firth consultants
environmental risk assessment

15 May 2024
Our file: fc37067

Douglas Weir
Malone O'Regan Consulting Engineers
2B Richview Office Park
Clonskeagh
Dublin 14, D14 XT57

Dear Douglas

Re: Expert hydro-geotechnical opinion, Coolaghknock Glebe, Kildare, Co. Kildare

Further to your instruction we are pleased to provide you with an expert hydro-geotechnical opinion relating to the thickness of unsaturated zone below the planned infiltration basin for the proposed housing development at the above site.

Background and Objectives

There is a planning application for a residential development comprising 131 no. units to be located in the townland of Coolaghknock Glebe, Kildare, Co. Kildare. The proposed surface water strategy for the development includes a number of Sustainable Drainage Scheme (SuDS) measures with the overflow directed towards a single infiltration basin. The basin has been designed to store runoff from extreme 1 in 100 year rainfall events while allowing the water to percolate into the ground.

A requirement of Kildare County Council (KCC) is that the base of the infiltration basin (from which infiltration occurs) is at least 1m above groundwater level. KCC have said that this requirement has not been clearly demonstrated for the proposed scheme. However, they will accept "*expert hydro-geotechnical opinion if it can be shown using the information we have that there is 1m unsaturated zone below the pond*."

The objective of this letter report is to provide an expert hydro-geotechnical opinion on the likely thickness of unsaturated zone below the base of the infiltration basin.

Professional Experience

This report has been prepared by Simon Firth of Firth Consultants Ltd. Simon is an environmental consultant with 27 years' experience in hydrogeology and land contamination and has worked with Malone O'Regan Environmental in Ireland over the past 14 years. Simon has a BSc Honours in Physical Geography and an MSc (with

Distinction) in Hydrogeology, the latter of which was obtained from University College London in 1995.

Simon is a fellow of the UK Geological Society and Chartered Geologist. He is also a member of the Society of Brownfield Risk Assessment (SoBRA) and accredited SoBRA risk assessor (including for groundwater risk assessments) (ASoBRA).

Full details of Simon's qualifications and experience are provided in Annex 1.

Site Description

The proposed development site is located on the eastern edge of the townland of Coolaghknock Glebe, approximately 1.5km east of Kildare town (see Figure A). The site is approximately rectangular in shape with approximate dimensions of 340m by 115m and an area of 4 ha. The site currently comprises two grassed fields and there is a small waste water treatment works within the southern field (adjacent the south western site boundary). Ground levels at the site range from approximately 104 m OD Malin in the northern corner to 98 m OD Malin in the southern corner.

Figure A: Site location

Proposed Development

The proposed development comprises 131 no. units with associated roadways and public open space areas. A drawing showing the proposed development layout is shown in Annex 2.

The proposed surface water strategy for the development includes a number of SuDS measures with the overflow directed towards a single infiltration basin in the south west corner of the site. The basin has been designed to store runoff from extreme 1 in 100 year rainfall events while allowing the water to percolate into the ground. The base of the basin will be at an elevation of 96.13 m OD Malin. A drawing showing the proposed SuDS layout is shown on Annex 3.

Geology and Hydrogeology

Regional Information

According to the Geological Survey Ireland (GSI) data mapping service the site is underlain by superficial deposits comprising gravels derived from limestone with limestone bedrock of the Rickardstown Formation below. According to the GSI the gravels are classed as a Regionally Important Gravel aquifer and the bedrock as a Regionally Important Aquifer - Karstified (diffuse).

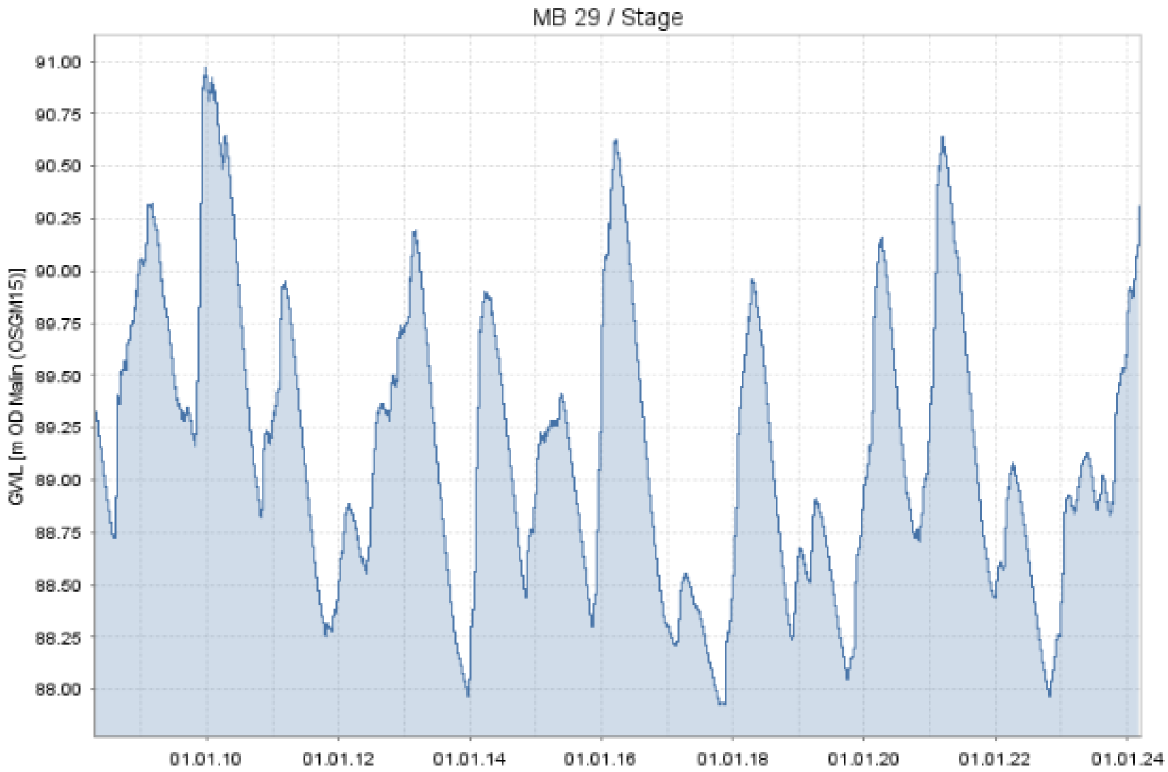
Further information about the gravel aquifer is provided in Hayes *et al.* (2001)[1] (see Annex 3). The gravels are part of the Curragh Aquifer which comprises sands, gravel and clays of glaciofluvial and glaciolacustrine origin which were deposited in a limestone trough at the end of the last glaciation. According to a map given in Hayes *et al.* (2001) the Curragh Aquifer extends over an area of approximately 22km by 13km and is centred on the Curragh racecourse approximately 4km east of the site. The thickness of the superficial deposits ranges from up to 60m in the centre of the aquifer to less than 20m at the edges.

Hayes *et al.* (2001) provides an interpreted piezometry of the Curragh gravel aquifer based on measured groundwater levels from October 1999 (see Annex 4). Groundwater levels range from approximately 100 m OD Malin to the southwest of Curragh Camp to 74 m OD

[1] Hayes, T., Cullen, K., Sutton, S. and Faherty, J. (2001). The Curragh Aquifer – Current Conceptual Understanding and Numerical Modelling. In Proceedings of the 21st Annual International Association of Hydrogeologists (IAH) (Irish Group) Groundwater Seminar: Gravel Aquifers – Investigation, Development and Protection.

Malin 4km west of Kildare town. According to Hayes the primary discharge points for the aquifer are Pollardstown Fen in the north of the aquifer, springs (including the Japanese Gardens) and the Tully River in the south and the Liffey in the east. Hydrographs of measured and modelled groundwater levels indicate that long-term variation in groundwater levels is generally less than 2m with seasonal highs typically occurring in February or March. Based on the information provided in Hayes, groundwater level in the gravel aquifer in the vicinity of the proposed infiltration basin is likely to be around 90 to 92m OD Malin.

The Environmental Protection Agency has a groundwater monitoring well (MB29) screened to a depth of 10.7 m in the sands and gravels located at grid reference 275044 easting, 213187 northing, 800m north east of the site. The long-term groundwater monitoring hydrograph for this well for the period 2009 to 2024 is shown in Figure B below[2]. This shows that groundwater level in the sands and gravels at this location has ranged from approximately 88 to 91 m OD Malin.



[2] From https://epawebapp.epa.ie/hydronet/#IE_SE_G_0133_1400_0011

Site Data

An intrusive investigation was conducted at the site in October to December 2023 and is reported in Causeway Geotech (2024)[3]. The investigation comprised the drilling of 17 no. boreholes (12 no. by light cable percussion and 5 no. by sonic drilling), three of which were installed as groundwater monitoring wells, excavation of 7 no. machine dug trial pits and 6 no. machine dug slit trenches and infiltration testing in 3 no. trial pits. Boreholes and trial pit locations are shown in Annex 5.

The encountered geology at the site generally comprised 0.1 to 0.5m thickness topsoil, underlain by sands and gravels often with layers of soft to firm sandy gravelly clay or silt becoming stiffer with depth. Made Ground was encountered at some locations generally within the uppermost 1m where encountered other than at BH08 where large fragments of wood and wire were encountered at 3.8 to 4.6 m below ground level (mbgl).

Sonic borehole RC04 is located within the area of the proposed infiltration basin in the south west corner of the site. The encountered geology at this location comprised 0.3m thickness topsoil underlain by sand and gravel to 5.55 mbgl (93.07 m OD Malin) underlain by stiff to very stiff sandy gravelly clay to the base of the borehole at 10.2 mbgl (88.42 m OD Malin). An interpreted geological cross-section drawn from RC04 in the south to BH09 to the north is shown in Annex 6. This shows the sands and gravels underlain by clay, with the base of the sands and gravels at an elevation of approximately 93 to 94 m OD Malin. Bedrock was not encountered during the investigation and so it is not known whether there are further layers of sand and gravel below the clay.

Three monitoring wells were installed at the site in boreholes, details of which are provided in Table A below.

Table A: Monitoring well installation details

Monitoring well	Screened interval		Screened lithology
	mbgl	m OD Malin	
BH03	1.5 – 3.5	99.18 – 101.18	Gravel
BH09	1.9 – 4.0	97.10 – 99.00	Gravel
BH11	1.5 – 3.5	95.75 – 97.75	Gravel

[3] Causeway Geotech (2024). NDFA Social Housing Lot 3, Coolaghknock Glebe – Factual Report. Report No.: 23-0881F. Final

The monitoring wells were monitored for groundwater level on five occasions from 14 November 2023 to 13 March 2024 and were noted to be dry on all occasions with the exception of BH09 which had recorded water levels of 3.87 mbgl (97.23 m OD Malin) on 14 November 2023 and 3.90 mbgl (97.20 m OD Malin) on 13 March 2023.

BH11 is located in the area of the proposed infiltration basin and was dry on all five occasions. The base of this well is at an elevation of 95.75 m OD Malin, 0.38 m below the base of the basin (96.13 m OD Malin).

BH09, where water was encountered on two occasions, is located 90m from the proposed basin. This well is 4m deep and so the thickness of water column in the well when detected was only 0.1 to 0.13m. The base of the well corresponds with the top of an interpreted clay lens and it is likely that this water is either trapped water in the basal cap of the well or perched water on top of this lens. Given that no groundwater has been encountered in BH11, the water encountered in BH09 is highly unlikely to be representative of the water table in the gravel aquifer, which based on the available site data is below 95.75 m OD Malin in the vicinity of the basin. According to the log for RC04 no groundwater was encountered during drilling. It should be noted however that a water flush was used during drilling and so any small ingress of groundwater would have been difficult to detect. Nevertheless, given the likely high permeability of the sands and gravels, groundwater would likely have been apparent if the water table had been reached. As such, it is reasonable to assume that the sands and gravels were dry to their base at 93.07 m OD Malin at this location.

Expert opinion on thickness of unsaturated zone below infiltration basin

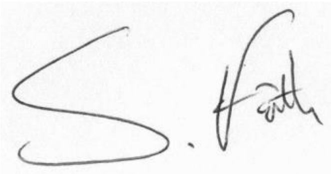
The intrusive investigation at the site has shown that the site is underlain by sands and gravels which are interpreted to be part of the Curragh gravel aquifer. At borehole RC04, drilled in the location of the proposed infiltration basin, the gravels are present to a depth of 5.55 mbgl (≈93 m OD Malin) and are underlain by clay. There was no evidence of groundwater being encountered when RCO4 was drilled and groundwater has not been measured in nearby monitoring well BH11, the base of which is at 95.75 m OD Main, 0.38m below the base of the infiltration basin. Whilst water has been detected on occasion at a higher elevation in BH09, this well is located approximately 90m from the proposed infiltration basin and the water is considered likely to be water trapped in the basal cap of the well or a thin layer of perched water on top of an underlying clay lens and not representative of the groundwater table in the gravels.

The intrusive investigation information is consistent with Hayes *et al.* (2001) and data from the EPA groundwater monitoring well located 800m from the site which indicates that groundwater level in the gravels in the vicinity of the infiltration basin is unlikely to exceed 92 m OD Malin. As such, the thickness of unsaturated zone below the base of the basin is considered to be at least 4m (96.13 m OD – 92 m OD), and well above the minimum requirement of 1m.

Closure

We trust that this information is suitable for your present requirements. Please do not hesitate to contact the undersigned if you have any queries or wish to discuss further.

Kind regards



Simon Firth, BSc, MSc, CGeol, ASoBRA

On behalf of Firth Consultants Ltd

ANNEX 1

CV

Simon Firth
Director
BSc MSc CGeol ASoBRA

1. SUMMARY

Simon is a chartered geologist (CGeol) and accredited risk assessor (ASoBRA) with 28 years of groundwater and contaminated land experience, working on numerous water resources and contaminated land projects, involving monitoring, assessment, design, modelling and risk assessment in the UK, Ireland, Norway, Spain, Argentina, Thailand, Libya, Algeria, Iraq, Canada and the US. During this time, he has developed significant expertise in human health and environmental risk assessment, and in the application of contaminant fate and transport models to predict the extent of contamination in both soil and groundwater. Simon has authored and contributed to a number of land contamination risk assessment guidance documents in the UK and was one of the co-founders of the Society of Brownfield Risk Assessment (SoBRA). Simon conducts training courses on risk assessment to both industry and regulators within the UK and abroad.

Specialisations

Simon has developed a range of specialist skills, including:

- Risk assessment. Simon has conducted numerous contaminated land human-health and environmental risk assessments for a variety of sites and land-uses. Simon has in-depth knowledge of UK and international risk assessment methodologies, tools and software and is fully averse with the key principles of contaminated land risk assessment: conceptual model development, exposure modelling (including vapour intrusion modelling), toxicological assessment, risk characterisation, uncertainty analysis and risk evaluation. Simon has also developed a number of bespoke risk assessment tools including stochastic models.
- Hydrogeology. Simon is a hydrogeologist by training and is an expert groundwater modeller. Simon is an experienced user of the groundwater model Modflow and associated contaminant transport package Mt3D and also has experience with other groundwater models such as Aqua3D, and fracture transport models Fracman and Mafic.
- Peer review/expert witness. Simon has built up a large portfolio of experience reviewing and conducting risk assessments on sites throughout the world. Simon's in depth knowledge of available risk assessment methodologies/tools combined with his practical site experience means that he is well placed to conduct effective reviews of site investigation, risk assessment or remediation strategy reports prepared by others. Simon is able to quickly determine whether there are errors or omissions that affect the report conclusions and will identify the key areas of uncertainty that impact the decision's made based on the report's findings. Simon has acted as technical expert on hydrogeology and risk assessment on a number of legal cases.
- Training. Simon has a thorough understanding of risk assessment and hydrogeology and excellent communication skills. He has delivered numerous courses on risk assessment, groundwater modelling and hydrogeology to local authorities, consultants, remediation contractors, land owners and students. He is an enthusiastic lecturer and his courses are always well received.

2. EDUCATION AND PROFESSIONAL STATUS

- Fully Accredited Risk Assessor (ASoBRA), Society of Brownfield Risk Assessment, UK, 2016
- Chartered Geologist (CGeol), Geological Society, UK, 2016
- M.Sc. Hydrogeology (Distinction), University College London, UK, 1995
- B.Sc. (Hons) Geography, 2:1, University of Bristol, UK, 1992

3. WORK HISTORY

2007 to present	Director, Firth Consultants Ltd, Bristol, UK
2005 – 2007	Risk Assessment Director, WorleyParsons Komex, Bristol, UK
2004 – 2005	Project Manager/Risk Assessor, Komex, Madrid, Spain
2000 - 2004	Risk Assessor, Komex, Bristol, UK
1996 - 2000	Hydrogeologist, Komex, Bristol, UK
1995 - 1996	Groundwater Modeller, University College, London, UK
1994	Groundwater Assistant, NRA, Solihull, UK

4. EXAMPLES OF EXPERIENCE

Human Health Risk Assessment

- Lead technical advisor on vapour intrusion risk assessment for fifteen residential properties adjacent a former industrial laundry where tetrachloroethene was the main constituent of potential concern. Project involved extensive site investigation and five months of soil vapour, sub-slab and indoor air monitoring, along with vapour intrusion modelling to determine whether there were unacceptable risks to the residents from volatile organic constituents associated with the former laundry. This project won the Brownfield Briefing Best Project Preparatory Work Award in 2023.
- Exposure modeller in UK Defra Project SP1010 to derive Category 4 Screening Levels (C4SL) for soils protective of human health. Simon conducted a detailed appraisal of the uncertainties in the exposure modelling aspects of the UK CLEA exposure model and developed a probabilistic version of CLEA as part of the C4SL project. Simon was also a key participant/presenter in various stakeholder workshops.
- Project manager for the Phase 2 C4SL project to derive C4SLs for a further twenty contaminants including trichloroethene, tetrachloroethene, naphthalene, beryllium and per- and polyfluoroalkyl substances (PFAS). Simon's role involves technical review of the toxicological and exposure assessments for the project.
- Assessment of exposure to workers from emissions of volatile organic compounds (VOCs) from manufacture, testing and operation of dry-type electrical transformers. This work included conceptualisation and modelling of emissions of VOCs from these transformers and design of a test programme to provide emissions data for the modelling.
- Project manager and principal author for EIC/AGS/CL:AIRE project to derive human health generic assessment criteria for approximately 35 contaminants using the CLEA methodology and guidance.
- Project manager and contributing author of the SoBRA's "Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater". February 2017.
- Contributing author to SoBRA's "Development of Acute Generic Assessment Criteria for Assessing Risks to Human Health from Contaminants in Soil". April 2019. This project won a Brownfield Briefing Award in 2019 for Best Public Sector/Not for Profit Lead Project.
- Part 2A Detailed Quantitative Risk Assessment (DQRA) of risk to residents from vapour intrusion of chlorinated solvents in groundwater for Peterborough City Council. Project involved modelling using the USEPA Johnson & Ettinger model and development of a bespoke model to

account for air bricks.

- Part 2A risk assessments of two housing estates on behalf of London Borough of Barking and Dagenham. Simon was technical director and lead risk assessor for these projects, both of which involved extensive site investigation and DQRA. Assessment included use of the CLEA model to derive site specific assessment criteria for polycyclic aromatic hydrocarbons (PAHs), heavy metals and asbestos in soils.
- Part 2A risk assessments of various sites on behalf of Cardiff City Council, including an infilled former canal and docks in two areas of Cardiff now used for housing and an area of allotments adjacent to a former landfill. Simon was project director and lead risk assessor for these projects, both of which involved extensive site investigation and detailed quantitative risk assessment (DQRA). The DQRA work included the use of the margin of exposure approach to assess risks to human health from benzo(a)pyrene, soil gas and vapour monitoring and modelling, vegetable sampling, assessing bioavailability, derivation of site specific assessment criteria using CLEA and controlled waters risk assessment.
- Part 2A risk assessments of lead contamination in garden soils of residential properties for East Lindsey District Council and Brent Council.
- Part 2A risk assessment of diesel spill on behalf of Bristol City Council. Simon was project director and lead risk assessor for this project, which involved soil sampling and DQRA using CLEA.
- Development of generic assessment criteria (GAC) protective of human health for soils at a Nuclear Fuel Reprocessing Site. Simon derived GAC for a range of contaminants (including uranium and asbestos) and exposure scenarios (including acute and chronic risk scenarios). His work included in-depth toxicological assessment reviews for asbestos and the non-radiological effects of uranium.
- Human health and groundwater risk assessment at two oil refineries in Spain. This project involved data review, extensive site investigation, development of site wide conceptual models of risk, fate and transport modelling and toxicological assessment to characterise risks. This work helped inform the remediation options appraisal for legacy contamination at those sites.
- Environmental risk assessment of a Superfund Site in Missouri, USA. This project involved the use of complex groundwater contaminant transport modelling to assess the risks from chlorinated solvents associated with a former electrical transformer works to human health and environmental receptors.
- Asbestos risk assessment. DQRA to derive site specific assessment criteria for asbestos fibres in soil for a university site. Project involved toxicological review and exposure assessment to determine acceptable concentrations of asbestos fibres in soil.
- Vapour risk assessment for elemental mercury contamination within the fabric of a building. Project involved toxicological review to determine acceptable indoor air concentration within a refurbished office building, development of a validation monitoring plan and design of a ventilation pilot test to reduce concentrations of mercury in the building to acceptable levels.

Hydrogeology and Groundwater Risk Assessment

- Expert witness for a legal case involving contamination of private water supply from leaking heating oil tank.
- Expert witness for a legal case involving cross-boundary migration of petrol and diesel contamination to neighbouring residential properties arising from a leaking underground storage tank on a former petrol station.
- Design and analysis of aquifer pumping tests to assess viability of groundwater for process water supply for a large dairy supplier in Ireland.
- Development of a regional groundwater flow model in Yemen to aid management of water

resources.

- Development of a regional groundwater flow model of the Great Oolite in the Malmesbury region in the UK to assess risk of over-abstraction on low flows in rivers.
- Groundwater and contaminant transport modelling of chlorinated solvents, ammoniacal nitrogen and bromide in the Chalk to assess the risk to a Public Water Supply well for various abstraction scenarios. Modflow MT3D was used to model the aquifer as a dual domain system.
- Groundwater risk assessment of per/poly fluoroalkyl substances (PFAS) contamination in soil and groundwater at an airport in Cambridgeshire.
- Groundwater contaminant transport modelling to assess risk from gas works contamination to Public Water Supply in fractured chalk aquifer in the UK. The model was conducted using stochastic Modflow MT3D so that the effects of uncertainty in model parameters could be better understood.
- Contaminant transport modelling to support risk assessment work for a US Superfund Site. Fracture transport modelling (using FRACMAN and MAFIC) was used to model contaminant transport in the fractured limestone aquifer from a site impacted with PCBs and chlorinated solvents. Results were compared with those using an equivalent porous medium approach.
- Contaminant transport modelling of chlorinated solvent contamination in a fractured limestone aquifer in Ireland to support risk assessment and remedial strategy. Modflow MT3D was used to model the aquifer as a dual domain system with anisotropy.
- LandSim modelling to assess the risk from a proposed inert landfill located on the Chalk aquifer. Project involved an initial desk study and Preliminary Risk Assessment to identify sources, pathways and receptors and then DQRA using LandSim to model risk from landfill with engineered cap and basal liner.

Research & Development

- Development of Statoil's Environmental Impact Factor (EIF) screening tool to assess potential for environmental impact from on-shore upstream oil and gas facilities. The tool involved c. 250 man days of development and enables users with little expertise in risk assessment to assess a sites potential for environmental impact and to identify parameters leading to the greatest uncertainty in model results.
- Research projects for the UK Energy Institute assessing the risks from the fuel components MtBE and ethanol on UK water resources. These projects involved the collation and analysis of data on MtBE contamination in UK groundwater and surface water and the development of a probabilistic risk models for assessing the current and future impact of MtBE and ethanol on UK groundwater quality.
- Development of bespoke risk assessment tools to prioritise risk management action at various oil refineries in Spain for Repsol. These tools are able to predict the risk from thousands of potential source components (e.g. individual tanks, pipes, pumps etc) on a refinery and identify which of these components present the greatest risk of environmental impact.
- Exposure modeller in UK Defra Project SP1010 to derive Category 4 Screening Levels (C4SL) for soils protective of human health. Simon conducted a detailed appraisal of the uncertainties in the exposure modelling aspects of the UK CLEA exposure model and developed a probabilistic version of CLEA as part of the C4SL project.
- Project manager and contributing author of SoBRA's Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater. Version 1.0. February 2017

5. PUBLICATIONS

- Firth, S., Musdalslien, U.I. and Hagemann, R.E., 2015. Evaluation of the EIF Onshore Discharges Tool for Assessing Environmental Risk from Accidental Spills and Leaks Associated with Hydraulic Fracturing Operations. Proceedings of SPE Annual Technical Conference and Exhibition, 28-30 September, Houston, Texas, USA.
- Morgan, P., Firth, S., Hildenbrand, B., 2014. Behaviour and effects of alcohol-blended petrol in the subsurface. Quarterly Journal of Engineering Geology and Hydrogeology. August 2014, 47(3):267-279
- Firth, S., Hildenbrand, B., Morgan, P., 2014. Ethanol effects on the fate and transport of gasoline constituents in the UK. Sci. Total Environ. Jul 2014; 485-486 March 2014.
- Carrillo, G., Rubial, M.J., Firth, S., 2011. Risk Analysis Tool Applied to Understand the Possible Negative Environmental Effects of Unlined Drilling Pits in Desert Environments. Proceedings of SPE 17th Middle East Oil & Gas Show and Conference, Bahrain, 28 September 2011.
- Firth, S., Stone, K., Hagemann, R., Smit, M.G.D., and Frost, T.K., 2010. EIF Onshore Discharges: a quantitative risk management tool for soil, groundwater and surface water. Proceedings of Consoil 2010, Salzburg, Austria, 22 to 24 September, 2010.
- Firth, S., Frost, T.K., Hagemann, R., Smit, M.G.D., Stone, K., 2009. EIF Onshore Discharges: A quantitative environmental risk assessment tool for onshore facilities. Proceedings of World Heavy Oil Congress, Venezuela, 5 November 2009.
- Firth, S., 2007. Biofuels – Potential Risks to Groundwater. Petroleum Review. August 2007.
- Firth, S. Dottridge, J., Kelly, T. and Tavernier, G., 2005. Probabilistic Groundwater Modelling as a Method of Reducing Uncertainty. International Workshop from Data Gathering and Groundwater Modelling to Integrated Management. Alicante, Spain, 4-8th. October 2005
- Bartlett, T., Tavernier, G., Dottridge, J. and Firth, S., 2005. Modelling of Surface-Groundwater Interactions to Assess Impacts of Groundwater Abstraction. International Workshop from Data Gathering and Groundwater Modelling to Integrated Management. Alicante, Spain, 4-8th. October 2005
- Dottridge J., Firth S., Hardisty P. and Tavernier G, 2004. Scaling up to predict Contaminant Transport in Fractured Aquifers. Proceedings of IAH/ALHSUD Joint Congress, Groundwater Flow Understanding From Local to Regional Scales, Zacatecas City, Mexico. 11th to 15th October, 2004.
- Firth, S., Bracken, R. and Hardisty, P.E., 2003. Assessing the Risks, Costs and Benefits of Managing/Redeveloping Contaminated Sites. Conference proceedings, 24th Annual IAH (Irish Group) Groundwater Seminar, “Groundwater Challenges of the National Development Plan”.

ANNEX 2

Proposed Layout

THIS DRAWING TO BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT DRAWINGS, SPECIFICATIONS AND THE PRELIMINARY HEALTH & SAFETY PLAN.

ALL DIMENSIONS ARE IN mm UNLESS NOTED OTHERWISE. DO NOT SCALE DIMENSIONS.

THE CONTRACTOR SHALL CHECK ALL DIMENSIONS PRIOR TO THE COMMENCEMENT OF CONSTRUCTION. ALL DISCREPANCIES SHALL BE REPORTED TO THIS OFFICE IN WRITING.

NOTES

BY	DRAWING No. & REFERENCE	DATE
SURVEY		
ARCH	SHB5–CGK–DR–MCO–AR–P1–PL03–Proposed Site Plan Rev 6	08.03.24
LS Arch	Mitchell dwg LSOC003 CGB_Landscape Masterplan–0100 Rev0	09.02.24

LEGEND

–·–·–	PROPOSED STREET CENTRELINE
	PROPOSED LINK STREET
	PROPOSED FOOTPATH
	PROPOSED BUFF COLOURED ASPHALT
	PROPOSED GRASS AREA
	INDICATES PERMEABLE CAR PARKING SPACES

REV	DESCRIPTION	DATE	BY	CHK
4	LANDSCAPE ARCHITECT LAYOUT UPDATED SITE LAYOUT REVISED TO SUIT CHANGES	15.03.24	KD	PB
3	LAYOUT UPDATED	23.01.24	JC	PB
2	LAYOUT UPDATED	17.01.24	JC	PB
1	LAYOUT UPDATED	13.12.23	JC	PB
0	ISSUED FOR INFORMATION	29.11.23	JC	PB

STATUS
P3 – PLANNING

MALONE O'REGAN
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CLIENT
KILDARE COUNTY COUNCIL

JOB NAME
SHB 4&5 – CGK – COOLAGHKNOCK GLEBE, KILDARE TOWN

DRG. NAME
PROPOSED SITE LAYOUT

JOB REF	SHEET	SCALE	DATE	BY	ENG	APP	REV.
23006	A0	1:500	AUG'2023	JC	PB	DW	4

DRG. NO.
SHB5–CGK–DR–MOR–CS–P3–101

ANNEX 3

SuDS Design

DON'T FORGET SAFETY

DETENTION BASIN

SIDE SLOPE = 1:3
TOP OF EMBANKMENT = 97.560m
LOWEST ROAD LEVEL = 97.530m – 0.3m FREEBOARD = 97.230m
MAX 1:100YR STORM WATER LEVEL = 97.230m
LEVEL AT BASE OF BASIN = 96.130m

LEVELS CHECK
LOWEST FFL = 97.750m i.e. 520mm FREEBOARD
LOWEST ROAD LEVEL = 97.530m i.e. 300mm FREEBOARD

TOP AREA OF BASIN AT 1:100YR STORM WATER = 1166.700m2
BOTTOM AREA OF BASIN AT 1:100YR STORM WATER = 506.090m2
AVERAGE AREA = 836.390m2
1:100YR STORM VOLUME PROVIDED = 836.390m2 x 1.10m = 920.030m3
1:100YR STORM VOLUME REQUIRED = 905.161m3

REFER TO DRAWING 151 FOR DETENTION BASIN SECTION AND DETAILS

THIS DRAWING TO BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT DRAWINGS, SPECIFICATIONS AND THE PRELIMINARY HEALTH & SAFETY PLAN.

ALL DIMENSIONS ARE IN mm UNLESS NOTED OTHERWISE. DO NOT SCALE DIMENSIONS.

THE CONTRACTOR SHALL CHECK ALL DIMENSIONS PRIOR TO THE COMMENCEMENT OF CONSTRUCTION. ALL DISCREPANCIES SHALL BE REPORTED TO THIS OFFICE IN WRITING.

NOTES

BY	DRAWING No. & REFERENCE	DATE
SURVEY		
ARCH	SHB5-CGK-DR-MCO-AR-P1-PL03-Proposed Site Plan Rev 6	08.03.24
LS Arch	Mitchell dwg LSOC003 CGB_Landscape Masterplan-0100 Rev0	09.02.24

DRAINAGE LEGEND

- PROPOSED SURFACE DRAINAGE LINE
- PROPOSED SURFACE MANHOLE
- SW AJ — PROPOSED SURFACE ARMSTRONG JUNCTION
- G — PROPOSED SURFACE ROAD GULLY
- EXISTING SURFACE DRAINAGE LINE
- EXISTING SURFACE MANHOLE
- EXSW AJ — EXISTING SURFACE ARMSTRONG JUNCTION
- G — EXISTING SURFACE ROAD GULLY
- PROPOSED TREE PIT
- PERMEABLE PAVING
- SWALE AREA
- GRATED MANHOLE
- RAIN GARDEN AREA
- PERMEABLE PAVING UNDERDRAIN 150ø
- SWALE/ RAIN GARDEN UNDERDRAIN 150ø
- TREE PIT UNDERDRAIN 150ø
- PERFORATED COLLECTOR PIPE 150ø
- DROPPED KERB AT 5m C/C
- INSPECTION CHAMBER
- LINEAR TRENCH 3mx2m

REV	DESCRIPTION	DATE	BY	CHK
0	ISSUED FOR INFORMATION	15.03.24	KA	PB

STATUS
P3 – PLANNING

MALONE O'REGAN CONSULTING ENGINEERS
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CLIENT
KILDARE COUNTY COUNCIL

JOB NAME
SHB 4&5 – CGK – COOLAGHKNOCK GLEBE, KILDARE TOWN

DRG. NAME
SUDS LAYOUT

JOB REF	SHEET	SCALE	DATE	BY	ENG	APP	REV.
23006	A0	1:500	SEPT' 23	KA	KA	PB	0

DRG. NO.
SHB5-CGK-DR-MOR-CS-P3-150

DON'T SCALE DIMENSIONS

ANNEX 4

Hayes *et al.* (2001)

9. The Curragh Aquifer - Current Conceptual Understanding and Numerical Modelling

Teri Hayes, Kevin Cullen, Stuart Sutton, and John Faherty. KT Cullen & Co. Ltd. and Entec (UK) Ltd.

THE CURRAGH AQUIFER

CURRENT CONCEPTUAL UNDERSTANDING & NUMERICAL MODELLING

By Teri Hayes, Stuart Sutton, Kevin Cullen and John Faherty
K.T. Cullen & Co. Ltd. & Entec (UK) Ltd.

Abstract

The Curragh Aquifer comprises sands, gravels and clays of glaciofluvial and glaciolacustrine deposits. These were deposited in a limestone trough at the end of the last glaciation. Glacial deposits up to sixty metres thick are encountered near the centre of the trough. This aquifer depth decreases to less than 20 metres at the edge of the Curragh plain. The vertical and lateral extent of the sediment type and inherent permeability varies depending on the glacial environment in which the sediments were deposited. In simplified terms a clayey till overlies sands and gravels. The primary discharge points for the aquifer are the springs and seepage zones in Pollardstown Fen in the north of the aquifer, springs (including the Japanese Gardens springs) and baseflow to the Tully River in the south and the Liffey Catchment in the east. As surface water drainage is absent from most of the aquifer recharge is high. Aquifer storage is relatively high and the regional groundwater regime shows little seasonal variation.

Based on the conceptual model of the aquifer, a credible groundwater mathematical model has been developed. This has permitted an acceptable assessment of the impact of a number of proposed road designs and construction sequences on groundwater levels and flows within the aquifer. Modelling has confirmed that the impacts associated with the final road design are within acceptable limits. Continuous updating of the model with field data ensures that the impact of construction activities can be measured to allow further mitigation if necessary. Confidence in the model and monitoring programme is essential for all stakeholders in the Kildare By-Pass project.

1 INTRODUCTION

The Curragh Aquifer (also known as the "Mid Kildare Gravel Aquifer") is an extensive gravel aquifer located in eastern Co. Kildare. A 4.5 kilometre section of the Kildare-Monasterevin By-Pass will be located in a cutting through the aquifer (Figure 1). Approximately 3.5 kilometres of this cutting will require dewatering to maintain dry conditions during construction and the installation of an impermeable liner for the final "tanked" section. Dewatering during construction will generate a cone of depression in the surrounding water table and subsequently alter the groundwater flow regime within the aquifer. As the aquifer discharges at springs in the Japanese gardens (a major tourist attraction) and Pollardstown Fen (a proposed Special Area of Conservation and supply to the Grand Canal), a clear and precise understanding of the impacts of dewatering on the groundwater regime was required by all stakeholders.

The initial section of this paper summarises the current understanding of the hydrogeology of the aquifer based on work undertaken prior to and, during this study. The latter section of the paper summarises the basis of the mathematical model and its implications for the road design to mitigate impacts on the sensitive receptors.

2 SITE SETTING

The Curragh Aquifer is located in an area of low relief, extending from Naas in the north to Nurney in the south, and from Kildare in the west to Killcullen in the east, (Figure 1). The Curragh is underlain by Carboniferous limestones and topographically rises to the "Chair of Kildare", an anticlinal ridge of porphyritic volcanic and sandstone bedrock of pre-Carboniferous age in the north–northwest. The aquifer as defined by G. Wright (GSI) extends to the Hill of Allen in the north, and to Dunmurry Hill and Read Hill in the west where bedrock comes close to the ground surface. To the southeast the aquifer is defined by outcrops of Lower Palaeozoic rocks (slates etc) of the Leinster Massif. Elsewhere the borders of the aquifer are less well defined. The overburden aquifer extent as implemented in the mathematical model is presented in Figure 1.

The Curragh Aquifer straddles the boundary between the Lifey & Barrow Catchments. Groundwater discharges to Pollardstown Fen in the north through a series of major springs and marginal seepages, ultimately discharging to the Grand Canal. To the south, groundwater discharges at a number of springs including those within the Japanese Gardens and provides baseflow to the Tully Stream, a tributary of the Barrow River and the Liffey River in the east of the aquifer.

3 GLACIAL ORIGIN

The Curragh Aquifer is dominated by glaciofluvial and glaciolacustrine deposits of Pleistocene Age. Charlesworth (1928) put forward the theory that Ireland was covered by an ice dome positioned in the north Midlands with its axis oriented northeast to southwest close to Donegal and Antrim. This theory suggests that the deposits in mid-Kildare are proglacial outwash gravels resulting from an ice margin retreating northward with meltwater draining southward to the River Barrow drainage system.

A more recent theory (Warren and Ashley 1994) suggests that Ireland was covered by an ice sheet with multiple ice domes centred in the north, central and south of Ireland during the last glaciation. Recent work undertaken by Glanville (1997) concur with the multiple dome theory suggesting that the sediments in the Curragh region were deposited from two retreating ice margins depositing sediments into an ice marginal lake.

Pollardstown Fen is located on the northeastern margin of the Curragh plain. Interpretation of sediments in the quarries excavated near the southern margin of the Fen suggest that the Fen was formed from meltwater flowing from the south through a narrow channel and depositing in a shallow flat bottomed lake basin (Glanville1997). Logs described by Glanville from this area are interpreted as glaciolacustrine fan sediments:fine sands (lower unit) overlain by gravels (middle unit) which are overlain by a gravelly diamicton (upper unit). The finer sediments (silts & clays) were encountered during drilling in the Fen plain during recent drilling by K.T. Cullen & Co. Ltd and earlier by the GSI (Daly 1981). The interpretation of the middle unit beds (foreset dip and fining to sediment eastward) suggest that they represent a prograding subaqueous fan or delta depositing into a body of standing water occupying the Fen with a sediment input point below the lake surface (Ashley and Smith 1995). The upper sediments are similar in lithology to the lower sediments and are believed to be a re-mobilisation or re-working of the upper units of the gravels during a local advance fluctuation in the ice margin.

The model suggested by Glanville and others is that a considerable amount of ponded water was required at the margins of the ice in order to accommodate the formations of a glaciolacustrine fan and deltaic deposits. One ice margin appears to have been located along the western margin of Pollardstown Fen and retreated in a westerly direction and another lay along the Ballysax fan moraine and retreated in a northerly/north-westerly direction. These margins were likely to be part of the same ice lobe. A third margin of a separate ice mass was located to the northeast of Kilcullen, which was retreated in a northerly or easterly direction. As these lobes retreated they uncoupled in the area of the present River Liffey basin, opening up an area where water ponded. The surface deposits of gravels in the Curragh may have been deposited as outwash into a shallow lake, which rapidly became sediment filled as the ice margins retreated and the shallow lake drained. Drainage was likely to be southwards along meltwater channels, southward from Kilcullen as seen today towards the Barrow and Slaney basins. As the ice margins retreated, lower ground to the north was opened and water could then flow towards the north in the present direction of the River Liffey. It is likely that the meltwater channel to the Fen occurred at this stage.

4 GEOLOGY & HYDROGEOLOGY OF THE CURRAGH GRAVELS.

4.1 Geology

To determine the nature and extent of the Curragh aquifer deposits, Cullen (1993) collated overburden stratigraphy information from archived mineral exploration and geological information provided by the Geological Survey of Ireland. As part of Kildare County Councils Project Specification (1997), 32 shallow boreholes into overburden and 5 deep boreholes to bedrock were installed in 1998 under the supervision of K.T. Cullen & Co. Ltd. These boreholes provided further information on the depth to bedrock and the glacial sequence (Kildare Town By-Pass, data sets used in the development of the conceptual and numerical models of the Curragh Aquifer 1999). From this dataset the base of the aquifer and the base of the overlying clayey till were defined.

The Curragh gravel occupies a trough in the limestone bedrock surface with the limits of the aquifer clearly defined in the west and northwest by more resistant sandstone and volcanic outcrop. Elsewhere the limits of the gravel aquifer are less clearly determined as the sand and gravel outwash deposits pass into clayey till dominated deposits. In general the glacial overburden cover is usually less than 20 metres thick in the area surrounding the Curragh. This increases to 20 – 40 metres at the edge of the bedrock trough. The maximum thickness encountered during the 1998 drilling programme was 60 metres.

As is typical of glacial sequences the Curragh aquifer shows little vertical or lateral continuity in sediment type. The thickness and extent of glacial till varies across the surface, as does the nature of the underlying glacial outwash deposits. This view is consistent with the changing and dynamic glacial environment in which these sequences were deposited. However, to represent a "worst-case" scenario, the mathematical model assumes both vertical and lateral continuity beneath the till deposits.

4.2 Hydrogeology

Watertable monitoring was undertaken in domestic wells in 1992/1993, (K.T. Cullen & Co. Ltd, June 1993). Since 1997, water level monitoring has continued at two weekly intervals in both domestic wells and the specially designed monitoring boreholes installed in 1998 (K.T. Cullen & Co. Ltd, 1998-2001). Local meteorological records and a total of 156 boreholes and standpipes are monitored two weekly to determine the recharge pattern. Monitoring points include 5 wells which are included in the EPA national database and which were previously monitored by the GSI, thus providing the longest monitoring record for the area. This data is analysed and recorded in quarterly monitoring reports to Kildare Co. Co. Figure 1b presents the current monitoring points and the interpreted groundwater flow regime.

As surface flow is absent in much of the area, recharge to the aquifer is considered to be high (350-450 mm/yr) and run-off is taken as minimal. Where the ground is steeper and depths of till increase some run-off to nearby rivers occurs. Groundwater discharges to the south of the road cutting at springs in the Japanese Gardens and further south in Kings Bog and Nurney Bog and to the Tully Stream. To the north groundwater discharges at Pollardstown Fen and the Miltown Stream. To the east the aquifer discharges to the Liffey catchment. The regional groundwater pattern (Figure 1b) varies little seasonally.

Meteorological data has been collated from nearby Osberstown. The aquifer hydraulics can be determined from an assessment of the many hydrographs produced as part of the monitoring programme. As indicated in the drilling logs the aquifer is not homogenous. Recent assessment has indicated that three recharge patterns occur within the aquifer. Limited reaction to recharge events is recorded in wells near the Fen and Japanese Gardens where discharge is occurring and the shallow gravel aquifer is constantly saturated and shows a slow reaction to rainfall events. Four wells in the south west of the aquifer are highly sensitive to recharge events. This pattern is indicative of low storage capacity in this area of the aquifer. Most wells within the mid-aquifer have a "typical" reaction to recharge events i.e. with lowest levels recorded in October rising to peaks in February/March. The annual fluctuations in the water table here is typically 1.25 – 2.5 metres, indicating a high storage aquifer (porosity c. 30 – 40 %). The response time to rainfall events in this area is generally two to three months depending on the thickness of clayey till within the overburden. Further work is currently been undertaken in the assessment of this data.

The Curragh aquifer is taken to operate as a single aquifer. This position is based on the known geological and groundwater flow pattern and is supported by hydrochemical data. Pumping tests as described in the K.T. Cullen & Co. Ltd 1993 report indicate a horizontal hydraulic conductivity value of 30 metres/day. However, a permeability value of 100 metres per day has been applied to the aquifer as a whole to reflect the observed water table fluctuations, the geology encountered in subsequent drilling and internal water balances.

4.3 Surface Flow data

Manual flow measurements have been undertaken at the various surface water discharges since 1997. The results show wide fluctuations in flow rates particularly in the Tully Stream, the

Milltown Stream and Milltown Feeder. Little information regarding discharges of groundwater to the River Liffey from this aquifer is available. Flows at major springs in the Fen were recorded manually where feasible, however flows at small springs and seepages are not available. Automatic flow recording equipment is currently being installed to allow further calibration of the model as required.

To overcome the difficulty of determining discharges as surface water flow from the aquifer, flow was taken to be proportional to the difference between the groundwater head and the elevation of the stream, spring etc, i.e. where the groundwater head is greater than the surface discharge point. These derived flows were compared with estimates from the sparse information available and observations of the various discharges.

In general the aquifer is considered to be semi-confined by the surface till deposits. The piezometric surface is located in a near surface layer. Therefore drainage for the road construction will result in a cone of depression extending out from the line of the cut, altering the natural groundwater flow regime. Removal of water from the cut area reduces the flow to the discharge zones. The impact of this reduction has been assessed by modelling, based upon the conceptual model outlined above and confirmed/modified by the on-going monitoring programme.

5 GEOLOGY & HYDROGEOLOGY OF THE FEN MARGIN

Drilling at the Fen prior to the 1997 study (Daly 1981) indicated a vertical thickness of 10 metres of [fen deposits underlain by gravel deposits. Recent drilling by K.T. Cullen & Co. Ltd indicated fen deposits of up to 17 metres at one location. Outflows at the Fen consist of free flowing springs and marginal seepages. Tufa is deposited at these discharge locations and particularly at seepage zones provides a habitat for rare species such as a microscopic snail (*Vertigo Geyeria*) protected by the Habitat Directive (92/43/EEC).

Artesian flow within the fen standpipes indicates that upward flow does occur. Presently the mathematical model allows discharge to the Fen solely based on the concept of upward flow and groundwater outflow from the upper part of the aquifer gravels. However, recent drilling work at the Fen margin indicates that the source of water at the seepages (habitat *Vertigo Geyeria*) may be due to recent recharge at the fen margin percolating through the very shallow till deposits. Further hydrochemical and recharge analysis is currently being undertaken to confirm this theory.

6 THE GROUNDWATER MODEL

6.1 Model Representation

The Kildare Aquifer Model, uses the public domain MODFLOW model code. Data input and output is managed through the Groundwater Vistas pre and post processing software package. Following the integration of the available information into a conceptual understanding of the gravel aquifer the model was constructed in 1998 and has evolved since that time to meet the changes in cutting design and construction programme.

The model is a four-layer representation of the Kildare Gravel Aquifer placed on a rectangular grid aligned with the National Grid. The basic grid size is 250m and this is progressively reduced in the region of the cutting to 62.5 m to permit realistic representation of the construction and dewatering sequence (Figure 2.1 and 2.2).

Model boundaries are set to coincide with the geological interpretation of the limits of the gravel aquifer and are effectively 'no-flow' boundaries with the exception of areas in the north-west and south-east where flows onto the aquifer can provide a source of runoff recharge and to the south-west of the Tully catchment where head dependant outflows could occur.

The aquifer is represented as a four layer (three gravel and one till) unconfined system. The base of the till and gravel are derived from information from about 150 boreholes and the upper till layer is not continuous across the area. The layered representation is necessary to represent the conditions that give rise to vertical flow, which is clearly an important mechanism in the support of Pollardstown Fen and minimal constraint is imposed on flow between layers.

The model is based on the conceptual understanding of the hydrogeological system derived from the synthesis of available hydrogeological, climatic and river flow data. In areas of uncertainty the assumptions adopted are invariably conservative (i.e. designed to ensure that that the predicted impact at the Fen is maximised). For example no flow is permitted from the underlying limestone into the gravel.

Recharge is calculated using actual rainfall and potential evaporation data (in the current realisation up to April 2001) and future predictions are based on a repetition of the May 2000 to April 2001 climatic sequence on a 'same day' basis.

6.2 Representation of Springs/Streams

Detailed representation of the fen is not attempted. The model predicts the impact of dewatering of water levels on the gravel aquifer and assumes no constraint between the aquifer and surface water features (streams, springs etc) on the basis that this again is a conservative assumption.

Rivers and springs are represented by cells which permit flow into or out of the aquifer proportional to the difference between stage or spring elevation and the water level in the aquifer.

Around the Fen individual springs and seepages are represented at or close to their observed levels and locations and a leakance factor (flow per unit head difference) that permits realistic representation of observed flow rates.

6.3 Representation of the Cutting

Dewatering of the cutting will proceed in stages from west to east progressively lowering groundwater levels to around 0.5 m below the base of the excavation in the section under construction. On completion and lining of each section groundwater levels will be controlled by drainage pipes set 1.75 m above the finished carriageway level.

The effect of dewatering is achieved using nodes which abstract water at a rate dependant on the difference between the natural groundwater level and these pre-set drainage levels but which do not permit water to enter the model when the groundwater level is below the drainage level. The conductance of these nodes is set at a high level that does not constrain the ability of the aquifer to deliver water to the drainage system.

Early model runs were based on construction in 500m steps in two-month periods with a break in construction from November through to the end of February. The most recent model run uses the Contractors proposed construction sequence with variations to allow for contingencies such as delays during the periods of highest volume dewatering.

6.4 Model Operation

The recharge input to the model occurs in daily time steps and the groundwater model operates in 15-day time steps. Model simulation with real climate data starts in January 1992 and current predictive output continues to the end of 2006, four years after scheduled completion.

For any one node model output can be obtained as a time series representation of either groundwater levels, or flows out of the groundwater system. The location of the data output points used (Figure 2.3) is controlled by the observation network, as confidence in the model predictions can only be developed from comparison with historical observation. Figure 2.4 provides examples of these comparisons. During model development iterations necessary to obtain these credible representations of reality were based on variations of hydraulic parameters within credible limits. The hydraulic parameters adopted as providing this credibility were:

	Hydraulic Conductivity (m/d)		Specific Yield	Specific Storage (/m)
	Hor	Ver		
• Gravel	100	4	0.13	0.0001
• Till	3	0.1	0.13	0.0001

2.5 Model Results

Throughout the period 1998-2001 the groundwater model has been used to represent a range of cutting designs and construction dewatering scenarios. The current predictive output run (KILD62) uses the Contractor' proposed dewatering sequence and real climate data to May 2001 with the final years climate data repeated through construction and up to the end of 2006.

A key output, both in that it is ultimately the source of any environmental impact and that it provides a means of anticipating such impact as dewatering is in progress is the outflow from the cutting (Figure 2.5). After construction measured outflows from the drainage system can also be compared with model predictions.

Figure 2.6 illustrates the predicted impact of the cutting outflows at four locations:

- The base flows from groundwater to Milltown Stream
- The groundwater levels close to the cutting (Obs Well 41)
- The groundwater levels midway between the cutting and Pollardstown Fen (GW3)
- The groundwater levels close to the Fen (GW4)

7 CONCLUSIONS

Establishment of a credible groundwater model of the Kildare Gravel aquifer has permitted a realistic assessment of the impact of a number of proposed road designs and construction sequences on groundwater levels within the aquifer. Sufficient data does not exist to permit detailed representation of the mechanisms that support the wetland cSAC at Pollardstown Fen. Consequently the groundwater impact predicted by the regional model represents the maximum credible limit of such impact. This groundwater prediction has in turn been used by ecological experts to assess the potential impact on the Fen ecosystem and has ensured that a final road design and monitoring mechanism has been adopted that constrains anticipated environmental impacts within acceptable limits.

Maintenance of the groundwater model as a live tool regularly updated with climate data and modified in response to flow and groundwater level observations during construction ensures that effective monitoring and control of construction activities is practicable. This is essential both for the management of construction activities and to provide confidence for all stakeholders in the preservation of the unique ecosystem that is Pollardstown Fen.

Acknowledgements

The work and results reported in this paper are product of many individual efforts but particular acknowledgement must be made of the contribution of Professor K. Rushton, who not only aided in the formulation of the conceptual understanding and design of the groundwater model but has acted as independent reviewer of the model output through much of the last three years.

Acknowledgement is also given to the immense contribution of the Working Group set up under Professor K Rushtons chair. This group involved Duchas and its consultants, Inland Waterways, the National Road Authority, Kildare Co. Co. and its consultants. The contribution of the Hydrogeology Subgroup (chaired by Dr Bruce Misstear) and Ecology Subgroup (chaired by Dr. G van Wirdrum) in the assessment of on-going monitoring and modelling data is gratefully acknowledged. Special acknowledgement is given to the staff of K.T. Cullen & Co. Ltd. who have worked over many years in the collection and interpretation of this data. These include K Fitzsimmons, V. Conlon, L. Brown, J. Rutherford, D. Ledwidge, S. Bradley and G Connell.

The support and understanding of Kildare County Council throughout the work period has been invaluable and their permission to present this data is gratefully acknowledged.

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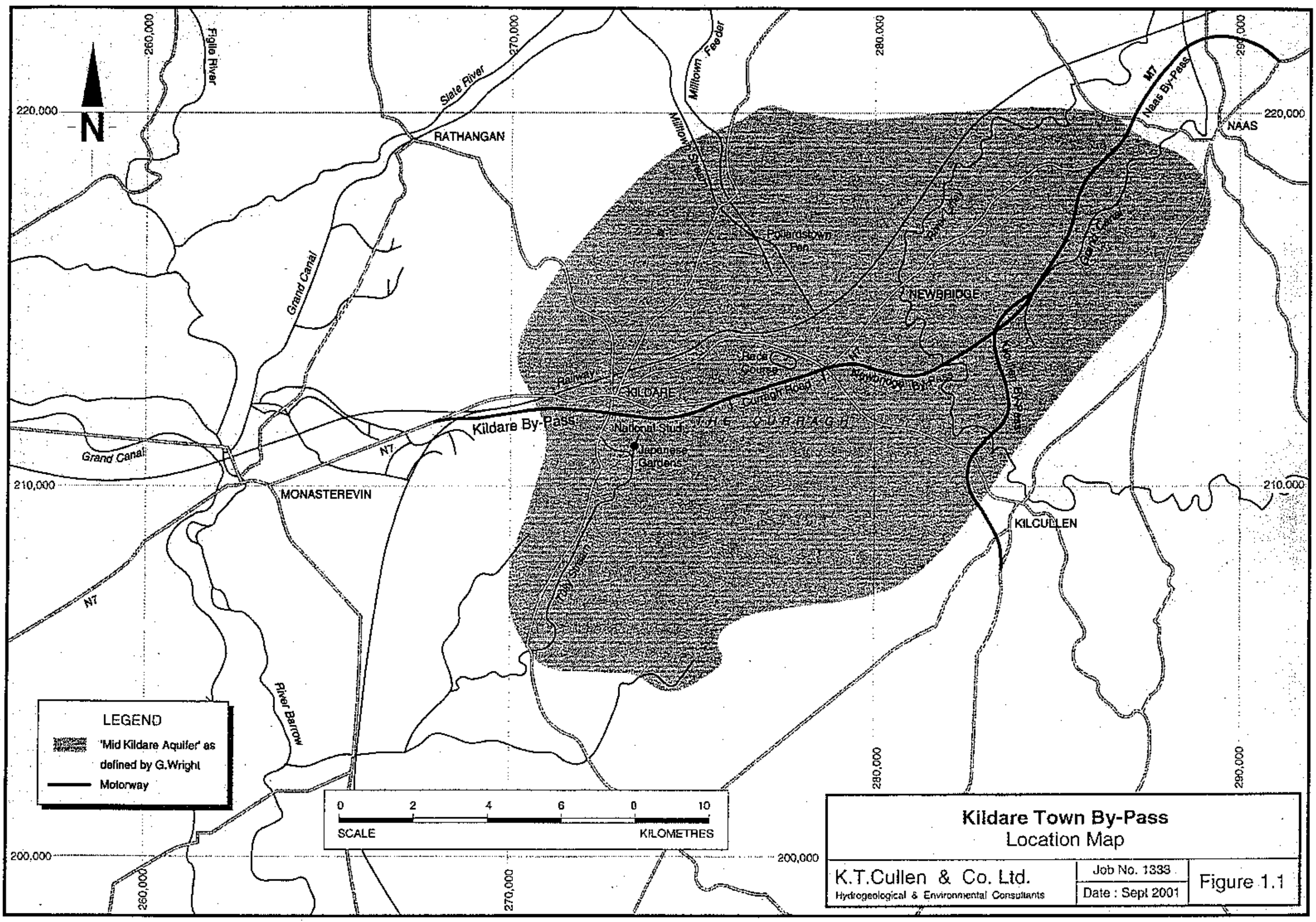
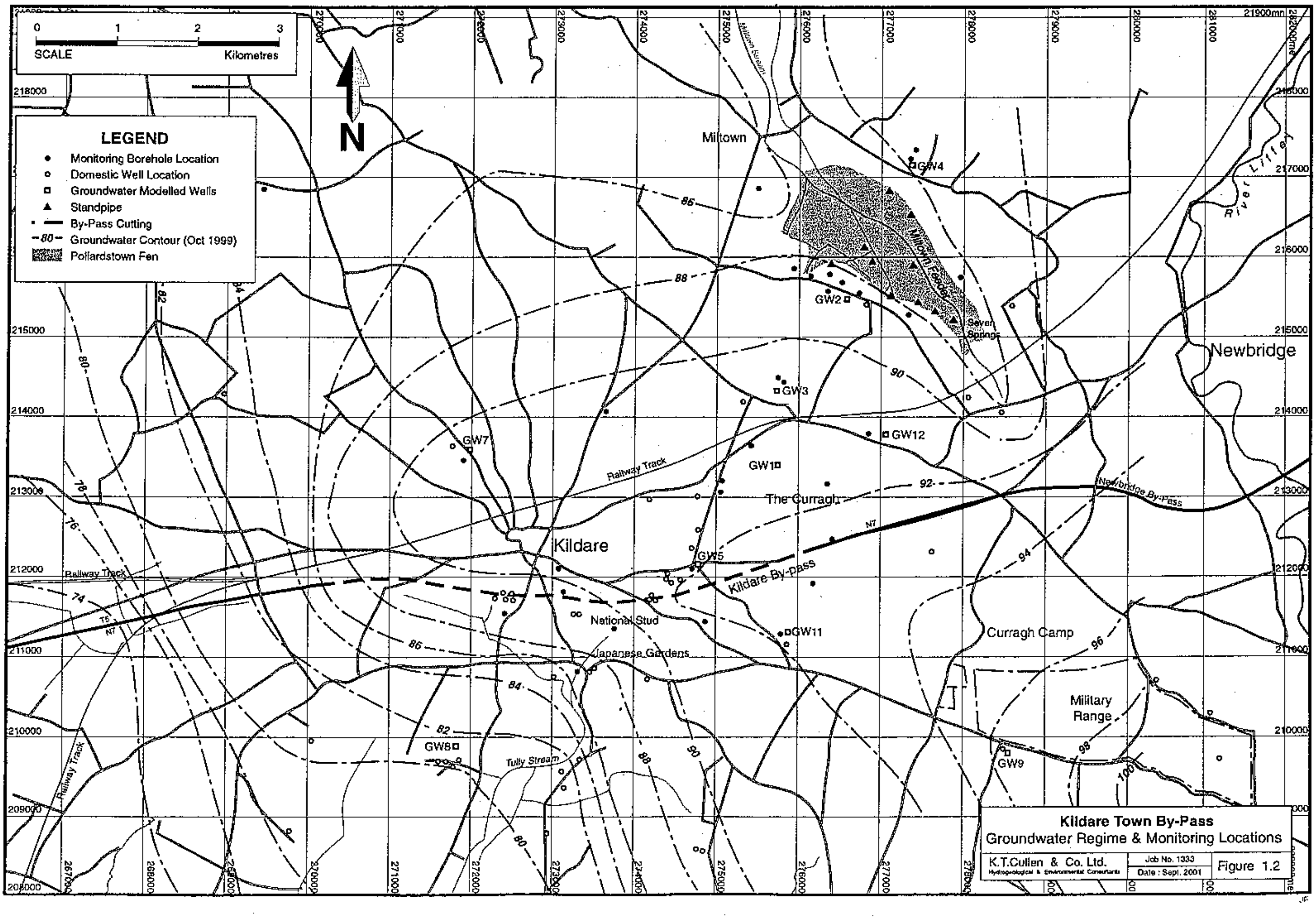


Kildare Town By-Pass
Location Map
K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants
Job No. 1333
Date : Sept 2001
Figure 1.1



Kildare Town By-Pass
Groundwater Regime & Monitoring Locations
K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants
Job No. 1333
Date : Sept. 2001
Figure 1.2

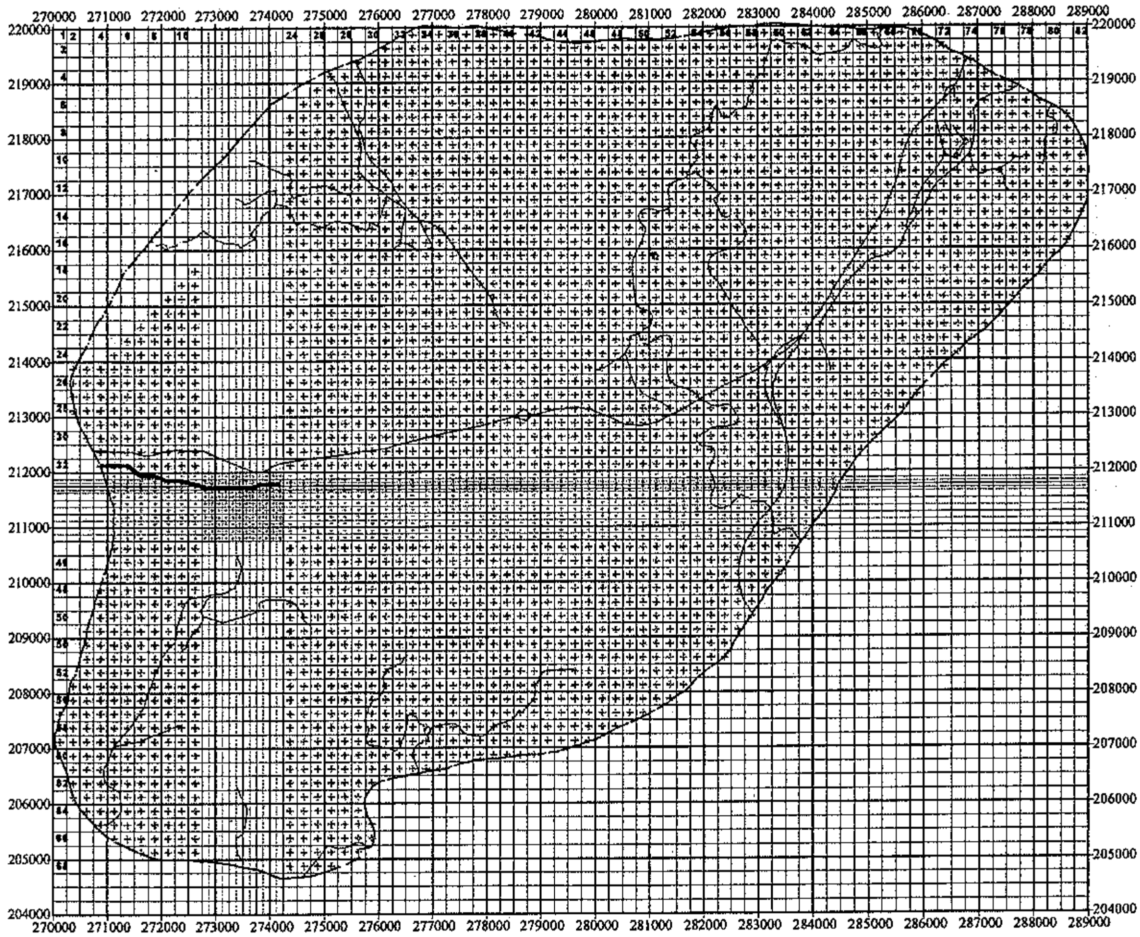


Figure 2.1 Model Extent and Node Positions

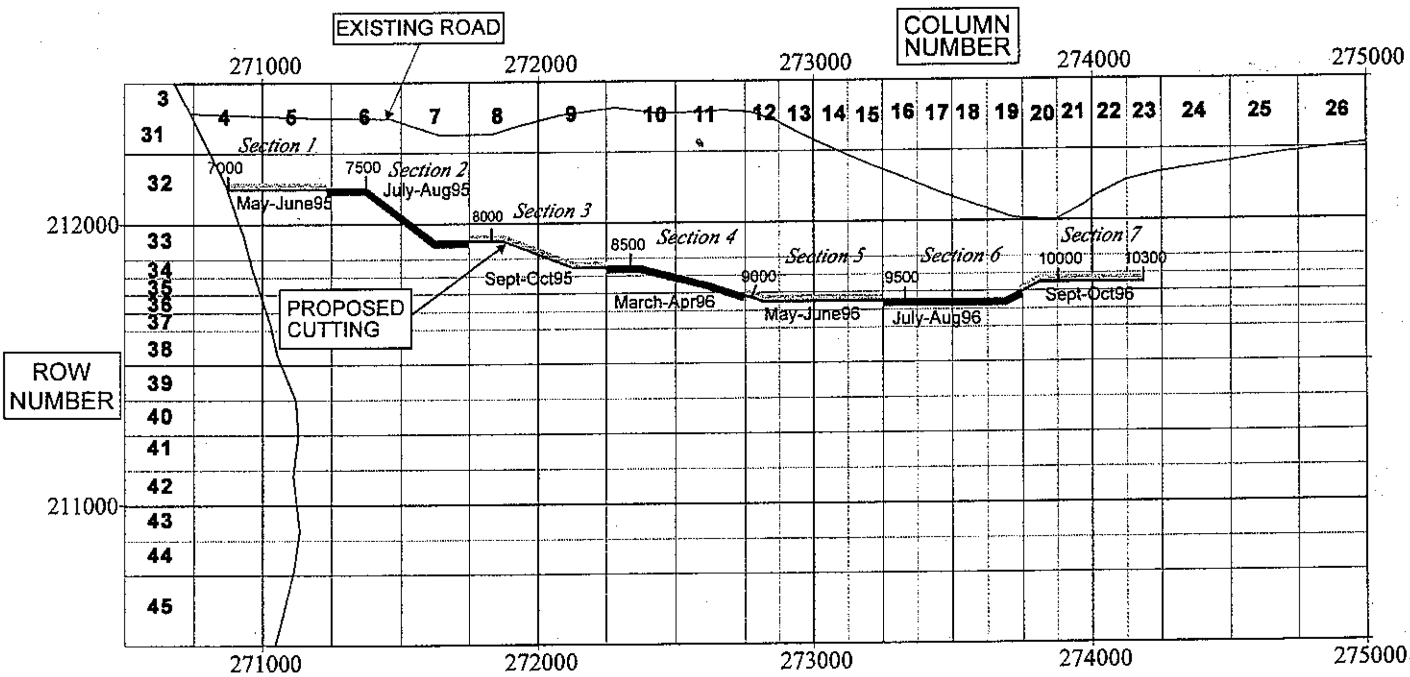


Figure 2.2 Detail of Model Grid Along Line of Cutting

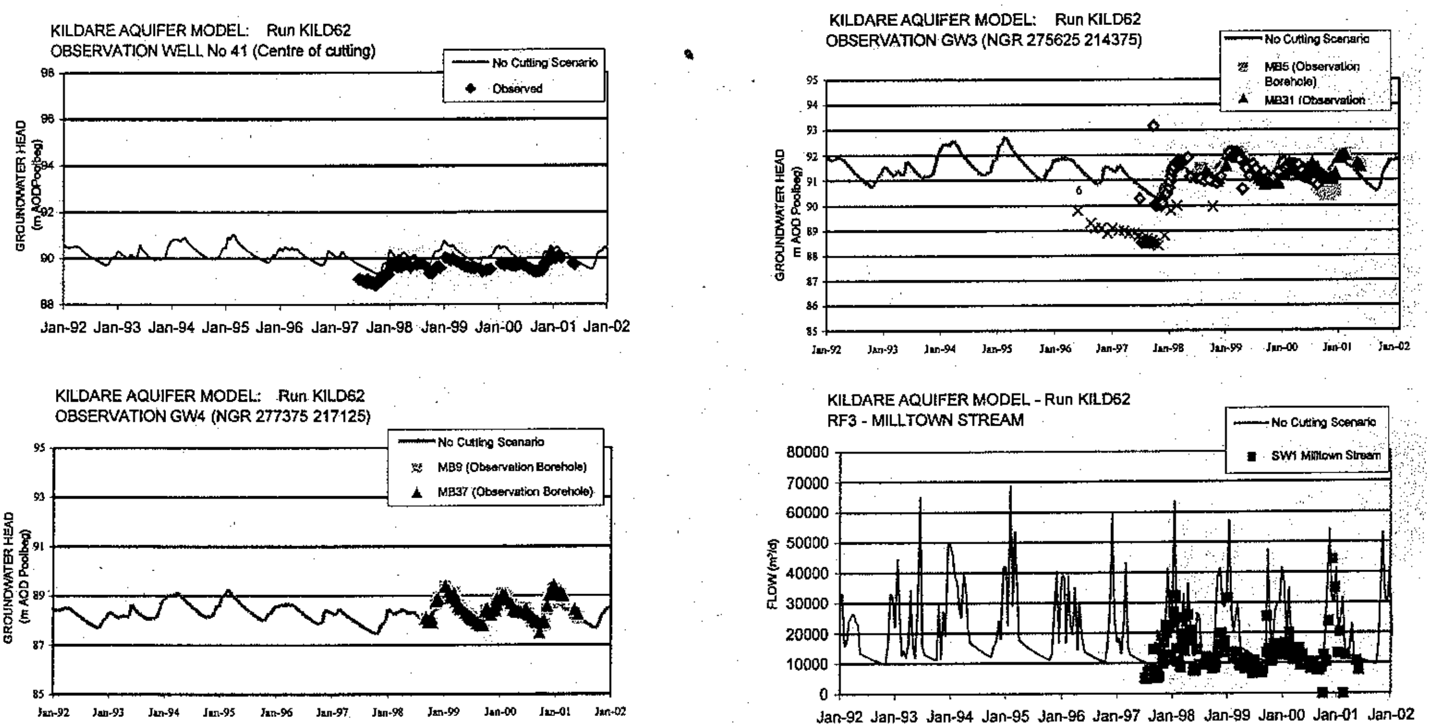


Figure 2.3 Comparison of Model Output and Observation

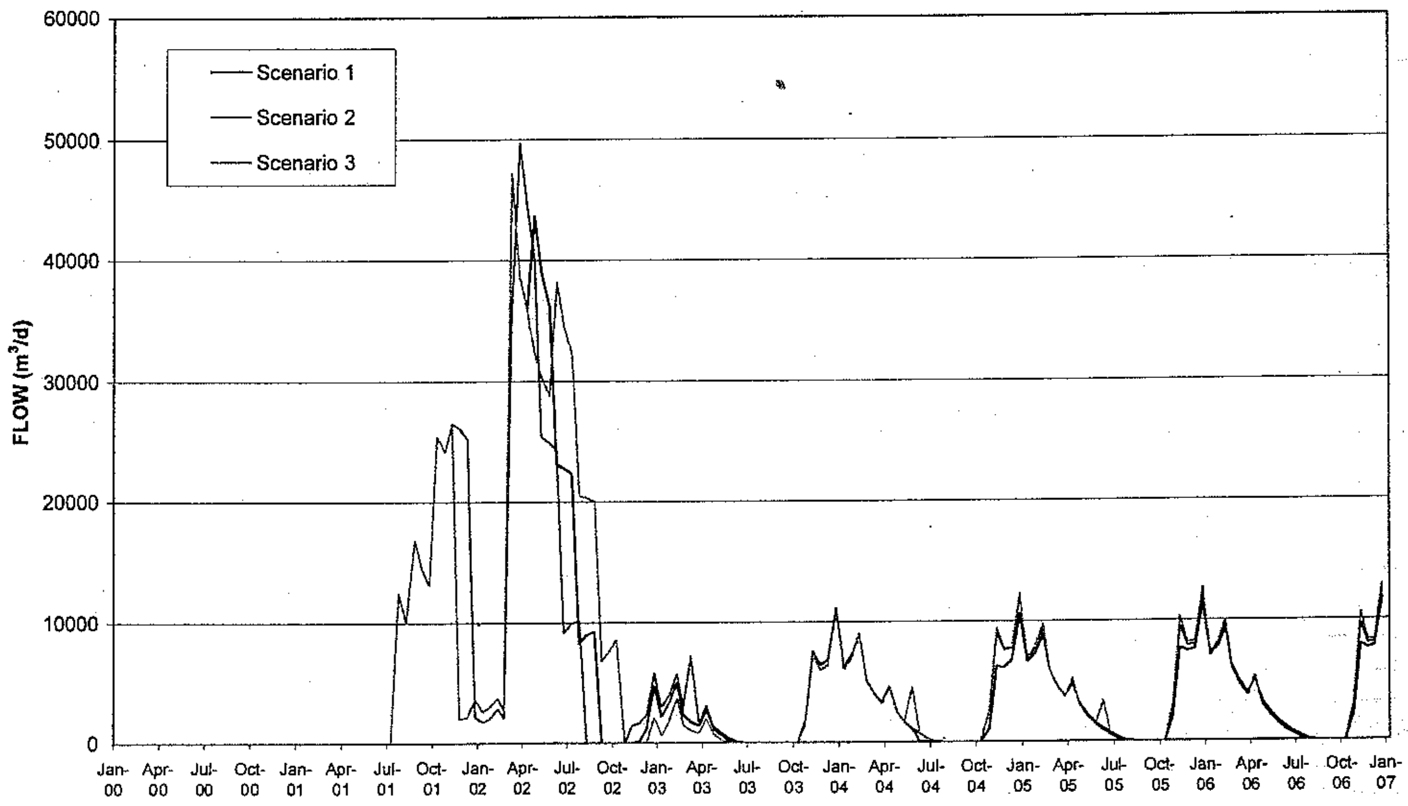


Figure 2.4 Predicted Flows from the Bypass Cutting During and After Construction

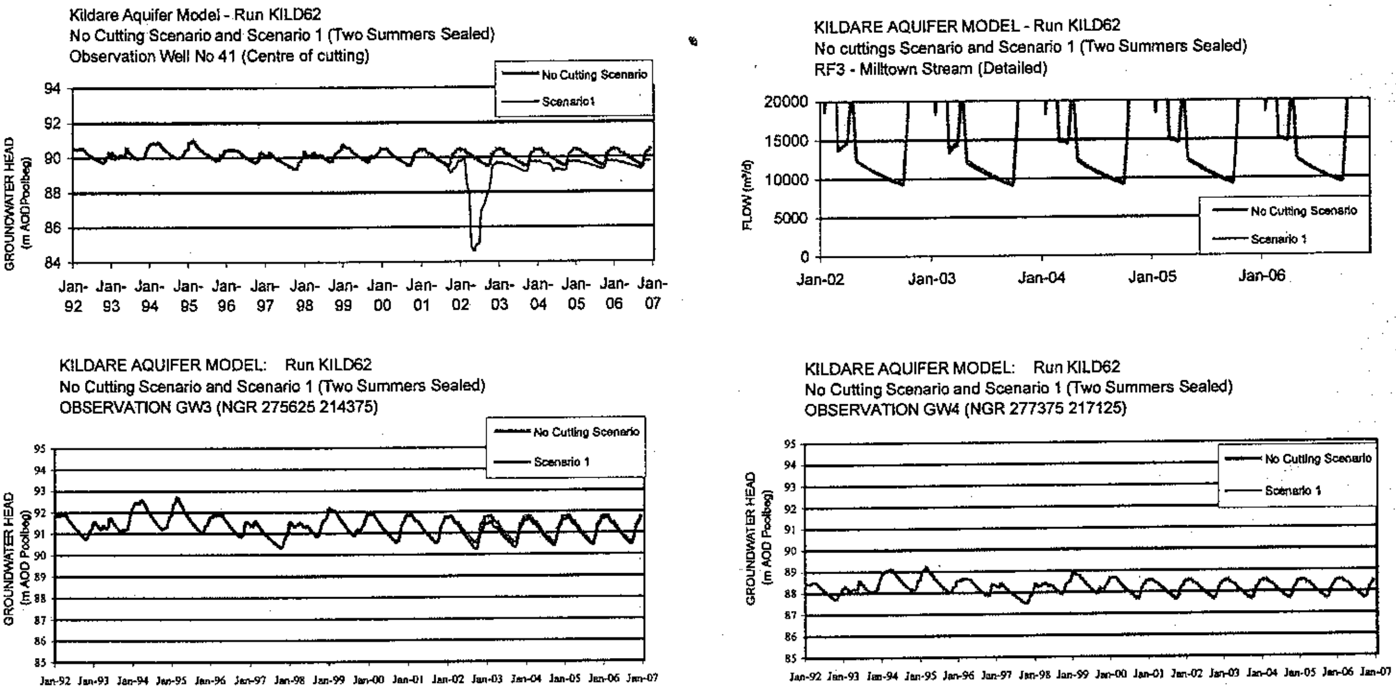


Figure 2.5 Impact Predictions

firth consultants
environmental risk assessment

ANNEX 5

Site Investigation Locations

CAUSEWAY GEOTECH

Project No.:	23-0881F	**Client:**	NDFA
Project Name:	NDFA Social Housing Lot 3 - Coolaghknock Glebe	**Client's Representative:**	Malone O'Regan Consulting Engineers

Legend Key

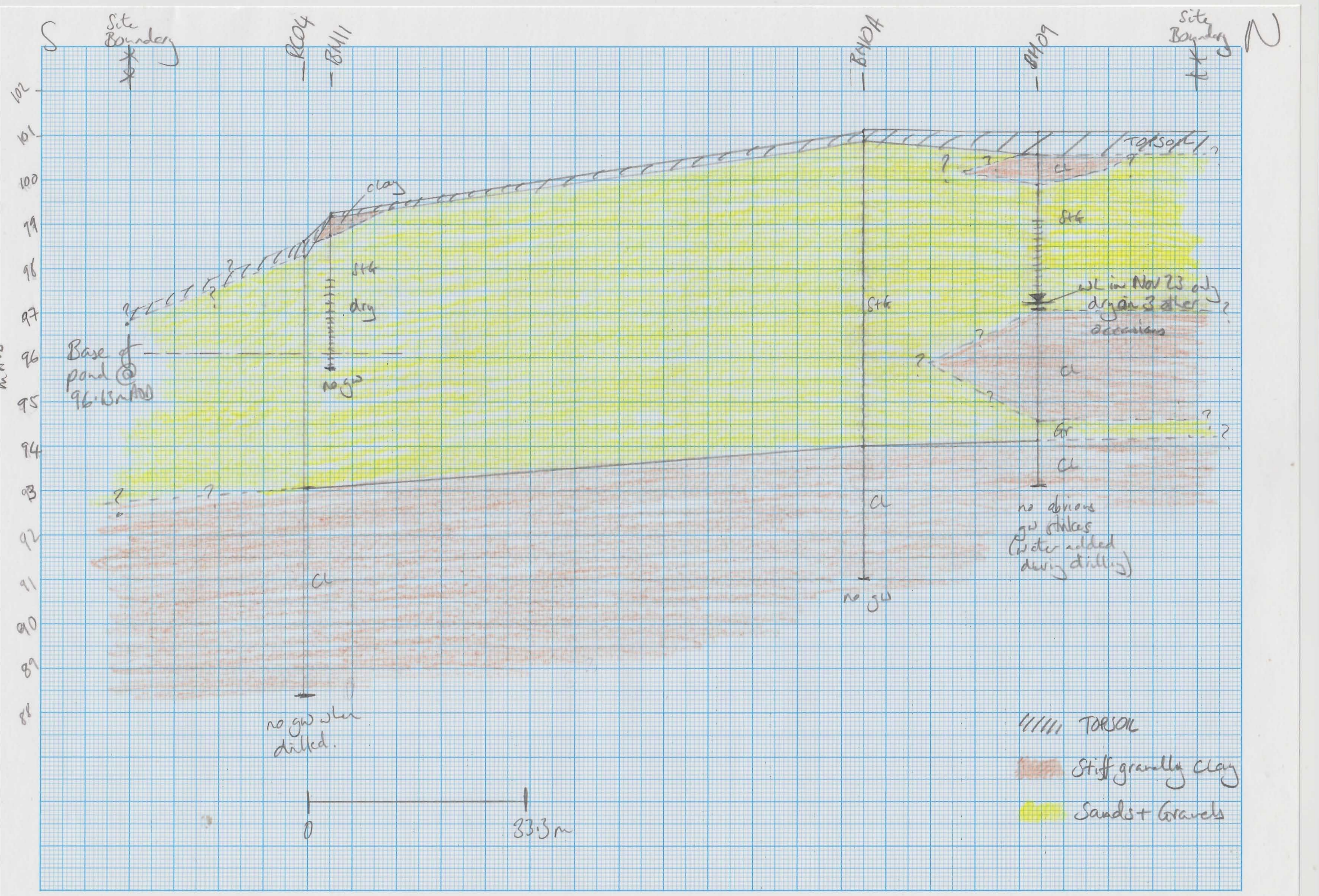
- Locations By Type - CP
- Locations By Type - SNC
- Locations By Type - TP

Title:
Exploratory Hole Location Plan

Last Revised:	**Scale:**
09/01/2024	1:2000

ANNEX 6

Interpreted Geological Cross-Section



S
N
Site Boundary
RC04
BH11
BH10A
BH09
102
101
100
99
98
97
96
95
94
93
92
91
90
89
88
TOPSOIL
clay
CL
StG
dry
no gw
WL in Nov 23 only dry on 3 other occasions
Base of pond @ 96.13mAOD
Gr
no obvious gw strikes (water added during drilling)
no gw when drilled.
0
33.3m
TOPSOIL
Stiff gravelly Clay
Sands + Gravels