CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
REFERENCE: DG/CB/190/11

FOR
DUMFRIES AND GALLOWAY COUNCIL
&
SCOTTISH POWER

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1 INTRODUCTION

1.1 PREAMBLE

The physical geography around Castle Douglas is generally flatter that the surrounding hill land with the Dee valley widening considerably to the east and west. The River Dee thus meanders through this undulating countryside and exhibits an extensive functional flood plain.

The Carlingwark Loch has, from earliest historical times, occupied the low lying marshland to the south of Castle Douglas. The Loch was partly drained by the construction of the Carlingwark Lane in 1765 to facilitate the excavation and transportation of marl for agricultural purposes.

The development of the River Dee hydro-electric scheme (the Galloway Hydros Scheme) in the 1930s included the linking of the Loch Doon and Clatteringshaws catchments to the River Dee system, which results in an overall increase in water flow through the Dee. Other elements of the system provide peak rainfall attenuation leading to a reduction in peak river flow but an overall increase in base flow. The hydro scheme therefore brought with it an increased seasonal risk of flooding to local farmland and, as a result, a number of small pump stations were placed in the low lying areas to the west of Castle Douglas. These pumps, coupled with a series of flood bunds, assisted and continue to assist the drainage of local farmland.

Notwithstanding the presence of the Blackparks Pumping Station on Carlingwark Lane the drainage of the area around Carlingwark Loch and Castle Douglas itself remains highly dependent on the state of the River Dee to the north and west. Raised water levels in the Carlingwark Loch are known to occur and present a known hazard to the town of Castle Douglas.

Dumfries and Galloway Council, in partnership with Scottish Power, is seeking to carry out a flood risk appraisal for the town of Castle Douglas with specific reference to the risk posed by interaction of the Carlingwalk Loch and the River Dee. Terrenus CDH Ltd was appointed by the Council to carry out this work.

Cognisance of a number of related flood risk and flood assessment reports for the Carlingwalk Lane watercourse and Castle Douglas has been included in the assessment with the effect of the Blackparks Pumping Station being a key element of the study.

The Council is seeking to gather information in order to allow informed decisions to be made regarding the future of the pumping station and the related flood defences.

First and second drafts of the report have been presented to the Council with initial findings. This current report represents the Final report and includes comments on a number of issues raised by the Council and by SEPA together with additional information where necessary. This report is provided for discussion by relevant parties and will include data and shape files in separate electronic format.

1.2 OBJECTIVES OF INVESTIGATION

From the project brief and subsequent discussions with the Council the principle aims of the assessment are to:

"enable Dumfries and Galloway Council to make an informed decision on the criticality of the Blackparks pump station in protecting Castle Douglas from flooding events primarily from the Carlingwark Loch and Lane and associated catchment and some consideration of improvements to the current situation."

The above broad objective anticipates that a review of the current situation will be carried out as well as detailed two dimensional flood modelling of the area as a whole under a variety of circumstances.

Information from the investigation and watercourse modelling was used to inform possible mitigation measures relating to Carlingwark Loch and Carlingwark Lane.

1.3 REPORT STRUCTURE

The structure of this report firstly sets out the geography and hydrological environment of the Castle Douglas area prior to considering the historical relationship of the town to the water environment and, specifically, the Carlingwark Loch.

The detailed model of the Carlingwark Loch, Carlingwark Lane and River Dee surface water environment is set out and the model results presented.

Finally, potential mitigation measures to reduce the risk of flooding to Castle Douglas whilst enhancing the local environment are considered.

1.4 LIMITATIONS OF REPORT

Terrenus CDH Ltd. has prepared this report for the sole use of Dumfries & Galloway Council and Scottish Power, in accordance with generally accepted consulting practice and for the intended purpose as stated in the related contract agreement. No other warranty, expressed or implied, is made as to the professional advice included in this report.

To the best of our knowledge, information contained in this report is accurate at the date of issue. It should be noted, however, that this report is based on the information obtained from the sources listed in Section 2 below. There may be conditions pertaining at the site not disclosed by these sources, which might have a bearing on the recommendations provided if such conditions were known. We have, however, used our professional judgement in attempting to limit this during the investigation.

It is important therefore that these implications be clearly recognised when the findings of this study are being interpreted. In addition, this should be borne in mind if this report is used without further confirmatory investigation after a significant delay.

The report is not, however, suitable for detailed planning and design purposes.

2 DATA SOURCES, GEOGRAPHY & HYDROLOGICAL ENVIRONMENT

2.1 DATA SOURCES

A wide variety of data sources were consulted during the course of the investigation including:

- The Scottish Environment Protection Agency (SEPA) indicative flood risk map;
- Current Topographic Maps;
- Additional topographic information for Castle Douglas as provided by Dumfries and Galloway Council;
- LiDAR data procured from SEPA via Dumfries and Galloway Council comprising a 5m horizontal grid with a vertical accuracy of +/-50cm;
- Aerial Photography of the Castle Douglas Area;
- Geological & Hydrogeological Maps;
- Scottish Power Galloway Hydros – Culvennan Land Drainage Pumps, November 2009;
- Scottish Power Blackparks Facility Report (Rev 2), April 2009;
- Scottish Power Review of Blackparks Facility, November 2005;
- Scottish Water Solutions Castle Douglas Waste Water Treatment Works Flood Risk Assessment, October 2008;
- Dumfries and Galloway Infrastructure Engineering Guide – Project Risk Management;
- Some Stewartry Sketches, Alistair Penman 1981;
- Causewayend to Castle Douglas, Alistair Penman 1986

Discussions were also held with the National Trust for Scotland Ranger service, Dumfries and Galloway Countryside Ranger, Hydros Manager Scottish Power and SEPA offices.

A full list of references is included in the appendix to this report.

2.2 GENERAL GEOGRAPHY OF THE CASTLE DOUGLAS AREA

The valley of the River Dee in Galloway is clearly defined throughout the hills surrounding New Galloway and in the vicinity of Loch Ken. The southern part of the River Dee valley around Tongland is similarly topographically well defined. The physical geography around Castle Douglas is however generally flatter and gently undulating with the Dee valley widening considerably to the east and west.

Although the bulk of Castle Douglas is located at a higher level, the area around Carlingwark, which is fed by the Gelston Burn from the south east, is at a similar level to that of the wider Dee valley. At the north western periphery of Carlingwark Loch the land rises slightly, effectively forming a low ridge that impounds flow from the south east towards the north west and the River Dee. The Carlingwark Lane cuts through this ridge and allows partial drainage of the Loch.

The Carlingwark Lane watercourse also drains the Dee Marshes and agricultural grazing land between Carlingwark Loch and the River Dee, including the outfall from the wastewater treatment works for Castle Douglas.

The Dee Marshes are an internationally important ecological site and are registered as a:

- Site of Special Scientific Interest (SSSI);
- Special Protection Area (SPA); and
- RAMSAR site.

The SSSI citation notes that the marshes contain areas of swamp, fen, grassland and carr woodland and is one of the best examples of a semi-natural freshwater system in north west Europe. The SSSI site covers an area of some 770ha.

2.3 GENERAL GEOLOGY

The superficial deposits around the existing line of the River Dee and Carlingwark Lane are dominated by alluvium comprising Silt, Sand and Gravel of Quaternary Period origin. To the north and east of these deposits Fluvio-glacial deposits are recorded comprising Gravel, Sand and Silt. Around the Carlingwark Loch the superficial deposits comprise Glacial Till.

The solid geology below the Castle Douglas area, including the Carlingwark Loch and Carlingwark Lane, is dominated by deep marine Greywacke sedimentary rocks of the Silurian Carghidown Formation.

2.4 HYDROLOGICAL ENVIRONMENT

2.4.1 Galloway Hydros Scheme

The River Dee catchment is a managed hydrological environment as part of the Galloway Hydros Scheme. This hydroelectric system, built in the earlier part of the 1930's, has a combined catchment of over 1,300km^2 in Ayrshire and Galloway and comprises eight dams and six power stations together with associated tunnels, aqueducts and pipelines.

Loch Doon lies at the head of the scheme and is a natural loch whose level has been raised and augmented by diverted flow from the Water of Deuch and the Bow Burn. Prior to the hydro-scheme Loch Doon solely fed the River Doon which flows to the north. A compensation flow continues down the River Doon however the scheme now feeds the headwaters of the River Dee and thus the downstream power stations.

Clatteringshaws Loch is a man-made water body created by the damming of the upper Black Water of Dee. A compensation flow is released to this watercourse with a further piped water supply being provided for the Glenlee Power Station. Outflow from this power station enters the River Dee upstream of Loch Ken. Overflow water from Clatteringshaws as well as catchment run-off downstream of the loch enters Loch Ken opposite the village of Parton.

Loch Ken is a naturally flat bottomed valley where, historically, the River Dee has spread out to form a shallow extent of water during periods of peak flow. The hydro scheme barrage at Glenlochar results in Loch Ken being a larger permanent body of water which acts as a storage reservoir for the downstream Tongland Power Station. Beyond this final power station the River Dee enters Kirkcudbright Bay and thus the wider Solway Firth.

2.4.2 Hydrological Impact of Hydro Scheme

Since the scheme was completed local records suggest that average annual rainfall in the Dee catchment has increased by about 20%. In addition, Loch Doon being added to the River Dee catchment results in an overall increase in flow.

Loch Doon and Clatteringshaws Loch together with the associated catchment connectors provide attenuation to the peak River Dee flow effectively resulting in a reduction in peak flow but an increase in base and less extreme flows.

Reports on the impact of the Galloway Hydros Scheme on the River Dee downstream of Loch Ken estimate that the system increases base flows by some 6m3/s on average although this increase is highly variable due to seasonal and annual fluctuations.

Management of the hydro scheme seeks in part to reduce the risk of downstream flooding, chiefly by restricting the flow from Loch Doon and Clatteringshaws Loch during flood conditions. Loch Ken has a limited storage capacity and during peak flow events the Glenlochar Barrage is opened such that the output flow from the loch is not impeded.

2.4.3 Impact of Water Framework Directive on the Hydro Scheme

The Water Framework Directive (WFD) was introduced by the European Commission in 2000 and aims to protect, improve and ensure the sustainable management of water resources. Under the WFD a programme of measures will be implemented in a formal River Basin Management Plan (RBMP). The Scottish Government has adopted this directive and, therefore, the Galloway Hydros Scheme as a heavily modified water system will seek a 'Good Ecological Potential' via the provision of a maximum net environmental benefit without impacting on the operation of the scheme.

The Galloway Hydros lies chiefly within the Solway Tweed River Basin District and partly within the Scotland River Basin District. As a result SEPA and the Environment Agency have a joint responsibility for co-ordinating the key areas of work.

A key hydrological impact of the drive towards good ecological potential for the Galloway Hydros is the maintenance of adequate levels of compensation flow to achieve the ecological wellbeing of the catchment.

2.4.4 Carlingwark Lane

Carlingwark Lane drains just under 14km^2 of land around Castle Douglas, including the Gelston Burn and the output from Carlingwark Loch.

It has been suggested in the earliest maps of the area that, prior to being partly drained in 1765 by the construction of the Carlingwark Lane, the loch was at a sufficient depth to allow drainage to the south and the Solway Firth via the Doach Burn. A review of the local land form and available height data suggests that this was not the case and that the Loch has always drained to the north to enter the River Dee across the wide flood plain around Threave Island.

In addition to the drainage of Carlingwark Loch the Lane also accepts water from a number of local drainage channels across the lower lying ground in the vicinity (see Figure 2). These channels are coupled with a number of bunds that prevent the free flow of flood waters over the area during extreme storm events. These drainage bunds are likely to be chiefly agricultural in nature and are not thought to provide any significant protection against the flow of water during larger storm events such as the design 1 in 200 year event.

2.4.5 Carlingwark Loch

The Countryside Ranger together with local residents indicate that vegetation growth around the upper end of the Carlingwark Lane (around Buchan Bridge) is known to become heavy and to impede the flow of water. A number of local residents stated that this vegetation growth has resulted in periodic raised water levels in the loch itself.

2.4.6 Watercourse Monitoring Information

SEPA runs a gauging station immediately downstream of the Glenlochar Barrage. The data from this station is severely compromised by the function of the barrage itself, which controls the normal flow from Loch Ken.

A total of five Scottish Power automatic water level monitors were placed by MWH from the upstream side of Carlingwark Loch to the confluence of the Carlingwark Lane and the River Dee. Some 30 months of data was available for three of these monitoring stations; two of the stations were lost or compromised.

2.5 BLACKPARKS PUMPING STATION

The station is a run of river facility placed within the Carlingwark Lane, adjacent and to the north east of Meikle Wood Hill. Scottish Power confirms that the station comprises two sluice gates of 1.5m wide by 1.2m high, each with flap valves which prevent water flow from the River Dee upstream towards Castle Douglas. In addition, the station accommodates two pumps to assist the water flow from Carlingwark Loch to the River Dee. These pumps are rated at 1.35m3/s each and are operated automatically by means of level switches immediately up and downstream of the pumping station. The pumps are fully automatic however the precise start up trigger levels are not known.

Potential flood waters are prevented from circumnavigating the pumping station by means of bunds that connect the station to Meikle Wood Hill to the south and the Blackparks Smallholdings to the north (Blackparks 3). These bunds show some sign of degradation and no longer form a level crest height. The lowest point on the bunds is understood to be at 44.1m OD.

3 REVIEW OF RECENT AVAILABLE REPORTS

3.1 SCOTTISH POWER REVIEW OF BLACKPARKS FACILITY

This interim report was commissioned by Scottish Power and undertaken by The Carnie Consultancy and MWH. The report entails consultations with a number of organisations in the local area as well as some tenant farmers, limited topographic surveying of the area and an assessment of the Blackparks Pumping Station.

This report suggests that the Blackparks station may have been built to allay fears of flooding to the land downstream of the Glenlochar Barrage following the construction of the Galloway Hydros Scheme. The report notes that the area around the Blackparks station forms part of the Threave Estate. Within the Estate a Special Protection Area and RAMSAR site lies downstream of the pumping station and a Site of Special Scientific Interest covers parts of the low lying marsh land around the station.

The report states that the there is no record of the bunds on either side of the Blackparks station being overtopped. The worst storm event record in the report is in December 1994.

The Countryside Ranger is reported to note that the level of the Carlingwark Loch typically varies by up to 0.6m above normal level but can, on occasions, rise by up to 0.9m above normal which causes surface water drainage problems in low lying areas of Castle Douglas.

The report concludes that the Blackparks station cannot be decommissioned but that optimisation of the pumps could reduce running costs without presenting an additional risk of peak water level in Carlingwark Loch.

3.2 SCOTTISH POWER BLACKPARKS FACILITY REPORT (REV 2)

This report, compiled by MWH, updates and expands the findings of the above, earlier, report, including the installation and analysis of a number of long term water level monitors.

The report basis was the analysis of the automatic level monitors coupled with hourly water level data from the Glenlochar gauging station immediately downstream of the Glenlochar Barrage. Of the five water level monitors two were lost or compromised during the monitoring period.

The report re-iterates the earlier investigation that the Blackparks Pumping Station and related protection bunds play an important part in the mitigation of flood risk to the lower lying areas of Castle Douglas.

It is noted in the report that if the embankments were to breach during a flood event in the River Dee this would inundate Carlingwark Loch.

The report make a number of recommendations with respect to the upkeep of the water level monitoring stations and the maintenance of the flood bund associated with the pumping station. Of the recommendations made it is understood from Scottish Power that, to date, the flanking bunds have not been raised or maintained and that the level monitoring points have been shut down. Scottish Power is putting into place meters that will record the use of the Blackparks pumps in order to allow refinement of its operating regime.

3.3 SCOTTISH WATER SOLUTIONS CASTLE DOUGLAS WASTE WATER TREATMENT WORKS FLOOD RISK ASSESSMENT

As part of the background preparations for the new Castle Douglas wastewater treatment works (WWTW) Scottish Water Solutions commissioned Mouchel to carry out a flood risk assessment.

The location of the WWTW is on the south western outskirts of Castle Douglas and, following concerns raised by SEPA, a flood model was compiled using topographic information from a digital terrain model (DTM) coupled with survey cross-sections through the River Dee and Carlingwark Lane. A review within the report of the DTM information and the topographic survey undertaken at the same time indicates a good correlation between the two datasets.

Although the flood model includes a survey cross-section through the Blackparks Pumping facility it appears that this represents the ground level to the east of the bund that links the pumps to the perimeter of the functional flood plain. The height of the bund is therefore not known and has been estimated in the model to be 45.00m OD throughout.

The flood model itself entailed a one dimensional assessment of the principal water courses, resulting in a peak water level for a variety of potential storm event hydrographs. The function of the Blackparks pumping station was considered within this investigation.

The report indicates the following with respect to recent local flooding;

> *Some historical flooding was recorded in Castle Douglas,* (in the 1995-2007 period) *however this was largely related to the blockage of culverts and road gullies on the other side of the town to the WWTW* (i.e. in the south east of the town). *Flood prevention activities noted were largely routine cleaning and maintenance of culverts, culvert screens and road gullies on the other side of the town.*
>
> *.....there have been no fluvial flooding events which have affected properties in the vicinity of the WWTW in recent years. However agricultural land close to the Castle Douglas bypass (A75) is flooded up to approximately five times a year. This is understood to be largely due to the operation of the barrage at Glenlochar. During extreme rainfall events the barrage is opened to relieve flooding upstream, resulting in flooding of farmland around Castle Douglas.*

The report comments that the Glenlochar Barrage regulates flows to the Tongland Power Station, and that, in addition, the barrage is raised to alleviate flooding downstream following high rainfall. The barrage is however also opened if levels upstream are too high, an action that occurs approximately 5 times a year. A recent case where the barrage was opened due to extreme flows was in November 2006 when there was flooding in Dalry and Galloway. At this time the flooding along the River Dee floodplain in the vicinity of Castle Douglas was considerable but was not observed to overtop the flank embankments associated with the Blackparks pumping station.

The report identifies that Carlingwark Loch does not drain well due to the flat lying nature of the valley bottom and due to the water levels in the River Dee being too high to allow free drainage. The requirement of the Blackparks station is noted to be reduced during the Summer months indicating that some natural drainage of the Carlingwark Loch to the River Dee may occur.

Peak flow analysis of the River Dee and Carlingwark Lane was carried out using the statistical procedure for the River Dee and the rainfall runoff method for the Carlingwark Lane.

The report concludes that sizable parts of the low lying areas around the Carlingwark Lane will be inundated during the design 1 in 200 year storm and that the Blackparks Pumping Station would be overwhelmed during such an event.

3.4 SCOTTISH POWER GALLOWAY HYDROS CULVENNAN LAND DRAINAGE PUMPS

The Halcrow Group was commissioned to assess the effects of the Galloway Hydros Scheme on drainage at Culvennan Farm near the River Dee about 1km downstream of the Glenlochar Barrage.

This investigation included an assessment of the impact of the hydro scheme on the peak flow of the River Dee in comparison to the calculated natural flow of the watercourse. Outputs from this study were combined with a DTM within a 1D steady state hydraulic model in order to examine the peak water level under a variety of hydrographs for both before and after the implementation of the hydro scheme.

This report concludes that the hydro scheme increases the average base flow of the River Dee downstream of Loch Ken by about 6m3/s. The report does however note that the magnitude of the base flow increase is highly variable due to seasonal and annual fluctuations.

The flood model adopted by the report indicates that there is an increase in water level under mean flows in the River Dee with the magnitude of increase reducing with the increased severity of the flood event.

4 ADDITIONAL INFORMATION INPUTS

4.1 SCOTTISH POWER

Discussions with Scottish Power were held at Glenlee Power Station. These discussions confirmed that the pumps at Blackparks are rated at over 40 cubic feet per second and it was concluded that each pump may be considered to have a capacity of 1.35m3/s. The pump trigger mechanism at Blackparks is confirmed to be automatic via an electronic level indicator. A stop alarm has been installed using the available mobile phone network which is triggered by a pump stoppage or screen blockage. The same mechanism is used to indicate the pump on / off periods.

4.2 DUMFRIES AND GALLOWAY COUNCIL COUNTRYSIDE RANGER

Discussions were held with the Dumfries and Galloway Council Countryside Ranger, Mr Keith Kirk. From these discussions an additional understanding of the history of Carlingwark Loch was reached as well as local historical information and more recent bathymetry data for the loch.

4.3 NATIONAL TRUST FOR SCOTLAND RANGER SERVICE

Additional discussions with Mr Karl Mundey of the NTS ranger service were carried out providing information concerning the general habitat of the Carlingwark Lane area, plant growth along the Lane and the nature and effectiveness of the Scottish Power pumping stations in the area.

4.4 DUMFRIES AND GALLOWAY LIBRARIES

Background historical data for the Castle Douglas areas was available from the local library in Castle Douglas.

4.5 ADDITIONAL INFORMATION

A significant local flooding event occurred on Loch Ken in both November 2010 and December 1978 when the level of the Loch was noted to be at the floor level of Parton Village Hall. A recent topographic survey establishes the peak water level during these two events to be 47.2m OD. It is understood that a similar storm event occurred in 1909 prior to the construction of the hydro scheme.

The bathymetric survey of Loch Ken carried out in 1903 suggests that a substantial part of Loch Ken already existed at that time. This survey also suggests that the River Dee outflow bed level from Loch Ken at Glenlochar effectively dictates the natural upstream water level of the loch.

5 FLOOD RISK ASSESSMENT

5.1 MODEL SETUP

General

The modelling of the River Dee/Carlingwark Lane watercourse system is relative to the key features identified by the Council and during the site walkover, and by the review of the available maps and surveys. For the purpose of this report particular attention is given to the area between the confluence of the Carlingwark Lane and River Dee and the Gelston Burn upstream of the Carlingwark Loch.

The full model of the system covers approximately 3.76km of the River Dee and about 2.1km of the Carlingwark Lane. An additional 2km of the Gelston Burn was added to the model together with a 1.1km portion of the Threave Castle Island eastern spur. The reach of watercourse modelled was to obtain an approximate parity with the earlier Mouchel 1D model and established to be long enough to avoid any adverse affects on the water flow from any significant features within the channel. Water storage upstream of the Carlingwark Loch was also a consideration in the design of the model facilitated by an extension to the Gelston Burn reach. The number of cross sections utilised in the model is in relation to areas of restriction in flow and to construct a suitably representative analysis. In this respect the cross sections mimicked those undertaken be Mouchel, using the same topographic information. Additional cross sections were added in order to improve the model at selected points.

For the purpose of this Flood Risk Assessment the Mike 11 software has been utilised in conjunction with Mike21 and the MikeFLOOD software to produce a fully dynamic 2 Dimensional Model, that models the effects of flood plain storage and overland flow. As the open channel flow software Mike11 provides the basic backbone to the model, all cross sections within Mike11 have been adapted and incorporated in the model to provide an accurate representation of the channel width and form. The Mike 21 entails the use of a ‘bathymetry’ file which is based on the available Digital Terrain Model (DTM) dataset. At the point of overtopping the water in the model transfers from the Mike11 channel into the Mike21 bathymetry where it may spread out in 2 dimensions by cell to cell transfer. The 1D and 2D integration comprises a dynamic link based on flow and momentum.

Model Survey Inputs

Topographic information obtained for the Mouchel flood model comprised a series of cross sections through the Carlingwark Lane and River Dee and was utilised in this assessment as discussed with the Council.

Bridges and culverts relating to the watercourses were compiled either using data from the Mouchel report or, where applicable, by discussions with Scottish Power or measurements undertaken by Terrenus during the site walkover inspection. Additional topographic information was provided by the Council for the lower lying parts of Castle Douglas, particularly the area adjacent to the Carlingwark Loch. This survey information took the form of spot height data and was used to amend the Lidar ground surface elevations in the ‘bathymetry’ layer of the 2D model.

Where variations in elevations were identified the grid cell was amended to conform to the available survey information. It is noted that the variation between the survey information and the Lidar data set in the southern part of Castle Douglas is modest and generally less than 300mm. The topographic survey data is included in the appendix to this report.

This information was combined with the survey information and digital terrain data obtained from SEPA via Dumfries and Galloway Council to provide as accurate an overall representation of the river profile as possible.

The, or ground surface elevation model, was created using SEPA sourced Lidar data. This provided height information consisting of Digital Terrain (bald Earth) Model (DTM) at 5m posting intervals. It is understood that the height data was created from the aerial photography which was captured with a 60% overlap between frames using Photo-Grammetric techniques. The resulting data is highly accurate when compared to other existing datasets, typically having a vertical accuracy of +/- 50cm RMSE.

It is confirmed that the 1D element of the model is based solely on the available topographic survey information via the Mouchel 1D model. The 2D element of the model is based on the above DTM information as amended in the southern part of Castle Douglas using the additional available survey information from the Council. Where amended the DTM was adjusted to the more accurate topographic survey information and consideration given to the impact of such adjustments on adjacent cells.

With respect to larger water bodies SEPA made the following comment:

> *.... conventional LiDAR pulses may not be returned from waterbodies and will not provide suitable penetration to capture bathymetry. This means that the accuracy of such areas is lower in comparison to dry areas. Returns from the LiDAR sensor may be received from the water surface - giving a representation of the water surface in the DTM. However, in many cases there may be no returns from a water surface, leading to gaps in the dataset which are sometimes infilled by interpolation.*

The pre-storm surface water level of the key Carlingwark Loch water body was established to be 43.5m OD using local knowledge and the detailed topographic data throughout the low lying area of Castle Douglas. In addition the Lidar data was adapted in certain other key areas including the loch side area of Castle Douglas and the A75 based on the known topography and information established from the Council provided survey data.

Additional small inflows from field drainage ditches were noted along the line of the Carlingwark Lane. The general topography of these features was picked up as part of the DTM data for the area.

In order to keep the model manageable yet representative of important and significant land features (such as the A75 road embankment) a map grid of 10m was adopted for the flood model. Minor corrections were imposed on the model where the DTM was considered to include possible height errors.

Downstream River Dee Boundary and initial Model Conditions

The location of the downstream boundary corresponds with the final 1D cross section on the River Dee. In this case the boundary has been placed sufficiently far downstream to be remote from the Carlingwark Lane and any structures in the vicinity. The downstream boundary conditions for the site have been set in hydrodynamic mode with an open boundary. The Hydrodynamic (HD) Module has been applied to the boundary and is defined by the Time series (TS). The Q-h relationship at the downstream boundary is computed using a Manning's value of 0.045 and a slope of 0.002.

The 1D element of the model is set with an initial 0.5m water in the river channel system prior to the commencement of the storm hydrograph.

The initial conditions for the 2D element of the model are dry at the commencement of the storm hydrograph. The flood plain inundation is set to hydrodynamic only with a drying depth of 0.01m and a flooding depth of 0.02m.

Structures

An important feature with all structures when modelling with MIKE11and MikeFLOOD is that they must impose a constriction to the flow. That is, an inlet and an outlet loss must be present over the structure and the structure's geometry definition (with respect to flow-area) must be smaller than both the up and downstream cross sections for all levels defined in the structure.

Features such as the A75 embankment, the bridge over the Carlingwark Lane and the outfall from the Carlingwark Loch via the Buchan Bridge have been picked up by the DTM and input to the flood model.

Details of the Blackparks Pumping station, the pumping rates and associated non-return culverts were established from previous reports, discussions with Scottish Power and the site walk-over. The model assumes that the pumps will stop working when the peak water level rises to 46m OD (i.e. above the existing pump bund).

River Banks and Model Domain / Active Area

The 2D active model area is shown on Figure 5 in the Appendix and extendes throughout the lower lying flood plain area of the River Dee from north of the Glenlochar Barrage to approximately the Lodge of Kelton downstream of Threave Island. The 2D element of the model also includes the flood plain of the Black Bridge Burn to the west of the River Dee and the entire Carlingwark Lane, Carlingwark Loch and Gelston Burn tributary system.

Figure 5 also indicates the blocked cells along the principal water courses (River Dee, Gelston Burn and Carlingwark Lane), where the 1D elment of the model defines the water flow and peak water level.

As noted above the 1D and 2D integrated model comprises a dynamic link based on flow and momentum. This link relies on the 1D cross-sectional data to initiate flooding in the 2D element of the model and hence is based on topographic survey information provided with the Mouchel 1D model data set.

Additional ground truthing has not been carried out for the DTM dataset however, as noted above, the variation between the survey information in the south of Castle Douglas and the Lidar data set is generally less than 300mm.*Additional Notes*

For ease of reporting and consideration the model outputs in this report represent fixed data from each model run. Full model outputs including shape files are presented separately in electronic format.

The model outputs within this report, unless otherwise recorded, represent the peak water level during related return period model design. As such the output drawings show the extreme water levels throughout the entire storm hydrograph and not a particular moment during the storm period. Likewise, the data provided in the model output tables represents the peak water level at selected points.

The nominal simulation period in all model runs covers the combined Dee / Gelston peak flood hydrographs during a 41 hour period. The computational time step for all model runs is 4 seconds resulting in 36900 time steps for the full model run.

5.2 RIVER FLOW

Although some gauging station data is available from the Glenlochar Barrage the quality of this data is limited by the workings of the hydro-power facilities and the station itself.

With respect to the design 1 in 200 year storm event, rainfall records and catchment descriptors have been obtained from the Flood Estimation Handbook (FEH) with flow rates calculated using the following methodologies.

- FEH (2007) QMED (Index Flood) calculation;
- Improved FEH estimate of QMED (2008);
- Mean Annual Flow (MAF) using Institute of Hydrology Research paper 124 (for comparison);
- Statistical analysis as provide by SEPA;
- Statistical analysis as undertaken by Mouchel;
- Rainfall Runoff Method as undertaken by Mouchel; and,
- FEH Rainfall Runoff method.

An analysis of these methods was discussed with SEPA and the Mouchel statistical method found to be reasonable. This resulted in a peak flow for the design storm of 495m3/s.

Peak flows for other storm events were, in agreement with the Council, adopted from the Mouchel flood risk assessment.

A summary of the possible peak design flows for the watercourse is provided in Table 1 in the Appendix.

The current Scottish Executive guidance ‘UKCIP02 Update (2003)’ suggests that peak river flows may increase by between 15% and 20% in the south-west of Scotland by the mid 2080’s due to global climate change. In line with SEPA recommendations and following discussions with the Council an additional allowance of 20% has been added to the peak flow over and above the estimated 1 in 200 year probability flood event. This increase brings the peak flow for the River Dee and Carlingwark Lane to approximately 594m3/s and 43m3/s respectively.

The catchment of the River Dee is some 810km2 to the Glenlochar Barrage and 864km2 to the Bridge of Dee. The Carlingwark Lane including the Gelston Burn adds some 13.8km2 upstream of the Bridge of Dee. The likelihood of an extreme storm occurrence throughout the entire Dee catchment is low and, due to the differing sizes of the Dee and Carlingwark catchments, the time to peak is likely to occur at differing times. In this assessment separate flood hydrographs have been compiled for the Dee and Carlingwark catchments. For the design 1 in 200 year storm event the time to peak of the Dee is about 18 hours after the commencement of the storm. For the same event the time to peak of the Carlingwark is 12 hours after the start of the storm and hence some 6 hours prior to the peak of the River Dee.

This variation in peak flow is considered to offer a reasonable worst case scenario for the local area. Additional model runs were carried out to investigate the impact of differing storm events on the Carlingwark Loch and are provided as model outputs in the appendix.

5.3 MODEL RESULTS UNDER EXISTING GROUND CONDITIONS

Using standard hydrodynamic software modelling techniques for open channel flow, information between cross sections is interpolated through the Mike 11 software and the river flood levels calculated accordingly. Integration of this data with Mike21 through dynamic linkages and the MikeFLOOD software via cell to cell transfer produces a 2 Dimensional Model, which models the effects of flood plain storage and overland flow.

Uncertainties remain regarding the channel roughness that affects the relationship between flow rate and water level. The analysis must, therefore, be regarded as approximate.

In order to fully analyse the watercourse, runs were carried out at a variety of flow volumes as discussed below. The Manning roughness ‘n’ numbers used in the model were in line with those adopted in the 1D Mouchel model, varying between 0.04 and 0.045 for the watercourse channels. The flood plain was assigned a global Manning roughness factor of 0.045. Sensitivity analysis was carried out on the 1D element of the model as used in the 2D model where the channels were adapted to dynamic linkage. Small variations in Manning ‘n’ value were found to have only a modest impact on the 1D model results.

The results of the MikeFLOOD output are shown on the drawings contained within the appendix to this report. It should be borne in mind that the actual movement of water throughout the flood plain is affected by the timing of the storm events, a fact that is displayed in the additional electronic submission. The drawings provided in the appendix show peak levels around Castle Douglas for simple clarity.

The area of the Carlingwark Loch is included in the model with the radar data and a review of both local knowledge and the detailed survey data supplied by the Council used to provide the standing water level (43.5mOD) into which the storm hydrograph flows. Peak water levels for the Carlingwark Loch in the vicinity of the Isle of Whitepark (in the north of the loch) are provided in Table 3 in the appendix. Table 3 also provides details of the various mitigation measures considered and their impacts on the Carlingwark Loch.

Under existing ground and pump operating conditions the model indicates that the function of the upper Carlingwark Lane, Carlingwark Loch and Gelston Burn represents poorly drained land. The level of Carlingwark Loch thus rises as the local storm event progresses and remains high during the entire period of the Dee catchment storm period.

These results indicate that the Blackparks Pumps represent a very small portion of the peak flow within the Carlingwark Lane and become ineffective at any significant return period (1 in 2 years and above). The chief effect of the pumps is therefore at the more modest average flows within the Dee-Carlingwark system.

Notwithstanding the above it is clear that under existing ground conditions and at relatively modest flows the pumps improve the overall drainage of the area and thus may be seen to assist the general agricultural assets in the local area. In addition the pumps may be seen to provide increased potential water storage of the Carlingwark Loch and upper Gelston Burn at the commencement of a peak storm event. Nevertheless the pumps are not seen to mitigate the overall risk of flooding during an extreme storm event.

The DTM indicates that the lower lying areas of Castle Douglas at the northern end of the Carlingwark Loch are at between about 44m OD and 45m OD. Detailed surveying carried out by the Council indicates that the near Loch area of the town (around Lochside Park) the existing levels are between 43.9m OD and 44.5m OD. Ordnance Survey spot heights and detailed survey information along Marl Street and Queen Street to the north and King Street to the west of the Loch range between 47m OD and about 45m OD on Queen Street. The land falls gently from these streets towards the Carlingwark Loch. Storm events in excess of 1 in 25 years will inundate parts of the near loch area within Castle Douglas. The risk to Queen Street and associated areas during such events will chiefly be dependent on the initial level of the loch. It is likely that the initial loch conditions will result in parts of the park area, loch bank and caravan park being at risk of inundation during lesser storm events.

It should in addition be noted that the local drainage known to discharge into the Carlingwark Loch is likely to back up during such events and that the Loch is known to respond early in the local hydrograph.

6 DISCUSSION AND RECOMMENDATIONS

6.1 FINDINGS UNDER EXISTING CONDITIONS

The model runs allow a number of overall conclusions to be made;

- Increasing storm severity (from the 1 in 2 year event to the 1 in 200 year event) results in a steady increase in water levels through the Carlingwark area;
- The Carlingwark Loch water level rises early in the storm hydrograph and tends to be sustained thereafter, suggesting that the constriction of the channel below the Buchan Bridge and the very flat fall of the Carlingwark Lane itself limits outflow from the loch at the peak of the hydrograph;
- The peak water level near the Isle of Whitepark (Lochside Park) varies from 44.63m OD during the 1 in 2 year event to 44.98m OD during the 1 in 200 year event. In reality due to possible vegetation growth around Buchan Bridge and local storm drainage from Castle Douglas itself the latter conditions are likely to inundate some parts and environs of Queen Street.
- The impact of the Blackpark Pumps on the drainage of the Carlingwark Lane during an extreme storm event is negligible; however the pumps do have an impact in regulating local agricultural water levels during normal flow conditions between the pump facilities and Castle Douglas.

6.2 BLACKPARK PUMP FACILITY

The Scottish Power report 41515757 – Rev2 dated April 2009 on the Blackparks Pumps indicates the following:

> *It is clear that the Blackpark pumping station plays an essential role in allowing a reasonably efficient discharge from Carlingwark Loch below Buchan Bridge, and therefore alleviating the risk of inundation to the urban spread of Castle Douglas. Equally the flank embankments that complete the Blackpark facility must remain intact in order to alleviate the risk of inundation to the urban spread of Castle Douglas.*

The current assessment broadly agrees with the above statement concerning the flank embankments but notes that the pumps become less significant during significant storm events. During a more isolated storm event the pumps may result in an increased capacity within the Carlingwark Loch system to attenuate the peak storm flow and thus reduce the risk of flooding to Castle Douglas however such an effect is negligible in the current model.

It is concluded that the pumps do provide an agricultural advantage in the local area (as they were originally designed to do) but that they provide no significant mitigation to the risk of flooding in the Castle Douglas area during the design 1 in 200 year storm event.

6.3 POSSIBLE MITIGATION MEASURES

Following discussions with the Council consideration has been given to possible flood mitigation measures which would reduce the risk of flooding to Castle Douglas whilst retaining the overall aesthetic and environmental well-being of the local area. Passive measures were preferred when considering appropriate mitigation measures.

Such measures include the following;

1. Improvement and raising of the Blackpark flank embankments (bunds) to 45.45m OD;
2. Provision of upstream control measures on the Gelston Burn to attenuate storm water inflow to the Carlingwark Loch thus allowing a longer period for the loch to drain during the design storm event;
3. Provision of the Gelston Burn control measures coupled with additional downstream control at the A75.

The location of the above possible control measures is shown on Figure 2 in the Appendix.

The Gelston Burn control comprises a simple flap valve non-return culvert with flank embankments at a crest level of 45.5m OD. Two differing culverts were modelled at this location; the first being a box culvert measuring 3m width by 1m high. Such a culvert would allow some $10m^3/s$ to pass when full but with no upstream head. The second culvert comprised a circular pipe 0.9m in diameter which would have a capacity of about $2.5m^3/s$ when full with no upstream head.

The measures modelled at the A75 comprised a 5m wide by 1m high non-return gate which did not affect the downstream water flow but did prevent flow from the River Dee to the Carlingwark Loch. In this case the road embankment provides suitable flank embankments.

The peak water level around the Isle of Whitepark during the model runs employing these mitigation measures are provided in Table 3 in the Appendix.

Raising of the Blackpark Flank Embankments

It is noted that raising the flank embankments at the Blackpark Pumps results in a small increase in peak water level in the Carlingwark Loch during the 1 in 2 year return period and a slight decrease during the 1 in 50 year storm. It is likely that this effect is due to the early time to concentration of the Gelston Burn catchment initially filling up the area upstream of the pumps. Thereafter the water in this area is unable to exit due to the increasing water levels arising from the River Dee.

Gelston Burn Control Measures

The use of the larger box culvert in the upstream Gelston Burn control does not provide any significant attenuation of the catchment runoff and the peak water levels are found to increase slightly in the Carlingwark Loch.

Using a reduced culvert size significantly restricts the storm flow of the Gelston Burn and results in the attenuation of storm water over the lower part of the Gelston Burn valley floor. The peak water levels upstream of the control measures during the 1 in 2 year storm are in the order of 44.79m OD rising to 45.36m OD for the 1 in 50 year event.

The impact of this attenuation is to lower the peak water level of the loch by about 110mm during the 1 in 2 year event and raise it by some 640mm during the 1 in 50 year event. The rise in peak water level during the 1 in 100 year event is 170mm suggesting an impact during the more extreme storm events.

Additional A75 Control Measures

Applying control measures at the A75 allows the water immediately upstream of the A75 to drain during the early part of the storm event, however, the peak water level within the Carlingwark Loch remains unchanged during the 1 in 2 year event when compared with the Gelston Burn control only and shows only a modest fall during the 1 in 50 year event.

6.4 GENERAL CONCLUSIONS ON POSSIBLE MITIGATION MEASURES

The flow of water around Castle Douglas during peak storm events is complex entailing overall poor drainage, differing times to peak flow, the presence of the Blackpark Pumps and the variable nature of the peak flow in the River Dee due to the hydro power scheme.

Whilst the Blackpark embankments do work in tandem with the pumps themselves, raising these features does not in itself reduce the risk of flooding at Castle Douglas.

Passive mitigation measures have been modelled but fail to provide a definitive course of action that will reduce the risk of flooding to Castle Douglas during all storm events.

Whilst the Gelston Burn control measures do provide upstream attenuation the model indicates that the flow from the Carlingwark Loch is restricted through the Carlingwark Lane in the vicinity of Buchan Bridge. Such an effect is shown when comparing the Gelston control measures with the additional A75 control where the area between the A75 and the loch drains early in the peak storm event but the loch itself does not. Any use of the Gelston Burn for attenuation purposes would therefore have to be coupled with an improvement of the flow of water from the loch to the area upstream of the A75.

6.5 OUTLINE RECOMMENDATIONS

The model outputs suggest that the Blackpark Pumps greatest effectiveness is on a normal day to day basis where the water levels upstream of the pumps is kept low thus normal field operations are maintained. Such an action formed part of the original purpose of the pumps and should be maintained if possible, however it should be recognised that the pumps themselves do not provide any significant flood mitigation to the Castle Douglas area.

Passive water control and flood risk methods on the Gelston Burn and A75 could be implemented with the existing Blackpark Pumps in place and could result in a stabilisation of the peak level in the Carlingwark Loch should the flow of water from the loch be improved. Additional modelling would be required to confirm this.

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Terrenus CDH Ltd wishes to thank Dumfries and Galloway Council and Scottish Power for the opportunity to prepare this report. We trust that the report meets with your requirements at this stage. However, should you wish to discuss the contents of the report then please contact the undersigned.

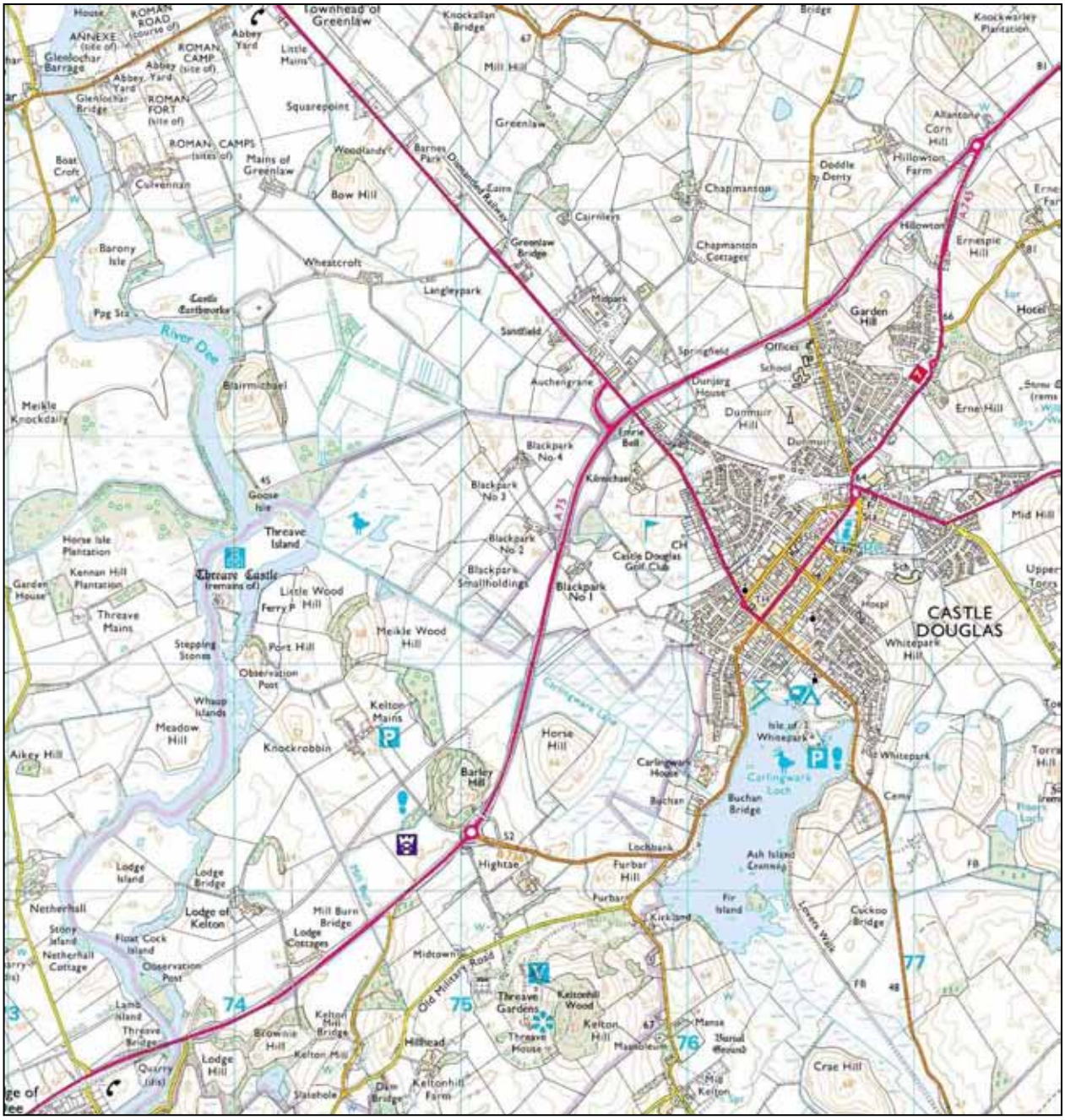
Signed for and on behalf of

Terrenus CDH Ltd

W. Hume	**S. Curran**
Director	**Director**

APPENDICES

FIGURES & DRAWINGS



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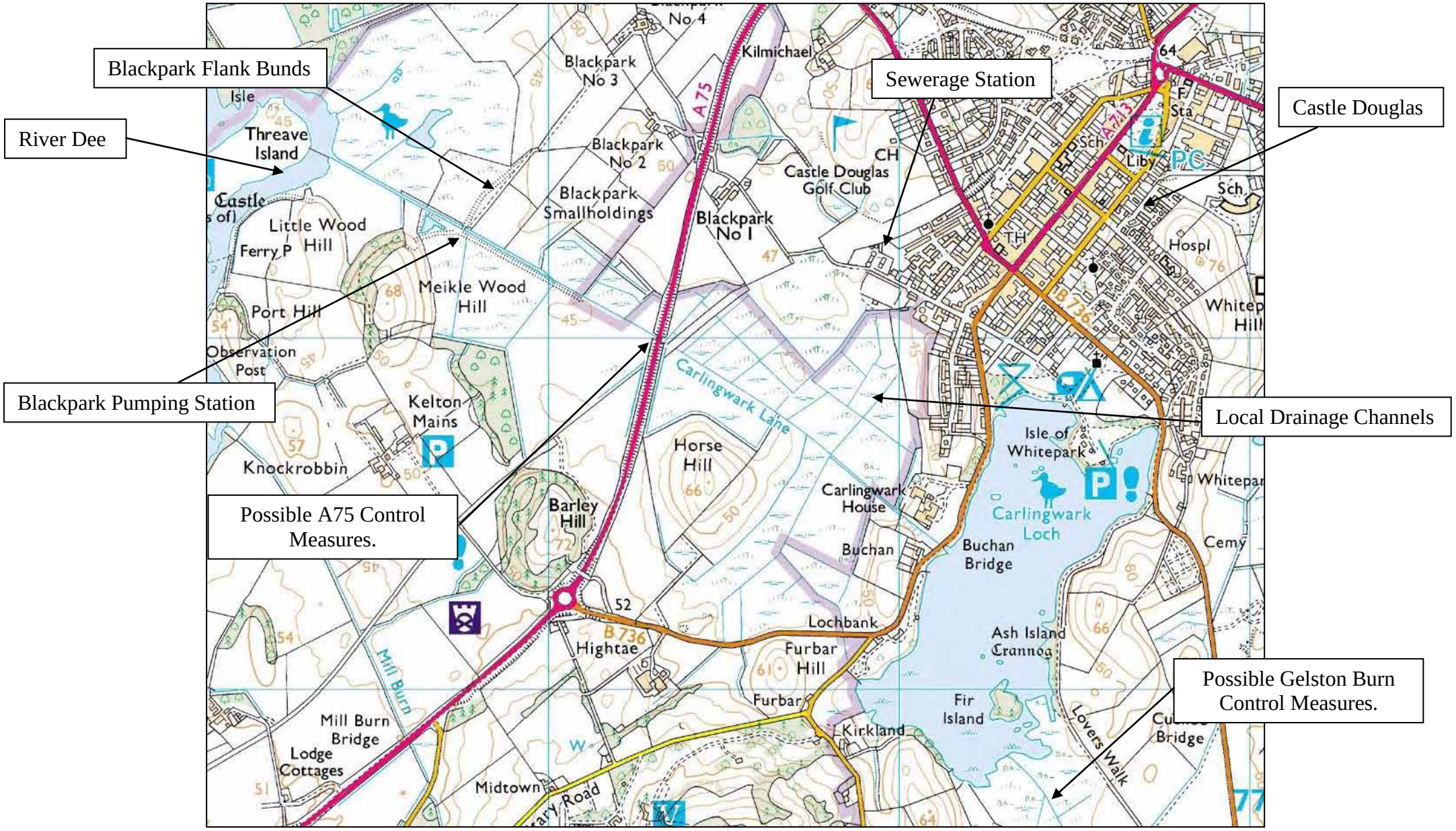

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Project: Castle Douglas Flood Risk Assessment		
Date: 24-03-12	Figure 2	
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Untitled

Chainage 0
Chainage 10
Chainage 73
Chainage 85
Chainage 514
Chainage 942
Chainage 1365
Chainage 1788
Chainage 2236
Chainage 2497
Chainage 2875
Chainage 3086
Chainage 3455
Chainage 3760
Chainage 0
Chainage 120
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Chainage 362
Chainage 508
Chainage 626
Chainage 1100
Chainage 2300
Chainage 2450
Chainage 2300
Chainage 1800
Chainage 1000
Chainage 670
Chainage 470
Chainage 0

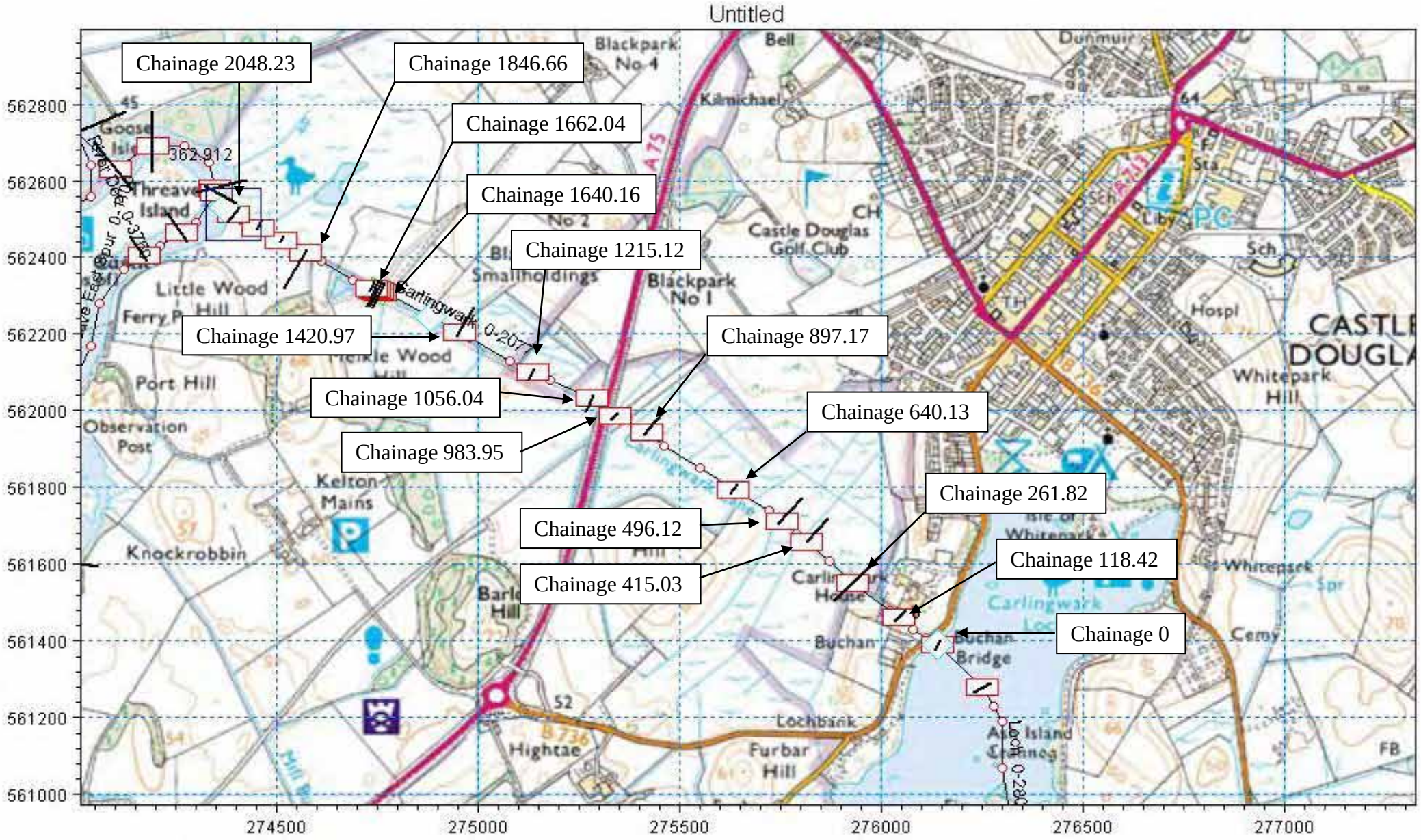
RIVER DEE
THREAVE EAST SPUR
LOCH

565000
564500
564000
563500
563000
562500
562000
561500
561000
560500
560000
559500
559000
272000
273000
274000
275000
276000
277000
278000

Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Cross Sections Location
Date
20th June 2013
Dwng No.3
Figure 3a



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Project: Castle Douglas Flood Risk Assessment		
Date: 20-06-13	Figure 3b	
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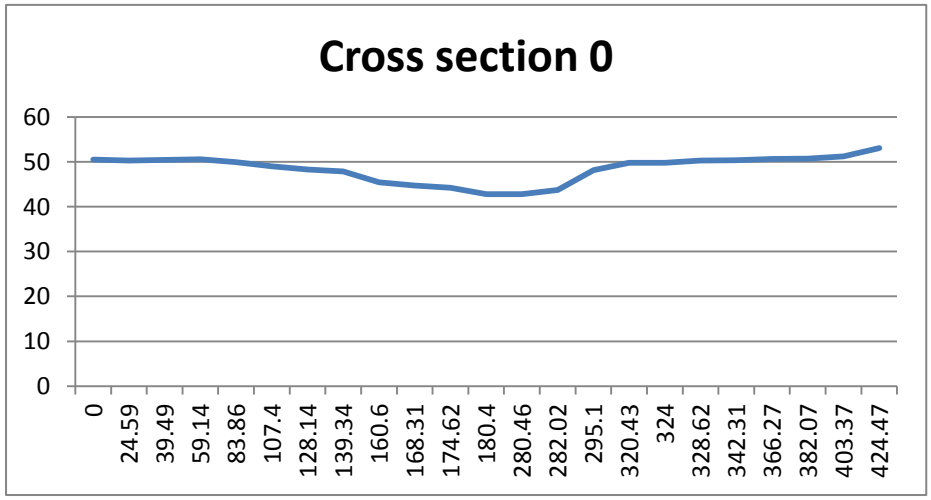
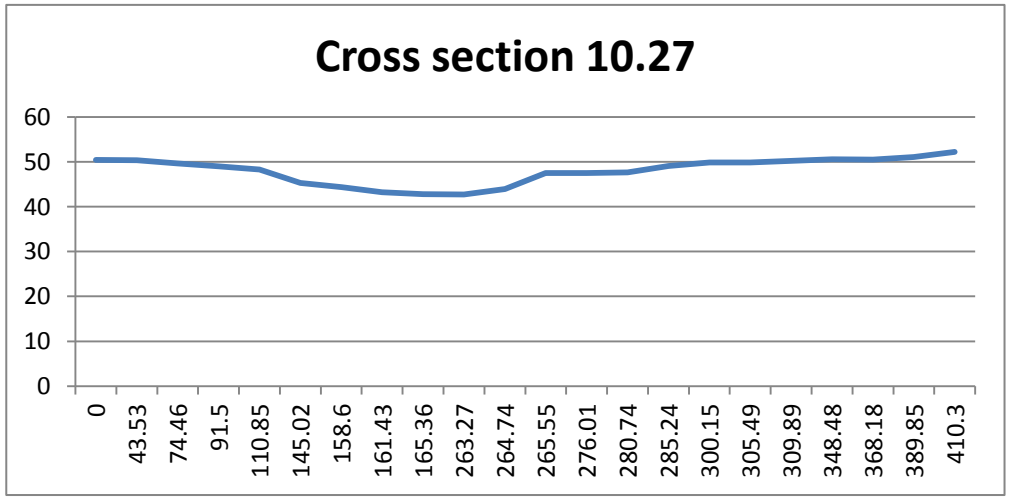
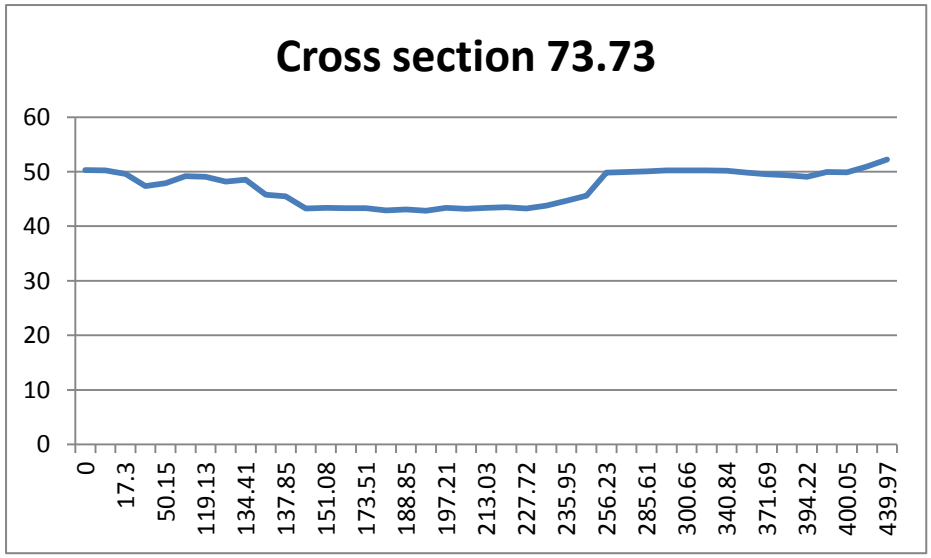
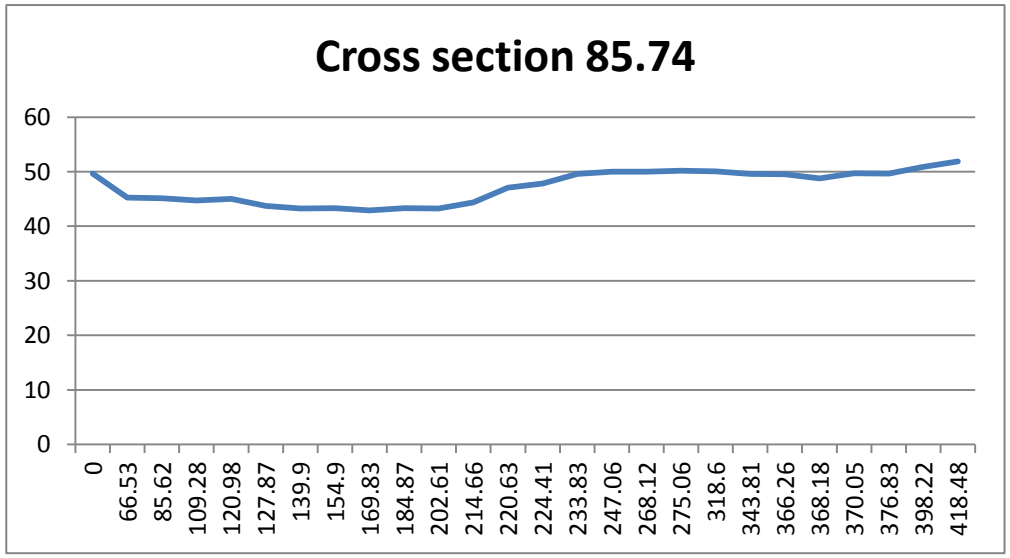
CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



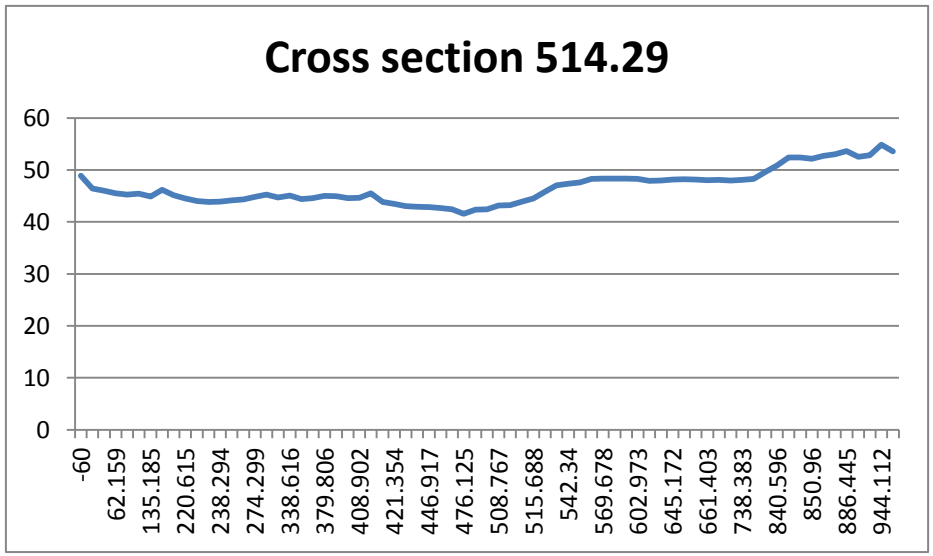


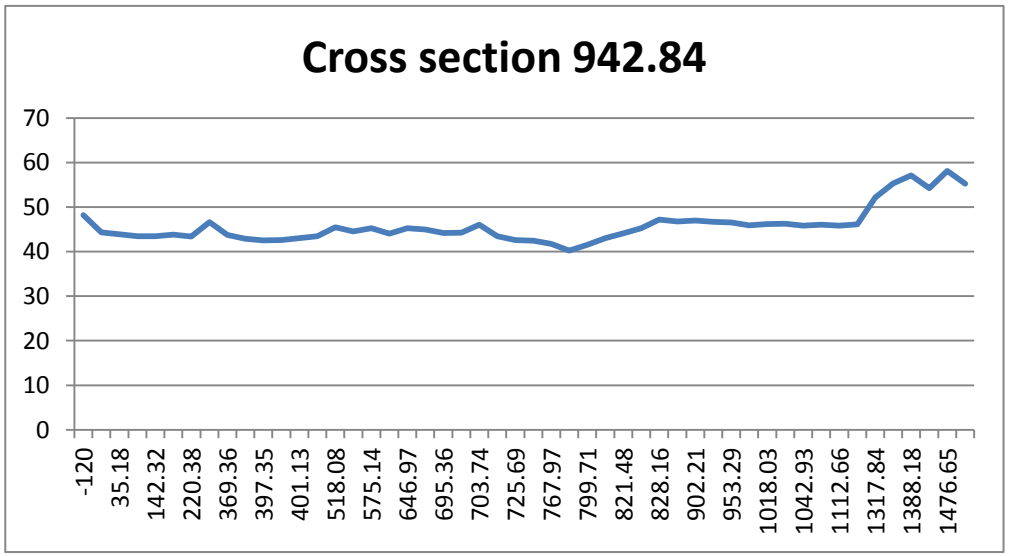


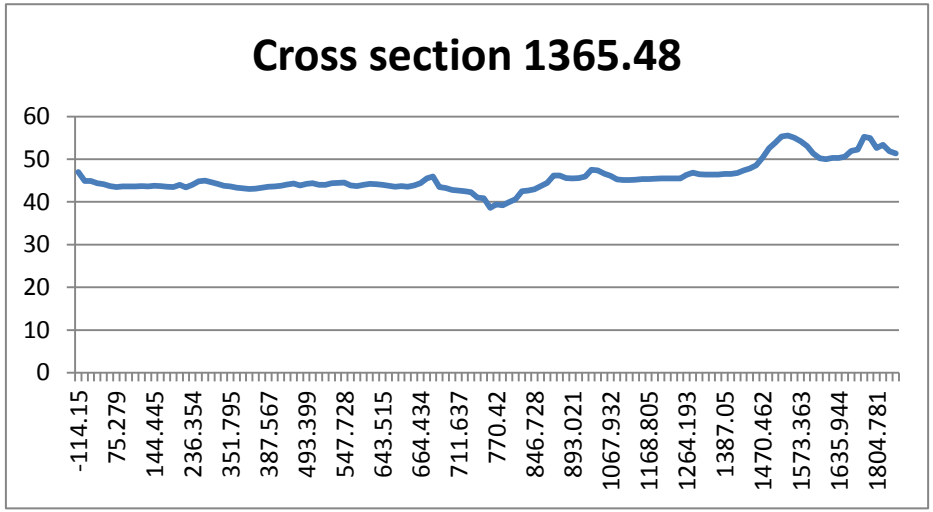


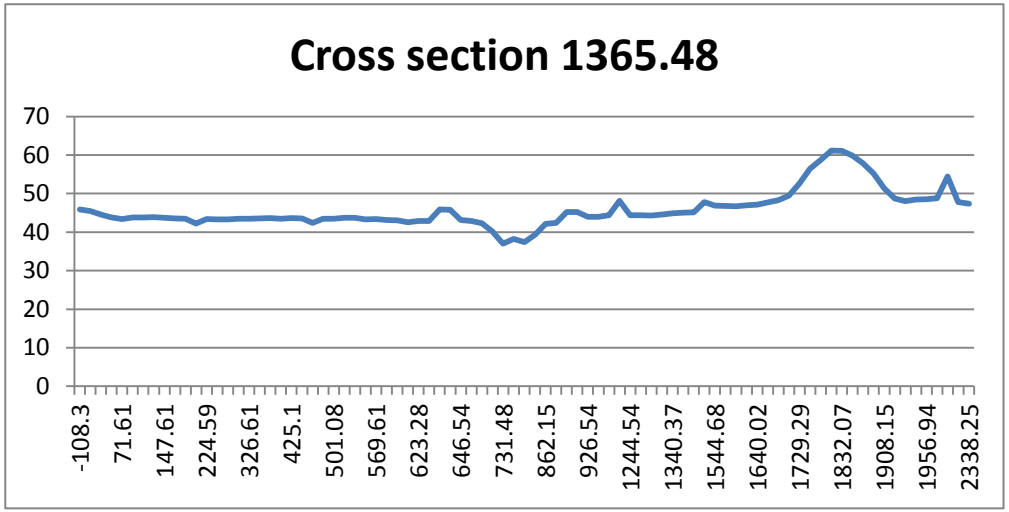
River Dee

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



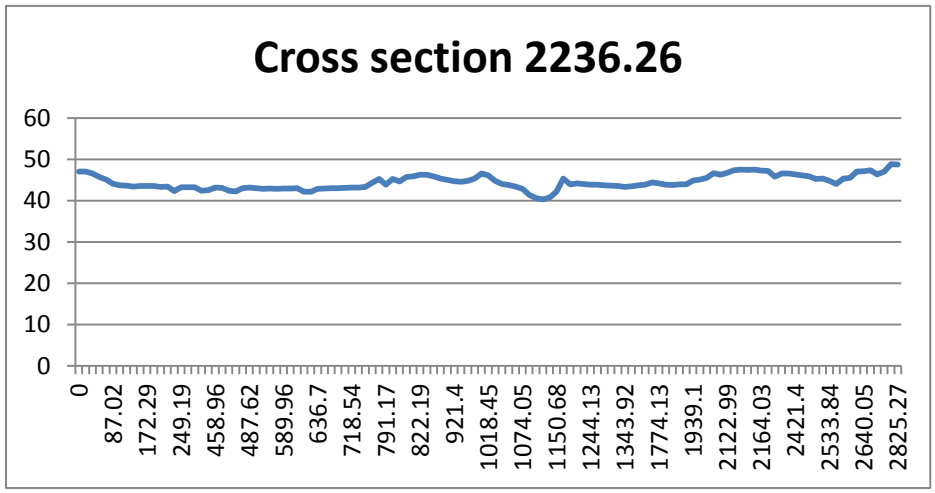


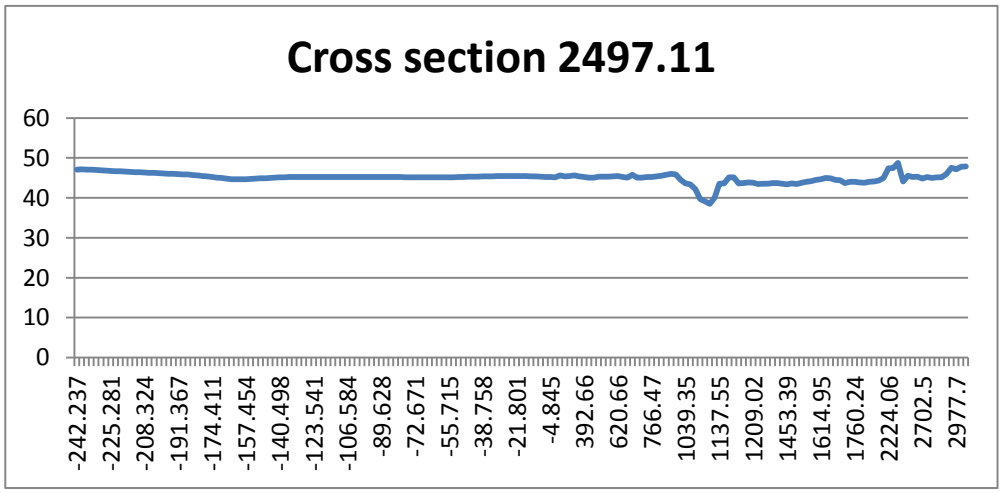


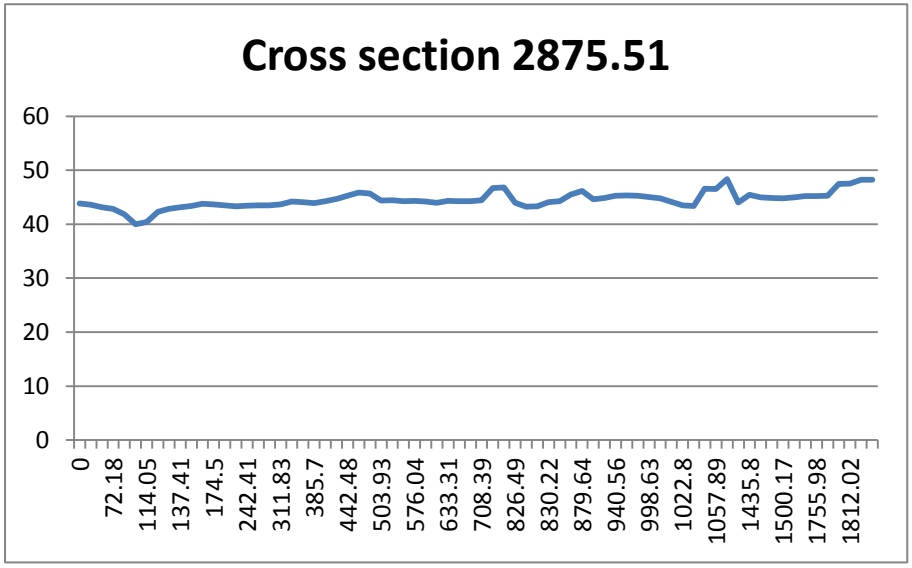


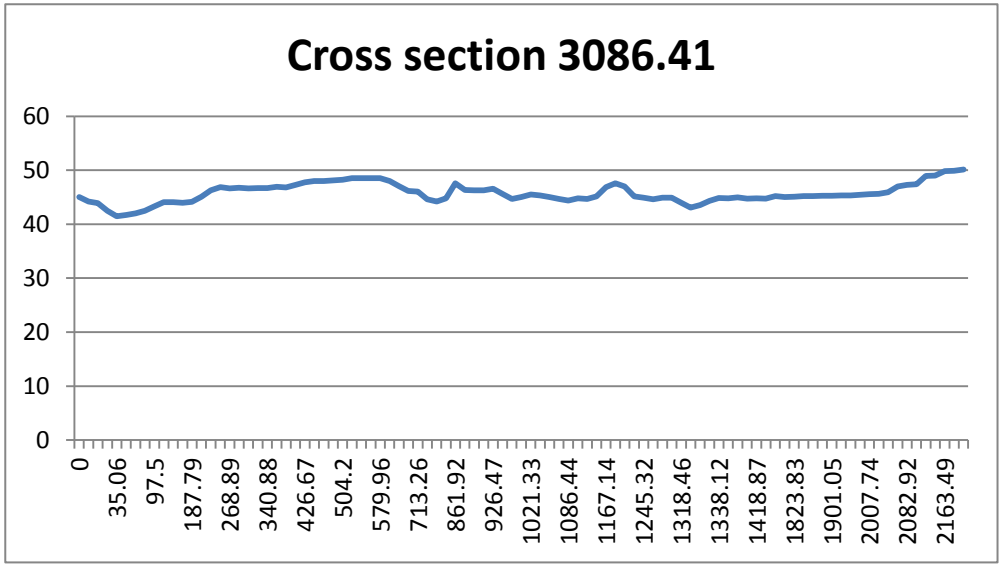
River Dee

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



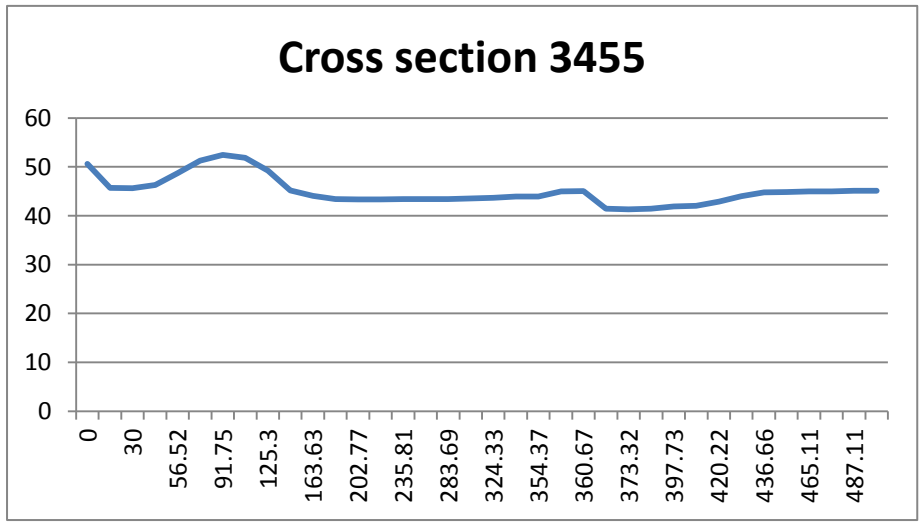


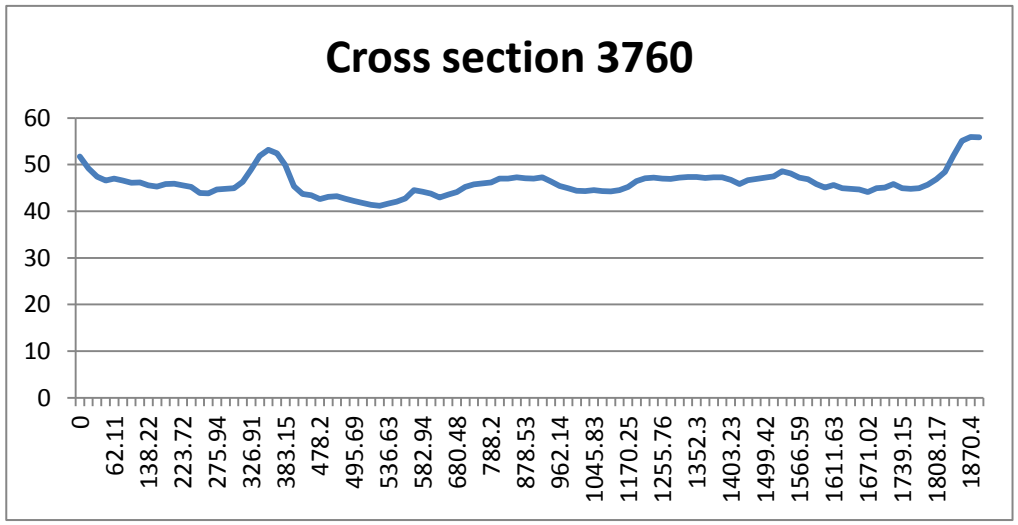


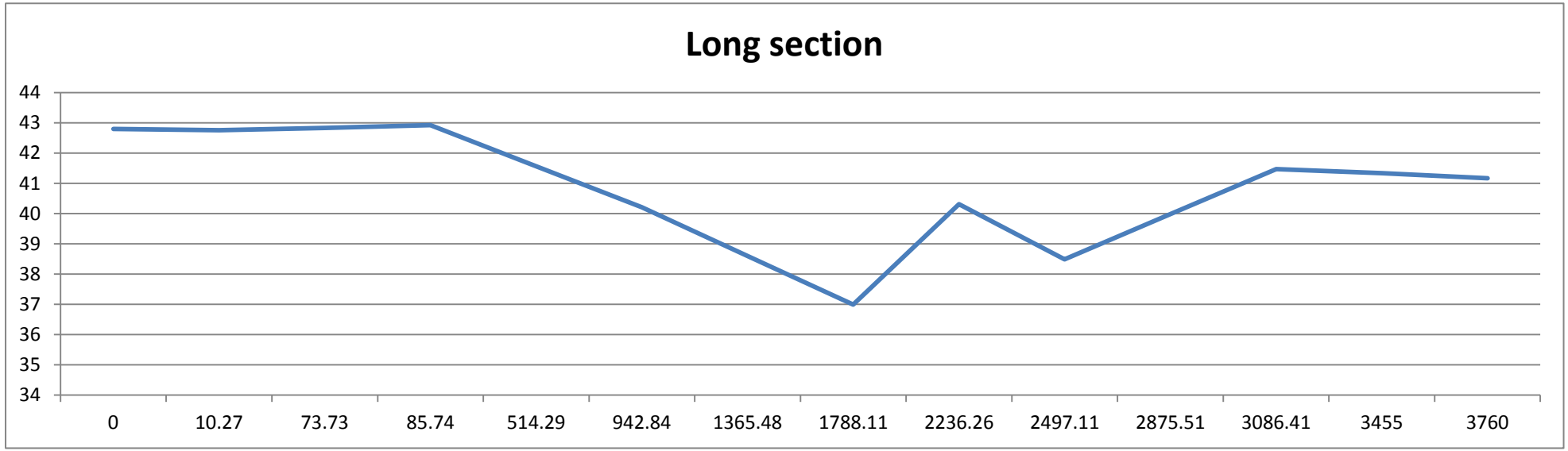


River Dee

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4

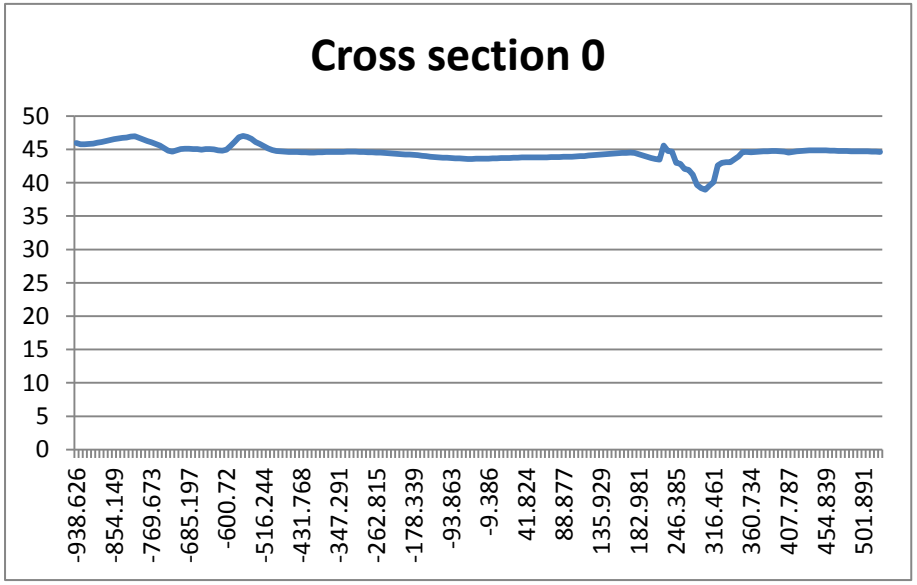


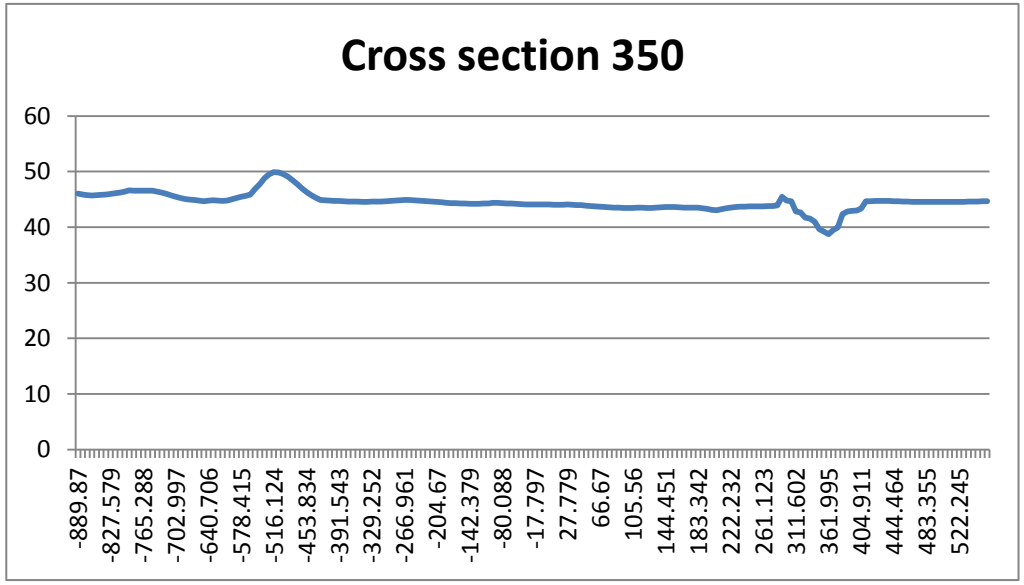


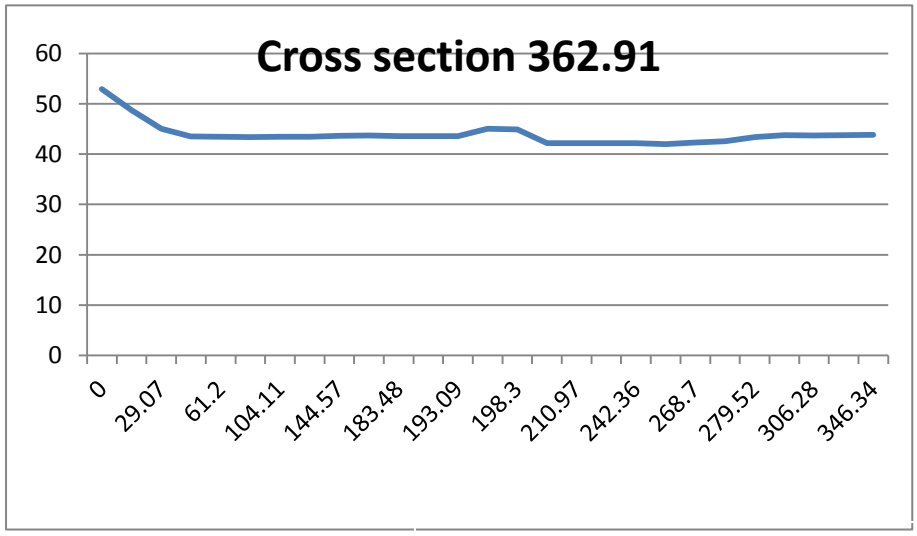


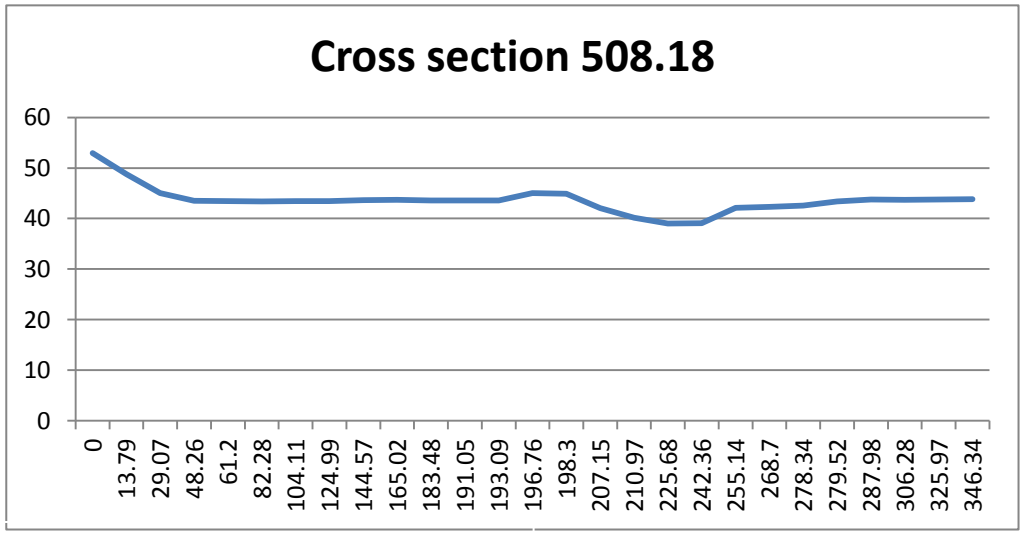
River Dee

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



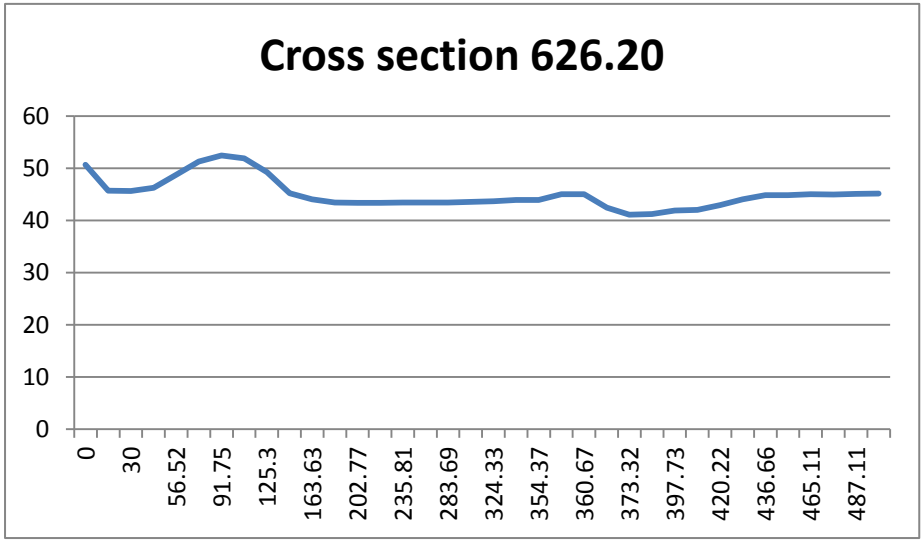


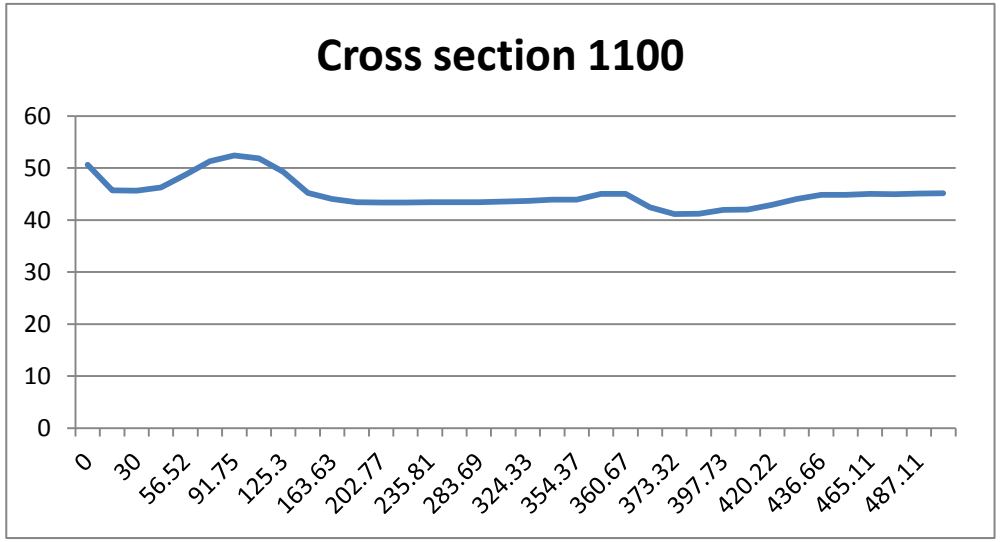


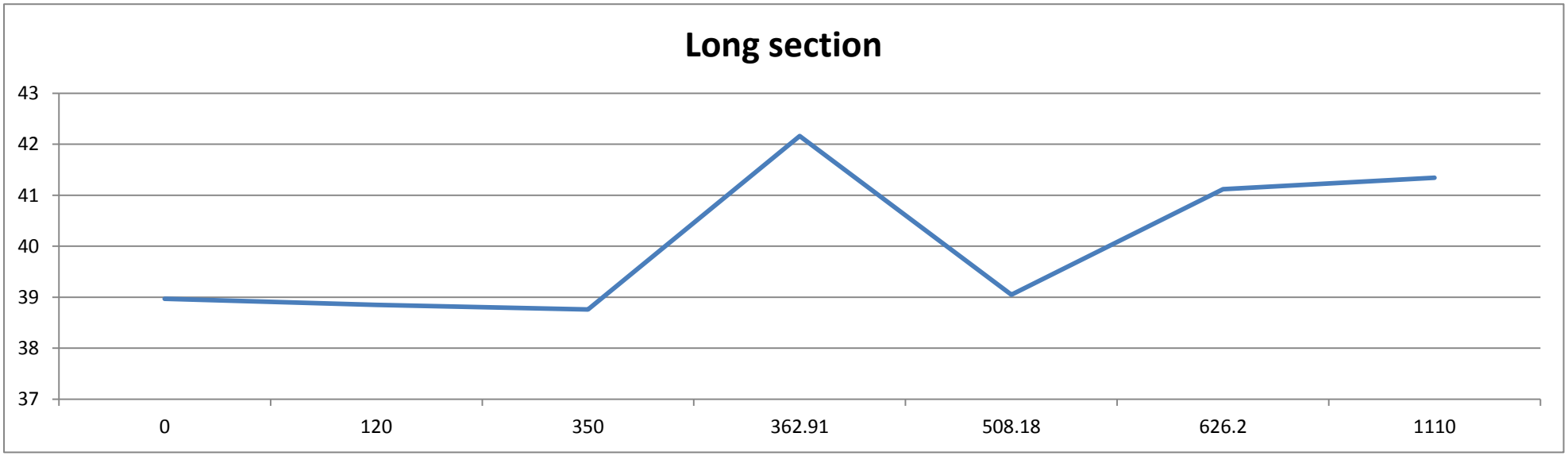


River Dee (Threave East Spur)

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4

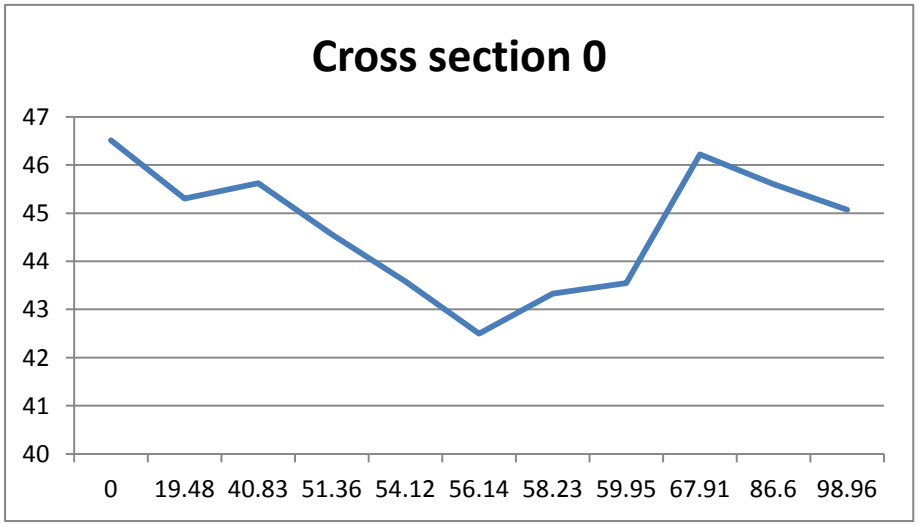


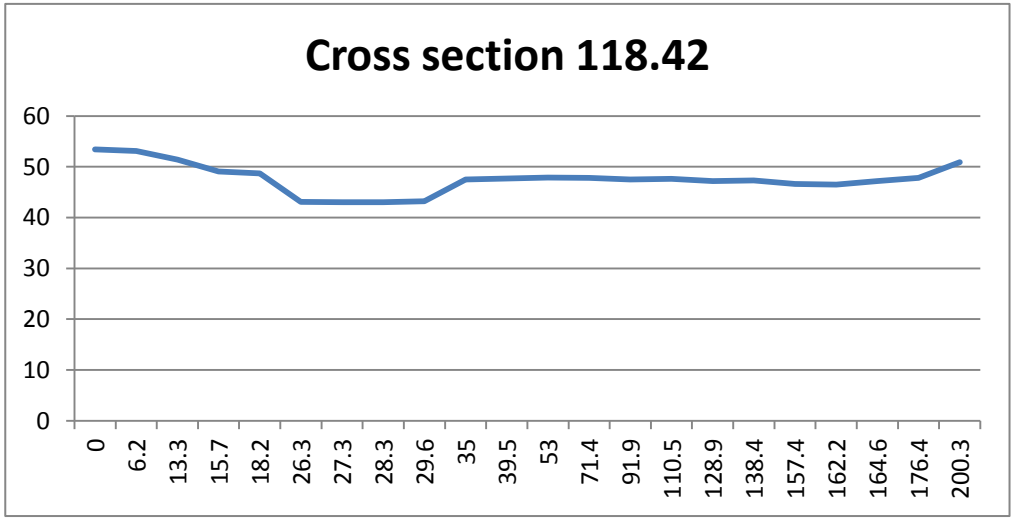


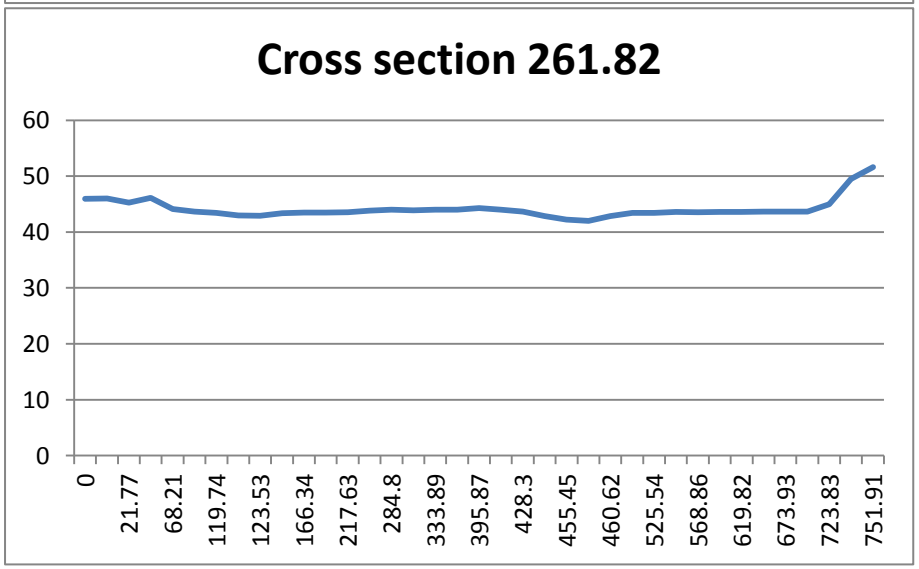


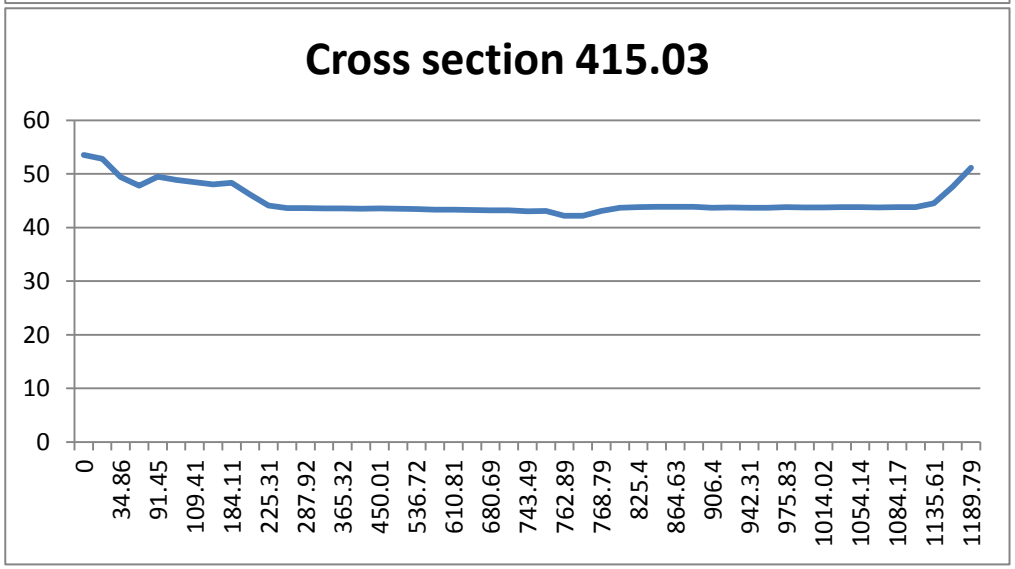
River Dee (Threave East Spur)

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



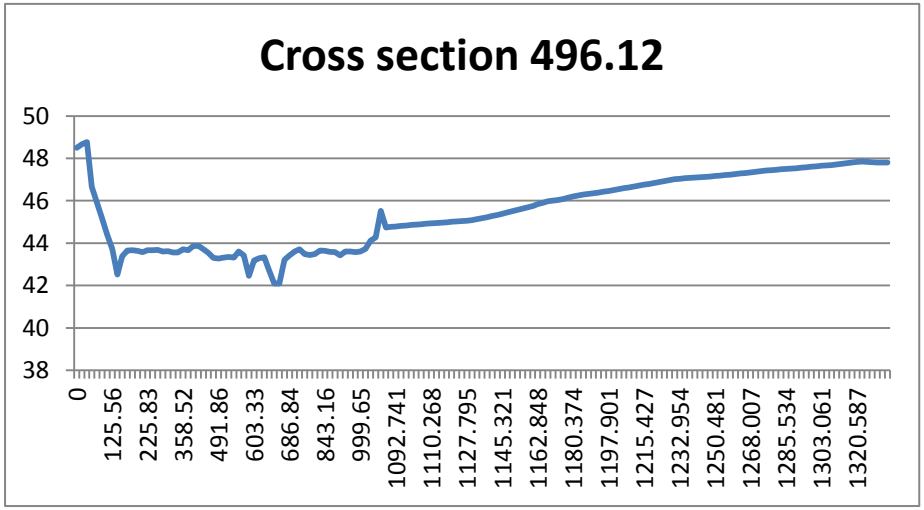


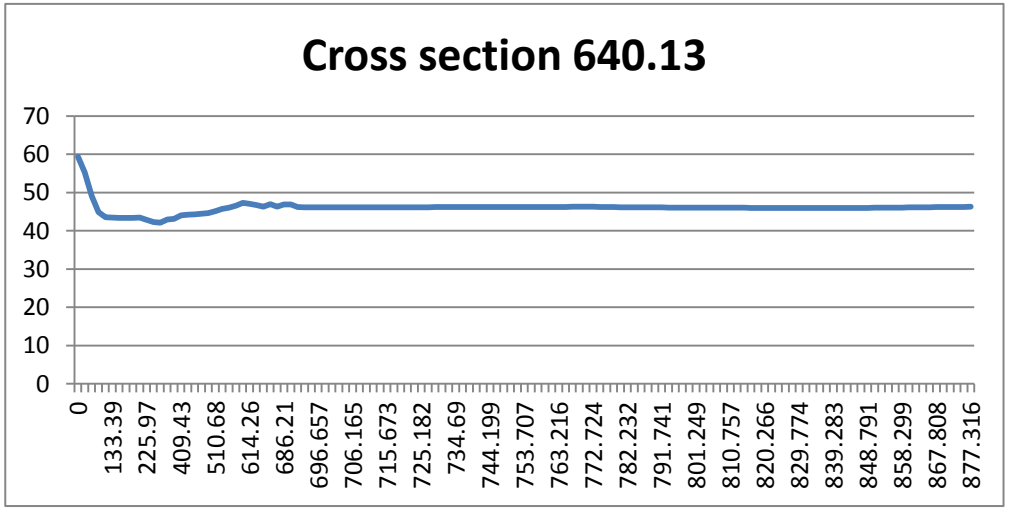


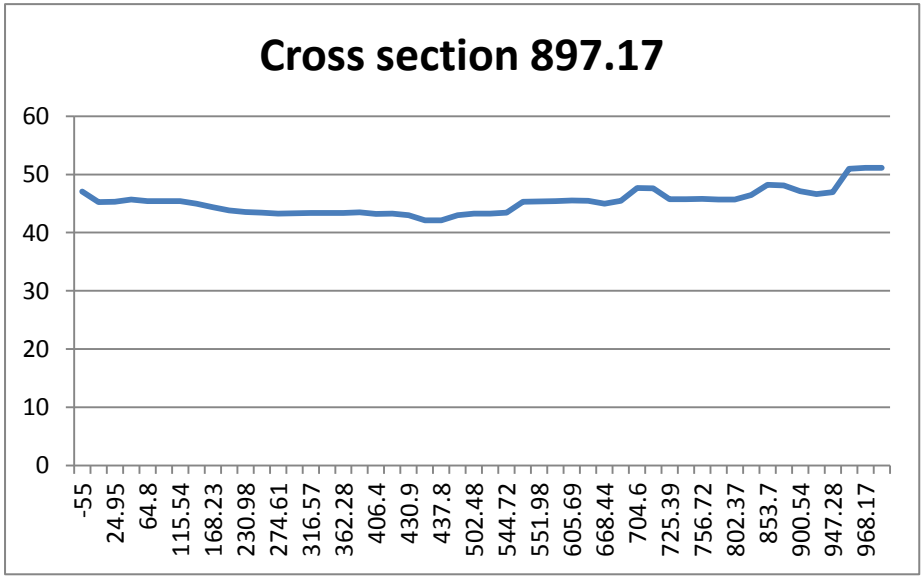


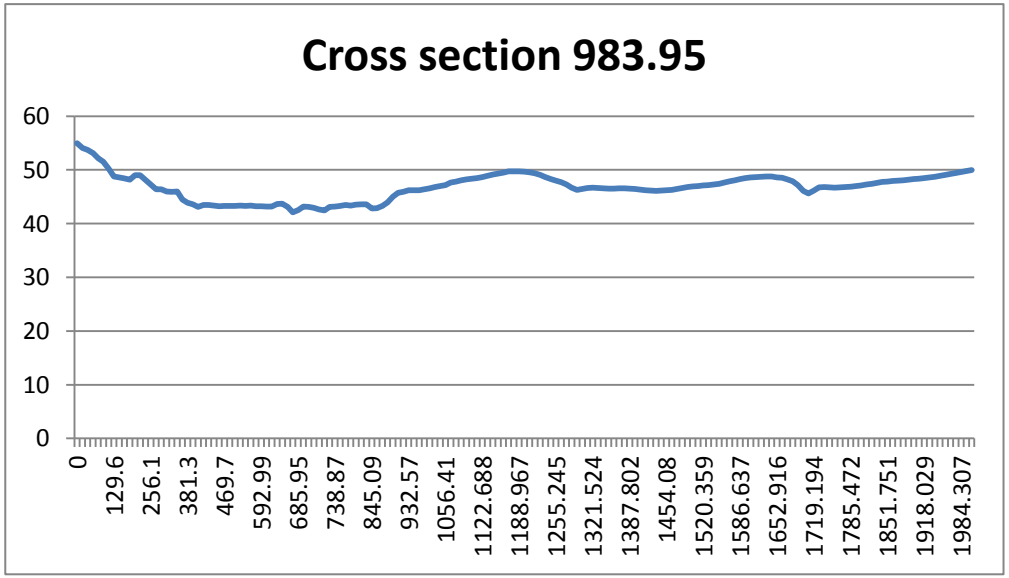
Carlingwark Lane

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



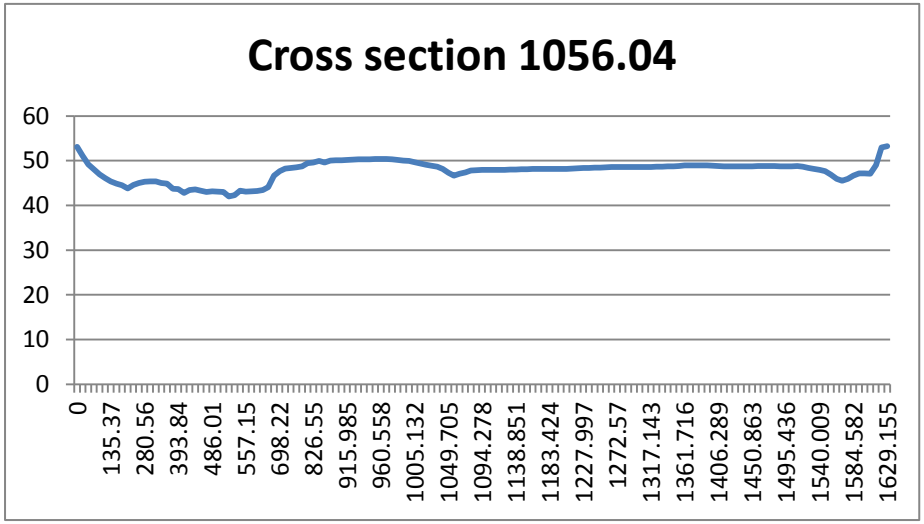


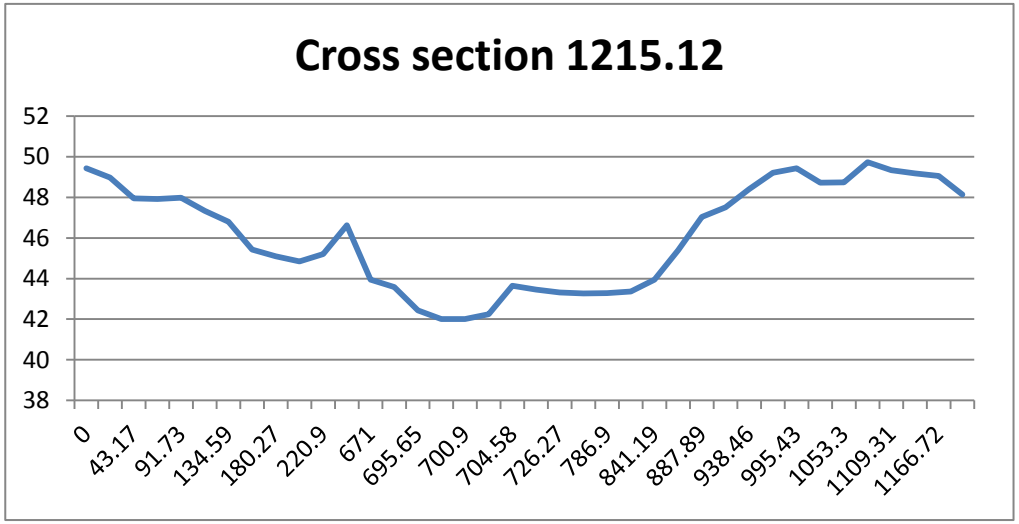


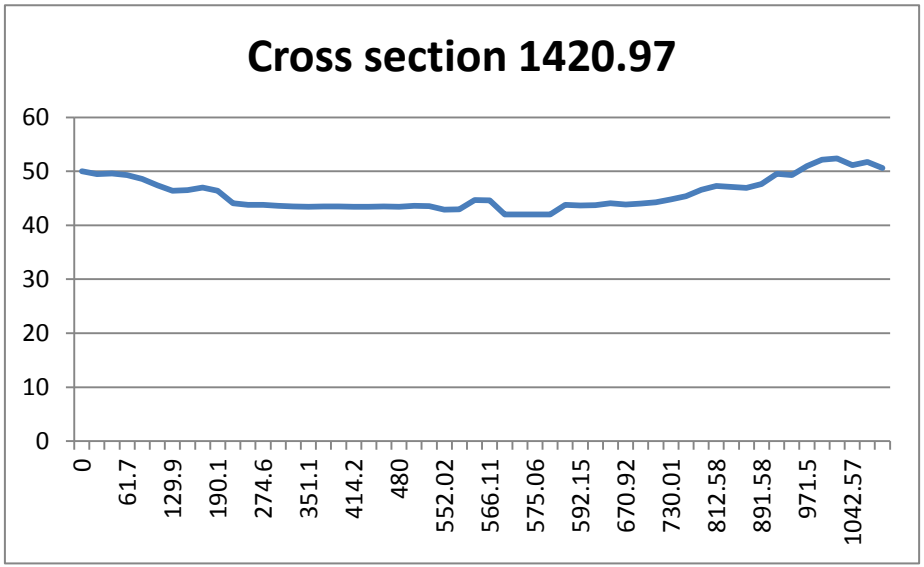


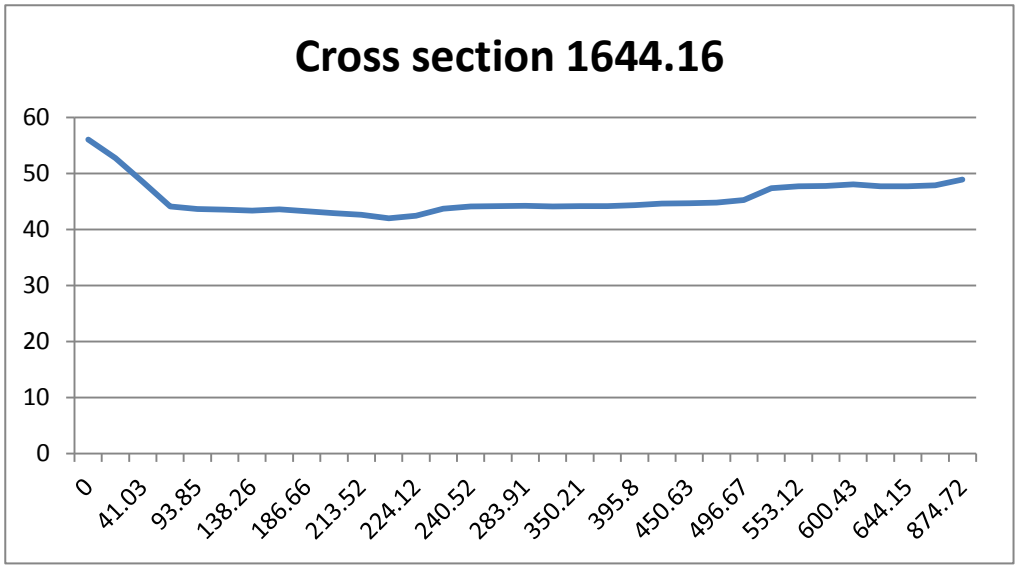
Carlingwark Lane

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



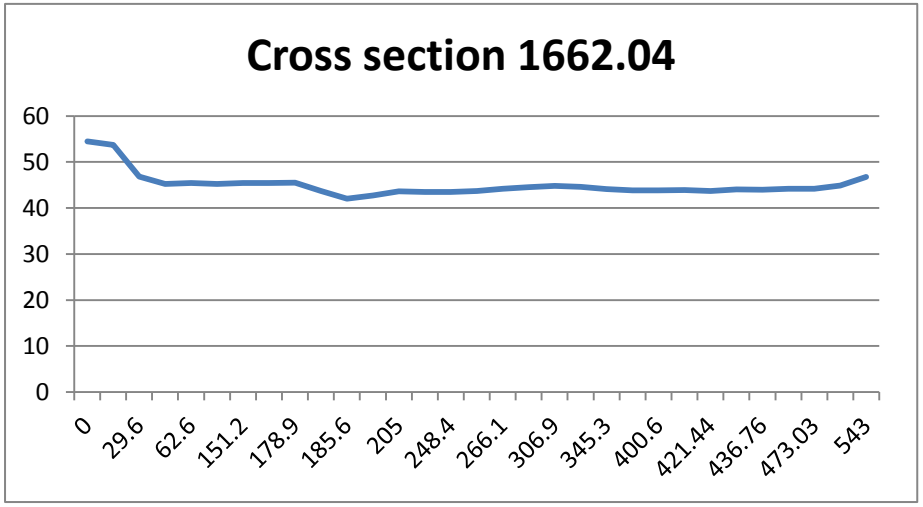


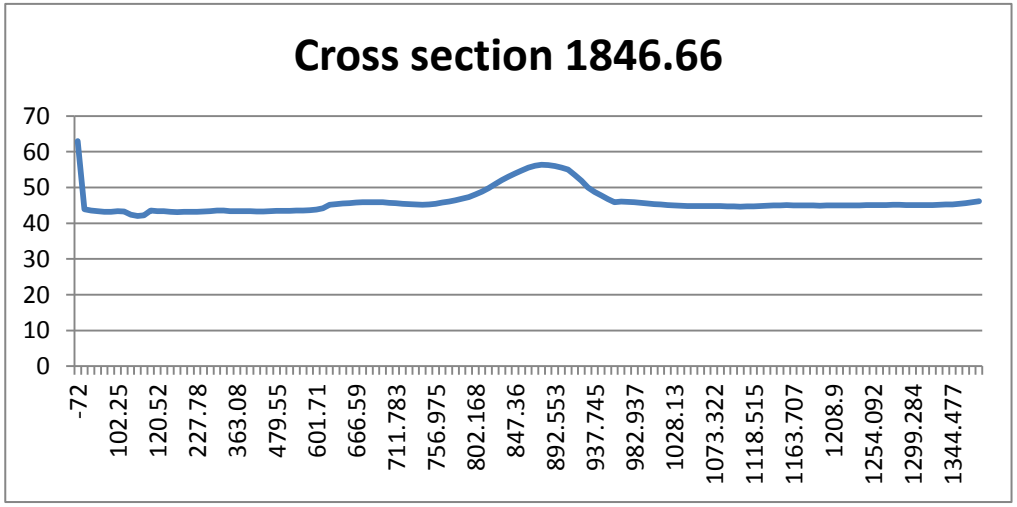


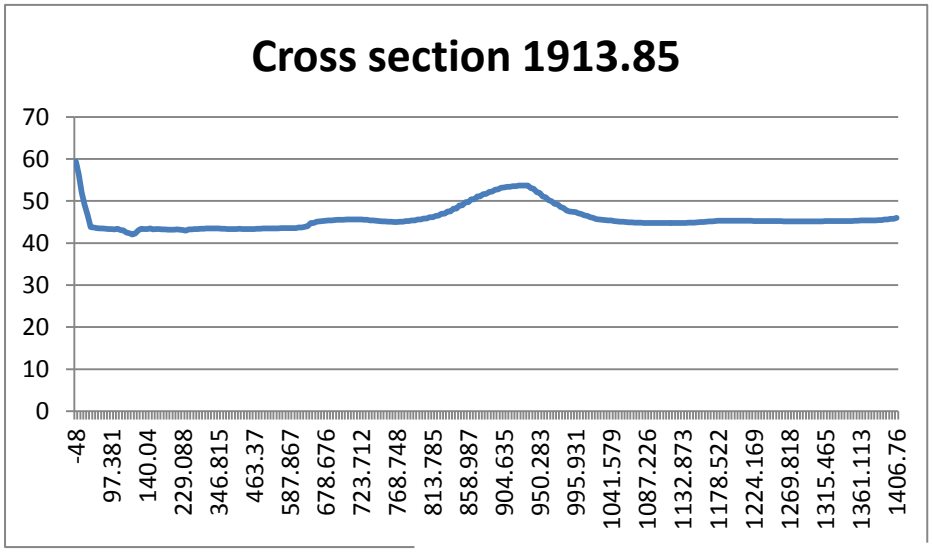


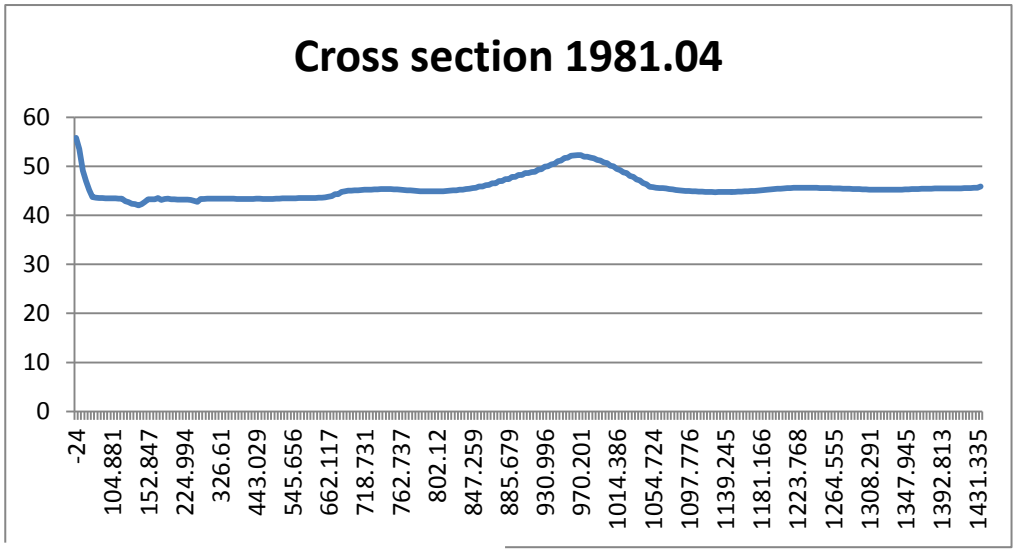
Carlingwark Lane

CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4



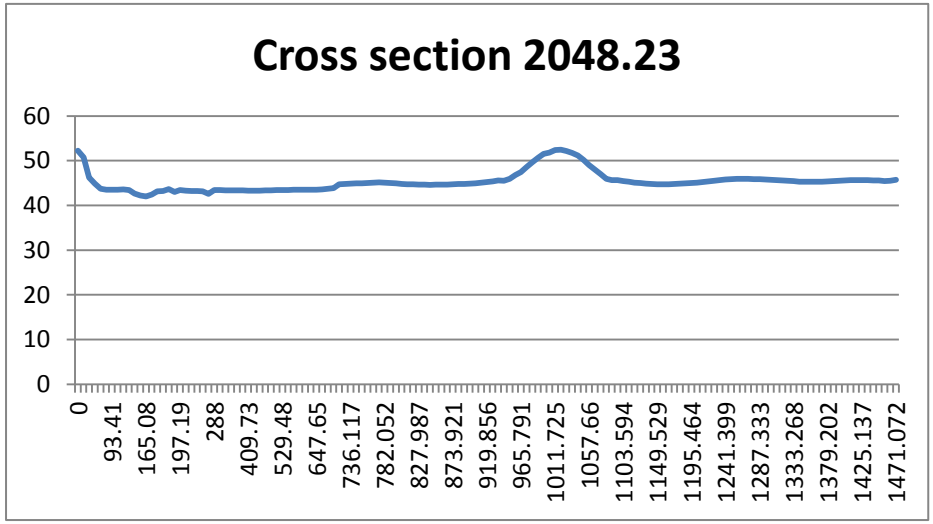


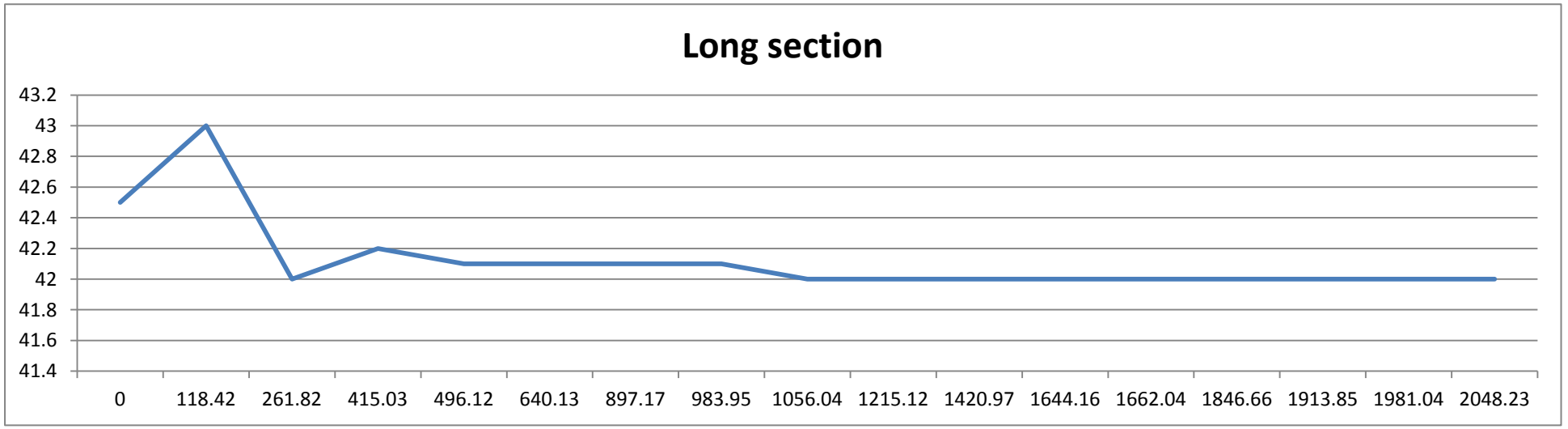




Carlingwark Lane

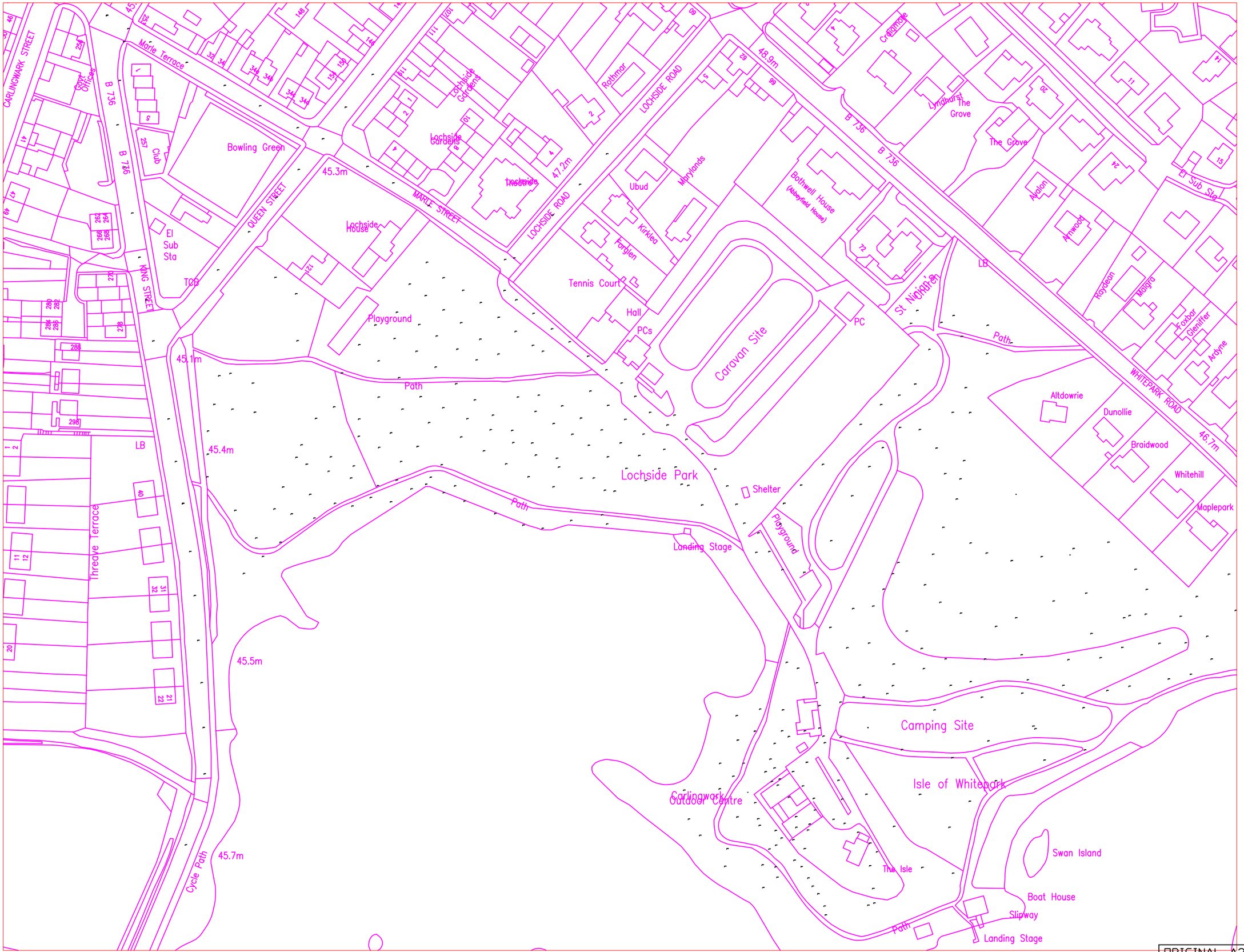
CASTLE DOUGLAS
FLOOD RISK ASSESSMENT
FOR
DUMFRIES & GALLOWAY COUNCIL
Figure 4





Carlingwark Lane

DO NOT SCALE



ORIGINAL A3

LEGEND

Rev	Description	By	App	Date

TERRENUS CDH LTD
1 Orbital Court, Peel Park,
East Kilbride, G74 5PH
Tel: - 01355 279 000 : Fax:- 01355 263 629

Client
DUMFRIES AND GALLOWAY COUNCIL & SCOTTISH POWER

Project
CASTLE DOUGLAS FLOOD RISK ASSESSMENT

Drawing Title
COUNCIL TOPOGRAPHIC DATA

Drawn	Checked	Approved
WH	SSC	SSC

Date	Scale	
19/06/13	NTS	1168-202-C01

[-]

H Water Depth

H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

Peak Water Level 43.63m OD

(Grid spacing 10 meter)

820 800 780 760 740 720 700 680 660 640 620 600 580 560 540 520 500

300 350 400 450 500 550 600 650 700 750

(Grid spacing 10 meter)

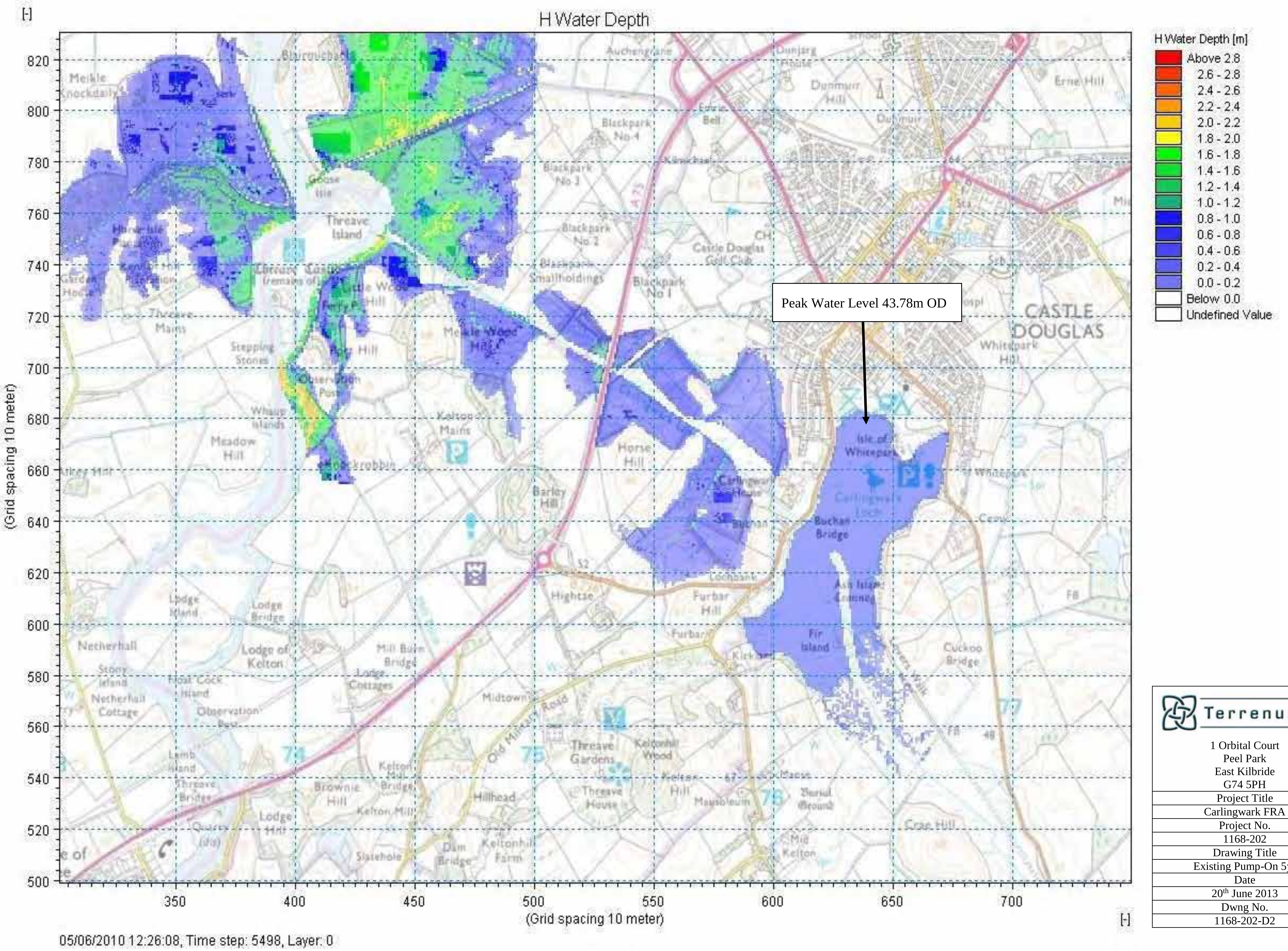
[-]

05/06/2010 13:15:44, Time step: 5684, Layer: 0

Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Existing Pump-On 2yr
Date
20th June 2013
Dwng No.
1168-202-D1

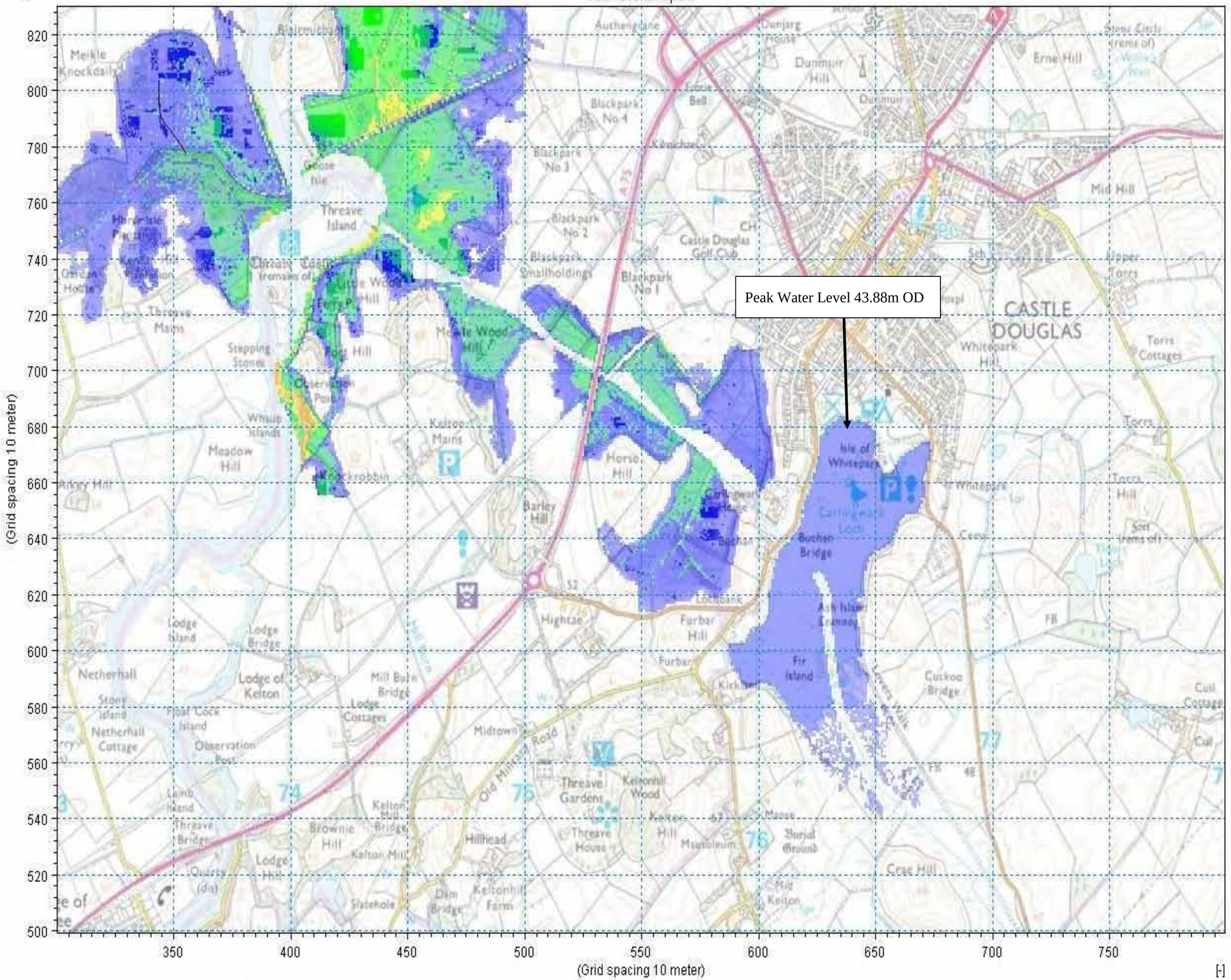


Terrenus CDH

1 Orbital Court Peel Park East Kilbride G74 5PH
Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Existing Pump-On 5yr
Date
20th June 2013
Dwng No.
1168-202-D2

[-]

H Water Depth



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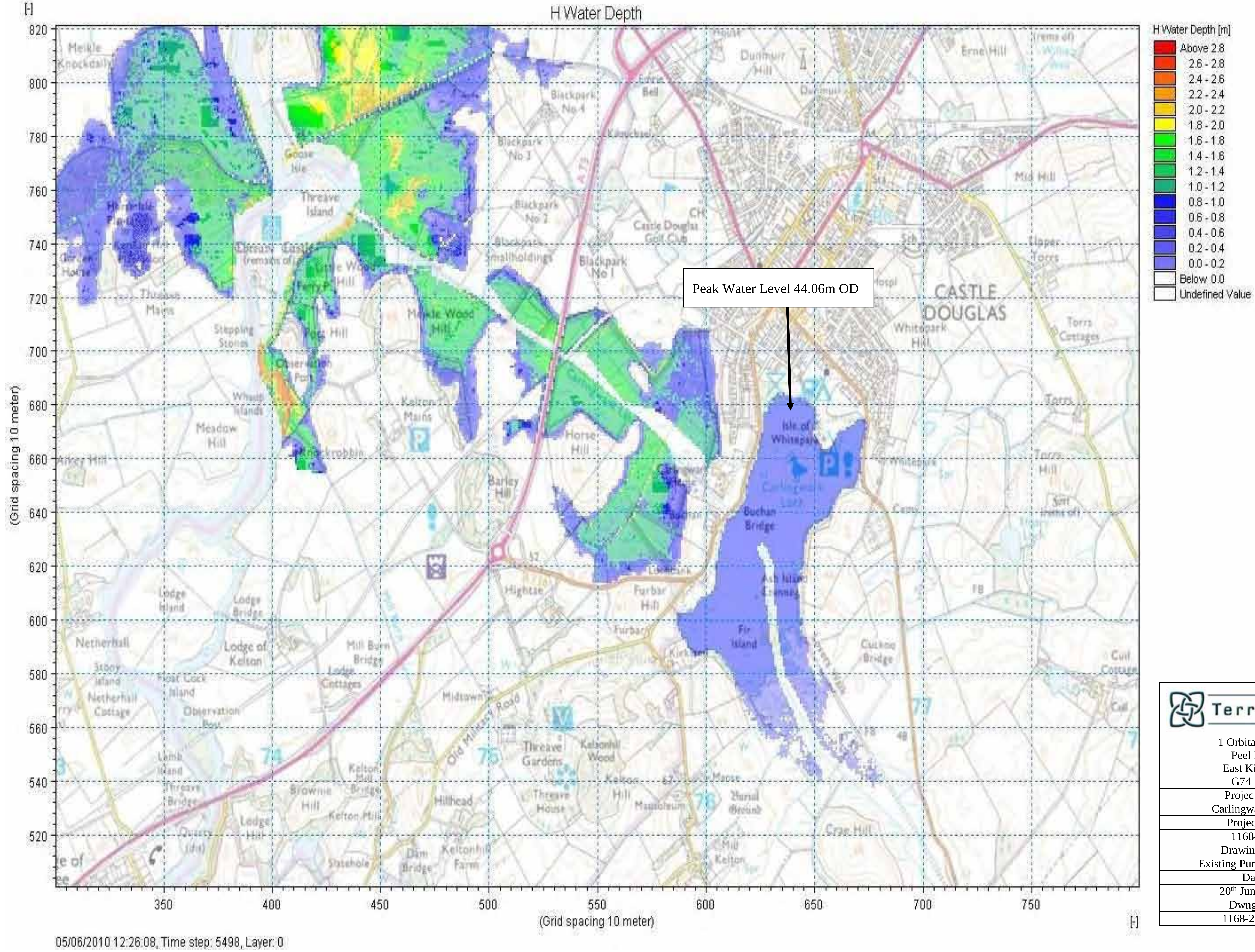
Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

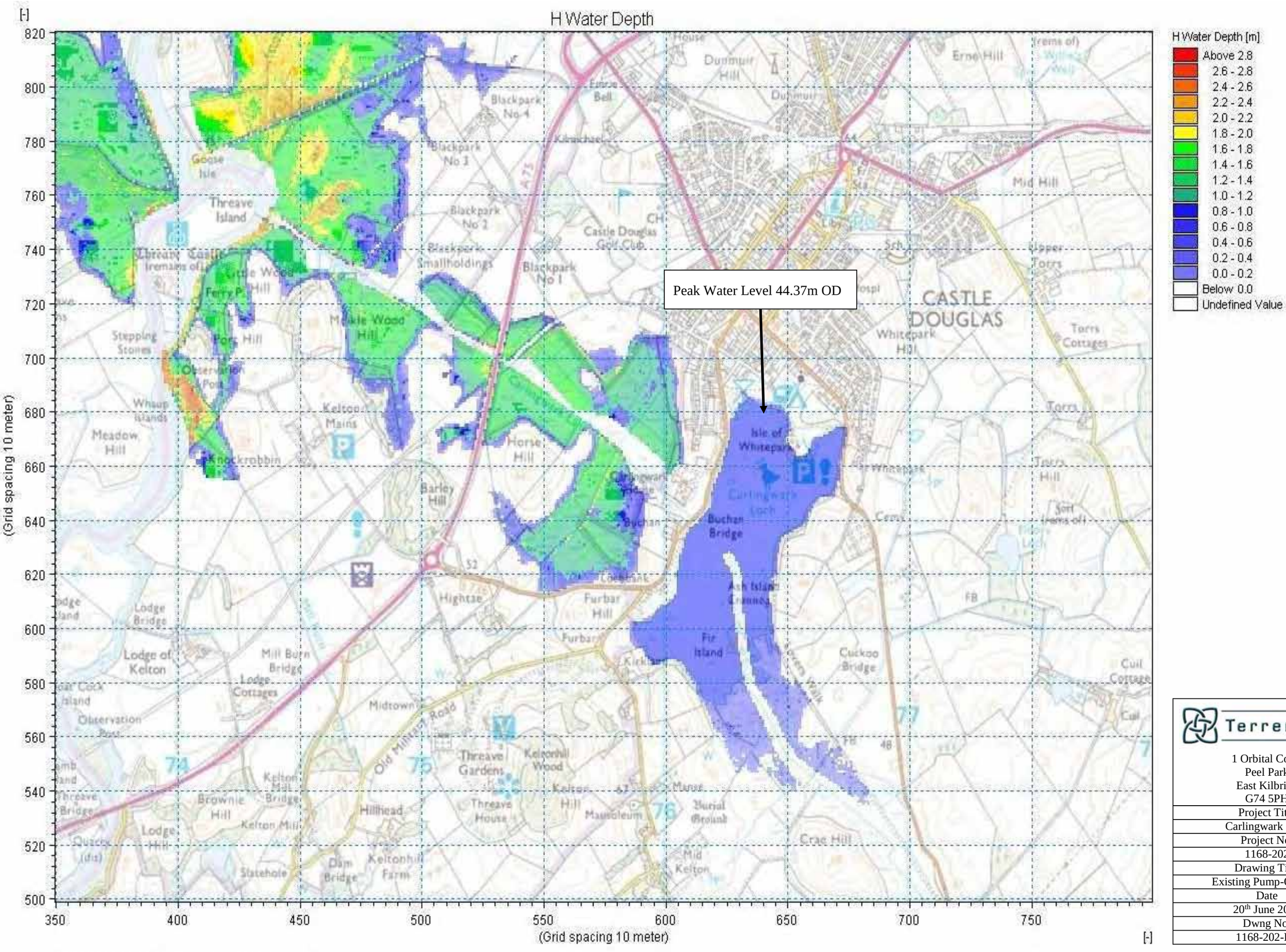
Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Existing Pump-On 10yr
Date
20th June 2013
Dwng No.
1168-202-D3



Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Existing Pump-On 25yr
Date
20th June 2013
Dwg No.
1168-202-D4



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Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Existing Pump-On 50yr
Date
20th June 2013
Dwng No.
1168-202-D5

[-]

H Water Depth

H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

Peak Water Level 44.76m OD

(Grid spacing 10 meter)

(Grid spacing 10 meter)

[-]

05/06/2010 12:26:08, Time step: 5498, Layer: 0

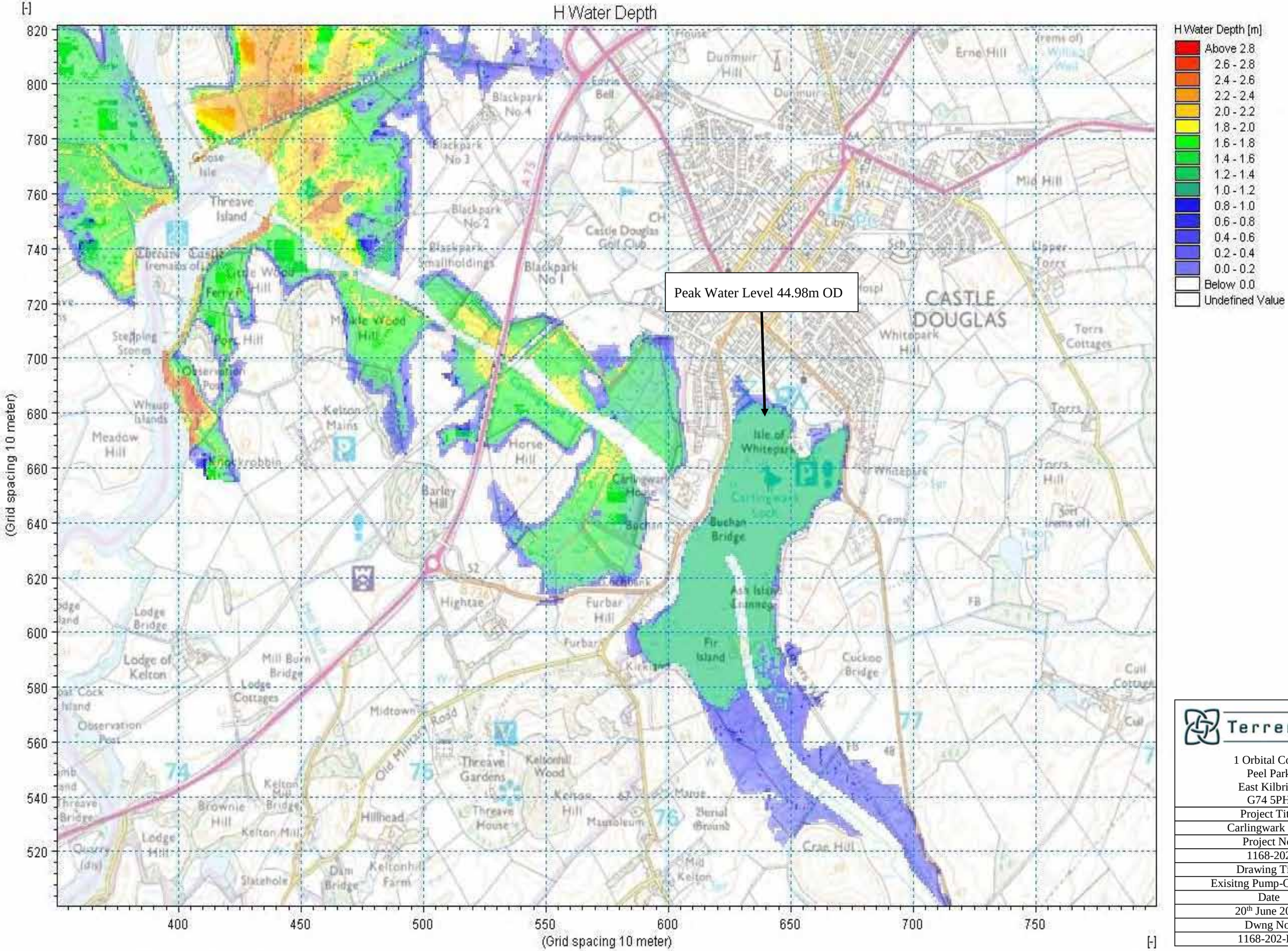
Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Existing Pump-On 100yr
Date
20th June 2013
Dwg No.
1168-202-D6

[-]

H Water Depth



H Water Depth [m]

- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

(Grid spacing 10 meter)

820 800 780 760 740 720 700 680 660 640 620 600 580 560 540 520

400 450 500 550 600 650 700 750

(Grid spacing 10 meter)

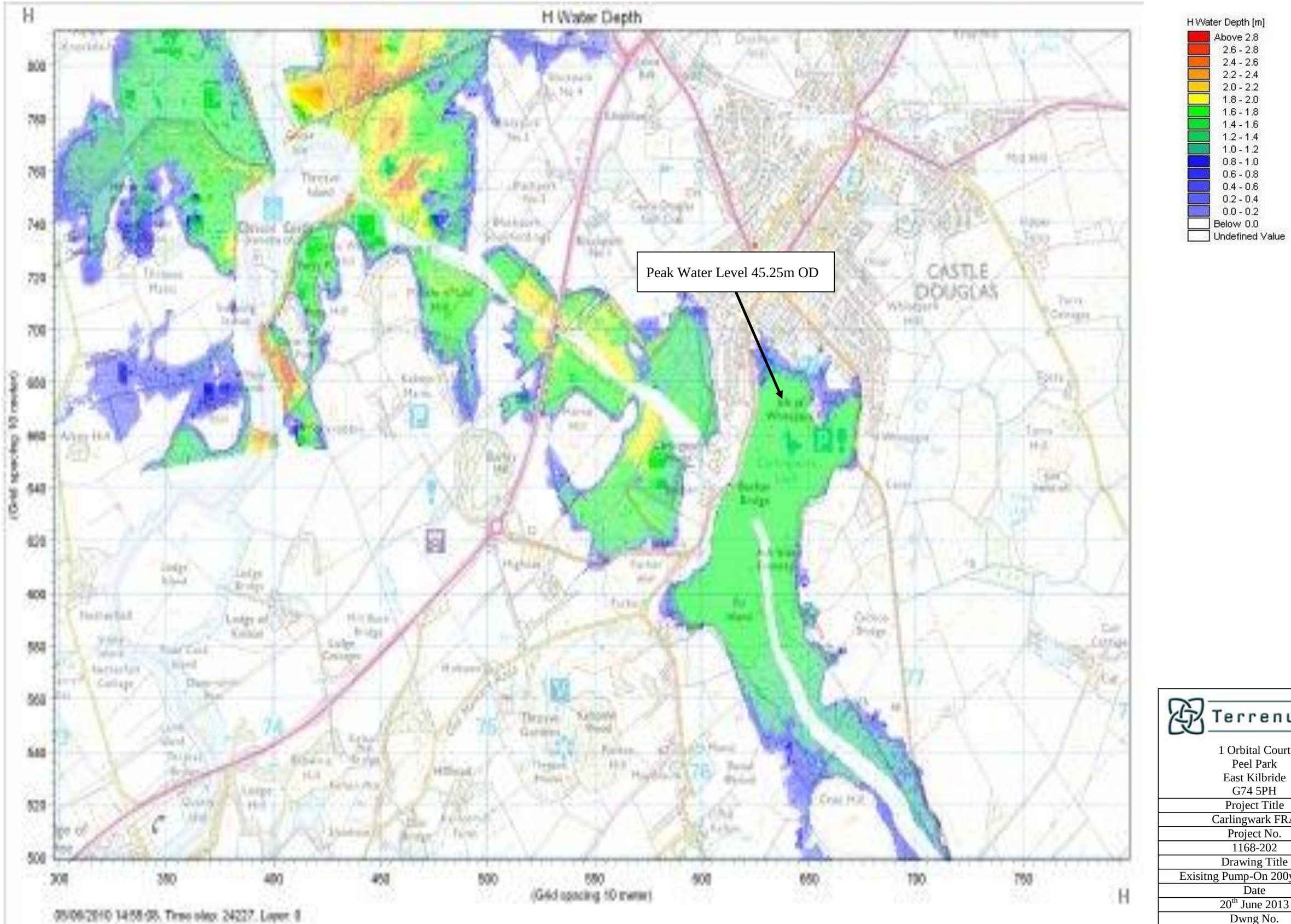
[-]

05/06/2010 11:11:32, Time step: 20873, Layer: 0

Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Exisitng Pump-On 200yr
Date
20th June 2013
Dwng No.
1168-202-D7



Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Exisitng Pump-On 200yr+GCC
Date
20th June 2013
Dwng No.
1168-202-D8

[-]

H Water Depth

H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

Peak Water Level 45.86m OD

(Grid spacing 10 meter)

840 820 800 780 760 740 720 700 680 660 640 620 600 580 560 540 520

350 400 450 500 550 600 650 700 750

(Grid spacing 10 meter)

[-]

05/06/2010 05:06:15, Time step: 61575, Layer: 0

Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Exisitng Pump-On 1000yr
Date
20th June 2013
Dwng No.
1168-202-D9

[-]

H Water Depth

Peak Water Level 43.63m OD

H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

(Grid spacing 10 meter)

840 820 800 780 760 740 720 700 680 660 640 620 600 580 560 540 520 500

350 400 450 500 550 600 650 700 750

(Grid spacing 10 meter)

[-]

05/06/2010 12:50:56, Time step: 5591, Layer: 0

Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Pump Off 2yr
Date
20th June 2013
Dwng No.
1168-202-D1 O

[-]

H Water Depth

H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

Peak Water Level 44.37m OD

(Grid spacing 10 meter)

840 820 800 780 760 740 720 700 680 660 640 620 600 580 560 540 520 500

350 400 450 500 550 600 650 700 750

(Grid spacing 10 meter)

[-]

05/06/2010 12:26:08, Time step: 5498, Layer: 0

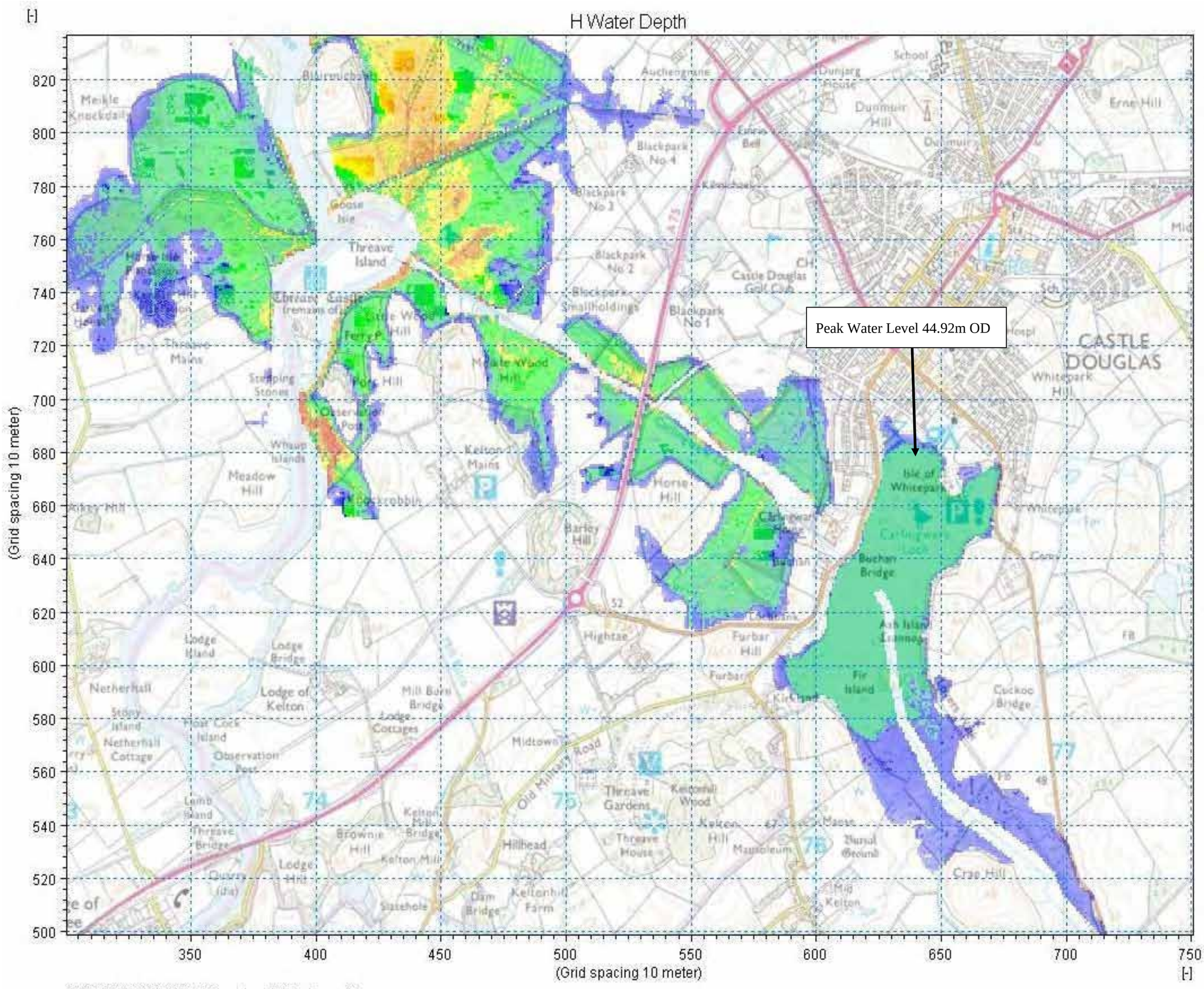
Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Pump-Off 50yr
Date
20th June 2013
Dwng No.
1168-202-D5 O

[-]

H Water Depth



(Grid spacing 10 meter)

(Grid spacing 10 meter)

[-]

05/06/2010 12:01:20, Time step: 5405, Layer: 0

H Water Depth [m]

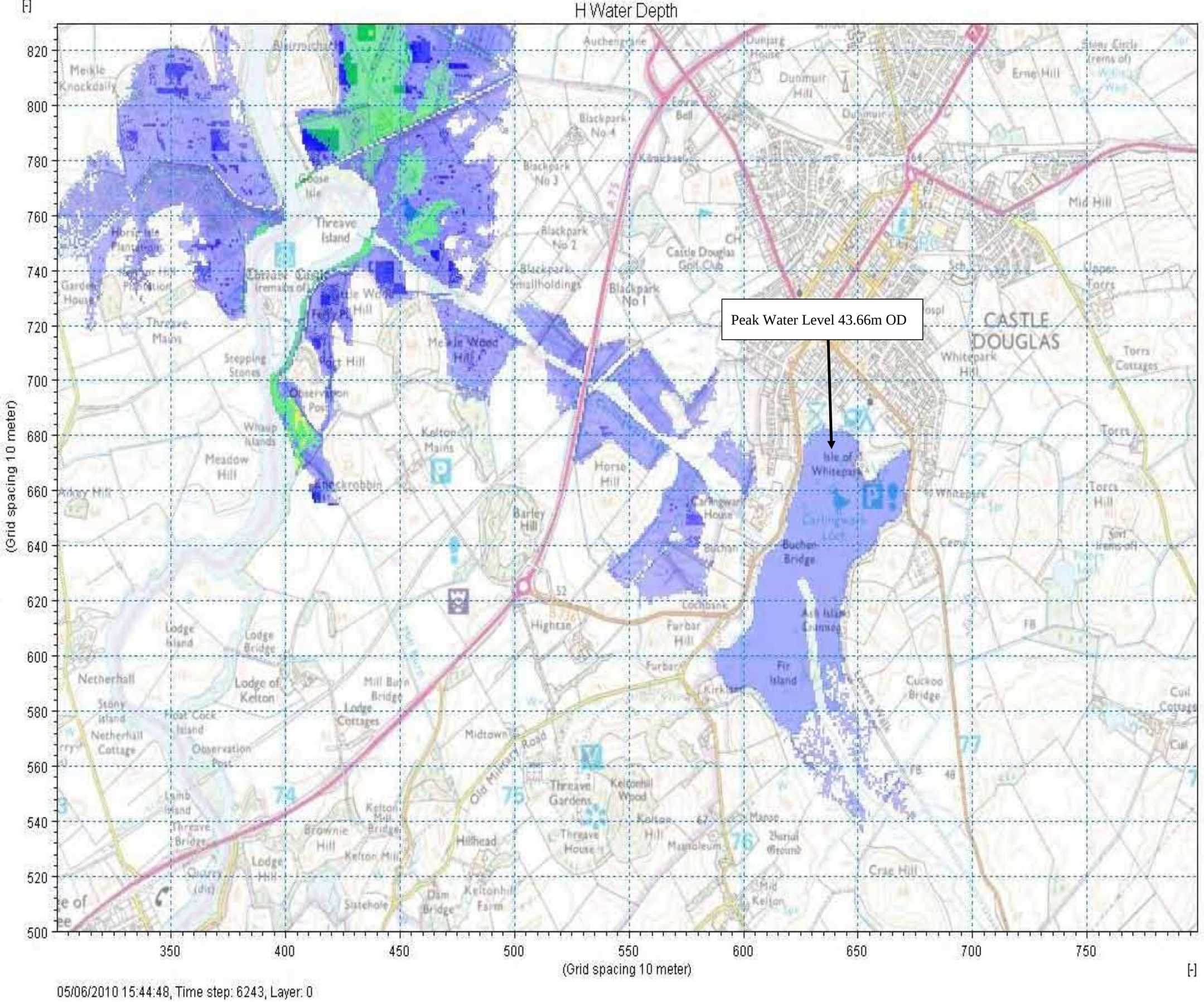
Above 2.8
2.6 - 2.8
2.4 - 2.6
2.2 - 2.4
2.0 - 2.2
1.8 - 2.0
1.6 - 1.8
1.4 - 1.6
1.2 - 1.4
1.0 - 1.2
0.8 - 1.0
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0.0 - 0.2
Below 0.0
Undefined Value

Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
Pump-Off 200yr
Date
20th June 2013
Dwng No.
1168-202-D7 O

H Water Depth



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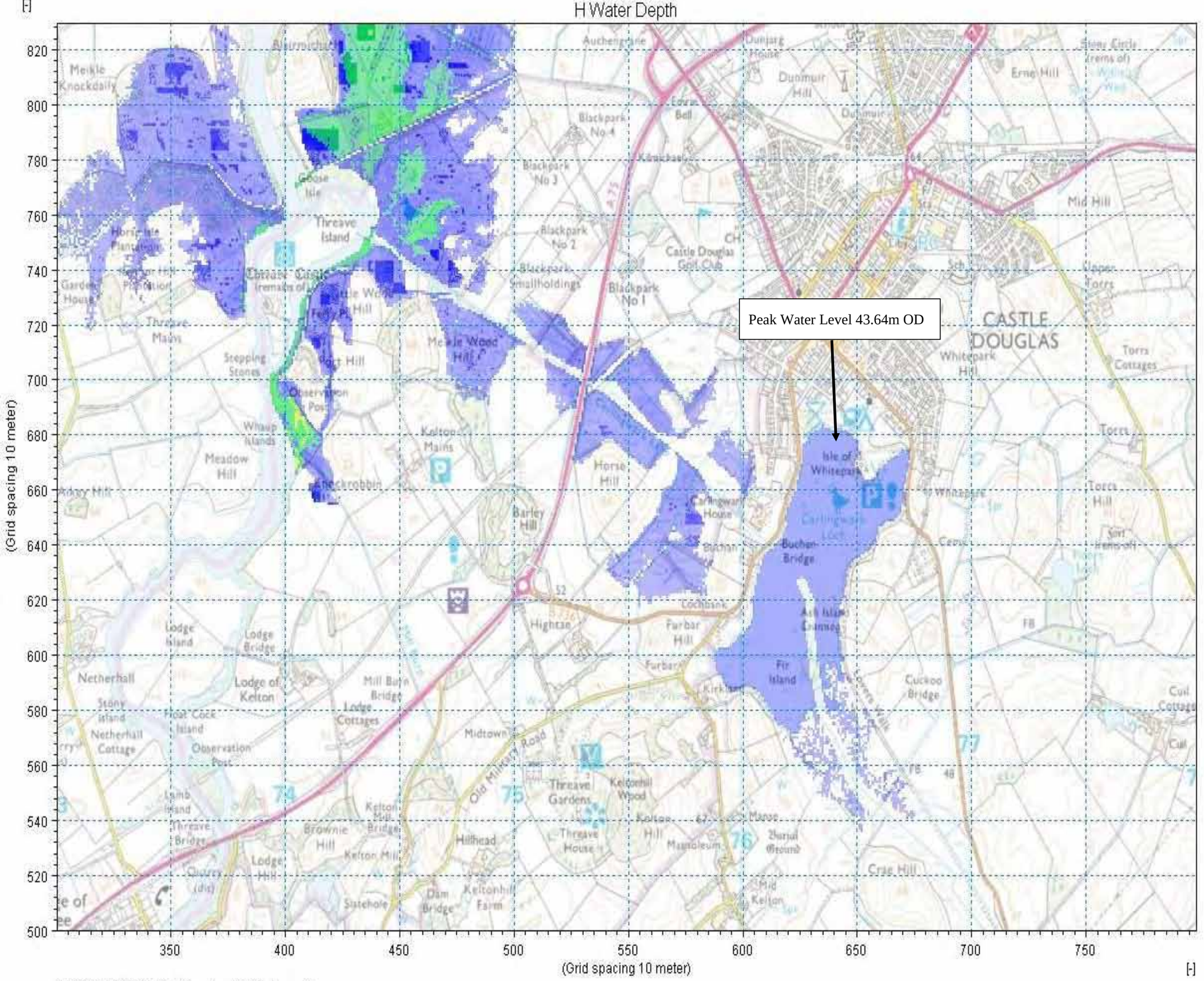
Terrenus CDH

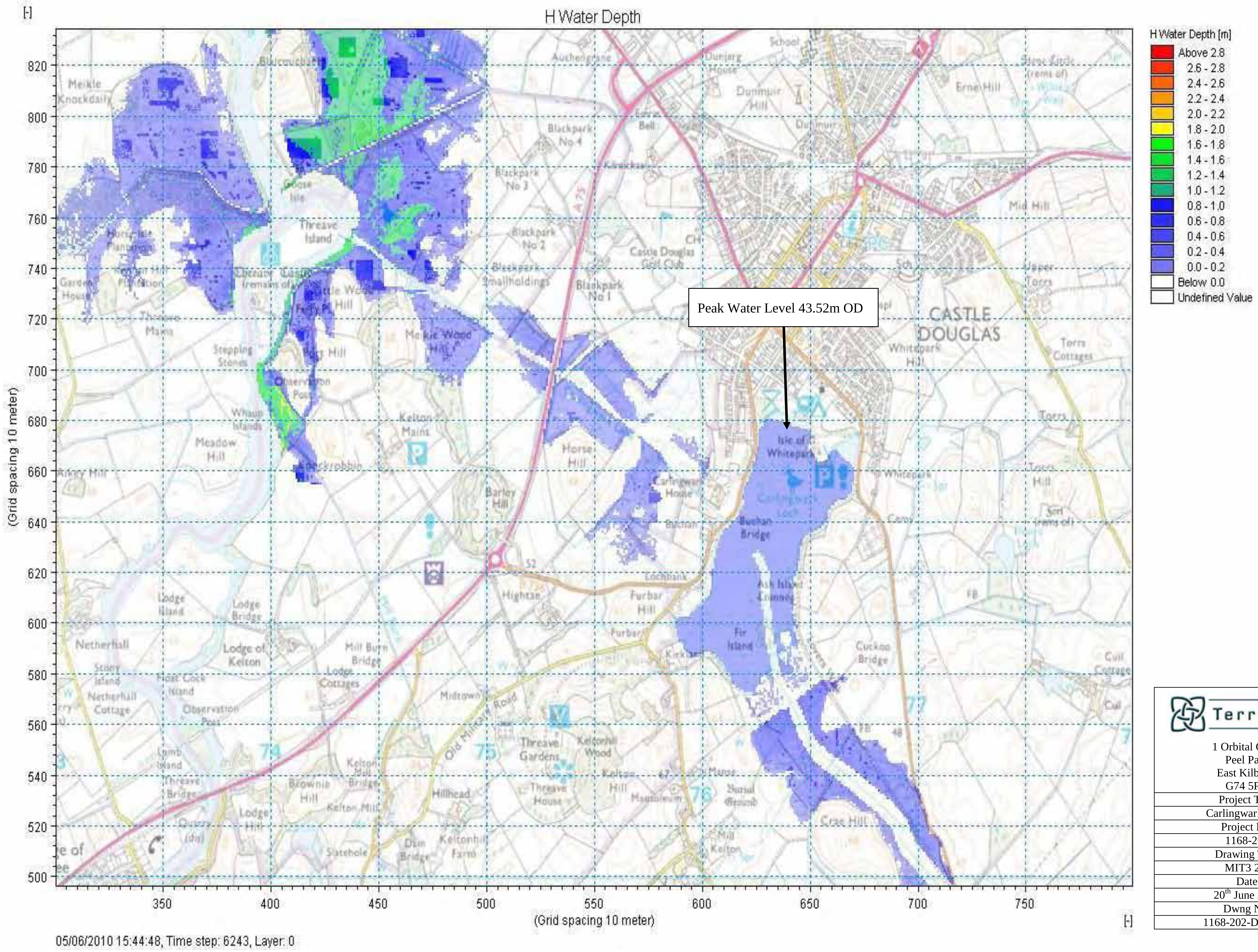
1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT1 2yr
Date
20th June 2013
Dwng No.
1168-202-D1MIT1

H Water Depth



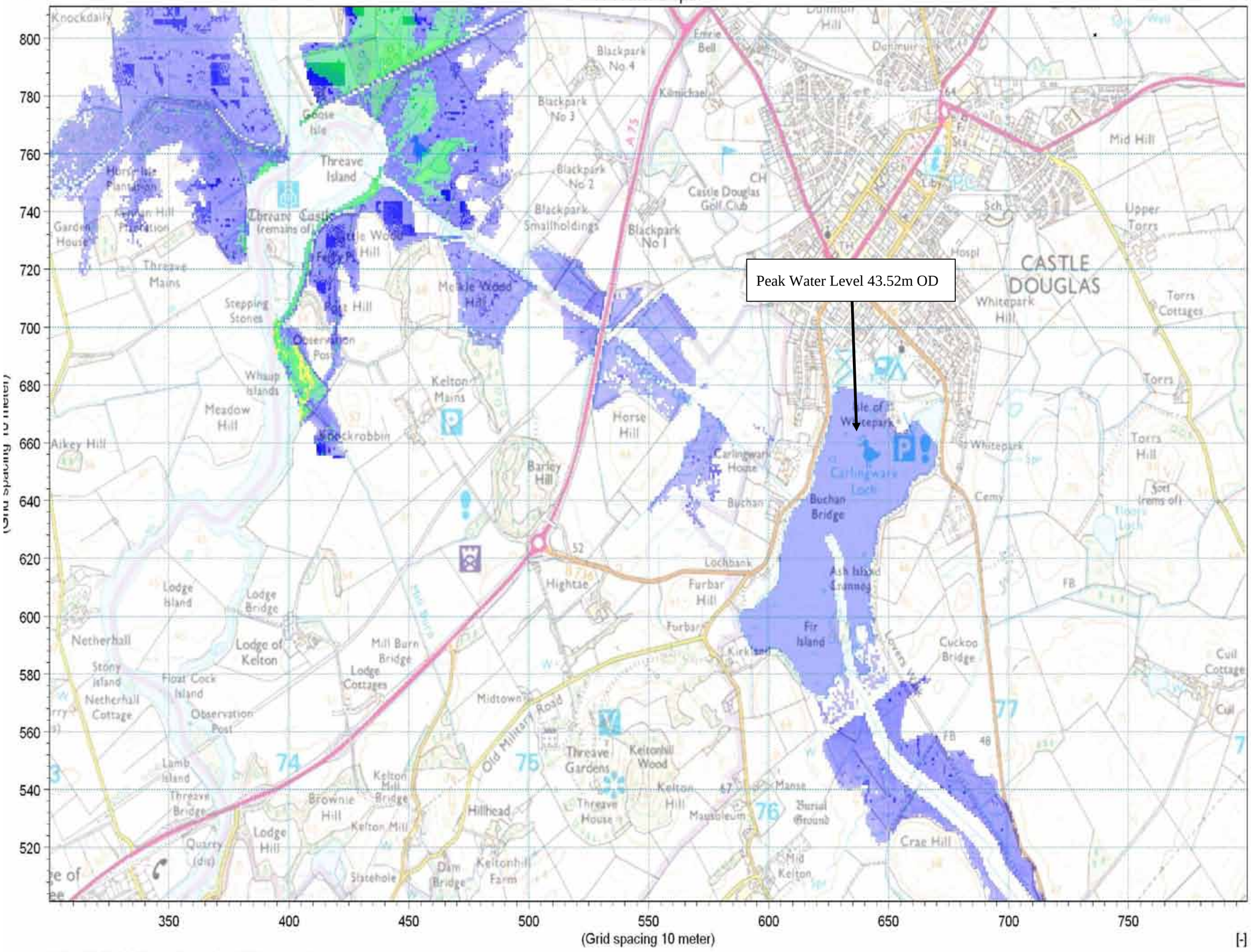
Terrenus CDH
1 Orbital Court Peel Park East Kilbride G74 5PH
Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT2 2yr
Date
20th June 2013
Dwng No.
1168-202-D1MIT2



Terrenus CDH
1 Orbital Court Peel Park East Kilbride G74 5PH
Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT3 2yr
Date
20th June 2013
Dwng No.
1168-202-D1MIT3

[-]

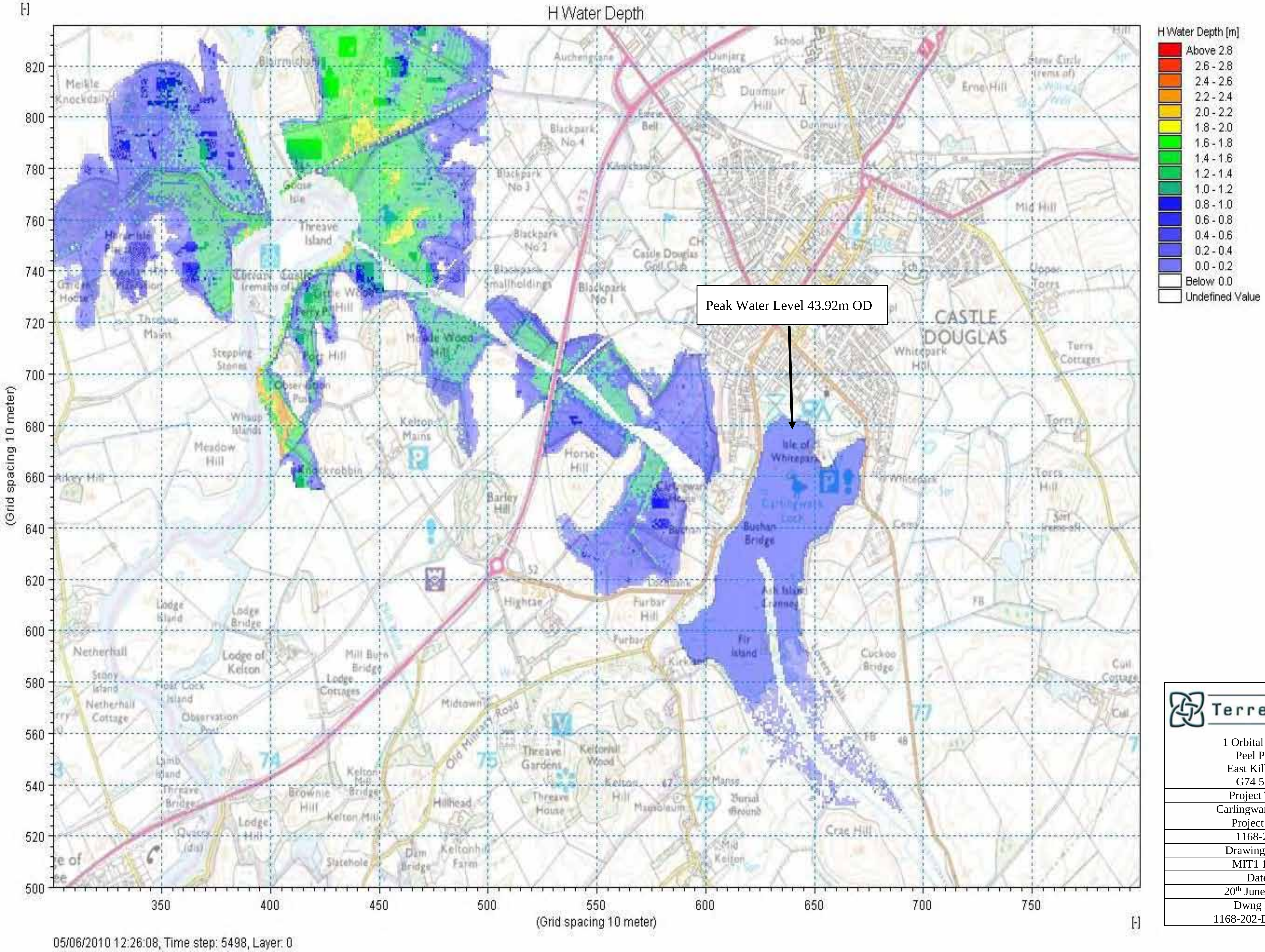
H Water Depth



Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT4 2yr
Date
20th June 2013
Dwng No.
1168-202-D1MIT4



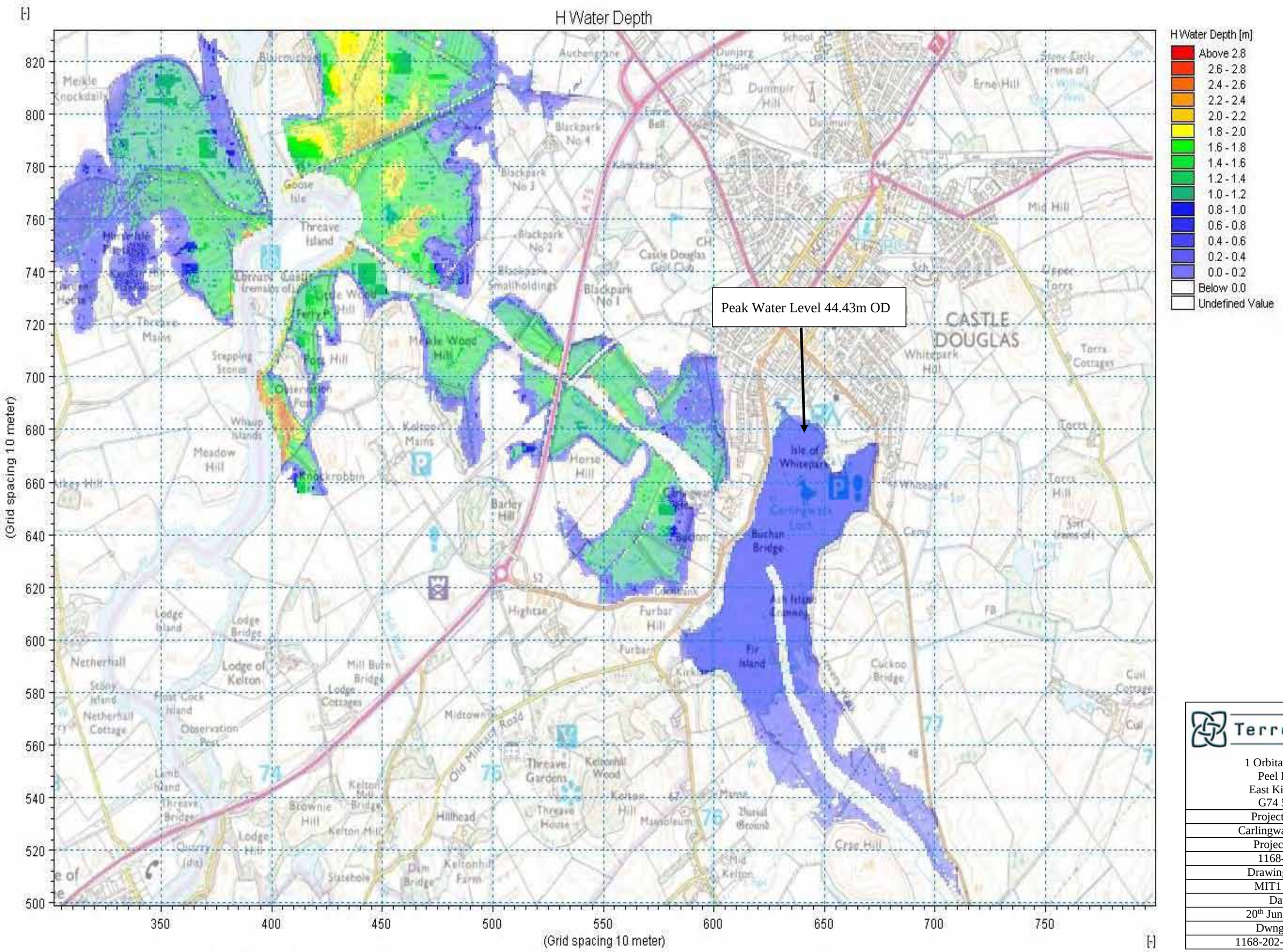
Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT1 10yr
Date
20th June 2013
Dwng No.
1168-202-D3MIT1

[-]

H Water Depth



H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

05/06/2010 13:40:32, Time step: 5777, Layer: 0

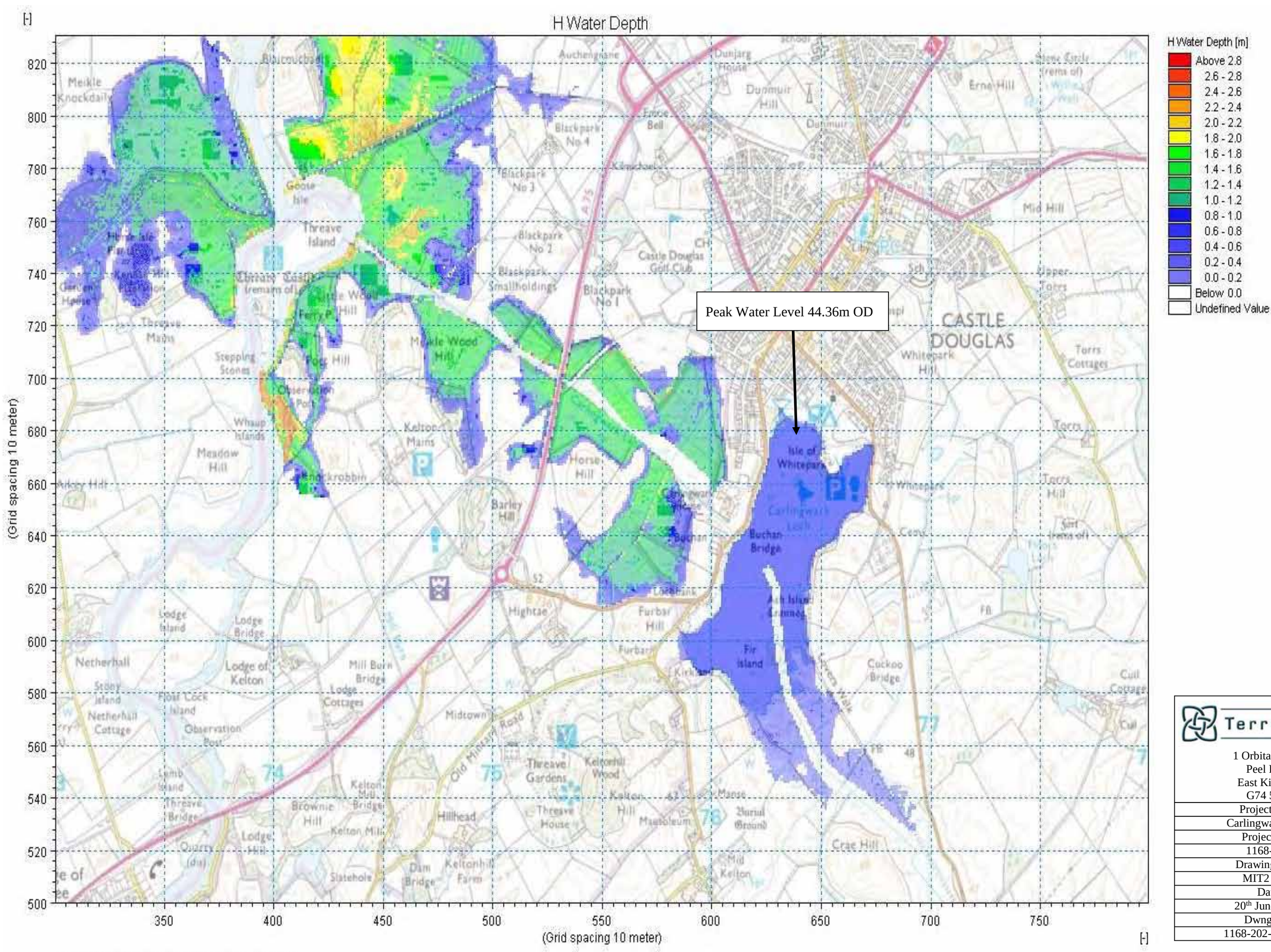
Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT1 50yr
Date
20th June 2013
Dwng No.
1168-202-D5MIT1

[-]

H Water Depth



H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

05/06/2010 12:50:56, Time step: 5591, Layer: 0

Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT2 50yr
Date
20th June 2013
Dwng No.
1168-202-D5MIT2

[-]

H Water Depth

Peak Water Level 45.01m OD

H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

(Grid spacing 10 meter)

840 820 800 780 760 740 720 700 680 660 640 620 600 580 560 540 520 500

350 400 450 500 550 600 650 700 750

(Grid spacing 10 meter)

[-]

05/06/2010 10:21:52, Time step: 5032, Layer: 0

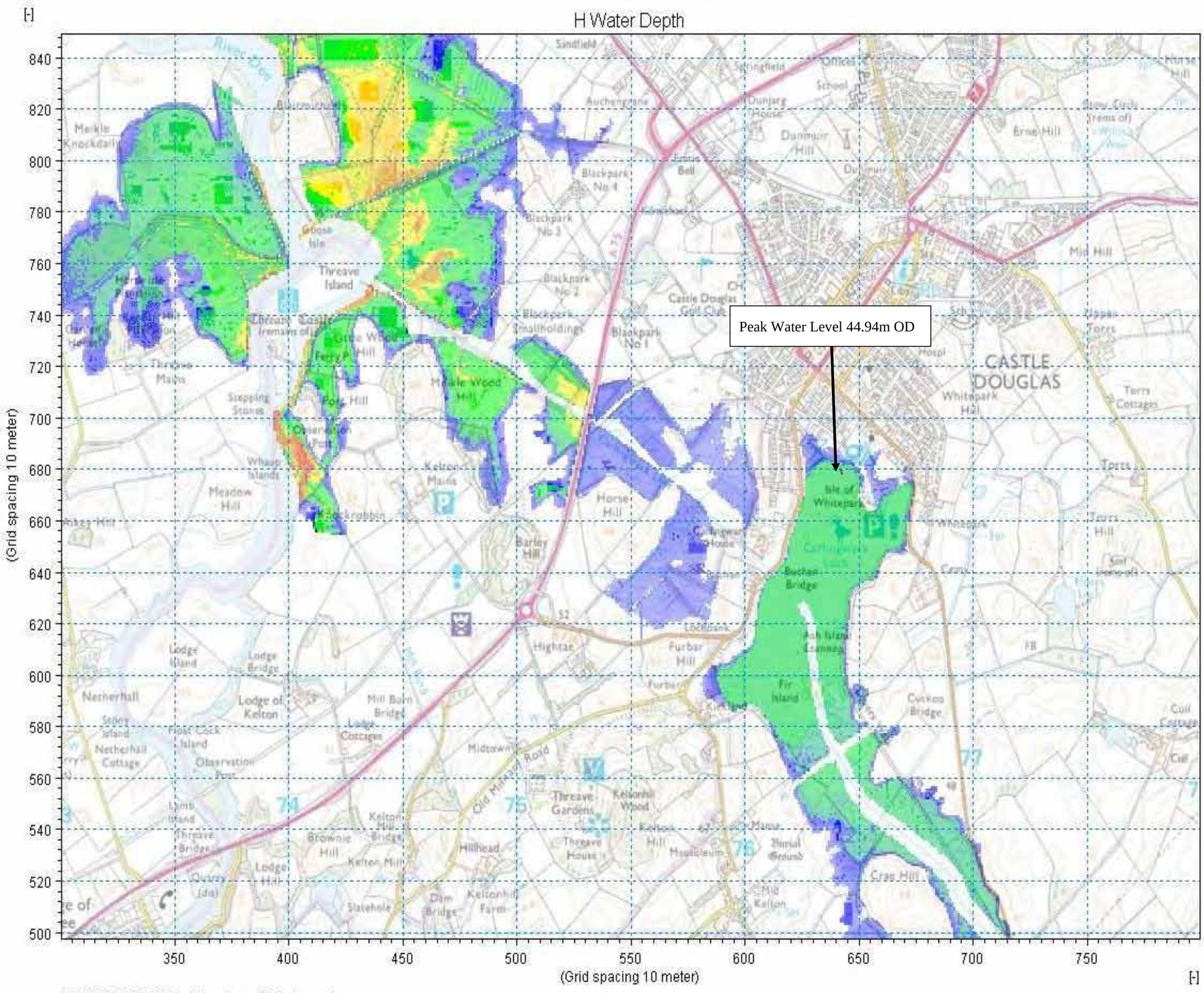
Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT3 50yr
Date
20th June 2013
Dwng No.
1168-202-D5MIT3

[-]

H Water Depth



H Water Depth [m]
- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

(Grid spacing 10 meter)

840 820 800 780 760 740 720 700 680 660 640 620 600 580 560 540 520 500

350 400 450 500 550 600 650 700 750

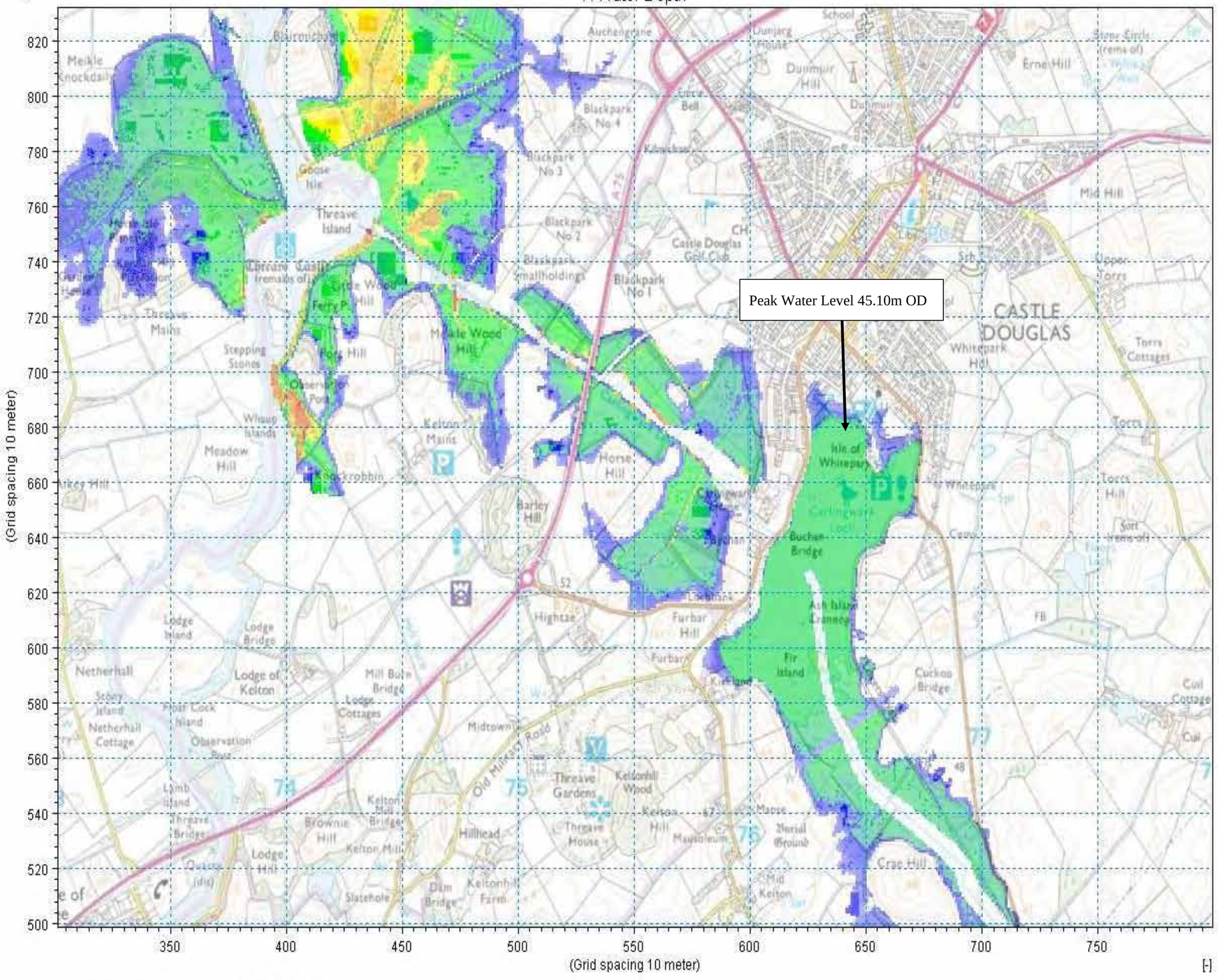
(Grid spacing 10 meter)

[-]

05/06/2010 09:57:04, Time step: 4939, Layer: 0

[-]

H Water Depth



(Grid spacing 10 meter)

(Grid spacing 10 meter)

[-]

H Water Depth [m]

- Above 2.8
- 2.6 - 2.8
- 2.4 - 2.6
- 2.2 - 2.4
- 2.0 - 2.2
- 1.8 - 2.0
- 1.6 - 1.8
- 1.4 - 1.6
- 1.2 - 1.4
- 1.0 - 1.2
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- 0.0 - 0.2
- Below 0.0
- Undefined Value

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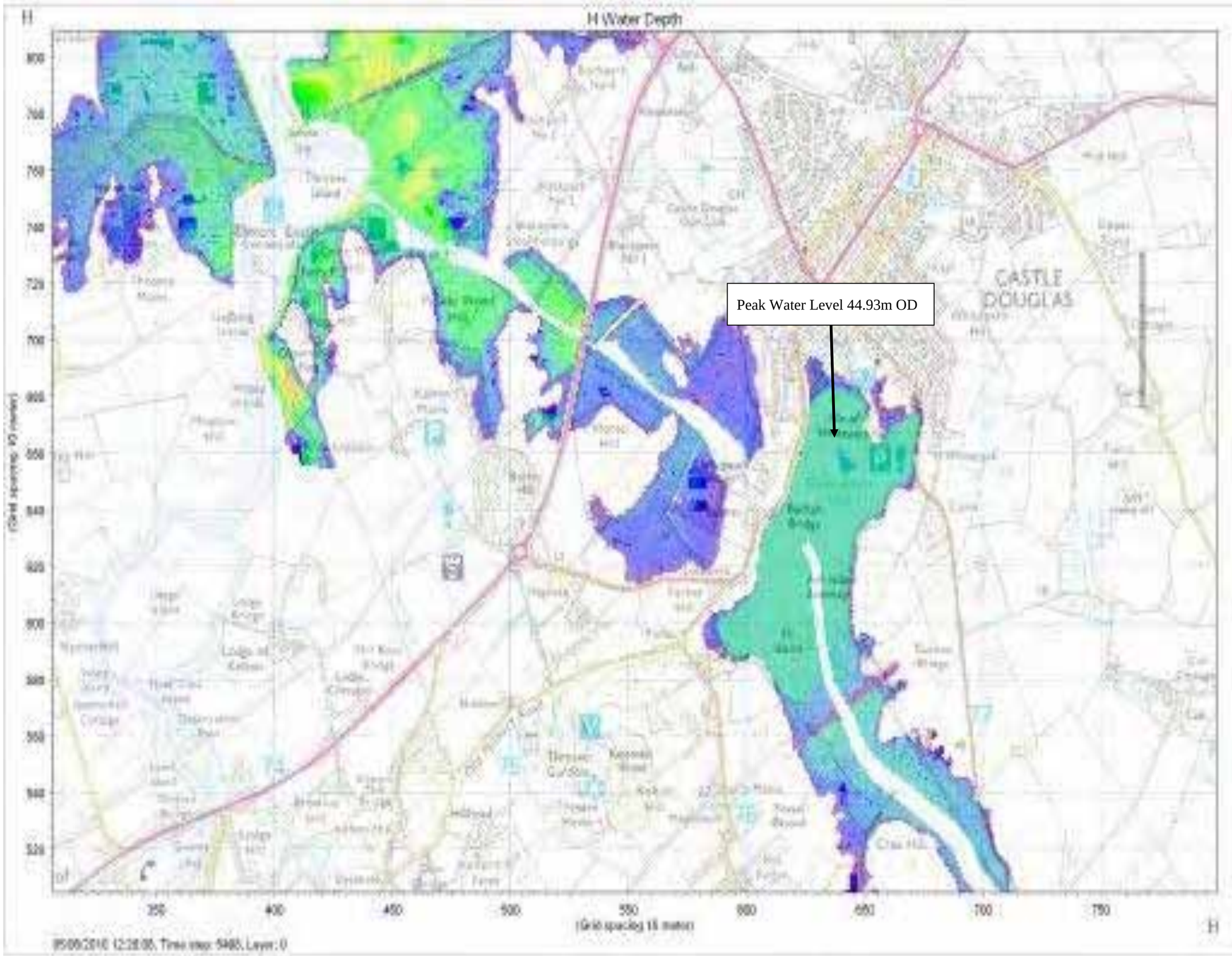
Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT3 100yr
Date
20th June 2013
Dwng No.
1168-202-D6MIT3



Terrenus CDH

1 Orbital Court
Peel Park
East Kilbride
G74 5PH

Project Title
Carlingwark FRA
Project No.
1168-202
Drawing Title
MIT4 100yr
Date
20th June 2013
Dwng No.
1168-202-D6MIT4

PHOTOGRAPHS

Plate 1 – View from upstream end of Gelston Burn looking north west.

Plate 2 – View of upper Gelston Burn looking south east.

Plate 3 – View of Carlingwark Loch looking north west.

Plate 4 – View of shore area around Carlingwark Loch near Isle of Whitepark.

Plate 5 – Looking south towards Carlingwark House. Note new sewage treatment facility on left.

Plate 6 – Carlingwark Lane looking north east from the A75 road bridge.

Plate 7 – Looking north west towards the Blackparks Pumps from the A75 bridge.

Plate 8 – Upstream side of the Blackparks pump station.

Plate 9 – View of low lying ground on the downstream side of the Blackparks Pump station.

Plate 10 – Looking south west from Blackpark Smallholdings towards the pump station.

Plate 11 – Looking north from Meikle Wood Hill towards Threave Castle.

Plate 12 – From Meikle Wood Hill looking north east with the Blackparks Pump station in the middle distance.

Plate 13 – Downstream side of Blackparks Pump station (pumps currently in action).

Plate 14 – Upper part of Carlingwark Lane showing constricting channel growth.

Plate 15 – View of upstream side of A75 road bridge.

Plate 16 – View of Carlingwark Lane from pump station looking downstream

Plate 17 – View of non-return culvert gates at Blackparks Pump station.

Plate 18 – Looking south from the pump station.

Plate 19 – View of upstream side of pump station.

Plate 20 – Carlingwark Lane looking towards the A75 bridge.

Plate 21 – Carlingwark Loch and the Buchan Bridge outfall.

Plate 22 – View below Buchan Bridge.

Plate 23 – Constriction downstream of Buchan Bridge.

Plate 24 – Excavated section of Carlingwark Lane downstream of Buchan Bridge.

TABLES

Job No: 1168-202

Table 1 - Summary of Peak 1 in 200yr Flow Rates

		All flow volumes are expressed in m3/s							
		FEH QMED (using 2007 methodology) combined with Growth curve	FEH QMED (using 2008 methodology) combined with Growth curve	IHR 124 Rural (Catchments <25km2)	Rainfall Runoff Methodology (MIKE)	SEPA Statistical Analysis	Mouchel 2008 report - Statistical Method	Mouchel 2008 report - Rainfall Runoff Method	**Adopted Peak Flow**
River Dee at Glenlochar	200 year	779	886	n/a	1401	541	495	n/a	**495**
	200 year plus potential Global Climate Change (GCC) of 20%	935	1063	n/a	1681	649	594	n/a	**594**
River Dee at Bridge of Weir	200 year	777	902	n/a	1417	n/a	528	n/a	**528**
	200 year plus potential Global Climate Change (GCC) of 20%	932	1082	n/a		n/a	634	n/a	**634**
Carlingwark Lane at Castle Douglas	200 year	13	18	29	86	36	n/a	36	**36**
	200 year plus potential Global Climate Change (GCC) of 20%	15	21	34	103	43	n/a	44	**43**

Note: FEH CD-ROM 3 Dataset used

Job Number 1168-202

Table 2 - Summary of Peak Flow Rates for a Variety of Return Periods

	All flow volumes are expressed in m3/s								
	2 year	5 year	10 year	25 year	50 year	100 year	200 year	200 year plus potential Global Climate Change (GCC) of 20%	1000 year
River Dee at Glenlochar	238	301	341	391	247	461	495	594	1938
Carlingwark Lane at Castle Douglas	11	15	18	23	27	32	36	43	53

Job Number 1168-202

Table 3 - Peak Water Levels around Isle of Whitepark

	Existing Conditions		Mitigation Measures							
	Blackparks Pump On throughout storm event.	Blackparks Pump Off (failed or switched off).	MIT 1	MIT 2	MIT 3	MIT 4				
2 Year	43.63	43.63	43.66	43.64	43.52	43.52				
5 Year	43.78									
10 Year	43.88		43.92							
25 Year	44.06									
50 Year	44.37	44.37	44.43	44.36	45.01	44.94				
100 Year	44.76				45.09	44.93				
200 Year	44.98	44.92	44.97							
200 Year plus GCC	45.25									
1000 Year	45.86									

Explanatory Notes: All levels are expressed in relation to OD,
Pre Storm Carlingwark Loch Water Level of 43.5m
Blackparks bund at about 45.00m OD

Exsisting Conditons Freeflow of water throughout system except at Blackparks with one way gate culverts and twin automatic pumps

MIT 1 Repair of Blackparks bund to 45.45mOD, Blackparks pumps off, Gill Burn control with weir at 45.5mOD and culvert with capacity of about 10m3/s

MIT 2 Repair of Blackparks bund to 45.45mOD, Blackparks pumps off

MIT 3 Repair of Blackparks bund to 45.45mOD, Blackparks pumps off, Gill Burn control with weir at 45.5mOD and culvert with capacity of about 2.5m3/s

MIT 4 Repair of Blackparks bund to 45.45mOD, Blackparks pumps off, Gill Burn control with weir at 45.5mOD and culvert with capacity of about 2.5m3/s, A75 one way gate.