Appendix A18.1 Ground Investigation Factual Reports

Report Title
Greater Dublin Drainage Ground Investigation – Phase II Terrestrial Investigation
Summary Report on the Bathymetric and Geophysical Data Integration for the GDD Scheme for Techworks Marine
Report on the Geophysical Investigation for GDD Scheme, Offshore Portmarnock
Report on the Geophysical Investigation for GDDP Portmarnock Golf Course, Dublin
Greater Dublin Drainage Offshore Site Investigation of Outfall Pipeline
Greater Dublin Drainage Scheme - Sub-Bottom Analysis
Greater Dublin Drainage Scheme - Hydrographic Survey Report GE013_GDD
Greater Dublin Drainage Scheme Fingal County Council TW/12/PRJ-007
Greater Dublin Drainage Scheme Preliminary Ground Investigation Contract - Phase 1 Factual Report on Ground Investigation (Report No. 16695)

CAUSEWAY GEOTECH

FINAL FOR ISSUE

Greater Dublin Drainage Ground Investigation – Phase II Terrestrial Investigation

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Client:	Irish Water
Client's Representative:	Tobin Consulting Engineers
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CONTENTS

APPENDICES

Document Control Sheet

Report No.:	14-645
Project title:	Greater Dublin Drainage Ground Investigation Phase II Terrestrial Investigation
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Revision	Status	Report prepared by:	Report reviewed by:	Report approved by:	Issue date
A01	Final	Matthew Gilbert MEarthSci FGS	Darren O'Mahony BSc MSc	Paul Dunlop BEng PhD CEng MIEI	10 April 2015

The works were conducted in accordance with:

Site Investigation in Construction Part 3: Specification for Ground Investigation, Site Investigation Steering Group, published by Thomas Telford Ltd (1993)

British Standards Institute (2010) BS 5930:1999 + A2: 2010, Code of practice for site investigations. Incorporating Amendment Nos. 1 and 2, as partially replaced by:

- BS EN 1997-2:2007: Eurocode 7. Geotechnical design. Ground investigation and testing
- BS EN ISO 22475-1:2006: Geotechnical investigation and testing. Sampling methods and groundwater measurements. Technical principles for execution
- BS EN ISO 14688-1:2002: Geotechnical investigation and testing. Identification and classification of soil. Identification and description
- BS EN ISO 14688-2:2004: Geotechnical investigation and testing. Identification and classification of soil. Principles for a classification
- BS EN ISO 14689-1:2003: Geotechnical investigation and testing. Identification and classification of rock. Identification and description
- BS EN ISO 22476-2:2005: Geotechnical investigation and testing. Field testing. Dynamic probing
- BS EN ISO 22476-3:2005: Geotechnical investigation and testing. Field testing. Standard penetration test

Methods of describing soils and rocks

Soil and rock descriptions are based on the guidance in Section 6 of BS 5930: 1999 + A2: 2010, The Code of Practice for Site Investigation. The amendments revised the Standard to remove text superseded by BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2004 and EN ISO 14689-1:2003 and refers to the relevant standard for each affected subclause. However, the following terms are used in the description of fine-grained soils, where applicable:

- soft to firm: fine-grained soil with consistency description close to the boundary between soft and firm soil (Table 13 of BS5930).
- firm to stiff: fine-grained soil with consistency description close to the boundary between firm and stiff soil (Table 13 of BS5930).

Abbreviations used on exploratory hole logs	
U	Nominal 100mm diameter undisturbed open tube sample
P	Nominal 100mm diameter undisturbed piston sample
B	Bulk disturbed sample
D	Small disturbed sample
W	Water sample
ES / EW	Soil sample for environmental testing / Water sample for environmental testing
SPT	Standard penetration test using a split spoon sampler (small disturbed sample obtained)
SPT (C)	Standard penetration test using 60 degree solid cone
x,x/x,x,x,x	Blows per increment during the standard penetration test. The initial two values relate to the seating drive (150mm) and the remaining four to the 75mm increments of the test length. The length achieved is stated (mm) for any test increment less than 75mm
N=X	SPT blow count 'N' given by the summation of the blows 'X' required to drive the full test length (300mm)
N=X/Z	Incomplete standard penetration test where the full test length was not achieved. The blows 'X' represent the total blows for the given test length 'Z' (mm)
V VR	Shear vane test (borehole) Hand vane test (trial pit) Shear strength stated in kPa V: undisturbed vane shear strength VR: remoulded vane shear strength
dd/mm/yy: 1.0 dd/mm/yy: dry	Date & water level at the borehole depth at the end of shift and the start of the following shift
Abbreviations relating to rock core – reference Clause 44.4.4 of BS 5930: 1999	
TCR (%)	Total Core Recovery: Ratio of rock/soil core recovered (both solid and non-intact) to the total length of core run.
SCR (%)	Solid Core Recovery: Ratio of solid core to the total length of core run. Solid core has a full diameter, uninterrupted by natural discontinuities, but not necessarily a full circumference and is measured along the core axis between natural fractures.
RQD (%)	Rock Quality Designation: Ratio of total length of solid core pieces greater than 100mm to the total length of core run.
FI	Fracture Index: Number of natural discontinuities per metre over an indicated length of core of similar intensity of fracturing.
NI	Non Intact: Used where the rock material was recovered fragmented, for example as fine to coarse gravel size particles.
AZCL	Assessed zone of core loss: The estimated depth range where core was not recovered.
DIF	Drilling induced fracture: A fracture of non-geological origin brought about by the rock coring.

Greater Dublin Drainage Ground Investigation Phase II

1 AUTHORITY

On the instructions of Consulting Engineers, Tobin Consulting Engineers ("the Client's Representative"), acting on the behalf of Irish Water ("the Client"), a ground investigation was undertaken at the above location to provide geotechnical and environmental information for input to the design and construction of a 17km long pipeline from Blanchardstown to Portmarnock.

This report details the work carried out both on site and in the geotechnical and chemical testing laboratories; it contains a description of the site and the works undertaken, the exploratory hole logs and the laboratory test results.

All information given in this report is based upon the ground conditions encountered during the site investigation works, and on the results of the laboratory and field tests performed. However, there may be conditions at the site that have not been taken into account, such as unpredictable soil strata, contaminant concentrations, and water conditions between or below exploratory holes. It should be noted that groundwater levels usually vary due to seasonal and/or other effects and may at times differ to those measured during the investigation.

This report was prepared by Causeway Geotech Ltd for the use of the Client and the Client's Representative in response to particular instructions. Any other parties using the information contained in this report do so at their own risk and any duty of care to those parties is excluded.

2 SCOPE

The extent of the investigation, as instructed by the Client's Representative, included boreholes, trial pits, soil and rock core sampling, in-situ and laboratory testing, geophysics survey, and the preparation of a factual report on the findings.

3 DESCRIPTION OF SITE

The Greater Dublin Regional Drainage Scheme consists of a waste water treatment works (WWTW) plant and accompanying pipeline with a marine outfall in North County Dublin. This phase of works focussed on the inland section of the pipeline, covering an area some 17km in length.

The route commences at the M50-N3 junction in Blanchardstown and progresses in an north-easterly direction, parallel to the northern side of the M50. The route diverges slightly to the north of the M50. The route continues easterly towards the southern side of Silloge Golf Club and the M50-R108 junction at Ballymun cross. The pipeline then runs towards Collinstown Business Park and heads to Clonshaugh, the site of the proposed WWTW. This is located approximately 2.2km southeast of Dublin Airport and between the M1 and Malahide Road. The pipeline from Clonshaugh to the marine outfall progresses in a northerly direction before then turning east and running past Kinsealy. The pipeline then turns south briefly, then finally east, crossing under the Dublin-Belfast railway line to the south of Portmarnock and north of Mayne Bridge.

The site use is a mix of agricultural lands and residential areas. Primarily, site operations were carried out in agricultural lands.

4 SITE OPERATIONS

Site operations which were conducted between 24th November 2014 and 12th February 2015, included:

- six percussion boreholes
- thirteen percussion boreholes with rotary follow-on
- one percussion borehole with Geobor S wireline rotary coring follow-on
- twelve rotary only boreholes
- thirteen trial pits.

The exploratory holes and in situ tests were located as instructed by the Client's Representative, as shown on the exploratory hole location plan in Appendix A.

4.1 Boreholes

A total of thirty-two boreholes were put down through soils and rock strata to their completion depths by a combination of methods, including light cable percussion boring by Dando 2000 and 3000 rigs, and rotary drilling by Comacchio 205, Comacchio 405 and Beretta T41 rotary drilling rigs.

The borehole logs state the methodology and plant used for each location, as well as the appropriate depth ranges.

A summary of the boreholes, subdivided by category in accordance with the methods employed for their completion, is presented in the following sub-sections.

4.1.1 Light cable percussion boreholes

Six boreholes (BH117, 120, 122, 134, 135 and 138) were put down to completion in minimum 200mm diameter using Dando 2000 and Dando 3000 light cable percussion soil boring rigs. All boreholes were

terminated either at their scheduled completion depths, or else on encountering virtual refusal on obstructions, including large boulders and weathered bedrock.

Hand dug inspection pits were carried out between ground level and 1.2m depth to ensure boreholes were put down at locations clear of services or subsurface obstructions.

Disturbed (bulk and small bag) samples were taken within the encountered strata. Undisturbed (UT100 and U100) were taken where appropriate and as directed within cohesive soils. Environmental samples were taken at standard intervals, as directed by the Client's Representative.

Standard penetration tests were carried out in accordance with EC7 at standard depth intervals using the split spoon sampler (SPT) or solid cone attachment (SPTc). The penetrations are stated for those tests for which the full 150mm seating drive or 300mm test drive was not possible. The N-values provided on the borehole logs are uncorrected and no allowance has been made for energy ratio corrections. The SPT hammer energy measurement report is provided in Appendix G. Details of the SPT hammer used are provided on the individual borehole logs.

Any water strikes encountered during boring were recorded along with any changes in their levels as the borehole proceeded.

Where water was added to assist with boring, a note has been added to the log to account for same.

4.1.2 Boreholes by combined percussion boring and rotary follow-on drilling

Fourteen boreholes (BH118, 121, 123-128, 130-133, 137 and 139) were put down by a combination of light cable percussion boring and rotary follow-on drilling techniques in bedrock. The boreholes were put down initially by Dando 2000 or Dando 3000 soil boring rigs until refusal was met, and they were then continued using a Comacchio 205, Comacchio 405 or Beretta T41 drilling rig.

Hand dug inspection pits were carried out between ground level and 1.2m depth to ensure boreholes were put down at locations clear of services or subsurface obstructions.

During percussion boring, disturbed (bulk and small bag) samples were taken within the encountered soil strata. Undisturbed (UT100 and U100) were taken where appropriate and as directed within cohesive soils.

Standard penetration tests were carried out in accordance with EC7 at standard depth intervals using the split spoon sampler (SPT). The penetrations are stated for those tests for which the full 150mm seating drive or 300mm test drive was not possible. The N-values provided on the borehole logs are uncorrected and no allowance has been made for energy ratio corrections. The SPT hammer energy measurement report is provided in Appendix G. Details of the SPT hammer used are provided on the individual borehole logs.

Where the cable percussion borehole had not been advanced onto bedrock, rotary percussive methods were employed to advance the borehole to completion/bedrock. Symmetrix cased full-hole drilling was used in some cases (if so, it will be detailed in the individual borehole log) with SPTs carried out at standard intervals as required.

Where coring was carried out within bedrock strata, conventional coring methods were used with a metric T2-101 core barrel, which produced core of nominal 84mm diameter, and was placed in triple channel wooden core boxes. One borehole (BH139) was taken to a depth of 78.4m using a Beretta T41 drilling rig. Core was recovered in a metric SK6L core barrel, producing core of nominal 102mm diameter.

The core was subsequently photographed and examined by a qualified and experienced Engineering Geologist, thus enabling the production of an engineering log in accordance with *BS 5930:1999 + A2: 2010, Code of practice for site investigations* (Incorporating Amendment Nos. 1 and 2). Core logging was carried out off site by the Causeway Geotech Engineering Geologist.

Appendix B presents the borehole logs, with core photographs presented in Appendix C.

4.1.3 Rotary drilled boreholes

Twelve boreholes (BH106-116 and BH119) were put to their completion by rotary drilling techniques only. The boreholes were completed using a Comacchio 205, Comacchio 405 or a Beretta T41 drilling rig.

Symmetrix-cased full hole rotary percussive drilling techniques were employed to advance the boreholes to bedrock. SPTs were carried out at standard intervals throughout the overburden, with small disturbed samples obtained where possible through the soils strata. In selected boreholes, rotary coring was employed to recover core samples of the bedrock.

The core was extracted in up to 1.5m lengths using a metric T2-101 core barrel, which produced core of nominal 84mm diameter, and was placed in triple channel wooden core boxes. At borehole BH139, rotary coring was carried out by Geobor S triple-tube wireline coring techniques, with core of nominal 102mm diameter produced.

The core was subsequently photographed and examined by a qualified and experienced Engineering Geologist, thus enabling the production of an engineering log in accordance with *BS 5930:1999 + A2: 2010, Code of practice for site investigations* (Incorporating Amendment Nos. 1 and 2).

Core logging was carried out off site by the Causeway Geotech Engineering Geologist.

Appendix B presents the borehole logs, with core photographs presented in Appendix C.

4.2 Standpipe installations

Groundwater monitoring standpipes were installed in all the boreholes.

Details of the installations, including the diameter of the pipe and depth range of the response zone, are provided in Appendix B on the individual borehole logs.

4.3 Trial Pits

Thirteen trial pits (TP100-TP106, TP108-110 and TP112-114) were excavated using a 7t tracked excavator fitted with a 600mm wide bucket, to maximum depth of 4.5m.

Disturbed (bulk bag) samples were taken at standard depth intervals and at change of strata. Environmental samples were also taken at regular depths in each trial pit.

Any water strikes encountered during excavation were recorded along with any changes in their levels as the excavation proceeded. The stability of the trial pit walls was noted on completion.

Appendix E presents the trial pit logs with photographs of the pits and arising provided in Appendix E.

5 LABORATORY WORK

Upon their receipt in the laboratory, all disturbed samples were carefully examined and accurately described and their descriptions incorporated into the borehole logs.

Laboratory testing of soils comprised:

- soil classification tests: moisture content measurement, Atterberg Limit tests and particle size distribution analysis.
- rock strength testing: point load index and unconfined compressive strength tests
- soil chemistry tests (conducted by Chemtest): pH, water soluble sulphate and chloride content, and organic matter content
- environmental testing: carried out on selected environmental samples, this included metals, TPH and waste acceptance criteria (WAC) testing.

Laboratory testing of soils samples was carried out in accordance with British Standards Institute (1990) *BS 1377:1990, Methods of test for soils for civil engineering purposes. Parts 1 to 9.*

The test results are presented in Appendix F.

6 GROUND CONDITIONS

6.1 General geology of the area

Superficial deposits of the area consist of glacial tills, with localised marine deposits in the Portmarnock area. The line of the site crosses several geological formations, all of Carboniferous age, and all dominated by limestones (typically argillaceous, sometimes carbonaceous) with occasional interbedded clastic sedimentary rocks.

6.2 Ground types encountered during investigation of the site

The exploratory holes encountered the following ground types, listed in approximate stratigraphic order:

- Made Ground (concrete): found only in borehole BH06 in 100mm thickness.
- Topsoil: encountered in most exploratory holes, typically in 100-400mm thickness, up to 800mm in trial pit TP112.
- Made Ground (fill): reworked gravelly clay with fragments of brick, concrete, plastic, glass and/or timber. Found in at the surface or beneath topsoil in several trial pits and boreholes, to depths typically on the order of 0.5-1.2m, and to 2.2m in trial pit TP109.
- Glacial Till: brown to black sandy gravelly clay, frequently with low cobble content and rare boulders, typically firm or stiff. Present in all exploratory holes down to a maximum depth of 14.5m (borehole BH139).
- Bedrock: Rockhead was encountered at depths ranging from 0.95m in several trial pits, to 14.5m in borehole BH139. Bedrock typically consisted of weak to medium strong dark grey limestone (usually argillaceous, and often fossiliferous). Some boreholes also encountered very weak to weak black carbonaceous limestone and mudstone. Borehole BH139 went through a sequence of extremely weak mudstones, siltstones and sandstones between 39m and 47m, before returning to more competent grey limestone.

6.3 Groundwater

Details of the individual groundwater strikes, along with any relative changes in levels as works proceeded, are presented on the exploratory hole logs for each location.

It should be noted that any groundwater strikes within bedrock may have been masked by the fluid used as the drilling flush medium.

Standpipes were installed in every borehole, and continued monitoring of these will allow determination of the seasonal variation in groundwater level.

7 REFERENCES

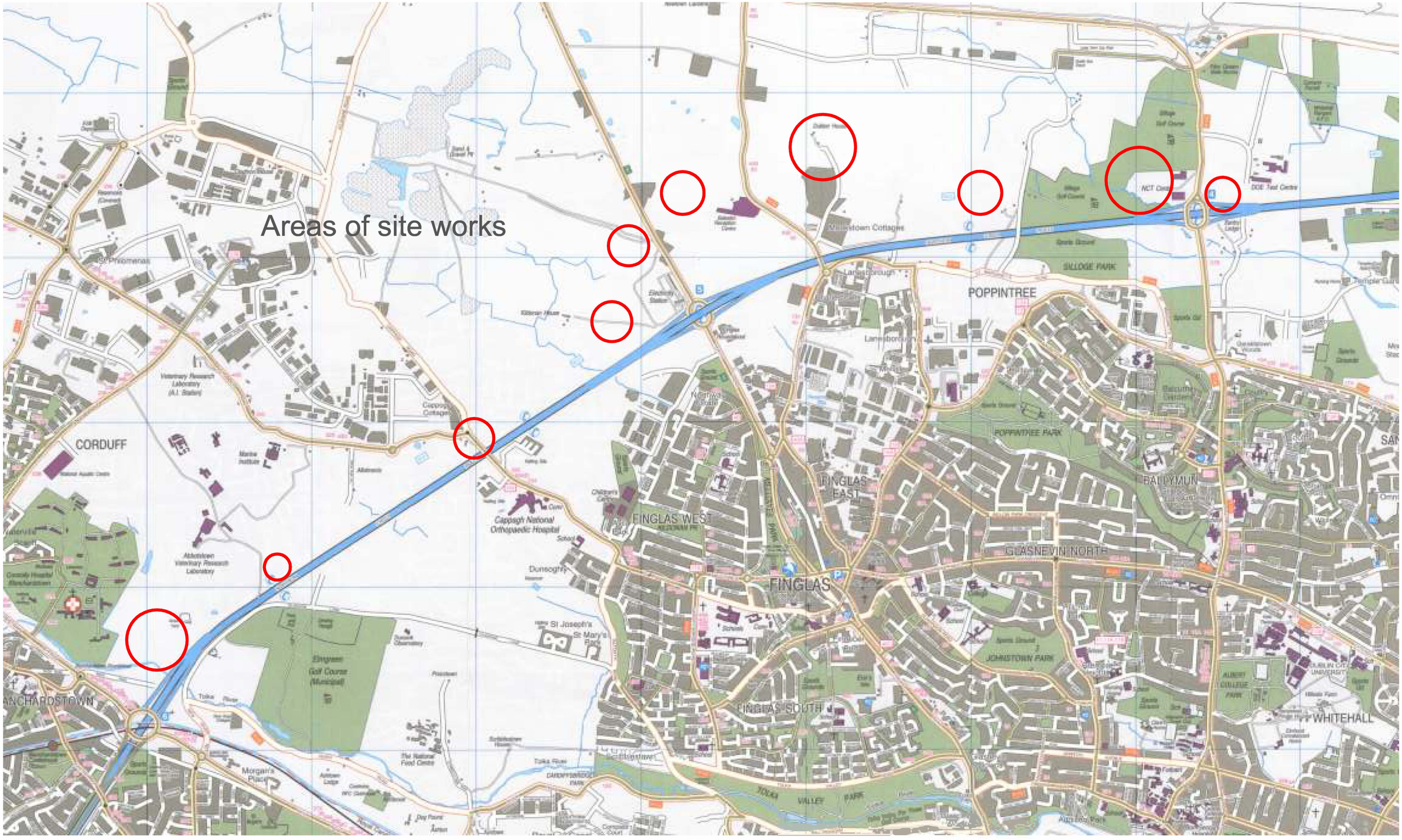
BS 1377: 1990: Methods of test for soils for civil engineering purposes. British Standards Institution.

BS 5930+A2: 2010: Code of practice for site investigations (Amendment 2). British Standards Institution.

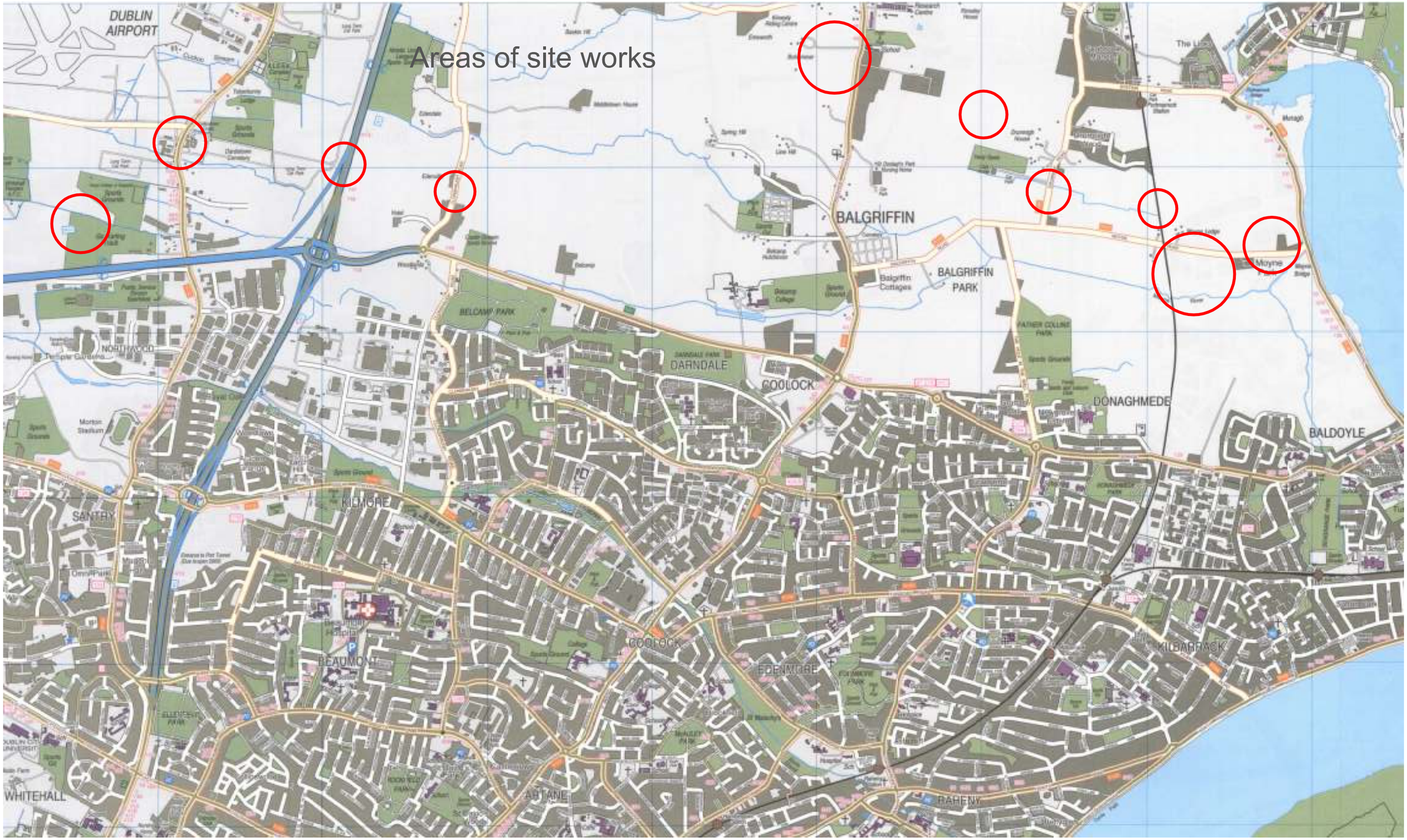
BS EN 1997-2: 2007: Eurocode 7 - Geotechnical design - Part 2 Ground investigation and testing. British Standards Institution.

BS EN ISO 14688-1: 2002: Geotechnical investigation and testing - Identification and classification of soil - Part 1 Identification and description. British Standards Institution.

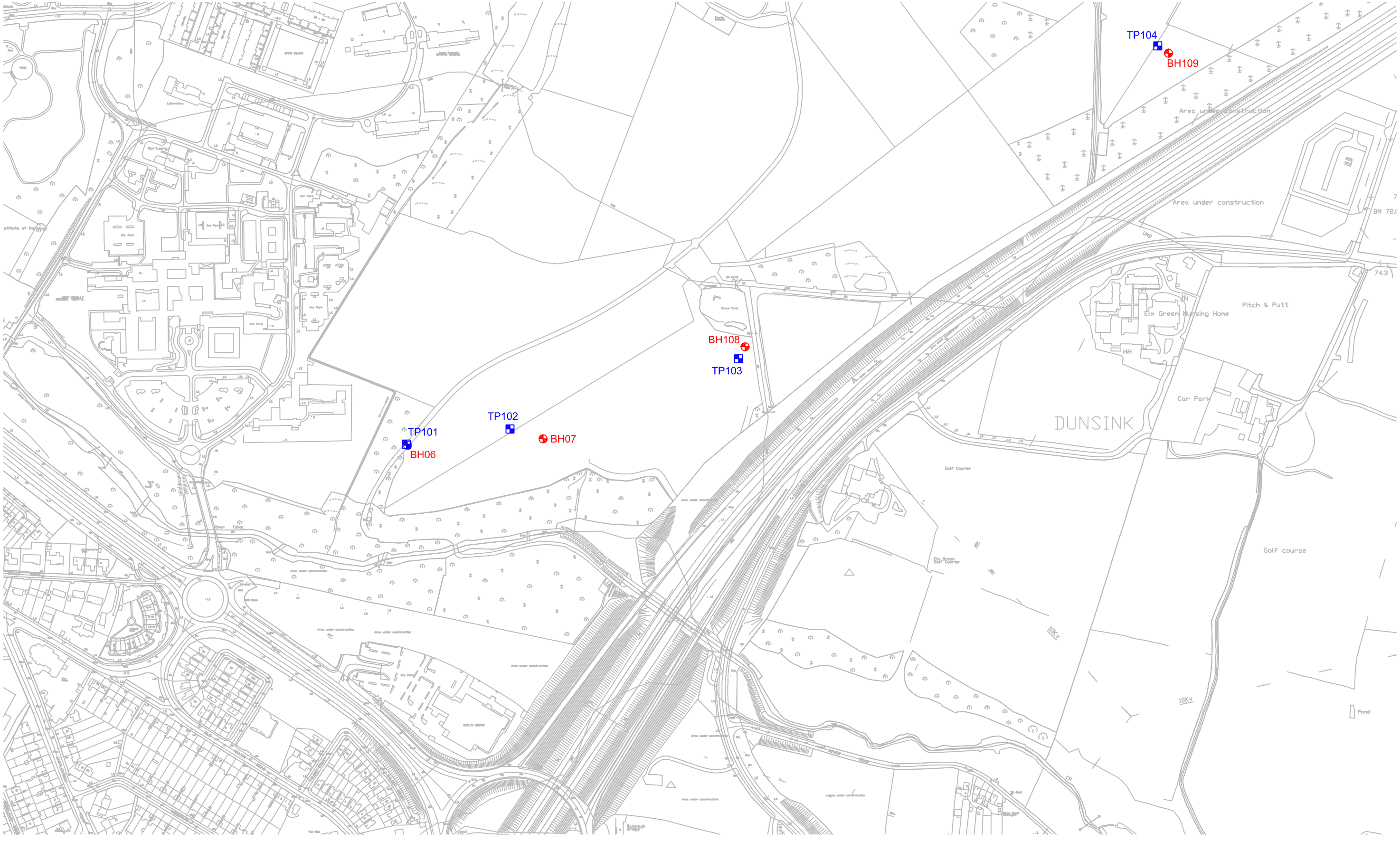
Appendix A
Site and exploratory hole location plans



PROJECT: Greater Dublin Drainage Scheme Ground Investigation		TITLE: Site location plan			
CLIENT: Irish Water	KEY:	CAUSEWAY GEOTECH	SCALE: NTS@A3	DATE: 19/02/2015	
ENGINEER: Tobin Consulting Engineers			DRWN: BS CHCK: DO'M	SERIES: 1 of 2	DWG No: 14-645-SL-001



PROJECT: Greater Dublin Drainage Scheme Ground Investigation		TITLE: Site location plan			
CLIENT: Irish Water	KEY:	CAUSEWAY GEOTECH	SCALE: NTS@A3	DATE: 19/02/2015	
ENGINEER: Tobin Consulting Engineers			DRWN: BS CHCK: DO'M	SERIES: 2 of 2	DWG No: 14-645-SL-002



PROJECT: Greater Dublin Drainage Scheme Ground Investigation		TITLE: Exploratory hole location plan			
CLIENT: Irish Water	KEY:	CAUSEWAY GEOTECH	SCALE: NTS@A3	DATE: 19/02/2015	
ENGINEER: Tobin Consulting Engineers			DRWN: BS CHCK: DO'M	SERIES: 1 of 10	DWG No: 14-645-EHL-001