Linen Green, Moygashel

Feasibility Report

Dfl Rivers

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Glossary of Abbreviations

1D	One Dimensional
2D	Two Dimensional
AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
BBC	British Broadcasting Corporation
BT	British Telecom
DfI	Department for Infrastructure
Dia.	Diameter
FCERM-AG	Flood and Coastal Erosion Risk Management – Appraisal Guidance
FFL	Finished Floor Level
FHRC	Flood Hazard Research Centre
NIE	Northern Ireland Electricity
NIW	Northern Ireland Water
NPV	Net Present Value
PPS 15	Planning Policy Statement 15
PSNI	Police Service of Northern Ireland
RDS	Regional Development Strategy
TNI	Transport NI
WFD	Water Framework Directive

1. Executive Summary

1.1 Introduction

AECOM was commissioned by the Department for Infrastructure (DfI) Rivers to appraise flood risk to properties in the Linen Green area, Moygashel from the Park Lake Stream and other contributing sources, and to investigate options (including economic viability) to alleviate any potential flooding from a 1% AEP.

In addition, the causes and mechanisms of the flood event at the Linen Green shopping complex and Transport NI (TNI) depot on the 6th December 2015 were investigated.

1.2 History of Flooding

Storm Desmond made landfall on 4th December 2015 which brought a period of extreme rainfall accompanied by widespread gale-force winds over a two day period. Wind gusts reaching 68mph and 77mph on 4th & 5th December respectively were recorded at Killowen, Co. Down with 71.4mm and 64.8mm recorded at Derrylin, Co. Fermanagh in the same period. Yellow weather warnings for both wind and rainfall were also issued by the Met Office prior to this event.

This period of extreme rainfall resulted in flooding from the Park Lake Stream affecting commercial properties in the Linen Green complex and a Transport NI (TNI) depot. It is stated within the DfI Rivers flood report that as these properties are located in the lowest point of the catchment, flood waters will flow to and collect at these sites.

DfI Rivers was notified about the flood event at 3am on 6th December by a Transport NI engineer reporting that the depot at Moygashel was flooded. The combination of extreme rainfall and high winds resulted in the inlet grille becoming blocked by debris. The same grille had been inspected on the 5th December which reported the structure in a satisfactory condition. At 6am an excavator was used to remove part of the grille at the inlet to the Linen Green culvert, approximately 30 minutes later flood waters from both sites had subsided.

DfI Rivers suggested in their report that as flood waters dissipated quickly after removing the grille, the only significant source of flooding on this occasion was from the Park Lake stream, however a number of other undesignated watercourses exist within both sites that have the potential to pose significant risk in future events. No other records exist of flooding from this watercourse.

1.3 River Modelling

A hydrodynamic one-dimensional hydraulic model of the watercourse integrated with a two-dimensional model of the surrounding topography was provided to AECOM by DfI Rivers in InfoWorks ICM format. AECOM truncated and updated the model between the Park Lake Dam and downstream of the Linen Green complex based on topographic survey information and asset information obtained by CCTV and walk-through surveys.

1.4 Flood Protection Options

To determine suitable flood protection options the Linen Green complex and Transport NI depot was examined and possible options include the upgrade of the existing culvert inlet grille and replacement of the culvert network. The proposed replacement grille would include an overflow facility that allows flow to gain entry to the culvert should the main section of the grille become blocked. It would also include adequate provisions to allow maintenance personnel to remove gathered debris.

Several route options were examined for a proposed replacement culvert to address both the structural issues and capacity inadequacies that have been uncovered through survey work undertaken following the flooding event on 6th December 2016. The preferred route (Option 6) involves the construction of 385m of 1.0x2.5m box culvert along the eastern side of the Transport NI depot towards Main Rd and then turning in a south-westerly direction parallel to the base of the embankment towards the Linen Green complex main entrance. From here it turns south and crosses

Main Road to connect to the existing 2100mm diameter culvert. Works will also be required within the Transport NI depot and Linen Green complex to prevent any disconnection of drainage when undertaking works to make safe the existing culvert.

1.5 Benefit Cost Analysis

The costs of damages for the 20%, 10% 4%, 2% & 1% AEP flood events were calculated based upon the Multi-Coloured Manual and discounted over a period of 100 years in order to determine the present value of benefits for each option.

The benefit cost analysis shows that options 3, 4, 5 and 6 are all economically viable as they have a benefit/cost ratio greater than 1. However the preferred solution is option 6 which has a benefit cost ratio of approximately 4.0.

2. Terms of Reference

AECOM was commissioned by the Department for Infrastructure (DfI) Rivers to appraise flood risk to properties in Linen Green and a Transport NI (TNI) depot, and to investigate options (including economic viability) to alleviate any potential flooding from a 1% AEP.

2.1 Scope of the Brief

The main requirements of the brief were to:

1. Investigate historical flooding/context (e.g. old mill, Park Lake).
2. Liaise with TNI, Linen Green (Management, Businesses etc.), relevant stakeholders (Council – Planning Records, Rivers Agency etc.).
3. Investigate the cause of the flooding in December 2015.
4. Assess the current standard of protection (open watercourses and culverts).
5. Investigate and evaluate possible procedures (e.g. new maintenance/inspection regimes, flood warning, minor civil engineering, etc.) to reduce the risk from flooding.
6. Investigate & evaluate larger scale engineering options to reduce the risk from flooding.
7. Recommend viable methods and/or options to reduce the risk from flooding.

2.2 Key Tasks

2.2.1 Stage 1 - Preparation:

- Review and verify the information contained within DfI Rivers Prefeasibility Report & Initial Report – Flooding Incident at Moygashel on the 6th Dec 2015.
  - Supplement where necessary with any new / additional information.
- Prepare a desk study of the site, obtaining such information as is reasonably accessible to the Consultant such as information on ground conditions; geology; previous uses of the site; flooding history; service locations; identification of business owners / landowners; environmental designations / restrictions etc.
- Carry out a survey and inspection of the site identifying existing buildings, services, site & access constraints, general topography (i.e. low lying floodplain) general land-use, presence of any structures, river channel / culvert features etc.
- Consult as necessary with all utilities, Government Bodies and other authorities on matters relating to the proposed Works Project.
  - Obtain such information as is reasonably available on the existence and extent of public and private services such as water, gas, electricity, sewerage, culverts, tunnels and telecommunications services. Comment on any effect that these may have on the project, both during construction and on completion.

2.2.2 Stage 2 - Feasibility / Proposals Stage:

- Topographical survey
  - Required to record the terrain, shape, features, infrastructure and levels (including Finished Floor Levels (FFL)), at and surrounding the TNI Depot & Linen Green shopping complex.
- Review flood history
  - From discussions with local DfI Rivers sources, businesses, TNI, residents, collating available information from local newspapers, internet, business owners/employees, residents accounts and DfI Rivers data.
- Hydrological assessment of flood flows

  - Details to be included in both the Feasibility and Model Reports.
- Review and update the existing hydrodynamic model
  - Using InfoWorks ICM. The river channel to be modelled in 1D, with the overbank areas modelled in 2D. The model shall be calibrated, verified and sensitivity tested.
  - Employer to be advised of details for boundary conditions and assumptions made during the model build. This information is to be included within the completed Feasibility Report and separate Model Report.
  - Consider a range of flows (present day Qmed, Q5, Q10, Q25, Q50, Q75, Q100, Q1000 return periods and the Q100 climate change (year 2030) scenario) and produce flood maps indicating flood outlines; flowpaths and the extent of flooding anticipated for each event in the undefended and defended states. *(The return periods requested have been translated in to corresponding AEPs throughout this report)*
  - Utilise the model to assess flood risk (determining flood extent & depth of flooding); and to assess the implications on flood levels of any proposed flood defence or mitigation methods / options (including upstream and downstream of the works location); and to compute a model simulation for the recommended solution as appropriate.
  - Range of options that would remove the threat of flooding up to and including the Q100 scenario
- Consider the effects of development, as proposed in the latest Area Plan, on flows in the watercourses.
- Determine the hydraulic capacity of the existing channel and pertinent structures on the watercourse and comment on their ability to contain the estimated flood flows.
  - Determine the integrity, by non-intrusive means, of any structures over, under or in the watercourse.
- Identify and quantify the flood damage
  - to properties presently at risk of flooding in flood events up to the predicted Q100 event *(1% AEP)* in accordance with the procedures outlined in the Flood Hazard Research Centre (FHRC) Multi-Coloured Manual.
  - Consider the flood damage avoidance benefit for each of the options considered as part of the economic assessment, highlighting any residual flood risk.
- Model Report to include:
  - Data Sources
  - Parameters Used
  - Calibration / Verification description
  - Sensitivity Analysis discussion
  - Audit Trail
  - Model Limitations
  - Data Formats and Meta Data.
  - The model information shall include an orthogonal schematic, and a geographically correct lineage presented in ESRI ArcGIS format.

3. Site Description

The Park Lake Stream (U4304) is a designated urban watercourse with several culverted sections which flows south-east though Dungannon. This report examines the section of the stream downstream of the Dungannon Park Lake flowing through the Linen Green complex and associated culvert towards the M1 Motorway. The Dungannon Park Lake provides attenuation of flood waters during an event for the upstream section of the Park Lake Stream. The Linen Green complex has been formed through the redevelopment of an historic mill complex in a staged process over the past approximately 20 years. See drawing LGMS-AECOM-XX-XX-DR-CE-01001 for a site location plan.

The catchment upstream of the model extent is approximately 9km² and is generally medium sloped and equally mixed between rural and urban land use including major and minor roads. The length of watercourse modelled for this study is 2km beginning just downstream of the Dungannon Park Lake and finishing upstream of the M1 motorway.

The model watercourse is comprised of 510m of open watercourse followed by 420m of culverted watercourse through the Transport NI depot and Linen Green shopping complex with a remaining length of 780m of open watercourse.

The section of culvert running beneath the Transport NI depot is comprised of 3 pipes in parallel, varying in diameter from 750mm to 1050mm, beginning at inlet U4304/INL through manhole U4304/08A and U4304/08 to U4304/07. The remainder of the culvert is predominately made up of red brick arch culverts with a short rectangular section adjacent to U4304/07 and a 2100mm pipe from U4304/OUT to the outlet.

Picture 3.1 Dungannon Park Lake Dam Wall

Picture 3.2 Channel between dam and culvert inlet

Picture 3.3 Channel immediately upstream of culvert inlet

3.1 Mill Race

An abandoned mill race which was originally fed from the Park Lake is still present along the side of the hill from the dam to the Linen Green on the west side of the development. There remains a connection from the Park Lake however the flows are controlled by means of a sluice. A small flow was observed in the mill race immediately downstream of the dam however this escaped a short

distance downstream through a gap in the bank to the main river channel. It is assumed that this flow originates due to seepage and leakage through the sluice inlet structure. Beyond this point the water in the channel is stagnant with algae growth observed.

Picture 3.4 Mill Race Inlet Sluice

It is thought that this mill race now acts primarily as a land drain and may receive surface water drainage flows from adjacent developments. Survey work has suggested that multiple connections exist between the mill race and the Linen Green culvert however these have not been proven. A sluice arrangement is present near the southern end of the mill race which also includes a spill weir which would regulate the level should flows be conveyed. Again, the sluice gate is closed and the small flow observed down the cascade is probably from seepage and leakage through the gate. A 900mm diameter precast concrete pipe exits a chamber at the bottom of the cascade through a vertical grille.

Picture 3.5 Outlet Sluice, Overflow and Cascade at Linen Green

4. Consultations

AECOM consulted with a number of parties in relation to the flood risk investigation for the Linen Green and the surrounding area.

4.1 DfI Rivers

AECOM consulted with DfI Rivers Area Staff regarding the history of flooding in the Linen Green area. DfI Rivers Area Staff were able to provide details of the extent of the flooding on the 6th December 2015 in the flood report included within the DfI Rivers Prefeasibility Report dated January 2016.

4.2 DfI Transport NI

AECOM contacted DfI Transport NI personnel based at the Dungannon Section Office (Mid-Ulster South) which was directly affected by the flooding incident which occurred on 6th December 2016. While no formal records of flooding at the depot are readily available, Transport NI personnel who have been based at the depot in excess of 25 years have not witnessed or experienced flooding during this period.

They also reported that remedial works to manhole U4304/08A have been undertaken in an attempt to provide a re-entry point for flows should overtopping of the inlet grille occur again. A section of the manhole chamber cover slab has been removed and a grille constructed over the opening.

4.3 Ecology and Amenity

AECOM consulted with DfI Rivers Environment Section in order to identify any ecological issues which may have to be considered during the flood risk investigation in line with the Water Framework Directive (WFD) and Floods Directive. These are summarised in Table 4.1 below.

Table 4.1 Ecological Issues Summary

Environmental Impact	Characteristics of Impact	Mitigation Measures
Human Beings	Accessibility requirement for houses and commercial buildings during proposed works.	Traffic Control Measures required.
Flora	Loss of mature tree and shrub cover.	Significant tree removal should be minimised where possible. Shrub removal may be required. Removal should be undertaken outside nesting season (1st March to 31st August). Care should be taken to minimise root disturbance to adjacent trees during removal.
Fauna	Potential impact on nesting birds and fisheries.	Timing of works as above to ensure no disturbance of nesting birds. Channel works should aim to maximise the potential for local and migratory fish.
Water	Potential Water Quality Issue	Sediment trapping mechanisms should be considered if any work is carried out.

4.4 Local Residents and Businesses

AECOM sent out letters to current occupiers/landowners of properties within the Linen Green area requesting any anecdotal information on previous flood events. To date a response has been received from one proprietor (Janet McCleary, Optician) who included photos of the flooding. A selection of these pictures are included below.





4.5 Existing Services Infrastructure

AECOM undertook a service investigation for the site using service information received from statutory authorities including Northern Ireland Electricity (NIE), Northern Ireland Water (NIW) and British Telecom (BT). These are illustrated on drawings LGMS-ACM-XX-XX-DR-CE-01005, LGMS-ACM-XX-XX-DR-CE-01006 and LGMS-ACM-XX-XX-DR-CE-01007 respectively.

NI Water apparatus consists of an extensive network of trunk and distribution water mains and combined, foul and surface water sewers. These include foul water pumping stations located at Ballynorthland Park and Linen Court and a major 900mm diameter trunk combined sewer along A29 Moy Road and Main Road which conveys flows from Dungannon town to the nearby Dungannon Wastewater Treatment Works. No information is available on the foul and storm drainage networks within the Linen Green complex as this is in private ownership.

NIE infrastructure includes a network of 11kV, mV and private connection cables both above and below ground. Associated with this are a number of ground level substations, some of which may be at risk during a flood event. BT infrastructure also includes above and below ground services and poles along with cabinets which would also be at risk during flooding.

5. Site Survey

5.1 Walkover Survey

DfI Rivers and AECOM undertook a joint site visit on 1st June 2016 with the following observations made.

Open watercourse upstream of culvert inlet

- Silt and fine gravel bed with minimal rocks/boulders
- Channel well defined with reasonable strong base flow
- Surrounding land heavily vegetated with grass, trees and small plants

Inlet Structure

- 3 pipes sized 750mm, 900mm, 1050mm with all taking flow and running clear at time of visit
- Grille; angle approximately 45 degrees, bar spacing 100mm, clear at time of visit

Temporary Measures Implemented

- Horizontal grille introduced at first manhole on culvert system
- Maintenance regime upgraded

Other Notes

- There is no gauging on the watercourse

5.2 Local Hydraulic Features

The study reach is made up of a section of the Park Lake Stream between Dungannon Park Lake and M1 Motorway. This is comprised of 510m of open watercourse followed by 420m of culverted watercourse, through the Transport NI depot and Linen Green shopping complex, and a remaining length of 780m of open watercourse.

Along this length there are five hydraulic structures excluding the culverted section which is covered in more detail below. The hydraulic structures are as detailed in Table 5.1 below and a location plan can be found on drawing LGMS-ACM-XX-XX-DR-CE-01010 in Appendix A.

Table 5.1 Hydraulic Structures Details

Structure Name	Information	Image
Footbridge (Modelled as DAMD01.0005)	Wooden footbridge over watercourse located downstream of the reservoir dam. Dimensions : Sprung Arch 3.14m Wide x 1.28m High Spring Height 1.06m U/S Invert Level : 51.46m D/S Invert Level : 51.46m Soffit Level : 52.74m Deck Level : 53.07m	
Abandoned Bridge (Modelled as DAMD01.0004)	Abandoned stone arched bridge over watercourse. Dimensions : Sprung Arch 3.07m W x 1.99m H Spring Height 1.34m U/S Invert Level : 49.88m D/S Invert Level : 49.88m Soffit Level : 51.87m Deck Level : 52.58m	
Concrete Inlet Structure (Modelled as DAMD01.0000)	Inlet structure with grille for 3x culverts of varying sizes. Structure Dimensions: 3.34m W x 2.27m H Culvert Dimensions : 1050mm Dia. Conc. Culvert 900mm Dia. Conc. Culvert 750mm Dia. Conc. Culvert Invert Levels : 47.136m AOD 47.23m AOD 47.24m AOD Respectively	

Open Manhole (Modelled as U4304/08A)	A section of the manhole chamber roof has been removed and a grille constructed over the open area allowing overland flow to enter the culvert. Dimensions: Orifice size 2m W x 0.5m L Ground Level : 48.676m Invert Level : 46.400m *Note : this grille was added after the event in December 2015*	
Outlet (Modelled as SH81600403)	Concrete headwall for circular concrete culvert. Structure Dimensions: 5.10m W x 3.06m H Culvert Dimension : 2100mm Dia. Conc. Culvert Invert Level : 45.350 AOD	

5.3 Condition Survey

A defect analysis of the culverted section of the Park Lake Stream was conducted by DfI Rivers on the 3rd January 2016 which included man entry/walk through and CCTV surveys. The purpose of this survey was to assess the current condition of the culvert and assess levels and dimensions of all key features including inlet and outlet structures and manholes that may contribute to the flood risk assessment.

During this survey 14 manholes on the culverted section between inlet U4304/INL and outlet SH81600403 were identified. Data on these has been provided in Table 5.2 below and is illustrated on drawing LGMS-ACM-XX-XX-DR-CE-01011 in Appendix A.

Table 5.2 CCTV Culvert Records

Manhole No.	Culvert Information	Description
U4304/INL	Invert 47.14m AOD 1050mm Dia. Conc. Culvert 97.6m in length	Piped Culvert to Manhole U4304/08A
	Invert 47.23m AOD 900mm Dia. Conc. Culvert 97.6m in length	Piped Culvert to Manhole U4304/08A
	Invert 47.24m AOD 750mm Dia. Conc. Culvert 97.6m in length	Piped Culvert to Manhole U4304/08A
U4304/08A	Invert 46.40m AOD 1050mm Dia. Conc. Culvert 54.8m in length	Piped Culvert to Manhole U4304/08
	Invert 46.40m AOD 900mm Dia. Conc. Culvert 86.3m in length	Piped Culvert to Manhole U4304/07
	Invert 46.40m AOD 1050mm Dia. Conc. Culvert 86.3m in length	Piped Culvert to Manhole U4304/07
U4304/08	Invert 46.21m AOD 1050mm Dia. Conc. Culvert 31.5m in length	Piped Culvert to Manhole U4304/07
U4304/07	Invert 46.15m AOD 1200x3300mm Brick Arch 41.0m in length	Arched culvert to Manhole U4304/06
U4304/06	Invert 46.12m AOD 1380x1850mm Brick Arch 24.7m in length	Arch culvert to Manhole U4304/05
U4304/05	Invert 46.10m AOD 1380x1850mm Brick Arch 22.8m in length	Arch culvert to Manhole U4304/04
U4304/04	Invert 46.08m AOD 1400x1850mm Brick Arch 22.0m in length	Arch culvert to Manhole U4304/03
U4304/03	Invert 46.05m AOD 1330x1900mm Brick Arch 72.6m in length	Arch culvert to Manhole U4304/02
U4304/02	Invert 45.80m AOD 1170x2250mm Brick Arch 17.5m in length	Arch culvert to Manhole U4304/01
U4304/01	Invert 45.30m AOD 1000x1200mm Brick Arch 1600x2600mm Box Culvert 14.5m & 10.7m in length	Arch culvert & Box culvert to Manhole U4304/OUT
U4304/OUT	Invert 45.31m AOD 2100mm Dia. Conc. Culvert 15.4m in length	Piped Culvert to Manhole SH81600401

Manhole No.	Culvert Information	Description
SH81600401	Invert 45.32m AOD 2100mm Dia. Conc. Culvert 12.5m in length	Piped Culvert to Manhole SH81600402
SH81600402	Invert 45.33m AOD 2100mm Dia. Conc. Culvert 18.2m in length	Piped Culvert to Outlet SH81600403
SH81600403	Invert 45.34m AOD	Outlet

The survey found multiple defects along the entire culvert and in particular several sections of the masonry arch culverts in a state of serious disrepair. DfI Rivers engineers recorded other issues with the culvert in addition to concrete spalling and missing masonry. Many of the culverts contained ducts, ground beams and slabs, redundant water mains, some debris and silting. Drawing LGMS-ACM-XX-XX-DR-CE-01012 in Appendix A illustrates the structural and serviceability grades of the culvert network.

The survey also identified a large number of connections to the culvert; the majority of these are likely to be storm drainage connections from the surrounding development however two major additional connections have been identified. A twin 900mm dia. pipe arrangement joins the culvert approximately 22m downstream of manhole U4304/03 with a brick arch connecting to manhole U4304/02 from the north west. The size of this arch is unknown along with its condition. It is believed that these culverts may connect to the abandoned mill race to the west of the site and while this is no longer functional as a mill race it still acts as a land drainage feature and also receives storm water from the surrounding area.

5.4 Topographical Survey

AECOM was provided with a hydraulic model that required updating to make it representative of the current conditions. A topographical survey was commissioned and undertaken and included sections along the Park Lake Stream and finished floor levels for commercial properties in The Linen Green, Transport NI depot and residential properties in Linen Court. The survey data received including the channel cross sections are shown on drawings LGMS-ACM-XX-XX-DR-CE-01015 to LGMS-ACM-XX-XX-DR-CE-01018 in Appendix A.

6. Desk Study Investigation

6.1 Planning Issues

The District development proposals for Dungannon form part of the Dungannon Area Plan 2010. Dungannon is the principal administrative and commercial centre for the Borough, providing a wide range of services for its population in terms of public administration, professional and commercial offices, education services and community and leisure facilities.

The Regional Development Strategy (RDS) identifies the town as a main hub that will continue to provide a range of industrial, commercial, education and community services. The town will also continue to provide significant opportunities for residential growth with approximately 250ha of land zoned for residential development within this plan. Of this 250ha, approximately 115ha of this is located within the catchment area for the Park Lake Stream. An additional 7.5ha of land for industrial development is also sited within the catchment boundary.

Any new development should not increase flood risk elsewhere in line with Planning Policy Statement 15 – Planning and Flood Risk. In principle this means the storm water runoff rates and volumes of storm water discharged from urban developments should be approximate to the existing greenfield run off over a range of storm events. Therefore any future industrial and residential development within the study area should not have any adverse effects on the predicted flooding events.

6.2 History of Flooding

The site of the Linen Green complex was previously a mill which utilised a mill race and the power of water to drive equipment. Extensive flooding occurred to a Transport NI depot and commercial properties on 6th December 2015 however there are limited past recorded instances of flooding at the site.

During a site visit on 15th November 2016, contact was made with employees who work in the Print Press who said that the building (which is located on the line of the culvert) has flooded numerous times in the past 25 years with flooding having occurred more than once annually. It is understood that the flooding is a result of surcharge of the system, including poorly sealed redundant floor gullies inside the building, with employees reporting that “water bubbles up through the floor”.

Picture 6.1 Redundant sealed floor gully inside Print Press building

6.2.1 Flood Event on 6th December 2015

Information provided by DfI Rivers gives a good description of the flooding which occurred on the above date. This flood event was also covered extensively by regional and local press which also provided useful information to input into the study. Some local residents reported flood depths of two feet.

A primary cause of the flooding is believed to have been the blockage of the grille on the culvert inlet structure to the north of the Transport NI depot. This grille is reported to have been inspected on 30th November as part of DfI Rivers maintenance process with the removal of debris occurring. It was further inspected on 5th December following the issue of a yellow weather warning in anticipation of Storm Desmond and was reported as being in a satisfactory condition.

The local DfI Rivers Area Engineer was notified by a Transport NI Engineer at 3.00am on 6th December that their depot at Moygashel was flooded. A DfI Rivers Engineer visited the site at around 3.30am but was unable to gain access to the culvert inlet due to flood water. The Linen Green site was also flooded at this stage. After several attempts to gain access a Transport NI excavator was used to remove part of the grille structure at approximately 6.00am, which allowed water to enter the culvert. The flood subsided on both sites within approximately 30 minutes of the grille being cleared.

Section 9, Summary of Causes of Flooding, outlines in detail the various factors associated with the flood event of December 2015.

Picture 6.2 Inlet to culvert showing platform removed (DfI Rivers Flooding Incident Report)

Flood waters at the Transport NI depot were reported to be of depth approximately equal to the height of the window sill along the eastern side of the garage. Site measurements were taken during a walkover survey which show that this was a depth in the order of 1.1m; see Picture 6.3 below.

Picture 6.3 Windows along eastern side of Transport NI Garage

Picture 6.4 and Picture 6.5 below, taken from regional media coverage, illustrate that the flood waters reached depths in the region of 500-600mm within the Linen Green complex. It should be noted that these levels are only an indication of the depth of flood waters. Flow levels may be exaggerated via the wake of vehicles passing through the flows, although the depth of flow would suggest that vehicles would have been unable to pass. It is more likely that levels would be exaggerated through soaking of the wall i.e. the capillary action of the materials involved would draw water into drier areas.

Picture 6.4 Screengrab from BBC News footage showing depth of flooding at east end of "The Weaving Sheds" building (BBC)

Picture 6.5 Screengrab from Belfast Telegraph footage showing depth of flooding at northern end of "The Warehouse" building (Belfast Telegraph)

7. River Flow Assessment

AECOM was provided with an existing hydraulic model, which included the inflow data and boundary conditions, and accompanying hydrology report detailing how the hydrology was calculated.

7.1 Linen Green Inflows

The model provided was run for all the current scenarios ranging from 50% to 0.1% Annual Exceedance Probabilities (AEPs). These were reviewed prior to undertaking modelling and compared with flows calculated by AECOM. The flow and duration used were found to be accurate and therefore have been used during the modelling process. A detailed assessment of the hydrology can be found in the modelling report with a summary of the inflows used provided in Table 7.1 below:

Table 7.1 Peak Flows for Upstream Inflow Point

AEP	Peak Flow (m^3/s)
50%	2.941
20%	3.599
10%	4.029
4%	4.493
2%	4.876
1.33%	5.048
1%	5.214
1% + Climate Change	5.414
0.5%	6.144
0.1%	8.203

7.2 Reservoir Routing

Following initial runs of the updated hydraulic model, extensive flooding was evident, even at low return periods, which does not reflect the history of flooding at this location. This was attributed to the utilised hydrology not taking account of the attenuation provided by the Park Lake dam. Following discussion with DfI Rivers it was agreed that AECOM should undertake routing calculations for the reservoir and re-run the model with revised flows.

The routing calculations provided a reduced peak flow and a delayed time to peak but the effect on flows was minimal compared to those envisaged. A detailed report on the calculation and findings of the routing exercise has been included in the modelling report.

7.3 Future Development

The current Dungannon Area Plan 2010 shows there are significant areas of land zoned for development within the upstream catchment of the watercourse. Any new development should not increase flood risk elsewhere in line with Planning Policy Statement 15 – Planning and Flood Risk. In principle this means the storm water runoff rates and volumes of storm water discharged from urban developments should be approximate to the existing greenfield run off over a range of storm events. Therefore any future industrial and residential development within the study area should not have any adverse effects on the predicted flooding events.

8. Hydraulic Modelling of the Existing System

The Blackwater catchment model was provided to AECOM by DfI Rivers in InfoWorks ICM (version 6.0) format for use in this study. This model provided flood extents for varying Annual Exceedance Probabilities (AEPs), ranging from 50% AEP to 0.1% AEP inclusive, for the whole Blackwater catchment.

8.1 InfoWorks ICM Modelling

The hydraulic model is a hydrodynamic one-dimensional hydraulic model of the watercourse integrated with a two-dimensional model of the surrounding terrain.

The primary objectives of the hydraulic modelling were to:

- Assess the hydraulic capabilities of the existing culverted watercourse
- Use the hydraulic model to generate water and surcharge levels, over land flows and flood outlines for a range of AEPs
- Assess the impact of a blockage at inlet DAMD01.0000 located in the Transport NI depot
- Assess the application and impact of proposed flood alleviation options on the system

The Blackwater catchment model provided was truncated to the study area. A stretch of watercourse upstream and downstream of the area was also included to allow lead in and outflow stability to best replicate existing conditions. The truncated model was updated using the most up to date information available, detailed in Section 4.

When the initial build is complete the model is run with the flows generated through the hydrological assessment described previously. The results are checked and the model is calibrated and verified to ensure the results replicate existing conditions and flooding history. Once this process is complete the model can be modified to assess options to alleviate flooding and flood risk.

8.2 Model Calibration and Verification

The availability of hydrometric data determines the modelling approach in terms of detailed calibration and validation. Gauged information was not available for this area; therefore the model was calibrated using best estimates of values for hydraulic variables using best practice and experience. Model results were examined and a “reality check” was made to determine if the results were realistic. This involved carrying out a site visit to determine the correct levels and comparing these with anecdotal evidence collected from the 6th December 2015 flood event.

For detail on the calibration and verification process please see the modelling report.

8.3 Modelling Results

On completion of the calibration and verification on the existing system the model is run for all of the AEP events and flood extents produced, see Appendix A.

The model was then subject to sensitivity analysis to see how changes to variables within the model affect the modelling outputs. It was during this analysis that the blockage at the grille was investigated. Other variables edited for comparison included roughness and flows. For detail on the sensitivity analysis and its results please see the modelling report.

The flood event experienced on the 6th December 2015 was in the magnitude of a 2% AEP. This was combined with a 100% blockage which escalated the flooding experienced.

The results indicate that at the time of the event the system became surcharged allowing flows to escape through the existing drainage system. While the system was surcharged, and flow was escaping, a blockage formed at the inlet which increased to a 100% blockage allowing no flow to enter the culverted system. All flows in channel became overland flood flows and supplemented the existing flood levels being experienced already in the complex.

The blockage of the inlet allowed the surcharged system to empty but the overland flows that The Linen Green complex was then experiencing were larger than the drainage system was able to cope with therefore flood levels were maintained. Once the blockage at the grille was cleared the overland flows were stopped and the drainage network was able to reduce the level of flooding in the complex.

This hypothesis is supported by information provided by DfI Rivers staff who stated the flood event subsided quickly after the blockage was cleared at the inlet grille.

8.4 Options

On completion of the stages noted above the model was tasked with assessing proposed options. The model was modified to reflect each of the model options that required assessment. Each of these models was run with the 1% AEP and 1% climate change AEP flows. In all instances the proposed options alleviated flooding for both flows. For details on each of the proposed options refer to Section 11. For more detail on the models produced see the modelling report.

9. Summary of Causes of Flooding

The flooding of the Linen Green Complex can be attributed to a combination of factors including:

1. Extreme Flows
2. Blockage of culvert inlet grille;
3. Condition of culvert and hydraulic inefficiencies;
4. Topography of site;

These factors have been expanded on below.

9.1 Extreme Flows

Storm Desmond made landfall on 4th December 2015 which brought a period of extreme rainfall accompanied by widespread gale-force winds over a two day period. Wind gusts reaching 68mph and 77mph on 4th & 5th December respectively were recorded at Killowen, Co. Down with 71.4mm and 64.8mm recorded at Derrylin, Co. Fermanagh in the same period. Yellow weather warnings for both wind and rainfall were also issued by the Met Office prior to this event. This storm event generated a flow of greater magnitude than previously recorded or observed.

9.2 Blockage of Culvert Inlet Grille

The model demonstrated that the culvert system has sufficient capacity to vent flows up to a 50% AEP with minor flooding occurring from a 20% AEP event however this does not impact on property. Flooding to property is experienced from a 10% AEP event and this is supported by historical accounts of flooding at the Print Press as documented in Section 6.2. The blockage of the culvert inlet grille has been well documented as causing a key role in the flooding which occurred on 6th December even though the structure was inspected and found to be in a satisfactory condition on 5th December.

The extreme rainfall and high winds which formed part of “Storm Desmond” led to extreme flows being generated in the watercourse and it is likely that these were unable to be contained within the channel upstream of the culvert inlet. The area through which the watercourse traverses between the dam wall and the Transport NI depot is heavily wooded with deciduous trees and given the time of year and the high winds it is probable that out of bank flows in this reach would have accumulated large quantities of debris including branches and leaves.

The report of the incident provided to AECOM by DfI Rivers highlights that flooding was occurring at the Transport NI prior to 3am which was confirmed when a DfI Rivers Engineer visited the site at approximately 3:30am. Several attempts were made to access and clear the grille however these were unsuccessful due to the resulting flooding. Access to the grille was normally gained by going around the Transport NI buildings (see Figure 9.1) however given the topography, flood waters had effectively cut off this route.

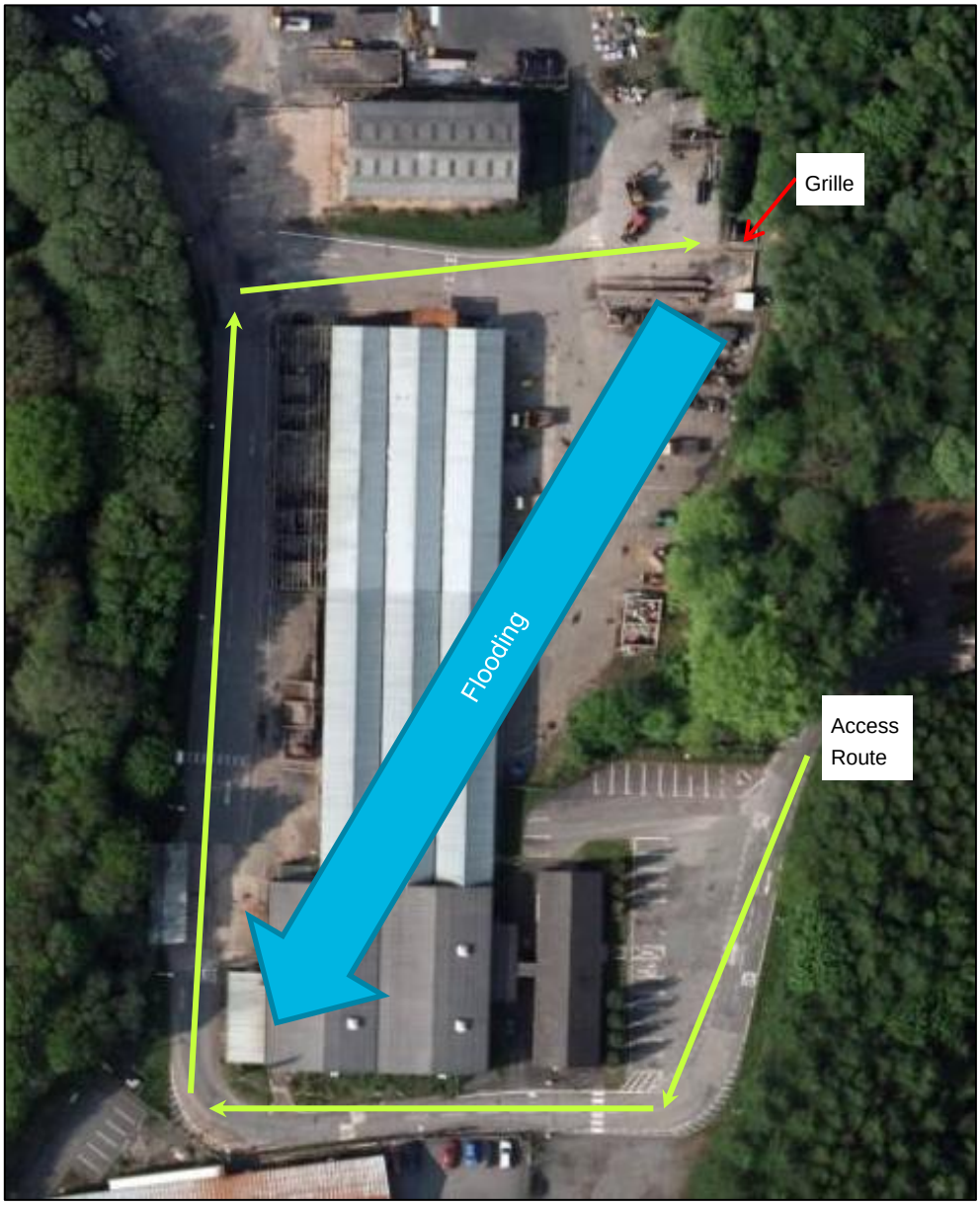


Figure 9.1 Grille Access

On removal of part of the grille at approximately 6am the flooding was observed to subside in approximately 30mins suggesting that there were no apparent obstructions in the culvert network downstream of the inlet. The extent of the flooding can partly be attributed to the duration over which the flows were unable to enter the culvert with reports suggesting overland flows had been occurring for at least 3 hours and probably longer.

The grille structure on the Park Lake Stream appears to be in reasonable condition with a formal headwall structure and working platform to allow access for cleaning and maintenance. This grille would have been to standard when it was installed and has not been reported to be problematic in the past.

9.3 Culvert Condition and Hydraulic Inefficiencies

While the blockage of the inlet grille has been shown to be a primary cause of flooding, investigations of the culvert following the event has highlighted that there are a significant number of issues with the current system.

A condition survey of the culvert network was undertaken as detailed in Section 5.3 and the results of this are presented on drawing LGMS-ACM-XX-XX-DR-CE-01012 along with a summary in Table 9.1 below.

Table 9.1 Summary of Structural and Serviceability Grades and Capacity

Upstream Structure	Downstream Structure	Culvert Size (mm)	Structural Grade	Serviceability Grade	Capacity[1] (m^3/s)
U4304/INL	U4304/08A	1050 dia. Pipe	4	4	3.145
		900 dia. Pipe	2	4	2.238
		750 dia. Pipe	1	2	1.398
		Triple Pipe Section; Combined Capacity			*6.781*
U4304/08A	U4304/07	900 dia. Pipe	1	4	1.276
		1050 dia. Pipe	2	4	1.912
U4304/08A	U4304/08	1050 dia. Pipe	1	4	2.100
		Triple Pipe Section; Combined Capacity			*5.288*
U4304/08	U4304/07	1050 dia. Pipe	1	1	1.534
		Triple Pipe Section; Combined Capacity			*4.722*
U4304/07	U4304/06	3300 x 1200 Box	4	5	6.790
U4304/06	U4304/05	1850 x 1380 Arch	4	5	2.940
U4304/05	U4304/04	1850 x 1380 Arch	5	5	3.067
U4304/04	U4304/03	1850 x 1400 Arch	4	5	3.938
U4304/03	U4304/02	1900 x 1330 Arch	5	5	6.191
U4304/02	U4304/01	2250 x 1170 Arch	1	5	19.357[2]
U4304/01	U4304/OUT	1000 x 1200 Arch 1600 x 2600 Box	1	5	1.218 8.532
U4304/OUT	SH81600401	2100 dia. Pipe	1	1	6.719
SH81600401	SH81600402	2100 dia. Pipe	3	1	6.719
SH81600402	SH81600403	2100 dia. Pipe	1	2	6.719

Notes to Table 9.1

[1] – The culvert capacity has been calculated using the Colebrooke White equation which assumes free flow through the pipe. The capacity stated in Table 9.1 above does not take account for debris or obstructions etc. which will reduce the capacity and in some cases this reduction may be significant.

[2] – This section of culvert has a much steeper gradient than the adjacent sections which causes a significant increase in capacity

The table above suggests that the primary restriction point on the culvert network is the section of 1000x1200 arch with a capacity of only 1.218m^3/s. The peak flow for a 50% AEP event is 2.941m^3/s which is significantly more however it could be expected that the flows are contained within the culvert due to capacity upstream of this constriction.

It has also been found that some of the other culverts in the system have limited capacities well below current design standards which is likely to have been another factor in the flooding. This would also have caused backing up of flows leading to overtopping of the inlet structure and surcharging of manholes and connected drainage infrastructure along the culvert such as gullies. The culverts also have a very shallow gradient which may also impact on their ability to adequately convey flows.

The culvert changes size and profile a number of times as it traverses the study area which causes the constriction of flows through reduction in velocities. This is of particular impact in the first section of the culvert which is formed from a triple pipe arrangement. The arrangement significantly increases the surface area of the culvert which in turn reduces the velocity of the water.

Defects encountered include debris, siltation, holes, poor connections, missing bricks, and a redundant water main in the base of the culvert from U3404/05 to U3404/01 which include valves and

thrust blocks. A sample set of screenshots has been obtained from the CCTV footage and is included below by means of illustration of the severity of the defects that are present. Some of the defects have been noted as causing significant reductions in capacity with up to a 50% loss given at multiple locations. The condition survey observations are presented on drawing LGMS-ACM-XX-XX-DR-CE-01012. The capacity restrictions introduced by these defects have not been considered in the capacity calculations presented in Table 9.1 above.

The investigations have revealed that parts of the culvert are in a very poor condition with major structural issues, some of which appear to have been recently caused during redevelopment works on the Linen Green site. Obstructions and debris lead to a reduction in the capacity of the culvert which is likely to have been a key factor in the flooding that occurred on 6th December 2015.

Picture 9.1 Obstruction across culvert upstream of manhole U4304/05

Picture 9.2 Missing bricks in roof of culvert near manhole U4304/06

Picture 9.3 Obstruction (water main) along culvert between manholes U4304/02 and U4304/03

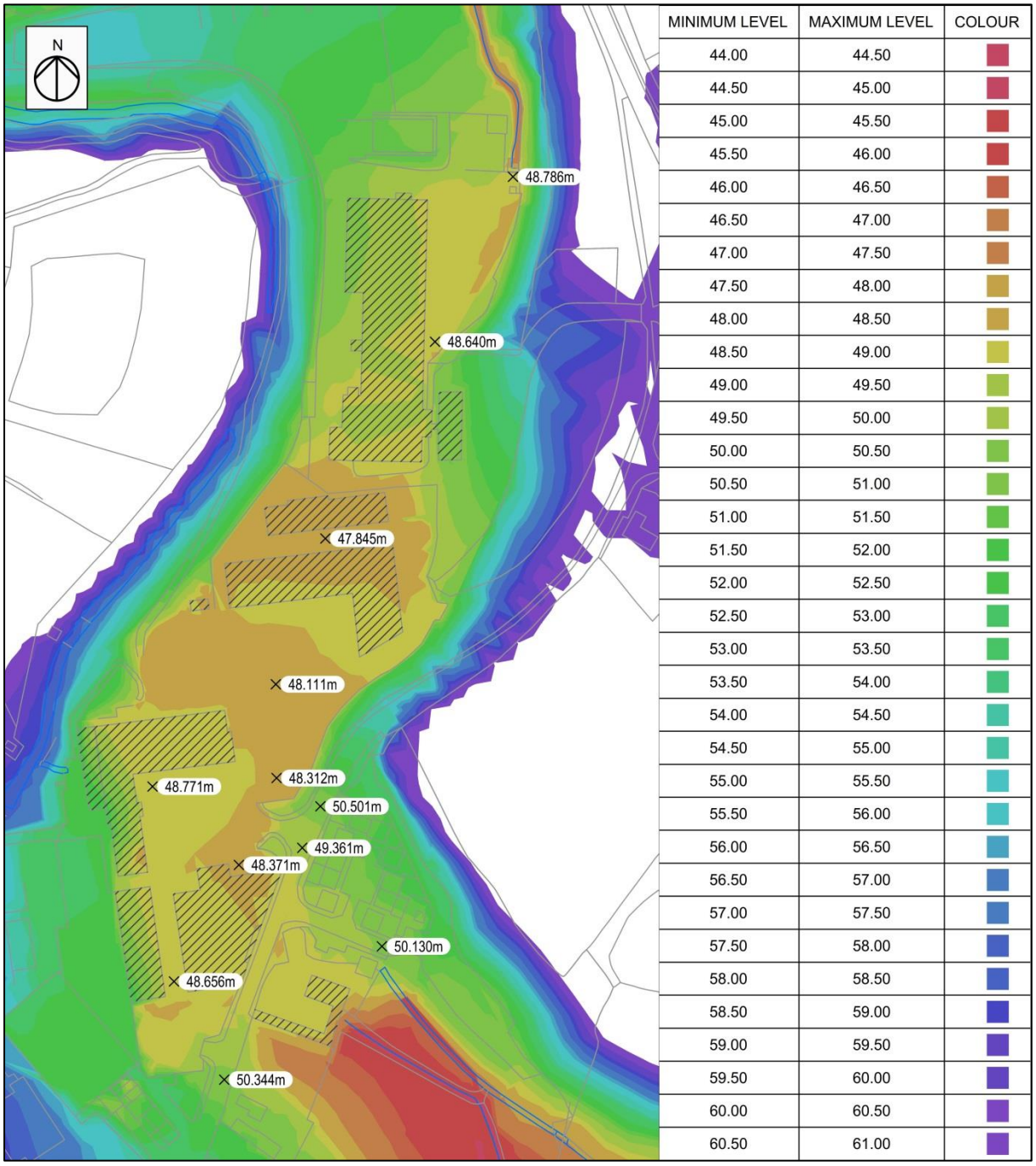
The structural grade of the culvert relates to the fabric of the asset and the severity of the structural defects that affect its integrity. Structural defects are addressed by repairing or replacing the asset. The serviceability grade relates to the performance of the asset and the severity of the defects that affect its serviceability, but is independent of the structural condition. Service defects are addressed by maintenance of the asset such as cleansing or vegetation clearance. Table 9.2 below summarises the structural and service grade definitions.

Table 9.2 Structural and Service Grade Definitions

Grade	Structural Condition	Service Condition
1	Acceptable condition	Clear, no loss of performance
2	Minimal collapse risk in short term but potential for further deterioration	Superficial deposits with no loss of performance
3	Collapse unlikely in near future but further deterioration likely	Deposits, performance slightly reduced
4	Collapse likely in foreseeable future	Large deposits, performance severely reduced
5	Collapsed or collapse imminent	Blocked or unsafe condition

9.4 Topography of Site

The topography of the area is such that when flow overtops the inlet structure or surcharges from the culvert it follows the approximate line of the culvert travelling around buildings firstly within the Transport NI depot before progressing into the Linen Green Shopping Complex. As flows proceed overland, flood water becomes trapped in the lower section of the Linen Green development which is approximately 1m below the adjacent Main Road leading to flood depths in excess of 0.5m. This is illustrated in Figure 9.2 below.



MINIMUM LEVEL	MAXIMUM LEVEL	COLOUR
44.00	44.50	
44.50	45.00	
45.00	45.50	
45.50	46.00	
46.00	46.50	
46.50	47.00	
47.00	47.50	
47.50	48.00	
48.00	48.50	
48.50	49.00	
49.00	49.50	
49.50	50.00	
50.00	50.50	
50.50	51.00	
51.00	51.50	
51.50	52.00	
52.00	52.50	
52.50	53.00	
53.00	53.50	
53.50	54.00	
54.00	54.50	
54.50	55.00	
55.00	55.50	
55.50	56.00	
56.00	56.50	
56.50	57.00	
57.00	57.50	
57.50	58.00	
58.00	58.50	
58.50	59.00	
59.00	59.50	
59.50	60.00	
60.00	60.50	
60.50	61.00	

Figure 9.2 Site Ground Levels

The surface water drainage infrastructure in the Linen Green car park and around the Transport NI depots would not have been designed to cope with such flows and hence became overwhelmed and unable to dissipate the ensuing flood waters.

10. Assessment of Flood Risk

Modelling based on the assumptions outlined in the hydraulic assessment has shown that flooding occurs to the Transport NI depot and Linen Green shopping complex during a 10% AEP event and greater without any blockage of the culvert inlet grille. While flooding occurs at a 20% AEP event it does not have any impact on property. Model runs with varying blockage amounts of the culvert inlet grille were also completed in order to replicate the flood event that occurred on 6th December 2015.

The flood event experienced on the 6th December 2015 was in the magnitude of a 2% AEP. This was combined with a 100% blockage which escalated the flooding experienced as described in Section 8.3. The extents of the flooding in these areas for multiple exceedance probabilities including blockage are shown on drawings LGMS-ACM-XX-XX-DR-CE-01020 to LGMS-ACM-XX-XX-DR-CE-01029.

It should be noted that flooding is likely to have occurred on this occasion without any blockage of the culvert given the inability of the culvert network to vent the estimated flows.

10.1 Areas at Risk

Analysis of the model shows that the flood event that occurred on 6th December 2015 was a combination of factors including a blockage of the culvert inlet grille leading to overtopping of the structure and also a lack of capacity in the existing culvert network.

The topography of the area is such that when flow escapes from the system, either by overtopping at the inlet structure or from surcharge of manholes etc., it follows the approximate line of the culvert. Flows travel around buildings firstly within the Transport NI depot before progressing into the Linen Green Shopping Complex. As flows proceed overland, flood water becomes trapped in the lower section of the Linen Green described in Section 9.4.

Survey work following the event has revealed that the culvert network through the Linen Green complex is in a very poor condition with parts of it significantly under capacity and acting as control points. As detailed in Section 5.3, the presence of obstructions including building foundations, service ducts and water main crossings and siltation have had varying impacts with loss of local capacity in some sections as high as 50%. The poor structural and serviceability grades of the culvert are likely have restricted flows at high exceedance probabilities and are likely to have had a contribution to the flooding which occurred on 6th December.

10.2 Flood Risk Identification

The flood model was assessed to identify the consequences and risks of flooding on the following receptor groups.

10.2.1 Human Health

Consideration was given to any significant impact of flooding on human health including the risk of loss of life. This relates to the speed of flooding, the depth of flooding and local demographics. This is quantified within the Linen Green, Moygashel Economic Appraisal. It is also possible to assess the economic effects of loss of life, stress, etc, caused by flooding.

10.2.2 Environment

The environmental impacts of flooding include effects on the natural environment from floodwater intrusion and the impacts of associated pollution on important habitats and biodiversity. This includes any landscape, recreation or conservation areas within the Moygashel area.

10.2.3 Economy

Economic impacts comprise all impacts which have an economic element, including environmental impacts and indirect effects such as stress if the impacts can be quantified in financial terms.

10.2.4 Critical Infrastructure

The study identified any vulnerable buildings which may be at risk from flooding, e.g. Schools, Police stations, government offices, NI Water Pumping Stations, NIE Sub Stations, BT telephone exchanges, etc. Consideration was also given to the road and transport network in the area.

10.3 Risk to Receptor Groups

The impact upon the receptor groups was considered for the Park Lake Stream.

10.3.1 Human Health

There is a low risk to human life given the depth of water and the number of properties affected.

10.3.2 Environment

As detailed in Section 3 of this report the Park Lake Stream catchment area is an equal mix of rural and urban areas and hence during extreme flooding events the amount of pollutants (i.e. oils) entering the watercourse via increased run-off from hard standing areas could be significant.

In particular, the presence of a Transport NI depot, which includes vehicle refuelling areas and storage of construction materials such as bitumen and road salt, just upstream of the Linen Green shopping complex leads to a higher risk of a major pollution incident occurring in conjunction with flooding. Press coverage of the event stated that flood waters appeared to contain traces of fuel such as diesel.

10.3.3 Economy

Flooding would potentially lead to inundation of shops, restaurants and other businesses within the Linen Green shopping complex along with damage to a Transport NI depot. It should be noted that the business premises located within the Linen Green are viewed as “high end” boutique style shops are therefore their stock could be considered more valuable than a standard shopping centre.

10.3.4 Critical Infrastructure

The infrastructure affected by flooding would include several NIE ground level substations, BT telecoms infrastructure, potentially an NIW foul sewage pumping station and the local road network, in particular Main Road. Main Road is the primary means of access to Moygashel village and flooding of this road would lead to long diversions for residents for the duration of the event.

Disruption to the Transport NI depot could also have potential consequences by delaying emergency response work and deployment of resources to deal with any flooding.

11. Flood Protection Options

To determine suitable flood protection options the Linen Green complex and Transport NI depot was examined and possible options are presented below. Thirty eight commercial properties, one residential property, the local road network and other infrastructure are affected during a 1% AEP event as a result of the factors outlined previously in this report.

The factors influencing the choice of options include:

- Ability to provide flood protection against a 1% AEP
- Impact on any proposed developments
- Remove risk of flooding
- Environmental Impact
- Ground Conditions
- Aesthetics
- Cost

The proposals and the viability of each option are considered in the following sections.

11.1 Consideration of Flood Alleviation Options

Each of the options considered suitable for the Linen Green complex and Transport NI depot was individually considered and assessed in relation to their impact upon the surrounding area.

11.1.1 Option 1 – Do Minimum

The “Do Minimum” scenario considers the continuation of the current maintenance regime of the watercourse given that it is currently designated. This would include routine annual maintenance of Park Lake Stream along with regular grille inspections and maintenance.

The threat of blockage of the grille remains, along with the issues of the culvert capacity and therefore flooding may occur again with damage costs being incurred. This option would not give adequate flood protection for a 1% AEP event however it will be used as a baseline scenario for this report to assess all other options. It also fails to address the structural and serviceability issues that have been uncovered during recent investigations.

11.1.2 Option 2 – Upgrade Culvert Inlet

Option 2 considers the upgrading of the current culvert inlet grille along with the provision of an alternative pedestrian access to the grille from the higher land to the eastern side.

The new grille should be designed to current best practice and standards, and include an overflow facility that would still allow flows to gain entry to the culvert should the main section of the grille become blocked. It should also include adequate provisions to allow maintenance personnel to remove gathered debris. Drawing LGMS-ACM-XX-XX-DR-CE-01035 illustrates the works required for Option 2.

The risk of flooding occurring as result of blocked openings is not eliminated but would be significantly reduced by providing a grille with an overtopping/bypass feature, however this would not address structural and serviceability issues with the culvert system that have been uncovered during recent investigations.

Provision of a pedestrian access route from the higher land to the east is proposed to allow access to the screen to be gained should flooding occur within the Transport NI depot. The current access route (as highlighted in Section 9.1) involves personnel going around the buildings and having to cross the culvert or path of the overland flows and potentially introduces the risk of the structure being cut-off as happened during the December 2016 event. It is noted that this area contains a wooded embankment so it may be necessary to include stepped access.

Annual maintenance will also be required as part of this option. The inlet grille will require inspections at intervals as determined by DfI Rivers guidelines to ensure that no build-up of debris is allowed to occur which could compromise the functionality of the structure.

11.1.3 Option 3 – Upgrade Culvert; Western Route

Option 3 considers the construction of new culvert to the northern and western side of the Transport NI depot and online replacement of the culvert through part of the Linen Green complex. It continues south and connects to the existing 2.1m dia. pipe on the south side of Main Road. Drawing LGMS-ACM-XX-XX-DR-CE-01036 illustrates the works required for Option 3.

Hydraulic calculations have shown that a 1.8m dia. pipe would be sufficient to convey the flows however initial investigations have raised issues over possible cover problems to the culvert so it is proposed to use a 1m deep by 2.5m wide box culvert as an alternative. In some areas it may also be necessary to construct a relieving slab above the culvert due to this lack of cover.

This route would require approximately 450m of culvert along with a minimum of 9 manholes along its length, works to existing manhole U4304/OUT and also the construction of a new inlet structure similar to that proposed in Option 2 above. The route also contains two sharp changes of direction at the proposed culvert inlet and the north-west corner of the Transport NI depot which are not ideal from a hydraulic perspective. However this could be examined in further detail at later design stages and the issue may be able to be reduced.

Using an alignment close to the existing culvert in the Linen Green Complex would mean that all connections could be picked up as required including the major unidentified connections, so preventing any loss of connectivity. No record information is available for the drainage networks within the Linen Green complex which is likely to be in private ownership so the impact on these is not known.

The culvert would, however, be in close proximity to a number of buildings and has the potential to cause major disruption during the construction phase to the day to day operation of the Linen Green and Transport NI depot. It is also noted that there is an NIE 11kV underground service running from Main Road in a northerly direction which crosses the existing culvert between manholes U4304/05 and U3404/04.

11.1.4 Option 4 – Upgrade Culvert; Central Route

Option 4 considers the construction of new culvert to the northern and western side of the Transport NI depot and then crossing to the north east of the Linen Green complex. It continues south along the eastern side of the building and turns to parallel the base of the embankment to Main Road before connecting to the existing 2.1m dia. pipe on the south side of Main Road. Drawing LGMS-ACM-XX-XX-DR-CE-01037 illustrates the works required for Option 4.

Hydraulic calculations have shown that a 1.8m dia. pipe would be sufficient to convey the flows however initial investigations have raised issues over possible cover problems to the culvert so it is proposed to use a 1m deep by 2.5m wide box culvert as an alternative. In some areas it may also be necessary to construct a relieving slab above the culvert due to this lack of cover.

This route would require approximately 485m of culvert along with a minimum of 9 manholes along its length, works to existing manhole U4304/OUT and also the construction of a new inlet structure similar to that proposed in Option 2 above. The route also contains four sharp changes of direction; at the proposed culvert inlet, the north-west and south-west corner of the Transport NI depot and the east side of the Linen Green which are not ideal from a hydraulic perspective. However this could be examined in further detail at later design stages and the issue may be able to be reduced.

A new drainage system may be required within the Linen Green complex downstream of the interception of the existing culvert to prevent any loss of connectivity however the existing culvert could still be utilised with remedial works to address the structural issues. The unidentified major connections would also need to be adequately diverted to the new culvert. Outline calculations suggest that a 450mm diameter pipe would be sufficient for surface water drainage purposes. No record information is available for the drainage networks within the Linen Green complex which is likely to be in private ownership so the impact on these is not known.

The culvert would be in close proximity to a number of buildings and has the potential to cause major disruption during the construction phase to the day to day operation of the Linen Green and Transport NI depot. It is also noted that there is an NIE 11kV underground service running from Main Road in a northerly direction which crosses the existing culvert between manholes U4304/05 and U3404/04.

11.1.5 Option 5 – Upgrade Culvert; Eastern Route

Option 5 considers the construction of new culvert on a direct southerly route to the eastern side of the Transport NI depot and Linen Green complex, crossing under Main Road and a high area of land before discharging to the open channel approximately 50m downstream of the existing outfall structure. Drawing LGMS-ACM-XX-XX-DR-CE-01038 illustrates the works required for Option 5.

Hydraulic calculations have shown that a 1.8m dia. pipe would be sufficient to convey the flows however initial investigations have raised issues over possible cover problems to the culvert in the upstream section so it is proposed to use a 1m deep by 2.5m wide box culvert, 165m long, as an alternative between the inlet structure and Main Road. In some areas it may also be necessary to regrade land or construct a relieving slab above the culvert to achieve a better depth of cover. It also includes for the construction of a new inlet structure similar to that proposed in Option 2 above.

The section beneath Main Road is proposed to be constructed using trenchless technologies due to the depth of the culvert. The ground rises steeply from the south-eastern end of the Transport NI depot and so the culvert is required to be constructed at depths of approximately 15m as it crosses beneath Main Road. Options such as micro-tunnelling and pipe jacking can utilise pipes up to 3m diameter and achieve drives of several hundred metres in a straight line or to a radius. This would require the construction of a temporary drive pit which could be located in the south eastern corner of the Transport NI depot. A total of 240m of 1.8m diameter pipe is proposed for this section of Option 5. Due to the depth of the pipe it is not proposed to provide any chambers along this part of the culvert. The culvert would pass beneath an NI Water 900mm diameter concrete trunk sewer twice along its route however there would be more than sufficient clearance due to the depth of construction.

A new drainage system may be required within the Linen Green complex to prevent any loss of drainage connectivity however the existing culvert could still be utilised with remedial works to address the structural issues. The unidentified major connections would also need to be adequately diverted however an assessment on the flow which they convey would be required to determine the required pipe size and the resulting route. Outline calculations suggest that a 600mm diameter pipe would be sufficient for surface water drainage purposes. No record information is available for the drainage networks within the Linen Green complex which is likely to be in private ownership so the impact on these is not known.

The construction of a new culvert offline would significantly reduce the impact on the Linen Green but would still have an impact on the operation of the Transport NI depot. Works to construct a residual drainage network or undertake remedial works on the existing culvert in the Linen Green complex would have an impact but this would be much reduced in comparison to the construction of a new culvert.

11.1.6 Option 6 – Upgrade Culvert; East Central Route

Option 6 considers the construction of a new culvert to the eastern side of the Transport NI depot and south-eastern side of the Linen Green. It would follow the proposed route of Option 5 to the south-east corner of the Transport NI depot and then connect across to the Option 4 route, paralleling the base of the embankment to Main Road before connecting to the existing 2.1m dia. pipe on the south side of Main Road. Drawing LGMS-ACM-XX-XX-DR-CE-01039 illustrates the works required for Option 6.

Hydraulic calculations have shown that a 1.8m dia. pipe would be sufficient to convey the flows however initial investigations have raised issues over possible cover problems to the culvert so it is proposed to use a 1m deep by 2.5m wide box culvert as an alternative. In some areas it may be necessary to regrade land or construct a relieving slab above the culvert to achieve a better depth of cover. This route would require approximately 385m of culvert along with a minimum of 7 manholes along its length, works to existing manhole U4304/OUT and also the construction of a new inlet structure similar to that proposed in Option 2 above.

A new drainage system may be required within the Linen Green complex to prevent any loss of drainage connectivity however the existing culvert could still be utilised with remedial works to address the structural issues. The unidentified major connections would also need to be adequately diverted however an assessment on the flow which they convey would be required to determine the required pipe size and the resulting route. Outline calculations suggest that a 600mm diameter pipe would be sufficient for surface water drainage purposes. No record information is available for the drainage networks within the Linen Green complex which is likely to be in private ownership so the impact on these is not known.

The culvert would be in close proximity to a number of buildings and has the potential to cause major disruption during the construction phase to the day to day operation of the Linen Green and Transport NI depot. It is also noted that there is an NIE 11kV underground service running from Main Road in a northerly direction which crosses the existing culvert between manholes U4304/05 and U3404/04.

11.1.7 Discounted Options

A number of other potential options were considered; these are as described below:

11.1.7.1 Use Reservoir for Storage

While there is a reservoir and dam within the upstream catchment area, routing calculations have shown that it offers minimal attenuation. More storage could be gained through drawing down the level of the reservoir prior to a storm event occurring, however this requires both human intervention to operate a scour valve and sufficient prior warning of the storm event to allow time for this to be undertaken. The current owner of the dam is Mid-Ulster District Council and so an agreement would have to be reached with DfI Rivers over its operation.

Draw-down of the reservoir would also impact on the amenity value of the lake which is currently stocked and used for fishing. It is understood that the dam contains two scour pipes each of 225mm diameter and therefore the reservoir would have to be drawn down a number of days in advance to gain sufficient storage. Given the nature of the catchment it is unlikely that sufficient warning would be received to allow time to achieve a degree of draw-down.

This proposal would also fail to reduce the likelihood of blockage of the inlet grille and would not address the issues raised surrounding the structural integrity of the culvert itself and has therefore been discounted from any further consideration.

11.1.7.2 Online Storage between Dam and Culvert Inlet

The topography of the land between the downstream face of the dam wall and the culvert inlet structure lends itself to use as online storage through the construction of a flow control structure in the channel and an associated embankment. It is important that flow control structures are accessible for maintenance and are protected from blockage and both of these would be hard to achieve in this area. No assessment has been undertaken of the storage volume that could be created however it is unlikely that this volume would be sufficient enough to provide adequate attenuation on the system.

The heavily wooded area significantly increases the amount of debris that would be present on the banks of the storage area which could easily be dislodged and cause blockage of the flow control device should it come into use. Again, this would also not address the issues raised surrounding the structural integrity of the culvert itself and has therefore been discounted from any further consideration.

11.1.7.3 Flood Wall downstream of Transport NI Depot

At the suggestion of others, consideration was given to providing a wall to cut off the flow path between the culvert inlet grille and the Linen Green complex. Such a structure, whilst not providing the required level of protection for a proposed flood alleviation scheme, could potentially increase the level of protection to the Linen Green complex should the culvert inlet grille block or the culvert network become surcharged.

An initial assessment indicated that the construction of a 3m high wall along the downstream boundary of the Transport NI Depot would not provide sufficient storage volume to contain the

escaping volume of flood water during a 1% AEP event when the culvert enters a state of surcharge. Also, the lowest residential property in Ballynorthland Park upstream of the Transport NI Depot has a floor level of 50.09m OD and would therefore be impacted by the flooded area created by such a proposal.

Other significant factors such as flood warning notice, evacuation and safety of TNI personnel and increased flood risk and damage to other properties are presented by this option and it has therefore been discounted from any further consideration.

11.2 Option Assessment

The options outlined above include both short term and long term options to address the flooding problems experienced at the Transport NI depot and Linen Green complex. Option 1 (Do Minimum) is not seen as a sufficient response to the problem as it will not provide any alleviation of the flooding. It also fails to address the issues surrounding the structural condition of the existing culvert.

Option 2, Upgrade Culvert Inlet, is seen as an essential part of any works to be undertaken. The current inlet structure and grille does not have the ability to provide a bypass should the grille become blinded by debris and so an upgrade is proposed to allow flows to enter the culvert should the grille become blocked. These works are seen as a short term measure to help reduce the likelihood of blockage but do not address issues surrounding the structural condition of the existing culvert. However such works could be incorporated into a more extensive scheme to replace and upgrade the culvert at a later stage.

Options 3, 4, 5 and 6 all consider the replacement of the culvert through various means with diversions around buildings as required. This would allow the structural and capacity issues with the existing culvert to be addressed. Options 3 and 4 both contain multiple sharp changes in direction which will introduce hydraulic inefficiencies into the culvert system. There are also potential issues with achieving a sufficient level of cover to the proposed culvert in the vicinity of the Print Press and Dye House buildings due to the topography of the site. An 11kV electrical substation is located at the north west corner of the Print Press building which would also be impacted by Options 3 and 4.

Option 5, while reducing the disruption caused during construction to a minimum, is the most expensive solution and most technically challenging given the trenchless technologies to be employed and the depth of the proposed culvert. Significant works would also be required to connect all residual drainage from the Linen Green complex and Transport NI depot however it may be possible to utilise the existing culvert by undertaking remedial works to address the structural issues.

Option 6 is seen as a compromise route which avoids the sharp bends and cover issues associated with Options 3 & 4 but avoids the cost associated with the trenchless techniques required for Option 5. As it crosses through part of the Linen Green car park it also provides the opportunity for connection of residual drainage. Option 6 is therefore deemed to be the preferred long term solution for addressing the identified structural and capacity issues.

12. Cost Estimation

12.1 Flood Alleviation Options and Cost Estimates

The flood risk assessment identified that there is the potential for flooding to the Transport NI depot and Linen Green shopping complex with approximately 38 commercial/business properties at risk during a 1% AEP event. Only one residential property is at risk of flooding within the study area. Flooding may also impact several NIE ground level substations, BT telecoms infrastructure, potentially an NIW foul sewage pumping station and the local road network, in particular Main Road. Disruption to the Transport NI depot could also have potential consequences by delaying emergency response work and deployment of resources to deal with any flooding.

Table 12.1 shows a summary of the costs for the options considered for the Linen Green study area. Option 1 was included in this assessment for the benefit of comparison. The costs have been estimated using tendered rates for similar schemes within Northern Ireland (costs in brackets include for optimism bias @ 37.8% – refer to Economic Appraisal). For a detailed breakdown of the costs for each option refer to Appendix B

Table 12.1 Option Cost Summary

Scheme Option	Capital Cost (£)	Annual Maintenance Cost (£)
Option 1 – Do Minimum	0.00 (0.00)	3,640.00
Option 2 – Upgrade Culvert Inlet	21,165.00 (29,165.37)	3,640.00
Option 3 – Upgrade Culvert; Western Route	722,895.00 (996,149.31)	3,640.00
Option 4 – Upgrade Culvert; Central Route	819,905,00 (1,129,829.09)	3,640.00
Option 5 – Upgrade Culvert; Eastern Route	1,263,090.00 (1,740,538.02)	3,640.00
Option 6 – Upgrade Culvert; East Central Route	714,420.00 (984,470.76)	3,640.00

12.2 Benefit Analysis

The benefits were calculated in accordance with the method described in Flood and Coastal Erosion Risk Management – Appraisal Guidance (FCERM-AG). The 2011 revision of 'The Green Book – Appraisal and Evaluation in Central Government' recommends the discount rate of 3.5% for years 0 – 30, 3% for years 31 – 75, and 2.5% for years 76 – 100.

The assessment indicates that the annual benefit for providing flood protection against a 1% AEP event amounts to:

Total Annual Benefit = £146,755.83

The net present value of annual benefits has been calculated using test discount rates and amounts to:

Present Value of Annual Benefits = £4,382,622.66

These figures indicate that discounted flood damage avoidance is £4,382,622.66.

12.2.1 Benefit Cost Comparison

The Net Present Value (NPV) has been derived and discounted to the same base date, using guidance from FCERM-AG. NPVs and benefit/cost ratios for the different options are shown on the Project Summary Sheet spreadsheet in Appendix D of the Linen Green, Moygashel Economic Appraisal and in Table 12.2.

Table 12.2 Summary of Benefits and Costs

Scheme Option	Total Discounted Cost (£) (inc. Optimism Bias)	Discounted Flood Damage Avoidance Benefit (£) (Inc. intangibles)	Net Present Value (NPV) (£)	Benefit / Cost Ratio
Option 1 – Do Minimum	89,162.91	-	-89,162.91	0.00
Option 2 – Upgrade Culvert Inlet	137,868.01	-	-137,868.01	0.00
Option 3 – Upgrade Culvert; Western Route	1,104,851,95	4,382,622.66	3,277,770,71	3.97
Option 4 – Upgrade Culvert; Central Route	1,238,531.73	4,382,622.66	3,144,090.93	3.54
Option 5 – Upgrade Culvert; Eastern Route	1,849,240.66	4,382,622.66	2,533,382.00	2.37
Option 6 – Upgrade Culvert; East Central Route	1,093,173.40	4,382,622.66	3,289,449.26	4.01

12.3 Summary

The benefit cost analysis shows that Options 3, 4, 5 and 6 are all economically viable as they have a benefit/cost ratio greater than 1. Options 1 and 2 do not provide any economic benefit. The preferred solution, however, is Option 6 which has a benefit cost ratio of approximately 4.0.

13. Conclusion

AECOM was commissioned by the Department for Infrastructure (DfI) Rivers to appraise flood risk to properties in the Linen Green area, Moygashel from the Park Lake Stream and other contributing sources, and to investigate options (including economic viability) to alleviate any potential flooding from a 1% AEP event. In addition, the causes and mechanisms of the flood event at the Linen Green shopping complex and Transport NI (TNI) depot on the 6th December 2015 were investigated.

A base hydraulic model was provided to AECOM by DfI Rivers which was subsequently updated using topographic survey and culvert condition information. Hydraulic analysis was carried out using this updated model which identified that the culvert system had significant capacity issues with damages realised for events greater than 4% AEP. For a 1% AEP event, damages are realised at 22 commercial units and 1 residential property.

It was known that blockage of the grille also played a significant role in the flood event of 6th December 2015. Model runs with a varying percentage of blockage using multiple AEPs indicated that a 2% AEP coupled with a 100% blockage replicated the flooding experienced.

Short term and long term options have been examined to address the issues with the inlet grille, culvert capacity, structural condition and serviceability. In the interim period, prior to undertaking works, DfI Rivers should continue with the current maintenance regime for the inlet grille. If not already implemented, consideration should be given to providing an enhanced inspection regime for the autumn and winter seasons and during periods of weather warnings which would present a greater risk of blockage due to the woodland nature of the catchment upstream of the culvert inlet. This may be able to be carried out in conjunction with Transport NI personnel based at the Moygashel depot.

The culvert inlet should be upgraded, as described in Option 2, to include a bypass feature which would allow flows to re-enter the culvert should the grille become blinded. The culvert structural and capacity issues should be addressed through the construction of a new culvert. The preferred route, as described in Option 6, involves the construction of 385m of 1.0x2.5m box culvert along the eastern side of the Transport NI depot towards Main Rd and then turning in a south-westerly direction paralleling to the base of the embankment towards the Linen Green complex main entrance. From here it turns south and crosses Main Road to connect to the existing 2100mm diameter culvert. Works will also be required within the Transport NI depot and Linen Green complex to prevent any disconnection of drainage when undertaking tasks to make safe the existing culvert.

The cost of damages for the 20%, 10%, 4%, 2% and 1% AEPs were calculated based upon the Multi-Coloured Manual and discounted over a period of 100 years in order to determine the present value of benefits for each option. The benefit cost analysis found that the proposed works to upgrade the culvert and the inlet structure are economically viable with a benefit cost ratio greater than 1 (4.01).

Finally, additional investigation works are required in order to gain a full understanding and ensure all potential connections are accounted for. The condition survey identified twin 900 diameter culverts and a brick arch culvert connecting from the west which were not in the original model. Also, the operation and purpose of the abandoned mill race to the west of the site should be confirmed along with the operation of the associated sluices. No information was available on the private drainage networks within both the Linen Green and Transport NI depots and survey work should be undertaken at design stage to establish its extent.

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Appendix A Drawings

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Drawing List

LGMS-ACM-XX-XX-DR-CE-01000 - Site Location Plan

LGMS-ACM-XX-XX-DR-CE-01005 - NIE - Electrical Infrastructure

LGMS-ACM-XX-XX-DR-CE-01006 - NIW - Water & Wastewater Infrastructure

LGMS-ACM-XX-XX-DR-CE-01007 - Telecom Infrastructure

LGMS-ACM-XX-XX-DR-CE-01010 - Hydraulic Structures Plan

LGMS-ACM-XX-XX-DR-CE-01011 - Condition Survey Observations

LGMS-ACM-XX-XX-DR-CE-01012 - Culvert Structural and Serviceability Grades

LGMS-ACM-XX-XX-DR-CE-01013 - Building Legend

LGMS-ACM-XX-XX-DR-CE-01015 - Topographical Survey; Sheet 1 of 3

LGMS-ACM-XX-XX-DR-CE-01016 - Topographical Survey; Sheet 2 of 3

LGMS-ACM-XX-XX-DR-CE-01017 - Topographical Survey; Sheet 3 of 3

LGMS-ACM-XX-XX-DR-CE-01018 - Topographical Survey - Channel Sections

LGMS-ACM-XX-XX-DR-CE-01020 - 50% AEP 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01021 - 20% AEP 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01022 - 10% AEP 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01023 - 4% AEP 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01024 - 2% 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01025 - 1.33% 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01026 - 1% AEP 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01027 - 1% AEP +CC 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01028 - 0.1% AEP 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01029 - 2% AEP + 100% Blockage 2D Flood Extents

LGMS-ACM-XX-XX-DR-CE-01035 - Option 2; Upgrade Culvert Inlet

LGMS-ACM-XX-XX-DR-CE-01036 - Option 3; Upgrade Culvert - Western Route

LGMS-ACM-XX-XX-DR-CE-01037 - Option 4; Upgrade Culvert - Central Route

LGMS-ACM-XX-XX-DR-CE-01038 - Option 5; Upgrade Culvert - Eastern Route

LGMS-ACM-XX-XX-DR-CE-01039 - Option 6; Upgrade Culvert - East Central Route

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N

Dungannon
Park Lake

Park Lake Stream

Direction of Flow

Transport
NI Depot

Abandoned
Mill Race

Culvert System; See drawing
LGMS-ACM-XX-XX-
DR-CE-01011 for details

The Linen Green
Shopping Complex

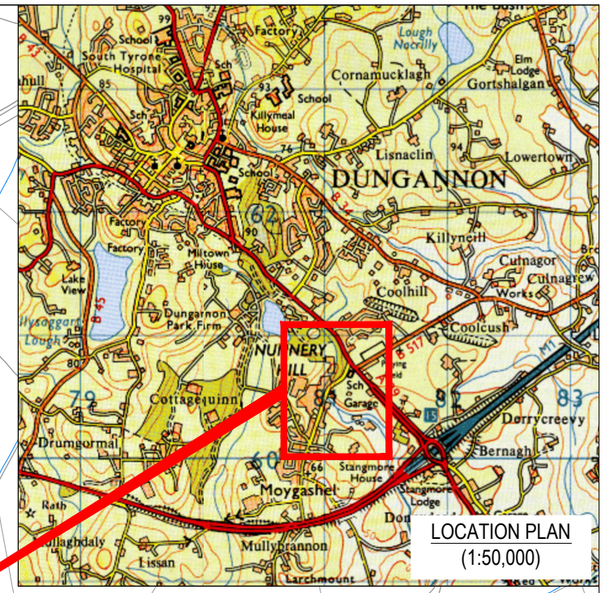
Far Circular Road

Direction of Flow

A29 Moy Road

Main Road

M1 Motorway



Key:

STUDY AREA

IG COORDINATES
(281038.5, 360628.3)

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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: SITE LOCATION PLAN	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: MM	Checked: RSR	Approved: KMcC	Date: OCT 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
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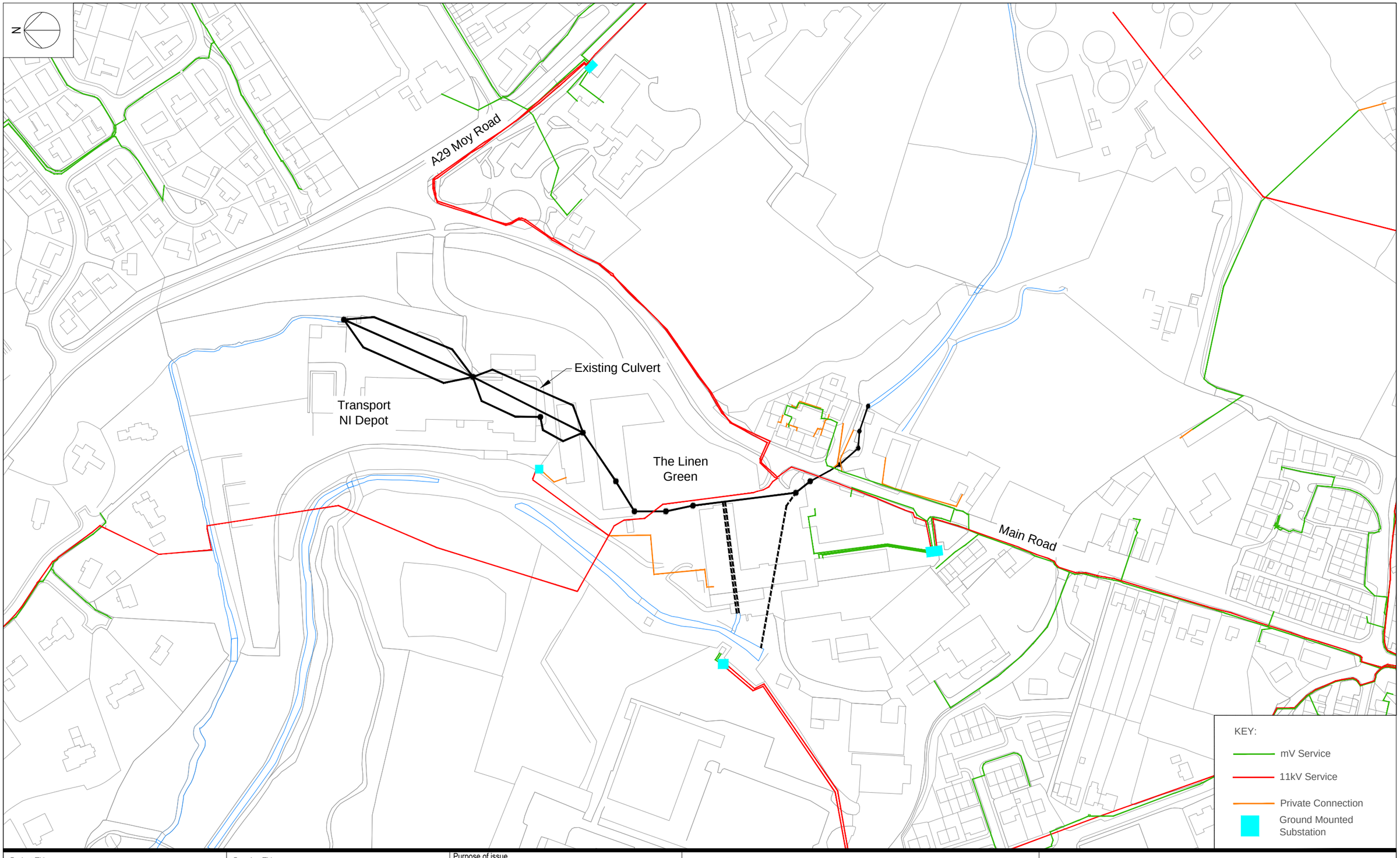

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N

A29 Moy Road

Existing Culvert

Transport
NI Depot

The Linen
Green

Main Road

KEY:

- COMBINED SEWER & MANHOLE
- COMBINED SEWER OVERFLOW
- FOUL SEWER & MANHOLE
- STORM SEWER & MANHOLE
- PRIVATE SEWER & MANHOLE
- DISTRIBUTION WATERMAIN
- TRUNK WATERMAIN
- PRIVATE CONNECTION
- SCOUR PIPE

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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: NIW - WATER & WASTEWATER INFRASTRUCTURE	Purpose of issue: PRELIMINARY			
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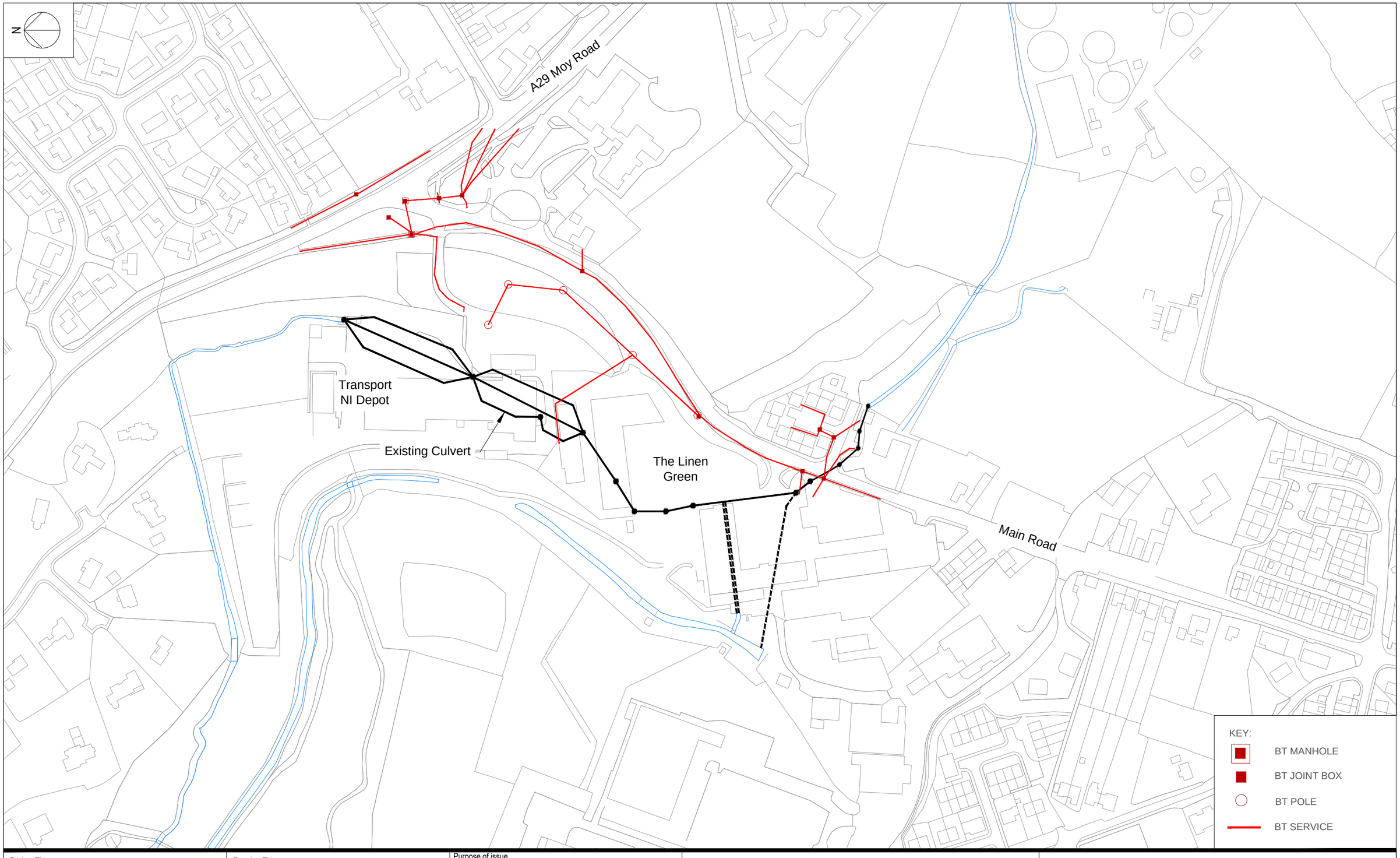

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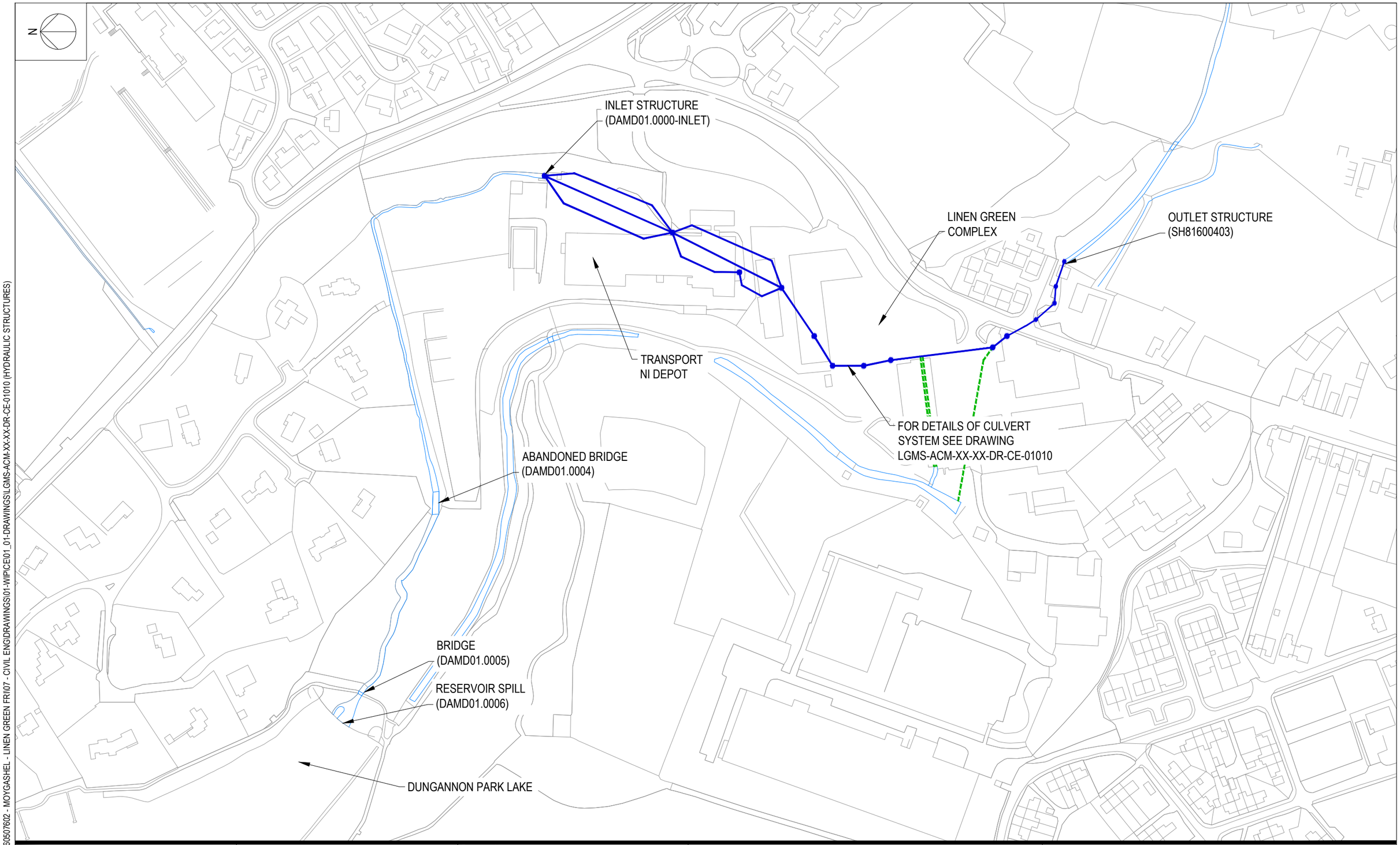

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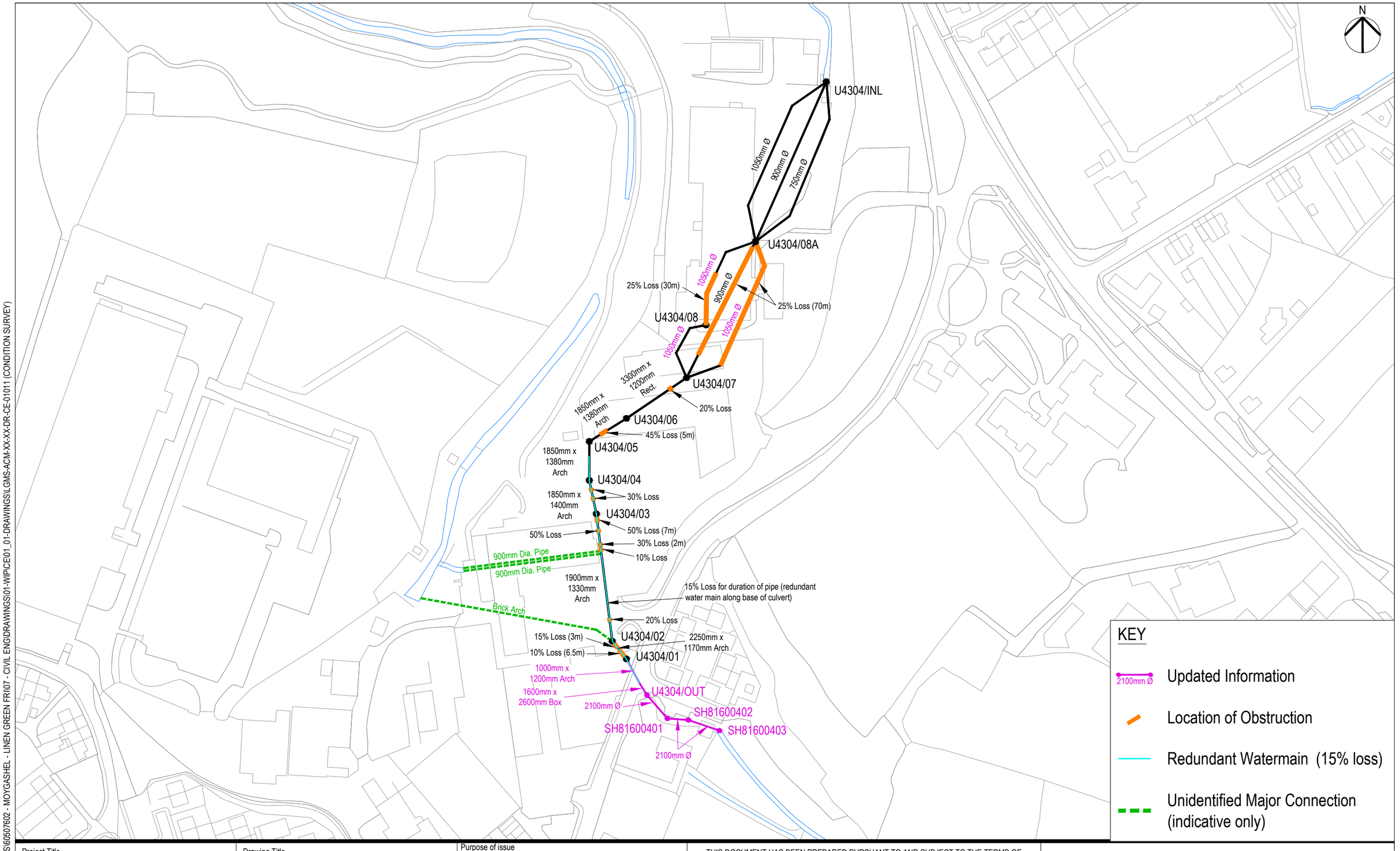

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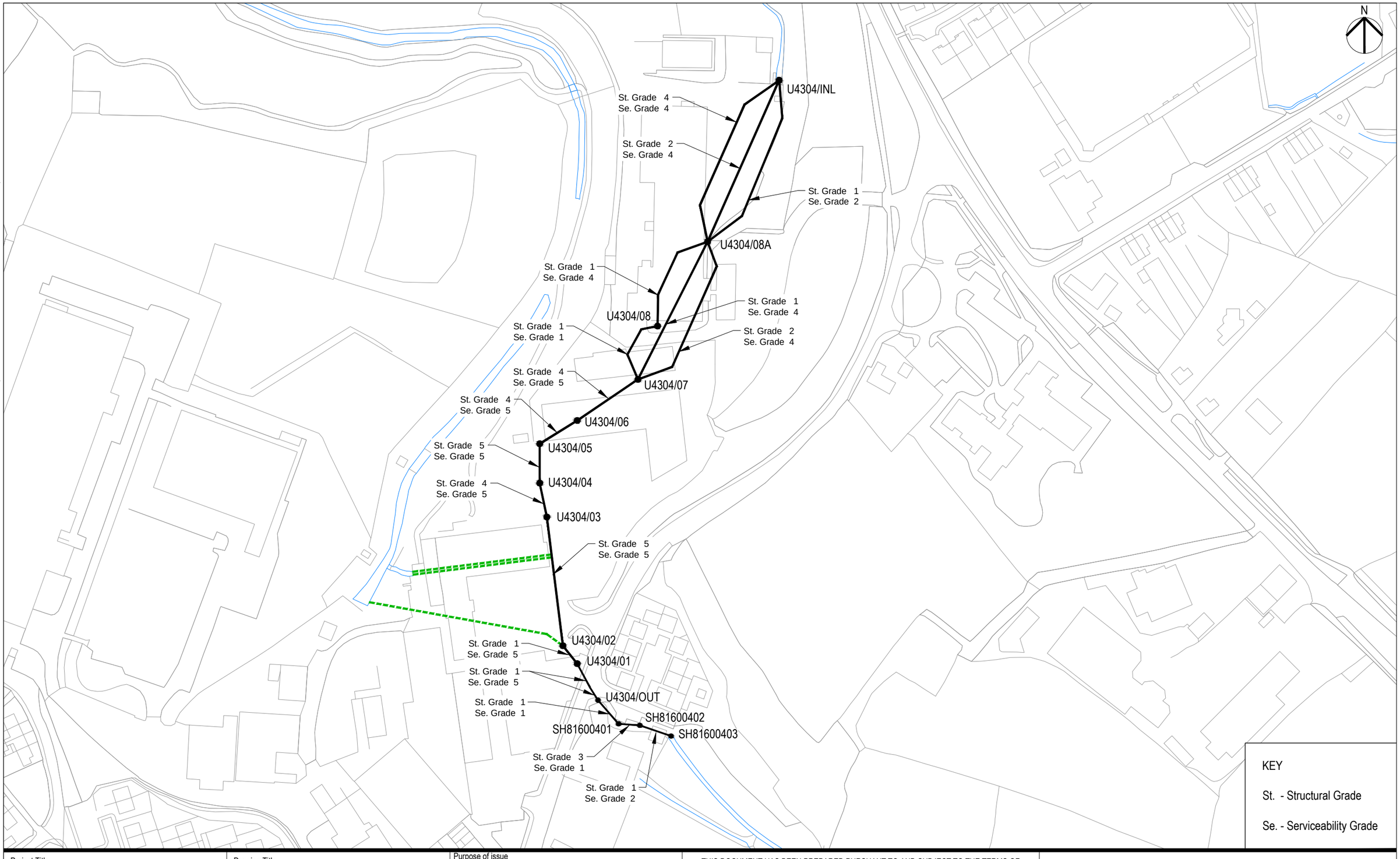

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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: CULVERT STRUCTURAL AND SERVICEABILITY GRADES	Purpose of issue: PRELIMINARY			
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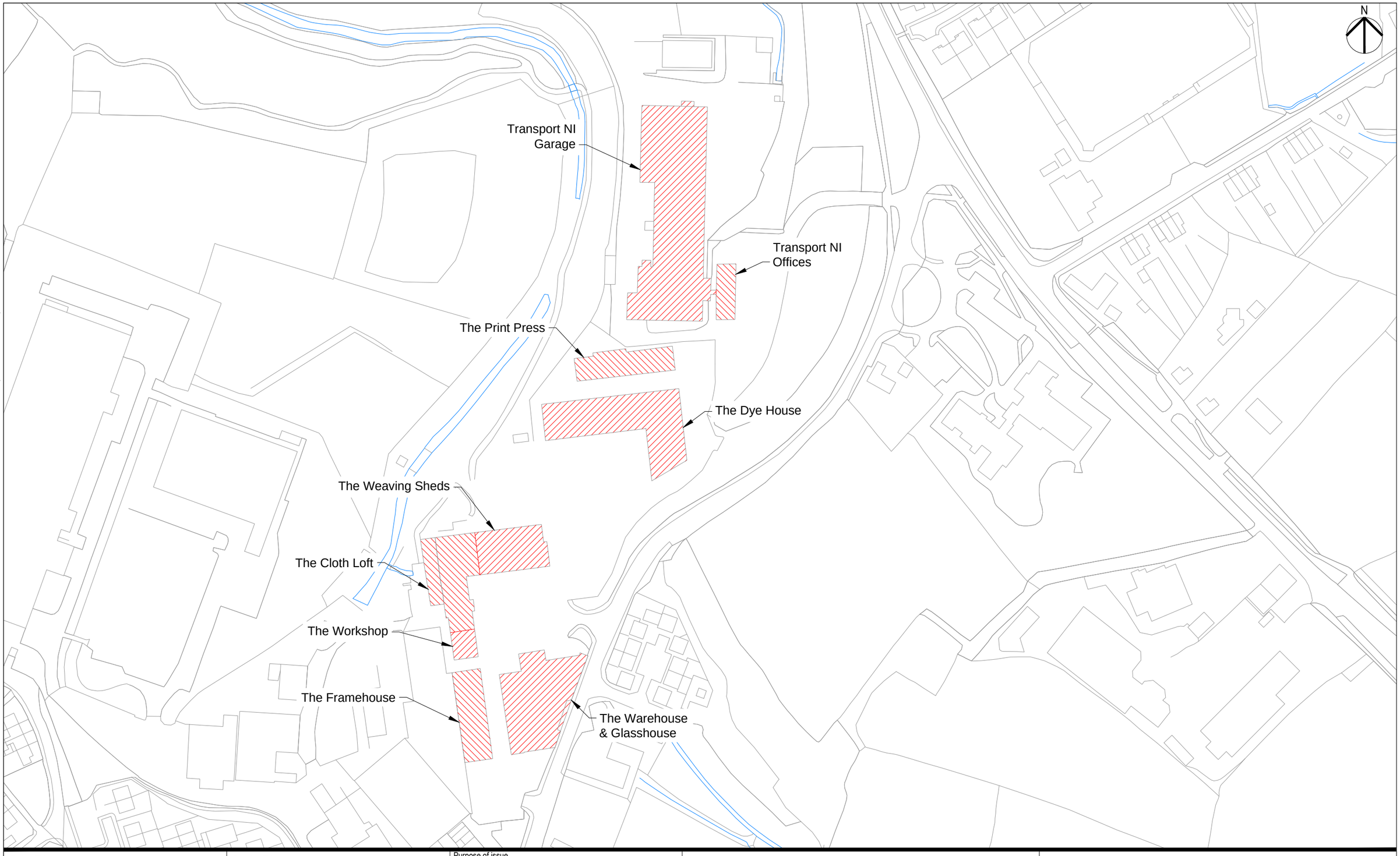

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File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FR\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01013 (BUILDING LEGEND)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: BUILDING LEGEND	Purpose of issue: PRELIMINARY			
		Designed: -	Drawn: MM	Checked: RSR	Approved: KMcC	Date: OCT 16
Client: RIVERS Agency		AECOM Internal Project No.: 60507602		Suitability: Suitability	
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Plot Date : 18 January 2017 12:35:13
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01015_16 (TOPOGRAPHICAL SURVEY)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: TOPOGRAPHICAL SURVEY SHEET 1 OF 3	Purpose of issue: PRELIMINARY	THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOMS APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOMS EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.
Client: RIVERS Agency		Designed: - / Drawn: MM / Checked: RSR / Approved: KMcC / Date: OCT 16	Drawing Number: LGMS-ACM-XX-XX-DR-CE-01015 / Rev: P1
		AECOM Internal Project No.: 60507602 / Suitability: Suitability	
		Scale @ A3: 1:1000 / Zone / Mileage: XX	

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Plot Date : 23 January 2017 09:24:51
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01015_18 (TOPOGRAPHICAL SURVEY)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: TOPOGRAPHICAL SURVEY SHEET 2 OF 3	Purpose of issue: PRELIMINARY		
Client: RIVERS Agency		Designed: -	Drawn: MM	Checked: RSR
		Approved: KMcC	Date: OCT 16	
		AECOM Internal Project No.: 60507602	Suitability: Suitability	
		Scale @ A3: 1:1000	Zone / Mileage: XX	

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Plot Date : 23 January 2017 09:27:54
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01015_18 (TOPOGRAPHICAL SURVEY)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: TOPOGRAPHICAL SURVEY SHEET 3 OF 3	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: MM	Checked: RSR	Approved: KMcC	Date: JAN 17
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:1000		Zone / Mileage: XX	

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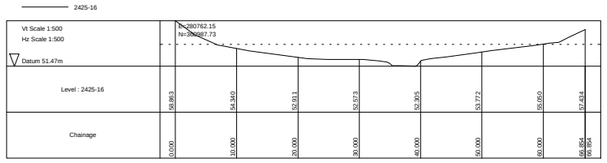

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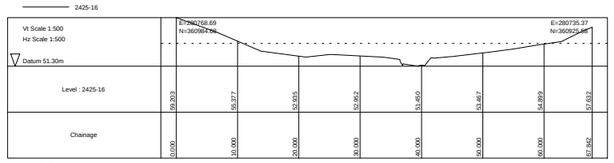

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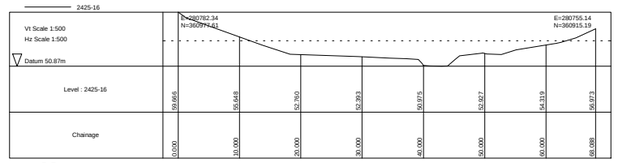

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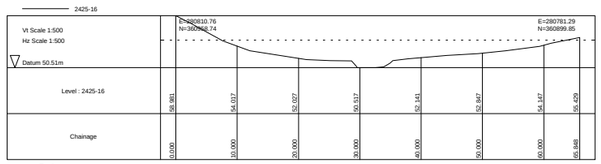

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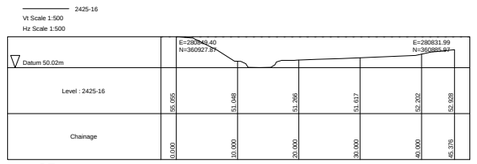

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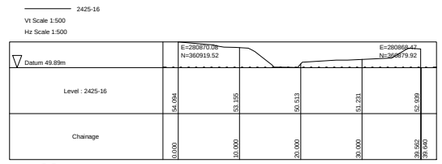

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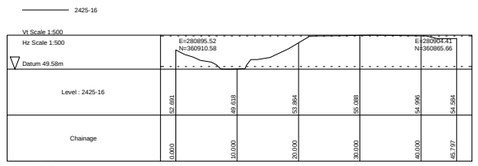

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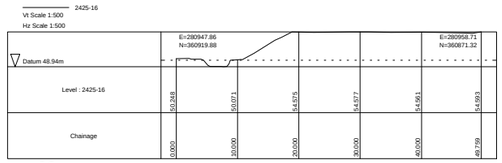

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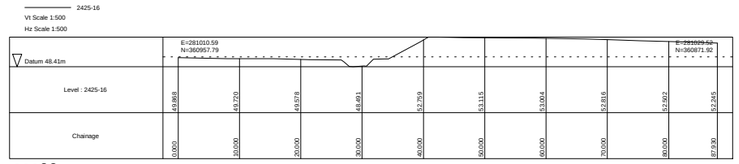

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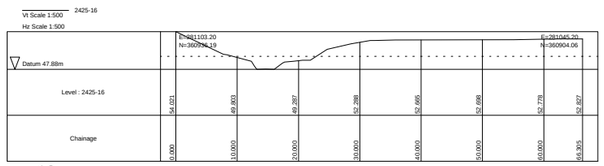

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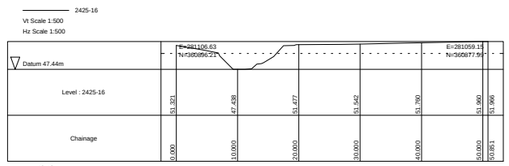

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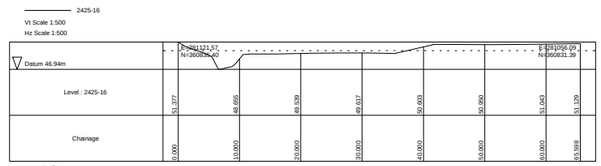

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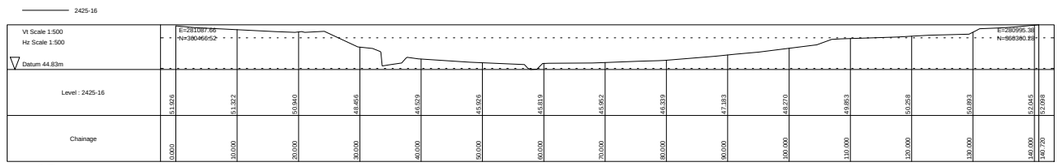

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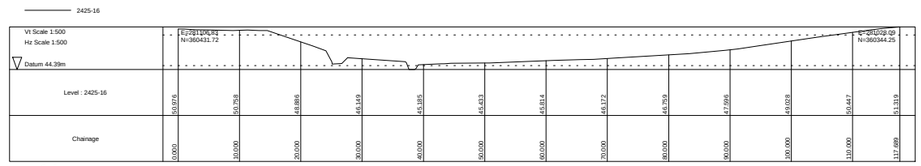

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Plot Date : 23 January 2017 09:33:20
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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: TOPOGRAPHICAL SURVEY CHANNEL SECTIONS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: MM	Checked: RSR	Approved: KMcC	Date: JAN 17
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:1000		Zone / Mileage: XX	

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Drawing Number	Rev
LGMS-ACM-XX-XX-DR-CE-01018	P0

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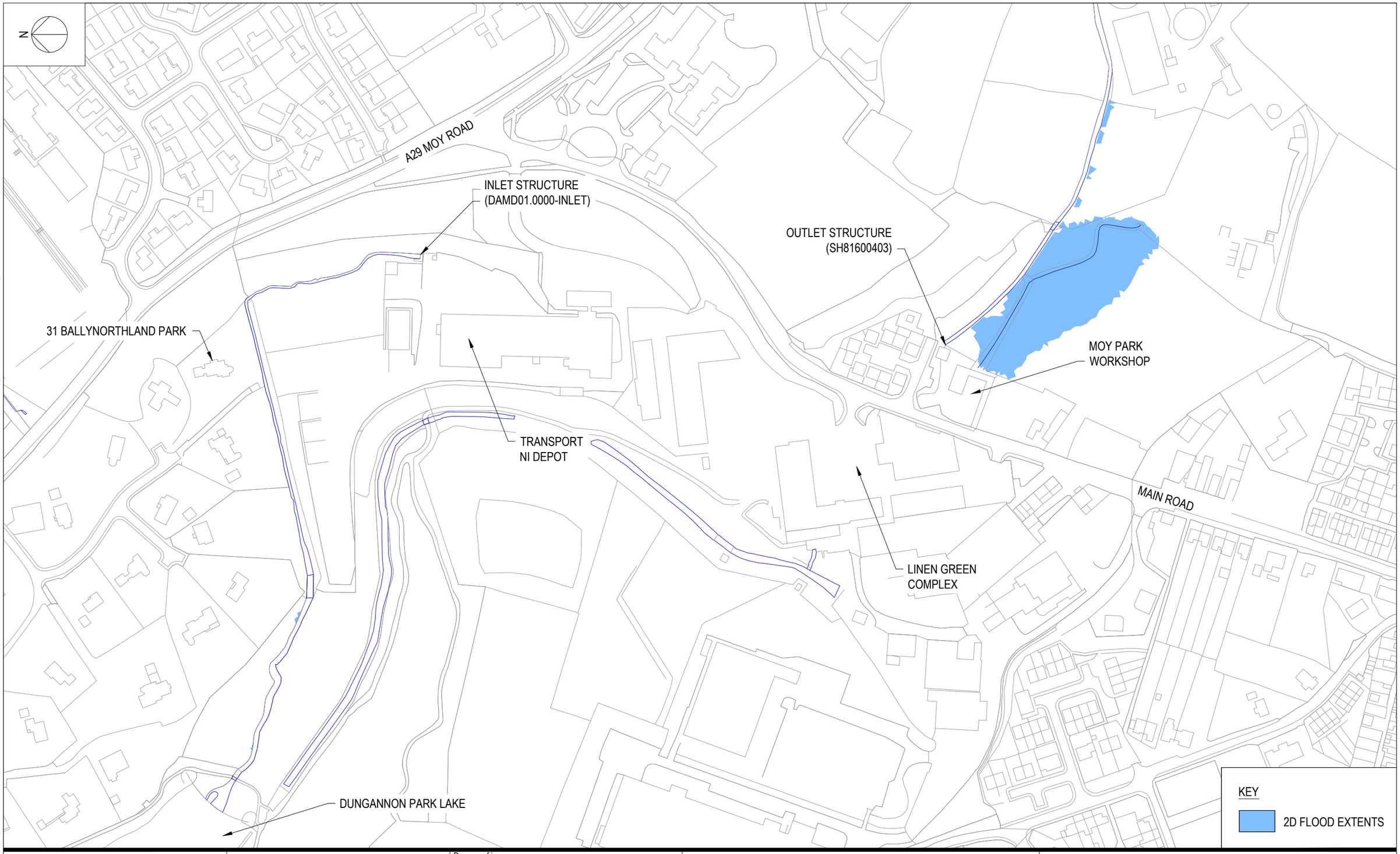

Plot Date : 11 November 2016 10:16:51
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01020 (50% AEP 2D FLOOD EXTENT)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 50% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY	THIS DOCUMENT HAS BEEN PREPARED PURSUANT TO AND SUBJECT TO THE TERMS OF AECOMS APPOINTMENT BY ITS CLIENT. AECOM ACCEPTS NO LIABILITY FOR ANY USE OF THIS DOCUMENT OTHER THAN BY ITS ORIGINAL CLIENT OR FOLLOWING AECOMS EXPRESS AGREEMENT TO SUCH USE, AND ONLY FOR THE PURPOSES FOR WHICH IT WAS PREPARED AND PROVIDED.
Client: RIVERS Agency		Designed: - / Drawn: SN / Checked: RSR / Approved: KMcC / Date: NOV 16	Drawing Number: LGMS-ACM-XX-XX-DR-CE-01020 / Rev: P0
		AECOM Internal Project No.: 60507602 / Suitability: Suitability	
		Scale @ A3: 1:2500 / Zone / Mileage: XX	

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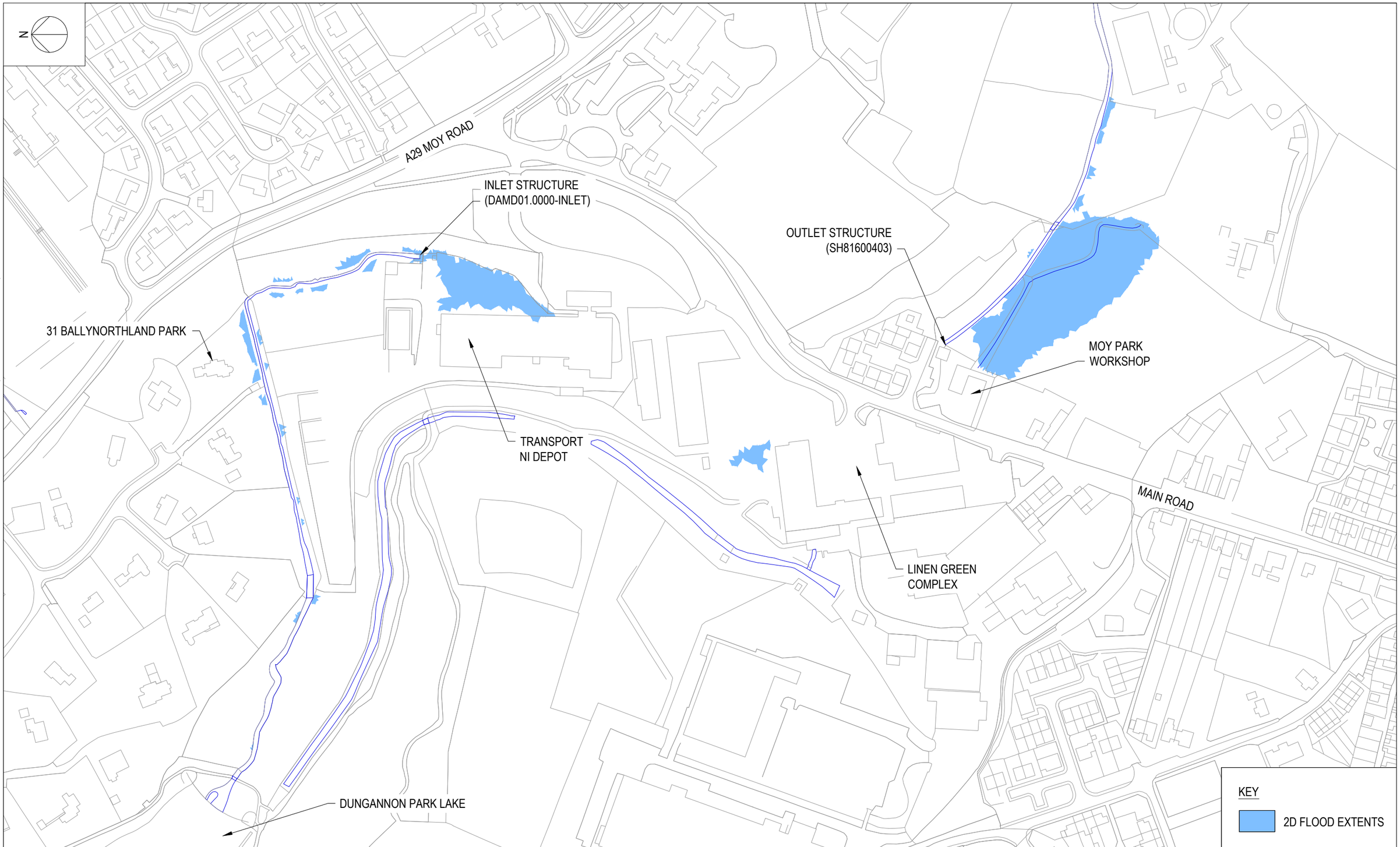

Plot Date : 11 November 2016 10:19:09
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01021 (20% AEP 2D FLOOD EXTENT)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 20% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2500		Zone / Mileage: XX	

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Drawing Number: LGMS-ACM-XX-XX-DR-CE-01021	Rev: P0

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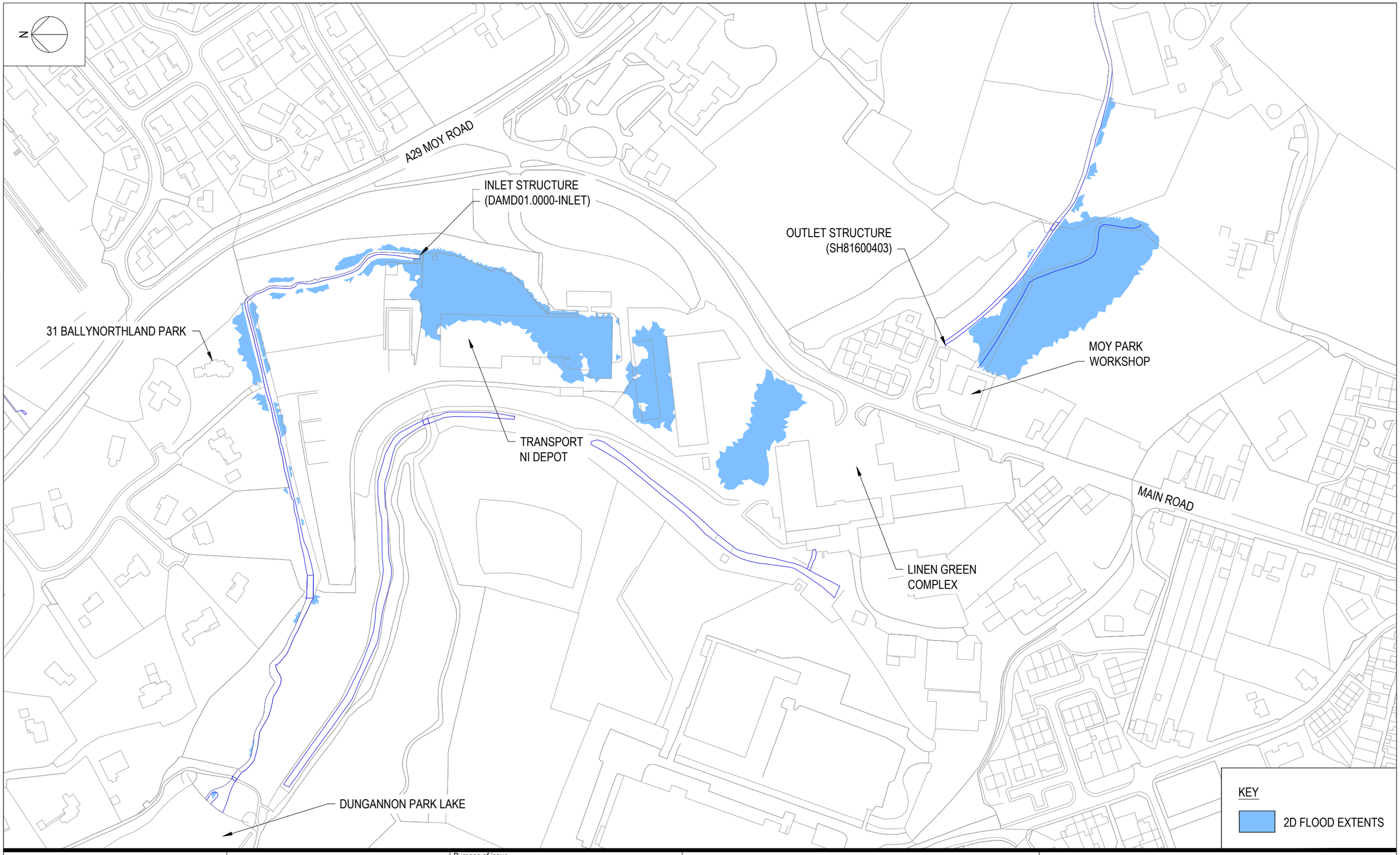

Plot Date : 11 November 2016 10:22:10
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01022 (10% AEP 2D FLOOD EXTENT)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 10% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY				
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability		
		Scale @ A3: 1:2500		Zone / Mileage: XX		

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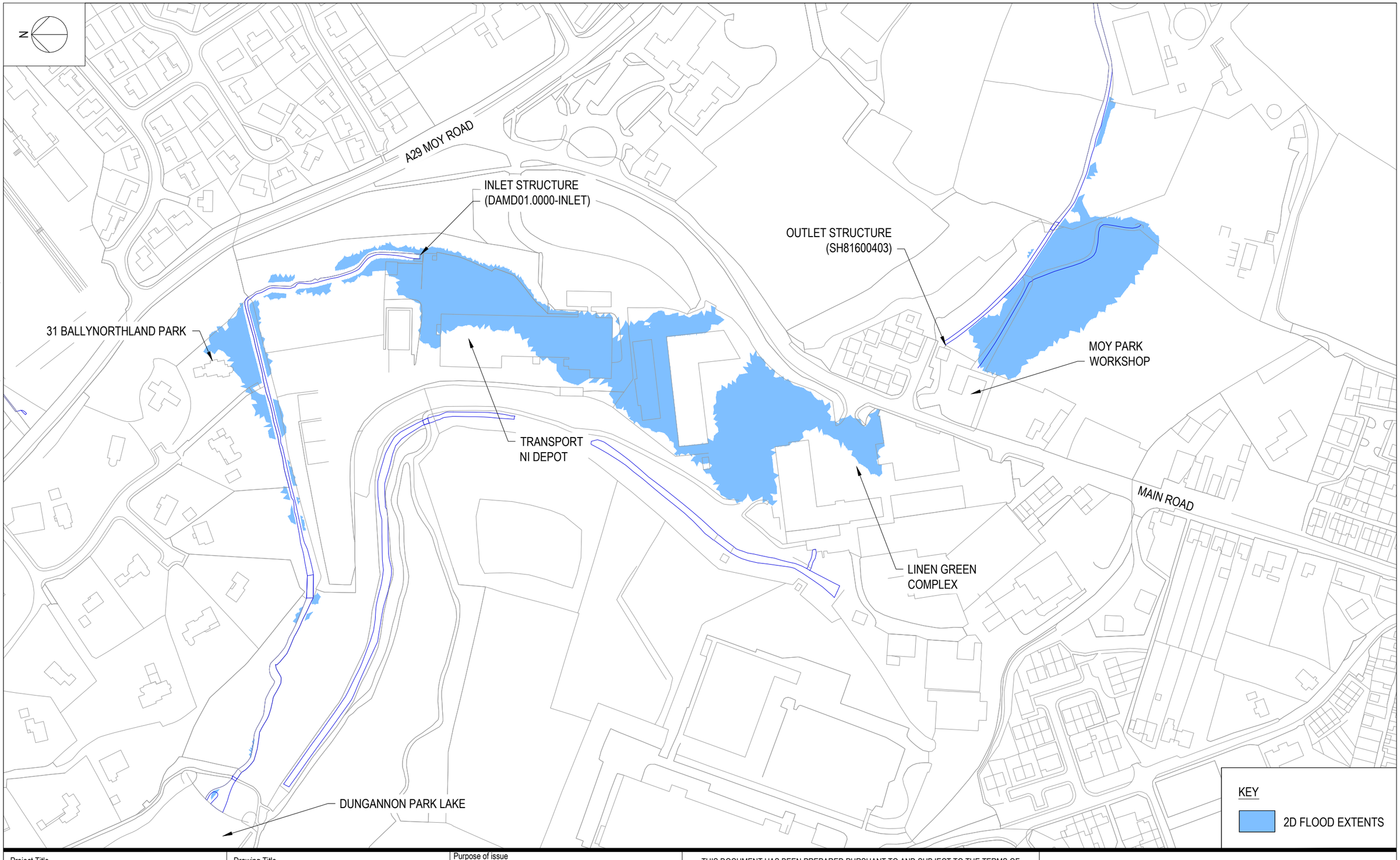

Plot Date : 11 November 2016 10:24:14
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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 4% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
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Drawing Number: LGMS-ACM-XX-XX-DR-CE-01023	Rev: P0

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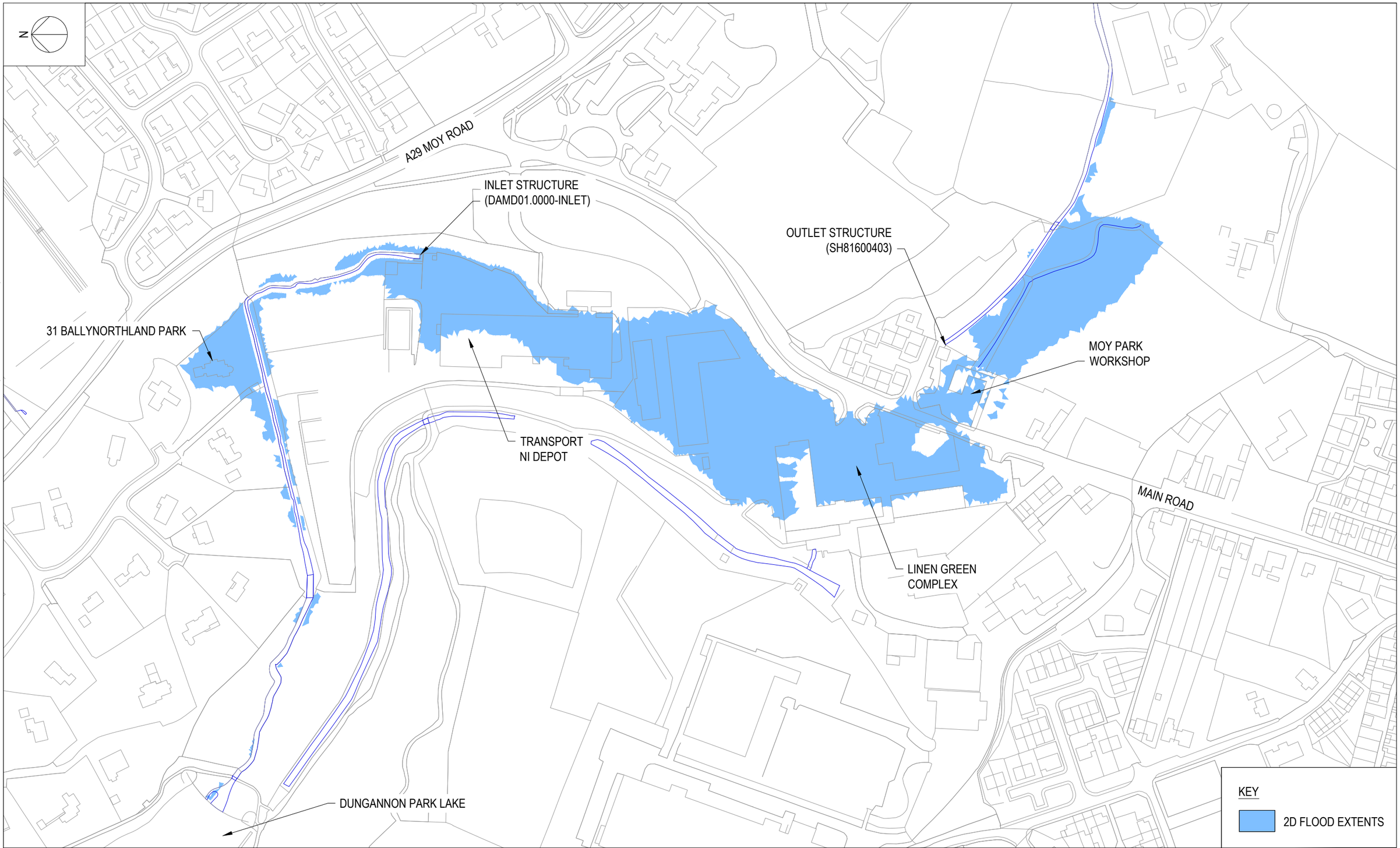

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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 2% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2500		Zone / Mileage: XX	

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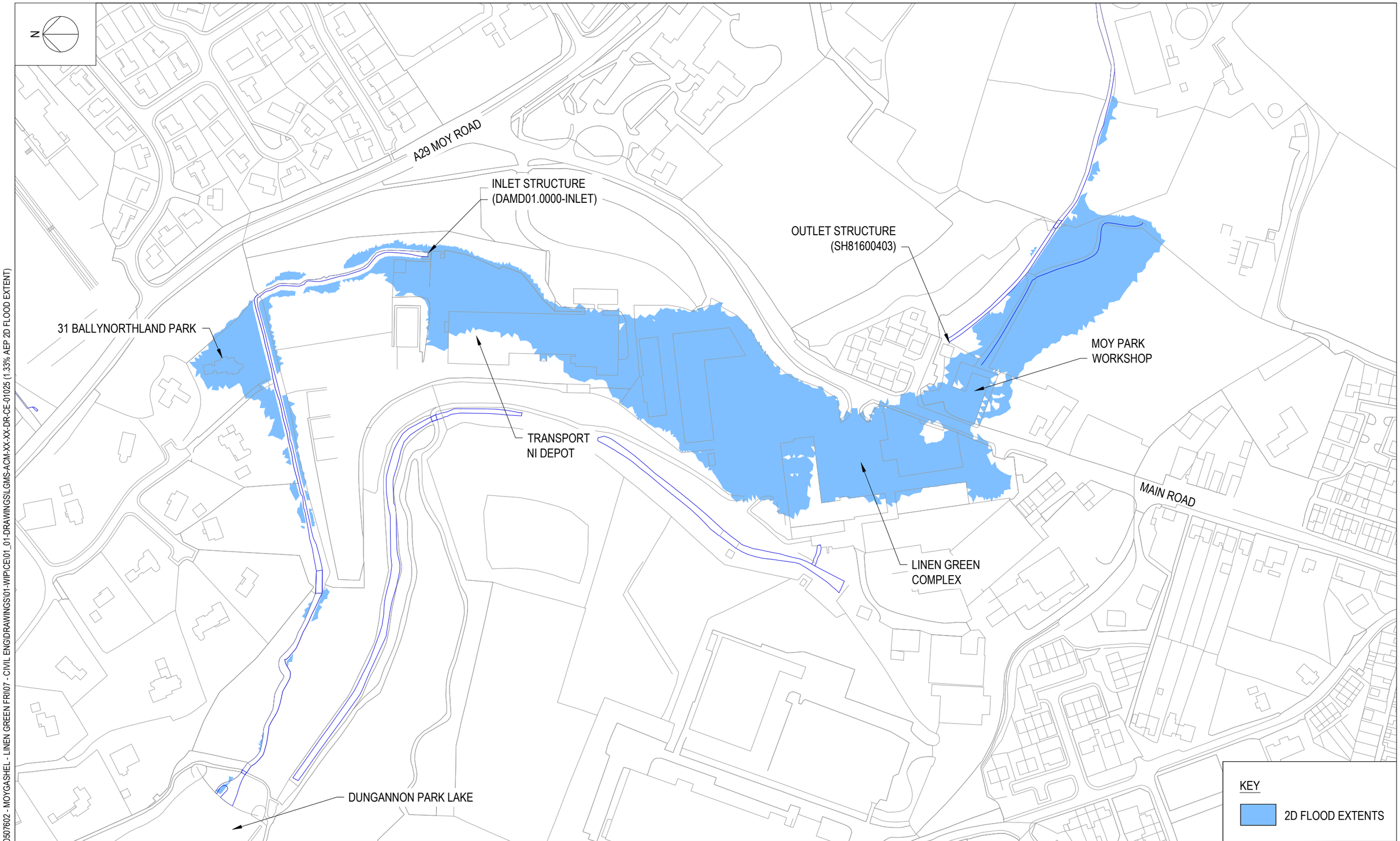

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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 1.33% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2500		Zone / Mileage: XX	

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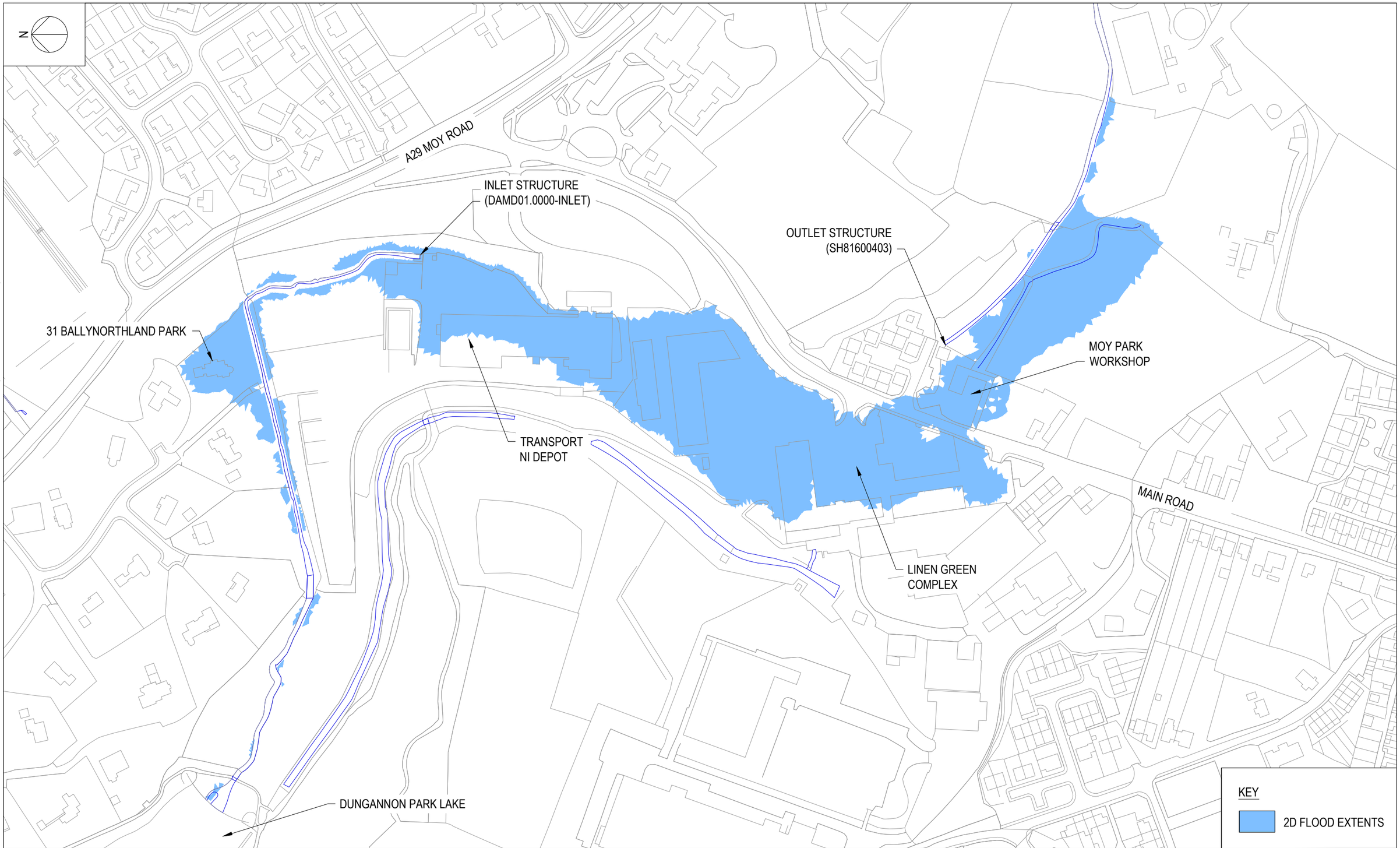

Plot Date : 11 November 2016 10:50:27
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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 1% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
Client: RIVERS Agency		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2500		Zone / Mileage: XX	

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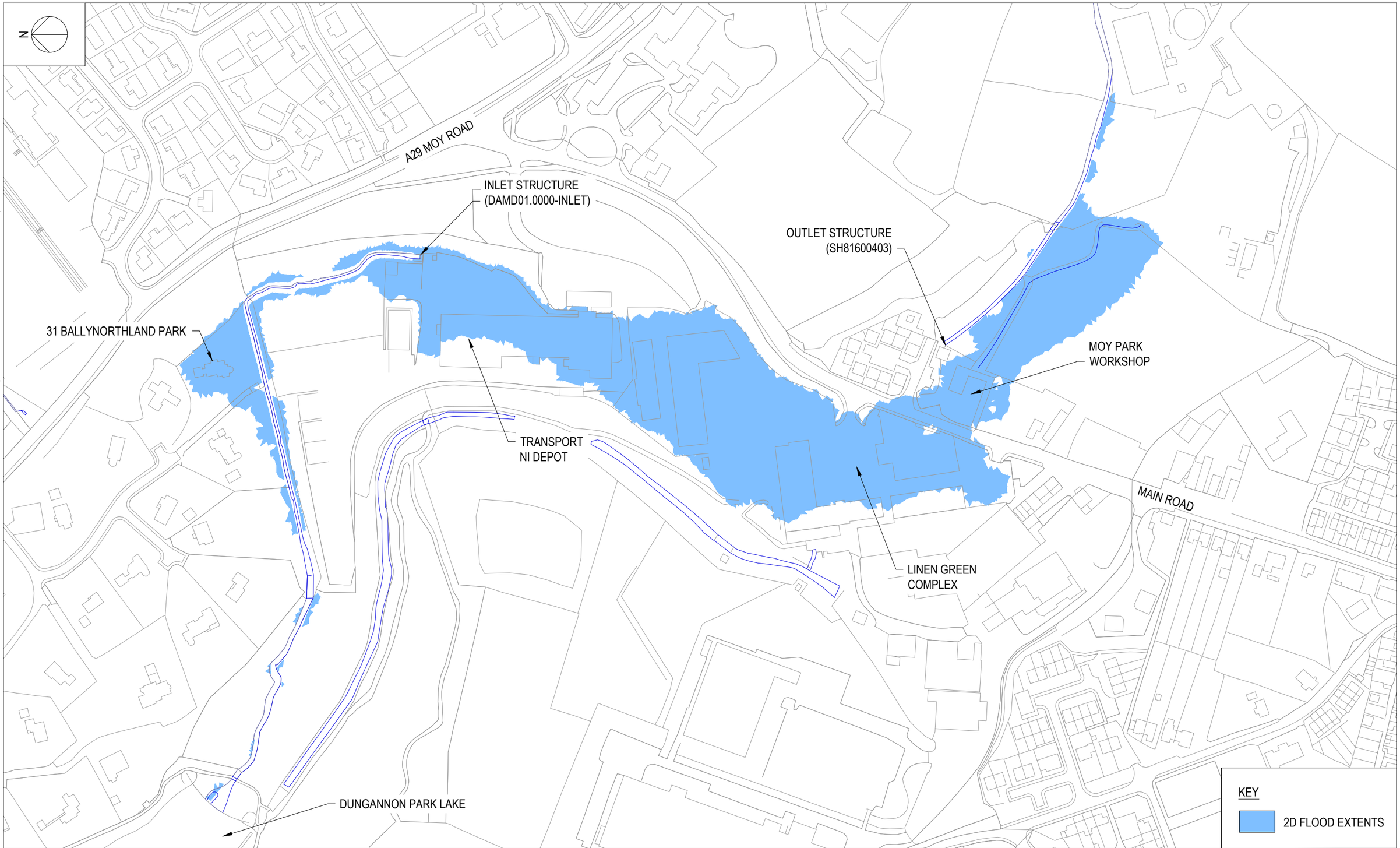

Plot Date : 11 November 2016 10:55:26
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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 1% + CLIMATE CHANGE AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2500		Zone / Mileage: XX	

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Drawing Number: LGMS-ACM-XX-XX-DR-CE-01027
Rev: P0

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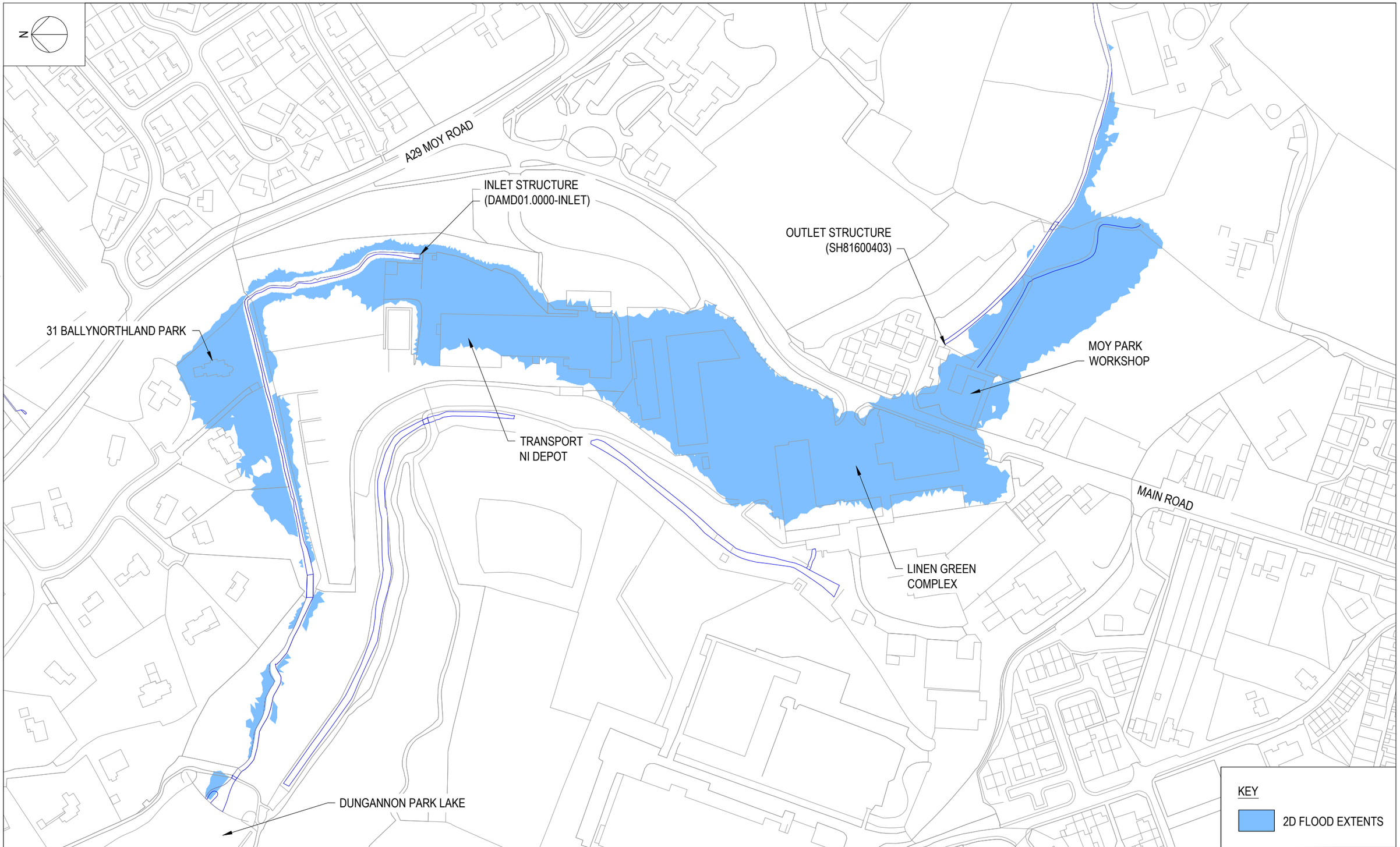

Plot Date : 11 November 2016 10:58:43
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01028 (0.1% AEP 2D FLOOD EXTENT)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 0.1% AEP 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2500		Zone / Mileage: XX	

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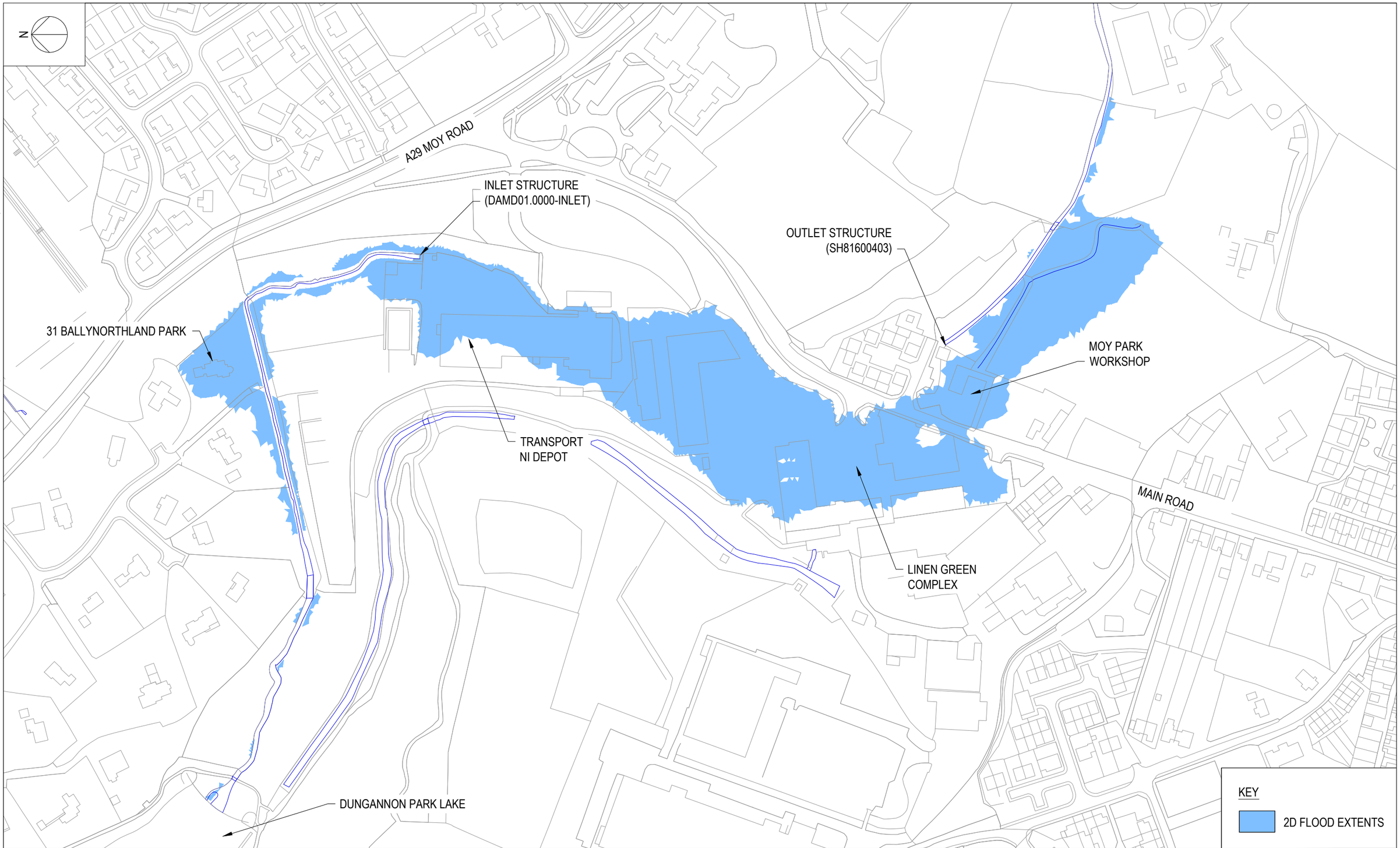

Plot Date : 16 November 2016 11:03:34
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01029 (2% AEP + 100% BLOCKAGE 2D FLOOD EXTENT)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: 2% AEP + 100% BLOCKAGE 2D FLOOD EXTENTS	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: -	Drawn: SN	Checked: RSR	Approved: KMcC	Date: NOV 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2500		Zone / Mileage: XX	

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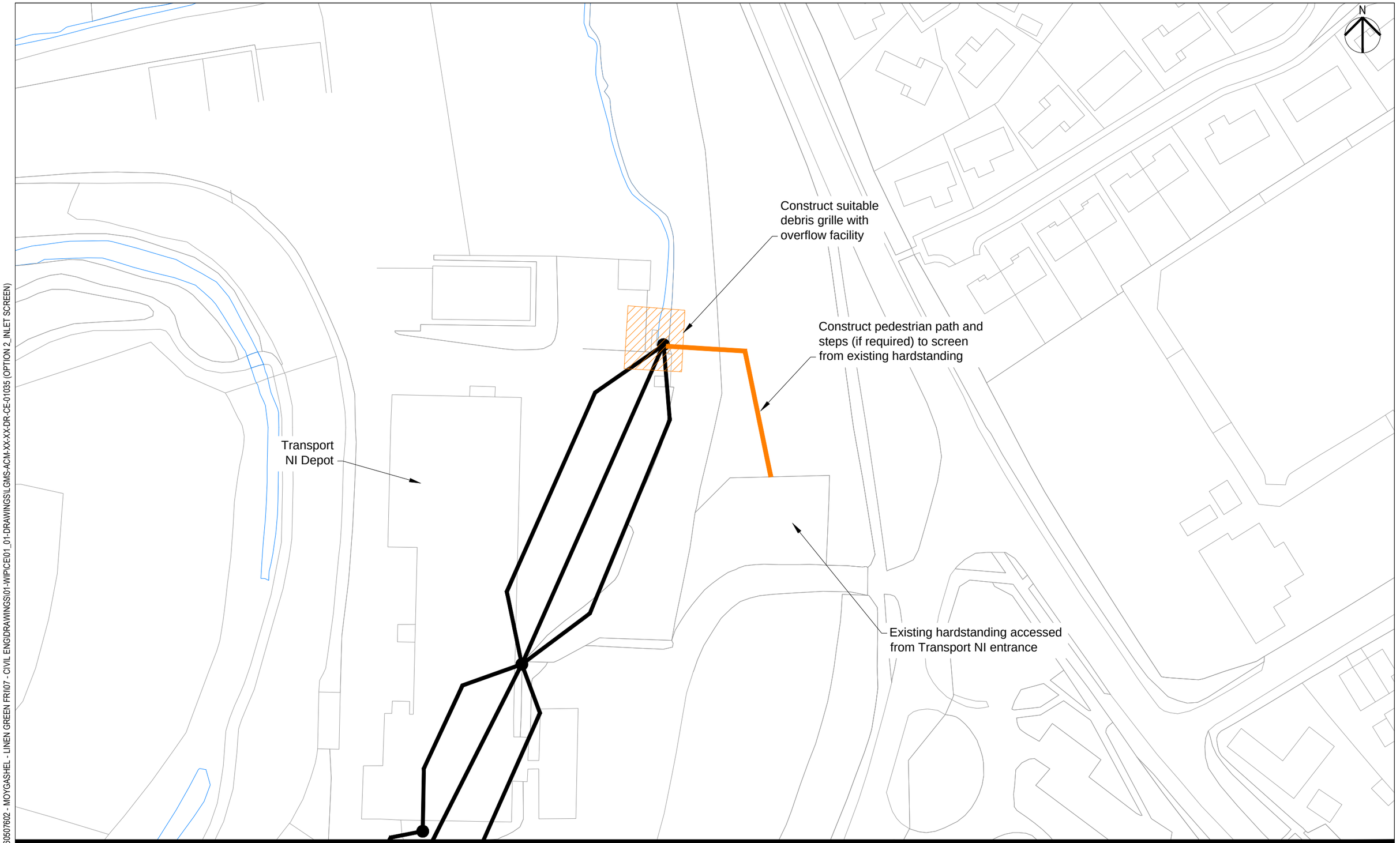

Plot Date : 11 November 2016 11:26:16
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01035 (OPTION 2_INLET SCREEN)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: OPTION 2 UPGRADE CULVERT INLET	Purpose of issue: PRELIMINARY	
Client: RIVERS Agency		Designed: RSR; Drawn: RSR; Checked: JA; Approved: KMcC; Date: OCT 16	
		AECOM Internal Project No.: 60507602	Suitability: Suitability
		Scale @ A3: 1:1000	Zone / Mileage: XX

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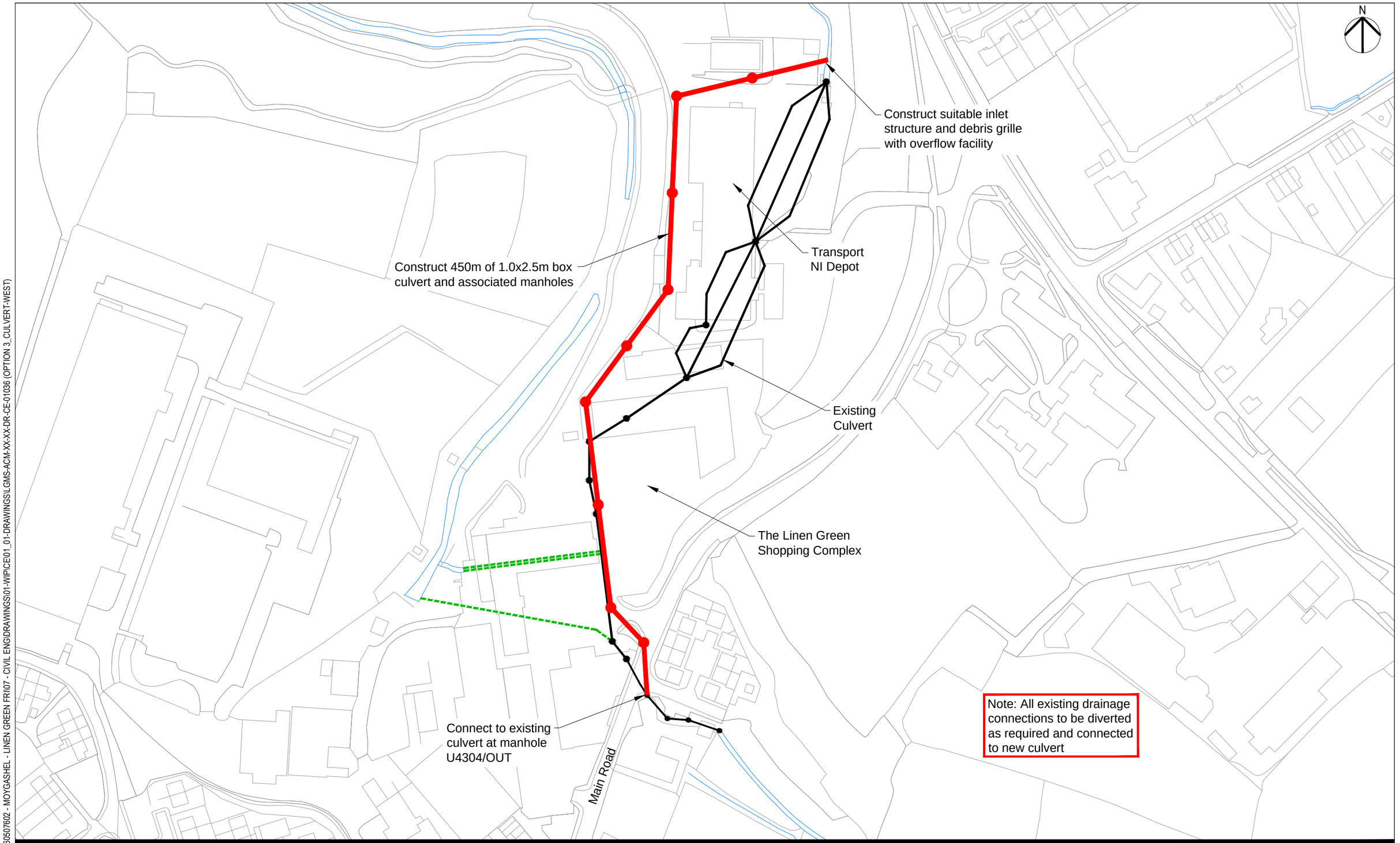

Plot Date : 11 November 2016 11:26:59
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FR\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01036 (OPTION 3_CULVERT-WEST)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: OPTION 3 UPGRADE CULVERT - WESTERN ROUTE	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: RSR	Drawn: RSR	Checked: JA	Approved: KMcC	Date: OCT 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2000		Zone / Mileage: XX	

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Drawing Number	Rev
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N

Construct suitable inlet structure and debris grille with overflow facility

Transport NI Depot

Construct 485m of 1.0x2.5m box culvert and associated manholes

Existing Culvert

The Linen Green Shopping Complex

Connect to existing culvert at manhole U4304/OUT

Main Road

Note: All existing drainage connections to be diverted as required and connected to new culvert

Plot Date : 11 November 2016 11:27:43
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01037 (OPTION 4_CULVERT-CENTRE)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: OPTION 4 UPGRADE CULVERT - CENTRAL ROUTE	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: RSR	Drawn: RSR	Checked: JA	Approved: KMcC	Date: OCT 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2000		Zone / Mileage: XX	

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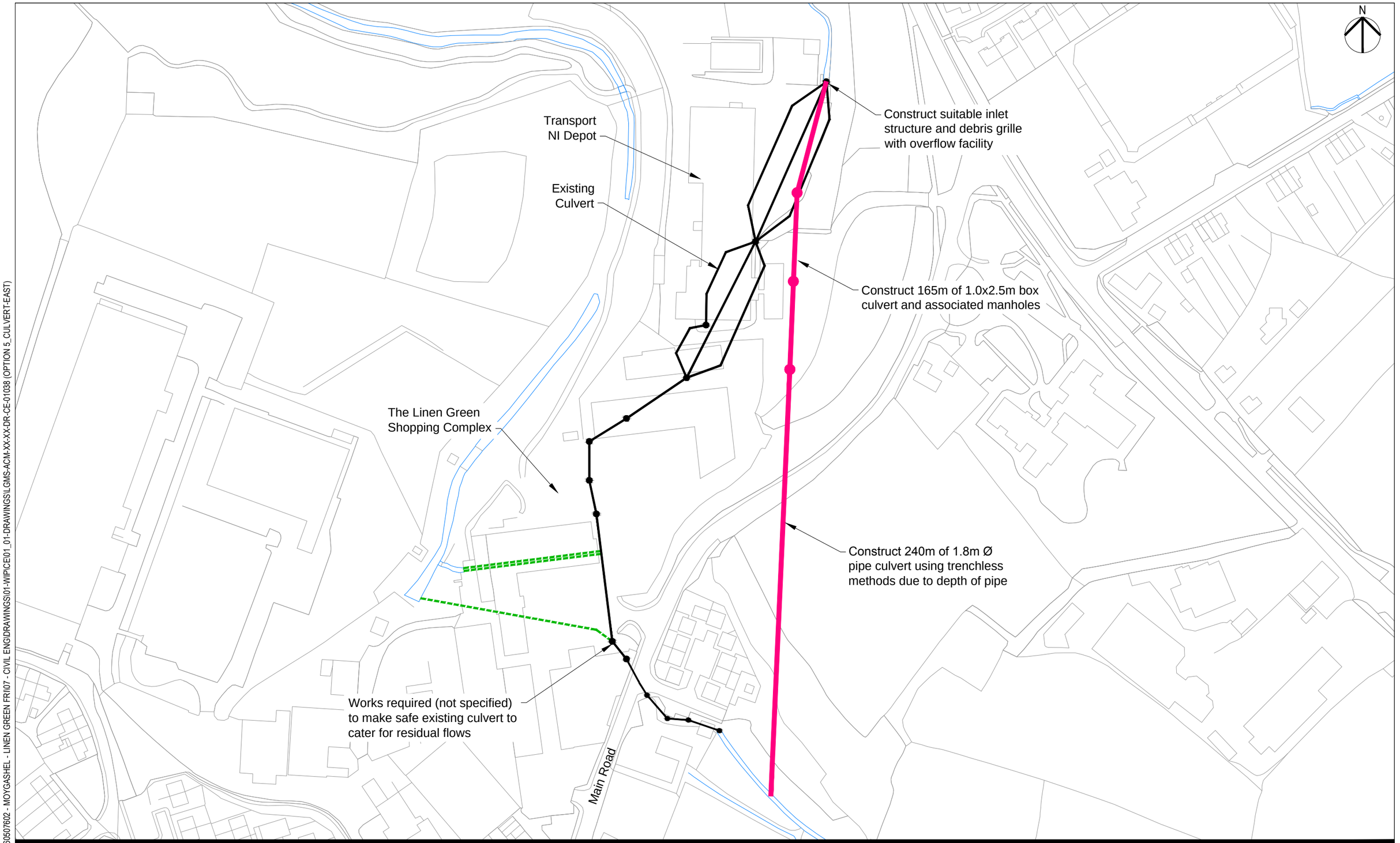

Plot Date : 11 November 2016 11:28:49
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Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: OPTION 5 UPGRADE CULVERT - EASTERN ROUTE	Purpose of issue: PRELIMINARY				
Client: RIVERS Agency		Designed: RSR	Drawn: RSR	Checked: JA	Approved: KMcC	Date: OCT 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability		
		Scale @ A3: 1:2000		Zone / Mileage: XX		

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Transport NI Depot

Existing Culvert

Construct suitable inlet structure and debris grille with overflow facility

The Linen Green Shopping Complex

Construct 385m of 1.0x2.5m box culvert and associated manholes

Connect to existing culvert at manhole U4304/OUT

Main Road

Note: All existing drainage connections to be diverted as required and connected to new culvert

Plot Date : 16 November 2016 11:07:53
File Name : G:\DOCUMENTS\60507602 - MOYGASHEL - LINEN GREEN FRI\07 - CIVIL ENG\DRAWINGS\01-WIP\CE\01_01-DRAWINGS\LGMS-ACM-XX-XX-DR-CE-01039 (OPTION 6_CULVERT-EAST-CENTRE)

Project Title: MOYGASHEL- LINEN GREEN	Drawing Title: OPTION 6 UPGRADE CULVERT - EAST CENTRAL ROUTE	Purpose of issue: PRELIMINARY			
Client: RIVERS Agency		Designed: RSR	Drawn: RSR	Checked: JA	Approved: KMcC	Date: OCT 16
		AECOM Internal Project No.: 60507602		Suitability: Suitability	
		Scale @ A3: 1:2000		Zone / Mileage: XX	

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