0-12.1m Boulder clay 12.1-18.3m Gravelly clay 18.3-24m Boulder clay 24-79.3m Limestone	24 hour (2000)	1938cu.m/day	251.7 cu.m/day/m	Class I
PW5	As above	7-day (2000)	2654cu.m/day	201.7 cu.m/day/m	Class I
PW5	As above	August 2004 August 2005 August 2006	1044cu.m/day 1171cu.m/day 1214cu.m/day	58.68cu.m/day/m 49.63cu.m/day/m 44.49cu.m/day/m	Class II Class II Class II

The data indicates that the operating hydraulic efficiency of the borehole has declined by approximately 77.94%. The borehole is classified as a Class II productive borehole.

Based on the available information, the maximum sustainable yield from PW5 is estimated as 1,100cu.m/day.

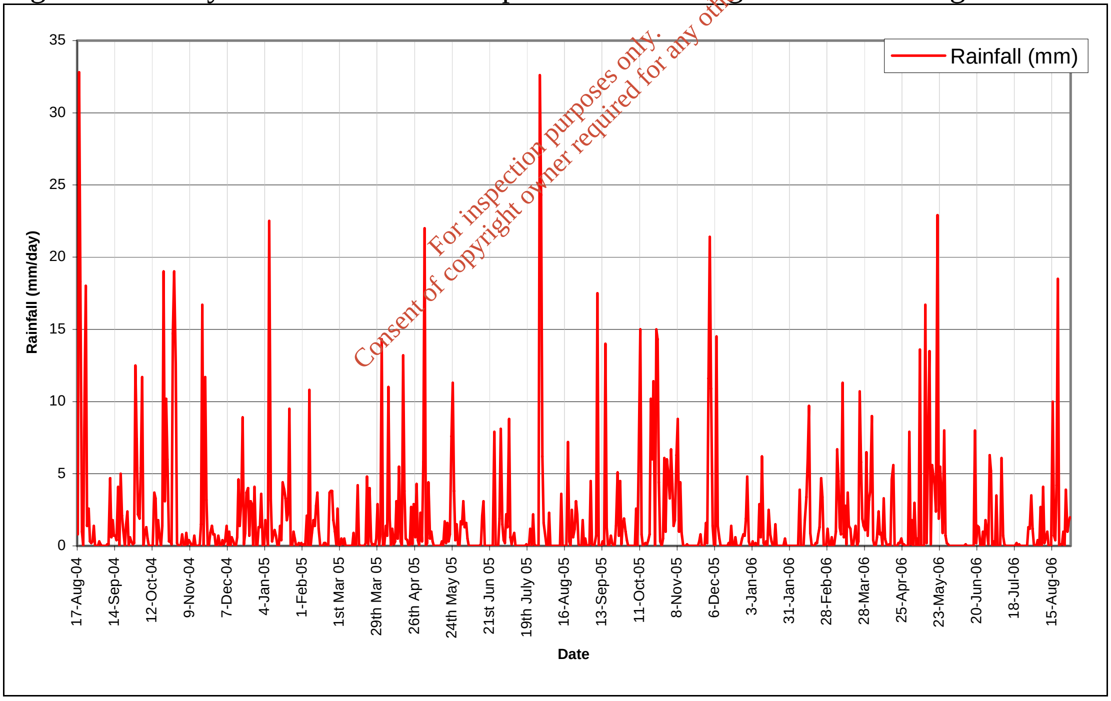
6 METEROLOGICAL CONDITIONS

The meteorological conditions occurring over the course of the groundwater water level monitoring programme were assessed. The rationale for observing the meteorological conditions was to determine if trends in water level fluctuation were as a result of climatic conditions.

There is no meteorological station in operation at Bog of the Ring. The most reliable meteorological station in operation in this region is the synoptic climate station at Dublin Airport. This synoptic station provides daily rainfall data and therefore represents the most accurate meteorological gauging station in the north Dublin region. Bog of the Ring is approximately 17km from Dublin Airport and is in a similar geographic setting in relation to distance from the Irish Sea.

The daily rainfall data collected from Dublin Airport Synoptic Station is presented in Figure 6.1 below. The full dataset of meteorological data in included in Appendix D.

Figure 6.1: Daily rainfall at Dublin Airport from 17th Aug 2004 to 31st Aug 2006



The daily rainfall data, gathered for 745 days, provides some useful information regarding rainfall intensity.

The three highest daily rainfall events occurred during summer/early autumn, namely on the 18th August 2004 (32.8mm), the 28th July 2005 (32.6mm) and the 21st May 2006 (22.9mm). The highest winter rainfall events occurred on the 7th January 2005 (22.5mm) and the 2nd December 2005 (21.4mm).

Summer downpours tend to be intense and of short duration. However, these intense rainfall events occur during periods of highest water loss, either through free evaporation, run-off to streams or plant transpiration. In effect a small percentage of rainfall infiltrates to ground to contribute summer recharge to the aquifer.

Winter rainfall, while occasionally very intense tends to occur over a longer duration, where pressure belts lead to rainfall over a number of days. During winter periods the aquifer receives the most significant recharge to replenish the aquifer. The limiting factor during winter months is due to the low infiltration capacity of the soil.

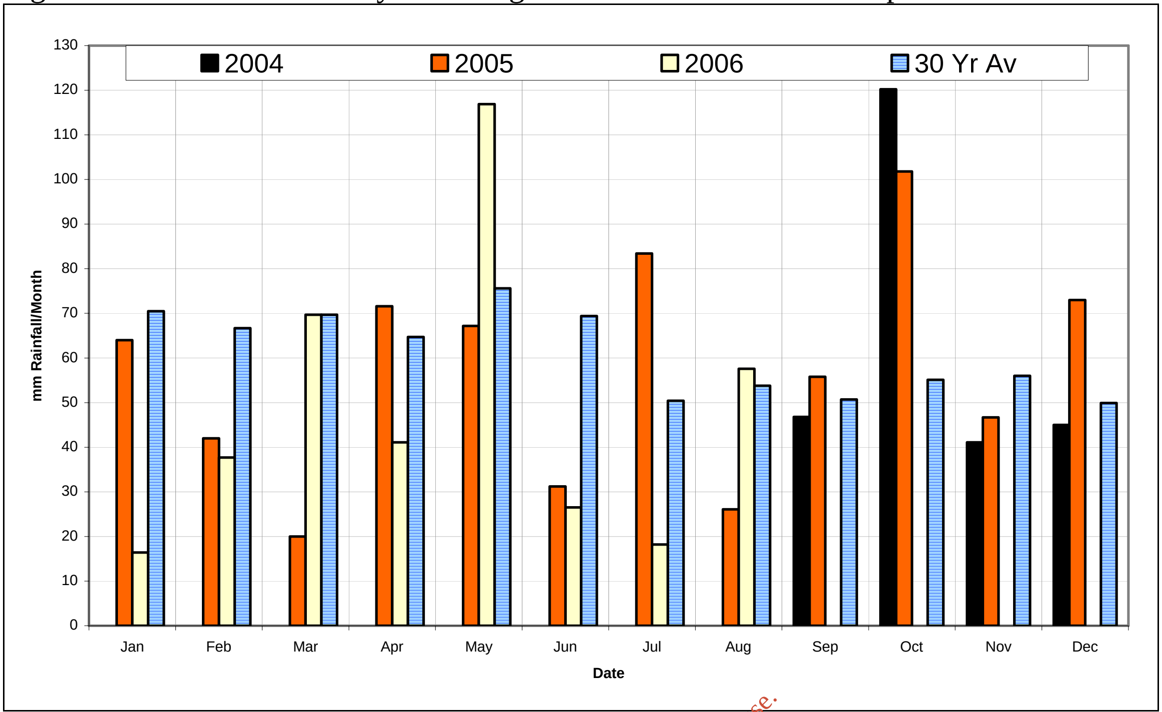
The longest duration of 0mm rainfall was 12 days, which occurred from the 30th May to 10th June 2006. The data indicates that from 30th May to 17th June 2006 only 0.1mm of rainfall occurred (0.1mm on 11th June 2006).

Extended dry periods were also noted during winter month, with 0mm rainfall recorded for 10 days from 28th January to 6th February 2006.

Based on the full daily rainfall dataset, the average daily rainfall is calculated as 1.9mm/day.

The meteorological data is also analysed as monthly rainfall rates. Analysis of the meteorological data on a monthly basis is considered more appropriate for comparison with the 30 year average rainfall rates. This allows interpretation of the data to access how typical the meteorological conditions have been over the monitoring period from 17th August 2004 through to end August 2006. The recorded monthly rainfall from September 2004 (August omitted as not full data for month) to August 2006 is presented on Figure 6.2 below, together with the 30 year monthly average rainfall rate.

Figure 6.2: Recorded and 30 year average rainfall rates at Dublin Airport



The data collected indicates that the recorded monthly rainfall rate varies significantly over certain periods from the 30 year average rainfall. Table 6.1 provides details of the variations on a monthly basis throughout the monitoring period, with this rainfall expressed as a percentage of the 30 year average monthly rate. This is presented to show the typicality of each particular month during the monitoring period, as this has a bearing on the water levels recorded in the monitoring boreholes.

The month of October in 2004 and 2005 recorded significantly higher rainfall than the 30 year average. March 2005 and January 2006 were significantly drier than the 30 year average. June 2005 and June and July 2006 was drier that the average. July 2005 and May 2006 were significantly wetter than the 30 year average.

Notwithstanding both daily and monthly variations, based on recorded data from September 2004-August 2005 and September 2005-August 2006, the annual rainfall was 90% of the 30 year average on both annual cycles.

Based on the meteorological dataset, the climatic conditions during the monitoring period can be considered relatively typical. Therefore, the measurements taken during the water level monitoring programme are considered a true reflection of current hydrogeological conditions and the trends can be associated to the pumping regime existing across Bog of the Ring.

Table 6.1: Monthly Meteorological Data for Dublin Airport

Month	Recorded Monthly Rainfall	30 Year Average Monthly Rainfall	Variation from 30 Year
September 2004	46.8mm	50.7mm	92.3%
October 2004	120.2mm	55.1mm	218.1%
November 2004	41.1mm	56mm	73.4
December 2004	45mm	49.9mm	90.2%
January 2005	64mm	70.5mm	90.8
February 2005	42mm	66.7mm	63%
March 2005	20mm	69.7	28.7%
April 2005	71.6mm	64.7mm	110.7%
May 2005	67.2mm	75.6mm	88.9%
June 2005	31.2mm	69.4mm	45%
July 2005	83.4mm	50.4mm	165.5%
August 2005	26.1mm	53.8mm	48.5%
September 2005	55.8mm	50.7mm	110.1%
October 2005	101.8mm	55.1mm	184.8%
November 2005	46.7mm	56mm	83.4%
December 2005	73mm	49.9mm	146.3%
January 2006	16.4mm	70.5mm	23.3%
February 2006	37.7mm	66.7mm	56.5%
March 2006	69.7mm	69.7mm	100%
April 2006	41.1mm	64.7mm	63.5%
May 2006	116.9mm	75.6mm	154.6%
June 2006	26.5mm	69.4mm	38.2%
July 2006	18.2mm	50.4mm	36.1%
August 2006	57.6mm	53.8mm	107.1%

7 OVERVIEW OF EXISTING MONITORING DATASET

TES Consulting Engineers have undertaken fortnightly groundwater monitoring of boreholes and standpipes within the Bog of the Ring area since 17th August 2004. The locations of all monitoring points are shown on Figure 2 herein. Available logs for all monitoring boreholes are included in Appendix B herein.

Groundwater monitoring of the network was previously undertaken by White Young Green (WYG) Consulting Engineers (previously K.T. Cullen and Co Ltd.) from 27 June 2000 to 17th July 2000, during the hydraulic testing programme of the production boreholes. WYG also undertook monitoring of the network from 9th October 2003 to 26th March 2004. This information was incorporated into the TES dataset to allow full assessment of water levels existing prior to groundwater abstraction (2000) and during the early phase to the present (August 2006) of groundwater abstraction.

The existing monitoring network has been progressively established since investigations began. All trial boreholes (Code TW) were drilled in 1984 and 1993. All observation boreholes (Code OW) and shallow standpipes (Code S) were installed in 2000, prior to the testing of the production boreholes.

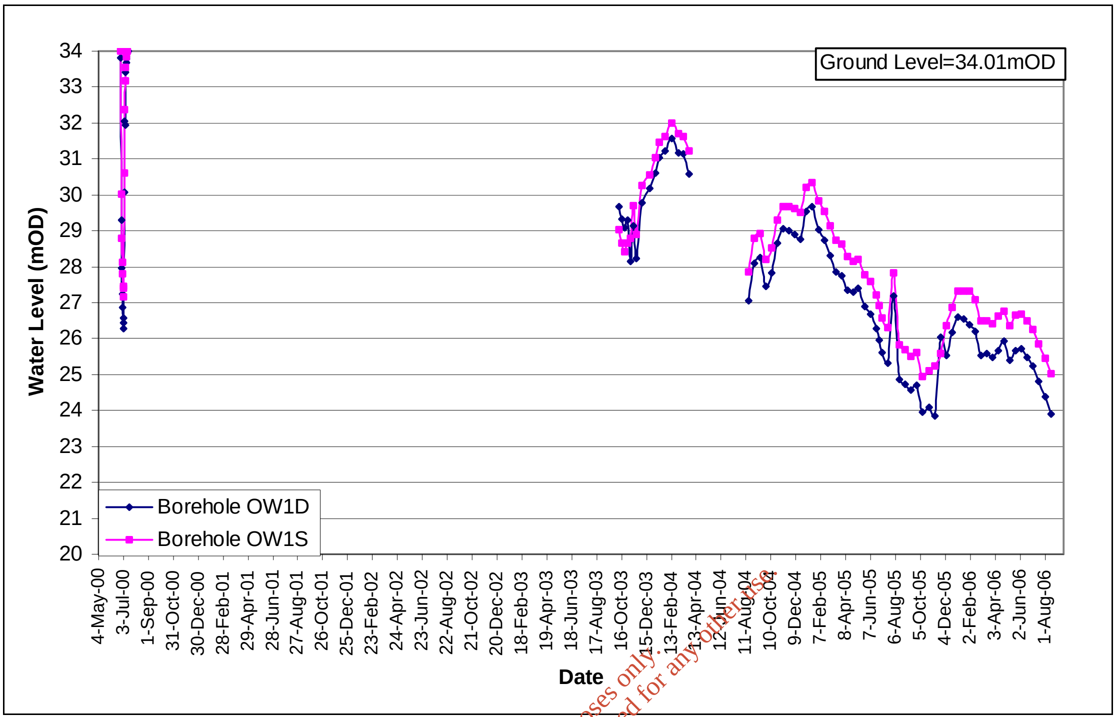
The design of each of the boreholes is different and therefore, for ease of assessment, boreholes logs for each have been included. The boreholes are screened in different sections therefore the hydraulic data retrieved varies.

As a general guidance, the following relates to the design of the monitoring points:

- Trial boreholes are drilled at 200mm diameter, with steel lining socketed 2m into rock. Drilling then preceded open hole with no screen or casing retrofit.
- Observation boreholes are usually paired, with one piezometer screened and isolated in the bedrock environment (OW1D, etc) and one piezometer screened in the subsoil environment (OW1S, etc). These borehole provide water level data in both the subsoil and bedrock environment at the same location. Borehole OW4 and OW7 are not paired and these monitoring points record the water level in the bedrock zone only.
- No information is available relating to the installation of the shallow standpipes, however it appears that the retrofit is 50mm wavin pipe, which was hand slotted to permit groundwater entry. The shallow standpipes act as monitoring points within the shallow soil/subsoil environment. These monitoring points are considered critical to determining if the Bog of the Ring Abstraction Scheme is having or will have an impact on the wet nature and continued ecological status of the Bog of the Ring.

The following section discusses the water levels recorded from available data.

Observation Borehole OW1S and OW1D



Observation boreholes OW1D (deep bedrock monitoring point) and OW1S (shallow subsoil monitoring point) are located approximately 513m to the east of PW2. This monitoring point is immediately on the verge of the designated area of Bog of the Ring.

Information available from the drilling of this borehole indicates that artesian conditions were encountered in both the shallow and deep borehole piezometer. Approximately 11m of boulder clay was encountered overlying a sand and gravel unit (18 thick) overlying limestone bedrock. The borehole was located very close to Production Borehole PW1 and PW2. During pump tests undertaken on the simultaneous test PW1/PW2/PW3 in 2000, an approximate 7m drawdown was observed in the shallow piezometer and 8m drawdown in the deep piezometer.

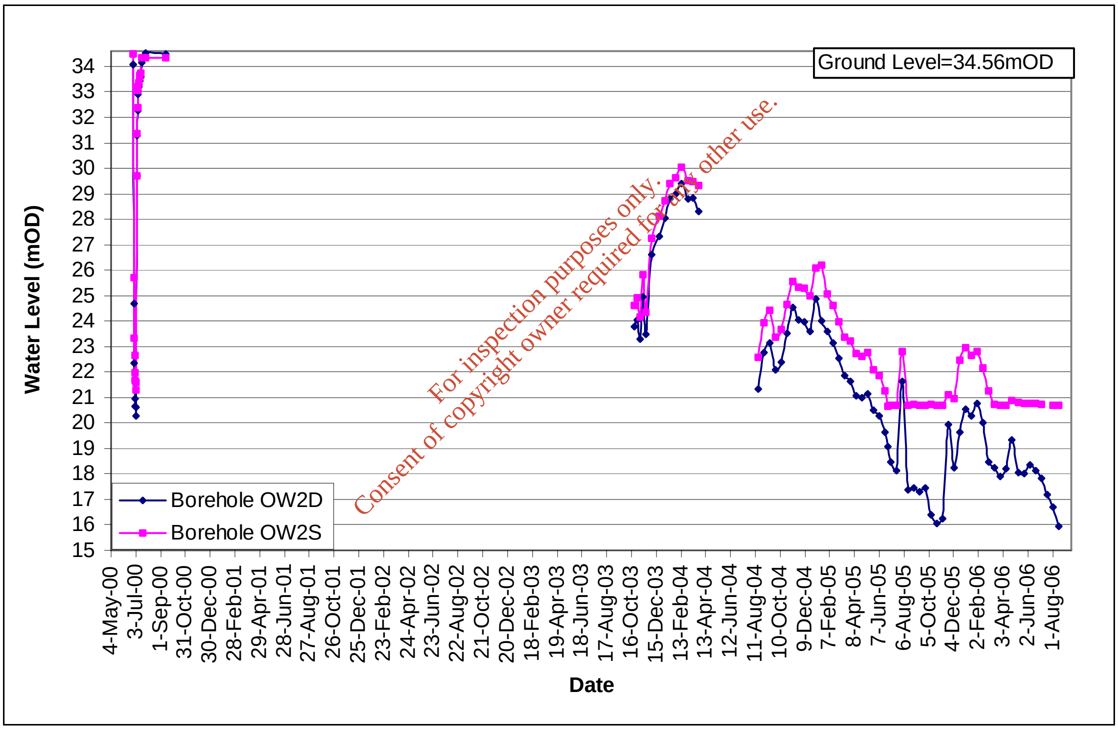
The data available from 9th October 2003 onwards indicates that, even though PW1 is not currently utilised, a progressive decline in both the subsoil water level and the bedrock water level is observed at this point.

The graph suggests a gradual decline in water levels over time, with a 3-3.5m recovery over winter months. The early dataset indicates that even though winter recovery is noted, the annual cycles show a declining trend. The annual cycle August 2005 to August 2006 shows a relatively stable cycle, which suggests that equilibrium conditions may have been achieved.

Based on the most recent data, it is suggested that a stable cone of depression induced due to pumping from the well-field has been established.

The water level in the subsoil environment is consistently 1m higher than in the bedrock. This suggests that the water in the bedrock is being transmitted to the borehole at a faster rate than from the subsoil. The recharge of the bedrock is dictated by the permeability rate of the sand and gravel.

Observation Borehole OW2S & OW2D



Observation boreholes OW2D (deep bedrock monitoring point) and OW2S (shallow subsoil monitoring point) are located approximately 170m to the west of PW2 and 215m to the east of PW3. This monitoring point is within the designated area of Bog of the Ring.

Information available indicates that prior to drilling, the water levels at this location were at or above the ground surface. Approximately 7.5m of boulder clay overlying

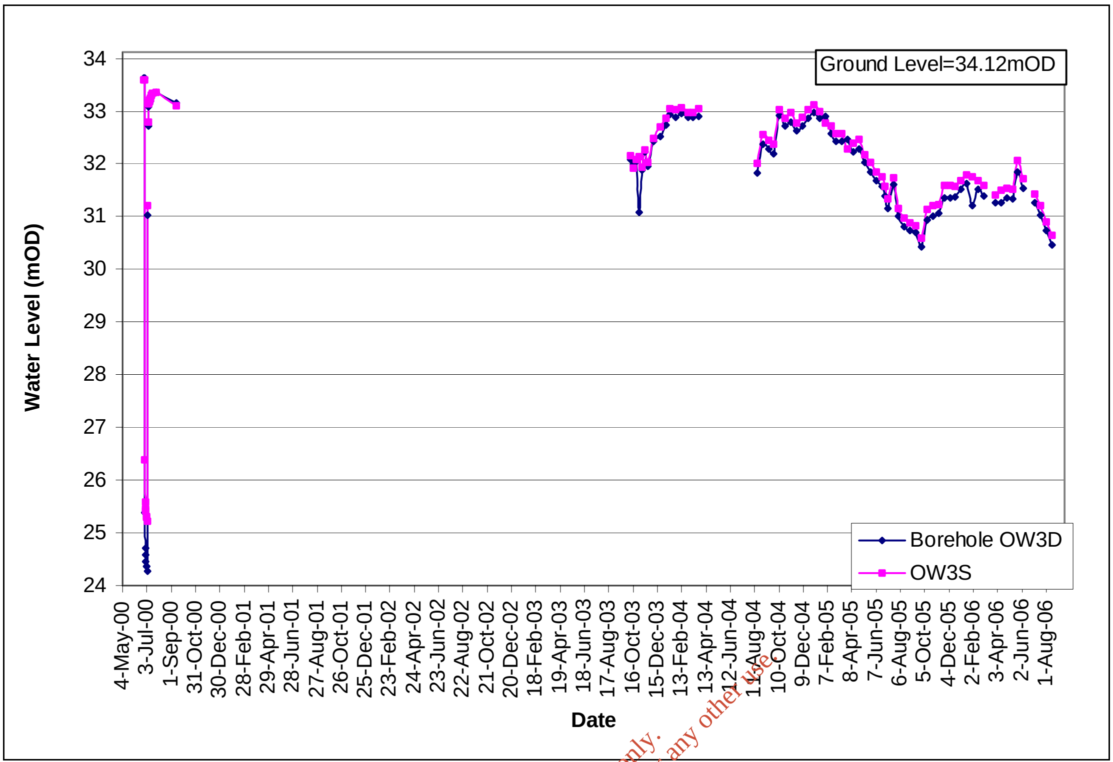
12.5m of clayey gravel overlying limestone bedrock was noted during drilling.

During initial testing of PW2 and PW3, significant drawdowns were observed in these piezometers. Drawdown of approximately 13m was observed in the subsoil piezometer and 14m in the bedrock piezometer.

The monitoring data from 29th September 2003 to the present indicates that the pumping from the well-field is impacting groundwater levels at this location. While winter recoveries are recorded, the water levels are continually lower than existing prior to commencement of abstraction from the scheme. The most recent annual cycle from July 2005 to August 2006 indicates that equilibrium conditions seem to have been established over the past 12 months or so. The water level in OW1 S was reduced to approximately 14m bgl, however it has remained relatively constant at this level, apart from recovery during winter periods. The water level in the bedrock continues to vary with recovery during winter months and decline during summer months.

The difference in water levels between the bedrock piezometer and the subsoil piezometer has been extending over time. Up to August 2005 the difference was almost 1m, however that has grown to 4.5m as of 8th November 2005. This indicates that the rate of recharge to the bedrock environment from the overburden sand and gravel to the bedrock has been decreasing.

Observation Boreholes OW3S &OW3D



Observation boreholes OW3D (deep bedrock monitoring point) and OW3S (shallow subsoil monitoring point) are located within the confines of the Bog of the Ring Water Treatment Plant and approximately 910m from PW2. This monitoring point is outside the designated area of Bog of the Ring.

Information available from the drilling of this borehole indicates that the natural water level, pre-abstraction was approximately 0.5-1m bgl. The borehole log indicates that 6.1m of boulder clay overlies 3.65m of sandy clay which overlies bedrock at this location.

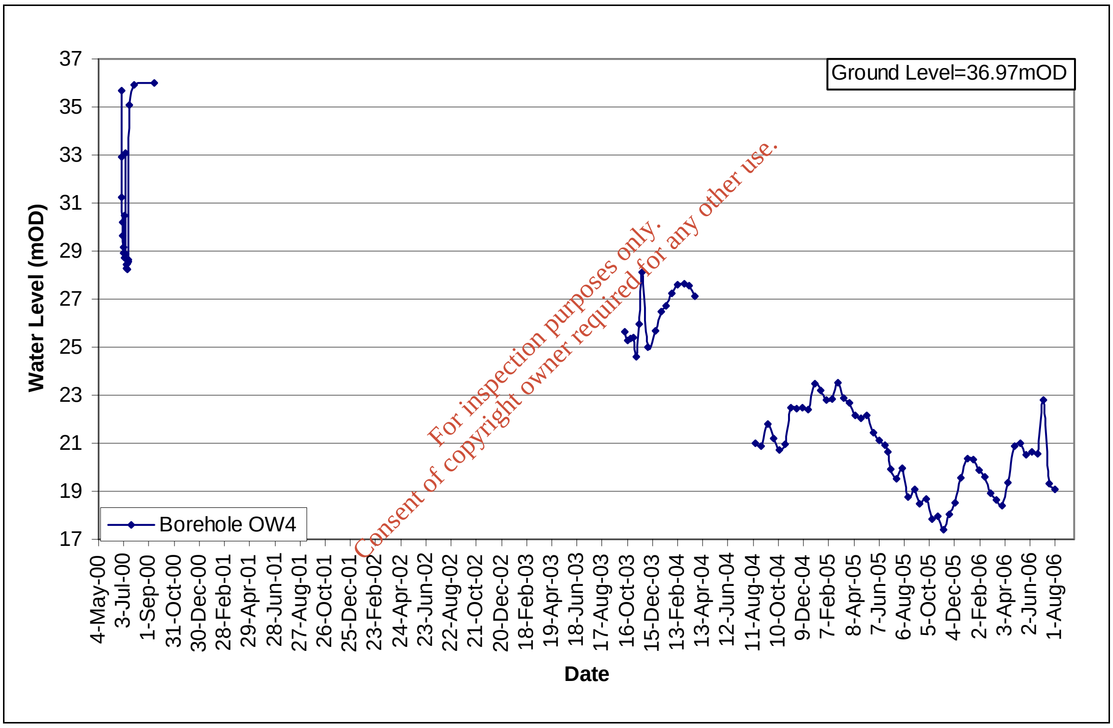
Observation data suggests that the water levels in these piezometers were significantly impacted during the hydraulic testing of PW1. Abstraction from PW1 is now discontinued.

The trend in the graph suggests that the Bog the Ring wellfield abstraction may be having a minor impact on the water levels in the OW3S and OW3D. However the level change is very minor and may be due to natural fluctuations rather than impacts due to abstraction.

Recovery in water levels had commenced at this borehole location in August 2004, when monitoring commenced. The level in August 2004 and August 2005 are relatively similar, however the recession on water levels in 2005 continued in these boreholes until early October 2005. The water level in October 2005 was approximately 1m lower than the lowest level in the previous year. The recovery in water levels in 2005/2006 was again approximately 1m lower than in the previous year. The water levels in August 2005 and August 2006 are very similar.

Water levels in the bedrock and the subsoil piezometers are very similar, therefore, there appears to be ready recharge to the bedrock environment from the overlying subsoils.

<u>Observation Borehole OW4</u>



Observation borehole OW4 is located approximately 5-10m from production borehole PW4. This observation borehole is immediately adjacent to the designated area of Bog of the Ring.

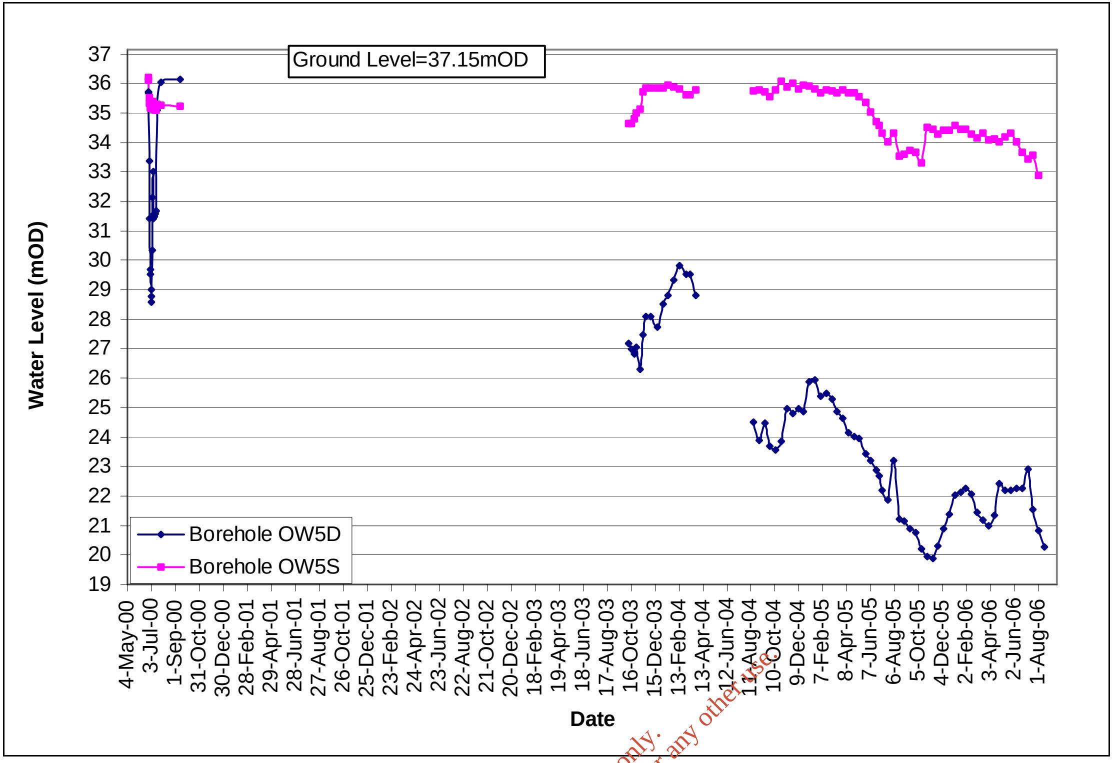
The borehole was drilled on an artificially raised platform (i.e. infilled platform). The historical data indicates that the water level in this area is approximately 1-1.5m bgl. The borehole was drilled through approximately 30.5m of subsoil and drilling continued open hole through the bedrock.

This borehole is located within the cone of depression induced by abstractions from PW4. The water level in OW4 is approximately 9-10m higher than PW4. This is considerable owing to the proximity of this monitoring point to the pumping well. This suggests that while the cone of depression induced by pumping is large, the most significant drawdown is very close to the actual abstraction point and this impact decreases within 10s of metres from the abstraction point.

The monitoring data indicates a declining trend overtime. Originally the water level at this point was approximately 1-1.5m bgl. Soon after commencement of abstraction from the scheme the water level had declined to 9-12.5m bgl (Sept 03-March 04). The monitoring undertaken by TES shows that, although winter recoveries occurred, a continuing declining trend is evident from August 2004 through to August 2005. However the monitoring data for August 2005 through to August 2006 shows a stabilisation in the water levels, with similar water level recorded in August 2005 as in August 2006. This suggests that equilibrium conditions may have been achieved.

Based on available data, the annual recovery in water levels in the bedrock occurs in this area in late September to early October and continues through to late February to early March.

Observation Boreholes OW5S & OW5D



This piezometer set are located approximately 55m from PW4. The shallow and deep boreholes are located immediately to the south of the public road and are drilled and the raised land platform for the road. They are within the designated area of the bog.

Information available from drilling indicates that approximately 40m of boulder clay exists in this area overlying bedrock.

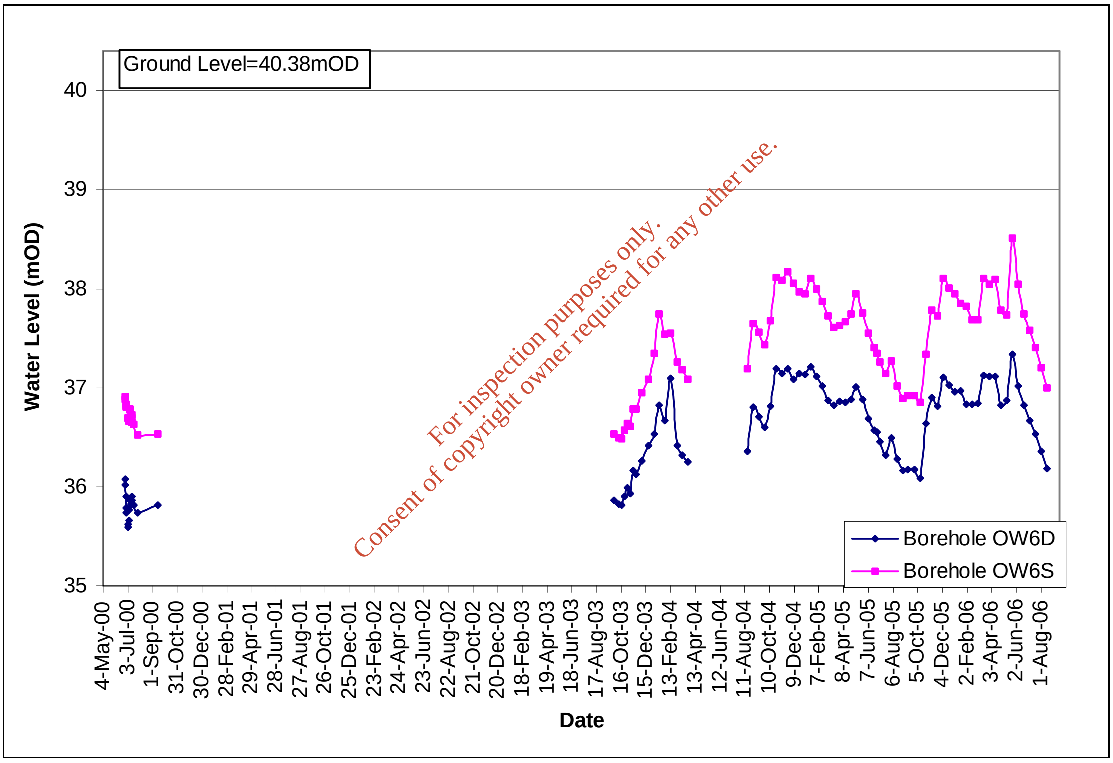
The available data from these piezometers suggests that water levels in the bedrock are significantly impacted as a result of pumping from the wellfield. This is not considered unusual owing to the proximity of PW4. The impact on the subsoil is very different to that occurring within the bedrock. Prior to commencement on abstraction in 2000, the water level in the shallow and deep boreholes was measured at approximately 1-1.5m bgl. The water levels in the shallow borehole since abstraction commenced have always been recorded within the interval of 1.5m to 3m bgl up to June 2005. From June 2005 onwards a decline in water levels has been observed, with the water level declining by approximately 3m up to October 2005 and thereafter recovering by 1m over the winter to early summer months of 2006.

A decline of 1m has been observed from June 2006 through to the end of monitoring in August 2006. This corresponds with a very dry summer.

The water level in the bedrock is 10-14m below that level recorded in the subsoil. The large difference in water levels in the bedrock is attributed to the low permeability of the subsoils with respect to the higher permeability of the bedrock.

On the whole it is suggested that while the bedrock water levels are significantly impacted, the shallow subsoil environment is not significantly impacted as a result of abstractions. This is most likely due to the thick low permeability subsoil cover over bedrock in this area. The water level in the shallow subsoil environment are more heavily impacted by meteorological conditions.

Observation Borehole OW6S & OW6D



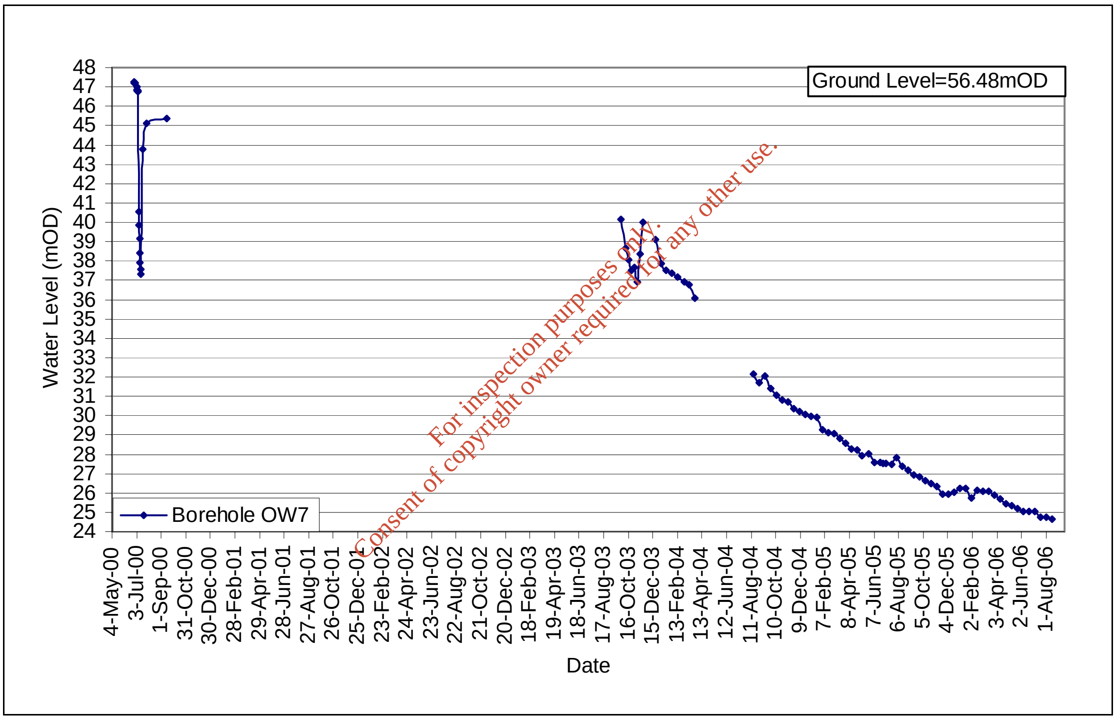
Observation borehole OW6S and OW6D are located approximately 1,380m from PW2 at Hynespark Crossroads. The boreholes are located well outside the boundary of the designated area.

A borehole log for these piezometers could not be located to determine the geological strata encountered.

The water levels in both the bedrock environment and the subsoil environment are relatively stable over the entire monitoring dataset. The water level in the bedrock is consistently 0.75-1m below the level recorded in the subsoil environment, during both summer recessions and winter recoveries. Also there are no apparent time lags for water level increase or decrease between the bedrock environment or the subsoil environment.

Owing to the regularity of the hydrograph from summer 2003 through to summer 2006, it is considered that the abstraction from the Bog of the Ring Scheme is not impacting the groundwater environment in this area. Therefore, the cone of depression induced by pumping does not extend to this area.

Observation Borehole OW7



Observation borehole OW7 is located 200m to the southwest of borehole PW5. The borehole is isolated to monitor the water level in the bedrock environment.

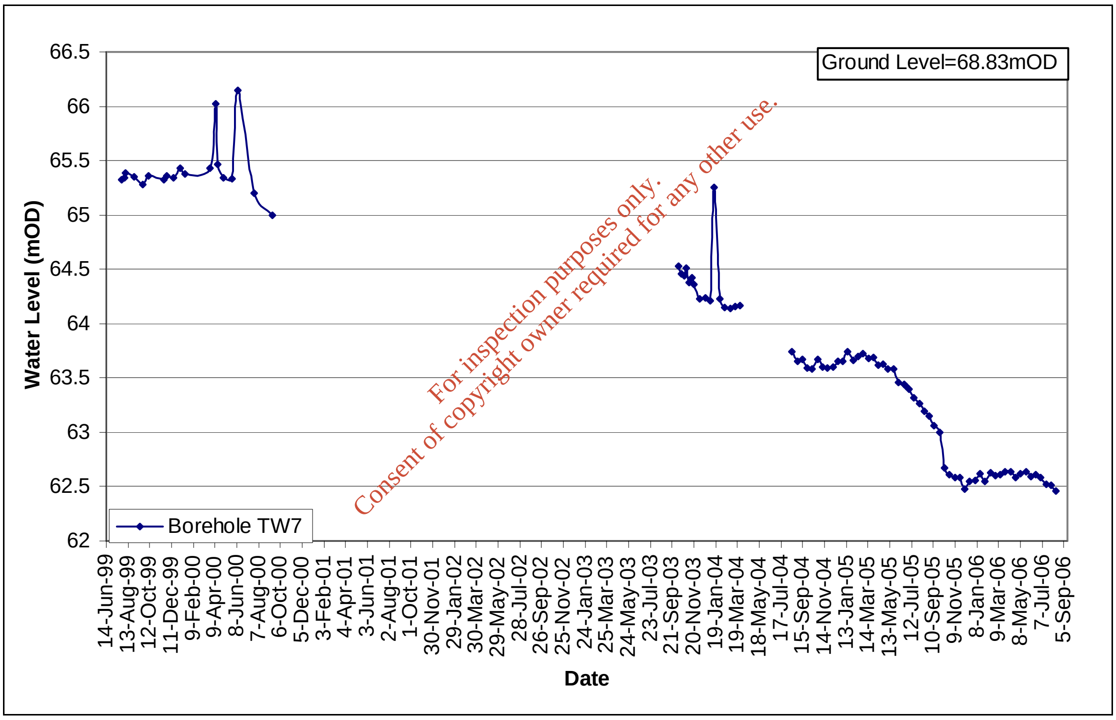
The borehole log indicates that approximately 24.4m of boulder clay was encountered overlying 21.3m of gravel overlying bedrock. This borehole is screened and isolated to monitoring bedrock water levels only.

The hydrograph indicates that during the testing of PW5, the water level in this borehole was impacted. A drawdown of approximately 10m maximum was recorded during July 2000.

Since pumping commenced from PW5 a consistent decrease in water level has been observed at this monitoring point. The shape of the drawdown curve at OW7 is very similar to that of PW5. The rate of water level decline has decreased in recent time (i.e. over the past 12 months or so), which was similarly observed in the curve for PW5. This suggests that the zone of depression is approaching equilibrium.

Based on the borehole log for this monitoring point, the water level in the aquifer remains in the gravel deposits.

Trial Borehole TW7



Trial borehole TW7 is located approximately 2km to the south of the wellfield and the drainage pattern suggests that groundwater flow in this area is to the east and not connected to the groundwater flow in the bog area.

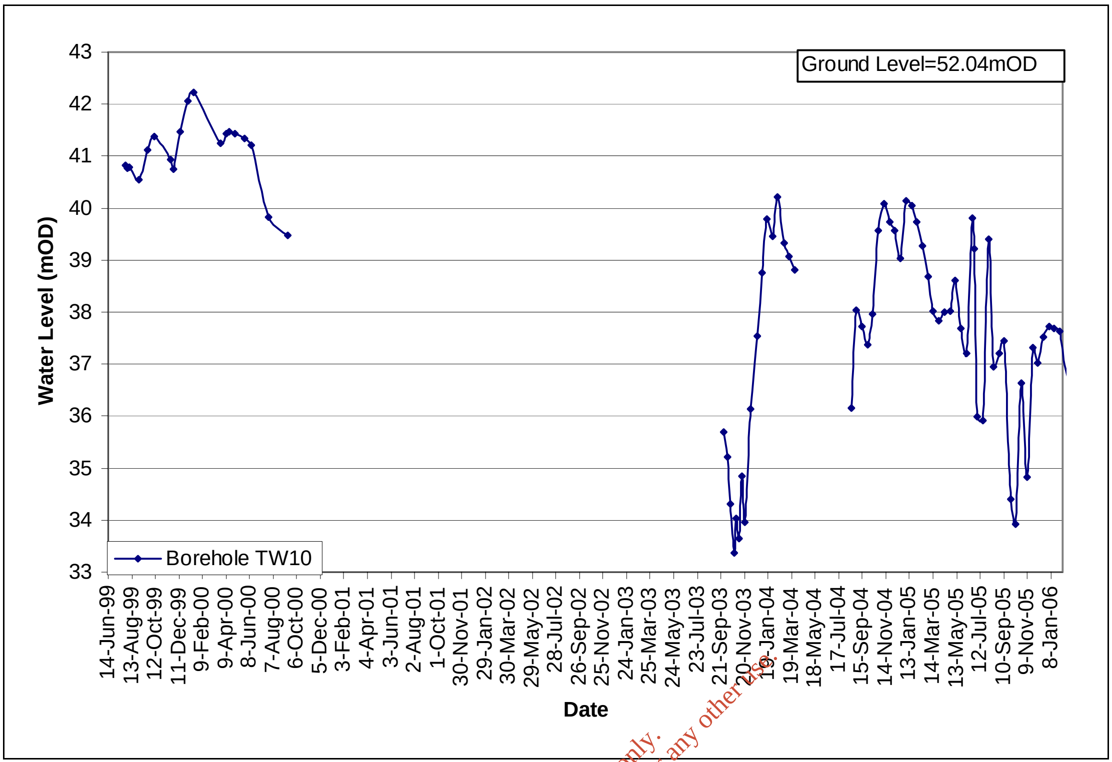
The borehole log indicates that approximately 22m of black boulder clay overlies black shale, which is highly weathered from 22m to 32m bgl.

The monitoring data suggests that the water level in this borehole was not impacted during the 2000 hydraulic testing programme. The monitoring data since abstraction commenced show a gradual decline. The precise reason for the decline is unproven. A water level decline of 3m at a distance of 2km would be significant if this were attributed to the groundwater abstractions.

The water level is relatively steady from August 2004 through to mid May 2005, at approximately 63.5-63.7m OD. From May 2005 to end September 2005 there is a consistent decline in water levels of approximately 1m. From September 2005 through to the end of monitoring in August 2006 the water level again is relatively steady at 62.5m OD.

Other monitoring points between the abstraction boreholes and trial borehole TW7 do not show the water level trends observed in TW7 (ref Trial Borehole TW10). Therefore it is concluded that the decline in TW7 is not associated with the abstraction scheme. It is suggested that the impact on TW7 is attributable to activities proximal to this source and is not associated with the abstraction from the Bog of the Ring Scheme. The groundwater level in the environs of PW1 was impacted by the construction of the M1 motorway. This may be a possible explanation for the fall in water level observed in TW7. Other possible explanations for such a fall are changes in abstraction rates in nearby households.

Trial Borehole TW10



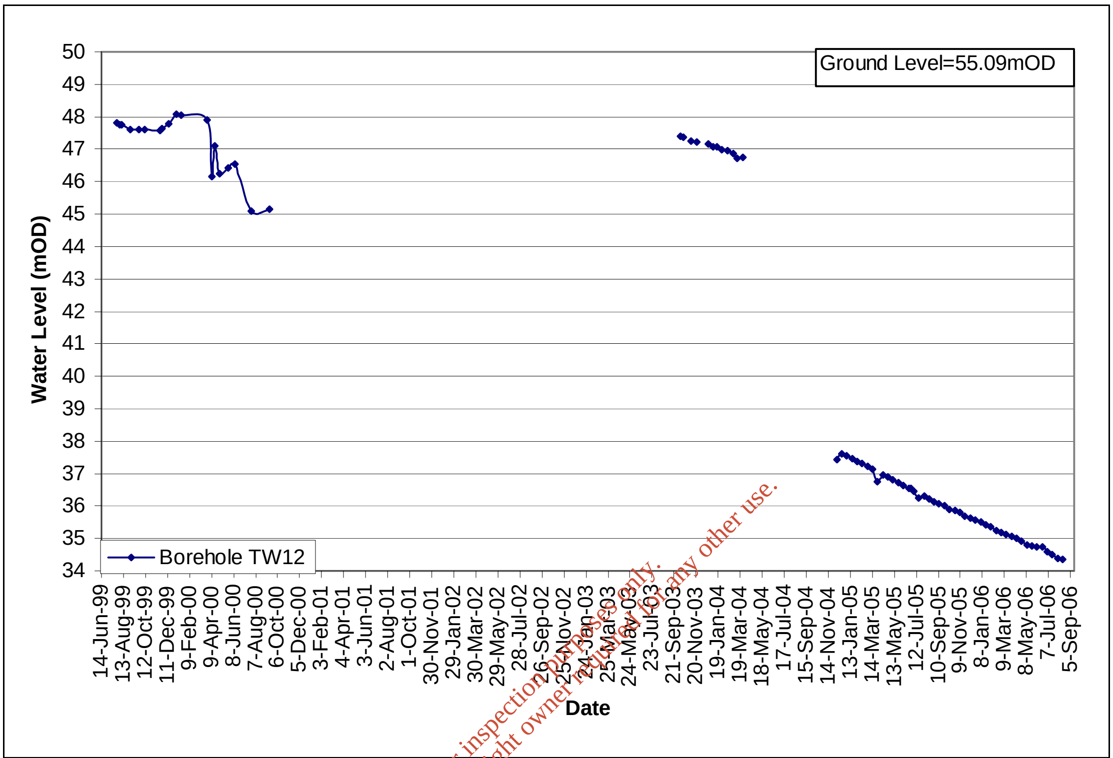
Trial borehole TW 10 is drilled on the flank of Knockbrack Hill. The borehole is located approximately 400m from abstraction borehole (PW2).

The borehole logs indicates that only 2m of clay/fill overlies shaley limestone bedrock.

The monitoring data for July 1999 to June 2000 suggests that the water levels in this borehole varied from 39.5-42.5m OD. This borehole appears to have been impacted during the hydraulic testing programme in the summer of 2000. The hydrograph from June 2003 through to August 2006 shows a relatively stable variation between summer and winter levels in successive years, with exception of winter 2005/2006 which was very dry. The water levels in the winter of 2005/2006 did not recover to levels achieved in previous winters, however this is considered to be due to meteorological conditions during this period (i.e. a dry winter period). The water levels in August 2003, 2005 and 2006 are very similar, however the water level in August 2004 is higher, suggesting more rainfall during the summer of 2004.

The relatively rapid change in the water levels suggests that the bedrock aquifer is readily recharged at this location during rainfall event, even during summer months, due to the thin overburden cover. This is consistent with the view that the majority of recharge to the Bog of the Ring aquifer is from the lands sloping toward the valley, rather than recharge within the valley itself.

Trial Borehole TW12



Trial borehole TW12 is located approximately 5m from production borehole PW5. The borehole log indicates that 30m of boulder clay overlies approximately 10m of gravel which overlies limestone bedrock.

The monitoring data indicates that prior to groundwater abstraction from the wellfield, the water level in TW12 was very stable with water levels recorded at 48m OD (7m bgl), with very little fluctuations between summer minimums and winter maximums.

The monitoring data also suggests that during the initial period of pumping from the well-field, the water level was not significantly impacted. A minor consistent reduction in water level was recorded up to March 2004, i.e. following 9 months of pumping, with the water level recorded at 47m OD. Following a short break in monitoring the water level was noted to have reduced significantly to 37.5m OD and this has continued to fall to a level of approximately 34.25m OD noted in August 2006.

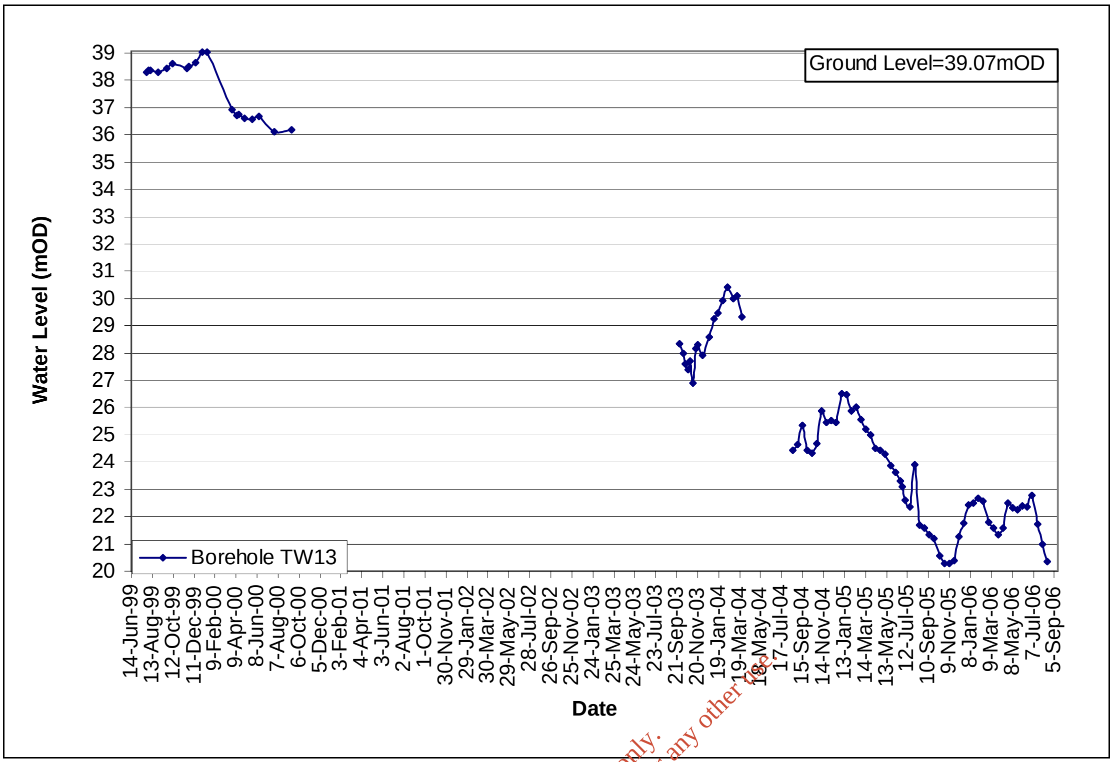
As detailed above, trial borehole TW12 is approximately 5m from PW5 and the current water level is 21m bgl. The water level in PW5 is currently 35m bgl. The water level in OW7, which is 200m from PW5 is 32m bgl. The variation in the recorded water level is not consistent with general groundwater flow principles, which would suggest that water levels falls are greatest proximal to the abstraction point, with a gradual lessening of impacts at greater radial distance from the abstraction borehole. However, the geological and hydrogeological environment at Bog of the Ring is complex.

A probable explanation for the water level being higher in TW12 than the other boreholes is a slow leakage of groundwater from the overburden into the bedrock environment. PW5 and OW7 are both isolated to record the water level in the bedrock only.

The drawdown in OW7 and TW12 suggests that groundwater in the bedrock is transmitted to the abstraction point PW5 more rapidly than the groundwater in the subsoil. The cone of depression around PW5 is quite large as a result of the low permeability of the boulder clay. Recharge of the bedrock is considered to be on the flanks of the hills adjacent to the valley.

The monitoring data from TW12 does not display any levelling of the water level decline observed in both PW5 and OW7. It is therefore concluded that there is continued downward percolation of groundwater from the overburden to the bedrock environment at the natural rate dictated by the permeability of the subsoil.

Trial Borehole TW13



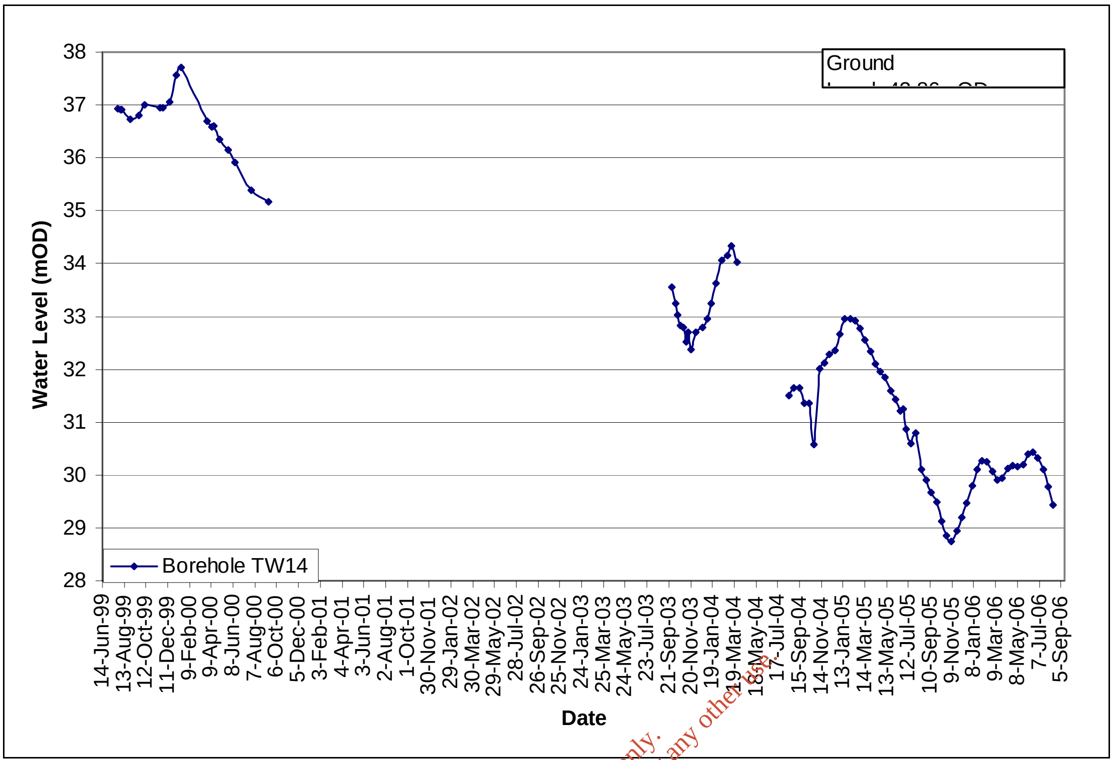
Trial borehole TW13 is located on the northern road verge approximately 310m to the northwest of PW4.

The borehole log for TW13 indicates that 36m of gravelly clay, with lenses of gravel overlies fissured and fractured limestone bedrock.

The monitoring data indicates that the initial water level at this location varied between 0m and 1m bgl. The borehole is located within the designated area therefore, such a water level is consistent with the wetland setting.

However, since the commencement of monitoring a consistent decline in water levels has been observed. This decline appears to have reduced in the past 12 months (i.e. from August 2005 to August 2006) and equilibrium conditions appear to be achieved. The water level in August 2005 is very similar to that of August 2006.

Trial Borehole TW14



Trial borehole TW14 is located on the hillside to the north of the bog valley. It is situated approximately 675m from the closest abstraction point (PW2). This borehole is located 250m from the alignment of the M1 motorway.

The natural water level in TW14 is recorded at approximately 6.5-8m bgl. The monitoring data suggests a reduction in the water level in this borehole over those recorded in 2000.

The water level monitoring since the commencement of abstraction from the scheme shows a decline in the water level in TW14. This decline has continued even though winter recoveries have been observed, i.e. a cumulative year on year decline. However the monitoring for 2005 to 2006 suggests that conditions approaching equilibrium have been achieved. The water level from June 2005 through to August 2006 are very similar.

Shallow Standpipes in the Organic Rich Clay Topsoil/Shallow Subsoil

A number of shallow standpipes have been installed within the designated area of the Bog of the Ring to determine if the groundwater abstraction is resulting in a progressive reduction in the watertable. This is of considerable importance as viability of continued groundwater abstractions from the pilot scheme will be dependent on ensuring that the water level in the soil environment is not significantly impacted.

Impacts on the soil environment as a result of the abstraction scheme would be apparent from progressive declining water levels in the shallow standpipes, indicating a drying out of the shallow soil/subsoil environment.

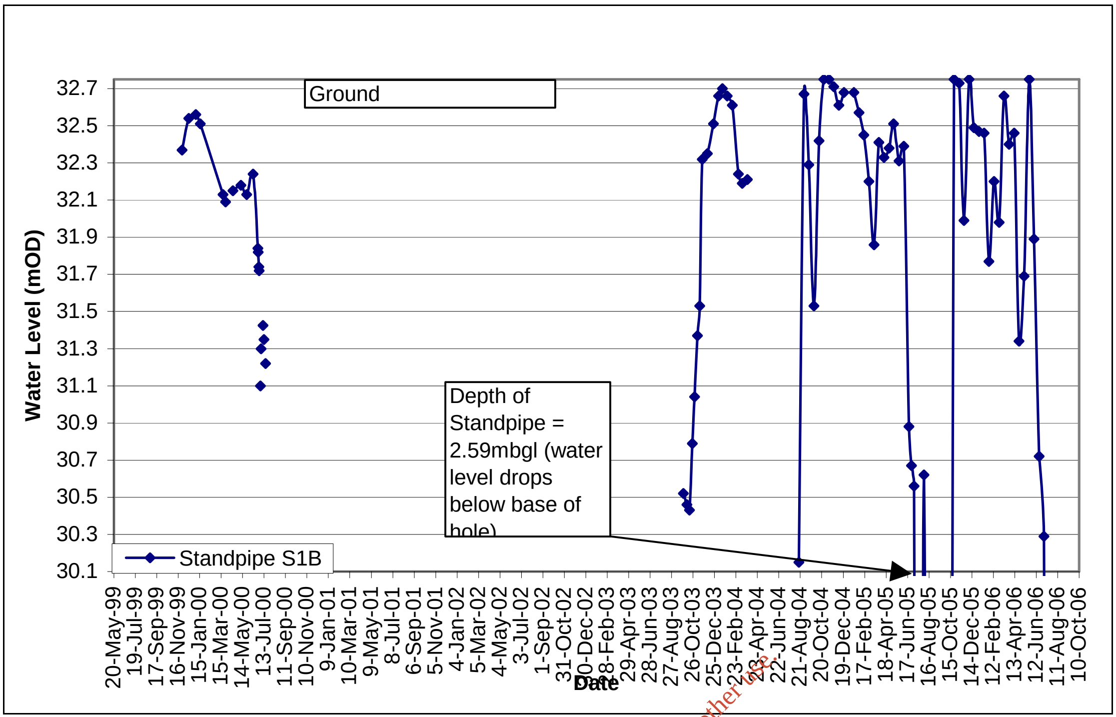
Site investigation undertaken across the designated area and adjacent lands indicates that the soil is predominantly an organic rich clay rather than a peat. Consequently natural watertable fluctuations are to be expected between winter maxima levels and summer minima levels.

Under natural conditions the watertable across the designated area is high and close to the surface to maintain growth of the wetland vegetation. A consistent lowering of this shallow watertable has the potential to significantly and permanently impact on the ecological status of the Bog of the Ring. Therefore, water level monitoring is a vital requirement to ascertain if the soil environment is being impacted over time (i.e. from commencement of abstraction from the scheme onwards).

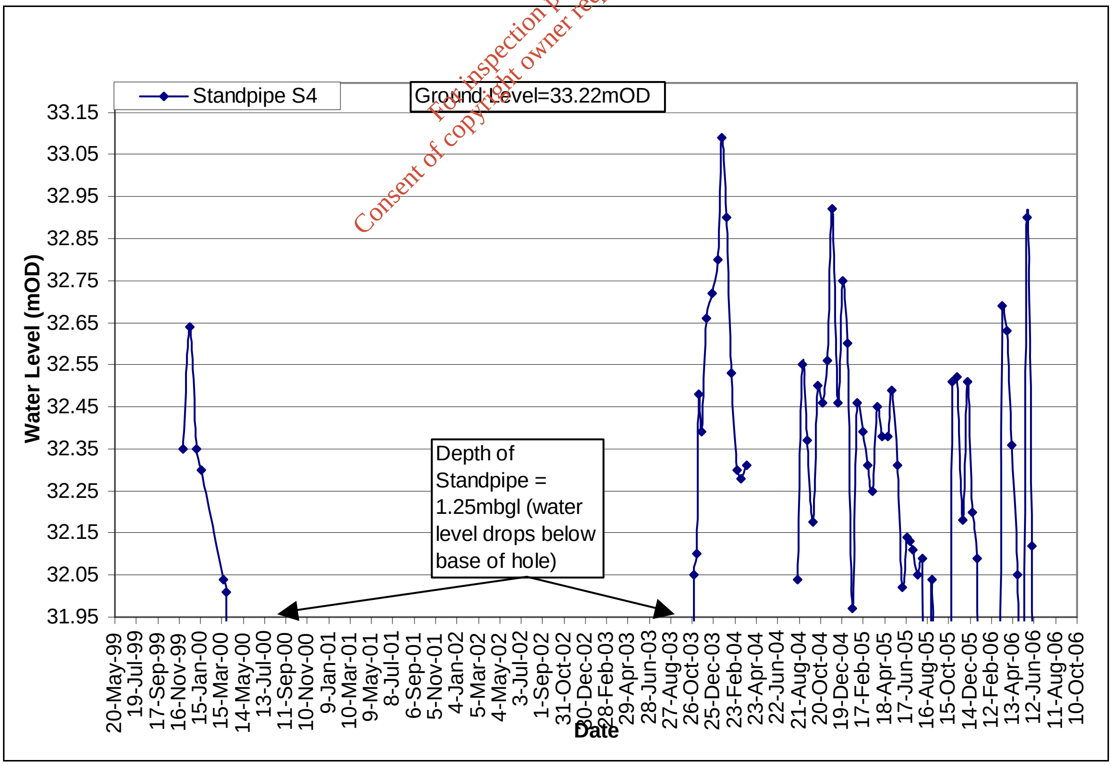
In 1999, prior to the commencement of abstraction from the Bog of the Ring Scheme, 23 No. shallow standpipes were installed across the designated area. A number of these shallow groundwater monitoring points (S1B, S4, S5, S6, S13, S14A, S14B, S17) have been in place since November 1999 and remained in-situ for the monitoring surveys undertaken by TES. A number of additional standpipes were installed in December 2005 to improve the coverage of monitoring points within the designated area. In total 4 No. standpipes were installed, 1 No. as a replacement to a previous monitoring point (S7) and 3 No. new monitoring points within the northern block of the designated area.

The monitoring data for all standpipes is presented below and the discussion of this data is grouped together, as the conclusions are very similar. All standpipes are located on the valley floor and within or immediately adjacent to the designated area (pNHA).

Standpipe S1B

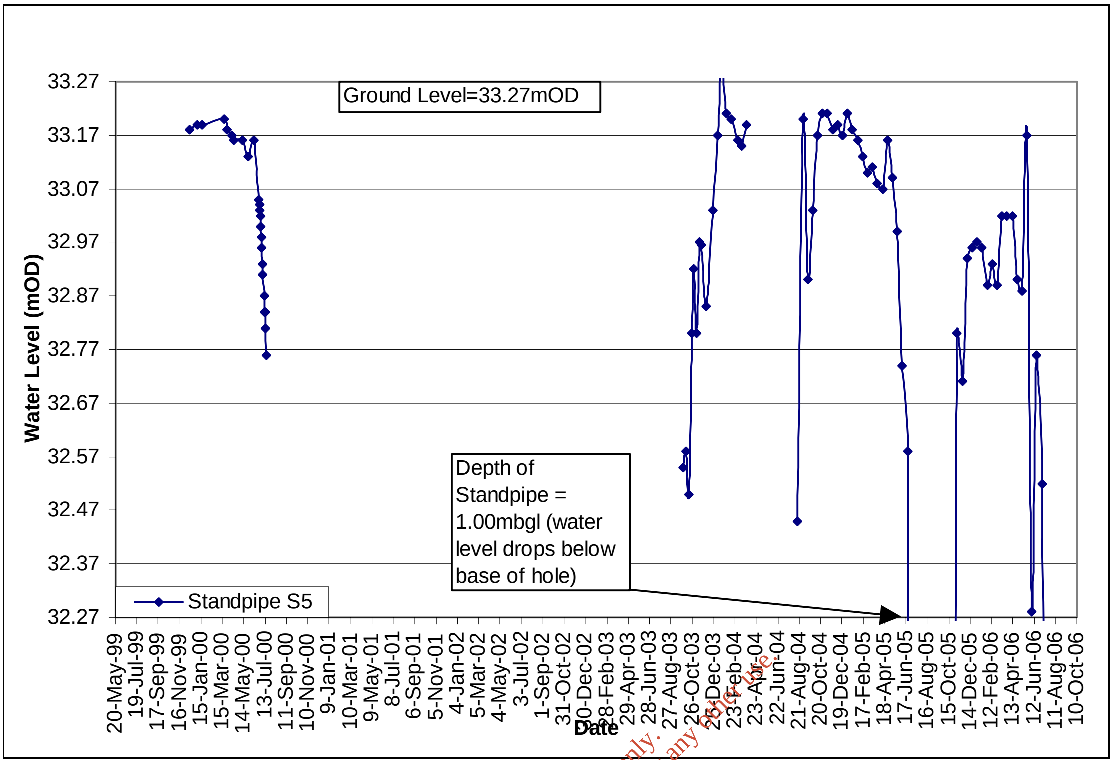


Standpipe 4

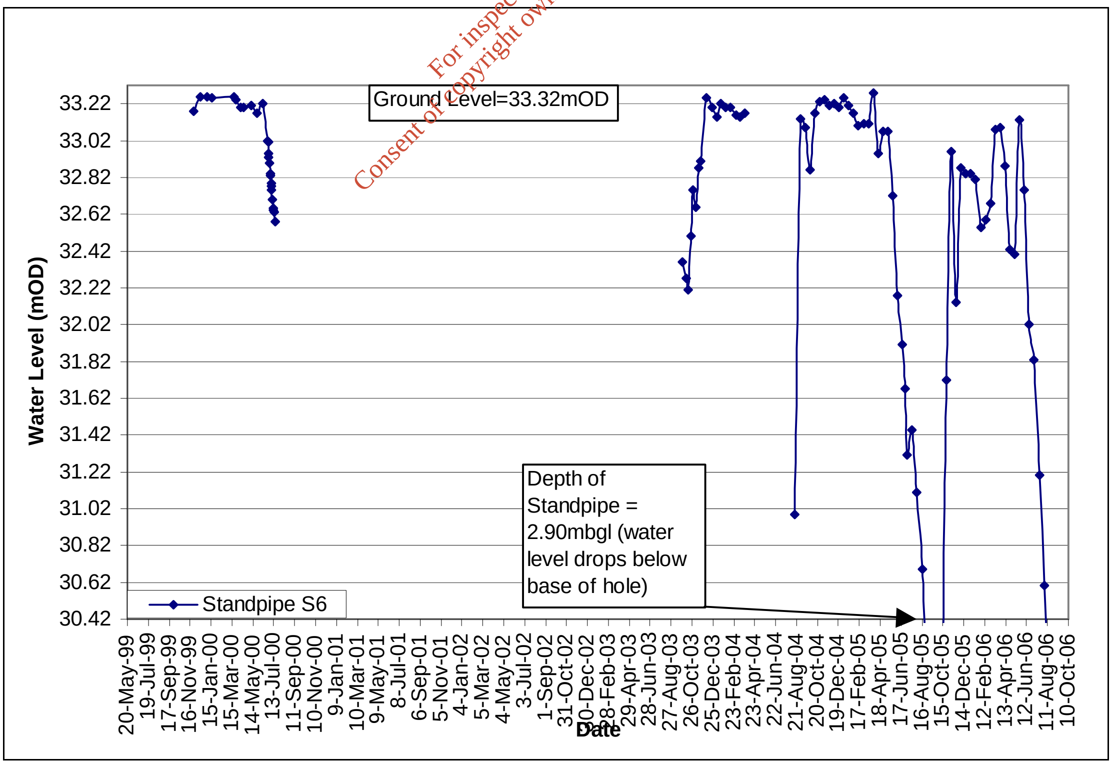


TES CONSULTING ENGINEERS

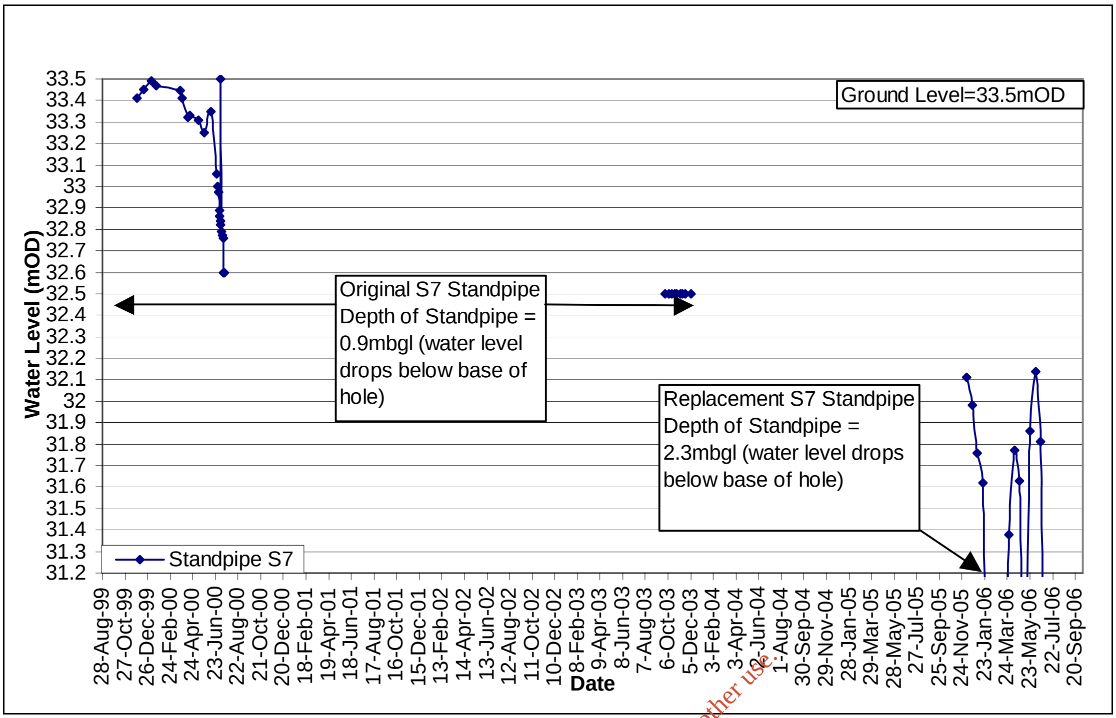
Standpipe S5



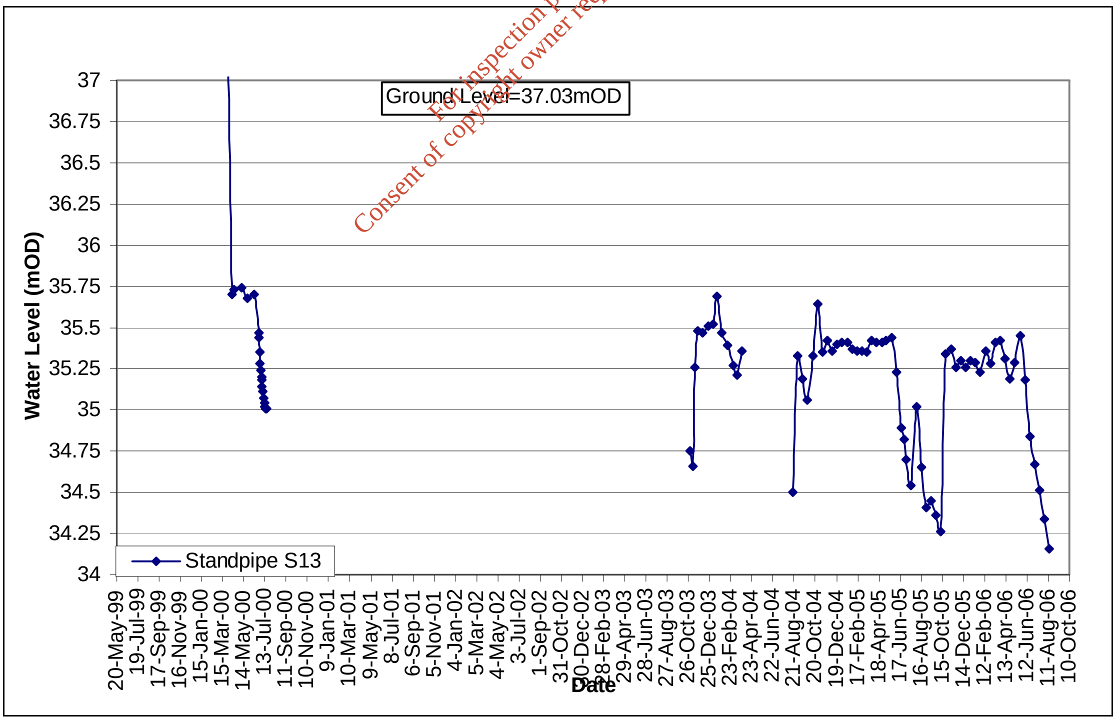
Standpipe S6



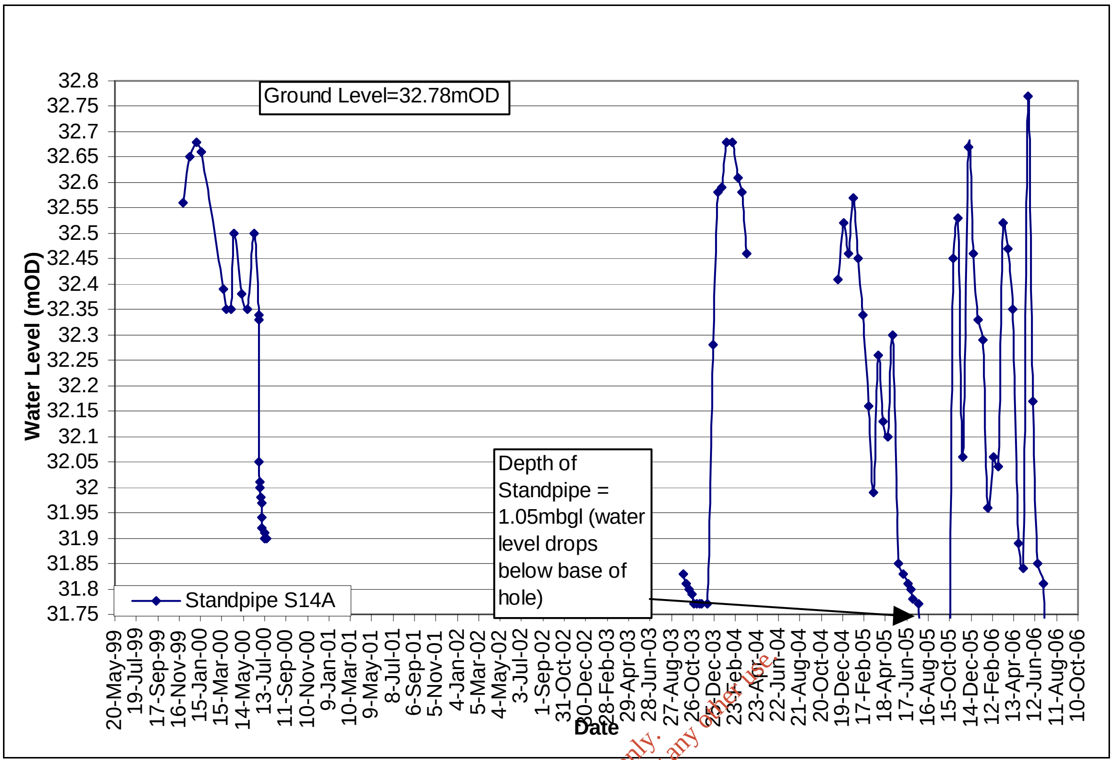
Standpipe S7



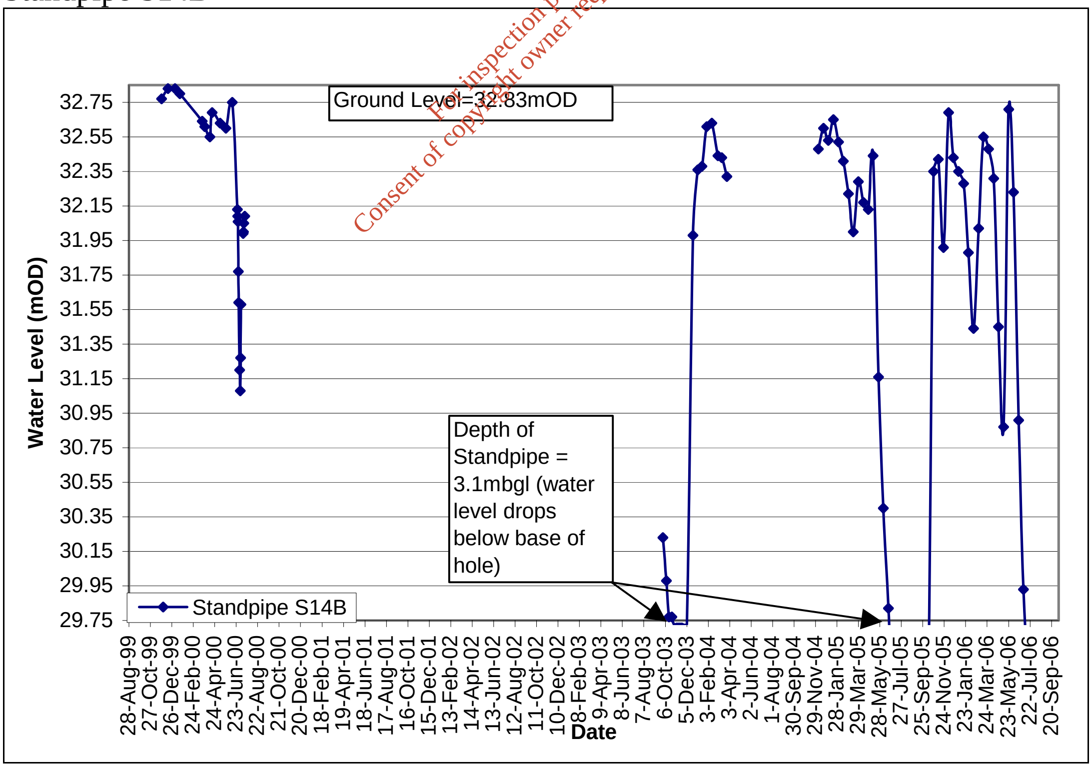
Standpipe S13



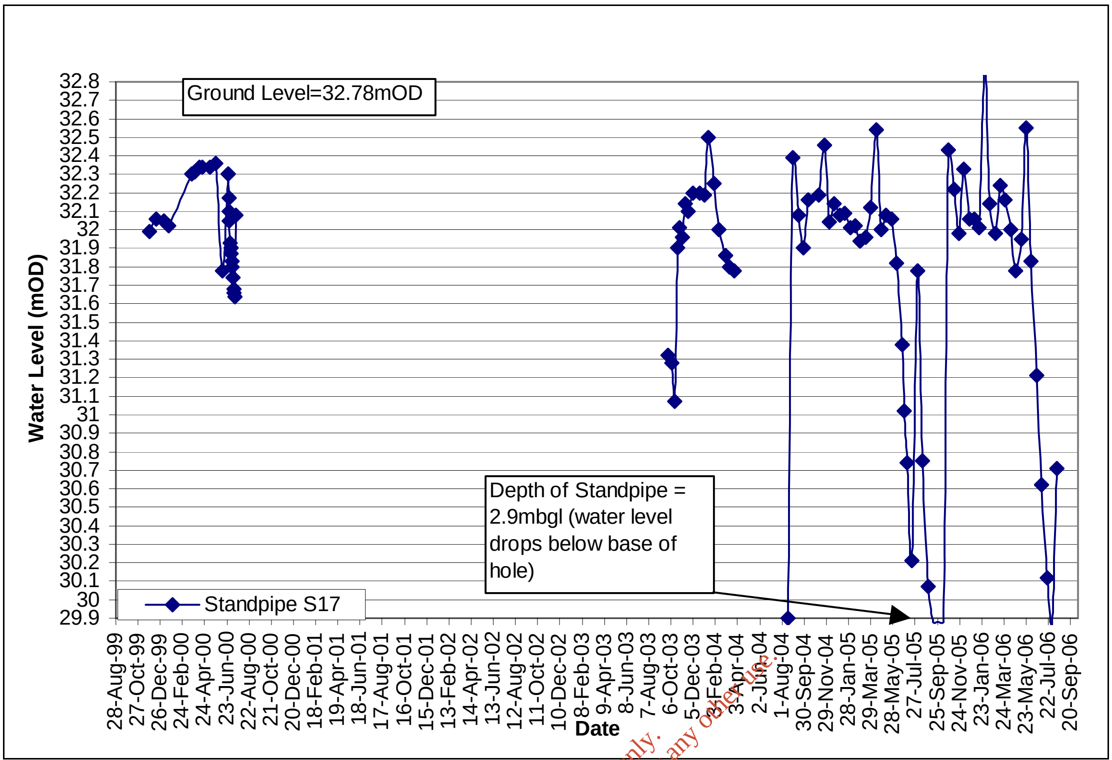
Standpipe S14A



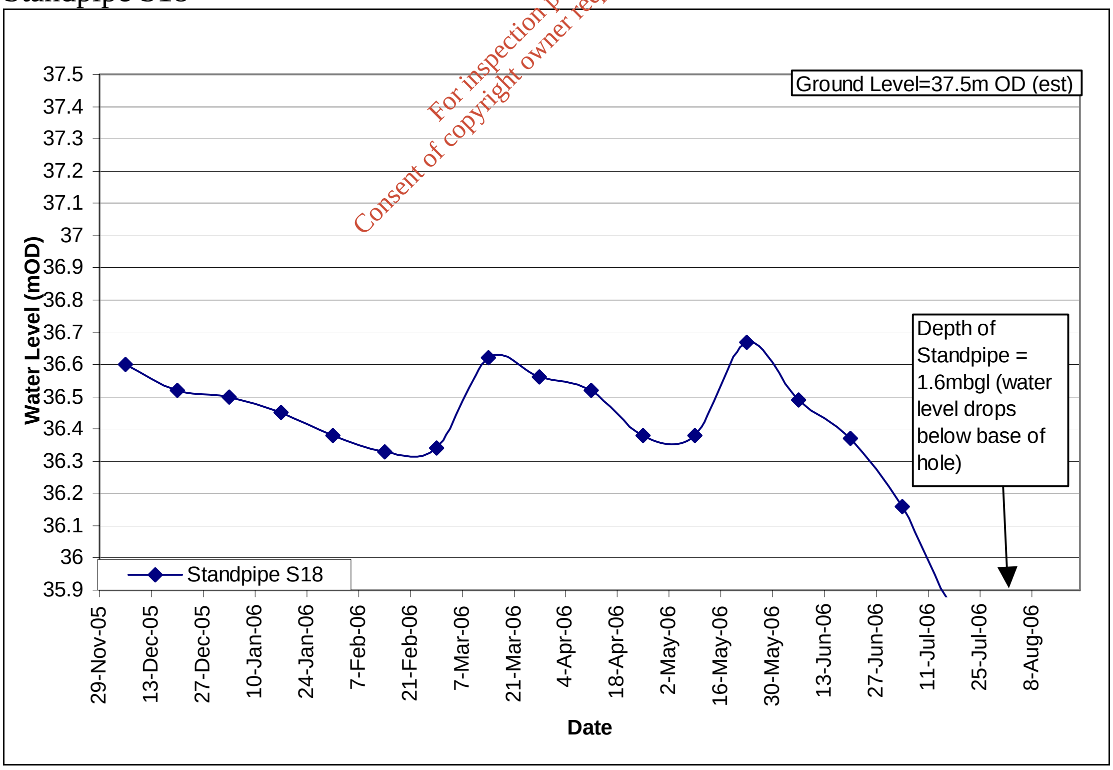
Standpipe S14B



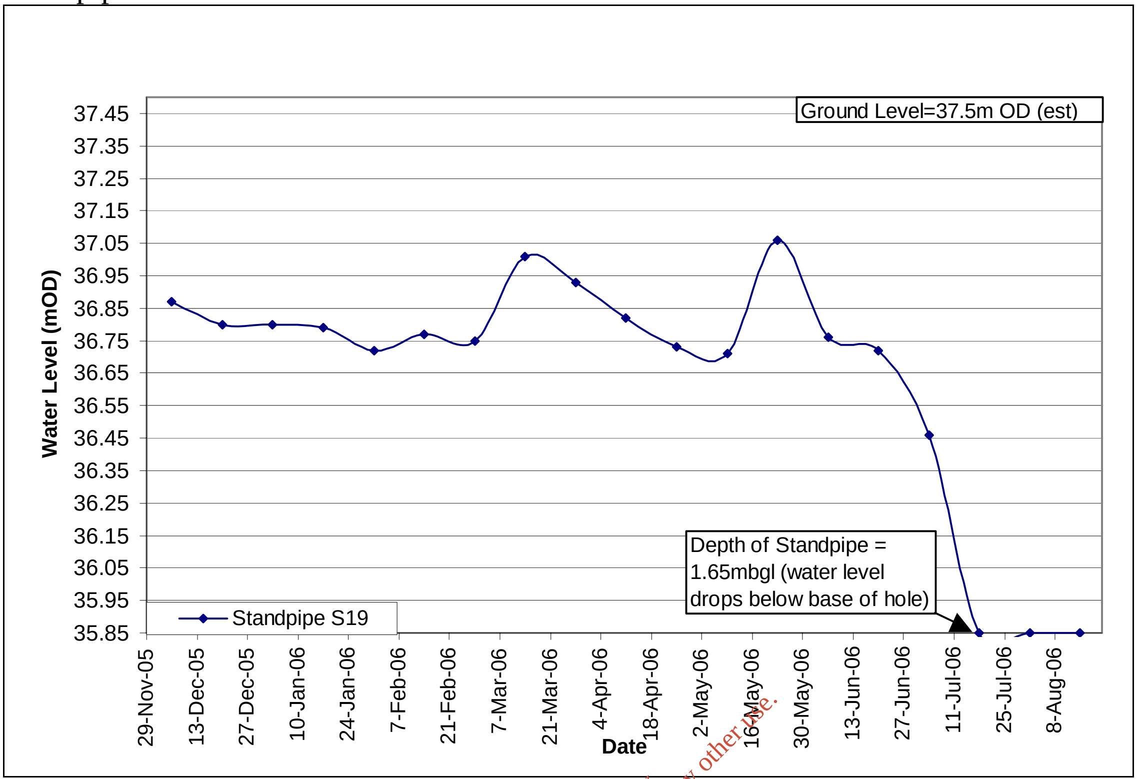
Standpipe S17



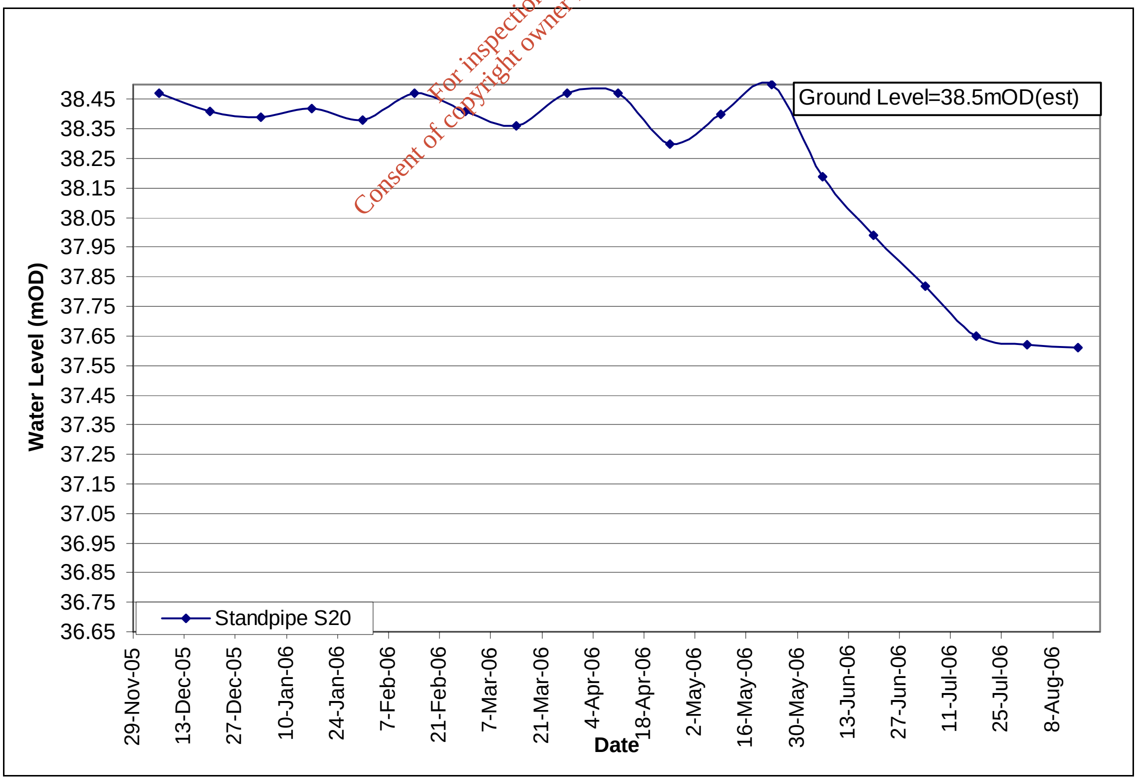
Standpipe S18



Standpipe S19



Standpipe S20



The objective of monitoring from these shallow standpipes is to ensure that the watertable across the designated area is not adversely impacted by the operation of the groundwater abstraction scheme. The long term viability of the abstraction scheme is subject to determining that abstraction scheme can be operated with no impacts on the wetland nature of the designated area.

The water level data for all shallow monitoring points indicates that the water levels fall during dry meteorological periods and corresponding periods of high plant moisture uptake. The water level within the bog floor can fall in excess of 3.1m (S14B). However the water levels increase rapidly following rainfall events. The water levels are generally steady and are generally high, i.e. watertable close to the surface, except during the summer months, when water levels in the Bog the Ring naturally decline. The water levels fall during summer. It would be expected that due to the low permeability of the clay topsoil/subsoil there would be a lag between rainfall and recharge. The response of increased water levels to rainfall suggests that the recharge is fast-tracked, through preferential flow conduits.

The available data suggests that the bog is not being consistently dried by groundwater abstractions. During much of the winter period the shallow topsoil environment is fully replenished.

Summary of Water Level Monitoring Programme

No significant impact has been displayed in the soil environment. The water level in the soil environment is dictated by the low infiltration capacity of the soil and the rainfall occurring throughout the year. The low infiltration rate holds the water at or close to the surface. There is a rapid response in water levels to rainfall events. This enables the growth of waterlogged vegetation throughout the year.

Where thick, low permeability overburden overlies bedrock, there is a significant difference between the subsoil and the bedrock water levels. This is apparent from the paired boreholes where the water levels in the subsoils are consistently higher than in the bedrock.

When assessing the water levels it is important to have regard to the proximity or distance to the abstraction boreholes. Very significant differences have been recorded in monitoring points within 10m of PW4 and PW5.

Bedrock water levels are generally lower than the subsoil water levels. This suggests that water flow through the bedrock is faster and less impeded than through the subsoil.

Recharge to the aquifer, and ultimately the production boreholes, is essentially a function of the infiltration capacity of the overburden. The overburden across the Bog of the Ring generally impedes infiltration. The overburden on the hillsides adjacent to the Bog of the Ring are generally free draining and act to provide significant recharge to the aquifer.

The monitoring data suggests that from mid 2005 to mid 2006 equilibrium conditions have generally been achieved or closely approached. The cones of depression induced by pumping have now stabilised, whereby there is sufficient catchment to enable recharge of the aquifer and thus maintain abstractions at a steady rate.

The water level monitoring has not produced evidence that the shallow soil environment is being progressively negatively impacted by the operation of the abstraction scheme. Ecological surveys of the Bog of the Ring have indicated that there is only a marginal drying of a small area of the designated area of the Bog of the Ring. It is concluded that the marginal drying is a factor of a very dry summer of 2006 and dredging works undertaken by the OPW in the past to improve land drainage.

8 GSI GROUNDWATER PROTECTION SCHEME REPORT

The Geological Survey of Ireland has prepared a Groundwater Protection Zones report for the Bog of the Ring, on behalf of Fingal County Council. A full copy of the GSI Groundwater Protection Scheme Report is included in Appendix E.

As part of the hydrogeological assessment, the GSI report was reviewed to assess the conceptual model of the aquifer hydraulic regime. The objective of the GSI report was to delineate source protection zones for the 4 No. production boreholes based on the principal hydrogeological characteristics of the Bog of the Ring area.

Some pertinent information regarding the geological and hydrogeological setting of the site are extracted from the GSI report:

- All in-service production boreholes are drilled into the Loughshinny Limestone Formation, which is described as a shaley limestone, which is presumed to be dolomitised. This limestone unit is grouped into a geological unit referred to as the Calp Limestone.

- The Calp Limestone occupies the low lying valley floor in this area, which is bound to the south and north by shales and sandstones. The distribution of geological units is shown on Map 1 of the GSI Groundwater Protection Zones report, included in Appendix E.

- The Calp Limestone is classified as a Locally Important Aquifer that is generally moderately productive (Lm). The Namurian Sandstones and Shales to the south of the valley are generally unproductive except in localised zones (i.e. Poor Aquifers). The Lower Palaeozoic rocks, which are faulted against the Bog of the Ring Limestone, to the north of the valley, are classified as Locally Important Aquifers.

- The description of the rock encountered during drilling is consistent with the mapped lithologies. The bedrock within the valley floor is highly fractured and fissured. Significant groundwater flow is recorded from these fractures and fissures. Water levels in the bedrock are generally lower than the subsoils suggesting that the bulk permeability of the bedrock is significantly higher than the subsoil.

- The subsoils in the region of Bog of the Ring comprise a mixture of fine to coarse grained materials, specifically till, lacustrine clays, alluvium and gravel. The GSI report indicates that the water level monitoring shows a variation in the response of rainfall recorded in subsoil monitoring boreholes. In places a rapid response to rainfall is observed in the subsoils, indicating high infiltration rates and permeability. In other places, especially within the Bog of the Ring area, the response is significantly delayed, indicating low permeability subsoils. It is concluded from the water level monitoring that the aquifer is readily recharged along the edge of the valley and on the hillsides following rainfall events.

- Over much of this region, the depth to bedrock is generally greater than 10m and on the valley floor the depth to bedrock typically exceeds 15m. The upper subsoil layer comprises boulder clay and the lower subsoil layer comprises saturated granular material.

- Meteorological data indicates that the 30 year average rainfall in this area is 808mm/year. Allowing for free evaporation and plant transpiration, the potential available recharge is 358mm/year. However, actual aquifer recharge is dictated by the permeability and thickness of mineral subsoils. In the Protection Zone report, the GSI have allowed recharge coefficients for each subsoil type and thickness. The recharge ranges from 0mm/year (where thick, low permeability conditions occur and the aquifer is confined) to 322mm/year (where the subsoil is thin and permeable). The GSI report concludes that the recharge over most of the area is estimated to be approximately 57mm/year.

- Owing to the presence of low permeability clays over much of the valley floor where the Bog of the Ring designated area occurs, the recharge is assumed to be very low to absent. The predominant recharge zones for the aquifer are on the higher elevation lands where the lands are freer draining.

- Hydrogeological data from the GSI report indicates a degree of hydraulic continuity between the mineral subsoils and the bedrock, however this is variable depending on the nature of the subsoil, i.e. whether low permeability clays or high permeability sands and gravels.

- An approximate 5-15m thick layer of sands and gravels are recorded overlying bedrock in the Bog area. The sands and gravel are overlain by an approximate 10m thick layer of low permeability clays.

- While hydrogeological data indicates the occurrence of high transmissivity zones in the Calp Limestone, the GSI report, supported by the TES water level monitoring findings, indicates that the limiting factor on sustained supplies from the Bog of the Ring scheme is low potential for the aquifer to receive recharge.

- The water level monitoring suggests that the percolation rate of groundwater from the subsoils to the bedrock is the limiting factor. The bedrock is capable of transmitting groundwater to the boreholes, however the sustainability factor is dictated by the recharge from the subsoils.

- In the immediate environs of the production boreholes, the pumped water level is lowered to within the bedrock zone. However, the water levels in the observation boreholes indicate that the water level is generally above or within the gravel.

- The groundwater vulnerability over the majority of the lands in the Bog of the Ring area are classified as low, due to the presence of a thick, low permeability subsoil. The vulnerability on the northern and southern flanks of the hills adjacent to the valley, which is the main recharge area for the Bog of the Ring, varies from low to extreme (defined GSI Vulnerability Categories) and is dependent on the thickness of the subsoil overlying bedrock.

- Groundwater flow in the bedrock is through faults and fractures in the bedrock, with the main fracture alignment believed to be along a west-northwest to south-southeast zone.

- The eastern extent of the cone of depression induced by abstraction from the scheme is situated between Decoy Bridge and the old N1 roadway. The western extent of the cone of depression induced by abstraction is situated near Hazardstown. The western boundary suggests that the groundwater divide for the Bog of the Ring Abstraction Scheme extends into the River Delvin surface water catchment. The northern and southern boundaries are coincident with the break in topography. Drainage from the north and south is dependent on gravity flow towards the valley floor through the subsoils.

- Numerical modelling of the groundwater regime in the environs of Bog of the Ring indicates an exceptionally complex hydrogeological regime. However, as submitted in the Groundwater Protection Zone report, an available catchment area exists to support abstractions up to 3,500cu.m/day, however significant uncertainties and assumptions are incorporated into the model. The GSI recommend further monitoring to assess the reliability of the model output. The water level monitoring and reporting herein addresses this recommendation.

- The numerical model was also used to assess the catchments for increasing abstraction up to approximately 5,000cu.m/day (i.e. by increasing abstraction by 50% from PW2, PW3 and PW5).

It not the purpose of this report to validate the findings of the numerical model prepared by the GSI in the Groundwater Source Protection Zones report. However the conceptual model and the justification of parameter inputs to the model appears to be well founded and the level of information available on the hydraulic monitoring data and constraints on recharge should allow for sufficient calibration.

The recharge rate is considered conservative, but was based on very little data at the time of the model simulation. The water level monitoring programme has shown response to rainfall events, suggesting that the recharge may be higher than used in the model. The water level monitoring indicates that the aquifer responds to rainfall. The recharge rate is higher in the valley edge and on the hillside and along the stream channel, where higher infiltration rates can be expected due to the occurrence of higher permeability subsoils.

The main numerical model was simulated for an abstraction rate of 3,500cu.m/day, a sensitivity analysis was undertaken at an abstraction rate of up to 5,000cu.m/day. The GSI analysis does not show a significant change to the main simulation. It is suggested that with a slightly higher recharge rate incorporated into the model, which would be justified based on the water level monitoring programme, an abstraction rate of 4,000cu.m.day would be readily achievable.

The GSI report does not purport to provide a basis for estimating the sustainable yield of the production borehole. The GSI report recommends a programme of water level monitoring to establish a reliable basis for such estimation.

Information detailed regarding the numerical model of the Bog of the Ring is a summary of the detailed information included in the GSI Source Protection Zones report (GSI, January 2005). It is strongly recommended that the GSI report is referenced as the primary data source when reviewing the groundwater regime within the Bog of the Ring area. A full copy of the GSI Source Protection Zone report, is reproduced in Appendix E of this report for ease of reference.

9 SUSTAINABILITY OF GROUNDWATER FROM BEDROCK AQUIFER

A specific assessment was required to assess the maximum sustainable yield of the Bog of the Ring aquifer, as opposed to sustainable yield from the current scheme. The objective of this assessment is to determine if any potential exists for expanding the Bog of the Ring Groundwater Abstraction Scheme.

The sustainable supply assessment of the production boreholes is fully detailed in Section 5 of this report. This assessment, based on borehole hydraulics and monitoring data, has estimated that the production boreholes are capable of the following long term yields:

- PW2 1,500cu.m/day
- PW3 1,100cu.m/day
- PW4 150cu.m/day
- PW5 1,100cu.m/day

Total: 3,850cu.m/day

This section addresses the potential of the limestone aquifer as a groundwater unit, as opposed to specifically assessing the production boreholes. This examination is based on an assessment of existing topographic and geological maps for the region, together with hydrogeological interpretations provided in the GSI Groundwater Protection Zones report and findings from the water levelling programme.

The site investigations undertaken within the Bog of the Ring area have indicated the major water bearing aquifer unit in this area is the Loughshinny Formation. Production borehole PW2, PW3 and PW5 are highly productive and drilled into this unit. Production borehole PW4 is also drilled into this unit but is of significantly lower potential than the other boreholes.

Production borehole PW1 was drilled to the east of the M1 alignment and records indicate that it encountered different geological material than PW2, PW3 and PW5 further west. It is suggested therefore that the a north-south trending geological fault in this area has impacted on the groundwater potential.

Therefore, the study of the aquifer potential in the Bog of the Ring area focuses on the aquifer potential of the limestone rock on the valley floor to the west of the M1, which is bound to the south by rock which is classified as a Poorly Productive Aquifer. The Bog of the Ring Aquifer is defined as the bedrock unit servicing the existing production boreholes.

The investigations undertaken in the Bog of the Ring area indicate that the major control of the hydrogeology is the low recharge rate. The occurrence of thick, low permeability subsoil overlying the Bog of the Ring valley floor significantly impedes infiltration of rainwater to the bedrock.

However, the monitoring undertaken by TES Consulting Engineers has shown a relatively quick response in subsoil and bedrock water levels to rainfall events. Therefore, it is concluded that the aquifer is recharged at a higher rate than used in the GSI numerical model. It is concluded that fast recharge occurs on the hillsides to the north and south of the valley (due to the occurrence of higher permeability subsoils), while slow recharge occurs within the valley floor (due to the occurrence of low permeability subsoils). For calculation purposes, based on site investigation data and subsoil distribution, 75% of the land feeding the aquifer is limited to a recharge rate of 57mm/year (i.e. owing to the prevalence of low permeability subsoils) and the remaining 25% of the area was recharged at a rate of 322mm/year (i.e. the maximum estimated actual recharge value quoted in the GSI Report).

The maximum abstraction rate used in this calculation was 4,080cu.m/day (1,490,220cu.m/year), which equates to the current operating capacity of the treatment works. The land area required (i.e. referred to as the 'Cone of Depression' or 'Zone of Influence') to provide recharge to the aquifer, using the recharge coefficients detailed above, to allow abstraction of 4,080cu.m/day is calculated as 12km^2. The cone of depression delineated by TES from both the water level monitoring programme data and the information gained from the GSI numerical model, is provided on Figure 3 herein.

The catchment area for the Bog of the Ring scheme presented by the GSI comprises an area of approximately 17.5km^2 (Ref. Map 5 of the Groundwater Protection Scheme). Based on the low recharge rate allowed in the numerical model, an area of 17.5sq.km is required to allow abstraction.

However, the water level monitoring programme has determined a conflict in the catchment area delineated by the GSI and the cone of depression delineated by TES. The main difference in the cone of depression delineated by TES and the catchment area delineated by the GSI results is the inclusion of a significant catchment area (approximately 5km^2) to the east of the M1 in the GSI map. The water level monitoring undertaken by TES indicates that the abstraction scheme is not impacting on water levels at observation borehole OW6. There is only a very small impact on water levels at trial borehole OW3. Therefore the cone of depression boundary is somewhere in between these points.

Therefore, it is submitted that the area to the east of the M1 should not be included in the cone of depression of the abstraction scheme.

The water level monitoring programme does indicate that the water levels are impacted at distances from the abstraction points. The cone of depression (i.e. the area around the abstraction point where water levels are reduced) formed by the abstraction is large. The large cones of depression have formed owing to the geology of the area, whereby recharge to the aquifer is low due to the dominance of the low permeability clay overlying the valley floor. The main recharge area for the aquifer is from the hillsides to the north and south of the valley, where the subsoils are more permeable and generally thinner, allowing higher infiltration of rainwater to the aquifer.

The cone of depression delineated by TES is generally consistent with the GSI catchment boundary, with the exception of the eastern area of approximately 5sq.km, which was removed by TES, based on water level monitoring findings. The cone of depression boundary to the north, south and west is generally consistent with the GSI catchment boundaries.

In the environs of PW5, groundwater flow is induced to flow across a sub-catchment boundary. Groundwater in the bedrock to the west of this area, that would normally contribute to the River Delvin catchment, is reversed to flow towards PW5. The large size of the cone of depression around PW5 is due to the very thick, low permeability clay cover in this area. The impact of this reversed groundwater flow is considered low to imperceptible, owing to the existence of a thick deposit (up to 20m) of low permeability subsoil. Therefore there is no risk of the abstraction reducing the baseflow to the River Delvin.

At present there are 4 No. production boreholes abstracting from the aquifer. The boreholes have been situated in areas of known aquifer productivity, however the cones of depression have gradually enlarged (owing to the limited recharge of the bedrock aquifer) to an extent where they overlap. This is not considered to significantly impact on the performance of any individual abstraction borehole or the overall scheme. The water level monitoring data indicate that it has taken up to two years for the scheme to achieve equilibrium conditions. The monitoring indicates that the water levels in the bedrock and subsoil have been relatively stable from June/July 2005 to August 2006.

The site investigations (i.e. trial borehole drilling) have shown that the bedrock is most productive within the limestones along the valley of Bog of the Ring. The fracturing within the bedrock has resulted in a high permeability media for groundwater movement. However, the sustainability of supplies from such an aquifer are ultimately dictated by the rate at which the bedrock is replenished by recharge, i.e. a balance has to be maintained between input and output.

The site investigation and the water level monitoring show that the overburden restricts the recharge of the limestone aquifer along the valley floor. This is considered a significant limiting factor on the aquifer as a whole. The cones of depressions induced by the current abstraction have enlarged to an extent whereby the area required to sustain the current abstraction is approximately 12sq.km. This is very large and crosses a surface water catchment boundary to the west.

As detailed earlier in this section, the Bog of the Ring Aquifer is defined as the bedrock unit servicing the existing production boreholes. It is therefore submitted that there is no significant scope for increasing abstraction from the Bog of the Ring Aquifer.

Increasing abstraction from the scheme has the potential to over-exploit the aquifer, whereby there is insufficient recharge to the aquifer to meet the abstraction. Any increase in abstraction would result in an enlargement of the zone of contribution that would be considered excessive and unsustainable.

While the current zone of contribution extends slightly into the River Delvin catchment, increased abstraction would result in a extension of the zone of contribution significantly into a River Delvin area, which could potentially result in an impact on the River Delvin.

Based on existing studies on the Bog of the Ring Aquifer, the estimated sustainable yield from this aquifer is approximately 4,000cu.m/day (+/- 15%).

10 CONCLUSIONS

This report has been prepared by TES Consulting Engineers for Fingal County Council, as the final hydrogeological assessment of the Bog of the Ring Groundwater Abstraction Scheme, following from the 2 year water levelling programme, ranging from August 2004 to August 2006 and all existing data back to 1994.

The Bog of the Ring is located in north County Dublin. The site is approximately 4km to the east of Naul and 5km to the southwest of Balbriggan. The M1 motorway carriageway encroaches on the eastern extremity of the site.

Fingal County Council operate the Bog of the Ring Groundwater Abstraction Scheme to augment potable water supplies to north County Dublin.

The Bog of the Ring Groundwater Abstraction Scheme sources raw groundwater from 4 No. Production Boreholes. The raw groundwater is transmitted to a Water Treatment Plant prior to being pumped to the distribution network. Groundwater abstractions for the scheme commenced in July 2003.

Bog of the Ring is an ecologically sensitive area and is designated by the Department of Environment, Heritage and Local Government as a proposed Natural Heritage Area (pNHA).

A network of groundwater monitoring boreholes and standpipes have been installed in the Bog of the Ring area since investigations begun on the Abstraction Scheme. The water levels have been monitored from the installations to establish if the groundwater abstraction is having any long term negative impact.

This report has been prepared to provide as detailed as possible responses to the following:

1. Is the Bog of the Ring Groundwater Abstraction Scheme impacting of the ecological status of the designated area (pNHA).
2. What is the maximum sustainable yield from the current array of abstraction boreholes.
3. What is the sustainable yield from the aquifer.
4. Are the findings of the water level monitoring and the current understanding of the aquifer consistent with previous studies undertaken in this area.

Ecological Status of the Designated Area (pNHA)

With respect to the assessment of ecological impacts as a result of the abstraction scheme, the following is concluded:

- Monitoring of the shallow soil water levels have been on-going over the two year survey period, to specifically focus of the potential impact on the abstraction on the wet nature of the site.

- The water level monitoring programme indicates that the shallow soil environment is rewetted rapidly following rainfall events. While drying of the soil environment is noted during prolonged periods of dry weather, the water levels rebound to at or close to the surface.

- Ecological surveys were also undertaken to assess the current status of the site (2006) relative to the status in 1999 (i.e. pre abstraction).

- There is no significant difference between the habitat surveys conducted in 1999 (prior to commencement of abstraction) and 2006 (3 years following commencement of abstraction).

- The hedgerow surveys indicate the findings of 1999 and 2006 are consistent, however it is noted that the hedgerows have received no management in the intervening years;

- The detailed vegetation monitoring observed a marginal change in some areas of the designated site from the 1999 survey to the 2006 survey. The change is attributed to lack of site management (i.e. lack of grazing and cutting) and some drying of land.

- The water level monitoring has concluded that the soil environment is rewetted rapidly following rainfall, it is concluded that the marginal drying is attributable to a very dry summer in 2006 coupled with the arterial drainage improvement works undertaken by the OPW in the past.

- It is concluded that the operation of the Bog of the Ring Groundwater Abstraction Scheme is not significantly impacting on the ecological status of the designated area.

Sustainable Yield from the Current Array of Abstraction Boreholes

With respect to the assessment of sustainable yield from the current array of abstraction boreholes, the following is concluded:

- Abstraction from Bog of the Ring has been on-going since July 2003.
- Raw groundwater is currently abstracted from 4 No. Production Boreholes (PW2, PW3, PW4 and PW5).
- The information available indicates that the hydraulic efficiency of the boreholes has decreased significantly from the original borehole hydraulic characteristics determined in 2000.
- The decrease in hydraulic efficiency has been calculated, based on August 2006 data, varying between 54.2% (PW2) to 77.94% (PW5).
- This report concludes that the 2000 pump test programme over-estimated the potential of the aquifer.
- The data available following almost 3 years of continuous abstraction is considered a more reliable indicator of the true potential of the overall system.
- The potential of the bedrock system cannot be separated from the overlying subsoil, as the overburden ultimately dictates the rate of aquifer recharge and thus impacts on the sustainable supply from a particular abstraction point.
- Based on assessment of the abstraction borehole yields and water levels, together with interrogation of the monitoring borehole data, the following are provided as the maximum sustainable yield:
    - Production Borehole PW2 1500cu.m/day
    - Production Borehole PW3 1100cu.m/day
    - Production Borehole PW4 150cu.m/day
    - Production Borehole PW5 1100cu.m/day

      Total 3,850cu.m/day
- It is recommended that the hydraulic efficiency of the boreholes is examined annually to assess the continued performance of the boreholes.

Sustainable Yield from the Aquifer

With respect to the assessment of the potential for expansion of the scheme, the following is concluded:

- The site investigations undertaken within the Bog of the Ring area have found that the major water bearing aquifer is restricted to the Limestone Aquifer occupying the valley floor.

- The thick deposit of low permeability clays within the valley floor generally impede infiltration of rainwater and recharge of the aquifer.

- The abstraction from the current array of production boreholes has resulted in the formation of large cones of depression, which have extended over a large area (calculated as 12sq.km). The cones of depression is essentially the area of land required to provide adequate recharge to the underlying aquifer.

- The extent of the cone of depression delineated from the water level monitoring data and the existing hydrogeological understanding of the site is essentially confined to the west of the M1 motorway. The cone of depression extends across a surface water catchment (i.e. into the River Delvin catchment) to the west. The impact of the groundwater cone of depression extending into the River Delvin catchment is considered imperceptible with respect to surface flows. The boundary of the cone of depression to the north and south are generally consistent with the topography and surface drainage into the Bog of the Ring Valley.

- It is concluded that there is no significant scope for increasing abstraction from the Bog of the Ring aquifer without an unsustainable enlargement of the cone of depression.

- Increasing abstraction from the scheme has the potential to over-exploit the aquifer, whereby there is insufficient recharge to the aquifer to meet the abstraction.

- Based on all monitoring data to date on the Bog of the Ring Aquifer, the estimated sustainable yield from this aquifer is approximately 4,000cu.m/day (+/- 15%).

Comparison of water level monitoring findings with previous studies

With respect to the findings of the water level monitoring with previous investigations, the following is concluded:

- Studies undertaken prior to the commencement of abstraction indicated that the water level in the soil environment within the designated area would naturally fall during prolonged dry periods, especially during the summer and recover during wet periods. The water level monitoring has verified this, with water level recovery in the soil environment rebounding rapidly in response to rainfall. The water level monitoring in the soil environment has demonstrated that there is no progressive lowering of shallow soil water levels.

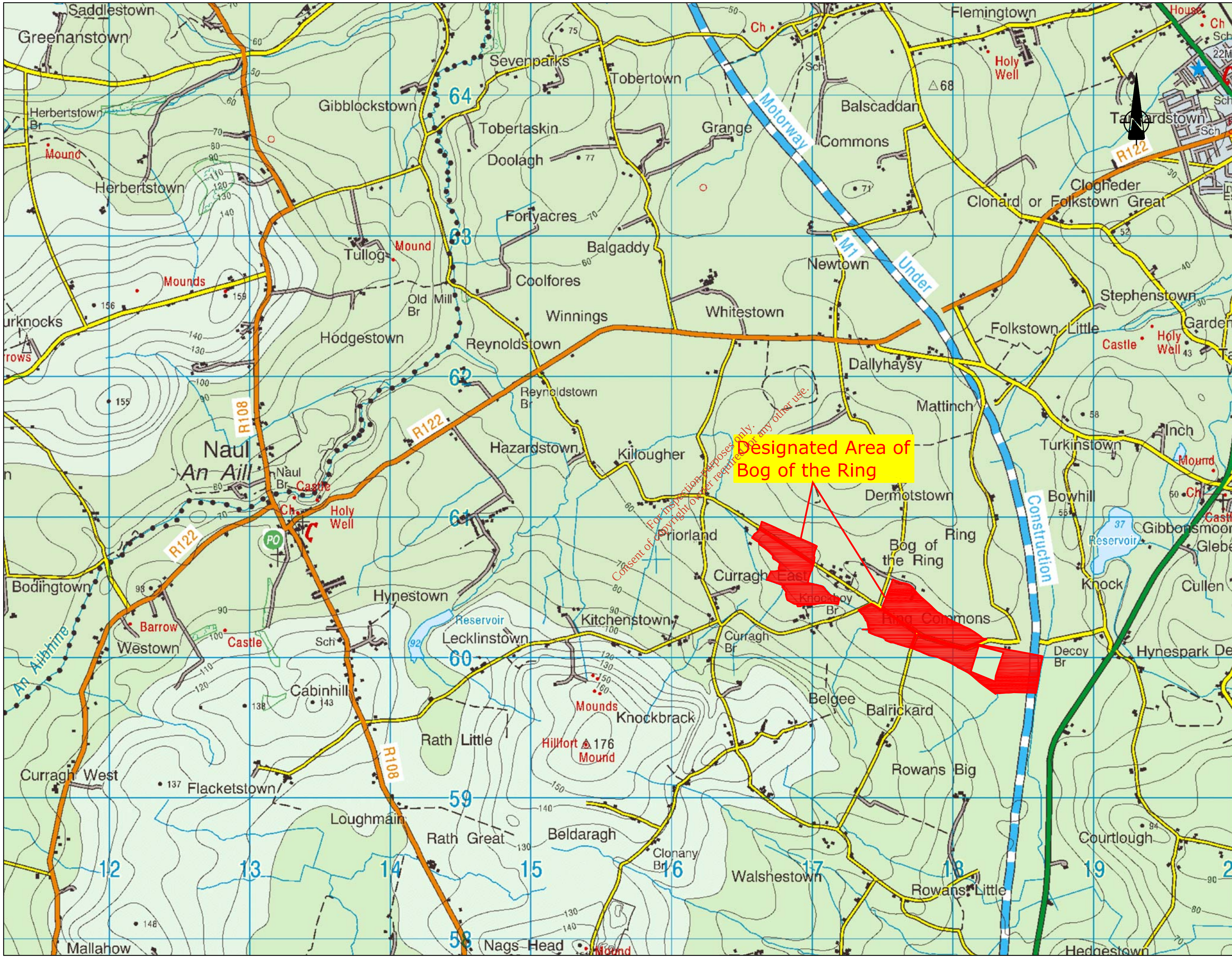
- The initial pump testing of the production boreholes indicated that the aquifer was highly productive, with very high productivity characteristics. However, following 3 years of almost continuous abstraction, the hydraulic characteristics have decreased significantly. It is concluded that the initial pump tests resulted in an over-estimation of the productivity of the aquifer. The most recent data is considered a more accurate reflection of the overall hydrogeological regime in the Bog of the Ring area.

- The water level monitoring programme indicates that a sustainable supply is available from the Bog of the Ring aquifer (4,000cu.m/day +/- 15%), which is consistent with the design capacity of the treatment works (4,080cu.m/day).

- The extent of the cone of depression delineated from the water level monitoring programme are generally consistent with the catchment area delineated by the GSI, which one notable exception. The GSI include a significant area to the east of the M1 motorway (approximately 5sq.km). The monitoring programme indicates that the cone of depression induced by abstraction does not extend into this area.

- It is noted that all previous site investigation data and GSI Source Protection information was assessed and utilised during the course of the monitoring programme. It is therefore acknowledged that similarities will inevitably be deduced by using some of the same dataset.

- It is suggested that further monitoring be undertaken at a lesser frequency (i.e. quarterly per annum) to verify the findings of this report and to provide further analysis of the performance of the Bog of the Ring Abstraction Scheme.



Legend:

Lands covered under the Bog of the Ring proposed Natural Heritage Area (Site Code 1204)

NOTE: Ordnance Survey Ireland Licence No. EN001602

Notes:

1. Figured Dimensions only to be taken from this drawing
2. All Drawings to be checked by the Contractor on site
3. Engineer to be informed of any discrepancies before any work commences
4. All levels relate to Ordnance Survey Datum at Malin Head

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Client

FINGAL COUNTY COUNCIL

Project

GROUNDWATER MONITORING
BOG OF THE RING

Drawing Title

REGIONAL LOCATION OF
BOG OF THE RING

Scale 1/25,000 @A3

Drawn by	Checked by	Date
SIOBHAIN TINNELLY	MARK CONROY	DECEMBER 2005

ENGINEER IN CHARGE:

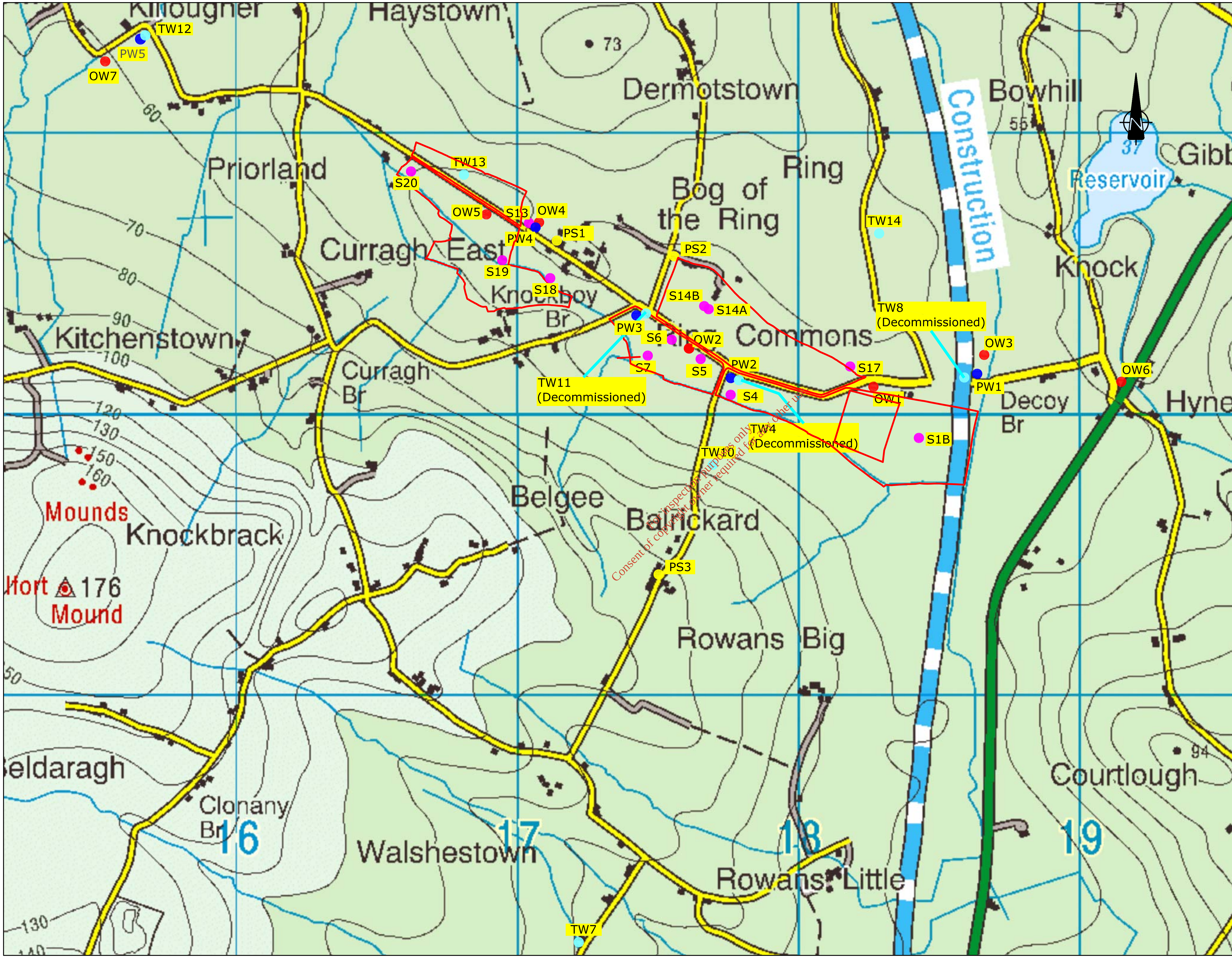
TES CONSULTING ENGINEERS

UNIT 4B/5,
BLANCHARDSTOWN CORPORATE PARK,
DUBLIN 15,
IRELAND
TEL. 01 8030401
FAX. 01 8030410
email administration@tesltd.ie

Drawing No.

Figure No. 1

Rev.



Legend:

- PRODUCTION WELLS
- OBSERVATION WELLS
- TRIAL WELLS (1994)
- STANDPIPES (SHALLOW MONITORING POINTS)
- DISUSED PUBLIC HAND PUMPS
- BOG OF THE RING BOUNDARY

Notes:

1. Figured Dimensions only to be taken from this drawing
2. All Drawings to be checked by the Contractor on site
3. Engineer to be informed of any discrepancies before any work commences
4. All levels relate to Ordnance Survey Datum at Malin Head

suffix	revisions	date	init

Client

FINGAL COUNTY COUNCIL

Project

GROUNDWATER MONITORING
BOG OF THE RING

Drawing Title

LOCATION OF MONITORING POINTS

Scale 1/12,500

Drawn by	Checked by	Date
SIOBHAN TINNELLY	MARK CONROY	DECEMBER 2005

ENGINEER IN CHARGE:

TES
CONSULTING ENGINEERS

Drawing No.

Figure No. 2

Rev.

Legend:

- PRODUCTION WELLS
- OBSERVATION WELLS
- TRIAL WELLS (1994)
- STANDPIPES (SHALLOW MONITORING POINTS)
- DISUSED PUBLIC HAND PUMPS
- BOG OF THE RING BOUNDARY
- GROUNDWATER CATCHMENT BOUNDARY

Notes:

1. Figured Dimensions only to be taken from this drawing
2. All Drawings to be checked by the Contractor on site
3. Engineer to be informed of any discrepancies before any work commences
4. All levels relate to Ordnance Survey Datum at Malin Head

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Client

FINGAL COUNTY COUNCIL

Project

GROUNDWATER MONITORING
BOG OF THE RING

Drawing Title

DELINEATION OF EXTENT
OF CONE OF DEPRESSION

Scale 1/20,000 @ A3

Drawn by	Checked by	Date
SIOBHAIN TINNELLY	MARK CONROY	SEPTEMBER 2006

ENGINEER IN CHARGE:

TES CONSULTING ENGINEERS
UNIT 4B/5,
BLANCHARDSTOWN CORPORATE PARK,
DUBLIN 15.
IRELAND
TEL. 01 8030401
FAX. 01 8030410
email administration@tesltd.ie

Drawing No.

Figure No. 3

Rev.