Lidl,
Newcastle, Dublin
Flood Risk Assessment

Technical Report

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Contract

This report describes work commissioned by Fintan Morrin of The Planning Partnership, on behalf of Lidl Ireland Dublin HQ. David Casey, Anastasiya Ilyasova and Ross Bryant of JBA Consulting carried out this work.

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Purpose

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Abbreviations

AEP ..... Annual Exceedance Probability

CFRAM ..... Catchment Flood Risk Assessment and Management

ECFRAMS ..... Eastern Catchment Flood Risk Assessment and Management Study

DoEHLG..... Department of the Environment, Heritage and Local Government

FB ..... Freeboard

FFL..... Finish Floor Levels

FRA..... Flood Risk Assessment

FSR..... Flood Studies Report

FSU..... Flood Studies Update

GSI..... Geological Survey of Ireland

LAP ..... Local Area Plan

mOD..... meters above Ordnance Datum (Malin Head)

OPW ..... Office of Public Works

PFRA ..... Preliminary Flood Risk Assessment

1 Introduction

Under the Planning System and Flood Risk Management Guidelines for Planning Authorities (DoEHLG & OPW, 2009) the proposed development must undergo a Flood Risk Assessment to ensure sustainability and effective management of flood risk.

1.1 Terms of Reference and Scope

JBA Consulting was appointed by Lidl Ireland Dublin HQ to prepare a Flood Risk Assessment (FRA) for a proposed commercial development of a site located in Newcastle, Dublin.

1.2 Flood Risk Assessment; Aims and Objectives

This study is being completed to inform the future development of the site as it relates to flood risk. It aims to identify, quantify and communicate to Planning Authority officials and other stakeholders the risk of flooding to land, property and people and the measures that would be recommended to manage the risk.

The objectives of this FRA are to:

- Identify potential sources of flood risk;
- Confirm the level of flood risk and identify key hydraulic features;
- Assess the impact that the proposed development has on flood risk;
- Develop appropriate flood risk mitigation and management measures which will allow for the long-term development of the site.

Recommendations for development have been provided in the context of the OPW / DECLG planning guidance, "The Planning System and Flood Risk Management". A review of the likely effects of climate change, and the long-term impacts this may have on any development has also been undertaken.

For general information on flooding, the definition of flood risk, flood zones and other terms see 'Understanding Flood Risk' in Appendix A.

1.3 Development Proposal

Permission for development to provide a new Lidl Store at Newcastle, Dublin. The proposed site layout is displayed in Figure 1-1. The proposed development comprises:

1) The construction of a single storey Discount Foodstore Supermarket with ancillary off-licence use (with mono-pitch roof and overall building height of c. 6.74 metres) measuring c. 2,207 sqm gross floor space with a net retail sales area of c. 1,410 sqm;

2) Construction of a vehicular access point to Main Street Upper and associated works to carriageway and including partial removal of boundary wall / façade, modification of existing footpaths / public realm and associated and ancillary works including proposed entrance plaza area;

3) Demolition of part of an existing rear / southern single storey residential extension (and related alterations to remaining structure) of 'Kelly Estates' building. The original 'Kelly Estates' building (a protected structure - Eircode: D22 Y9H7) will not be modified;

4) Demolition of detached single storey accommodation / residential structure and ancillary wall / fence demolitions to rear of existing 'Kelly Estates' building;

5) Demolition of existing single storey (stable) building along Main Street and construction of single storey retail / café unit on an extended footprint measuring c. 118 sqm and associated alterations to existing Main Street boundary façade;

6) Renovation and change of use of existing (vacant) two storey vernacular townhouse structure to Main Street, and single storey extension to rear, for retail / commercial use (single level throughout) totalling c. 61 sqm;

7) Repair and renewal of existing Western and Eastern 'burgage plot' tree and hedgerow site boundaries; and,

8) Provision of associated car parking, cycle parking (and staff cycle parking shelter), pedestrian access routes and (ramp and stair) structures (to / through the southern and western site boundaries to facilitate connections to potential future development), free standing and building mounted

signage, free standing trolley bay cover / enclosure, refrigeration and air conditioning plant and equipment, roof mounted solar panels, public lighting, hard and soft landscaping, boundary treatments and divisions, retaining wall structures, drainage infrastructure and connections to services / utilities, electricity Substation and all other associated and ancillary development and works above and below ground level including within the curtilage of a protected structure.

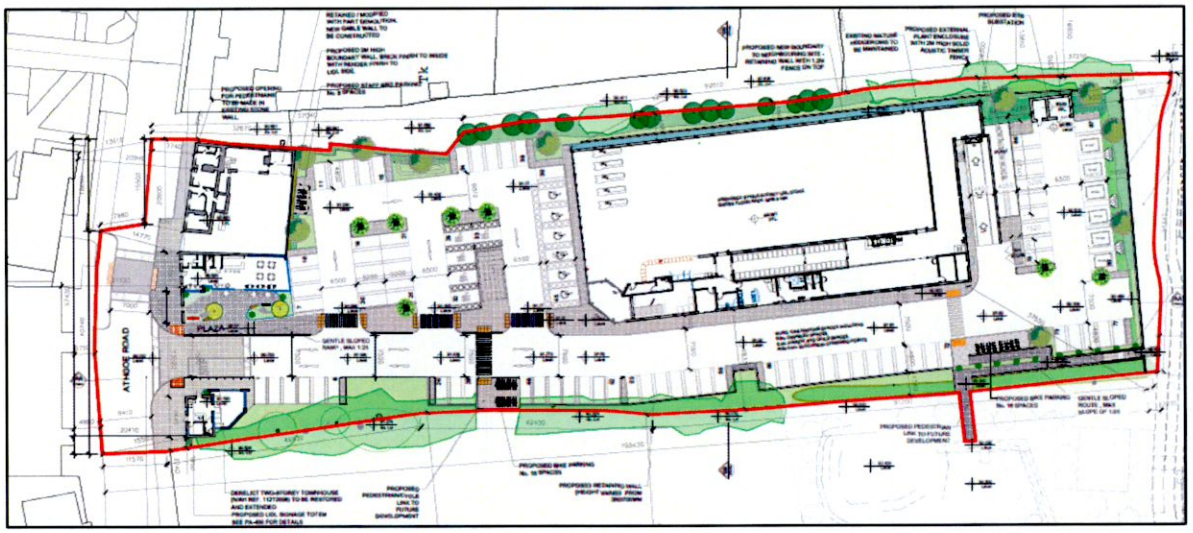


Figure 1-1: Proposed site layout

1.4 Report Structure

Section 2 of this report gives an overview of the study location and associated watercourses. Section 3 contains background information and initial assessment of flood risk. Site-specific mitigation measures are outlined in Section 4, while conclusions are provided in Section 5.

2 Site Background

This section describes the watercourses, geology and wider geographical area in Newcastle, Dublin.

2.1 Location

The proposed site is in Newcastle, c. 10km west of Dublin M50 as seen in Figure 2-1 below. The site is currently a mix of hardstanding area and grass within the proposed site boundary (red), and greenfield within the additional lands (blue boundary). An earthen embankment is dividing the two areas (Figure 2-2). There is existing building to the northeast, which will be demolished.

The site is bounded by greenfields to the west and south. Along the east side there are residential and commercial areas. The access will be via the R405 which is located to the north of the site.

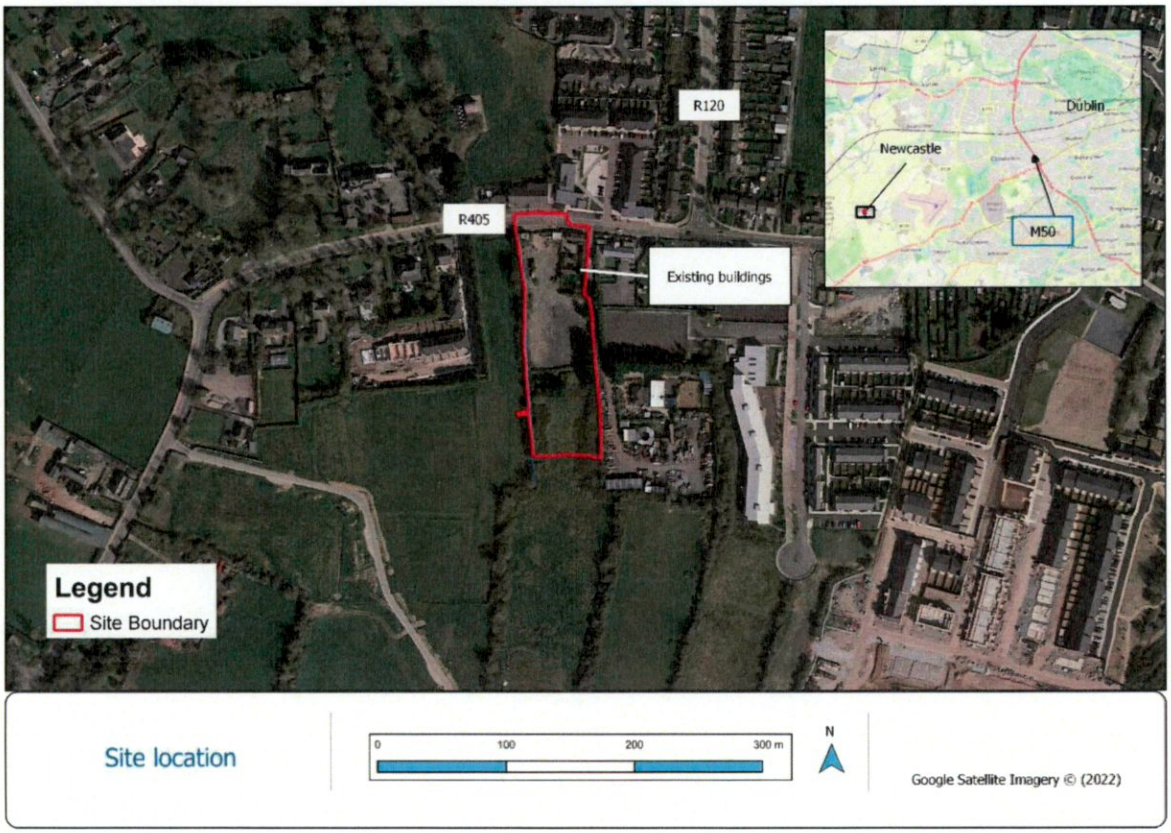


Figure 2-1: Site location

Figure 2-2: Existing earthen embankment (Site looking towards the south)

2.2 Watercourses

There are no critical watercourses near or close to the site boundary, and the closest watercourse to the site is a tributary of Grifeen River (Ref. Figure 2-3).

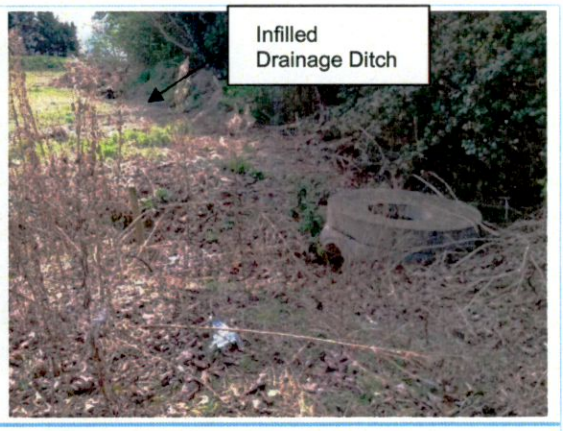
2.2.1 Drainage ditch, culvert

From the site survey it is known that there is a drainage ditch running partially **along the site's** western boundary. The ditch is overgrown upstream, and no flow was identified on the day of the site visit. The ditch enters an approx. 0.3m diameter culvert within the site boundary and upstream of embankment (Figure 2-4 a).

On a wet day site visit, a spring has been identified near a redundant culvert chamber (Figure 2-4 b-e), which splits the culvert. The culvert outlet is approx. 0.60m and enters at the site's north-western corner (inlet Figure 2-4 a). The outfall of the culvert is located outside the site and flows into an open channel stream which flows to the west away from the site (Figure 2-4 f). The detailed drain location is shown on Figure 2-5.

Figure 2-3: Watercourses (Source: EPA blueline network and Newcastle LAP)

a. Culvert inlet (ø300mm) (upstream of embankment to the west, facing north)



b. Culvert chamber

c. Spring water flowing to culvert

d. Spring inlet

e. Spring inlet (closer look)

f. Outfall of culvert into open stream (photo taken on wet day showing flow moving through culvert)

Figure 2-4: Drain features

Figure 2-5: Drain map

2.3 Site Topography

The site has previously been filled and ground levels along the site slopes from south to north with elevation varying between 94.75mOD to 90mOD. As it can be seen on Figure 2-6, at the border of the additional lands the existing embankment (Ref. to Figure 2-2) rise of c.1.5m which divides those lands.

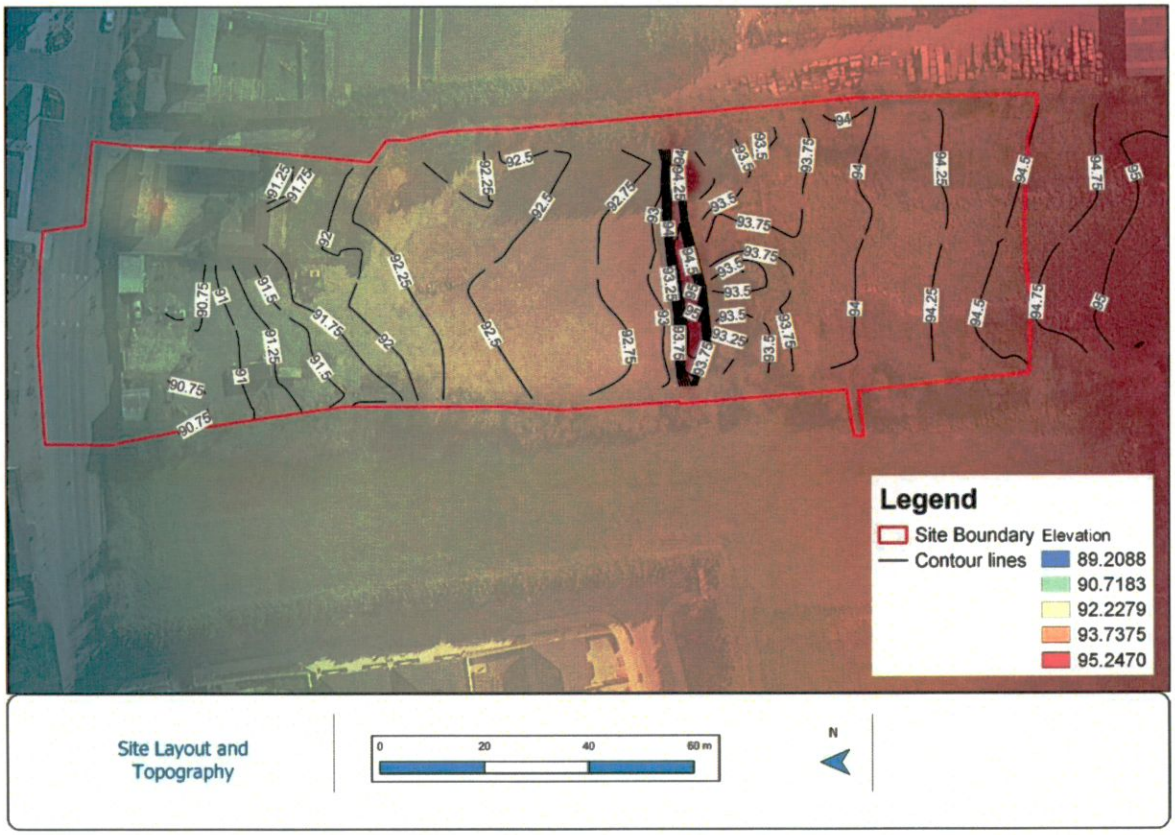


Figure 2-6: Site Topography (National Land Surveyors Ltd, October 2021)

Figure 2-7: Site looking towards the south from the north end of the site with visible slope (left) with closer look to the embankment (right)

2.4 Site Geology

The Geological Survey of Ireland (GSI) groundwater and geological maps of the site were reviewed. The quaternary sediments present under the site is Limestone till Carboniferous. The proposed site is manmade filled, and the soils type within the additional area is BminPD, described as poorly drained mineral soils derived from mainly basic parent materials, refer to Figure 2-8.

The underlying bedrock is classified as the Lucan Formation which is described as dark grey to black limestone and shale.

The associated groundwater vulnerability is classified as 'Extreme' for the proposed site which indicates that an extreme risk to the groundwater under the site and a bedrock depth of between 0-3 m. The groundwater vulnerability for the additional land to the south is classified as 'High' which indicates that a high risk to the groundwater under the site and a bedrock depth of between 3-5m These classifications are based on relevant hydrogeological characteristics of the underlying geological materials.

There are no karst features located within the site or the surrounding area.

Figure 2-8: Quaternary Sediments (Source: GSI Database)

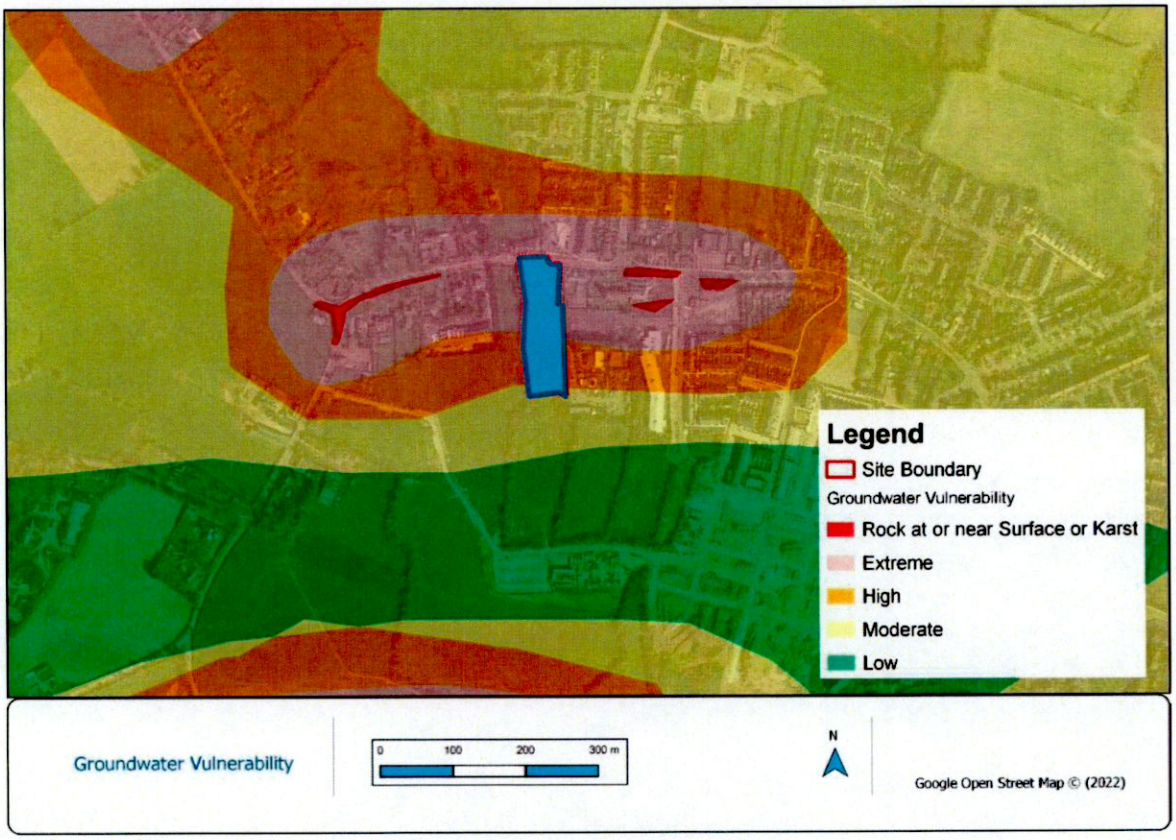


Figure 2-9: Groundwater Vulnerability (Source: GSI Database)

3 Flood Risk Identification

An assessment of the potential for and scale of flood risk at the site is conducted using historical and predictive information. This identifies any sources of potential flood risk to the site and reviews historic flood information. The findings from the flood risk identification stage of the assessment are provided in the following sections.

3.1 Flood History

Several sources of flood information were reviewed to establish any recorded flood history at, or near the site. This includes the OPW's website, www.floodinfo.ie and general internet searches.

3.1.1 Floodinfo.ie

The OPW host a National Flood hazard mapping website, www.floodinfo.ie, which highlights areas at risk of flooding through the collection of recorded data and observed flood events. See Figure 3-1 for historic flood events in the area.

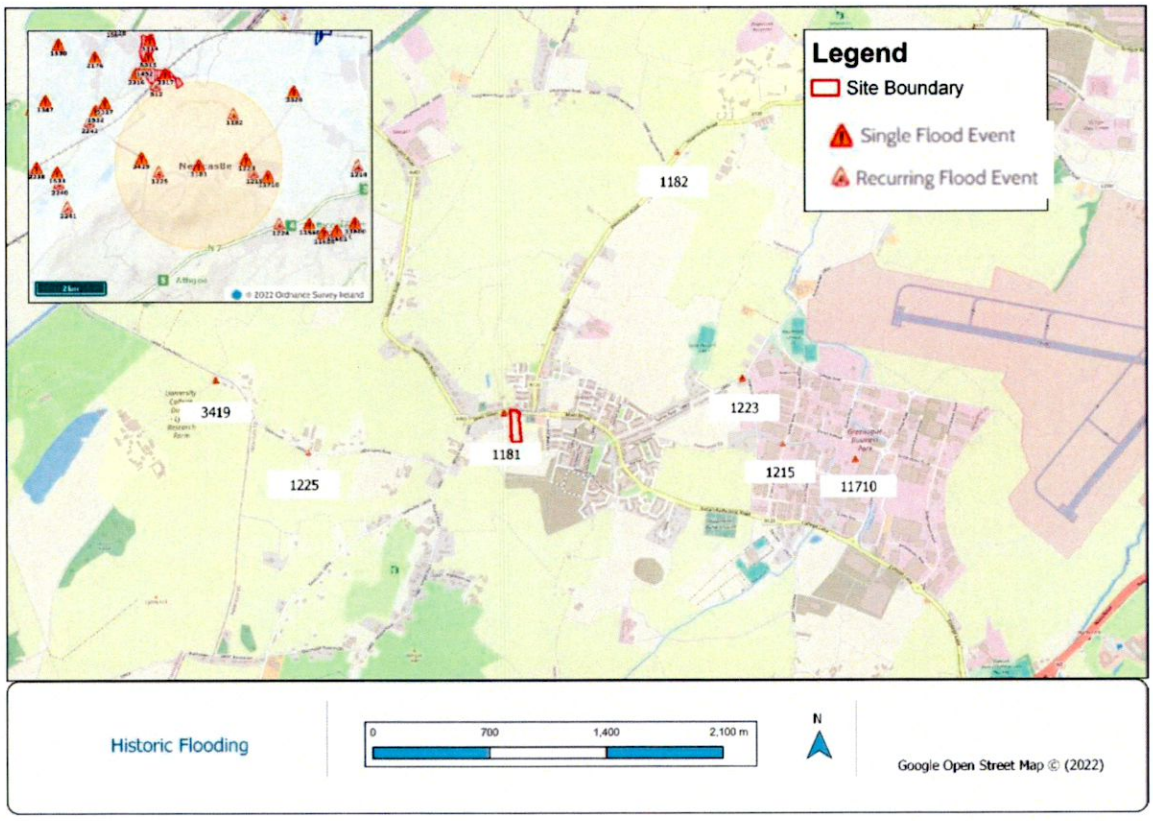


Figure 3-1: Floodinfo.ie

Review of Figure 3-1 shows the flood events recorded within the 2.5km radius from the site location. There are total of 9 food events recorded. One recurring surface water flooding has been recorded by OPW just is to the west of the site along Main Street (R405) c. 50m from the site and it is causing flooding in the basement of a residential house. Flood ID for this location on the OPW website is 1181. The location is mentioned in the minutes of meetings with SDCC. From the site topographical survey the Main Street slope between site boundary and this flood point is falling, it will therefore not impact the proposed site.

3.1.2 Internet Searches

An internet search was conducted to gather information about whether the site was affected by flooding previously. No flooding incidents were recorded at the site, but couple of articles referenced some flooding events in on Main Street in Newcastle village.

3.2 Predicative Flooding

The area has been a subject of the following predicative flood mapping or modelling studies and other related studies and plans:

- Newcastle Local Area Plan 2012
- Eastern Catchment Flood Risk Assessment and Management Study (ECFRAMS)

The level of detail presented by each method varies according to the quality of the information used and the approaches involved.

3.2.1 Newcastle Local Area Plan 2012

The Newcastle Local Area Plan 2012 (hereinafter referred to as the LAP) has been prepared in accordance with the requirements of the Planning and Development Acts 2000-2017 (P&D Acts). The LAP sets out an overall strategy for the proper planning and sustainable development of Newcastle in the context of the County Dublin Plan 2018-2024 (the CDP) and the Border Regional Authority's Regional Planning Guidelines 2010-2022 (RPGs).

Flood risk information covered in the LAP in relation to Newcastle Village is limited to Preliminary Flood Risk Assessment (PFRA) data and flood events recorded by the OPW. Pluvial data identifies the potential for small scale 1% or 1 in a 100 year events occurring in a number of locations along the Main Street. Fluvial data identifies the potential for a 1% or 1 in a 100 year event occurring within the catchment of the River Grifeen.

As it can be seen in Figure 3-2, the proposed development site is located in Flood Zone C, at low probability of flooding.

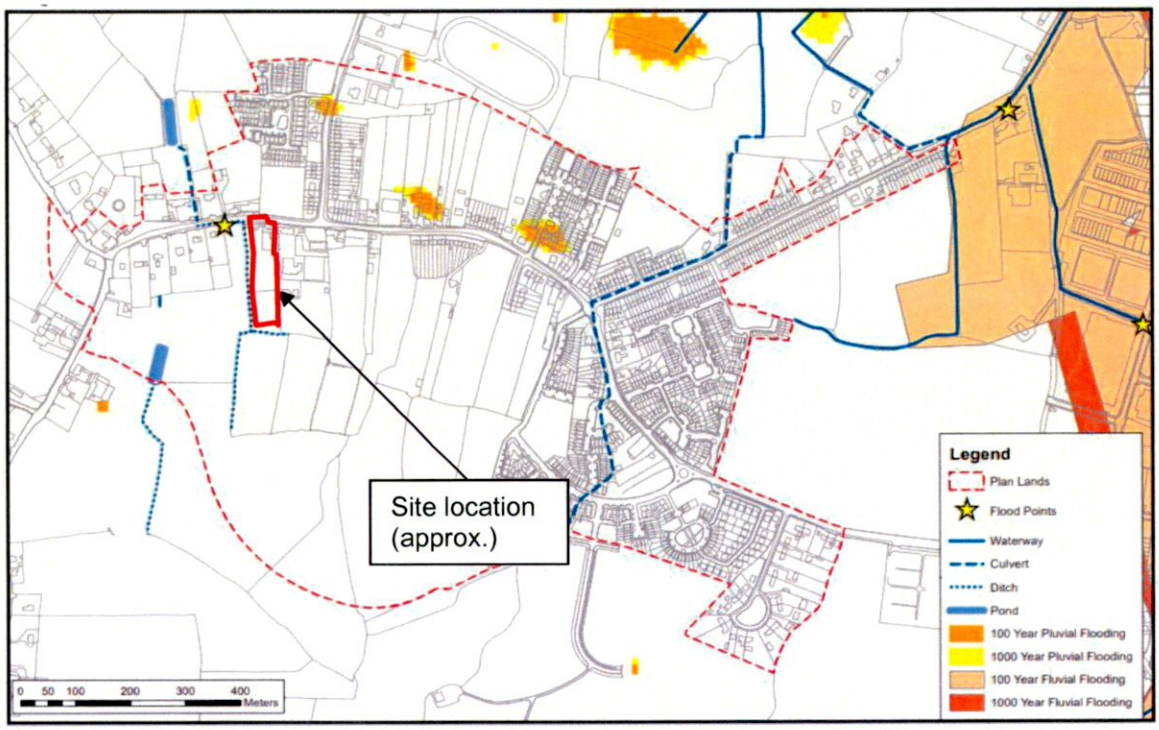


Figure 3-2: Newcastle Local Area Plan map extract (OPW PFRA)

3.2.2 Eastern Catchment Flood Risk Assessment and Management Study (ECFRAMS)

The primary source of data with which to identify flood risk to the site is the Eastern Catchment Flood Risk Assessment and Management Study (Eastern CFRAM Study).

The Grifeen River and its tributaries have been modelled under the ECFRAMS and flood extent maps for the fluvial scenario have been completed. The relevant flood maps are available through the OPW website.

The proposed site is at a significant distance from nearest fluvial extent and therefore the Eastern CFRAM Study identifies the site as being in Flood Zone C and at low risk of fluvial flooding. An extract of the flood map is presented in Figure 3-3.

Figure 3-3: Eastern CFRAM Study Fluvial Flood Map (Source: Floodinfo.ie)

3.3 Culvert Capacity

To estimate the possible flood risk from the existing drainage ditch, which flows along the western boundary of the site (Ref. to Figure 2-1), the channel capacity has been calculated. This was done using the Manning's equation:

$$Q = VA = \left(\frac{1.00}{n}\right) AR^{\frac{2}{3}}\sqrt{S}$$

As the channel is small and during the site visit was dry, the flow has been calculated using the following methods:

- Flood Study Updates Small Catchments (FSU Small Catchment)
- Rational Method
- Institute of Hydrology Report 124 (IH 124)

The full description of the methods is included in the Appendix B.

The results are presented in the table below:

Table 3-1: Flow Estimation of the drain

Return Period	FSU Small Catchment	Rational Method	IH 124	Average
1 % AEP	**0.035 m^3/s**	0.22 m^3/s	0.04 m^3/s	**0.098 m3/s**
0.1 % AEP	**0.09 m^3/s**	0.30 m^3/s	0.06 m^3/s	**0.15 m3/s**
Culvert Capacity[1]				
Discharge capacity Upstream (⌀300mm)[2] = 0.13 m^3/s				
Discharge capacity Downstream (⌀600mm) = 0.69 m^3/s				

From the above results the highest estimated flow is calculated using the Rational Method, the IH124 and FSU Small Catchment methods provide similar results to each other. As conservative approach it was decided to use the average flow of these methods.

Both 1% AEP and 0.1% AEP estimated flows are within the capacity of the culvert for the 0.6m diameter. For the 0.3mm diameter the 0.1% AEP is just 0.02m^3/s difference, which could be ignored at this scale.

[1] Benn et al (2019) Culvert, screen and outfall manual, C786, CIRIA, London.
[2] Culvert diameter is estimated from the site survey works

3.4 Flood Sources

The initial stage of a Flood Risk Assessment requires the identification and consideration of probable sources of flooding. Following the initial phase of this Flood Risk Assessment, it is possible to summarise the level of potential risk posed by each source of flooding. The flood sources are described below.

3.4.1 Fluvial

The proposed site in Newcastle is not located in proximity to any river waterbodies. The only hydrological feature near the site is the drainage ditch and associated culvert (refer to Figure 2-5) flowing from south to north along the western boundary of the site. However, there aren't any past flood events that have been associated with his ditch. Having reviewed the available sources of flooding outlined in Section 3.2, it is clear that the site is in Flood Zone C and at low risk of flooding.

Based on the site visit, although the ditch and culvert were dry it has been identified as the main flood risk to the development. Further analysis has been undertaken in Section 4.1.

3.4.2 Tidal

The site was not deemed to be at risk from coastal flooding.

3.4.3 Pluvial/ Surface Water

Pluvial flooding is the result of rainfall-generated overland flows that arise before run-off can enter a watercourse or sewer. It is particularly sensitive to increases in hard-standing ground/urbanised areas and is usually associated with rainfall events of high intensity.

Pluvial flood risk information is sourced from the PFRA indicative flood maps reviewed within the Newcastle LAP. Some localised flooding is suggested in the village, however none of the are within the proposed site boundary. Review of the historic flood locations identified a recurring flood event just approx. 50m west of the site on the Main Street, which cause a flooding into the basement of a residential house. Having reviewed the site topographical survey, the Main Street elevation between the site boundary and this house is decreasing, therefore it will not impact the proposed site.

Any increase in hardstanding area on the site will result in an increase in surface water ponding. Potential pluvial flooding issues and mitigation measures will be discussed further in Section 4.2.

3.4.4 Groundwater

Groundwater flooding results from high sub-surface water levels that impact upper levels of the soil strata and overland areas that are usually dry. The groundwater vulnerability has been classified as 'Extreme' and 'High' by the GSI groundwater vulnerability maps. Review of the gsi.ie web-portal confirms that there are no known karst features in the area.

In summary, there is no known risk of groundwater flooding in this area. Having reviewed the GSI data, groundwater flooding will not be considered and has been screened out at this stage.

4 Flood Risk Assessment and Mitigation

4.1 Flood Risk

From reviewing the available sources of flooding history outlined in Section 3, there is no identified historic flooding within the site boundary, however Floodmaps.ie indicates a localised recurring flooding along the Main Street (R405) to the west of the site, which is causing a flooding to the basement of a residential house (Ref. to Figure 4-1). The flood location is located in low lying ground, and the road difference in elevation between it and nearest site boundary is c.0.5m, therefore it will not impact upon the site.

Following review of the available information, the site is classified as residing in Flood Zone C therefore, the proposed works to the site are in agreement with "The Planning System and Flood Risk Management Guidelines".

Mitigation and potential residual flood risk will be discussed further in the following sections.

The identified drainage ditch, culverted downstream (Ref to Figure 4-1) that flows along the western boundary from south to north is the only hydrological feature that could cause potential flood risk to the site in case of overtopping during heavy rainfall event or culvert blockage. From the site visit it was noted that the current condition of the ditch is dry.

It is proposed to install a new culvert (300mm) with headwall through site to replace the existing culvert. The existing spring will be retained, and flows contained within the proposed culvert. The culvert capacity has been estimated and both can contain flows up to 0.1% AEP events. However, the spring, culvert and drain will be retained within the post-development design as shown on Figure 4-1.

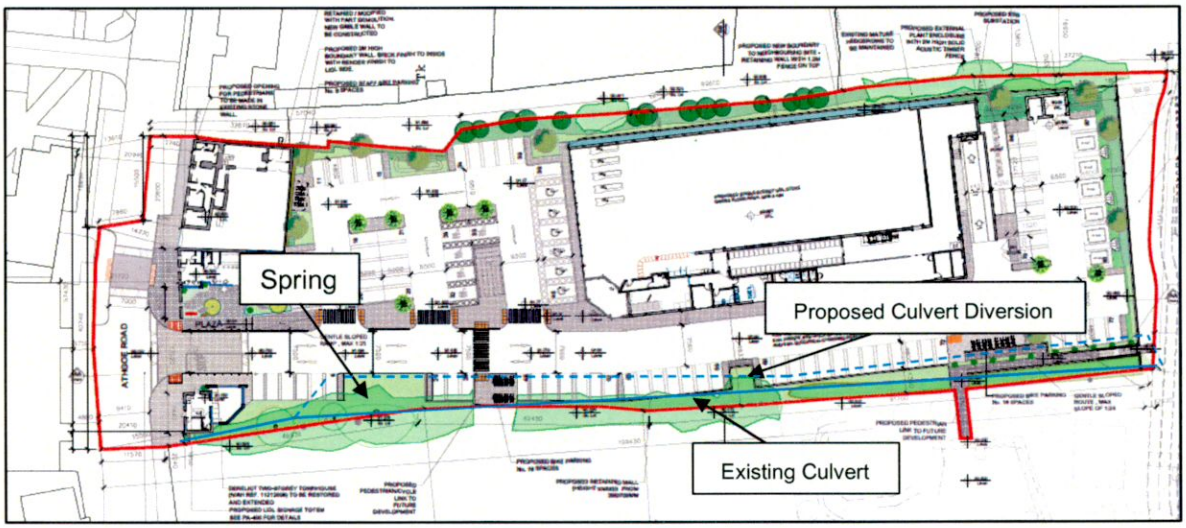


Figure 4-1: Site Layout & Culvert Diversion

4.2 Mitigation Measures

Although the site is located in Flood Zone C mitigation measures for the site are still necessary to consider due to the possible impact the new development may have especially in relation to pluvial flood events, and to ensure residual flood risks do not impact on the development.

4.2.1 Finished Floor Levels

There are no specific mitigation measures required to manage fluvial flood risk at the site, as it is located in Flood Zone C.

However, to further minimise the risk of inundation from pluvial flooding, which is discussed further in Section 4.2.3, a threshold of 100mm has been provided between the FFL and external hardstanding areas. The proposed FFL for the store is 92.00mOD while the external access road elevation is set at 91.90mOD which provides the required freeboard.

4.2.2 Access

Access to the site will remain unchanged in the proposed development. The access route to the site, located along the Main Street (R405) lies within Flood Zone C therefore there will be no restriction of access to the site during the 1% and 0.1% AEP fluvial flood events. In a worst-case scenario of heavy rainfall and the drainage ditch being overtopped, the excess water will flow through the entrance following the road slope to the west.

4.2.3 Surface Water / Pluvial Flood Risk

The proposed development will increase the hardstanding area onsite and therefore could potentially increase the surface water runoff from the site if not mitigated against. There is no identified pluvial flooding onsite based in the historic flood information and site survey data. There is a steep fall across the site (south-north) without any depressions that would be at risk of pluvial flooding.

Any surface water onsite will be managed post-development by the stormwater system, that has been designed in accordance with the GDSDS and governing Local Authority development plan standards. Stormwater discharge from the site has been limited to 2.06l/s and an attenuation storage volume of 618m^3 has been provided. This will ensure that surface water within the site is appropriately managed.

To minimise the risk of pluvial flooding, a threshold of 100mm is required from the FFL to the external ground levels.

4.3 Residual Risk/Climate Change

Residual risks are defined as risks that remain after all risk avoidance, substitution and mitigation measures have been taken. The flood risk assessment identifies the following as the main sources of residual risk to the proposed development:

- Failure of on-site surface water attenuation system,
- Failure of the proposed surface water flow culvert.

The proposed FFLs and recommended threshold of 100mm is sufficient to protect the development during a failure of the stormwater system. A steep fall is present onsite, therefore if the stormwater system was to fail the resulting surface water will be directed off site without impacting on the proposed store.

Regarding the proposed culvert replacement, the included headwall will reduce the risk of blockage and improve the efficiency of the culvert. If the culvert where to block, the resulting surface waters will flow along the greenway provided along the western boundary of the site. In a worst case scenario, the surface water flows can flow along the access road without impacting upon the store.

For climate change, an allowance has been included within the stormwater design calculations, therefore the development will be protected from the potential impacts from climate change.

5 Conclusion

JBA Consulting has undertaken a Flood Risk Assessment for the proposed development of a Lidl Store at Newcastle, Co. Dublin. The site is currently a brownfield site with small buildings that will be demolished.

Review of the Newcastle LAP and Eastern CFRAM study flood maps confirms that the site is not at risk of inundation from the 1% AEP or 0.1% AEP fluvial or coastal flood events. This places the site within Flood Zone C.

There is no recorded occurrence of pluvial flooding at the site but Floodmaps.ie indicate some localised recurring flooding along the Main Street (R405) to the west of the site causing flooding to the basement of residential building (Ref. to Figure 4 1). The flood location is located in low lying ground, and the road difference in elevation between it and nearest site boundary is c.0.5m, therefore it will not impact the site.

Pluvial flooding has been assessed for the site and none has been identified onsite. A steep fall is present onsite (south-north) towards the Newcastle Road, with no depressions onsite that would be at risk of pluvial flooding. A stormwater system has been included within the development to manage surface water flows onsite. The system discharges to the existing culvert at the site's north-western boundary, and the discharge has been limited to 2.06l/s which is the greenfield equivalent. The stormwater system has been designed in accordance with the GDSDS standards and an attenuation storage volume of 618m^3 has been provided.

The proposed FFL has been set at 92.00mOD which provides a threshold of 100mm above the surrounding hardstanding area. This will minimise the pluvial flood risk to the site post-development.

The identified drainage ditch, culverted downstream (Ref to Figure 4-1) that flows along the western boundary in a south to north direction is the only hydrological feature in the area. The ditch was dry during the site visit. The existing 300mm culvert will be re-routed thorough the site and a headwall will be installed to minimise flood risk. The existing spring and its connection to the culvert will be maintained within the proposed development. The culvert capacity has been estimated and it can contain flows up to 0.1% AEP events.

Regarding residual risks, if failure of the culvert or stormwater system was to fail in a worst case scenario surface waters will be contained within the car park access road and diverted offsite without impacting the store building.

In summary, the site is shown to be in Flood Zone C and therefore is appropriate for commercial development at this location.

The Flood Risk Assessment was undertaken in accordance with 'The Planning System and Flood Risk Management' guidelines and is in agreement with the core principles contained within.

Appendices

A Understanding Flood Risk

Flood Risk is generally accepted to be a combination of the likelihood (or probability) of flooding and the potential consequences arising. Flood Risk can be expressed in terms of the following relationship:

Flood Risk = Probability of Flooding x Consequences of Flooding

A.1 Probability of Flooding

The likelihood or probability of a flood event (whether tidal or fluvial) is classified by its Annual Exceedance Probability (AEP) or return period years, a 1% AEP flood 1 in 100 chance of occurring in any given year. In this report, flood frequency will primarily be expressed in terms of AEP, which is the inverse of the return period, as shown in the table below and explained above. This can helpful when presenting results to members of the public who may associate the concept of return period with a regular occurrence rather than an average recurrence interval and is the terminology which will be used throughout this report.

Table: Conversion between return periods and annual exceedance probabilities

Return period (years)	Annual exceedance probability (%)
2	50
10	10
50	2
100	1
200	0.5
1000	0.1

A.2 Flood Zones

Flood Zones are geographical areas illustrating the probability of flooding. For the purpose of the Planning Guidelines, there are 3 types of levels of flood zones, A, B and C.

Zone	Description
Flood Zone A	Where the probability of flooding is highest, greater than 1% (1 in 100) from river flooding or 0.5% (1 in 200) for coastal/ tidal Flooding
Flood Zone B	Moderate probability of flooding, between 1% and 0.1% from rivers and between 0.5% and 0.1% from coastal/ tidal.
Flood Zone C	Lowest probability of flooding, less than 0.1% from both rivers and coastal/ tidal.

It is important to note that the definition of the flood zones is based on an undefended scenario and does not take into account the presence of flood protection structures such as flood walls or embankments. This is to allow for the fact that there is a residual risk of flooding behind the defences will be maintained in perpetuity.

A.3 Consequences of Flooding

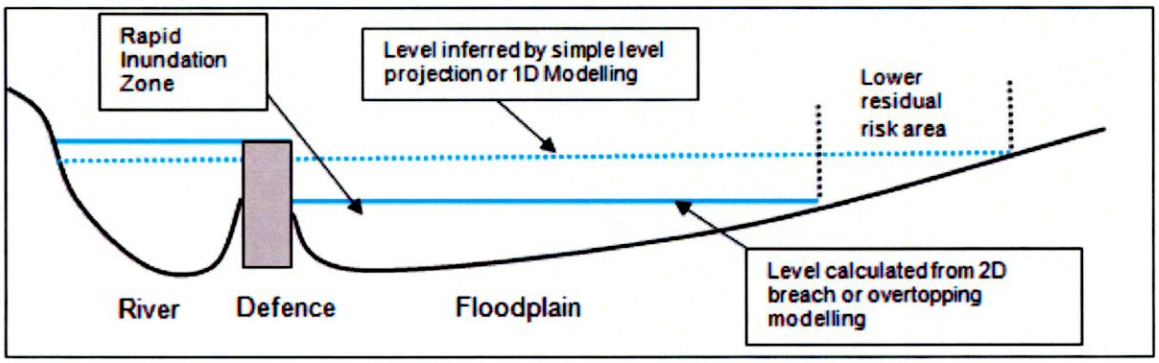
Consequences of flooding depend on the Hazards caused by flooding (depth of water, speed of flow. Rate of onset, duration, wave-action effects, water quality) and the vulnerability of receptors (type of development, nature, e.g. age-structure of the population, presence and reliability of mitigation measures etc.)

The 'Planning System and Flood Risk Management' provides three vulnerability categories, based on type of development, nature, which are detailed in Table 3.1 of the Guidelines, and are summarised as:

- **Highly vulnerable**, including residential properties, essential infrastructure, and emergency service facilities
- **Less vulnerable**, such as retail and commercial and local transport infrastructure, such as changing rooms.
- **Water compatible**, including open space, outdoor recreation and associated essential infrastructure, such as changing rooms.

A.4 Residual Risk

The presence of flood defences, by their very nature, hinder the movement of flood water across the floodplain and prevent flooding unless river levels rise above the defence crest level or a breach occurs. This is known as residual risk.



B Flow Estimation Methods

B.1 Flood Studies Update (FSU) Small Catchments Method

Where catchments are lower than 25km2 it is recommended that the FSU small catchment equation is used, as given below:

$$Qmed = (2.0951*10^{-5})*(AREA^{0.9245})*(SAAR^{1.2695})*(BFI^{-0.9030})*(FARL^{2.3163})*(S1085^{0.2513})$$

The multivariate regression equation was developed on the basis of data from 199 gauged catchments, linking Qmed to a set of catchment descriptors.

Where:
AREA is the catchment area (km2).
BFIsoils is the base flow index derived from soils data
SAAR is long-term mean annual rainfall amount in mm
FARL is the flood attenuation by reservoir and lake
S1085 is the slope of the main channel between 10% and 85% of its length measured from the catchment outlet (m/km).

The above equation provides a Qmed value of 0.035 m^3/s for the catchment.

The urban extent can be taken into account using the following equation:

$$Q_{MEDfinal} = Qmed\,(1 + URBEXT)^{1.482}$$

Where URBEXT is the percentage of the catchment covered by urban land use.

The growth factors for this site are also calculated from the FSU using pooling groups.

For pooled analysis within the FSU, gauges are chosen on the basis of their similarity with the subject catchment according to three catchment descriptors, i.e. AREA, SAAR and BFIsoil. The report on FSU WP 2.2 presents two alternative equations for calculating the similarity of catchments according to these three descriptors. For this study, equal weight was given to each of these variables, applying the similarity distance formula given as Equation 10.2 in the report on FSU WP 2.2.

For pooled growth curves, WP 2.2 recommends considering 3-parameter distributions, because the extra data provided by the pooling group ensures that the standard error is lower than it would be for single-site analysis. The report states that either the generalised extreme value (GEV) or generalised logistic (GLO) distributions are worth considering. For this study, GLO has been fitted for the pooled analysis.

B.2 IH124

The IH 124 Report examined the response of small catchments, less than 25km^2, to rainfall and derived an improved flood estimation equation (Marshall & Bayliss, 1994). A total of 87 sites were used to develop the method. The report developed a new equation to estimate the mean annual flood, QBAR (in m3/s), for small rural and urban catchments.

QBARrural = 0.00108 AREA0.89 SAAR1.17 SOIL2.17 and

QBARurban = QBARrural (1 +URBAN)2NC [1 +URBAN{(21/CIND) - 0.31]

Where: NC is "rainfall continenality factor".
NC = 0.92 – 0.00024SAAR, for 500 _ SAAR _ 1100mm,
NC = 0.74 – 0.000082SAAR, for 1100 _ SAAR _ 3000mm, and
CIND is a catchment index defined as a function of SOIL and catchment wetness index (CWI), both as in FSR (1975)

The estimated QBAR is then multiplied by the growth factors derived by the FSR to estimate design flows for specified return periods. For example, QBAR is multiplied by 1.96 to get the 100-year peak flow.

The IH 124 method uses a regional growth curve for estimating design event peak flows.

Table 5-1: FSR Regional Growth Curve for Ireland

Annual Exceedance Probability (%)	Growth curve
50% (2yr)	0.95
20% (5yr)	1.20
10% (10yr)	1.37
5% (20yr)	1.54
2% (50yr)	1.77
1% (100yr)	1.96
0.1% (1000yr)	2.60

B.3 The Rational Method

The rational method directly links rainfall within a catchment to the peak flows experienced within the watercourse or stormwater design. The rational method equation used is:

$$Q = kCiA$$

Where Q = flow (l/s), k = conversion factor (2.78), C = runoff coefficient (dimensionless coefficient determined using tables and assessing the catchment topography and landuse), i = rainfall intensity (mm/hr) and A = area (ha)

The estimated flow in l/s is then converted into m^3/s.

The use of a runoff coefficient allows the land use of the catchment to be accounted for in the equation in terms of how much of the total rainfall will in turn become flow. An area weighting was applied to allow different C values to be applied to the rural and urban sections of the catchments. The weighting of area was based on an estimated URBEXT value for each catchment.

To estimate rainfall intensity (i), the Time of Concentration (ToC) for each sub catchment was estimated. The following ToC equations was used in this study: **Bransby-Williams equation**: This equation is used for ToC estimation in rural or landscaped catchments:

Bransby-Williams Equation

$$ToC = Fc \times L/A1/10 \times S1/5$$

Where,

ToC = time of concentration (minutes)

Fc = conversion factor (58.5 for when metric units are used)

L = flow path length (km)

A = catchment area (km^2)

S = slope of flow path (m/km)

(information sourced from https://www.water.gov.my/jps/resources/auto%20download%20images/5846466de8441.pdf)

Following ToC estimation, rainfall depth data from Met Eireann was obtained for each catchment and used to calculate rainfall intensity in mm/hr. The rational method equation was then applied, and peak flows estimated.

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