

TRALEE FLOOD RELIEF SCHEME

Hydraulics Report



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TRALEE - FLOOD RELIEF SCHEME

HYDRAULICS REPORT

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Prepared by:

Prepared for:

RPS**Kerry County Council**

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rpsgroup.com

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RPS Consulting Engineers Limited, registered in Ireland No. 161581
RPS Engineering Services Limited, registered in Ireland No. 99795
The Registered office of each of the above companies is West Pier
Business Campus, Dun Laoghaire, Co. Dublin, A96 N6T7



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1 INTRODUCTION

1.1 Background

This report provides details of the hydraulic analysis and modelling undertaken as part of the Tralee Flood Relief Scheme. The objective of this project is the identification, design and submission (for planning consent) of a Flood Relief Scheme, that is technically, socially, environmentally and economically acceptable, to alleviate the risk of flooding to the town of Tralee to a determined Standard of Protection, and to procure, manage and oversee the construction of that Scheme. A Steering Group was established between the Office of Public Works (OPW) and Kerry County Council (KCC) to direct and guide the development of the FRS.

The hydraulic modelling is being undertaken in three distinct phases:

- *Phase 1:* To establish and replicate the existing hydraulic conditions.
- *Phase 2:* To assess the performance of potential options and the preferred Scheme.
- *Phase 3:* To establish and replicate the hydraulic conditions following construction of the Scheme.

This report describes the Phase 1 analysis, with details of the Phase 2 and Phase 3 analyses to follow in subsequent reporting.

1.2 Study Area and Catchment Overview

Tralee lies within the Lee sub-catchment, a large sub-catchment of the Tralee Bay-Feale catchment. The main source of flood risk to Tralee emanates from the River Lee and its two main tributaries, the Big River and Balloonagh River, which flow through Tralee Town and the study area. There are other tributaries of the Lee which also need to be considered, such as the Ballyvelly, Ballybeggan, Cloghers and Ballinorig Rivers. The study area and the watercourses to be modelled are shown in Figure 1.1.

Flood levels in the River Lee are tidally influenced from Tralee Bay at the mouth of the river. The topography of the area is also a contributing factor with the River Lee, Big River, Balloonagh, Ballinorig and Ballybeggan draining the steep sloping ground of the Stack's Mountains to the north and northeast of the study area, with the Slieve Mish Mountain range to the south being drained by tributaries of the River Lee, namely Ballyvelly and Cloghers. The development of flood relief options will consider the interaction of flows in each of these water bodies and the associated impact on flooding in Tralee.

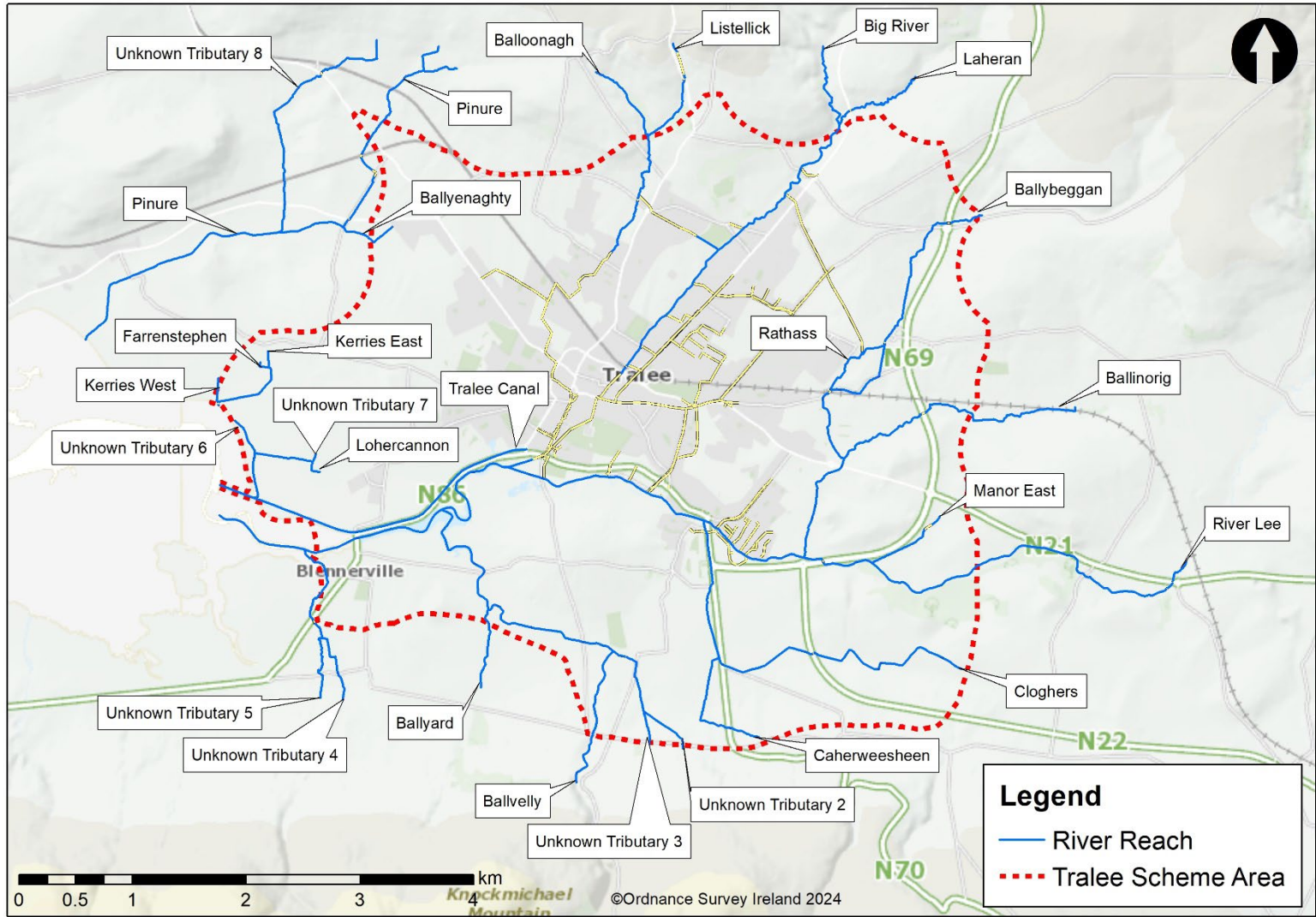


Figure 1.1: Tralee FRS Study Area Watercourses

2 DATA COLLECTION

2.1 Flood Event History

The Study Area has been subject to significant fluvial, pluvial and coastal flooding, most notably in November 1973, August 1986, November 2009 and December 2015 (Storm Desmond). The significant flood event on the 5th of August 1986 led to the development of the Tralee Flood Relief Scheme (TFRS). Following the completion of the TFRS in 1992, flood events in Tralee Town have decreased in frequency and severity but still occurs. A summary of the flood history at Tralee is presented in the Hydrology Report (Tralee FRS Hydrology Report, document no IBE1899, RPS, 2023)¹ Section 1.4.

2.2 Existing Hydraulic Models and Reports

2.2.1 Shannon CFRAM Study UoM23 Hydrology Report, OPW, 2011

The Shannon CFRAM Study UoM23 Hydrology Report² provides a detailed review of historic floods (up to 2011), analysis of river flow, water level and rainfall data. The report contains analysis of catchments and sub-catchments to derive estimates of event probabilities, peak fluvial flood flows and hydrographs, coastal flood levels and joint probability of occurrence throughout Tralee and other areas.

2.2.2 Shannon CFRAM Study UoM23 Hydraulics Report, OPW, 2011

The Shannon CFRAM Study UoM23 Hydraulics Report³ provides information relating to the modelling that was carried out within Tralee and other areas within Unit of Management 23. The report includes detail on hydraulic model build including input data, model schematisation and construction, sensitivity analysis, calibration, verification, model limitations and handover notes for future users.

2.3 Topographical Surveys

2.3.1 Existing Topographical Survey Data

As part of the Shannon CFRAM Study, a topographical survey was undertaken of the River Lee and River Big reaches along with a number of their tributaries. The survey was carried out by Murphy Geospatial in July 2013, with the raw survey data available for use in the Tralee FRS.

¹ [Tralee FRS Hydrology Report](#)

² [NWNB CFRAM Study UoM01 Hydrology Report](#)

³ [NWNB CFRAM Study UoM01 Hydraulics Report](#)

2.3.2 2021 Survey Data

2.3.2.1 Topographic Survey

Additional survey data was required to produce the more detailed Tralee hydraulic model required for flood relief scheme development. The survey specification was prepared based on the project brief, informed by KCC, OPW and RPS' knowledge of the area and procured through the 'OPW Multi Supplier Framework for the provision of Surveying Services'. Full details of the specification are provided in the Supplementary Request for Tenders report (IBE1899Rp001_SRFT_D01), and can be summarised as:

- **Building Threshold Surveys** – all buildings within the 0.1% AEP flood extent as defined in the Shannon CFRAM Study.
- **Channel and Structure** – Cross-sections and river infrastructure survey were specified along the River Lee, River Big, Ballyvelly, Ballybeggan, Cloghers and Ballinorig to be surveyed at the same location as previous survey (CFRAM Study) to allow comparison and assessment of the geomorphological changes (see 3.1.3.5). Survey cross sections were also required at new locations to provide the required resolution of the survey data for the hydraulic model. An overview of reaches specified for survey is shown in Figure 2.1, structure and flood defence surveys are outlined in Figure 2.2.
- **Flood Embankments and Flood Walls** – The flood defence survey covers approximately 19.42km of embankment and roads throughout Tralee. These include the Tralee Canal embankments and Tralee Bay Wetlands embankments.
- **Gauge Surveys** – There are six hydrometric gauging stations within the study area which required detailed survey as these will be subject to rating reviews. These include Station 23012 (Ballymullen), Station 23044 (Lisloose), Station 23045 (Ballyseedy), Station 23046 (Spring Water Lane), Station 23047 (Oakpark Road) and Station 23049 (Manor West, Ballybeggan). These rating reviews are discussed in more detail in section 2 of the Tralee FRS hydrology report. A further five hydrometric gauges relevant to the study area are to be surveyed but no rating review will be carried out on these. These five hydrometric gauges are Station 23011 (Ballycarty), Station 23013 (Oakview), Station 23022 (Clonalour), Station 23062 (Blennerville) and Station 23063 (Ballyard). An overview of the hydrometric gauge survey locations is shown in Figure 2.3.

Murphy Geospatial were appointed to undertake the survey, works commenced on site on the 27th of January 2021 and were completed on the 16th of February 2021. Final deliverables were issued to the Steering Group on 17th June 2021.

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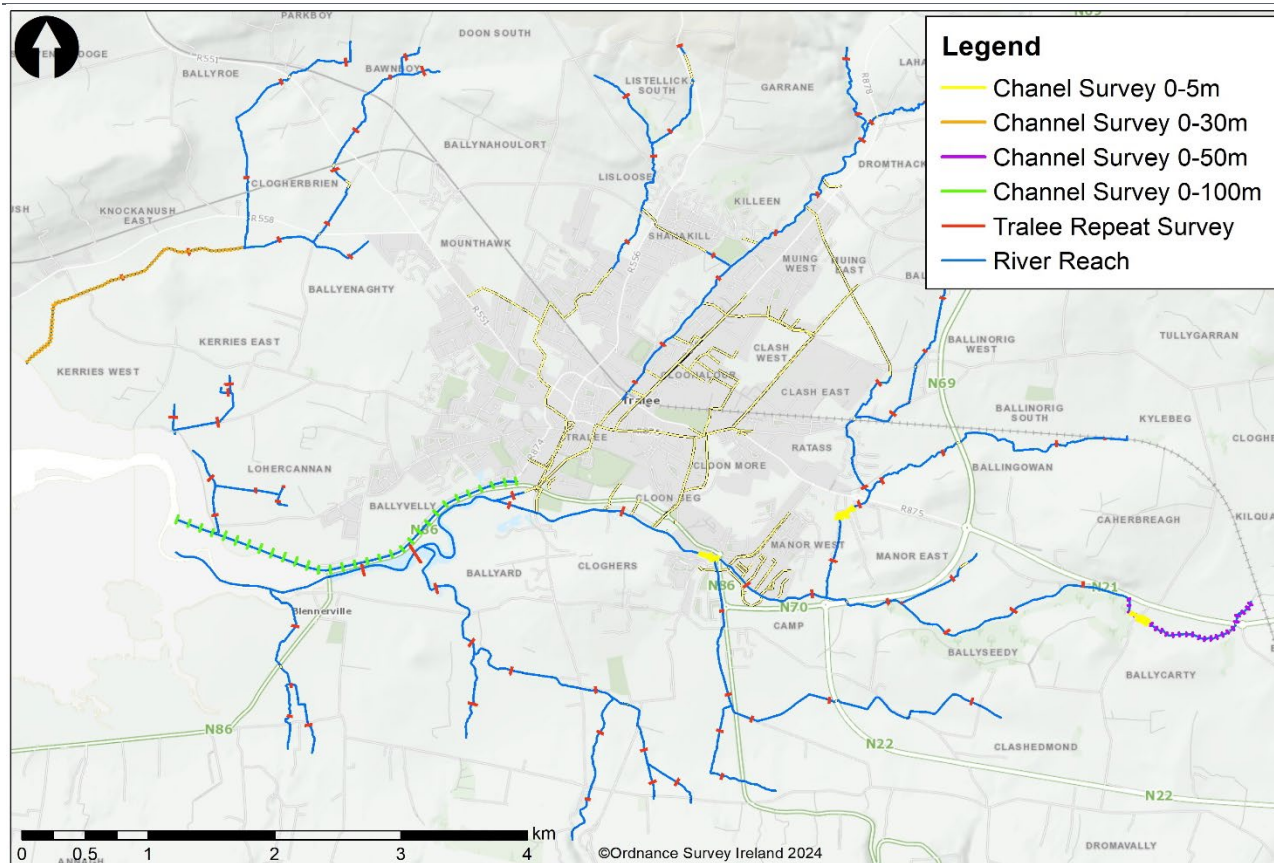


Figure 2.1: River channel survey specification

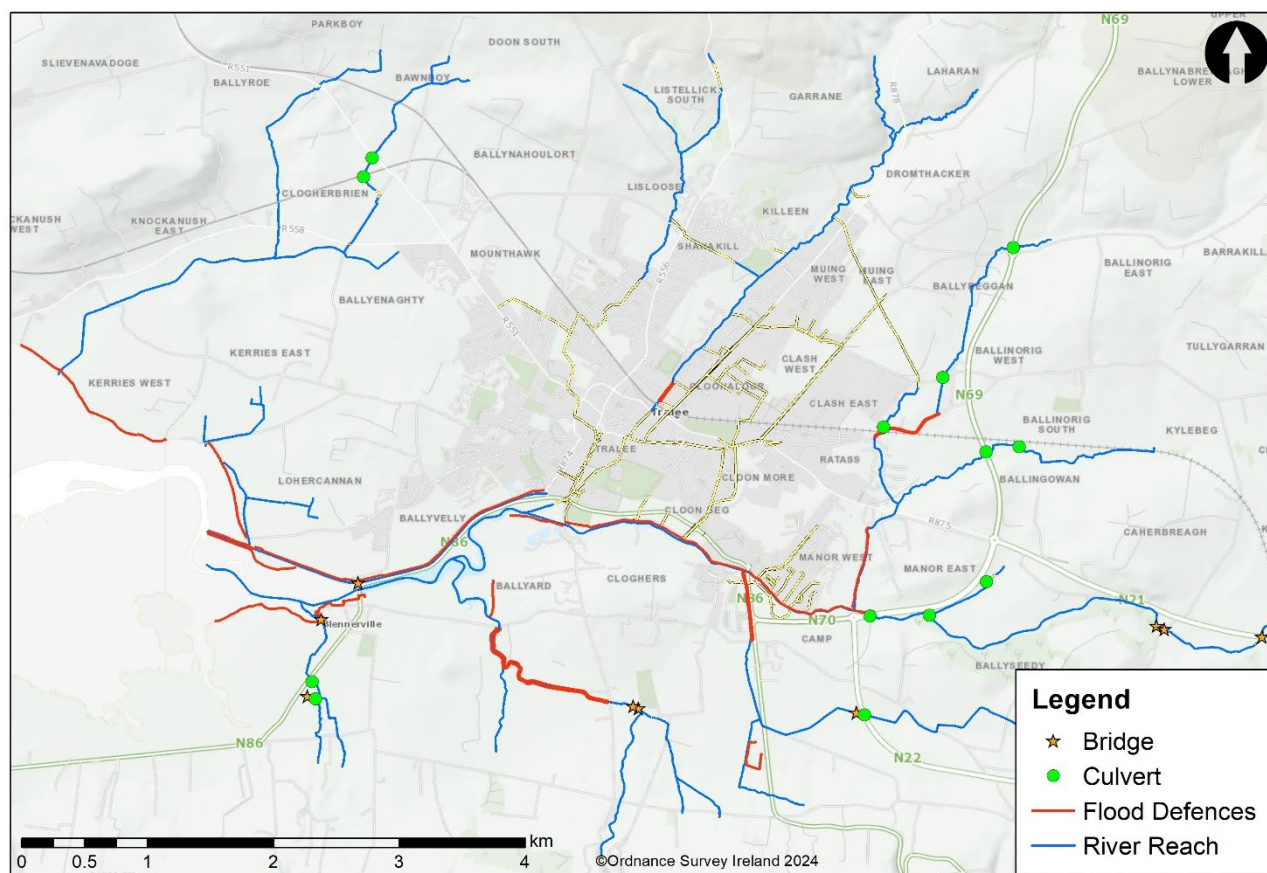


Figure 2.2: Structure survey specification

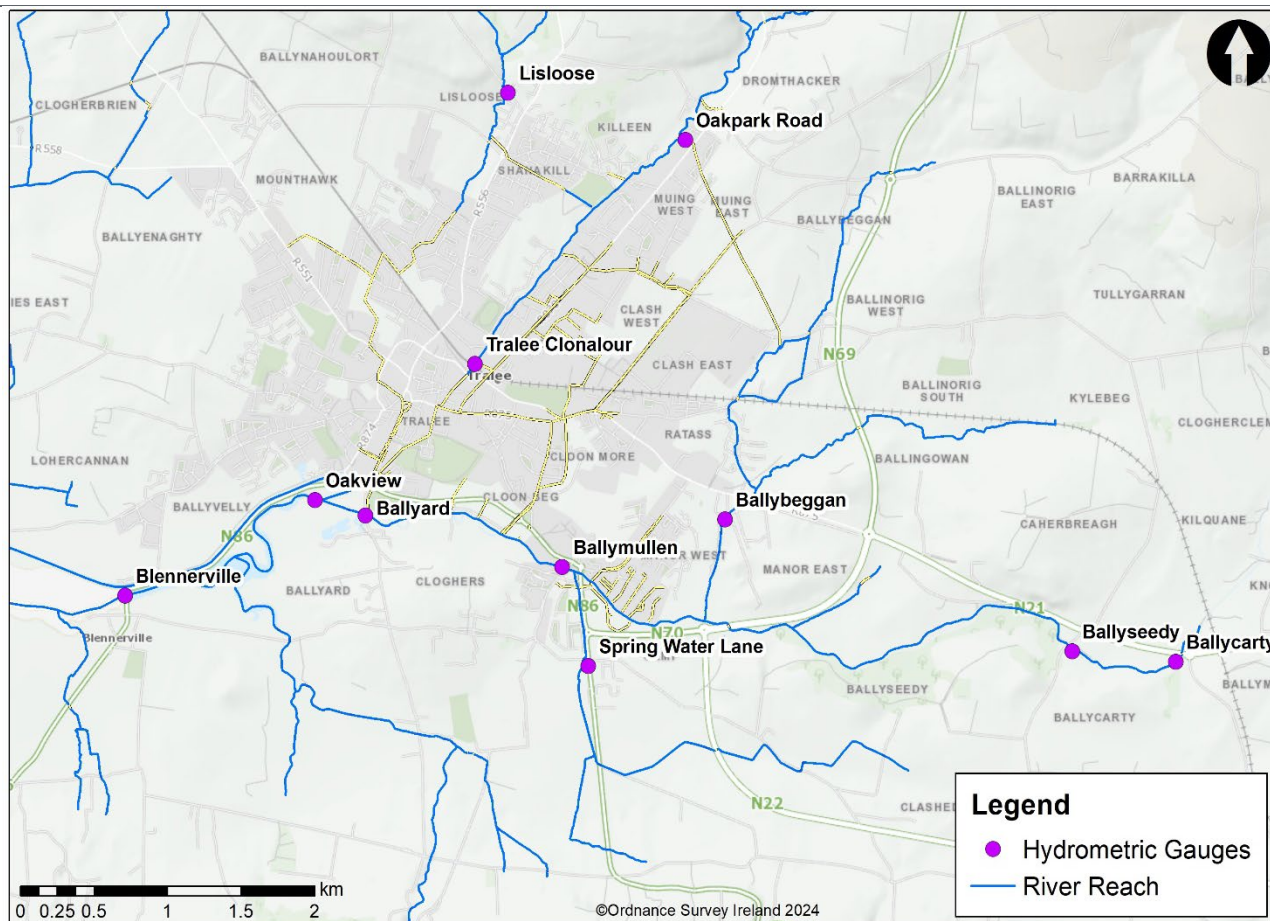


Figure 2.3: Hydrometric gauge survey specification

2.3.2.2 Flow Survey

A flow survey was carried out in various locations around the Tralee Scheme Area. The aim of the survey was to monitor flow at key locations of the storm water drainage network in Tralee, and record rainfall to provide data which may aid in the calibration of the model. The flow survey consisted of 14 flow/depth monitors and three rain gauges. The location of these monitors and gauges is shown below in Figure 2.4. The survey was carried out by Amelio between 17/06/22 and 16/08/22, during this period three rainfall events occurred which were considered significant enough to help inform the model calibration. These occurred on the 24-28/06/22, 30-31/07/22 and 15/08/22.

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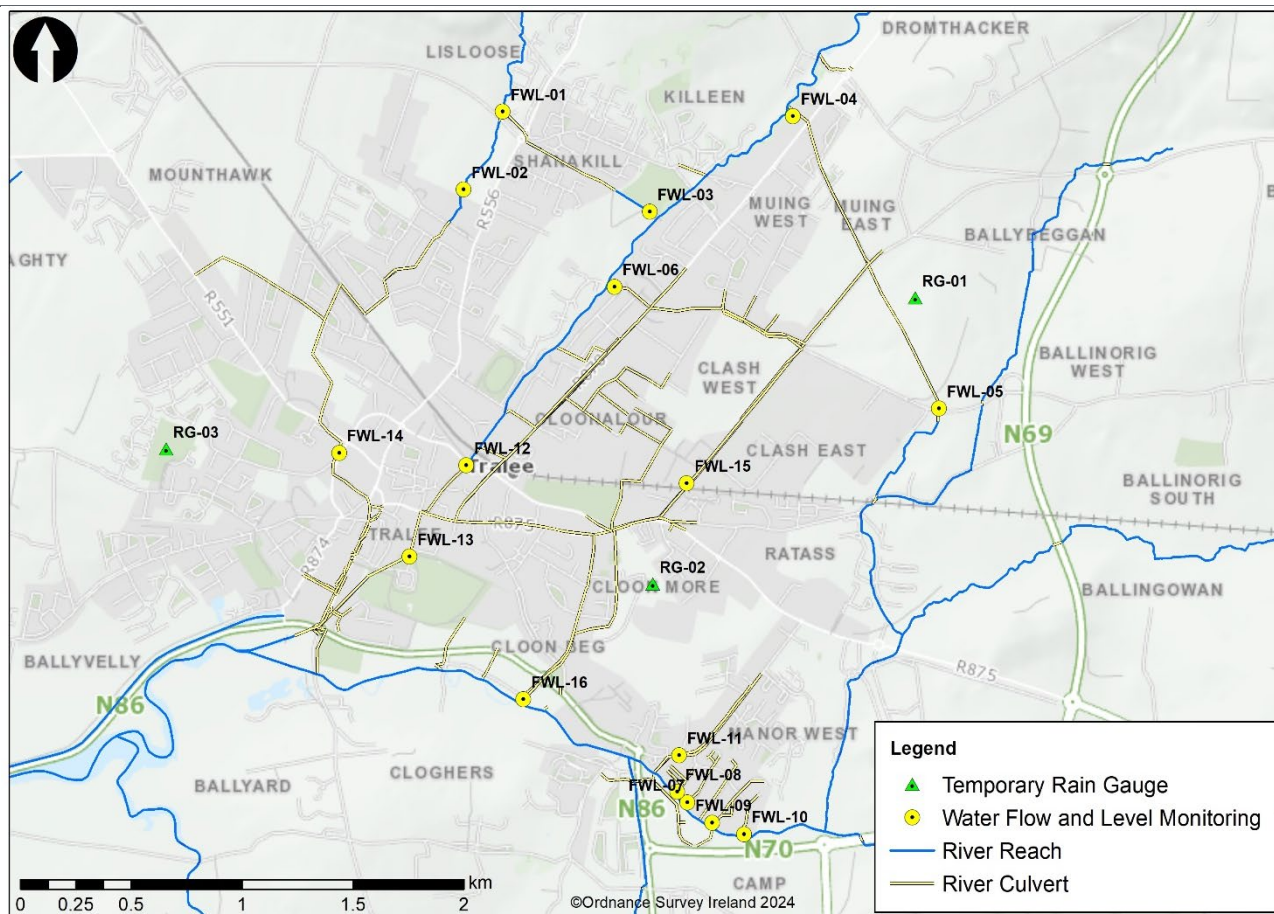


Figure 2.4: Flow Monitor and Rainfall Gauge Locations

2.3.2.3 Culvert Survey

Additional survey data was required for 29 culvert and drainage network systems within the Tralee Study Area to inform the detailed hydraulic model required for FRS development. The locations of these are shown in Figure 2.5. Included are drainage networks at Manor West, Hunters Wood and Clash Road along with the diversion culvert between the Balloonagh River and Big River. The procured culvert survey information included route tracing of culverts, photographs and video footage to understand internal conditions (any blockages or faults) and sizing of the culverts. The survey specification was prepared based on the project brief, informed by KCC, OPW and RPS' knowledge of the area and procured through the 'OPW Multi Supplier Framework for the provision of Surveying Services'. Full details of the specification are provided in the Supplementary Request for Tenders report (IBE1899Rp001_SRFT_DF01).

Murphy Geospatial were procured to undertake additional gully surveys which were delivered for in the model on the 21/12/2023. These were included in the model to better replicate flood risk along Prince's Street which is flooded during high frequency tidal events. Flooding along this street and other areas such as Castlecountess and James Street are often the result of tidal propagation through the drainage network and gullies. Gully locations are shown in Figure 2.5.

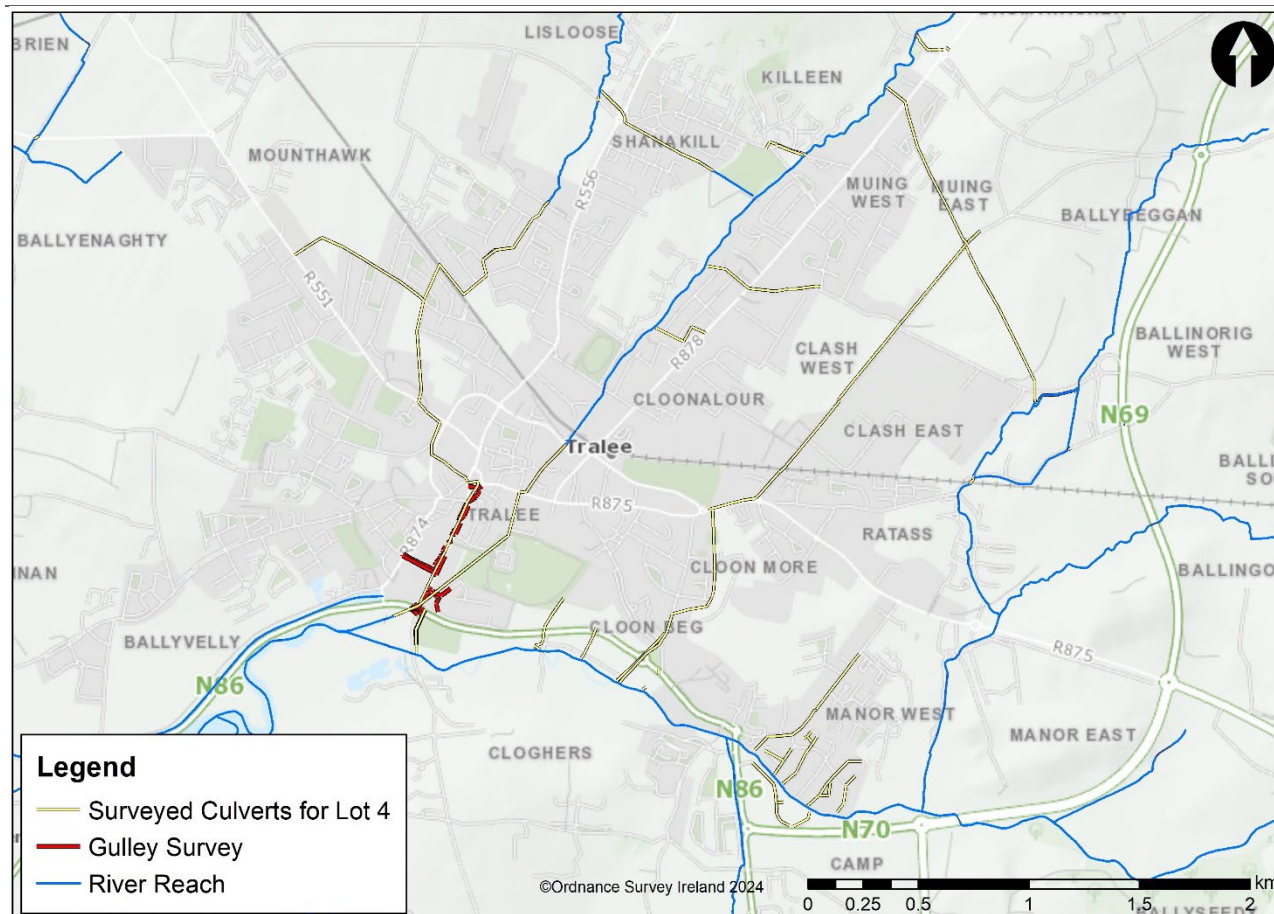


Figure 2.5: Culverts and pipes included in CCTV Survey, including additional Gulley Survey

2.3.2.4 Uisce Éireann DAP Model

The Uisce Éireann DAP model was supplied for the Tralee FRS. The DAP model was used to inform the surface water drainage networks which have been used in the Tralee FRS. The DAP model provided information on the surface water pipe sizes, dimensions and subcatchment parameters which were used in the Tralee FRS model. More detail on the DAP model is in Section 3.1.4.3.

2.4 Surface and Terrain Models

The LiDAR dataset collected for the Shannon CFRAM study was available for use in the Tralee FRS. However, the OPW were collecting new LiDAR data in other areas during the early stages of the project, as such the opportunity was taken to update the LiDAR for the study area to ensure any development and topographical changes were captured. The new LiDAR dataset has a 0.25m resolution providing a highly detailed representation of topographical features within the study area.

2.4.1 LiDAR Processing

When captured, LiDAR data contains features such as buildings and vegetation which must be removed to produce a bare earth Digital Terrain Model (DTM) dataset which can be used to accurately define overland

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flow paths in the 2D domain of the computational model. Due to the nature of the processing and the bespoke software used to undertake it, the processing to produce the DTM is undertaken by the contractors who collect the data. The large majority of this processing was undertaken by the contractor for the new Tralee LiDAR dataset, however upon receipt of the dataset a high level visual check indicated that some vegetation may not have been completely removed. Figure 2.6 illustrates the features in the LiDAR which were thought to be vegetation (lighter coloured lines), the majority of the areas of concern were located along field boundaries which would generally be defined by dense hedgerows. The elevation of some of these features was 2m – 3m above the adjacent ground and could therefore introduce a barrier to flow in the model.

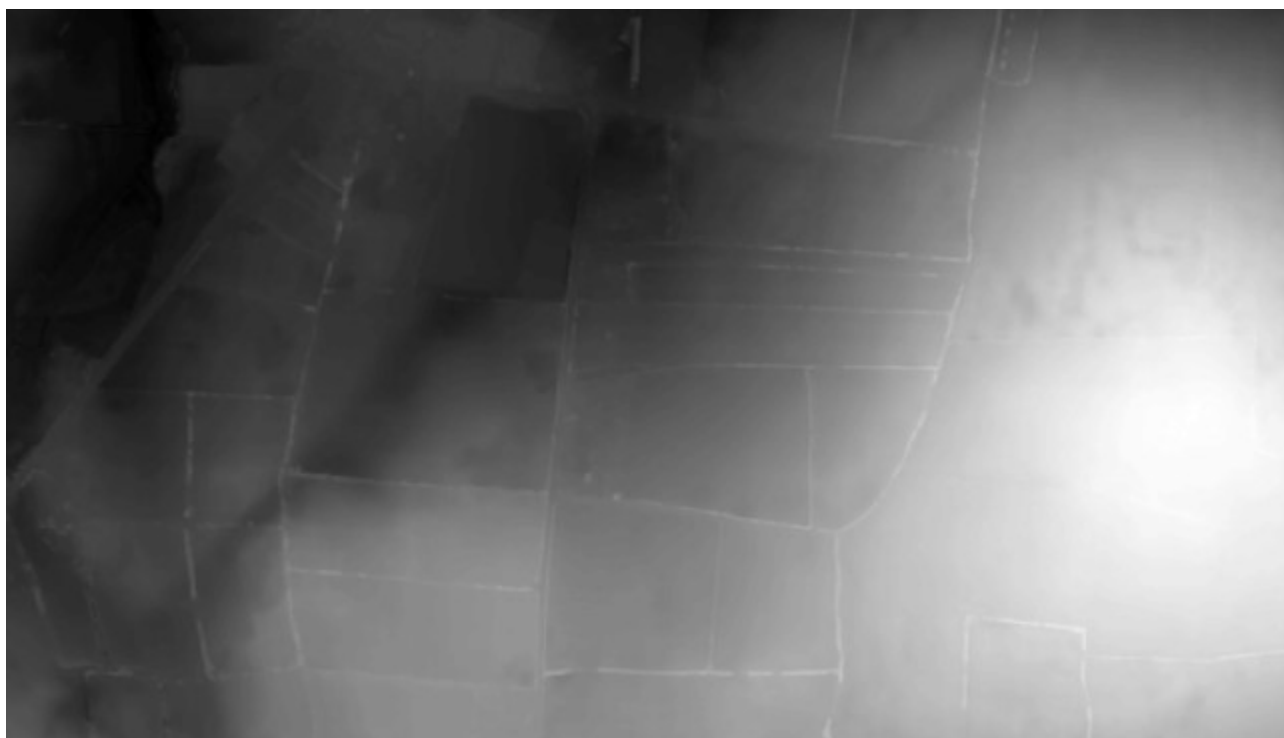


Figure 2.6: Potential Retained Vegetation

Upon consultation with the KCC, OPW and the LiDAR contractor, instruction was given to undertake additional processing of the LiDAR to remove the areas of concern. The proposed methodology was agreed by the Steering Group and is detailed below.

2.4.1.1 LiDAR Processing Methodology

1. Identify areas of concern – it was agreed with the Steering Group that the most efficient method of identifying the areas of concern was to undertake a comparison with the LiDAR captured for the CFRAM study as it did not contain the features. This comparison was carried out by undertaking a raster calculation using GIS software. The CFRAM data was subtracted from the new FRS data to produce a comparison raster containing all areas where the datasets differed in level as shown in Figure 2.7.
2. A visual analysis of the comparison raster indicated that the majority of the area had a difference of less than 250mm, this was therefore chosen as the differential threshold. It should be noted that there

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were areas where the difference between the rasters was negative, these were ignored during processing.

3. The comparison raster was processed to remove all areas below the chosen threshold. This processing produced an areas for assessment raster and highlighted all areas with in the new FRS LiDAR which had a higher elevation (greater than the chosen threshold) than the CFRAM LiDAR, Figure 2.8.

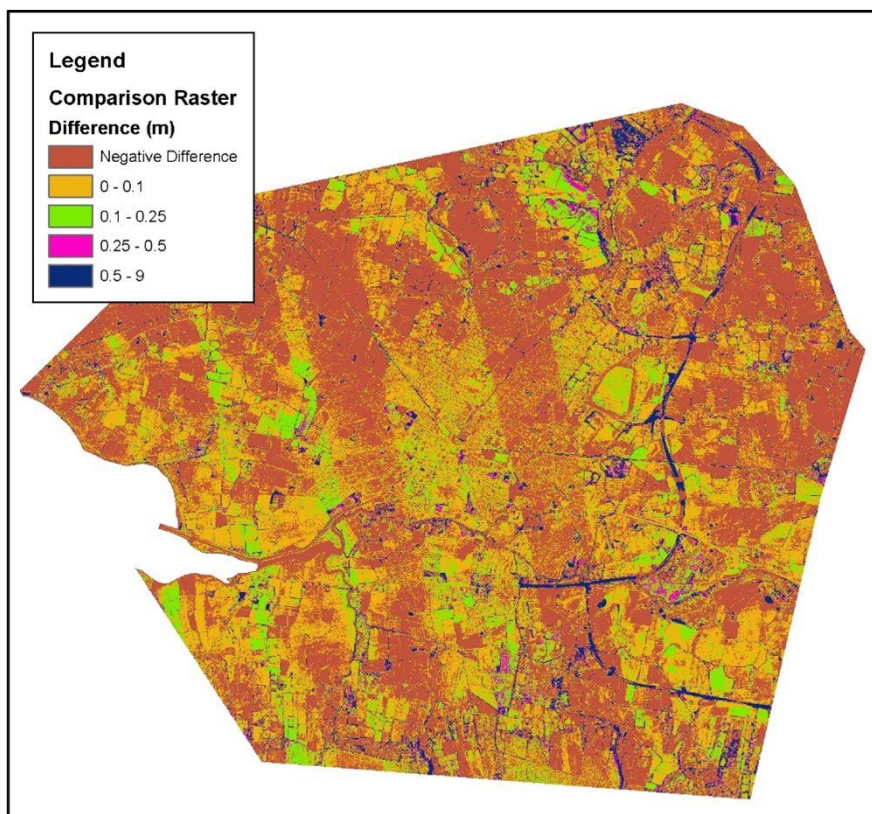


Figure 2.7: LiDAR Comparison Raster

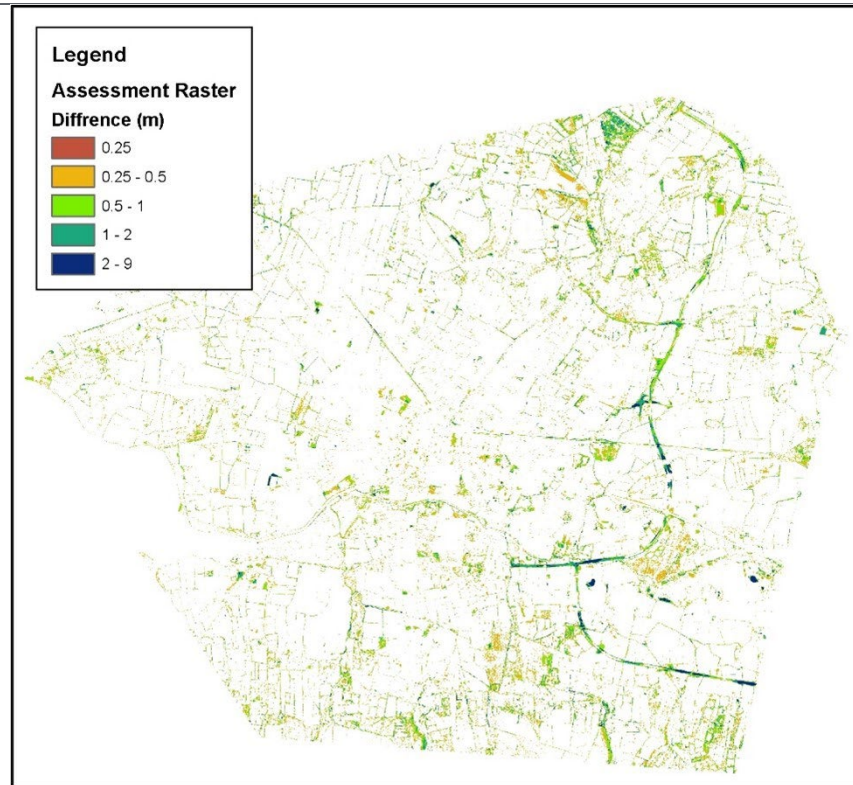


Figure 2.8: LiDAR Assessment Raster

4. The assessment raster was reviewed based on the extents of the CFRAM HEFS 0.1% AEP extent with a view to refine the area needing processed. The conclusion of this review was that areas outside the CFRAM HEFS 0.1% AEP extent should still be processed as there is potential for these areas to affect the FRS modelling outputs and the rain on grid modelling.
5. The assessment raster was then processed to a shapefile to enable portions to be removed or amended.
6. The assessment areas were reviewed against other available data (aerial photography, Google Street View etc.) to investigate whether they should be processed out of the FRS LiDAR. Areas deemed to be valid changes in topography were removed from the assessment shapefile. These areas are illustrated in red in Figure 2.9.

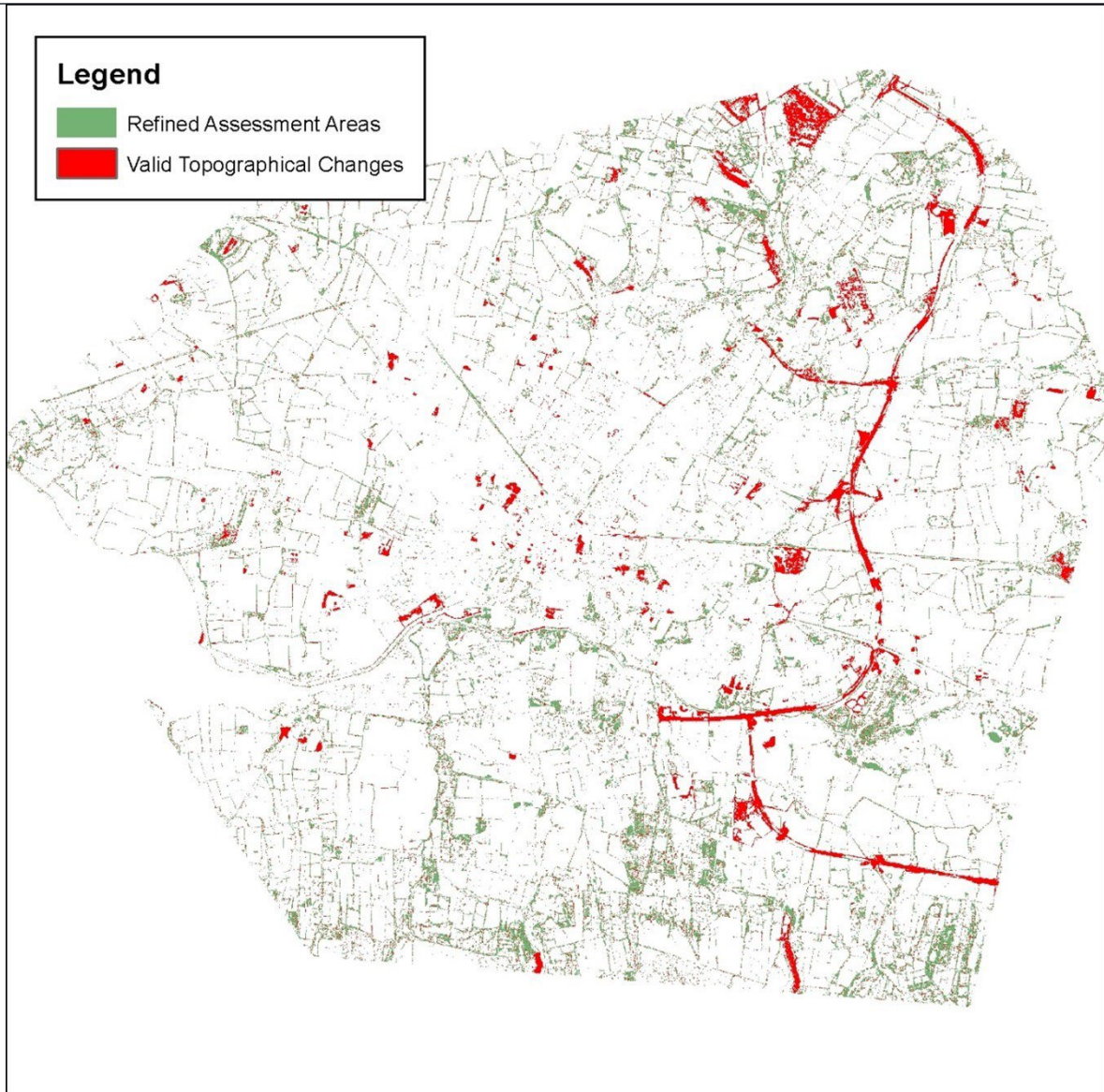


Figure 2.9: Refined Assessment Areas

7. The LiDAR was converted to a point shapefile with a point representing each cell in the raster dataset, a total of approximately 15,000,000 at 2m resolution and 966,600,000 at 0.25m resolution.
8. All points located within the refined assessment area were deleted from the point shapefile to leave only the points with elevations which have a differential value of less than 0.25m or were deemed to be valid topographic changes.
9. The refined point shapefile was then re-interpolated to a raster dataset with the areas which were removed being infilled based on extrapolation from the surrounding level data.

2.5 Kerry County Council Data

Kerry County Council (KCC) provided information on a number of different aspects of the study area. These were used to inform the Tralee FRS hydraulic model and to compare with the updated topographical survey. The information provided by KCC included:

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- Hand drawn figures of drainage outfalls within the study area.
- Information on the Tralee Canal, including cross section data which could be used to compare with the updated topographical survey for the Tralee FRS.
- Drawings of the 1992 Tralee Drainage Scheme at Mounthawk, Balloonagh area.
- Flood risk assessment reports on the Aperee Living Nursing Home embankment.
- Osi Prime2 Data which was used in the hydraulic model to determine the 2D roughness.
- Tralee flood history information including information on areas which have flooded and photos of some of this flooding.

3 HYDRAULIC MODELLING

3.1 Fluvial Model Construction

3.1.1 Model Conceptualisation

Model conceptualisation of Tralee includes the River Lee and main tributaries, modelled from the upstream extent of any potential receptors to the downstream extent of the model located at Blennerville at the mouth of the River Lee in Tralee Bay. The model centreline presented in Figure 3.1 shows the modelled extent within the Scheme Area. The extent of tributaries assessed was determined based on potential flood risk to receptors in the area.

At the outset the following data preparation and model build approaches were adopted:

- To comply with the brief, data was projected in ITM and converted to OSGM15. Geoid conversions were based off guidance provided within OSGM15 – Geoid Change for Ireland, Society of Chartered Surveyors Ireland.
- LiDAR captured during the initial stages of the Tralee FRS by the OPW was used for creating the Digital Terrain Model (DTM) (following the processing detailed in section 2.4.1.1).
- Given the extent of the model area a coarse 2D mesh zone was sufficient to represent the majority of the Tralee Study Area, with a more detailed mesh zone introduced to cover the urban area of Tralee Town itself.
- Surveyed building finished floor levels (where available) were imprinted onto the DTM to represent the sub-floor portion of the building. Porous polygons with a 1% porosity were used to represent the above threshold portion of the buildings.

The approach to model conceptualisation was discussed at the Hydraulics Technical Workshop (10/12/21) attended by representatives from KCC and OPW. Model conceptualisation was presented to the Steering Group and the model development process further discussed. A summary of the workshop and the presentation slides were circulated to the Steering Group following the workshop.

A detailed hydrological analysis was undertaken to determine the flood flow hydrographs and peak design flows for the Tralee study area. The design flow estimation requires a comprehensive understanding of the physical catchment characteristics/descriptors (PCDs) throughout the Tralee study area. Hydrological Estimation Points (HEPs) have been specified at the locations where peak design flows have been estimated shown in Figure 3.1.

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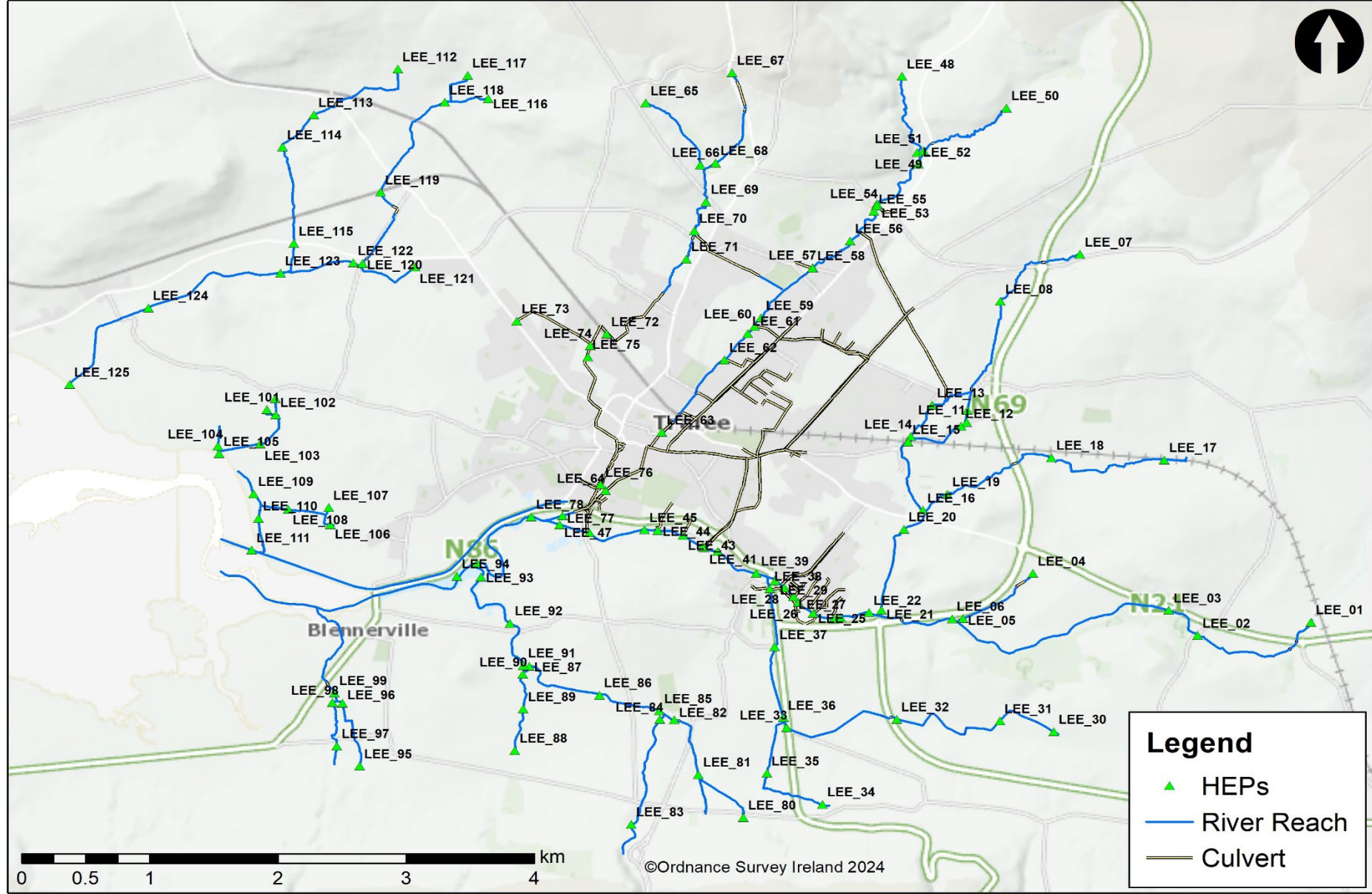


Figure 3.1: Tralee FRS Full model extent and Hydrological Estimation Point (HEP) locations

3.1.2 Modelling Software

RPS used InfoWorks ICM (version 2021.5) to undertake the numerical modelling of the watercourses. InfoWorks ICM is an integrated hydrological and hydraulic modelling package developed by Innovyze. InfoWorks ICM includes full solution modelling of open channels, floodplains, embankments and hydraulic structures. Additionally, the 2-dimensional areas within InfoWorks ICM are modelled through a triangular flexible mesh which allows for high levels of detail in specific areas (for example at riverbanks and around buildings) and a broader approach in other areas (for example open floodplains).

3.1.3 1D Model Domain

3.1.3.1 Survey Data

The CFRAM survey data was used as the initial basis for the model. Additional survey data collected in 2022 as part of the Tralee FRS was then used to update and extend the model extent along with validating the CFRAM data. This new survey included watercourses that were not assessed by the CFRAM study such as the Tralee Canal and improved detail around hydrometric gauging stations to facilitate rating reviews. Cross sections at duplicate locations were resurveyed to confirm that the CFRAM survey was still accurate (refer to Section 3.1.3.5). The extent of data used to inform the 1D model build is shown in Figure 3.2.

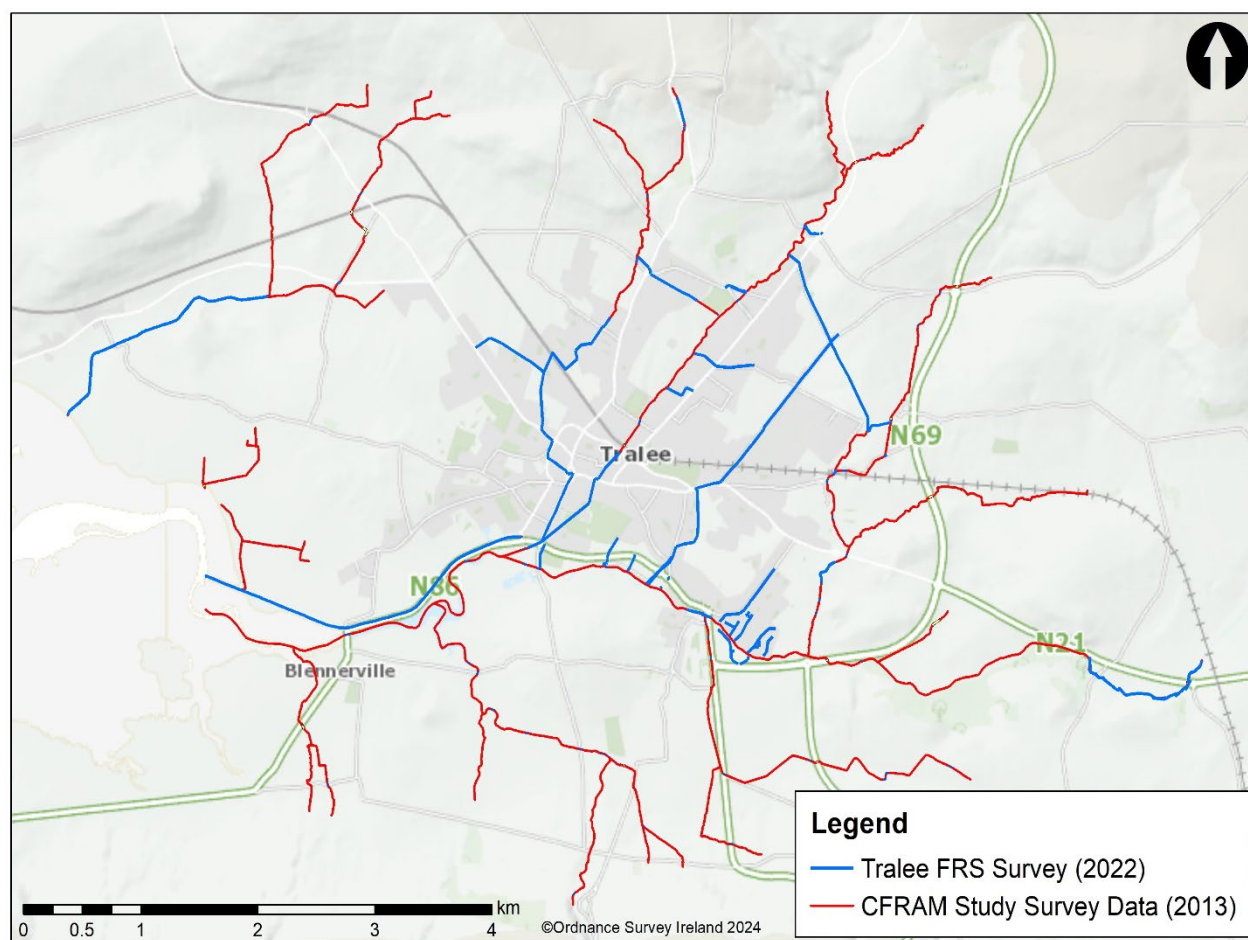


Figure 3.2: Survey Data Source

3.1.3.2 Roughness

Manning's coefficient of roughness (n) values (Chow, 1959⁴) were individually assigned to the channel cross sections of the 1D network based on observations from the walkover survey supported by survey photographs, in-channel value ranges from 0.015 to 0.06. These values were adopted as the reaches vary from concrete channel such as the diversion channel from Balloonagh to Big River (Figure 3.3), to open and clear watercourses, such as the reaches of the River Lee (Figure 3.4), to more winding sections with the presence of weeds and dense vegetation in the reaches of the Rathass watercourse (Figure 3.5). Values of 0.05 to 0.11 were assigned to the bank and near bank portions of all cross-sections.



Figure 3.3: Concrete Lined Channel of the diversion between Balloonagh and Big River

⁴ Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw Hill, 680 p.



Figure 3.4: Open and Clear River Reach on the River Lee (Manning's n value of 0.03)



Figure 3.5: River Reach with weeds and dense vegetation on the Rathass watercourse (Manning's n value of 0.06)

3.1.3.3 Structures

All in-channel structures were included in the model and defined by the surveyed geometry, an example of a bridge structure is shown in Figure 3.6. There are a total of 66 bridges, 75 culverts, 17 weirs, 11 flap valves and five trash screens included in the Tralee model, the location of these structures is shown in Appendix E.

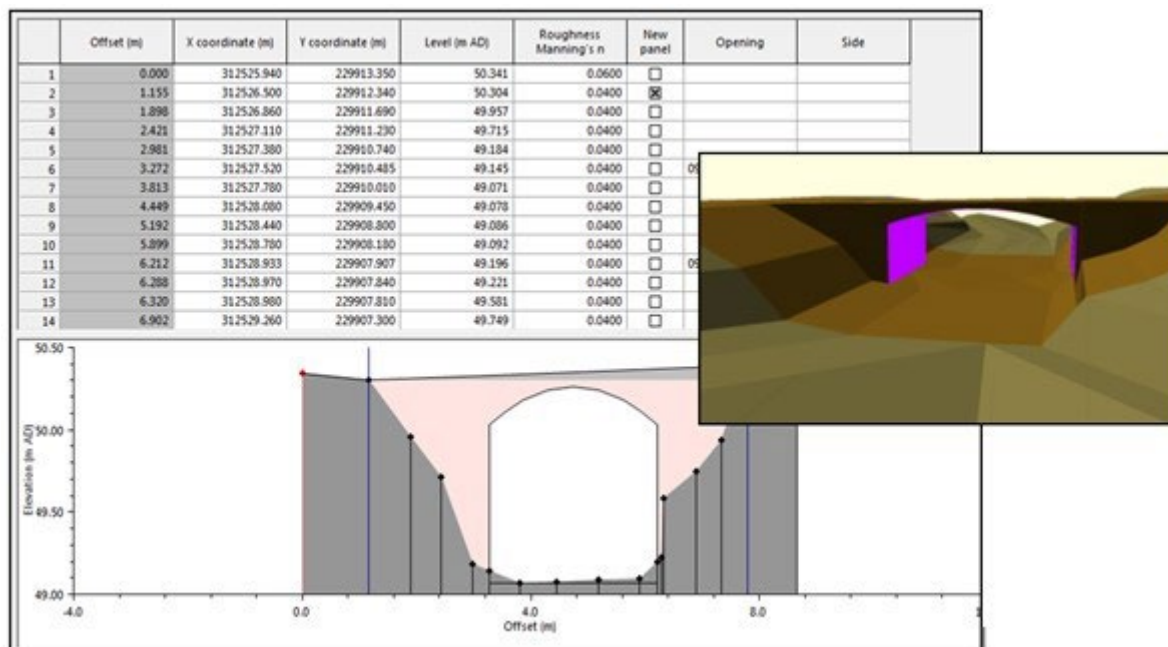


Figure 3.6: Example of ICM Model Input for In-Channel Structures

Six structures were identified as hydraulically significant to flood risk in Tralee, these are identified in Figure 3.7. These structures were selected based on one or more criteria that would indicate these were a critical structure to existing flood risk. These criteria included whether they had been highlighted to have caused flood risk in the past, if they were a structure that was contributing to flooding in the design 1% AEP flood model results or if their overall design was likely to lead to future blockages and therefore increase flood risk. These six structures which are considered critical to flood risk and therefore subject to blockage analysis (Section 3.8) have been grouped into three networks. These were confirmed with the Steering Group in advance:

1. The Balloonagh River Long Culvert that conveys flow under the Tralee Town Centre and the Big River long culvert that conveys flow under Denny Street.
2. The Big River Bridge (23BGR00160D_Screen) beside Roger Casement Avenue and blockage to the bridge beside the Rugby Club on the Ballyvelly watercourse.
3. The diversion culvert between Balloonagh and the Big River which takes most of the flow from the Balloonagh to the Big River.
4. The diversion culvert between the Big River and Rathass.

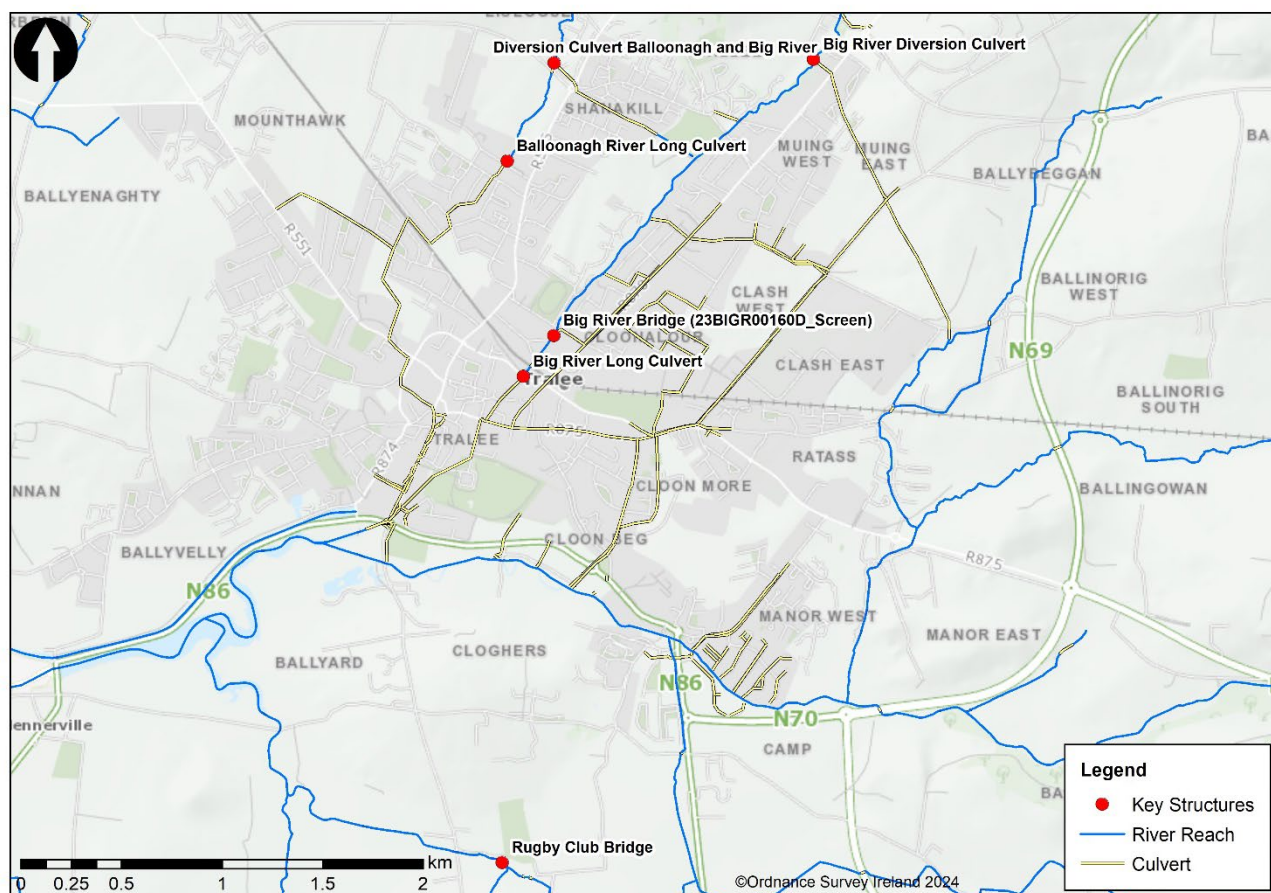


Figure 3.7: Location of Key Structures in Tralee which have been considered for blockage analysis

The results of the blockage analysis for the six key structures are described in more detail in Section 3.9. Additional structures were also identified for sensitivity analysis in Section 3.9. This sensitivity analysis is in relation to structure model parameters such as contraction and expansion losses and how these structures are represented in the model (i.e. as a culvert or bridge). The results of the sensitivity runs are described in Section 3.9.

3.1.3.4 Bank Lines

River channels were modelled in 1D and connected to the 2D floodplain using bank lines. Bank lines are created using the surveyed levels at the extremities of the river cross sections and updated using levels from LiDAR and surveyed topographic data where available.

3.1.3.5 Survey Dataset Comparisons

Newly procured survey was positioned, where possible, at the same location as previously surveyed cross sections (CFRAM Study survey). To validate the CFRAM data and to assess geomorphological change between survey periods, comparison between historic survey and updated survey was carried out. Figure 3.8 outlines the location of cross-section comparisons.

The comparisons (

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Figure 3.9) revealed a small degree of variation generally attributable to processes of erosion and deposition, but largely the datasets present little change between the survey periods.

There is no evidence of significant hydro-geomorphological change on any of the tributaries or along the River Lee. All cross-section comparisons between the Tralee CFRAM Study model and the Tralee FRS are included in Appendix D. This provides confidence in the CFRAM data and demonstrates that the watercourses have not significantly changed over the last 10 years (approximately).

Scheme development and design will consider the potential for hydro-geomorphological change arising from proposed measures.

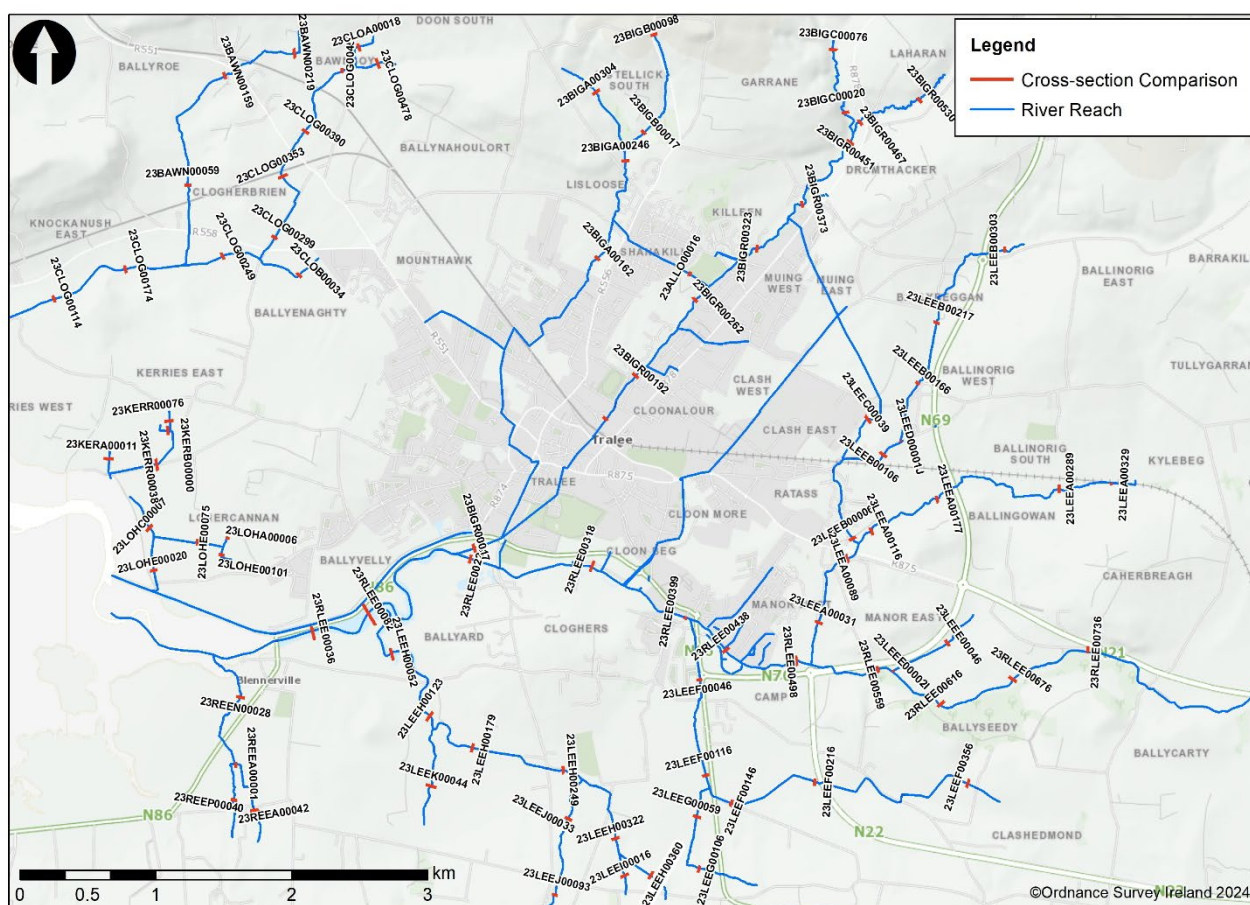


Figure 3.8: Location of cross-section comparisons between Tralee FRS survey and historic survey data

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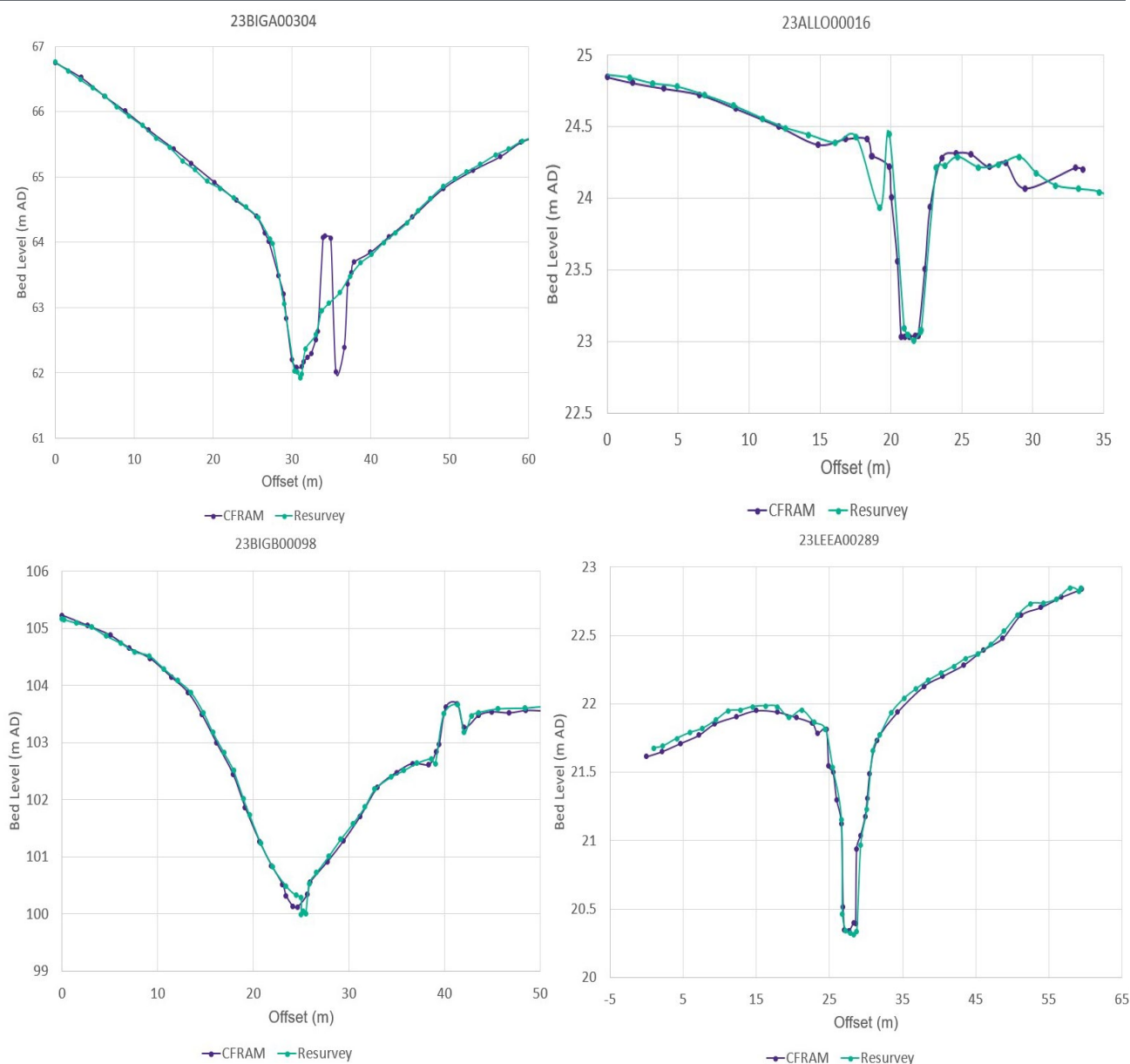


Figure 3.9: Example Cross-Section Comparisons for Tralee watercourses – Tralee FRS Survey and CFRAM Study Survey Data

3.1.4 2D Model Domain

3.1.4.1 Mesh

LiDAR data has been used within the modelling package to generate the computational mesh; this has produced an accurate assessment of 2D flow paths. Details on the LiDAR data are discussed in Section 2.4. The building floor level data obtained in 2022 (Section 2.3), was merged into the LiDAR dataset for representation within the model (Figure 3.10).

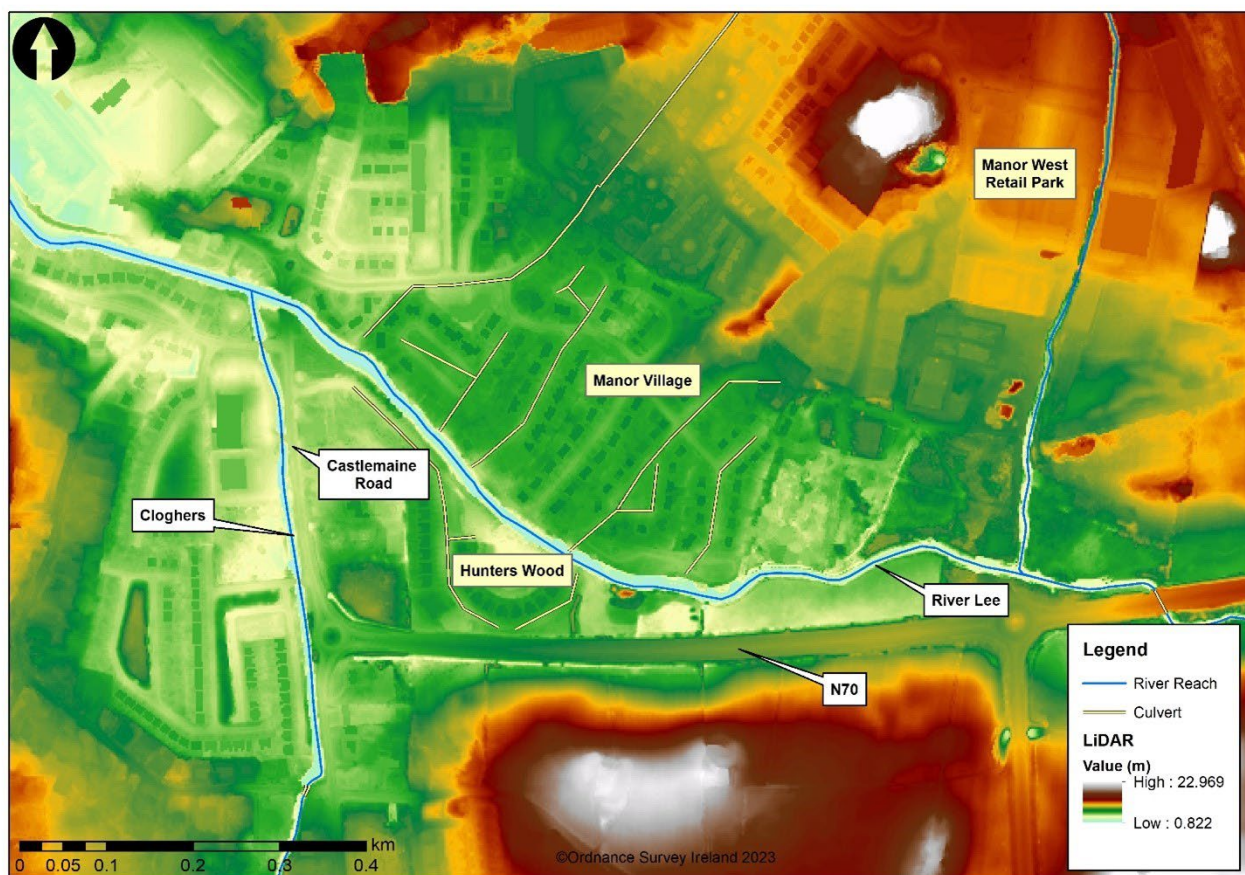


Figure 3.10: Extract from Final DTM used in model with building floor levels mosaicked into LiDAR

The mesh in the 2D zone has been augmented to include properties as imprinted floor levels (footprints raised to surveyed finished floor levels (FFL)) with porous polygons above the footprint. A porosity of 0.01 has been applied to all porous polygons, enabling buildings to store/slow water if flood levels surpass the raised finished floor levels providing a more accurate representation of flow paths. This approach is standard in Infoworks ICM models and referred to as “stubby” buildings. All flood receptors were contained within the 2D modelling domain.

The 2D zone of the model is made up of a coarse mesh (maximum triangle area 100m^2 and minimum element area of 25m^2) representing more rural areas of the Tralee study area. A more detailed mesh zone was included to represent the urbanised Tralee Town where there are receptors at risk (maximum triangle area 20m^2 and minimum element area 2m^2). Figure 3.11 and Figure 3.12 provide an overview of the 2D configuration within the model. This resolution of the coarse mesh is deemed suitably accurate to represent the flow paths on the Lee floodplain, as is the detailed mesh zone for representing accurate flow paths within the urban area.

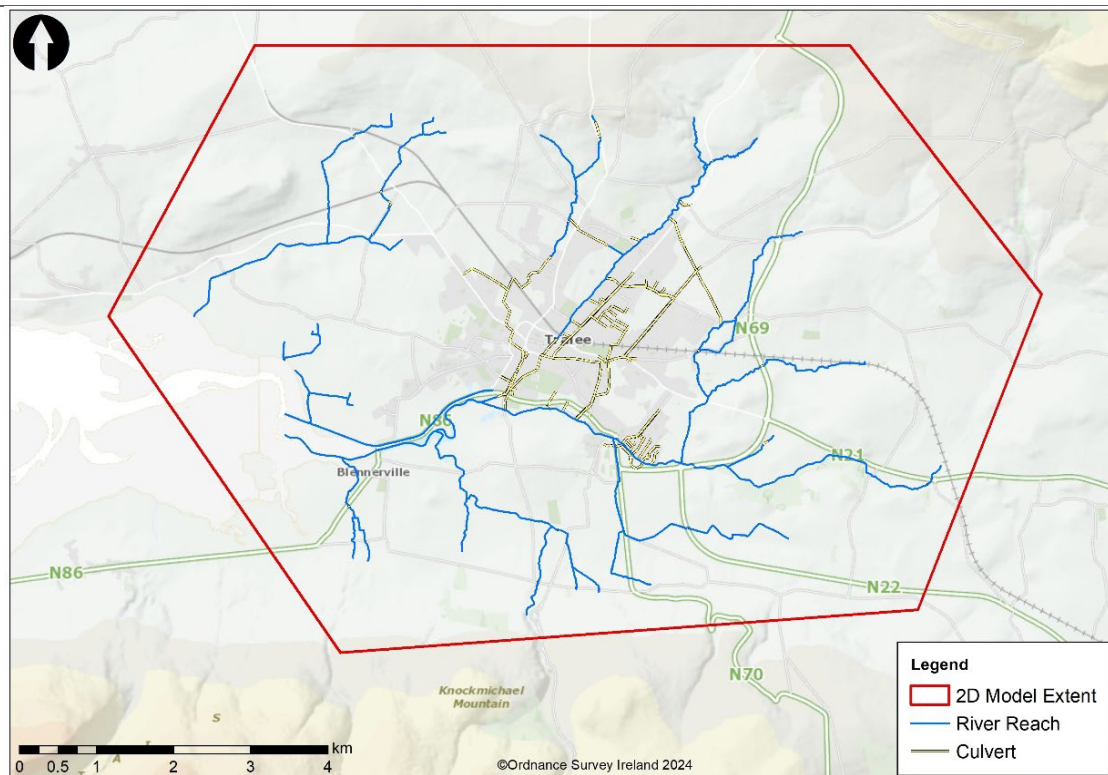


Figure 3.11: Modelled 2D Extent

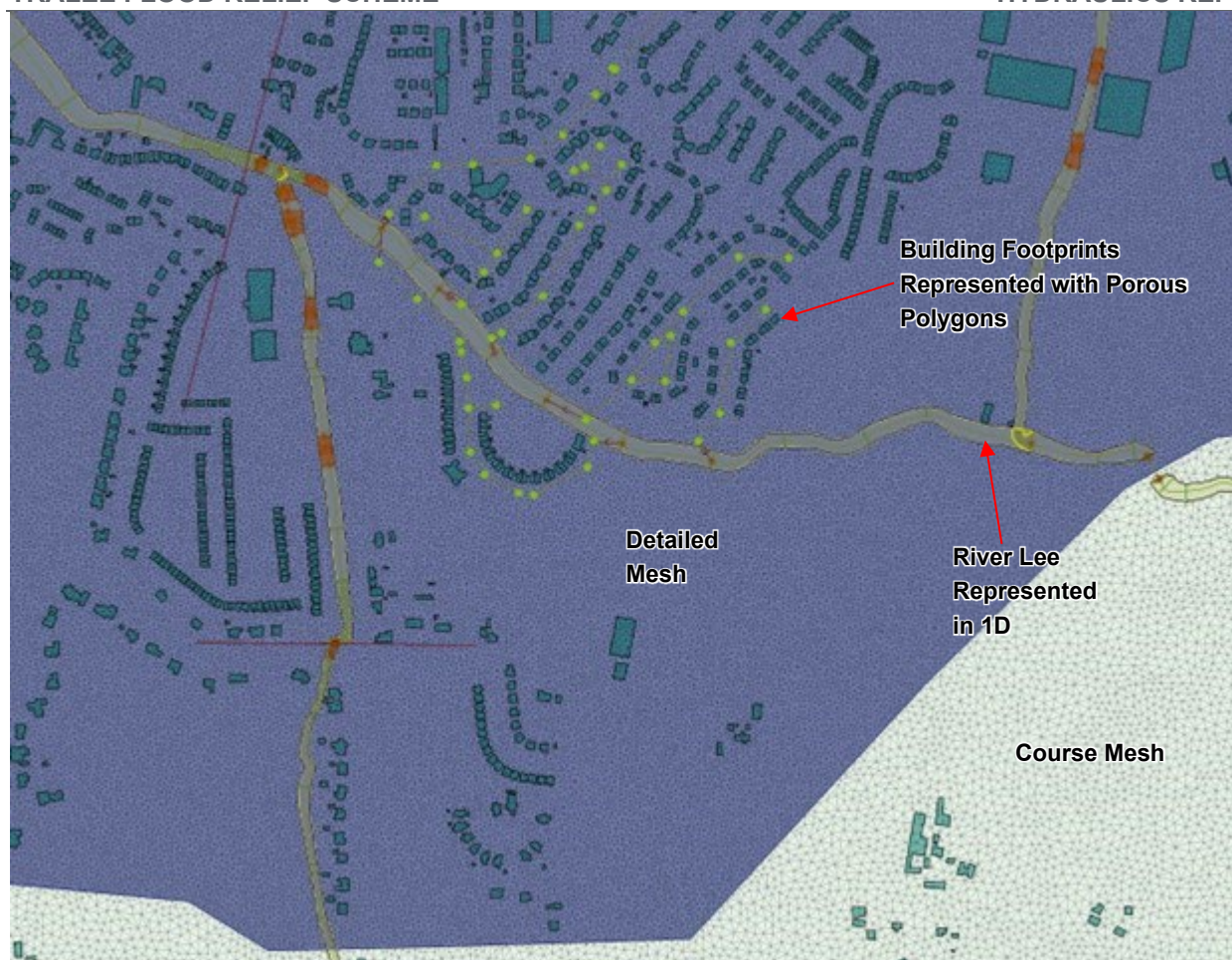


Figure 3.12: Portion of Modelled 2D Extent (showing mesh zone differences)

3.1.4.2 Roughness

The selection of roughness values used for the 2D domains was based on the land zones defined within the OSi PRIME2 dataset. Figure 3.13 outlines the extents of the OSi PRIME2 dataset (shown by the pink polygons). GIS processing removed areas of self-intersections within the dataset and assigned the appropriate Manning's n value based on Chow (1959) to land zones prior to being imported into the model to define roughness areas within the 2D model domain.

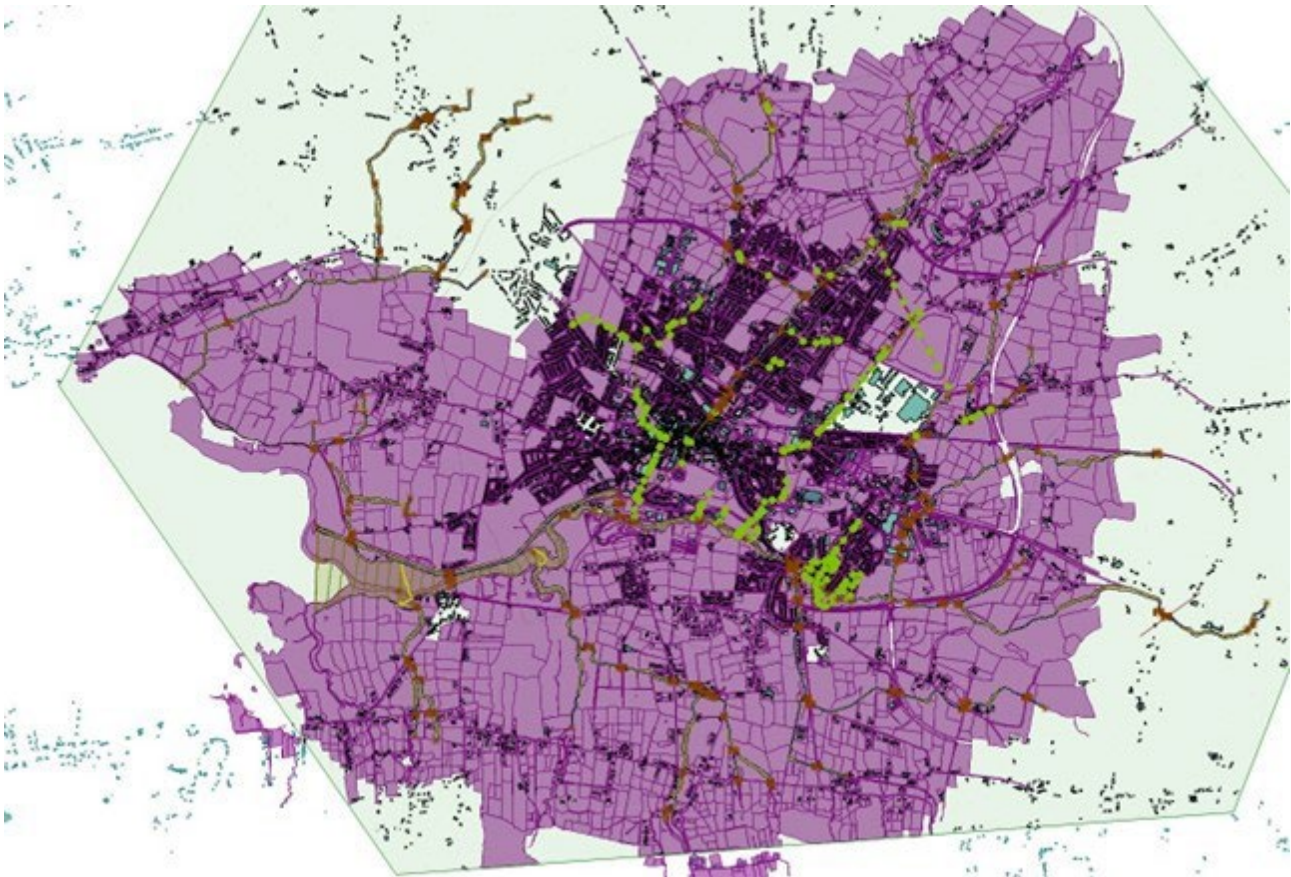


Figure 3.13: Extent of roughness zones in Tralee model

3.1.4.3 Drainage Network

Several areas of the Tralee drainage network were included within the model to replicate out of sewer flooding. Associated subcatchments were delineated within the model to generate runoff based on the rainfall applied to the model. These included the drainage network systems in the housing estates of Hunters Wood and Manor West. The subcatchments were delineated and their run-off parameters developed with reference to the Uisce Éireann DAP study for Tralee. These were adopted for the Tralee FRS model and verified using flow monitoring data where possible. Within the model each subcatchment has been set to drain to a specific drainage network conduit based on the DAP model where available. Each subcatchment has an associated land use which divides the subcatchment into different run-off surfaces. This allows different surface types to be represented taking account of whether a surface is pervious or impervious. These run-off surface parameters determine the rate at which runoff is generated during a rainfall event and therefore the volume of water making its way

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into the drainage network. In total 497 subcatchments were used in the model. The different parameters for each of the surfaces used within the model are listed in Table 3.1. The subcatchment locations and drainage network are shown in Figure 3.14.

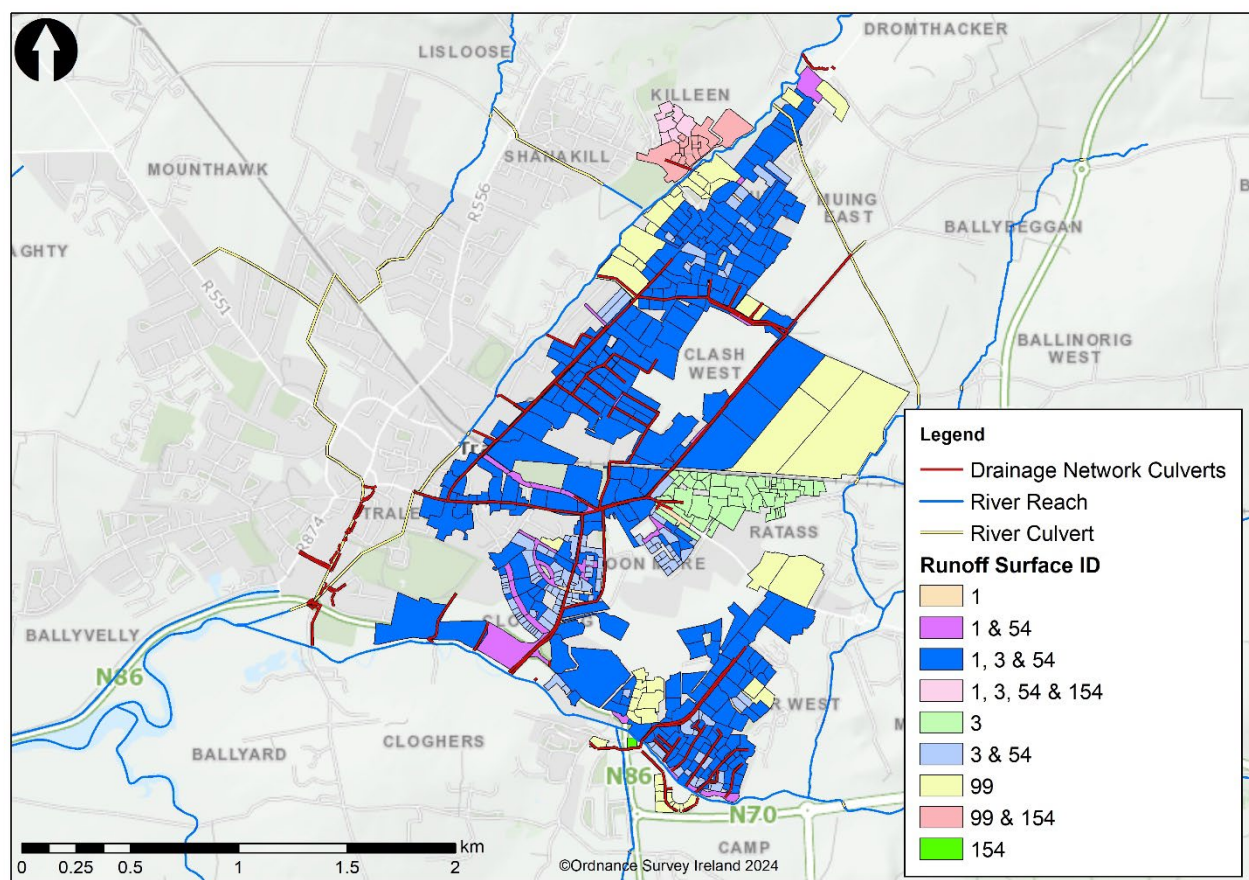


Figure 3.14: Modelled Drainage Network for Rainfall

Table 3.1 Surface Run-off Parameters

Runoff Surface ID	Runoff Routing Type	Runoff Routing Value	Runoff Volume Type	Surface Type	Ground Slope (m/m)	Initial Loss Type	Initial Loss Value (m)	Routing Model	Fixed Runoff Coefficient	New UK Depth (m)	Initial Loss Porosity
1	Relative	1.00	Fixed	Impervious	0.000	Slope	0.000071	Wallingford	1.00	N/A	1.00
3	Relative	1.00	Fixed	Impervious	0.050	Slope	0.000071	Wallingford	0.85	N/A	1.00
99	Relative	1.00	Fixed	Impervious	0.000	Slope	0.000071	Wallingford	1.00	N/A	1.00
54	Relative	4.00	NewUK	Pervious	0.000	Absolute	0.002800	Wallingford	N/A	0.2	1.00
154	Relative	1.00	Fixed	Pervious	0.000	Absolute	0.001000	Wallingford	0.00	N/A	1.00

3.1.4.4 Flood Defence

Figure 3.16 illustrates the location of all formal and informal defences with the study area. For calibration of the model all defences were included in the simulations as they are likely to have some impact on flow paths during the calibration events. The defences within Tralee include both embankments and walls, these have been included within the banklines of the river reaches where possible to reduce instability within the model. Where this was not possible due to the defences being set back from the river bank, these were represented as 'base linear structures (2D)'. These structures form part of the mesh generation process and are used to represent walls and embankments with a specified porosity and level. A number of the structures shown in Figure 3.15 were deemed to be ineffective or the defence asset condition survey concluded that they were not structurally sound. Figure 3.16 indicates the location of the defences considered to be formal effective and have been included in the design simulations.

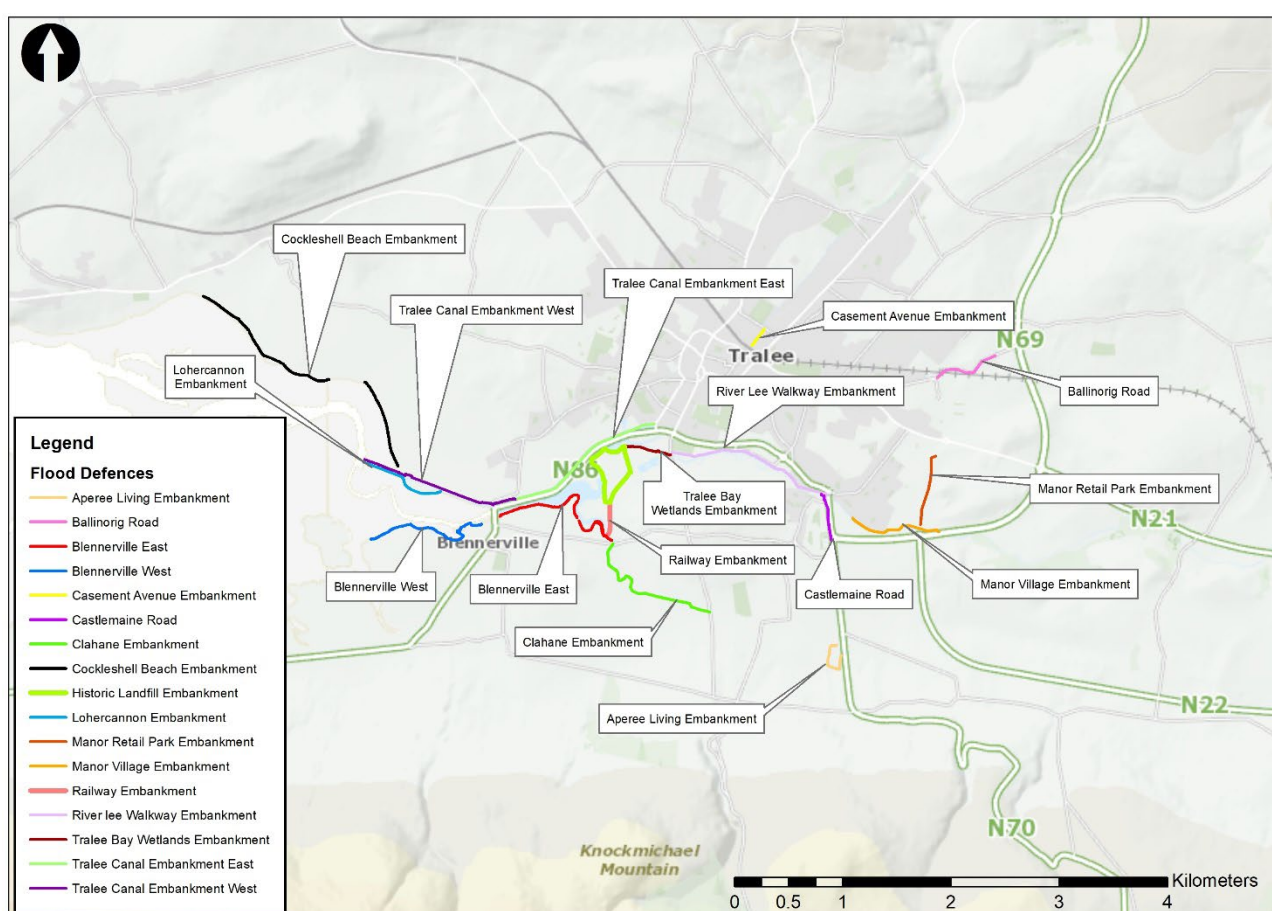


Figure 3.15: Location of formal and informal defence structures included in calibration simulations

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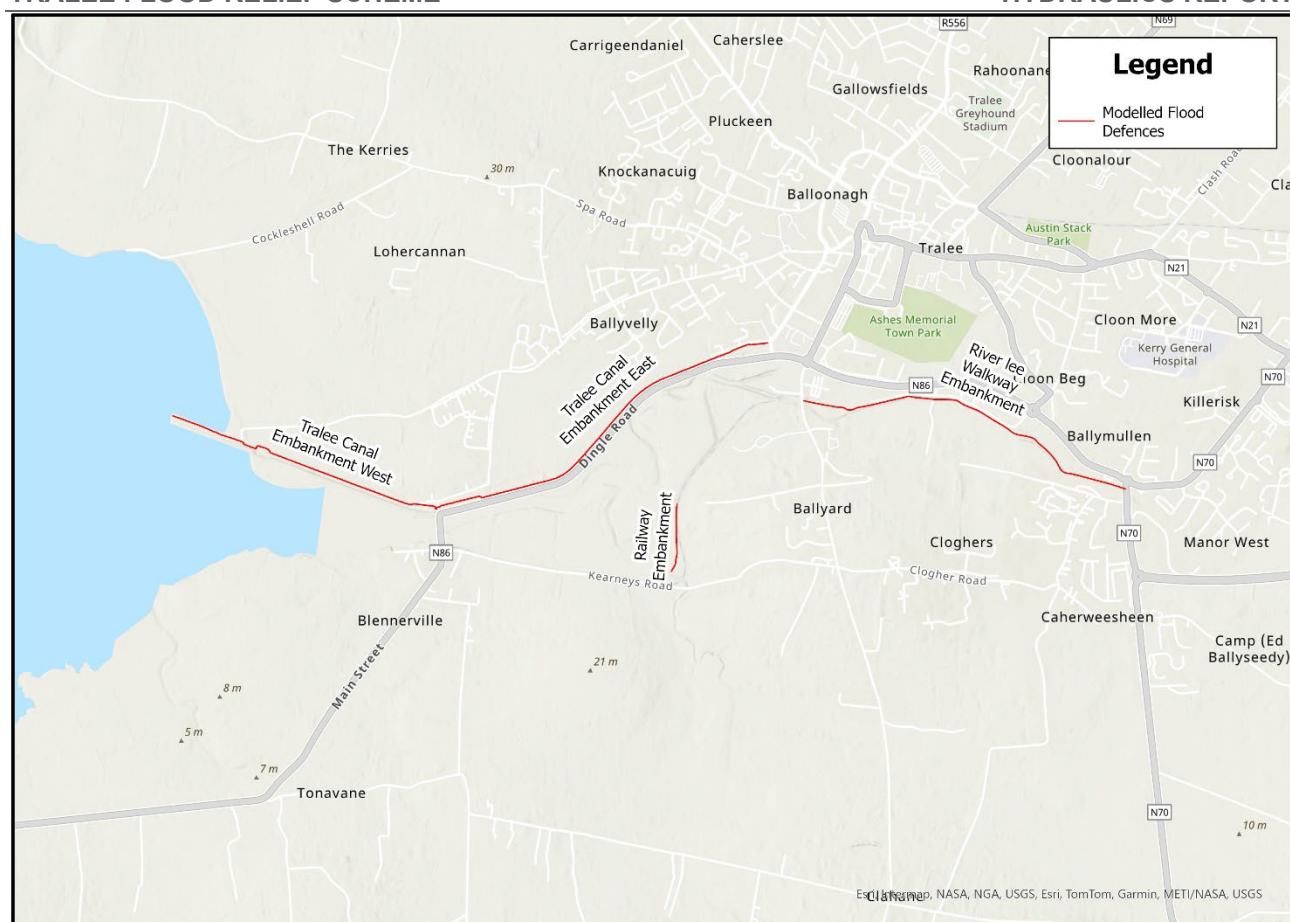


Figure 3.16: Location of modelled defences

3.1.5 Boundary Conditions

3.1.5.1 Upstream Boundary

Upstream boundary conditions and input hydrographs for the model (Hydrology Report Chapter 4) as determined at upstream Hydrological Estimation Point (HEPs) have been introduced as point inflows to the 1D model domain. The hydrological assessment determined lateral flows between HEPs, based on the downstream HEP total flow scaled to the area of the lateral catchment, which were disaggregated for the appropriate river reaches between HEPs based on length. Figure 3.17 illustrates the 1% AEP upstream point inflow hydrograph for the River Lee.

The Hydrology Report Section 7.2 details the assessment carried out for timings to ensure the model captured fluvial-fluvial joint probability consideration and accounted for the varying sub-catchment hydrograph response times.

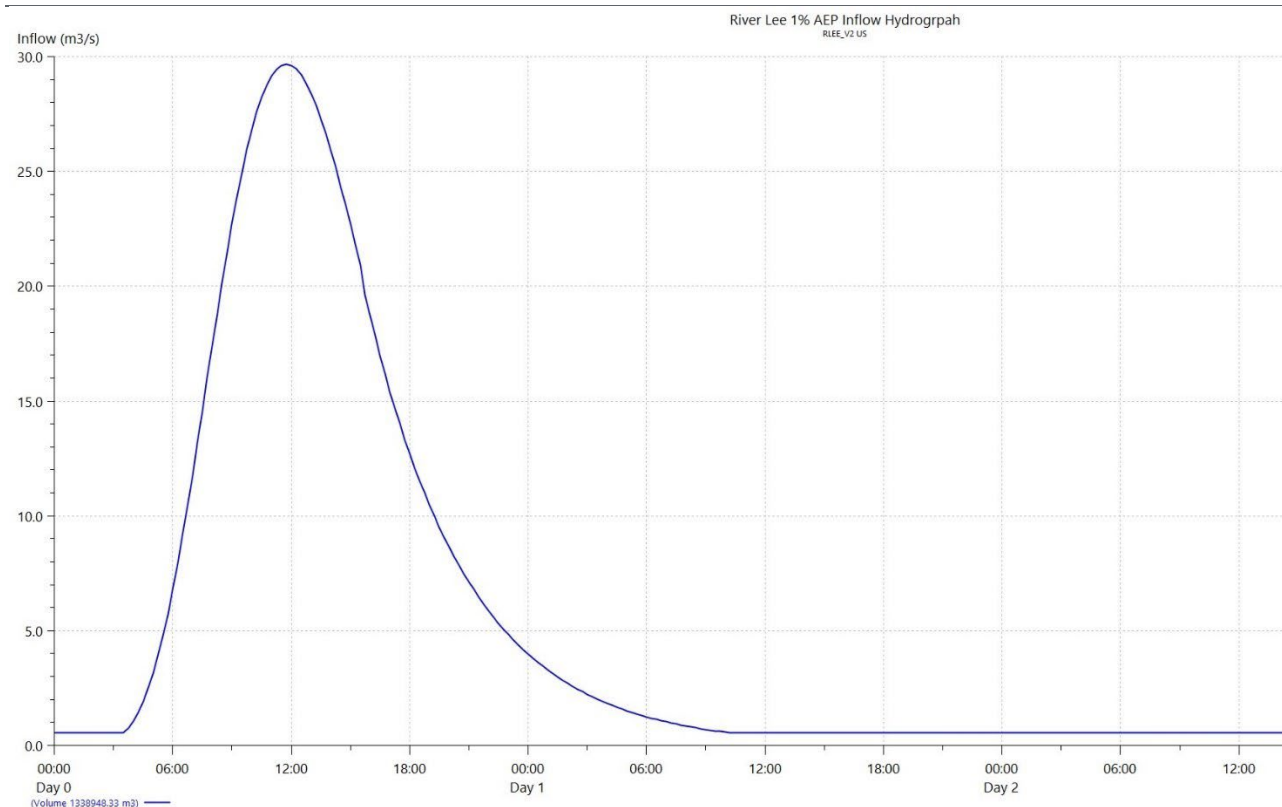


Figure 3.17: 1% AEP Upstream Inflow Hydrograph for the River Lee

3.1.5.2 Downstream Boundary

A detailed coastal model of Tralee Bay was developed during the ICWWS, using the MIKE21 Flexible Mesh Flow Model. This included extensive bathymetric and topographic data available within the model domain, which was primarily obtained from INFOMAR, a joint project between the Geological Survey Ireland (GSI) and the Marine Institute, with data collected from 2008 to 2014. This was supplemented with LiDAR data from Bluesky (2018) and Admiralty Chart data as digitally supplied by C-Map of Norway to ensure coverage of the entire domain. More detail on the coastal modelling and design water levels can be found in chapter 5 of the Hydrology Report.

The timing of the boundary condition is discussed in Section 7.3 of the Tralee FRS Hydrology Report. The hydrological assessment found that there was little dependence between fluvial and coastal events. A baseline boundary was therefore used for all fluvial events by generating a Mean High Water Springs (MHWS) tidal profile. The downstream boundary used for all present day fluvial events is shown in Figure 3.18. Due to there being an independent fluvial-coastal joint probability relationship, separate coastal events have also been created. Peak water levels were extracted from the MIKE21 coastal model result files and adjusted to OD Malin OSGM15 ready for incorporation into the ICM model. A separate tidal profile was created for the River Lee, Kerries East and Pinure. More information can be found in Section 5.2 of the Tralee Hydrology Report. The 0.5% AEP coastal boundary for the River Lee, Kerries East, and Pinure are shown in Figure 3.19, Figure 3.20 and Figure 3.21 respectively. The same boundary was used for both the River Lee and Tralee Canal due to their proximity to each other.

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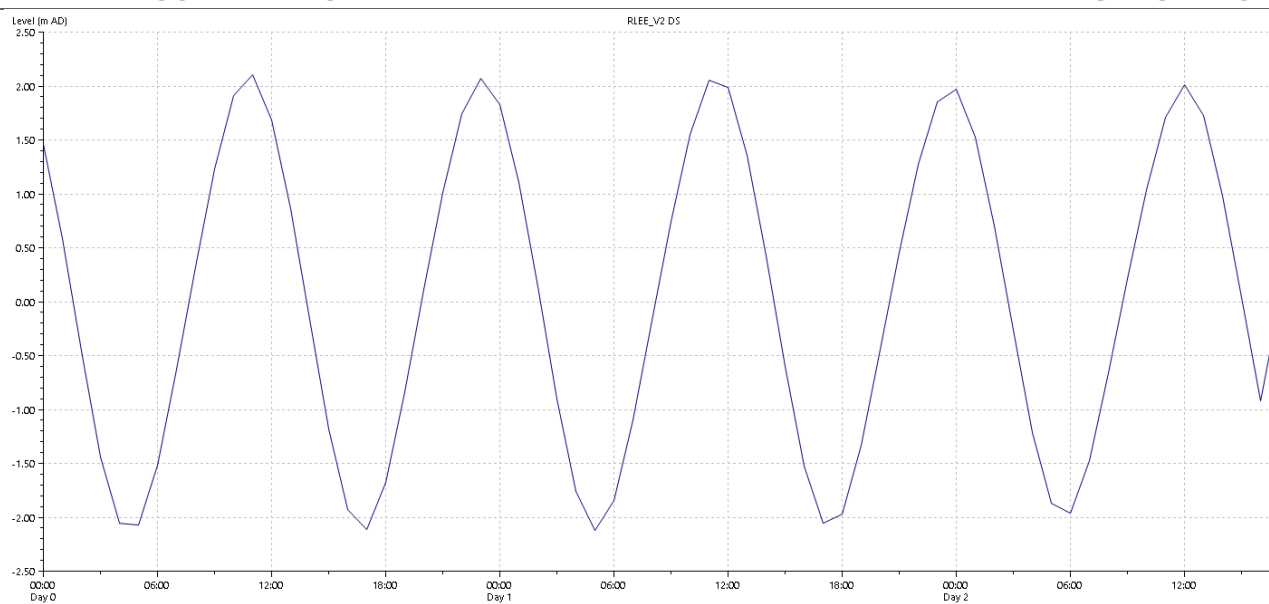


Figure 3.18: Baseline Fluvial Downstream Water Level Boundary

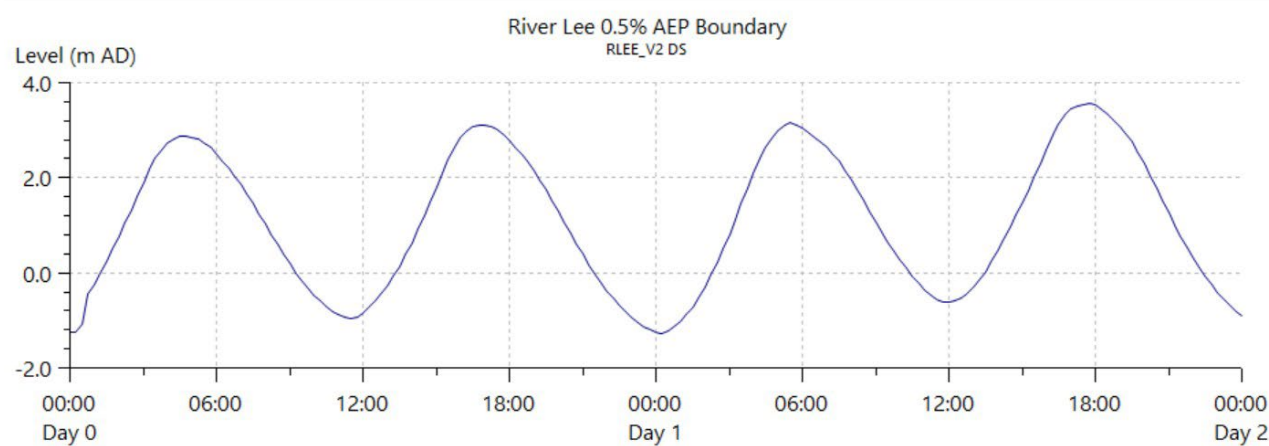


Figure 3.19: 0.5% AEP Coastal Boundary River Lee and Tralee Canal

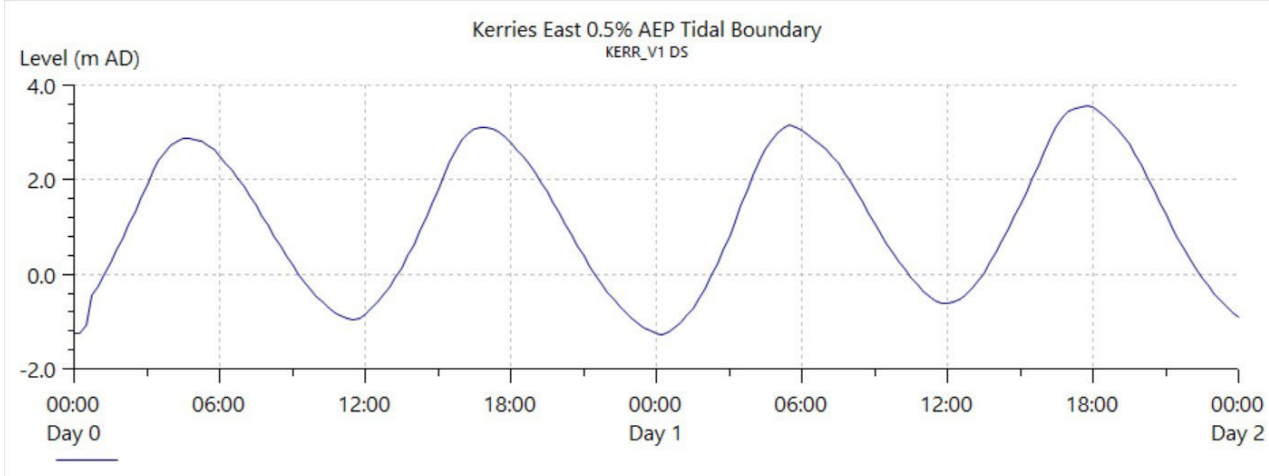


Figure 3.20: 0.5% AEP Coastal Boundary Kerries West

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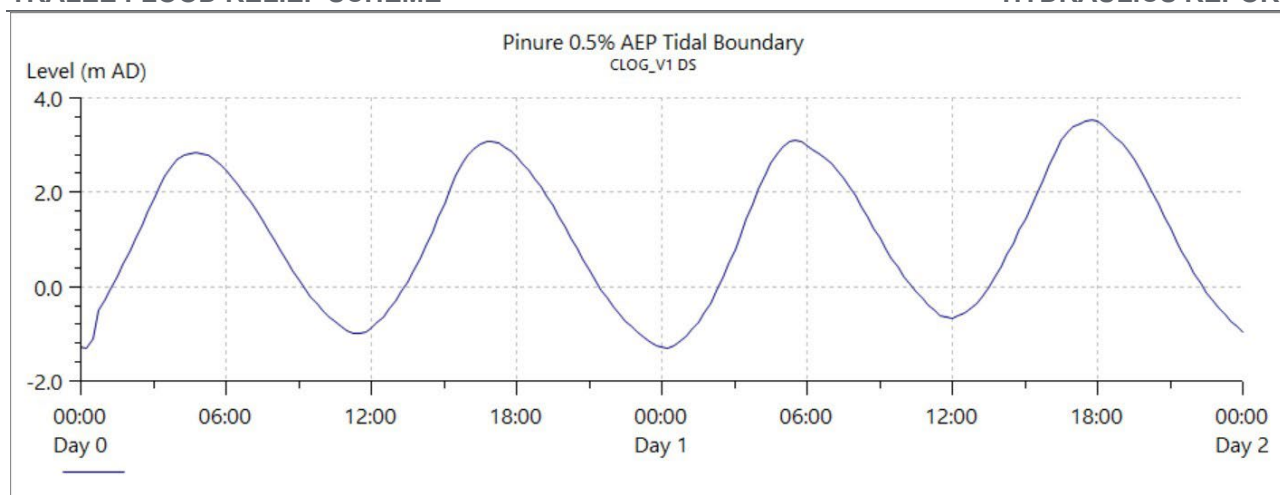


Figure 3.21: 0.5% AEP Coastal Boundary Pinure

3.1.6 Simulation Parameters

Table 3.2 presents the key simulation parameters used during all modelled simulations.

Table 3.2 – Simulation Parameters

1D Domain	
Timestep (seconds)	1
Min / Max space step	0.1m / 2m
Max Timestep Halvings	30
2D Domain	
Timestep (seconds)	Dynamic
Timestep Stability Control	0.95
Maximum Velocity	10
Theta	0.9
Inundation Mapping Depth Threshold	0.001m

3.2 Model Calibration and Verification

3.2.1 Model Stability

RPS have reviewed model stability through various checks such as flow plots, water level checks, bank line flow and mass balance to ensure the model outputs are reliable. Based on these checks there are no residual issues with the model that may impact on the overall accuracy of outputs for Tralee FRS.

3.2.2 Hydrological Anchoring

Hydrological anchoring has been outlined in Appendix B, overall, the model is well anchored to 31 HEPs as they are within tolerance of the hydrological flow for all four core events checked (50%, 10%, 1% and 0.1% AEP). There are 12 HEPs which are matched to more than one event but not to all four. These generally match

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in the lower return period events such as the 50% and 10% AEP events but may miss the required tolerance for the larger events such as the 1% or 0.1% AEP events. Generally, the reason for this is the larger events have significantly more out of bank flooding which leads to floodplain attenuation and reduces the peak flow through the HEP locations.

There are 35 HEPs which do not match the hydrology for any of the four events. The majority of these miss their expected flow due to the diversion culverts within Tralee, with 20 of the 35 HEPs missing due to this. The Big River diversion reduces flows downstream along the Big River which leads to the HEPs not matching the hydrology. This additional flow through the Big River diversion then has the impact of significantly increasing flows through the Ballinorig/Ballybeggan watercourses which means the flows in these channels are larger than the hydrological estimates. The Balloonagh diversion reduces flow downstream of it which also means that flows are lower than the hydrological estimation and therefore the check flows at the HEPs downstream of the diversion cannot match. Appendix B lists all the HEPs which fully or partially meet the hydrological anchoring and provides an explanation for each HEP which has missed the expected peak flow.

Table 3.3 – Flow Anchoring Summary

Total HEPs	Anchored to All Core Events	Anchored to 50% AEP and/or 10% AEP	Outside of Required Tolerance
78	31	12	35
	40%	15%	45%

3.2.3 Calibration and Verification

Five historic flood events were used to calibrate the Tralee model. Modelled flood extents and levels are considered to be representative of the five calibration events. This provides confidence in the model parameters, timing and magnitude of hydrographs and data included in the model.

3.2.3.1 Observed 3rd January 2014 Event

This event saw strong winds coincide with a high Spring tide of 5.0m, leading to flooding at Ballyvelly. It was estimated that 200mm of water flooded the tow path along the canal with residents of 20 years providing anecdotal evidence that they had never seen such a flooding event.

This event has been estimated by the hydrological assessment (Section 3.1) to be around a 1-year fluvial event. The model has been ran using the Blennerville gauge levels for the event to set the downstream levels of the River Lee and Canal. A 1 year event has been used to set the flows within the river reaches as this is a tidal event and no information was available to suggest that fluvial flooding significantly impacted the study area. The results of the model are listed below and the extents are shown in Figure 3.22.

- Area 1 - Flooding was noted at Ballyvelly, however the extents and depths of the flooding are not available. The model is showing flooding around the Ballyvelly area.
- Area 2 – Modelled flooding along the tow path ranges from below the estimated 200mm to over 400mm. The modelled depths are therefore lower or greater in some locations than reported on the 3rd January 2014. The

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reported levels from this event are an estimate only and it is likely that the flood depths varied along the tow path.

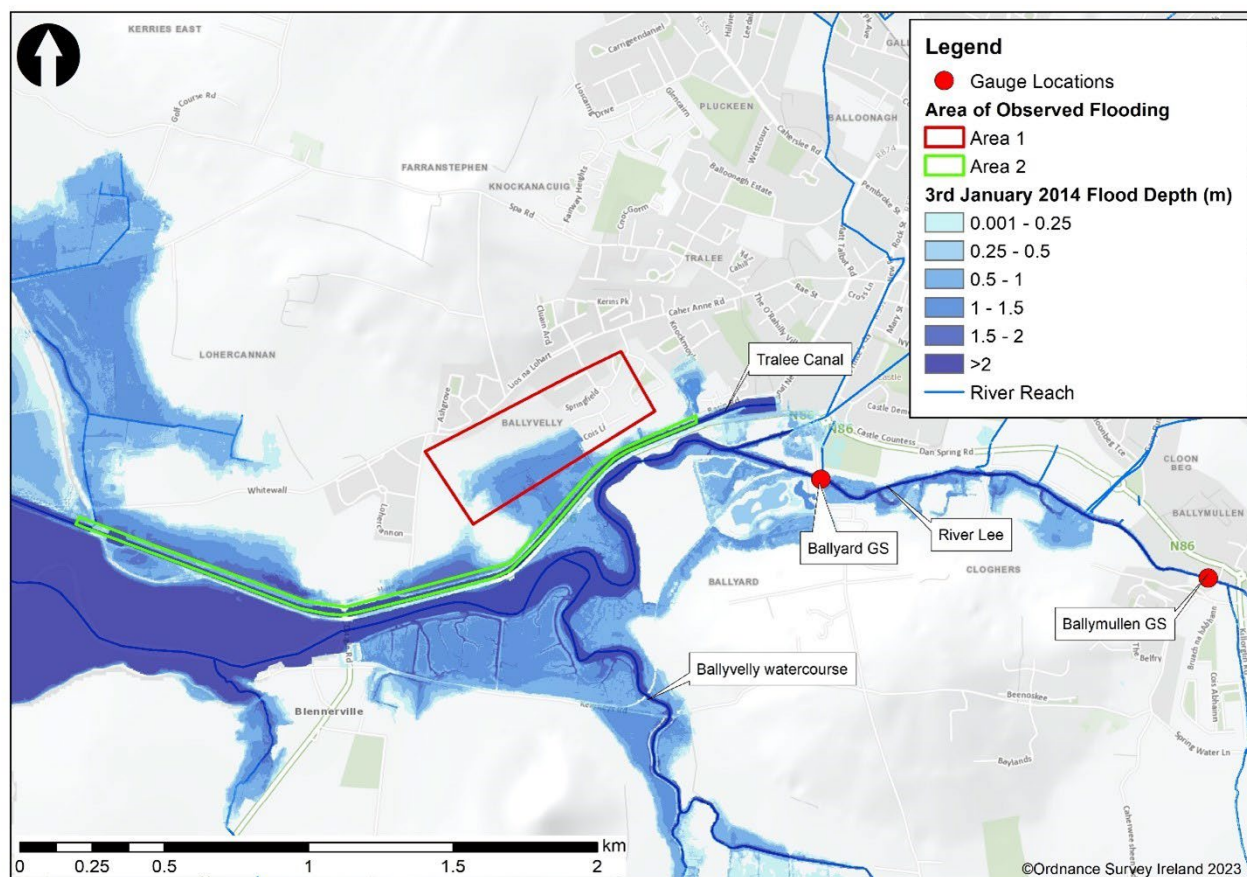


Figure 3.22: Modelled Flood Extents for the Dec 2015 Event

There were two water level gauges in operation during this flood event, the Ballyard gauge and the Ballymullen gauge, both located on the River Lee. The recorded and modelled peak water level are closely matched, within a 28mm difference at the Ballyard gauge. The Ballymullen modelled peak water level is 19mm outside of the 100mm tolerance, this likely due to the uncertainty in the fluvial flow during the event.

Table 3.4 Comparison of Gauged and Modelled Water Levels 3rd January 2014

Gauge	Peak Recorded Water Level (m)	Peak Modelled Water Level (m)	Difference (m)
Ballyard	2.98	3.008	0.028
Ballymullen	2.855	2.974	0.119

3.2.3.2 Observed 11th September 2015 Event

Figure 3.23 below shows the locations of observed flooding during the 11th of September 2015 event.

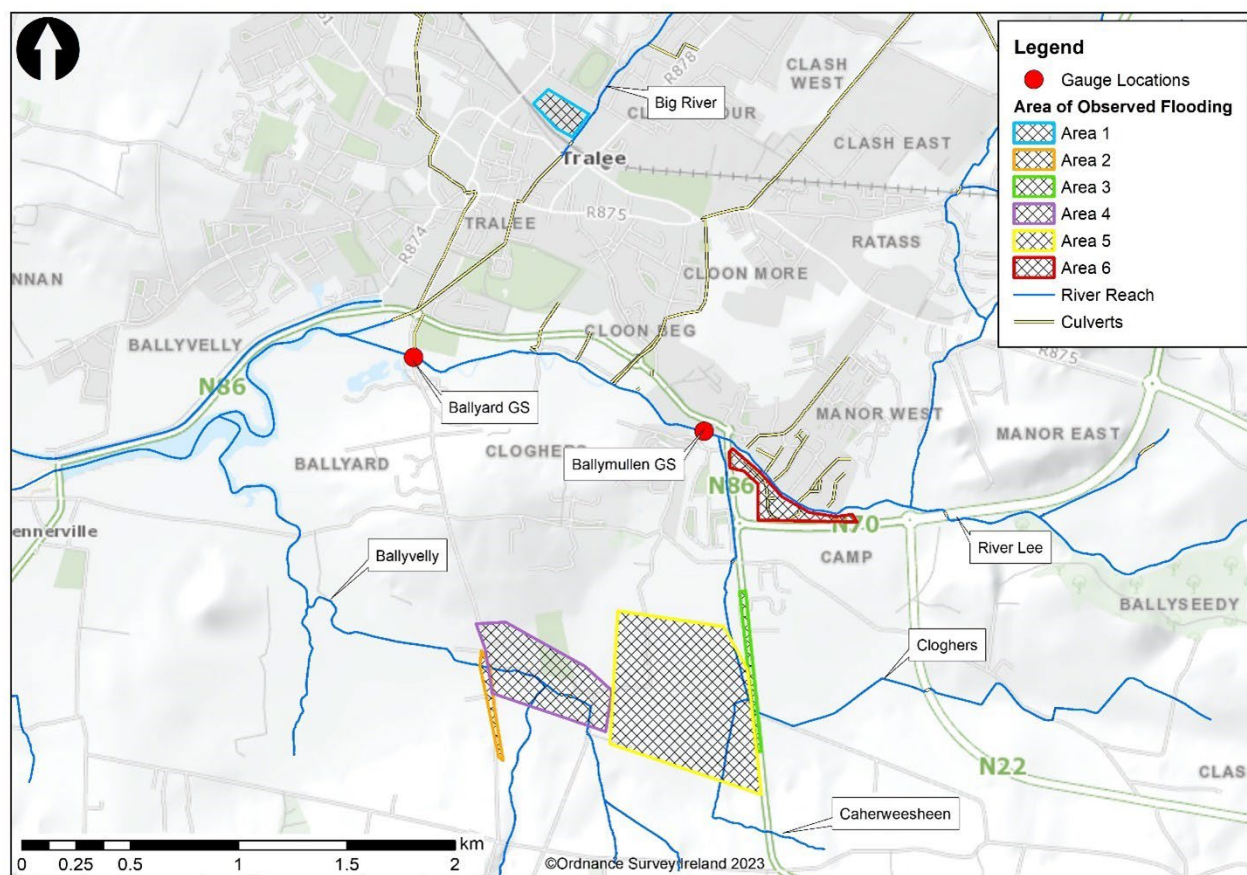


Figure 3.23: Areas of Observed Flooding During the 11th September 2015 Event

The observed flooding for this event is listed below:

- Area 1 – One resident evacuated from Roger Casement Avenue as their house was considered at risk but did not flood.
- Area 2 – Ballyard Road flooded.
- Area 3 - The Cloghers River overtopped its banks at the junction of the N70 and Ahern's Road and flooded this area of road and adjacent fields.
- Area 4 - the Ballyvelly River breached its banks in several locations south of the rugby club. Water flowed westwards from this location and flooded the Ballyard Road and properties off the Ballyard Road.
- Area 5 - The Caherweesheen River breached its left bank and flowed through adjacent fields resulting in a property (Caherweesheen House) experiencing flooding. Flooding extended to the area around the nursing home. There are no reports of this nursing home flooding.
- Area 6 - There was flooding in the area between the River Lee and the properties at Hunters Wood housing estate.

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Figure 3.24 to Figure 3.27 show photos and drawings of the flooding that occurred during the 11th September 2015 event.

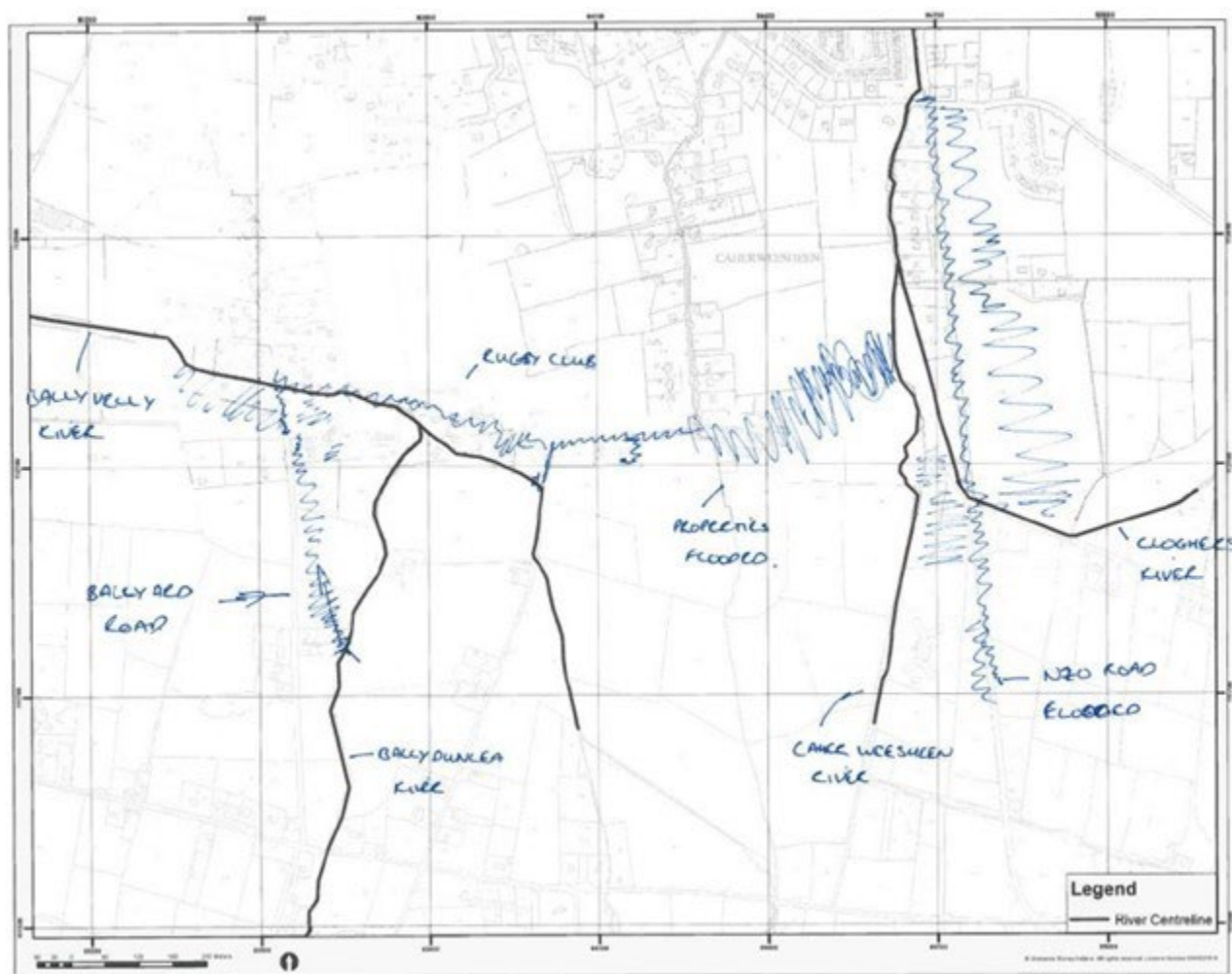


Figure 3.24: Areas flooded in September 2015 along the Ballyvelly, Cloghies and Caherweesheen Rivers



Figure 3.25: Flooding on Ballyard Road at the entrance to Tralee Rugby club (left) and flooding at the junction of the N70 and Ahern's Road, Nursing home entrance (right)

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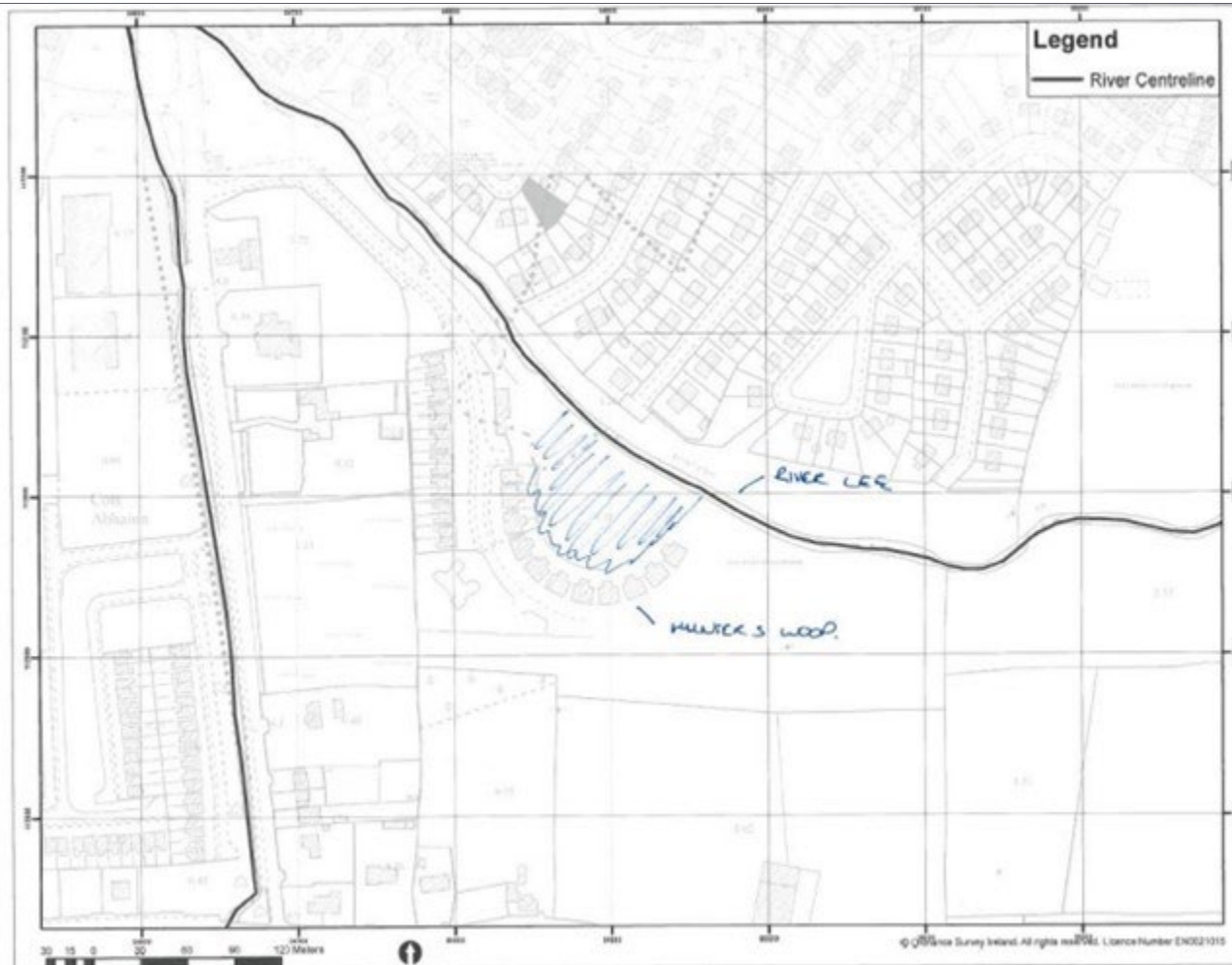


Figure 3.26: Hunters Wood River Lee Flood Drawing



Figure 3.27: Photographs of Flooding to the rear of Hunters Wood

Figure 3.28 below shows an overview of the modelled flood extents for the September 2015 event and highlights the areas which observed flooding throughout Tralee.

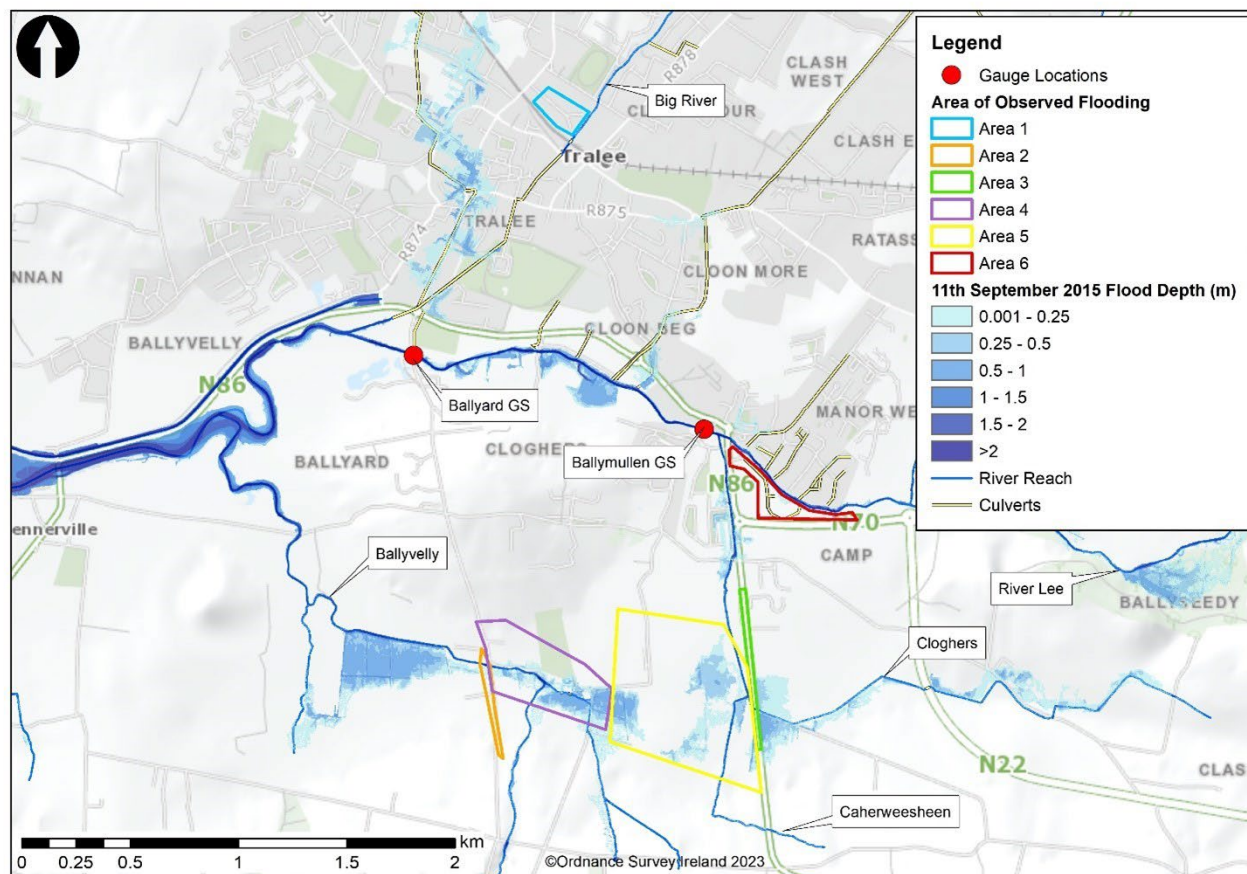


Figure 3.28: Overview of modelled flood extents for the 11th September 2015

Figure 3.29 shows the flooding along the Ballyvelly, Caherweesheen and Hunters Wood areas. Figure 3.30 shows the flooding along Area 1 beside the Big River.

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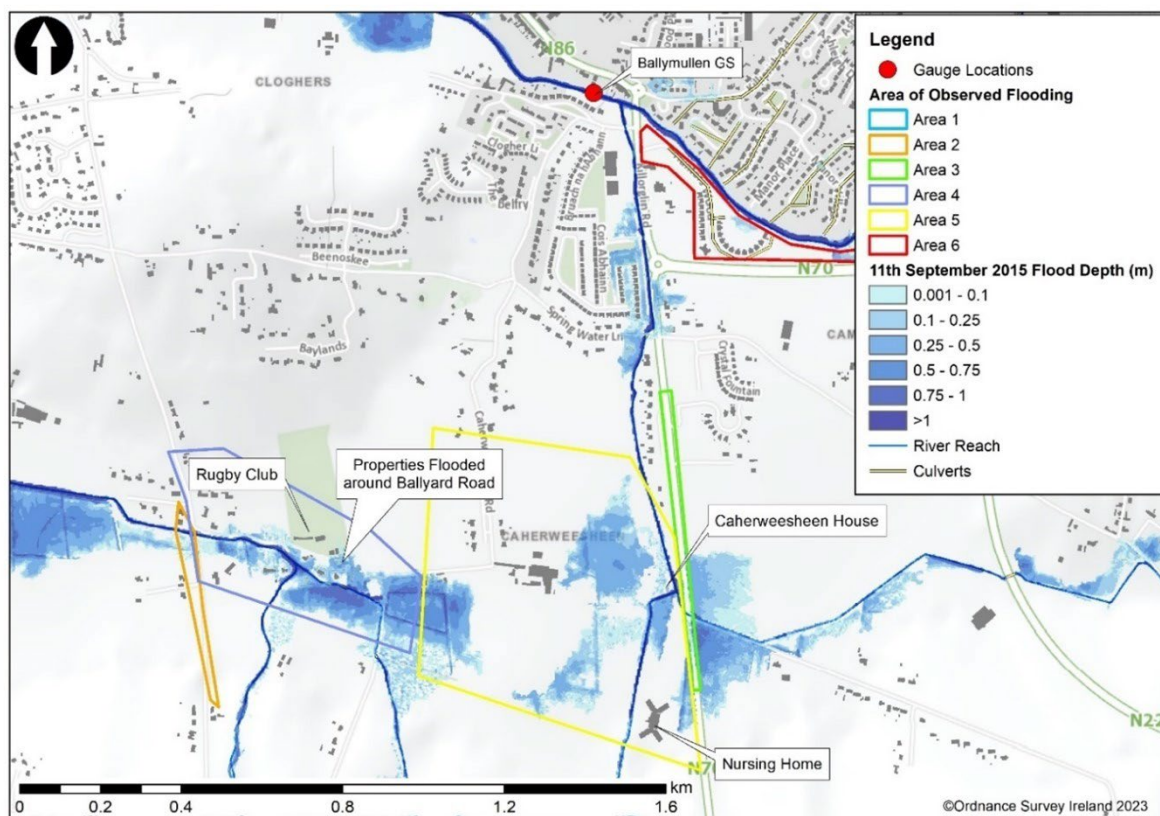


Figure 3.29: Overview of modelled flood extents on the Ballyvelly and Caherweesheen - 11th September 2015

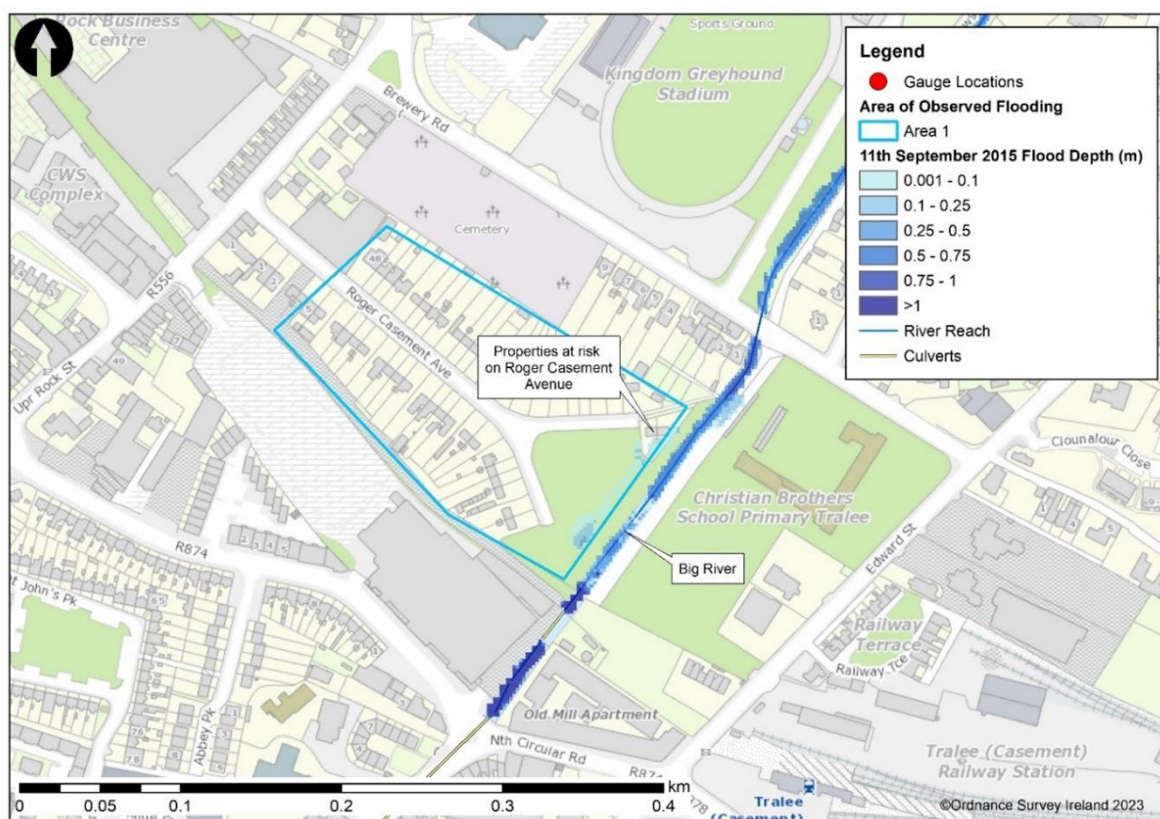


Figure 3.30: Overview of modelled flood extents near Roger Casement Avenue - 11th September 2015

This event has been estimated by the hydrological assessment (Hydrology Report Section 3.1) to be a 5-10 year fluvial event. The model has been ran using the Blennerville gauge levels for the event to set the downstream boundary of the River Lee and Canal. A 10 year event has been used to set the flows within the river reaches. Initially the model was not replicating flooding around the Ballyvelly watercourse. A landowner was contacted about any information regarding potential blockages observed in the area during the 15th September 2015 flood event. While the landowner did not recall any blockages, they did state that the capacity of the bridge at the Ballyard road has reduced significantly over the years. They estimated that the opening area of the bridge has been reduced by round 2 feet (610mm). The landowner also stated that the channel itself has reduced significantly over the years due to sedimentation. With this information the bed levels of the bridge beside the Rugby Club were altered. The results of the model are listed below.

- Area 1 – The modelled flood extents show flooding reaching two properties at Roger Casement Avenue but flooding does not enter these properties. This would match with the observed flooding as a resident was evacuated from their house due to the flood risk, but their property did not flood.
- Area 2 – There is a small amount of flooding along the Ballyard River and the road towards the Rugby Club.
- Area 3 – The model has replicated flooding out of the Cloghers River in the adjacent fields and on the N70 and Ahern's Road.
- Area 4 – Flooding around the Rugby club has been replicated with flooding out of the Ballyvelly River in several locations south of the rugby club. This flooding flows westwards from this location and onto the Ballyard Road. Properties off the Ballyard Road were reported as flooding, no information was available as to which of these properties flooded or any recorded depths of flooding, but several properties are within the modelled extents along the Ballyard Road.
- Area 5 - The model has replicated the flow path and flooding from the left bank of the Caherweesheen towards Caherweesheen House. Flooding also extends towards the Nursing Home entrance along the N70 similar to Figure 3.29.
- Area 6 - There is a small amount of flooding from the River Lee behind the properties on the Hunters Wood housing estate. This flooding is not as large as observed during the event, however a comparison of the CFRAM LiDAR and the updated LiDAR confirmed that the ground levels at this location were lower in the past (Figure 3.31). Based on the CFRAM LiDAR the ground levels behind Hunters Wood ranged from 3.6mOD to 4.2mOD. The updated LiDAR shows the ground has been raised to at least 4.0mOD for most of the area which has reduced the modelled flood extent. It is therefore likely that during the 11th September 2015 event the ground levels were lower which accounts for the larger flood extents when compared with the model outputs.

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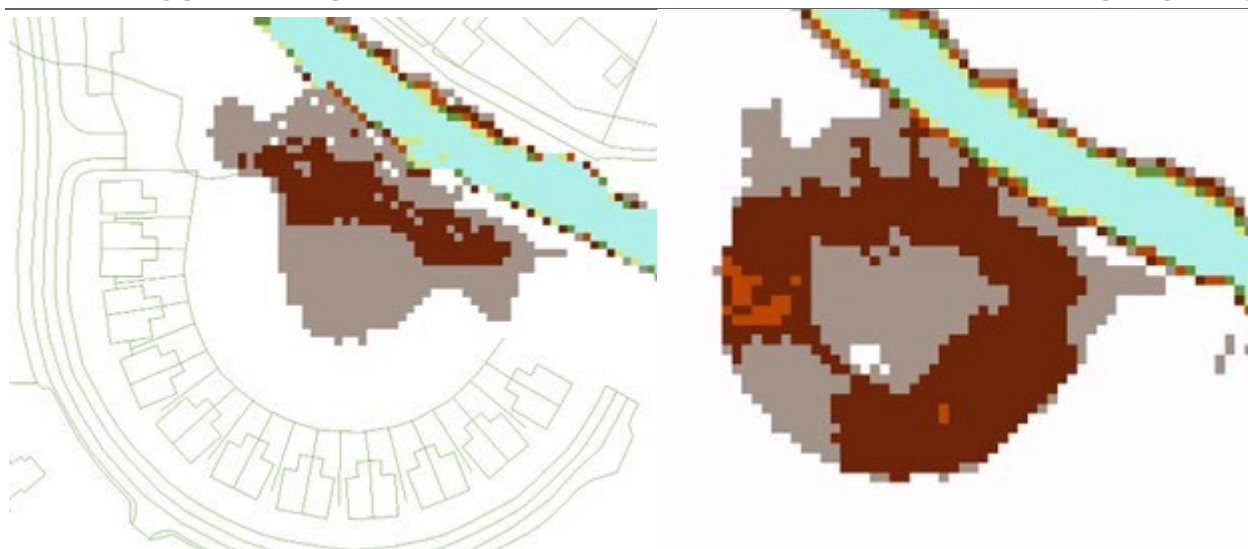


Figure 3.31: Comparison of Hunters Wood LiDAR between Updated (Left) and CFRAM (Right)

There are two water level gauges that were in operation during this flood event. These are the Ballyard gauge and the Ballymullen gauge which are both located on the River Lee. The recorded and modelled peak water levels are closely matched and within 100mm of each other. The recorded and modelled peak levels are shown in Table 3.5.

Table 3.5 Comparison of Gauged and Modelled Water Levels 11th September 2015

Gauge	Peak Recorded Water Level (m)	Peak Modelled Water Level (m)	Difference (m)
Ballyard	2.05	2.03	0.02
Ballymullen	3.534	3.576	-0.042

3.2.3.3 Observed 15th December 2015 Event

Figure 3.32 below shows the locations of observed flooding during the 5th December 2015 event.

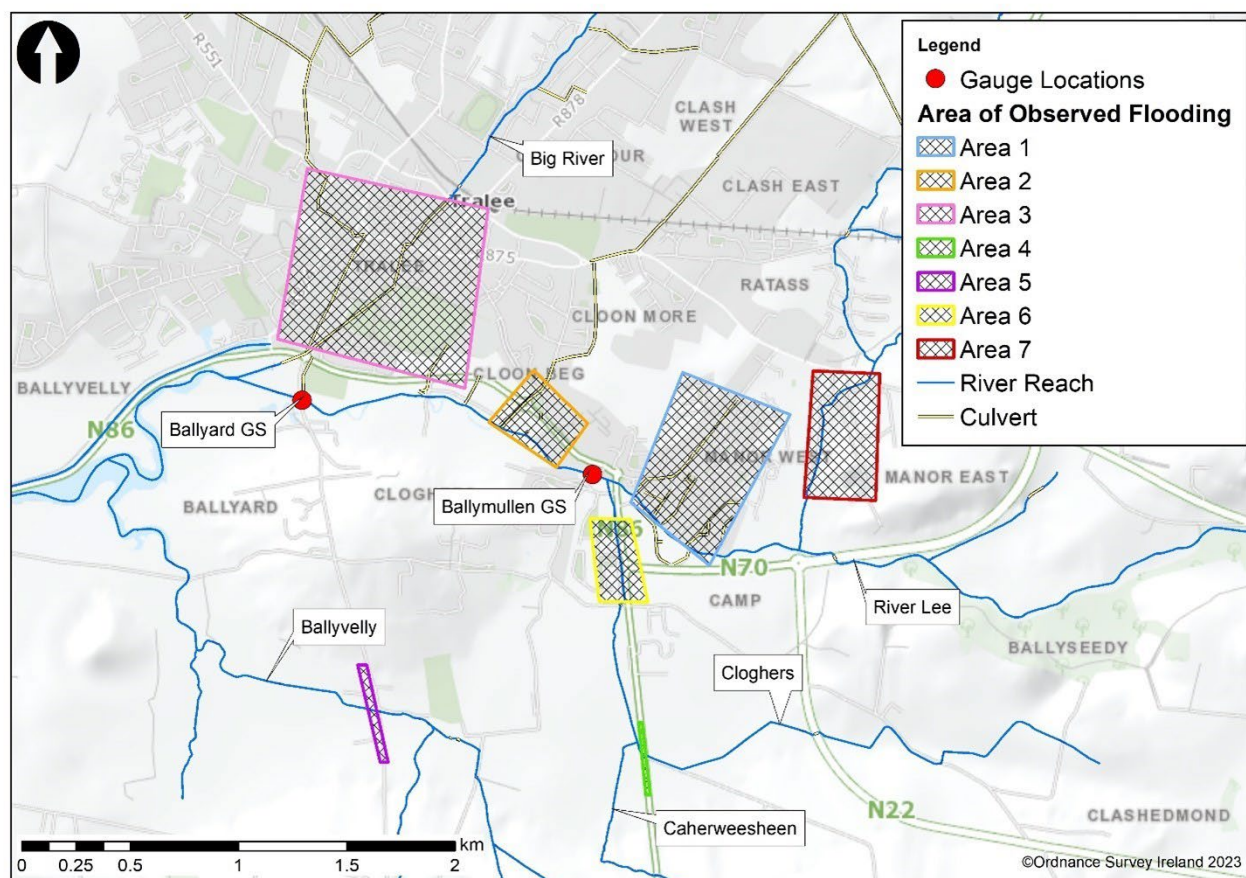


Figure 3.32: Areas of Observed Flooding During the 5th December 2015 Event

Heavy Rainfall accompanying Storm Desmond led to extensive flooding in Tralee. The recorded flooding for this event is listed below.

- Area 1 – Manor West flooding recorded including in the Manor Lawn area. (Figure 3.35).
- Area 2 - Flooding in the Ballymullen area including the Munster Bar. (Figure 3.33).
- Area 3 - Town Centre
- Area 4 - Flooding of the N70 at Ahern's junction.
- Area 5 - Some flooding to the Ballyard Road.
- Area 6 - Flooding at Castlemaine Road. (Figure 3.34).
- Area 7 - Flooding reported at the Clashlehan Roundabout.

Figure 3.33 to Figure 3.36 are photographs which show flooding around Tralee during the 5th December 2015 event.

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Figure 3.33: Flooding at Ballymullen Road (Looking towards Munster Bar)



Figure 3.34: Flooding at Castlemaine Road (Lidl carpark)



Figure 3.35: Flooding at Manor Lawn



Figure 3.36: Flooding in Townpark

Figure 3.37 to Figure 3.40 below shows an overview of the modelled flood extents for the December 2015 event and highlights the areas where flooding was observed.

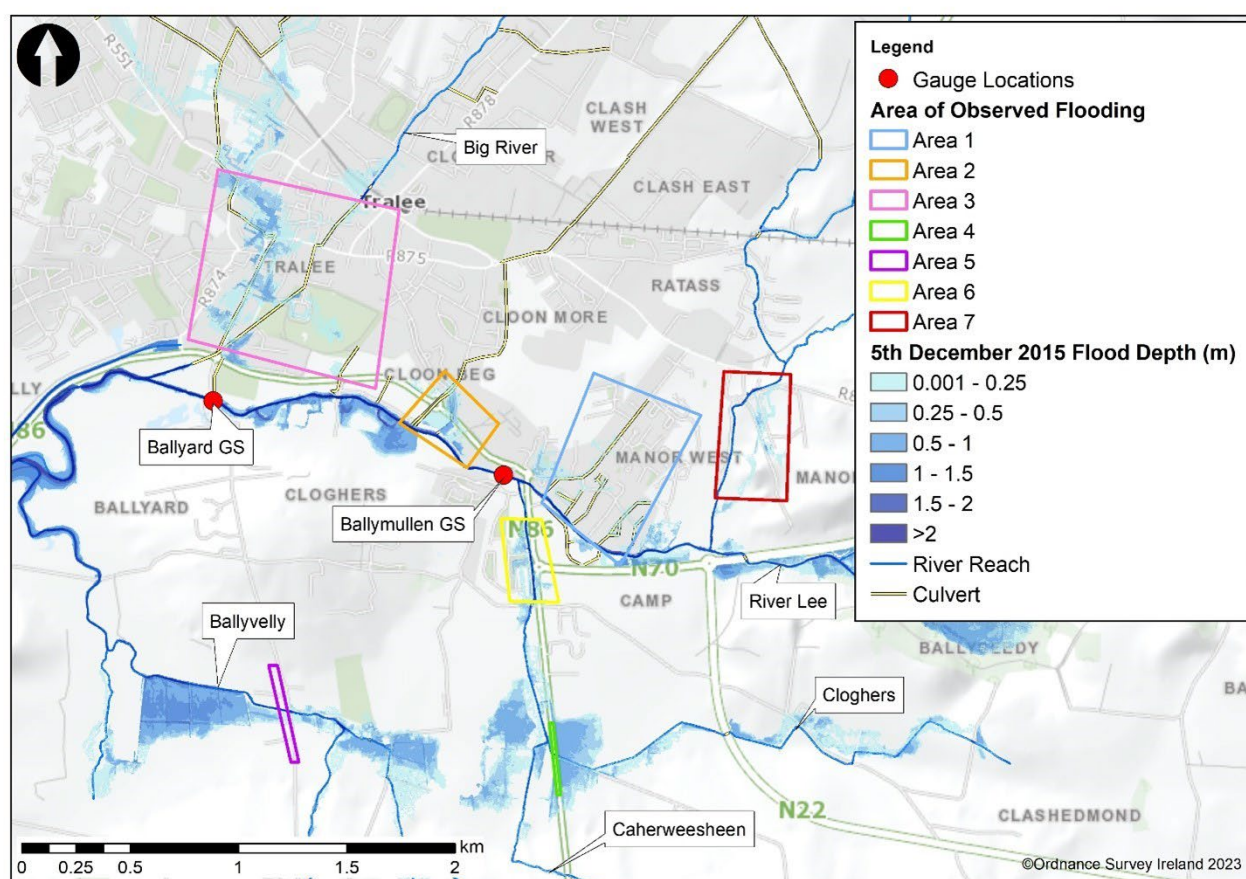


Figure 3.37: Overview of modelled flood extents for the 5th December 2015 flood event

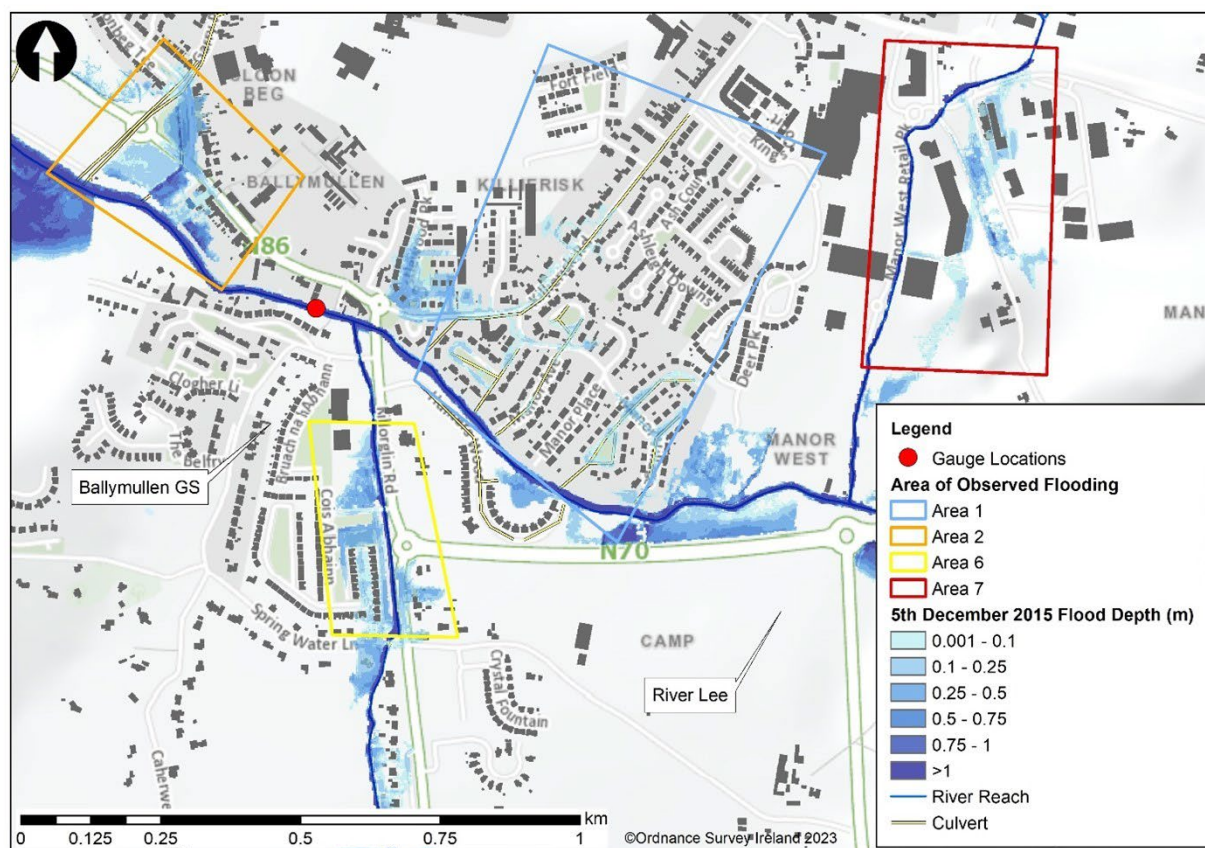


Figure 3.38: Modelled flood extents in areas 1, 2, 6 and 7 for the 5th December 2015 flood event

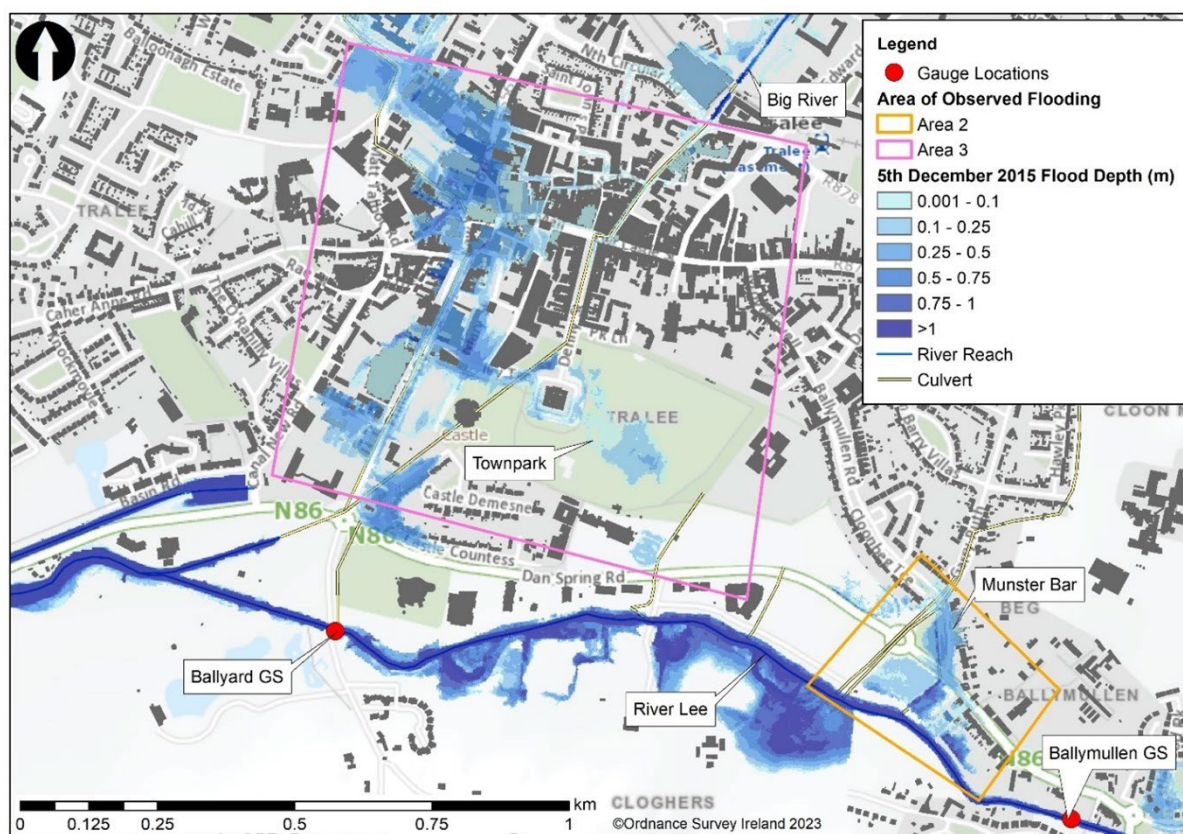


Figure 3.39: Modelled flood extents in areas 2 and 3 for the 5th December 2015 flood event

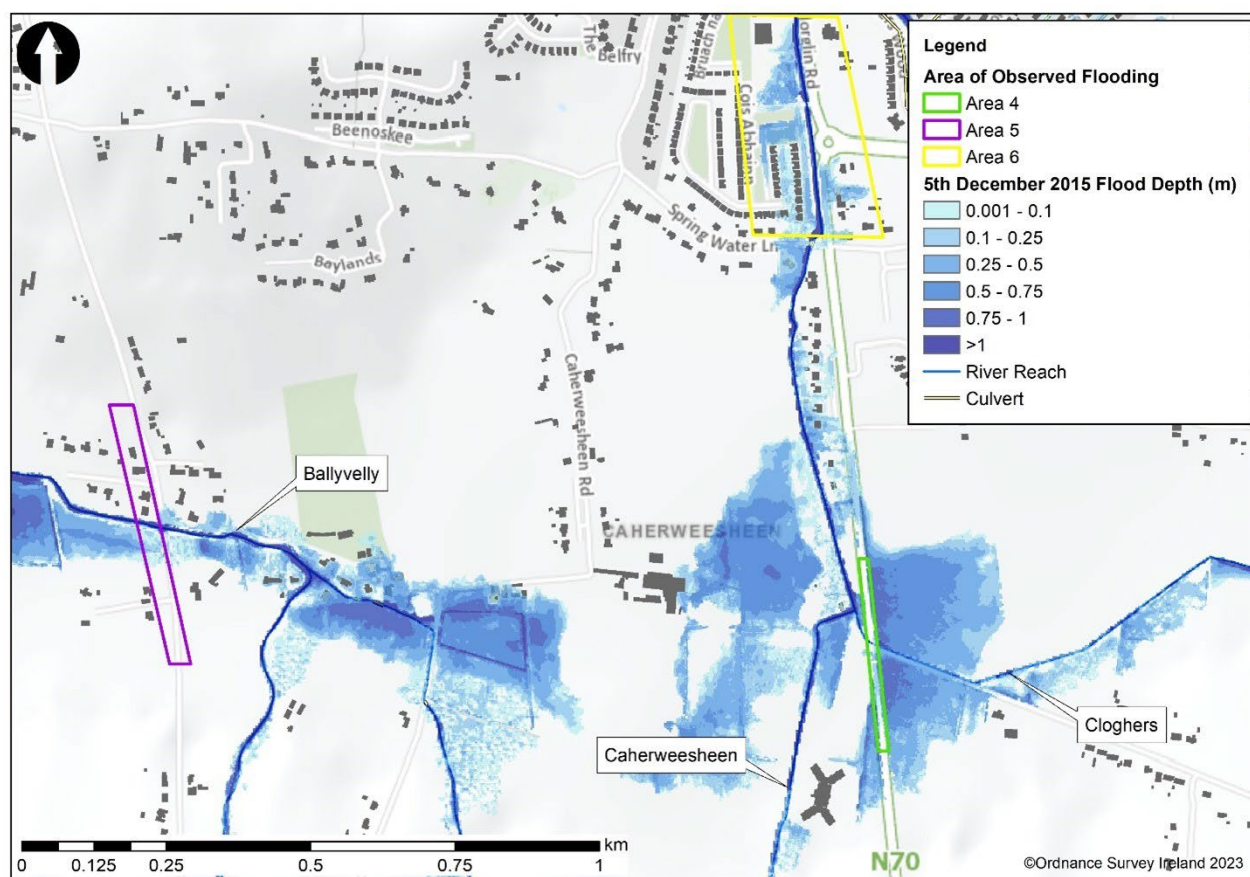


Figure 3.40: Modelled flood extents in areas 4, 5 and 6 for the 5th December 2015 flood event

This event has been estimated to be a 40–50 year fluvial event by the hydrological assessment (Hydrology Report Section 3.1). The model has been ran using the Blennerville gauge levels for the event to set the downstream boundary levels of the River Lee and Canal. A 50 year event has been used to set the flows within the river reaches. For the drainage network around Manor West, rainfall was applied to sub-catchments associated with manholes within the network to replicate the photographed flooding at Manor Lawn. The only available rainfall information was from the daily rain gauge at Lisaboula. This gauge recorded 49mm of rainfall for the 5th December 2015 event. This total rainfall depth was disaggregated into a typical rainfall profile for the area and applied to the model.

- Area 1 - The model has replicated flooding to the Manor West area. The photo of the Manor Lawn area flooding shown in Figure 3.35 shows flooding at the first step of a property. This would indicate that flood depths were around 100 – 150mm. Modelled flood depths reach around 160mm on the road outside the property where the photo in Figure 3.35 was taken. Overall modelled flood depths within Manor Lawn range from 1mm up to 170mm.

- Area 2 - The Ballymullen Road and surrounding area has significant flooding in the model. There is also flooding to the Munster Bar and to the Christus Rex Park which matches observed data for the event, shown in Figure 3.33. From these photographs flood levels reached close to the seat of the park bench and to the top of the silver cars front tyre. The estimated flood depth is therefore approximately 300 - 500mm at the time the

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photograph was taken, modelled depths in the park range are comparable to these observed values with a range of 300 – 400mm.

- Area 3 - The model is showing extensive flooding to the town centre, Tralee Town Park is also shown as flooded to a maximum depth of approximately 100mm which is comparable to the flooding shown in Figure 3.36.

- Area 4 - Flooding to N70 is occurring in the model.

- Area 5 - The model has replicated flooding on the Ballyard Road and surrounding area.

- Area 6 – Flooding along the N70 extends down to the Castlemaine Road and Lidl carpark which was photographed as flooding during the event as shown in Figure 3.34. Based on this photo it appears the flooding was less than 50mm in depth as it is not overtopping any of the kerbs along the road although the depth does appear to be increasing towards the location where the photograph was taken. The modelled flood depths in this range from 2mm to 100mm.

- Area 7 - A flow path past the Clashlehan Roundabout is present within the model. Flooding comes out of bank at the Old Killarney Road and flows through the Mile Height Retail Park.

There are two water level gauges that were in operation during this flood event. These are the Ballyard gauge and the Ballymullen gauge which are both located on the River Lee. The recorded and modelled peak water levels are closely matched and within 100mm of each other for the Ballyard gauge and Ballymullen gauge.

Table 3.6 Comparison of Gauged and Modelled Water Levels 5th December 2015

Gauge	Peak Recorded Water Level (m)	Peak Modelled Water Level (m)	Difference (m)
Ballyard	2.039	2.079	-0.04
Ballymullen	4.011	3.93	0.081

3.2.3.4 Observed 8th-9th February 2020 Event

Figure 3.41 below shows the locations of observed flooding during the 8/9th February 2020 event.

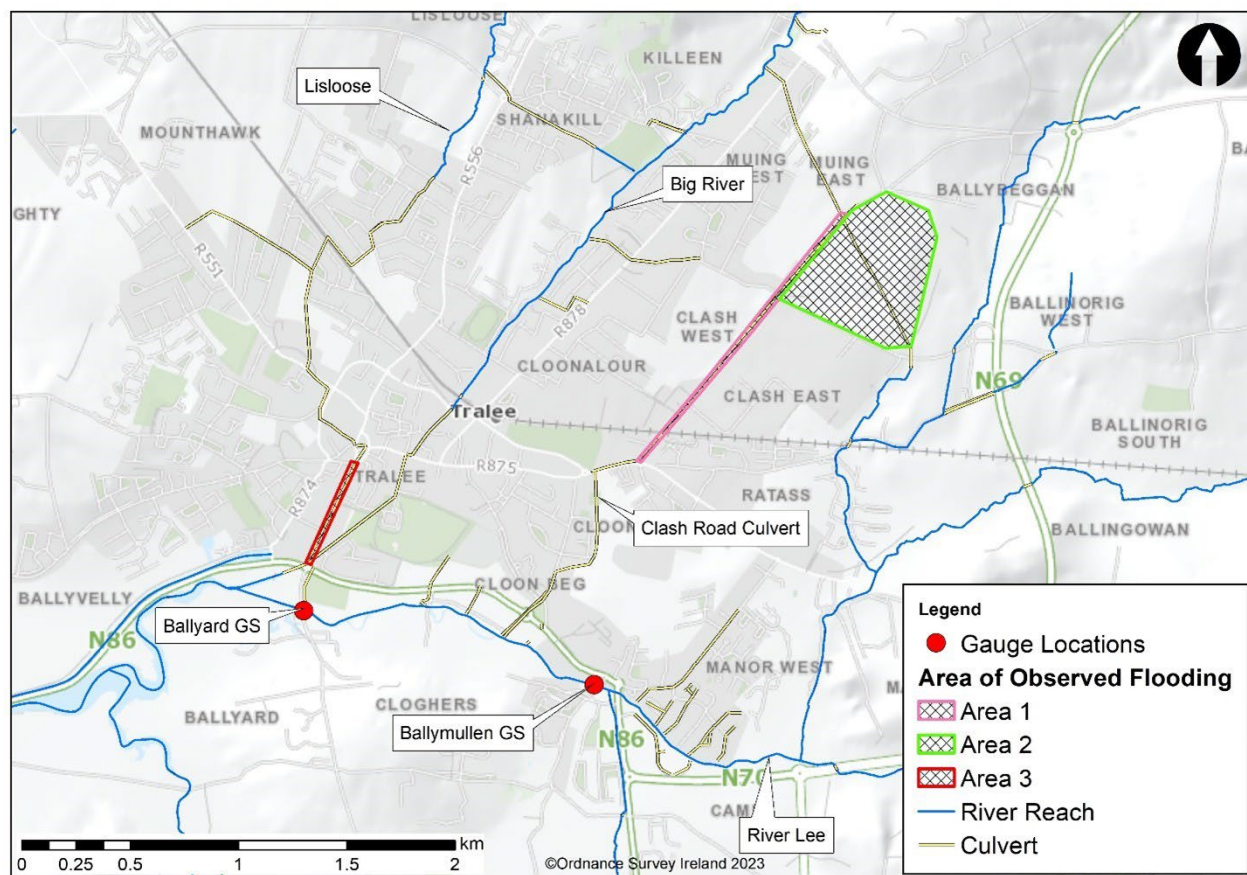


Figure 3.41: Areas of Observed Flooding During the 8/9th February 2020 Event

The recorded flooding for this event is listed below.

- Area 1 - Clash Road experienced flooding due to exceptionally heavy rain.
- Area 2 - The Ballybeggan racecourse was noted as a significant source of run-off.
- Area 3 - The Ballyard area of Tralee was impacted by fluvial and tidal flooding with James Street, Staughtons Row and Godfrey Place specifically being impacted.

Figure 3.42 shows photos of flooding taken during the February 2020 event. There are no recorded times for when these photos were taken nor are there levels or depths recorded for the event.

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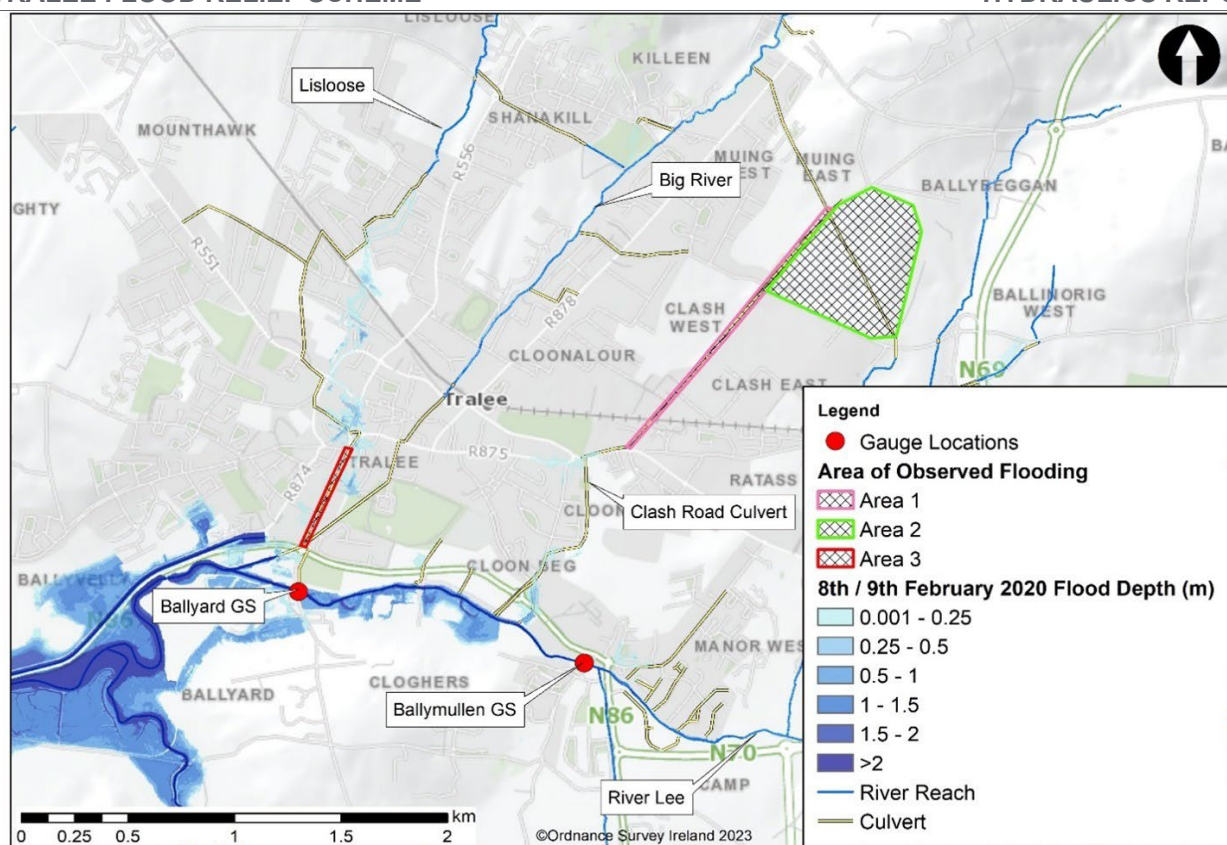
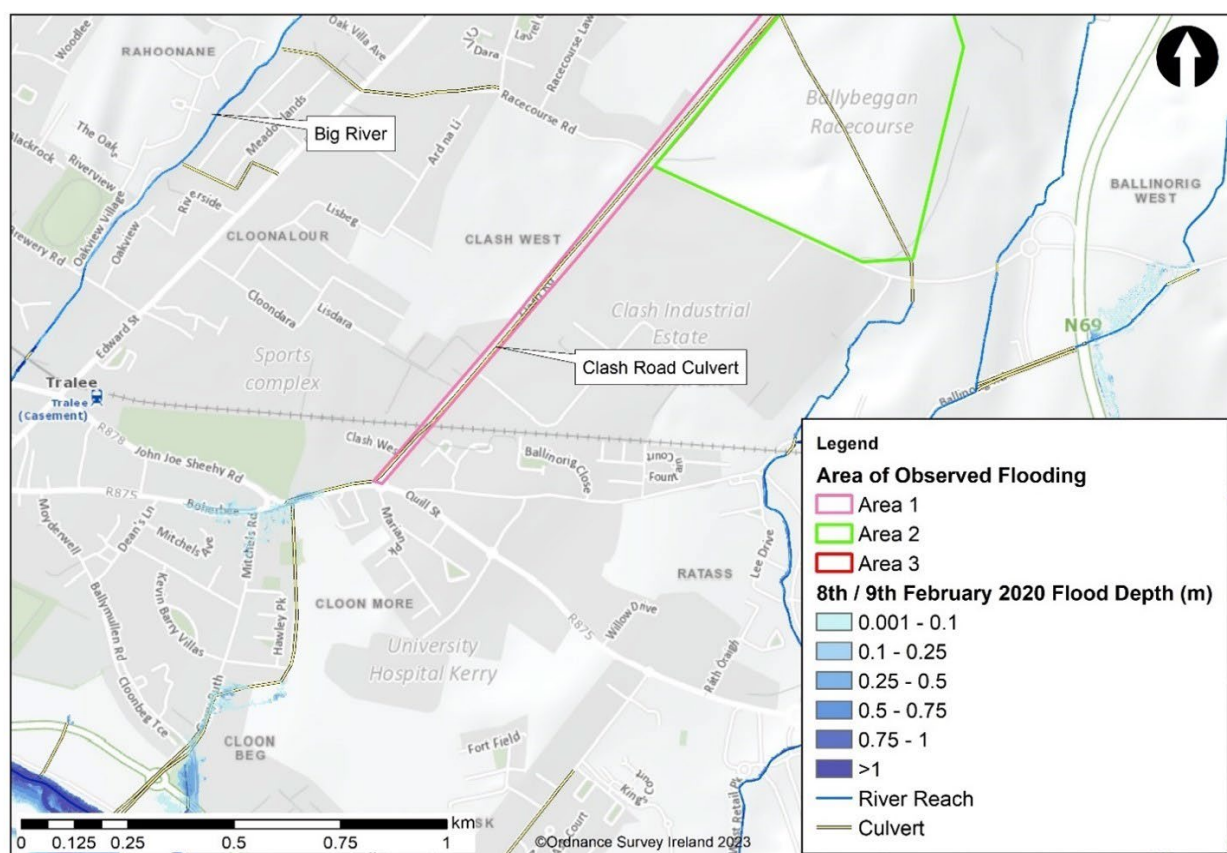


Figure 3.42: Flooding in the Brandon Car Park beside Prince's Street (top left), outside the Fabrik building on Godfrey's Place (top right), Flooding on James Street (bottom left) and Flooding on Prince's Quay (bottom right)

Figure 3.43, Figure 3.44 and Figure 3.45 below show an overview of the modelled flood extents for the February 2020 event and highlight the areas which observed flooding throughout Tralee.

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Figure 3.43: Overview of modelled flood extents during the 8th – 9th February 2020 flood eventFigure 3.44: Overview of modelled flood extents during the 8th – 9th February 2020 flood event at Clash Road

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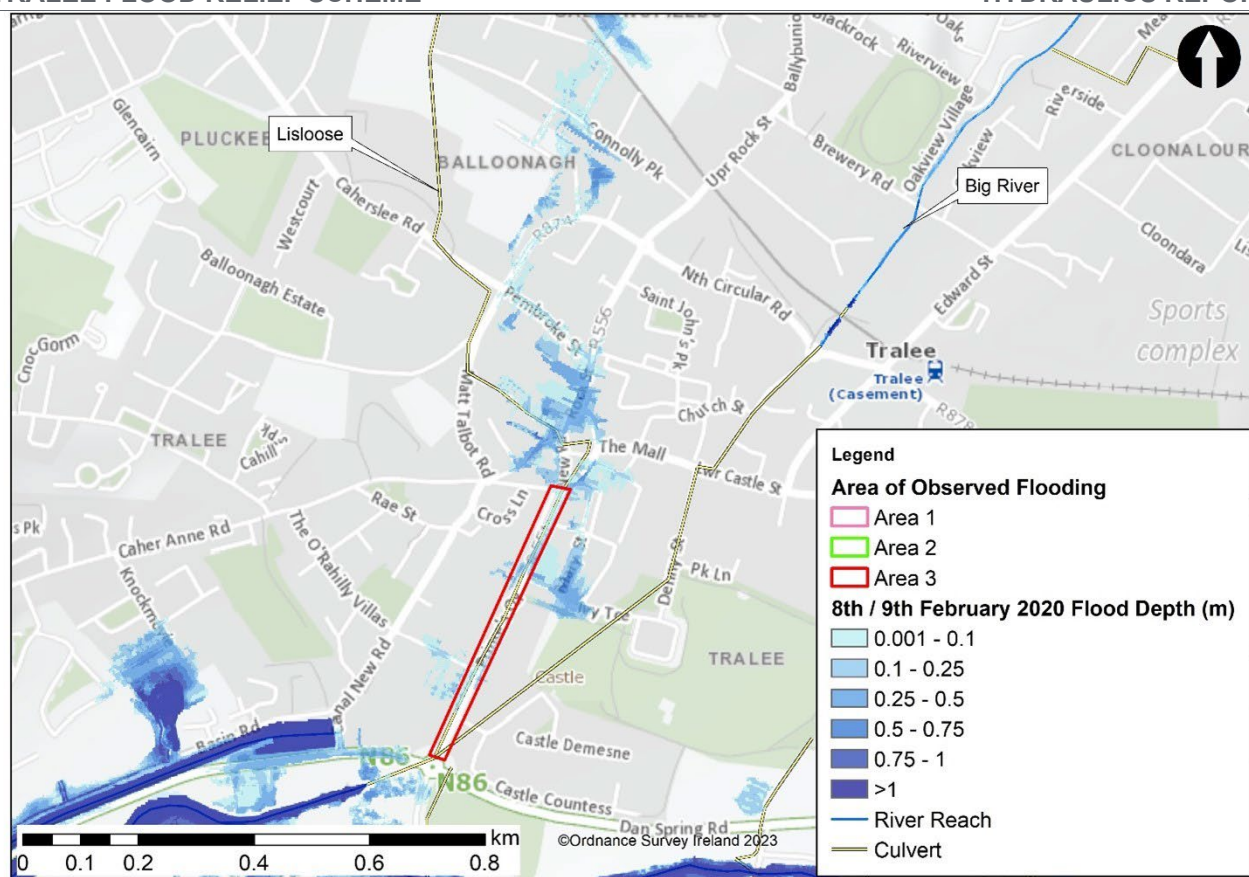


Figure 3.45: Overview of modelled flood extents during the 8th – 9th February 2020 flood event at Staughtons Row, Godfrey Place and James Street

This event has been estimated to be a 1-5 year fluvial event by the hydrological analysis (Hydrology Report Section 3.1). The model has been ran using the Blennerville gauge levels for the event to set the downstream boundary levels of the River Lee and Canal. Around a 1-year event has been used to set the flows within the river reaches. Rainfall was applied to the model around the Ballybeggan racecourse and Clash Road culvert. The rainfall was based on the Lisaboula daily rain gauge which recorded 50.7mm for the 8th and 6.1mm for the 9th February. This total rainfall depth was disaggregated into a typical rainfall profile for the area and applied to the model. The results of the model are listed below.

- Area 1 – Some flooding occurs out of the Clash Road culvert further downstream along Boherbee and Garrytruth Street.
- Area 2 - No flooding in the model at Ballybeggan racecourse. The reason for this is that flooding is most likely from surface water runoff which this model is currently not schematised to replicate. A separate surface runoff model was ran to confirm this. The results are shown in Figure 3.46. This indicates that surface water runoff is a risk from further upstream of the Clash Road culvert and in the area around the Ballybeggan racecourse. Therefore, the observed flooding in this area for this event and possibly others is a direct result of the surface water runoff.
- Area 3 - There is significant flooding along James Street, Staughtons Row and Godfrey Place within the model.

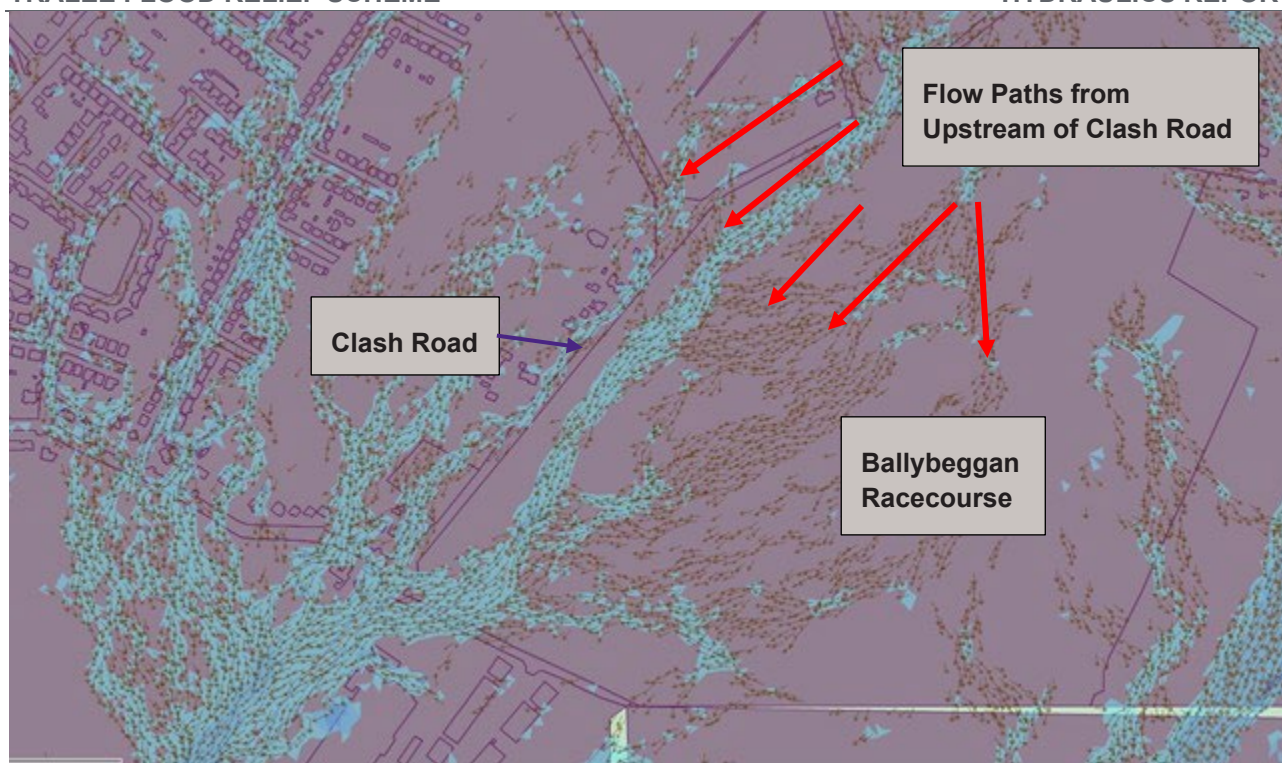


Figure 3.46: Modelled surface runoff flow paths at Ballybeggan Racecourse and Clash Road

There are two water level gauges that were in operation during this flood event. These are the Ballyard gauge and the Ballymullen gauge which are both located on the River Lee. The recorded and modelled peak water levels are closely matched and within 100mm of each other for the Ballyard and Ballymullen gauges.

Table 3.7 Comparison of Gauged and Modelled Water Levels 8th/9th February 2020

Gauge	Peak Recorded Water Level (m)	Peak Modelled Water Level (m)	Difference (m)
Ballyard	3.075	3.040	0.035
Ballymullen	3.189	3.221	-0.032

3.2.3.5 Observed 7th December 2021 Event

The recorded flooding for this event is listed below.

On the morning of the 7th December this event occurred and flooding of 7 inches (178mm) manifested on Princes Quay between Castlecountess and Godfrey Place. The depth of 7 inches was recorded outside the Tralee MD Offices on Princes Quay.

Initial flood extents and depths did not match what had been recorded for the event. The Steering Group highlighted that this flooding along Princes Quay and surrounding streets was the result of tidal flooding

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propagating through the drainage network and spilling from gullies. This flooding was determined to happen during high frequency events (>50% AEP). Upon review, it was found that the model was not replicating this flooding mechanism. The modelled culvert under Princes Quay could spill flow into the 2D domain through manholes included in the model. However, the cover levels of these manholes are at a higher elevation than the gullies which discharge into this culvert. To replicate this observed flooding mechanism the gully levels along Princes Quay, James Street and Castle Countess were surveyed and added to the model.

Once these gullies were added flooding was replicated along Princes Quay as described during the 7th December 2021 event. Figure 3.47 shows the modelled extents for the flood event. Flooding can be seen along Princes Quay, James Street and Castle Countess. During the event a depth of 178mm was recorded outside the Tralee MD offices on Princes Quay. The modelled depths in this area range from 1mm up to 323mm. Depths at the front of the Tralee MD offices are between 165mm to 201mm correlating with the observed depths.

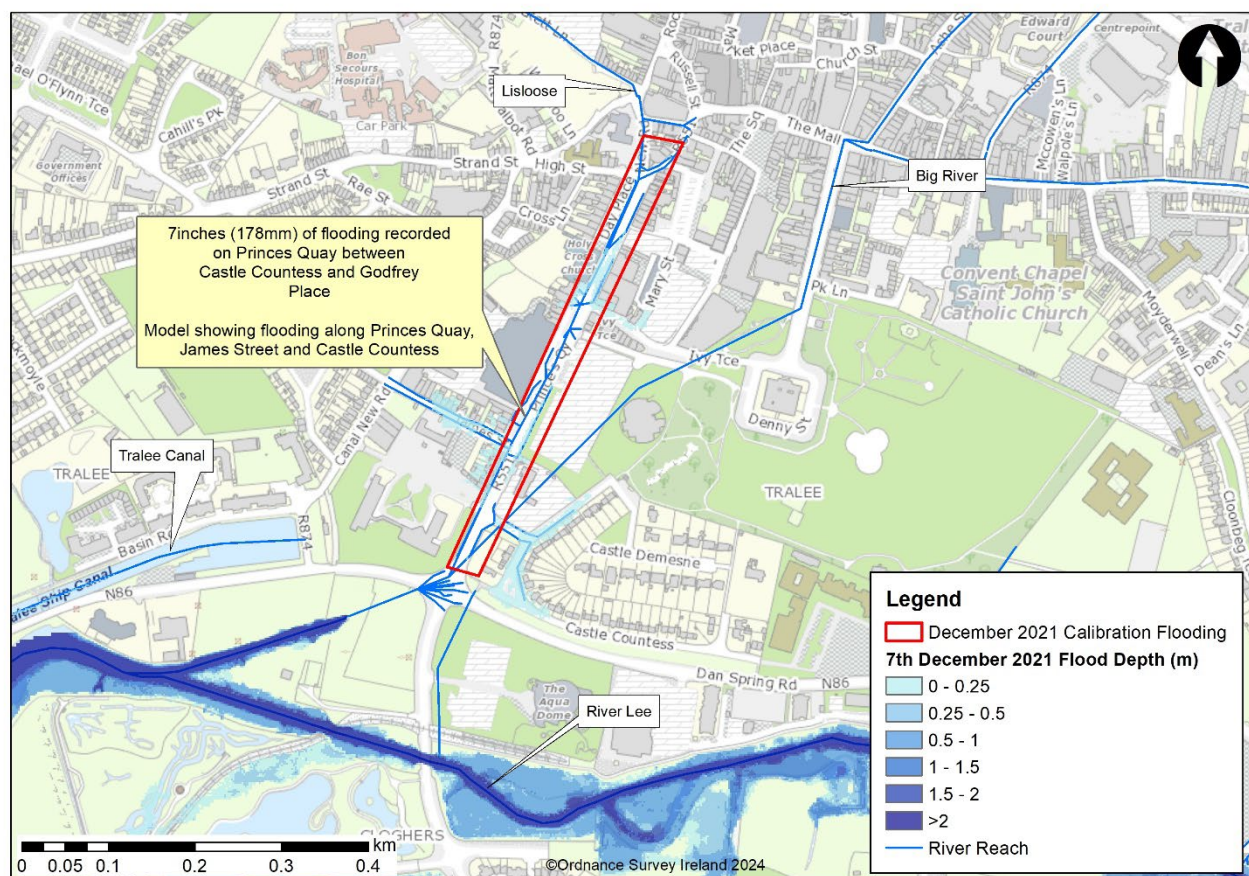


Figure 3.47: Overview of modelled flood extents for the 7th December 2021 flood event

This event has been estimated to be less than a 2 year fluvial event by the hydrological analysis (Hydrology Report Section 3.1). The model has been ran using the Blennerville gauge levels for the event to set the downstream boundary levels of the River Lee and Canal. The Ballyseedy gauge flows were available for this event and were directly input to the model to simulate flow at the upstream extent of the River Lee. An approximate 1-year event has been used to set the flows within all the other river reaches. The results of the model are listed below.

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There are seven water level gauges that were in operation during this flood event. These are the Ballyard Ballymullen, Ballyseedy, Lisloose, Manor West, Oakpark Road and Spring Water Lane gauges. The recorded and modelled peak water levels are closely matched and within 100mm of each other for all seven gauges, Table 3.8.

Table 3.8 Comparison of Gauged and Modelled Water Levels 7th December 2021

Gauge	Peak Recorded Water Level (m)	Peak Modelled Water Level (m)	Difference (m)
Ballyard	2.95	2.881	0.069
Ballymullen	3.108	3.039	0.069
Ballyseedy	12.046	12.047	-0.001
Lisloose	41.748	41.675	0.073
Manor West	8.078	8.110	-0.032
Oakpark	32.208	32.254	-0.046
Spring Water Lane	3.315	3.323	-0.008

3.2.3.6 Summary of Model Calibration

The principal model parameter reviewed and amended during calibration was the bed levels along the Ballyvelly at the bridge beside the rugby club.

As outlined in Section 3.2.3 there are five main flood events for which calibration and verification of the Tralee model was undertaken. The model has replicated peak water levels at all available water level gauges for 5 separate flood events. Flooding has been replicated in most areas where it has been observed for the 5 separate flood events. Where surface water runoff has been observed as a flood risk it has been confirmed using a 2d rainfall on grid model to replicate this source of flooding. The calibration has informed the baseline model to increase sedimentation at the Rugby Club bridge along the Ballyvelly watercourse. Overall, the model can be considered well calibrated and performing within the required tolerances.

3.3 Modelling of Existing Flood Risk for Scheme Development

The core fluvial design scenarios (50%, 10%, 1% and 0.1% AEP) were simulated for Tralee and are shown in Figure 3.48. The core coastal design scenarios (50%, 10%, 0.5% and 0.1% AEP) were also simulated and are shown in Figure 3.49.

Fluvial and coastal flood extent and depth mapping that includes pluvial influences for all AEP events is included in Appendices F to I respectively.

In addition, 3No. variations of flood zone mapping with differing pluvial contributions are included in Appendix J. The maps illustrate:

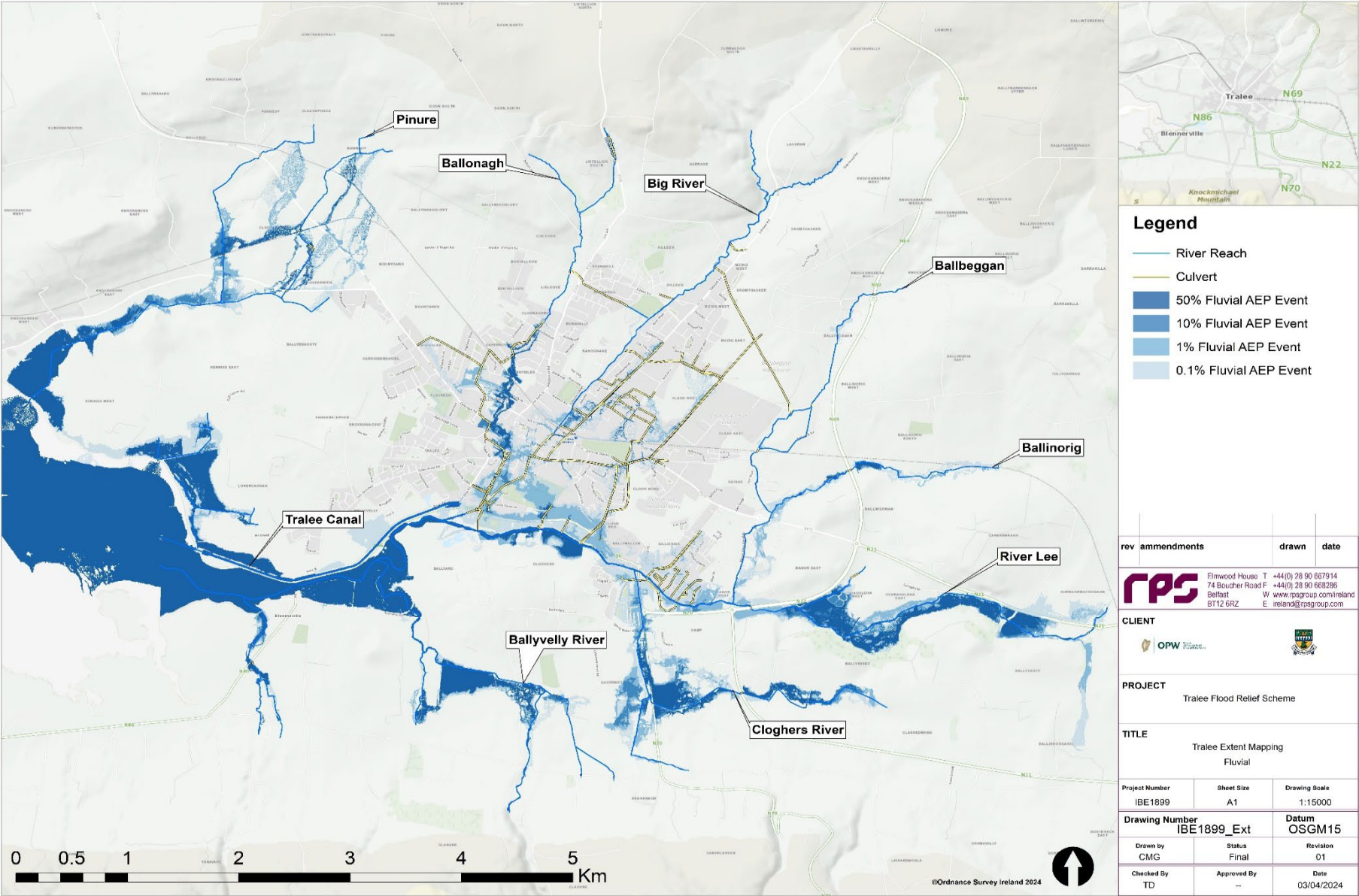
- flood zones with 1% AEP pluvial influence (baseline),
- flood zones with 20% AEP pluvial influence,
- flood zones with no pluvial influence.

GIS extent shapefiles and depth raster data has also been supplied as accompanying information.

The flood maps will form the basis for the flood risk management option phase, the economic assessment of flood risk and the benefits of such flood risk management options.

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Figure 3.48: Core Fluvial Flood Extents

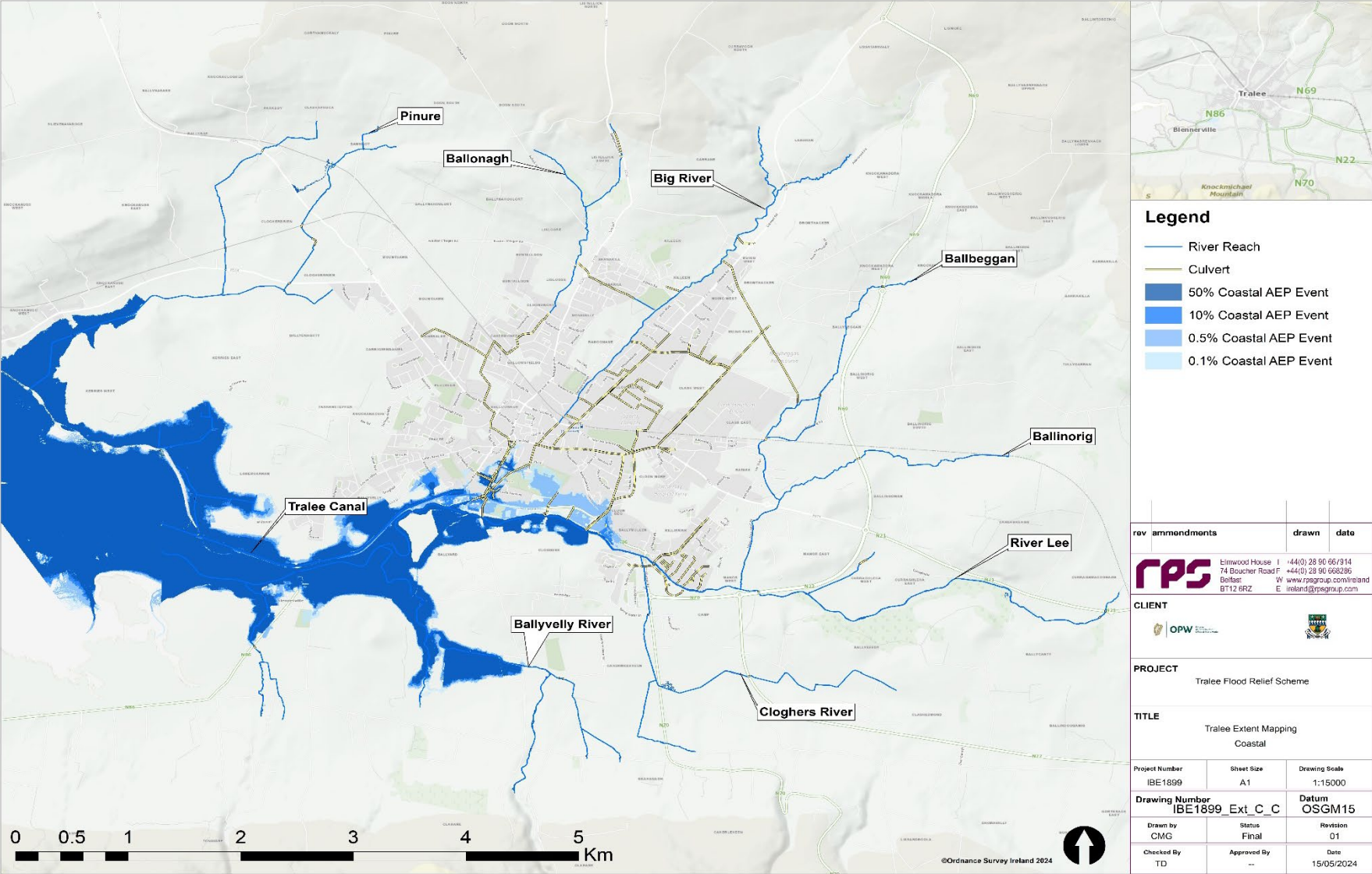


Figure 3.49: Core Coastal Flood Extents

3.4 Model Limitations and Assumptions

There are inherent assumptions, limitations and uncertainty associated with hydraulic modelling including:

- schematisation decisions regarding out-of-bank flow routes,
- culvert/bridge schematisation,
- data sources,
- changes to parameters from default.

Trunk and major surface water drainage networks assets have been included such as the Clash Road culvert. Where the culverts could not be surveyed fully some assumptions have been made in relation to culvert invert levels or culvert dimensions. Similarly, a number of outfalls along the River Lee were deemed too dangerous for surveyors to access, therefore the outfall locations and invert levels have been estimated based on available data. As demonstrated in Appendix B, the model is well anchored to the design flow estimation however there are a number of limitations and assumptions associated with the Tralee model, which include:

- Embankments were represented within the bank lines where possible rather than the 2D domain. This was to improve stability and prevent significant oscillation between 1D and 2D domains. Furthermore, only those defences considered formal were included in the model. A number of informal defences are located throughout the study area however there is no information to confirm whether these would be structurally capable of providing protection during flood events.
- Sub-floor levels of buildings are represented in the 2D domain by extruding the building footprint within the DTM to match the finish floor level recorded during the threshold survey. The threshold level of the buildings are represented by incorporating porous polygons, with a porosity of 0.01, into the 2D mesh. These “stubby” buildings enable low depth flow paths to be more accurately defined within the model while maintaining the ability to incorporate the storage of flood water within the building once the threshold level is reached.
- Modelled timestep is set at 1s. This is based off current Innovyze guidance and provides that the 1D part of the model is forced to run at a timestep closer to that of the 2D so there is a smoother interaction between the two domains, reducing the probability of stability and mass balance issues.
- Assumptions made on the condition of culverts that were informed by culvert CCTV survey were critical to the flood risk in Tralee as mentioned in Section 3.1.3.3.
- Simulation parameters are summarised in Section 3.1.6. Default software parameters were applied except for the drowned bank linearisation threshold. This was increased from a default value of 0.01m to 0.1m to improve stability at bank lines where flow is moving between the 1D river channel and 2D floodplain. This is a recommended approach by Innovyze where there are oscillating flows at the 1D-2D interface.

3.5 Pluvial - Rainfall on Grid Modelling

To aid with the assessment of pluvial flooding in Tralee a rainfall on grid runoff model was used. This method applies rainfall directly to the 2D mesh of the model and run-off is routed based on the topography of the area, simulating overland flow paths and ponding in Tralee. The model detailed in Section 3.1 was adapted to undertake this modelling.

3.5.1 Boundary Conditions

In order to ensure that flow paths and flooding generated during the simulations was a direct result of the rainfall being applied to the 2D mesh, only nominal upstream inflows were applied to the 1D domain of the network to replicate baseflow conditions in the rivers. Any increase in flow in the river and culverts during the simulations is therefore due to run-off making its way to the drainage network.

The rainfall is applied throughout the study area based on the FSU DDF grid for Tralee. The FSU DDF model developed by Met Eireann provide total rainfall depths for a given AEP and storm duration on a 2km square grid across Ireland. The total rainfall depths were extracted for all required AEPs and a range of storm durations from 15 minutes to 24 hours. FSR summer rainfall profiles were used to provide a temporal resolution to each design rainfall event. Since it is not known what the critical storm duration is for the study area, all durations were simulated for the 1% AEP to determine which duration will be taken forward for the rest of the simulations. The rainfall profiles for the 1% AEP event for durations 30, 60, 120, 360, 720 and 1440 are illustrated in Figure 3.50. The critical duration for the study area was determined to be 60 minutes.

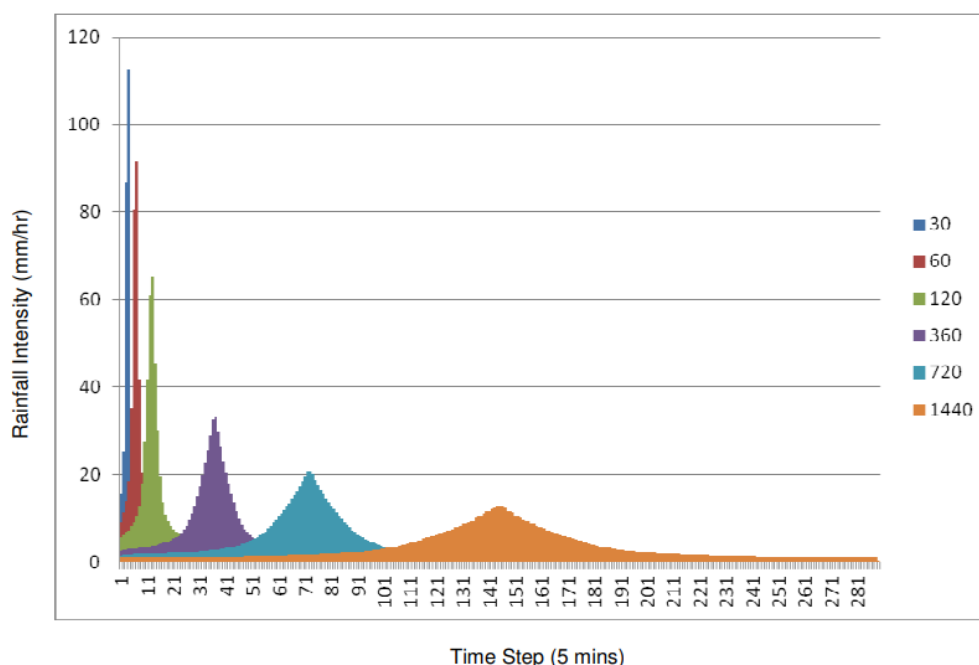


Figure 3.50: 1% AEP design rainfall profiles

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Initially a conservative approach was adopted by applying the design rainfall profiles with no account for losses such as infiltration/evapotranspiration or storage/conveyance within the underground surface water drainage network system. This represents a not-unrealistic scenario where all or some of the following are occurring to a varying degree:

- The catchment is already saturated prior to the storm event taking place;
- Rainfall is falling on impermeable surfaces;
- The surface water drainage network is at full capacity or blocked;

However after investigation of the model results and comparison with observed events it was evident that allowance for storm drainage was required. For design runs it was therefore assumed that the drainage network within the town had the capacity to collect and convey the 20% AEP event.

3.5.2 Pluvial Model Results

Figure 3.51 is an example of the pluvial flood mapping for the eastern side of the study area in the vicinity of Ballybeggan Racecourse and Clash Road. Due to the application of rainfall to the mesh all cells are deemed to be wet when maximum flood extents are extracted. In Figure 3.51 a minimum depth of 50mm has therefore been applied to enable flow paths and areas of ponding to be visible.



Figure 3.51: Pluvial Flood Mapping

3.5.3 Pluvial Optioneering

Pluvial flooding in Tralee is quantified through rainfall on grid modelling. Rainfall intensities, surface roughness, topographical features and appropriate model losses are incorporated into the model to represent the full suite of flood events from a 50% AEP event to a 0.1% AEP event, including the design event of 1% AEP.

Raw data outputs will show every 2D cell (every discrete area) as containing a depth of water and the entire Tralee urban area will therefore be shown as flooded for every flood event. This is obviously not the case and masks critical overland flow paths. The model results require post processing and interpretation to delineate the flood extents and then separation of local ponding from significant pluvial flooding.

Two steps are initially taken to delineate the flood extents.

1. Representing the existing drainage infrastructure. As mentioned above the rainfall inputs are reduced by the equivalent of a 20% AEP event which is typically the design standard of surface drainage infrastructure.
2. Removing shallow water depths. The raw data outputs are post processes to remove water depths of less than 20mm.

The next steps are taken to separate local ponding from significant pluvial flooding.

1. Model outputs are processed to enable the identification and appraisal of all discrete flood extents.
2. Ignore flood areas less than 3,000m² as local ponding, not part of a city scale FRS. An appraisal of discrete flood areas showed that 3,000m² struck the right balance between removing local areas of ponding and keeping the significant areas of pluvial flood risk within Tralee.
3. Export original 2D zones that centroids fall within the remaining flood areas. This will allow all the essential model data to be retained.

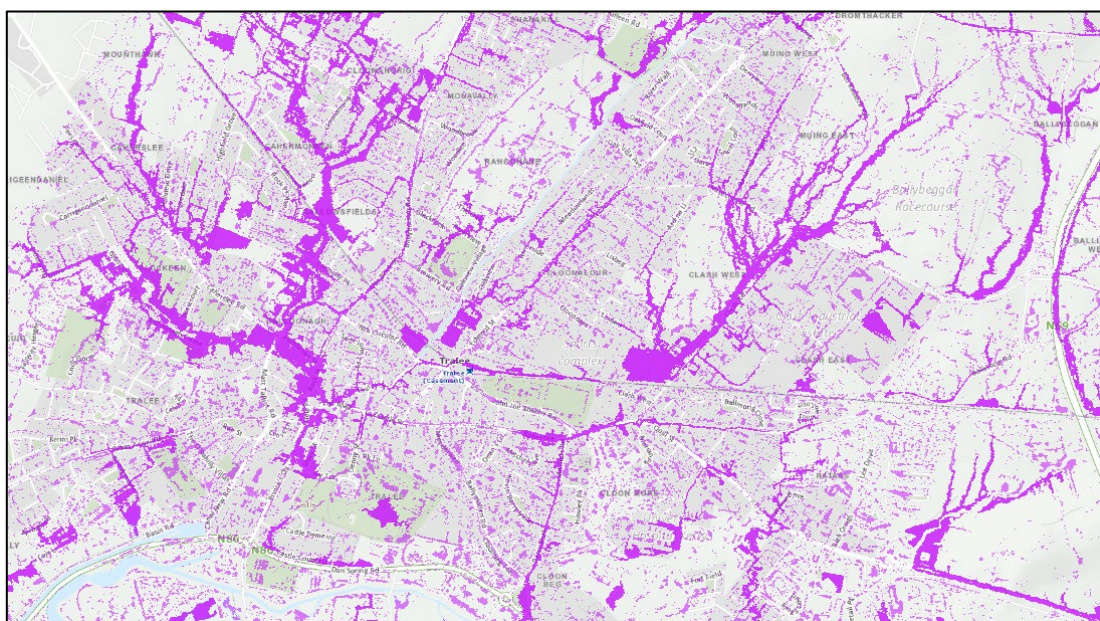
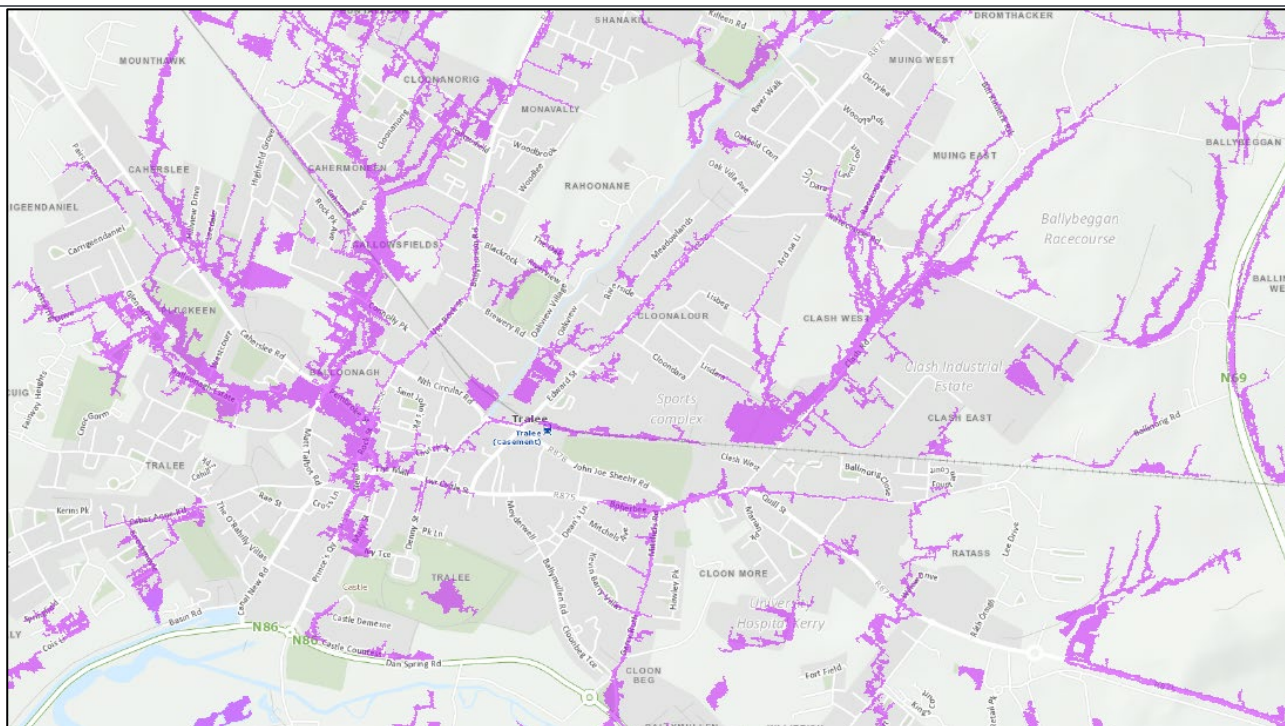


Figure 3.52: 1% AEP flood extent – Equivalent of 20%AEP rainfall event removed and water depths of less than 20mm removed



With flood extents delineated and significant pluvial flooding identified the next step is the identification of flood risk to properties and screening of measures. The optioneering process will undertake the screening of pluvial measures based on the following approach:

1. Can overland flow paths be diverted to a surface storage area (2D mesh change and/or defences)
2. Can overland flow paths be re-routed using either existing topography or through overland flow channels (2D mesh change and/or defences)
3. Can overland flow paths be intercepted by the storm network (add gullies [this is in addition to the assumed gullies that have removed the 20% AEP rainfall event]) A check will be required using the fluvial and DAP models to ensure the drainage network can convey the additional flow.

The results from the pluvial model will be used in combination with fluvial and coastal risk mapping to identify areas of combined flood risk which will be addressed as part of the Tralee FRS. Once a preferred option has been identified, a rainfall on grid model of the preferred option will be developed to assess the impact the proposed defences have on pluvial flood risk and further refine the option to deal with any residual pluvial flood

risk identified within the areas of combined risk previously highlighted or any increase in pluvial flood risk outside of those areas.

3.6 Wave Overtopping Results

A wave overtopping assessment was completed for the Tralee coastline using the results of the detailed assessment of wave climate and corresponding extreme water levels, derived during Phase 3 of the ICWWS 2018. This made use of the geometric information on the various coastal structures at Tralee, and the EurOtop empirical models to derive overtopping rates and hence inform associated flood risk. More details on the wave-overtopping assessment can be found in Section 6 of the hydrology report.

There are four overtopping locations within the Tralee study area. These Coastal Areas Potentially vulnerable to wave Overtopping (CAPOS) are located at Lohercannon East, Blennerville, Lohercannon West and Cockershell Beach, referred to as CAPOs A-D respectively. The location of the CAPOs is shown below in Figure 3.54.

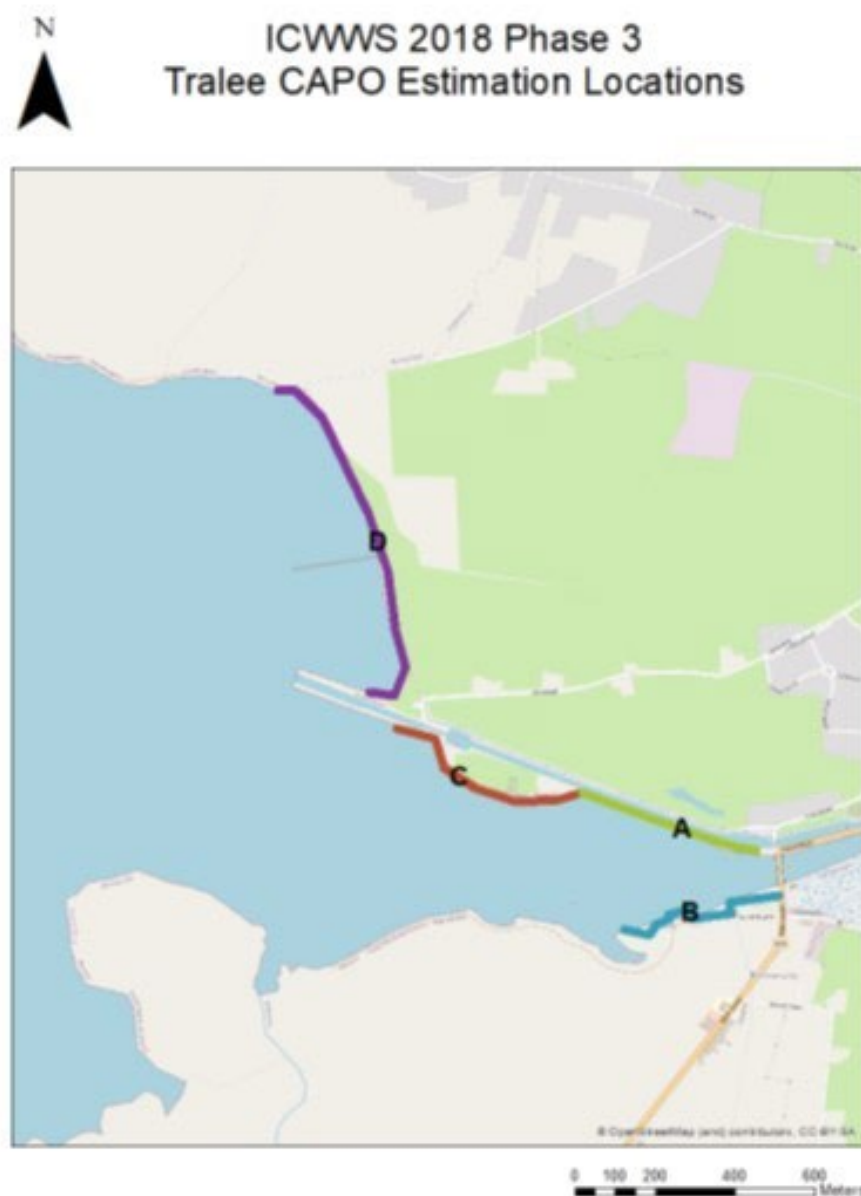


Figure 3.54: Locations of Tralee CAPOs

The results of the wave overtopping on flood extents are shown below for the 0.5% AEP event. Properties along Windmill Lane, Main Street, Lohercannon and Knockmoyle would be at risk from overtopping during this event. Appendix C contains figures depicting flood depth due to overtopping for all other return period events.

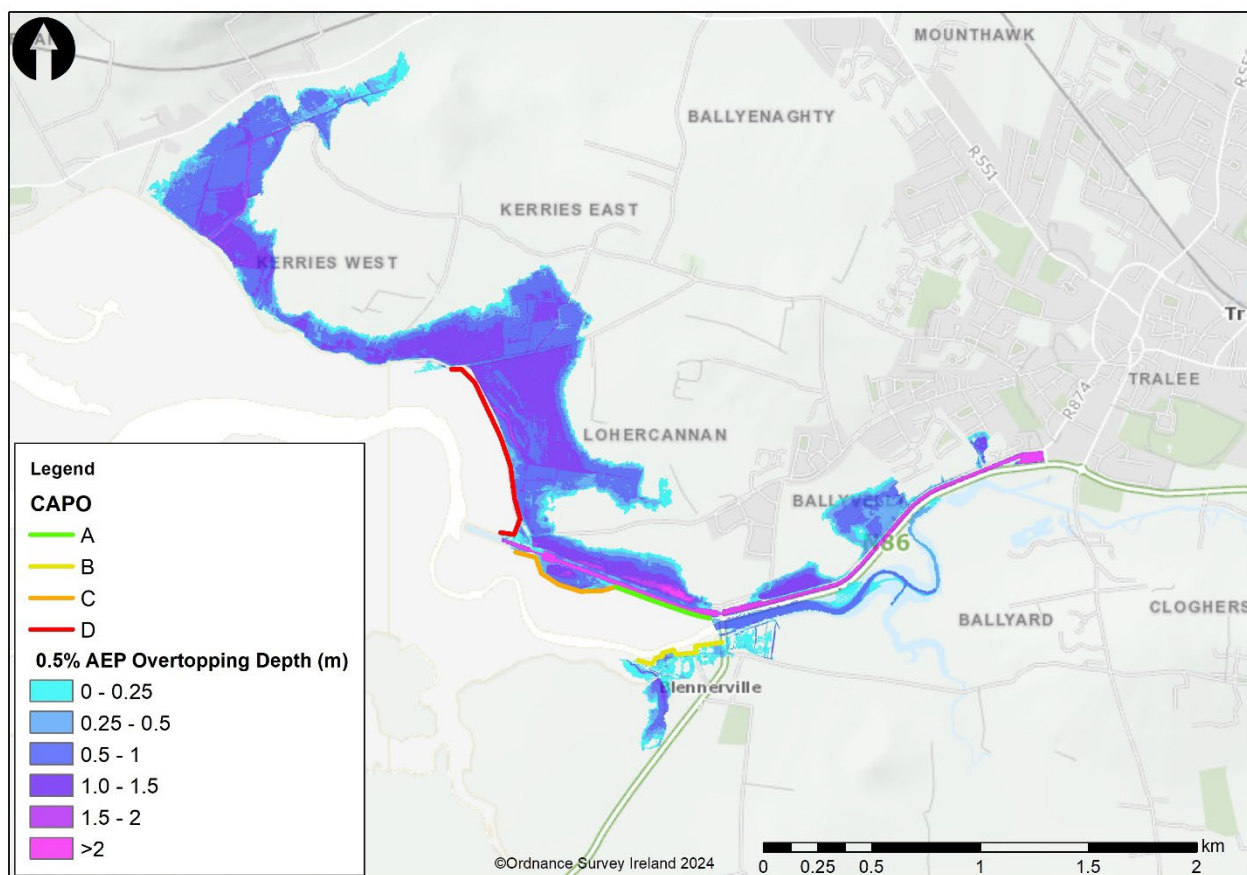


Figure 3.55: 0.5% AEP Overtopping Flood Depths

3.7 Breach Analysis

The geotechnical assessment indicated that the Tralee Canal East and West, the Aperee Living Embankment and the River Lee Walkway were viable defences and could be considered for upgrade during the optioneering phase. The Tralee Canal East and West were not considered during the breach assessment as they were not deemed to have suitable geometry to apply a breach assessment. Whilst the Aperee Living embankment was considered suitable for upgrade it was not included in the breach assessment as it was not deemed to be an effective defence and was removed from the baseline flood modelling. The River Lee Walkway embankment was therefore the only structure considered during the breach analysis and was determined to be a viable defence by the geotechnical analysis. Only one location along the embankment was deemed vulnerable to overtopping which could lead to a breach, which is an area of the walkway behind the Aqua Dome approximately 46m in length. The ground levels behind the walkway in this location are also low which would mean any breach of the defence would allow flooding to the land behind.

The breach analysis was carried out for the 1% AEP, 0.5% AEP and 0.1% AEP events using levels taken at the breach location from the respective coastal models. Within the ICM model the walkway defence was represented as a 2D base linear structure which allows the differing elevations of the walkway to be represented. This structure was then set to be removed once water levels in the River Lee reached the low point of the walkway. By removing the section of the walkway defence when water levels reached this low

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point it is possible to simulate the embankment breaching. The results of the breach analysis for the events are shown below in Figure 3.56 and Figure 3.57. These results show that any breach of the walkway defences would lead to flood risk to properties behind. The risk becomes significantly larger between the 0.5% and 0.1% AEP events.

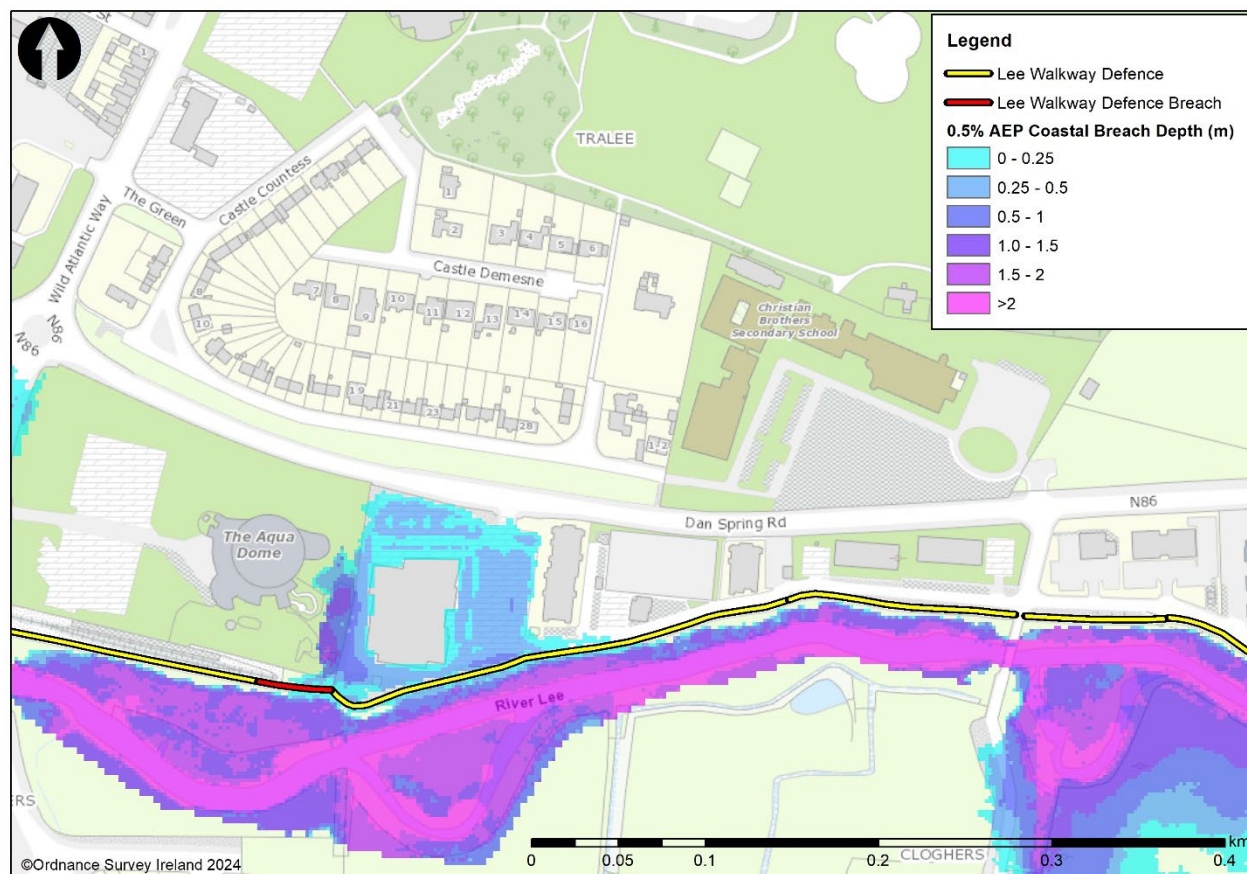


Figure 3.56: 0.5% AEP Breach Analysis Flood Depths

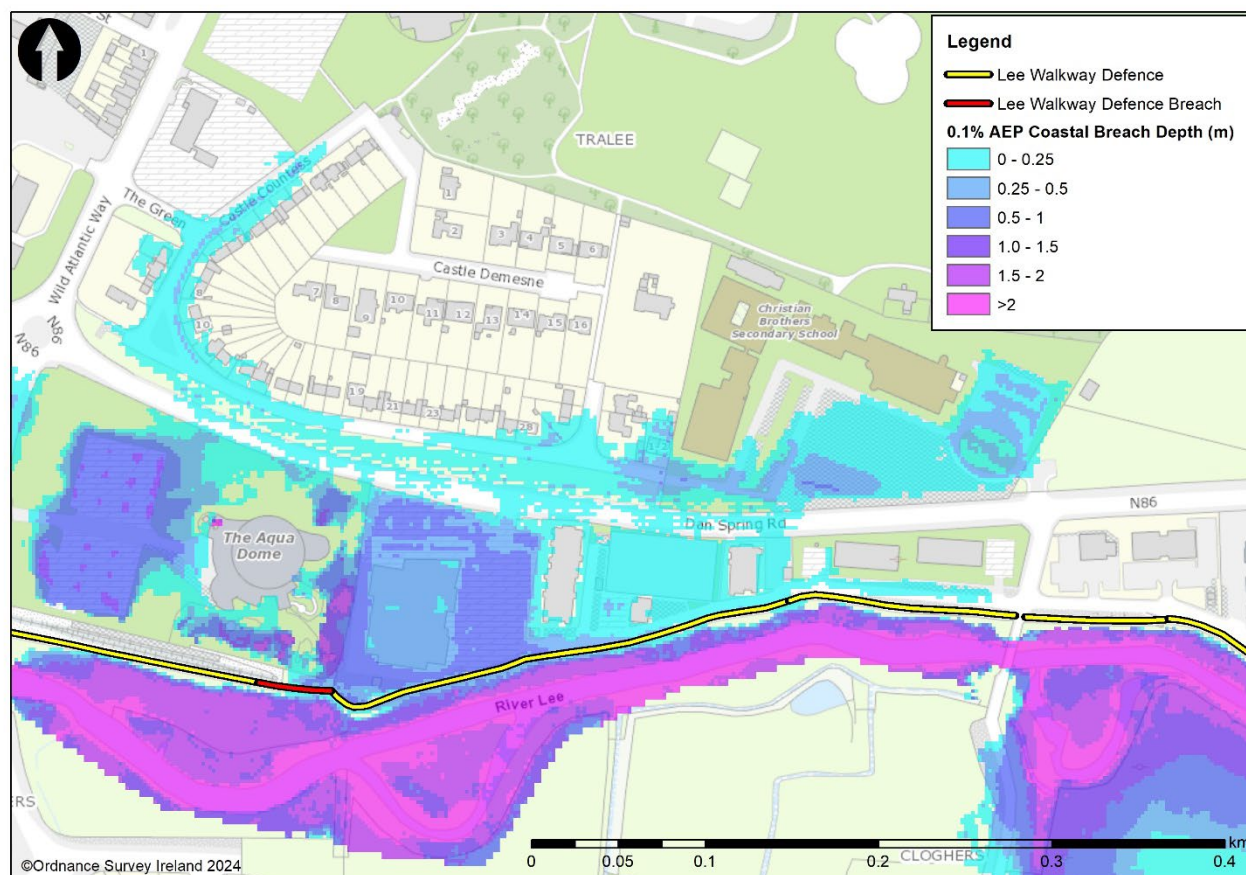


Figure 3.57: 0.1% AEP Breach Analysis Flood Depths

3.8 Blockage Analysis

Blockage model simulations will be used to inform the damage assessment and scheme analysis design for the Tralee FRS. In conjunction with the Steering Group, six structures were identified as being hydraulically significant to the flood risk in Tralee. An assessment to determine blockage ratios of these structures was undertaken as part of the blockage analysis. The likelihood of a blockage was assessed using guidance outlined in CIRIA C786 'Culvert, screen and outfall manual'⁵ which recommends a blockage between 80% - 100% is used to assess the consequences during an extreme event. Likelihood of blockage was also informed by internal culvert conditions as per the Culvert and CCTV survey. A scoring matrix has been used to assess the likelihood of blockage for each structure deemed hydraulically significant, outlined in Table 3.9. The higher the score for each category the higher the likelihood of blockage. The total score has been used to determine whether the structure should be included in the sensitivity test. The 1% AEP design scenario event is then simulated in the model to determine the envelope of potential flooding arising from a blockage.

Table 3.9 Blockage analysis scoring matrix

Scoring Criteria	Scoring	Description
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⁵ (Benn, 2019)

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Historical Evidence	10	Any historical evidence of flooding as a resulting of blockage of a structure would indicate a high likelihood of future blockage.
Existing Maintenance Regime	10	Lack of maintenance of culverts can result in increased blockage and therefore increase flood risk. Introducing a maintenance regime will reduce the likelihood of blockage.
Screen	10	If a well-designed screen is present the likelihood of blockage is reduced, as is the associated flood risk. A poorly designed screen and no screen being present may increase the likelihood of blockage.
Cross-Sectional Area (m²)	5	The likelihood of blockage is increased if a culvert has small cross-sectional area conveying a larger flow.
Culvert Capacity (m³/s)	5	Refers to the free-flowing capacity i.e. maximum amount of flow the structure can convey before surcharging. Any structures with current blockage (identified in Culvert CCTV Survey) will have a reduced capacity and therefore a high likelihood of further blockage and increased risk of flooding.
Catchment Type	10	Rural catchments pose an increased likelihood of blockage from sedimentation and natural debris and urbanised catchments pose an increased likelihood of blockage from manmade debris.

There is no known active maintenance regime for any culverts in the Tralee FRS Scheme Area, however there is a reactive maintenance regime, i.e. removal/clearing of culverts in response to flood events.

For the Tralee FRS only culverts with a moderate (10 – 30) or high likelihood of blockage (scoring 30+) were considered for further analysis. Table 3.10 outlines how the scoring and likelihood of blockage are linked, and the percentage of blockage applied for each. A 90% blockage is modelled to determine the maximum potential blockage for a culvert where the structure has a high likelihood.

Table 3.10 Likelihood of blockage and percentage of blockage applied

Scoring	Likelihood of blockage	Blockage sensitivity required (%)
0 – 10	Low	0
10 – 30	Moderate	60
30+	High	90

3.8.1 Clahane Road Bridge

The Clahane Road Bridge is located on the Ballyvelly watercourse (Figure 3.58).

Lat: 52° 15' 3.71" N
 Lon: 9° 42' 44.90" W



Figure 3.58 Clahane Road Bridge

The two bridge openings have had this blockage matrix applied to them separately to determine how much each opening should be blocked.

There is evidence of previous flooding along the Clahane Road and there is anecdotal evidence from Kerry County Council that blockage of the bridge and channel over the years has been a factor.

There is no knowledge of an existing maintenance regime, so a high score has been given to both openings. A slightly higher score has been given to the left opening as existing survey shows that this opening has more sedimentation build up than the right opening.

While there is no debris screen present at on the Clahane Road Bridge due to the size of the two openings a blockage is less likely at this structure. The 2 bridge openings are approximately 6m in length each and the total cross-sectional area is approximately 8m² at the upstream face of the bridge. Therefore, a low score has been applied to both openings for this parameter, but the left opening has been given a slightly higher score due to a larger area of the opening being blocked by sedimentation

The Ballyvelly catchment covers a mainly rural area, and both survey and aerial imagery shows that the watercourse is lined with trees and vegetation. Given its location and its surrounding vegetation, a higher score of blockages has been attributed to the catchment type as blockage from fallen trees is possible. A slightly higher score has been attributed to the right opening as based on survey photos there are trees overhanging

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into the channel near this opening and this would increase the likelihood that blockage from fallen trees would occur.

Table 3.11 details the scoring of the Clahane Road bridge to assess the requirement for blockage analysis on the left and right opening respectively.

Table 3.11 Clahane Road Bridge

Structure	Flooding Potential	Existing Maintenance Regime	Screen	Cross-Sectional Area (m ²)	Bridge Capacity (m ³)	Catchment Type	Overall Scoring
Clahane Road Bridge – Left Opening	9	9	2	2	4	7	33
Clahane Road Bridge – Right Opening	8	8	2	1	3	8	30

The recommendation is to assume a 90% blockage to the left opening and a 60% blockage to the right opening. The anecdotal evidence for this area has outlined that there is moderate sediment build up along this reach and at the bridge which has increased flood risk. The previous flooding events, combined with no debris screen and catchment type suggests a high likelihood of further blockage in the structure.

3.8.2 Balloonagh River Long Culvert

The Balloonagh culvert starts upstream of the Tralee Town Centre and conveys flow under the town centre before discharging into the River Lee (Figure 3.59).



Figure 3.59: Inlet of Balloonagh Long Culvert

There is no debris screen present on the Balloonagh Long Culvert. The culvert is approximately 2647m in length and the cross-sectional area varies as the dimensions of this culvert change over its length and range from 0.43m² – 3.32m², with a culvert capacity of ranging from approximately 1.23m³/s to 22.58m³/s. The capacity is calculated without any blockage applied as the CCTV survey did not find any significant sedimentation or blockages. This culvert has resulted in a higher scoring due to this culvert surcharging even in the most frequent events (50% AEP).

The Balloonagh watercourse sub-catchment is a relatively urbanised catchment as per Hydrology Report Section 4.1, which increases the risk of potential blockage from manmade materials for this culvert. The upper catchment is characterised as a rural landscape, which also comes with an increased risk of blockage from debris.

Table 3.12 details the scoring of the Balloonagh long culvert to assess its requirement for blockage analysis.

Table 3.12 Balloonagh long culvert scoring

Structure	Historical Evidence	Existing Maintenance Regime	Screen	Cross-Sectional Area (m ²)	Culvert Capacity (m ³)	Catchment Type	Overall Scoring
Balloonagh long culvert	5	8	8	3	3	6	33

Overall, the recommendation is to include this culvert in the blockage assessment, assuming a 90% blockage. While the CCTV survey has outlined the culvert does not currently have any significant blockages it is still likely that blockages will occur in the future. The rural upper catchment, combined with a lack of existing maintenance regime for the culvert and with no debris screen present suggests a high likelihood of blockage in the structure, therefore it is prudent that this culvert is assessed in the blockage analysis, with a 90% blockage of the entire culvert length.

3.8.3 Big River Long Culvert

The Big River long culvert is located on the Big River and conveys flow under Ashe Street and the Tralee Town Park before discharging into the River Lee. The entrance to the culvert is shown in Figure 3.60.

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Lat: 52° 16' 16.94" N
 Lon: 9° 42' 6.74" W



Figure 3.60: Big River Long Culvert Upstream Opening

This structure was surveyed during the CCTV survey and there was no information in relation to significant blockages or build-up of sedimentation within the culverts. The upstream opening showed a small build-up of both rural and manmade debris close to it (Figure 3.60) during the CFRAMS topographical survey.

The culvert is approximately 1025m in length and the cross-sectional area of this culvert ranges from approximately 5.27m² to 5.35m², with a capacity of approximately 16.26m³/s to 19.03m³/s. The capacity is calculated with no levels of blockage applied to the model as per the baseline scenario conditions agreed with KCC. This culvert is scored lower due to it only surcharging in the less frequent events (1% AEP and above).

The Big River sub-catchment is a relatively urbanised catchment as per Hydrology Report Section 4.1, which increases the risk of potential blockage from manmade materials for this culvert. The upper catchment is characterised as a rural landscape, which also comes with an increased risk of blockage from debris (e.g. cuttings, brash).

Table 3.13 details the scoring of the Hollow Road Bridge to assess its requirement for blockage analysis.

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Table 3.13 Big River Long Culvert

Structure	Historical Evidence	Existing Maintenance Regime	Screen	Cross-Sectional Area (m ²)	Culvert Capacity (m ³)	Catchment Type	Overall Scoring
Big River Long Culvert	2	8	8	2	2	6	28

Overall, the recommendation is to include this culvert in the blockage assessment, assuming a 60% blockage. Similar to the Balloonagh long culvert, the rural upper catchment, combined with a lack of existing maintenance regime and no trash screen suggests a high likelihood of blockage in the structure. However, since there is no historical evidence of this culvert causing flooding in the past the overall score suggests a moderate risk. Therefore, it is practical that this culvert is assessed in the blockage analysis, with a 60% blockage.

3.8.4 Big River Bridge (Roger Casement Avenue)

The Big River Bridge is located beside Roger Casement Avenue and conveys flow upstream of the Big River long culvert. The bridge is shown in Figure 3.61.



Figure 3.61: Big River Bridge and Trash Screen

A debris screen is present on the upstream face of the bridge. The purpose of a well-designed screen is to collect any large objects that may obstruct the culvert and allow small debris to pass through without causing

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blockage and effectively reducing the flood risk associated with the structure. The screen on the Big River Bridge is poorly designed and is not maintained adequately which in turn has increased the flood risk associated to this structure. As per Figure 3.62 there is already manmade debris of varying sizes caught within the trash screen. The screen itself only covers the upper half of the bridge opening leaving a gap between this and the riverbed. The gap between the screen and the riverbed also varies between 0.13m to 1m based on the topographical survey levels. Therefore, there is a risk that debris could become trapped between the screen and the riverbed in parts exacerbating the flood risk.



Figure 3.62: Debris caught in Trash Screen

The bridge is approximately 1.9m in length and the cross-sectional area is approximately 11.76m². The capacity is as per the baseline scenario conditions agreed with the Steering Group and as such is scored higher due to surcharging in the more frequent events (20% AEP and above).

As noted in Section 4.1 of the Hydrology Report, the Big River sub-catchment is at increased risk of blockage due its partially urbanised catchment.

Table 3.14 details the scoring of the Big River Bridge to assess its requirement for blockage analysis.

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Table 3.14 Big River Bridge scoring

Structure	Historical Evidence	Existing Maintenance Regime	Screen	Cross-Sectional Area (m ²)	Bridge Capacity (m ³)	Catchment Type	Overall Scoring
Big River Bridge	5	8	9	3	3	6	34

Overall, the recommendation is to include this culvert in the blockage assessment, assuming a 90% blockage. The presence of a debris screen that does not have an active maintenance regime and is already showing blockage is further reasoning for a high likelihood of further blockage in the structure. Therefore, it is prudent that this bridge is assessed in the blockage analysis with a 90% blockage.

3.8.5 Balloonagh to Big River Diversion Culvert

The Balloonagh to Big River diversion conveys flow from the Balloonagh watercourse just upstream of the Bracker O'Regan Road to the Big River (Figure 3.63).



Figure 3.63: Culvert inlet of the Balloonagh to Big River Diversion

This culvert was included in the culvert CCTV survey which determined there were no significant blockages or build-up of sedimentation within the culvert. Referring to Figure 3.63 there appears to be some sedimentation in the culvert, however for the purposes of the baseline scenario this culvert has been modelled as clear. There is no debris screen present on the Balloonagh to Big River culvert.

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The culvert is approximately 640m in length and the cross-sectional area varies as the dimensions of this culvert change over its length. The inlet diameter of the rectangular culvert is 1.3m x 1.23m, which leads into a 1.2m x 1.35m rectangular culvert at the outlet. The culvert cross-sectional area ranges between 1.62m² and 2.33m², with an overall culvert capacity of approximately 0.94m³/s to 3.93m³/s. The culvert has scored lower due to it not surcharging until the least frequent event (0.1% AEP and above).

The Balloonagh sub-catchment is a partly urbanised catchment as per Hydrology Report Section 4.1, which increases the risk of potential blockage from manmade materials for this culvert. The upper catchment is characterised as a rural landscape, which also comes with an increased risk of blockage from debris (e.g. cuttings, brash).

Table 3.15 details the scoring of the Balloonagh to Big River diversion culvert to assess its requirement for blockage analysis.

Table 3.15 Balloonagh to Big River diversion culvert scoring

Structure	Historical Evidence	Existing Maintenance Regime	Screen	Cross-Sectional Area (m ²)	Culvert Capacity (m ³)	Catchment Type	Overall Scoring
Balloonagh to Big River Diversion Culvert	2	8	8	3	3	6	30

Overall, the recommendation is to include this culvert in the blockage assessment, assuming a 90% blockage. Due to the changes in cross-sectional area of the culvert there is an increased chance of blockage, particularly in a mainly rural catchment with the chances of debris and silt building up within the structure. Similar to other culverts mentioned, the combined lack of existing maintenance regime for the culvert and no presence of a debris screen suggests there is a high likelihood of blockage in the structure, therefore it is prudent that this culvert is assessed in the blockage analysis, with a 90% blockage.

3.8.6 Big River Diversion Culvert

The Big River diversion conveys flow from the Big River watercourse just west of the Oakpark Road to the Rathass watercourse. The screen inlet to the culvert is shown below in Figure 3.64.



Figure 3.64: Culvert Inlet of the Big River Diversion

This diversion culvert was included in the culvert CCTV survey which determined there were no significant blockages or build-up of sedimentation within the culvert. Referring to Figure 3.63 there appears to be some sticks/debris caught in the culvert screen, however for the purposes of the baseline scenario this culvert has been modelled as clear. The debris screen is damaged in areas and would likely allow larger debris through than it was designed to as a result.

The culvert is approximately 1600m in length and the cross-sectional area remains relatively consistent throughout the entire length. The dimensions of the rectangular culvert is approximately 2.4m x 2.4m. The culvert cross-sectional area is approximately 5.76m², with an overall culvert capacity of approximately 28m³/s. The culvert has scored lower in parts of the analysis due to its large cross-sectional area and capacity.

The Big River sub-catchment is a partly urbanised catchment as per Hydrology Report Section 4.1, which increases the risk of potential blockage from manmade materials for this culvert. The upper catchment is characterised as a rural landscape, which also comes with an increased risk of blockage from debris (e.g. cuttings, brash). There has also been a history of blockage to this culvert in the past with clearing of debris having been carried out on more than one occasion. This has led to a higher score in these areas of the analysis.

Table 3.16 details the scoring of the Big River diversion culvert to assess its requirement for blockage analysis.

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Table 3.16 Big River diversion culvert scoring

Structure	Historical Evidence	Existing Maintenance Regime	Screen	Cross-Sectional Area (m ²)	Culvert Capacity (m ³)	Catchment Type	Overall Scoring
Big River Diversion Culvert	8	5	8	2	2	6	31

Overall, the recommendation is to include this culvert in the blockage assessment, assuming a 90% blockage. Due to the damaged screen, history of blockages, and due to it being in a mainly rural catchment with a higher chance of debris and silt building up within the structure.

3.9 Sensitivity Analysis

Sensitivity simulations have been completed. The purpose is to test the models sensitivity to various parameter changes, outputs of the analysis will inform the development of the options and detailed design of the Tralee FRS, particularly in making recommendations regarding adjustments to freeboard or other design considerations to ensure a 'no-regrets' approach. The sensitivity models were ran using a draft version of the model and compared against the draft baseline results. Therefore, they are still comparing like for like and are still a reliable indicator of what changes the model is sensitive to. A summary of the sensitivity simulations is outlined in Table 3.17. Sensitivity simulations which present the greatest impact are discussed in more detail. Simulations resulting in less impact are presented in Appendix A.

To assess model sensitivity 2D zones representing flooding have been extracted from the model for each scenario tested and compared to the baseline results. The 1% AEP design simulation and 1% AEP sensitivity outputs have been extracted the same way and therefore comparisons are like for like on a georeferenced basis.

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Table 3.17 Summary of Sensitivity Analysis

Sensitivity Test		Change in Buildings affected (%)	Model Sensitivity	Comment
Roughness	1D roughness upper bounds, 2D roughness lower bounds	8	Moderate	Refer to Section 3.9.1
Structures	Change structure type 23LEEF0018D	1	Low	A small change in flood extent was observed with a decreased risk to 1 receptor in the Scheme Area. (Appendix A Figure 1).
	Change structure type 23BIGR00160D	2	Low	An increased flood extent was observed with an increased risk to an additional 34 receptors in the Scheme Area. (Appendix A Figure 2).
	Change structure type 23LEEA00083D	4	Low	An increased flood extent was observed with an increased risk to an additional 73 receptors in the Scheme Area. (Appendix A Figure 3).
	Change structure type 23RLEE00407D	12	High	Refer to Section 3.9.2
Ineffective Flow (Refer to Figure 3.7 in Section 3.1.3.3)	Increased contraction and expansion structure 23BIGR00160	5	Low	An increased flood extent was observed with an increased risk to an additional 80 receptors in the Scheme Area. (Appendix A Figure 4).
	Decreased contraction and expansion structure 23BIGR00160	1	Low	An increased flood extent was observed with an increased risk to an additional 22 receptors in the Scheme Area. (Appendix A Figure 5).

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Sensitivity Test	Change in Buildings affected (%)	Model Sensitivity	Comment
Increased contraction and expansion 23LEEA00083D	5	Low	An increased flood extent was observed with an increased risk to an additional 83 receptors in the Scheme Area. (Appendix A Figure 6).
Decreased contraction and expansion 23LEEA00083D	2	Low	An increased flood extent was observed with an increased risk to an additional 40 receptors in the Scheme Area. (Appendix A Figure 7).
Increased contraction and expansion 23LEEG00038D	3	Low	An increased flood extent was observed with an increased risk to an additional 51 receptors in the Scheme Area. (Appendix A Figure 8).
Decreased contraction and expansion 23LEEG00038D	4	Low	An increased flood extent was observed with an increased risk to an additional 62 receptors in the Scheme Area. (Appendix A Figure 9).
Increased contraction and expansion 23REEP01005_2022	3	Low	An increased flood extent was observed with an increased risk to an additional 57 receptors in the Scheme Area. (Appendix A Figure 10).
Decreased contraction and expansion 23REEP01005_2022	3	Low	An increased flood extent was observed with an increased risk to an additional 47 receptors in the Scheme Area. (Appendix A Figure 11).
Increased contraction and expansion 23RLEE00407D	4	Low	An increased flood extent was observed with an increased risk to an additional 69 receptors in the Scheme Area. (Appendix A Figure 12).

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Sensitivity Test		Change in Buildings affected (%)	Model Sensitivity	Comment
	Decreased contraction and expansion 23RLEE00407D	5	Low	An increased flood extent was observed with an increased risk to an additional 81 receptors in the Scheme Area. (Appendix A Figure 13).
2D Cell Size	Increased 2D cell size	1	Low	Modelled flood extents changed when larger mesh triangles were used. This produced a slightly altered flood extent outline with 21 additional properties at risk when compared with the 1% AEP (Appendix A Figure 14).
	Decreased 2D cell size	5	Low	The Tralee model demonstrated a decrease of modelled flood extents when compared with the 1% AEP. It is estimated 78 additional buildings would no longer be impacted. (Appendix A Figure 15).
	Terrain sensitive meshing turned off	1	Low	There is a small change in flood extents which resulted in two less properties at risk when compared with the baseline 1% AEP event. (Appendix A Figure 16)
Sensitivity Climate Change	1% MRFS	20	High	Refer to Section 3.9.3
	1% HEFS	26	High	Refer to Section 3.9.3
Sensitivity Flow	10% AEP	25	High	Refer to Section 3.9.4
	1% AEP	27	High	Refer to Section 3.9.4
Blockages	Blockage Run 23BIGA00134I (Balloonagh River Long Culvert)	1	Low	A Blockage of 90% was applied to the 23BIGA00134I culvert. There is a small decrease in flood extents which resulted in a reduction of 13 properties at risk when compared with the baseline 1% AEP event. (Appendix A Figure 17)

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Sensitivity Test	Change in Buildings affected (%)	Model Sensitivity	Comment
Blockage Run 23CUL14_IN (Big River Long Culvert)	13	High	Refer to Section 3.9.5
Blockage Run 23BIGR00160D (Big River, Roger Casement Avenue Bridge)	10	High	Refer to Section 3.9.5
Blockage Run 23ALLO00083I (Balloonagh to Big River Diversion Culvert)	5	Low	A Blockage of 90% was applied to the 23ALLO00083I culvert. There is a small increase in flood extents which resulted in an additional 84 properties at risk when compared with the baseline 1% AEP event. (Appendix A Figure 18)
Blockage Run 23LEEH00236D (Clahane Road Bridge)	0	Low	A Blockage of 90% and 60% was applied to the Clahane Road bridge. There is a small increase in flood extents, but this did not result in an increase to the properties at risk when compared with the baseline 1% AEP event. (Appendix A Figure 19)
Blockage Run Big River Diversion Culvert	8	Moderate	Refer to Section 3.9.5

3.9.1 Roughness

The in-channel (1D) river reach roughness was increased to upper bound values and flood plain (2D) roughness was decreased to lower bound values. The change in channel and floodplain roughness values resulted in a moderate impact on flood extents, when compared to the 1% AEP flood extent as shown in Figure 3.65. The increase in flood extents has an impact upon properties located within the Tralee FRS Scheme Area including properties located close to the Killerisk Road, Glen Castle and Prince's Street. It is estimated 147 additional buildings are impacted accounting for an 8% increase compared to the 1% AEP.

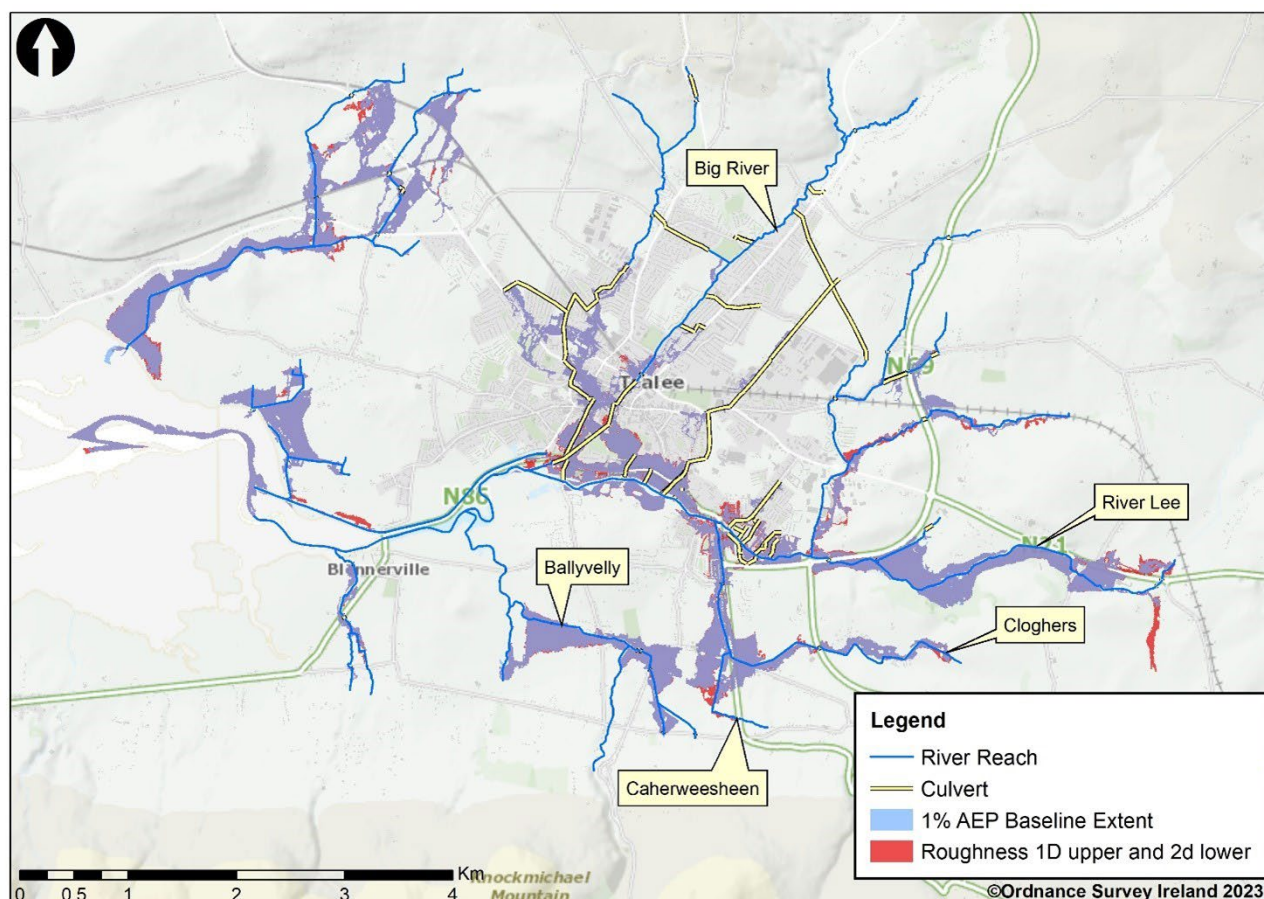


Figure 3.65: 1D upper / 2D lower Bounds Roughness Sensitivity Event

3.9.2 Structure Change

Some structures within the model were changed from bridges to culverts and vice versa, this was carried out to assess the impact on flow through these structures due to a different schematisation. The structure which was most sensitive to this is the Castlemaine Road Bridge over the River Lee at model cross section RLEE00407D. The change resulted in a high impact on flood extents when compared with the 1% AEP baseline flood extent as shown in Figure 3.66. The increase in flood extents has an impact upon properties in the areas around Killerisk Road, Glen Castle and Manor West. It is estimated 224 additional buildings are impacted; this equates to a 12% increase when compared to the 1% AEP.

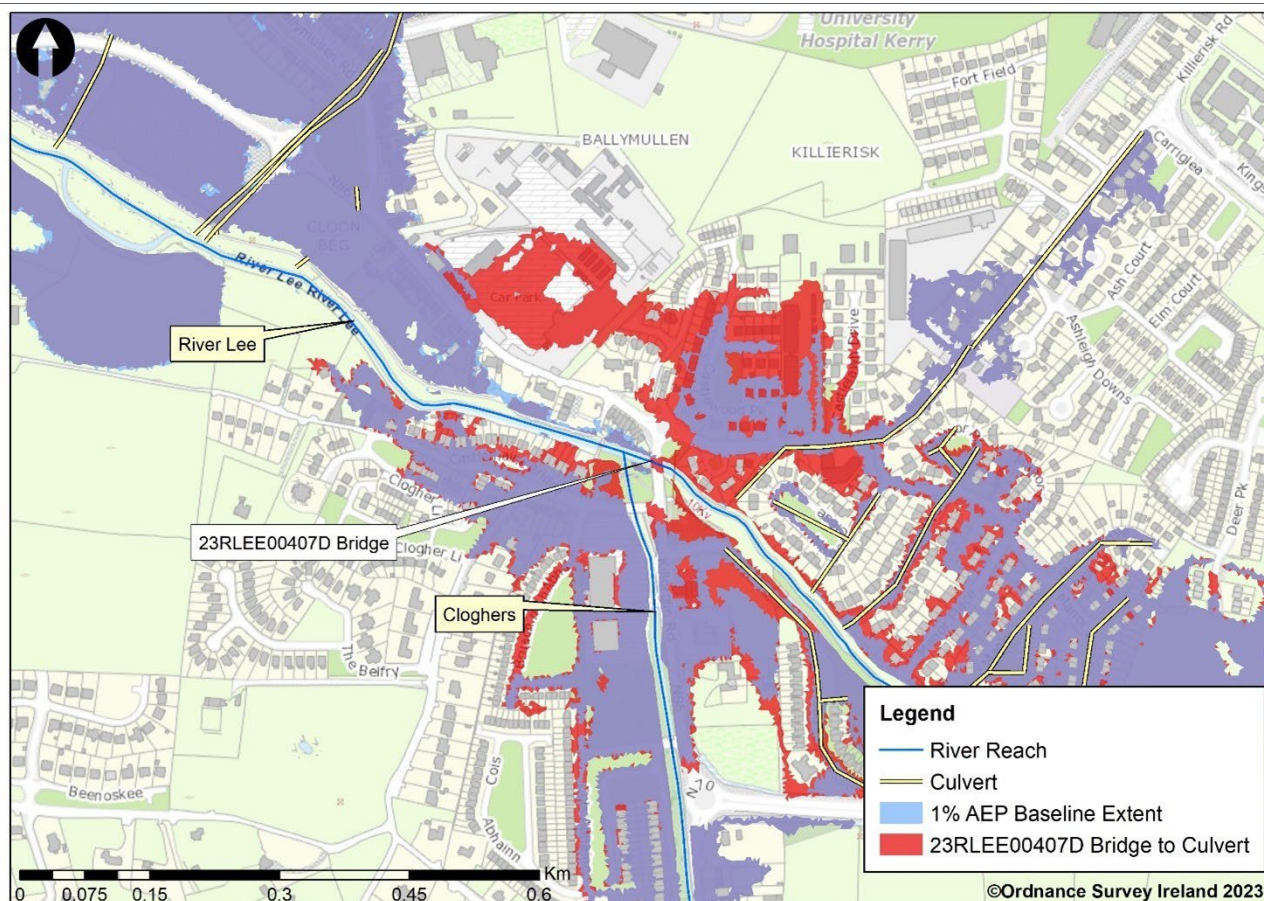


Figure 3.66: Structure Change

3.9.3 Climate Change Flow

The 1% Mid-Range Future Scenario (MRFS) and 1% High End Future Scenario (HEFS) were modelled to assess the impacts of climate change flows in Tralee outlined in Figure 3.67 and Figure 3.68 respectively. The Tralee model was assessed as having a high sensitivity to the effects of climate change flows.

Figure 3.67 compares the 1% MRFS with the 1% AEP baseline. The increase in flood extents has an impact upon properties located in Manor West, Cois Abhainn, Glen Castle and Prince's Street. These changes have a significant impact on receptors as approximately 433 additional buildings are affected, this equates to a 20% increase when compared to the 1% AEP baseline results.

Figure 3.68 compares the 1% HEFS with the 1% AEP. The increase in flood extents has an impact upon properties located in Manor West, Cois Abhainn, Glen Castle, Prince's Street and the town centre in general is affected in most areas. These changes have an impact on receptors as approximately 598 additional buildings are affected, equating to a 26% increase when compared to the 1% AEP baseline results.

Overall, the Tralee model displayed a high sensitivity to the effects of increased flow due to climate change in a 1% AEP fluvial scenario.

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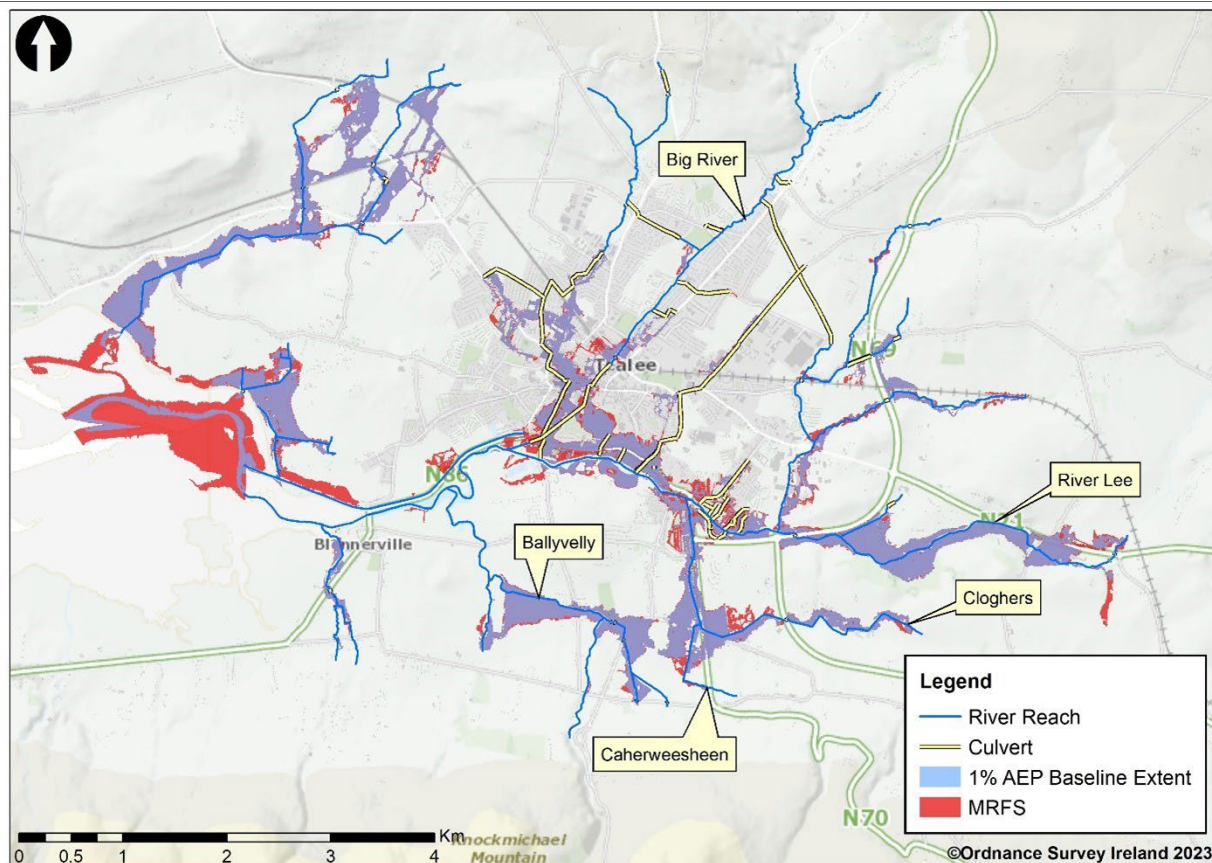


Figure 3.67: 1% AEP MRFS Sensitivity Event

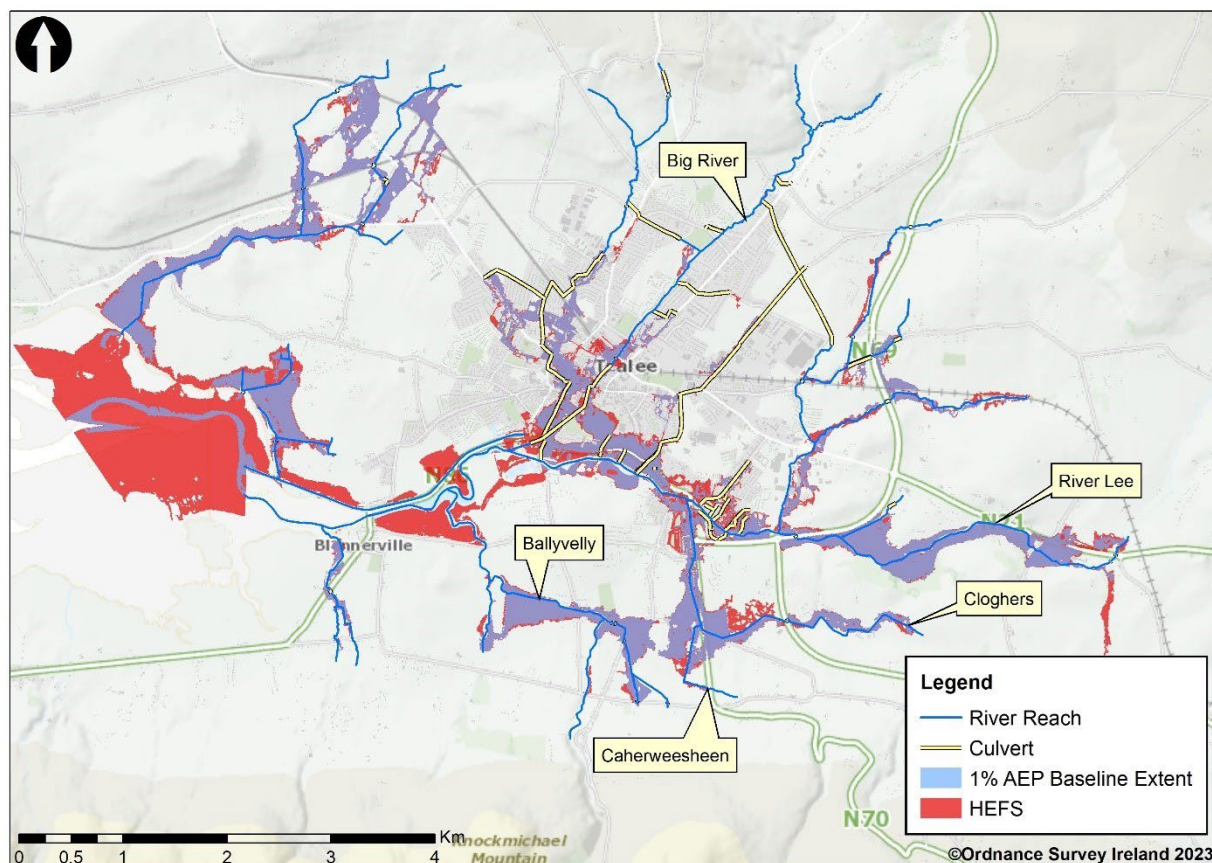


Figure 3.68: 1% AEP HEFS Sensitivity Event

3.9.4 Flow Sensitivity

Flow sensitivity was carried out to assess the impact on flooding within Tralee. With all hydrological assessments there is a degree of uncertainty with the flow data as there may be incomplete data records or ungauged catchments within a study area. To test the impact of flow sensitivity the model inflows and laterals are increased by an uncertainty percentage determined by the hydrological assessment. These uplifts will differ across watercourses based on the availability of gauge data, spot gauges and other information. Flow sensitivity was carried out for the 10% and 1% AEP fluvial events.

Figure 3.69 shows that the flood extents increase within the model when comparing the 10% AEP flow sensitivity with the baseline 10% AEP results. The increase in flood extents has an impact on properties located along the R551 due to additional flooding from the Pinure. Other areas that see an increase in flood risk are Princes Street, Rock Park Avenue, Ballymullen Road and Castlemaine Road. The increased flood extents account for a 25% increase in properties at risk.

Figure 3.70 shows that the flood extents also increase significantly within the model when comparing the 1% AEP flow sensitivity with the baseline 1% AEP results. The increase in flood extents has an impact on several areas throughout Tralee town centre including Princes Street, the R551, Dan Spring Road and Ballymullen Road. Other areas that also see a large increase in flood extents are Manor West, Manor Height Retail Park and Castlemaine Road. The increased flood extents account for a 27% increase in properties at risk.

Overall, the model showed a high sensitivity to the effects of increased flow based on the natural uncertainty within deriving flows for hydraulic modelling.

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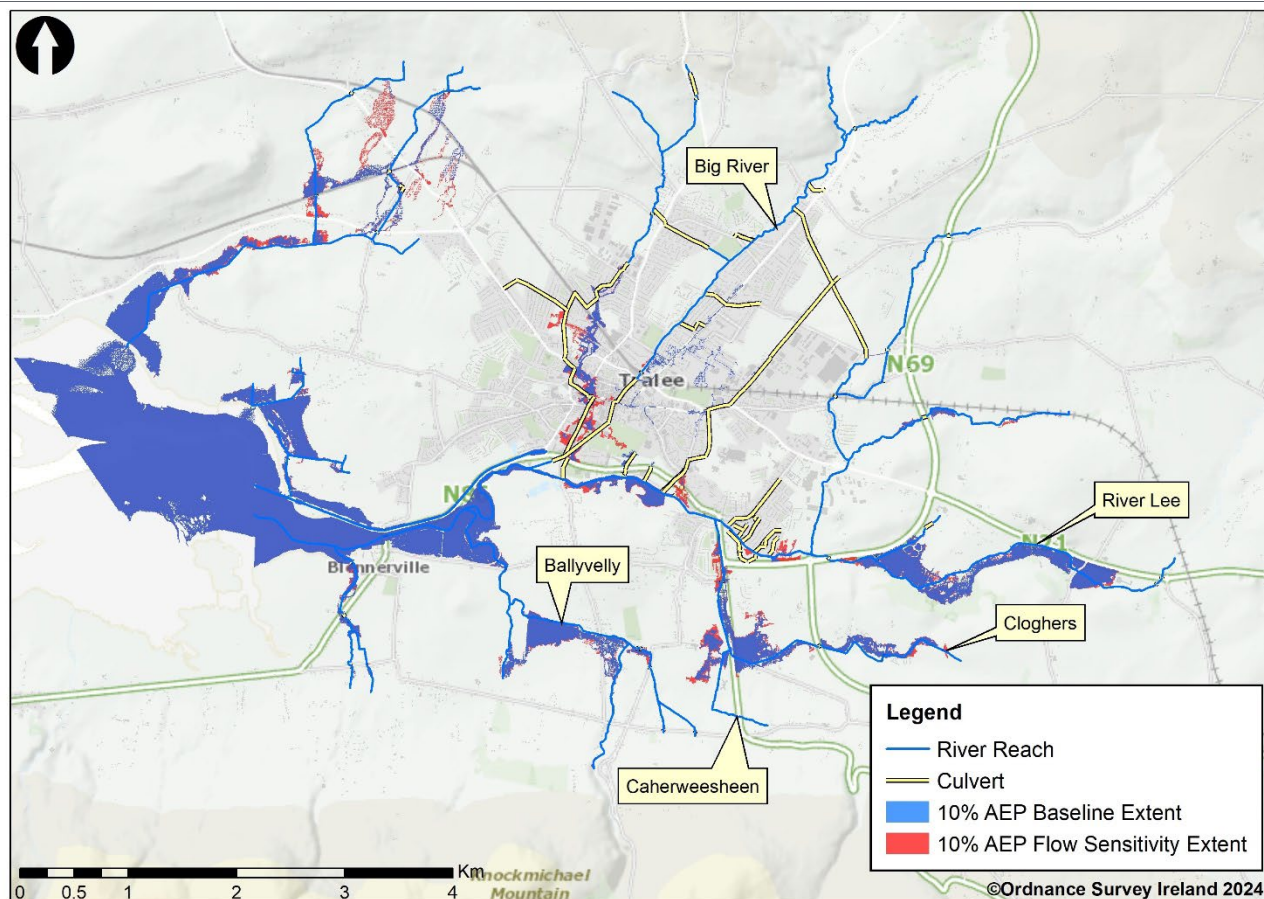


Figure 3.69: 10% AEP Flow Sensitivity Event

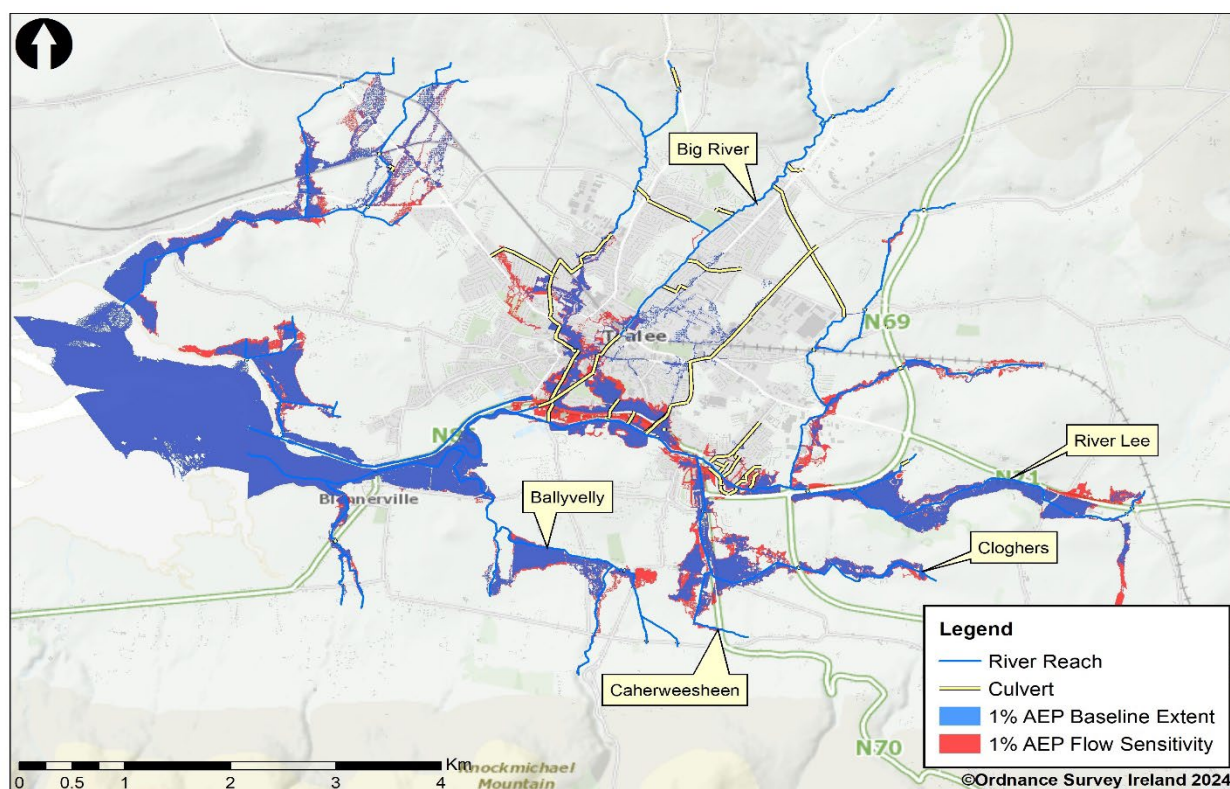


Figure 3.70: 1% AEP Flow Sensitivity Event

3.9.5 Blockages

The model was assessed as having moderate/high sensitivity to blockages. There were three areas where blockages caused the greatest increase in flood risk. These were all on the Big River. This included the Big River diversion culvert, the long culvert on the Big River and the bridge beside Roger Casement Avenue (23BGR00160D).

Figure 3.71 shows that the Tralee model has an increased flood extent when comparing the 90% blockage to the Big River diversion culvert with the 1% AEP baseline. The increase in flood extents has an impact upon properties located along Roger Casement Avenue, the R874 and increased flooding throughout the centre of the town. The change in flood extents also lead to a small reduction in flood risk in the Manor East area. These changes resulted in an overall increased impact on receptors as approximately 127 additional buildings are affected, accounting for an 8% increase when compared to the 1% AEP baseline results.

Figure 3.72 shows that the Tralee model has an increased flood extent when comparing the 60% blockage to the Big River long culvert with the 1% AEP baseline. The increase in flood extents has an impact upon properties located along the R874 and Ashe Street. These changes have an increased impact on receptors as approximately 248 additional buildings are affected, accounting as a 13% increase when compared to the 1% AEP baseline results.

Figure 3.73 shows that the model has an increased flood extent when comparing the 90% blockage to the Big River bridge with the 1% AEP baseline. The increase in flood extents has an impact upon properties located along the R874 and Ashe Street. These changes have an impact on receptors as approximately 175 additional buildings are affected, accounting as a 10% increase when compared to the 1% AEP baseline results.

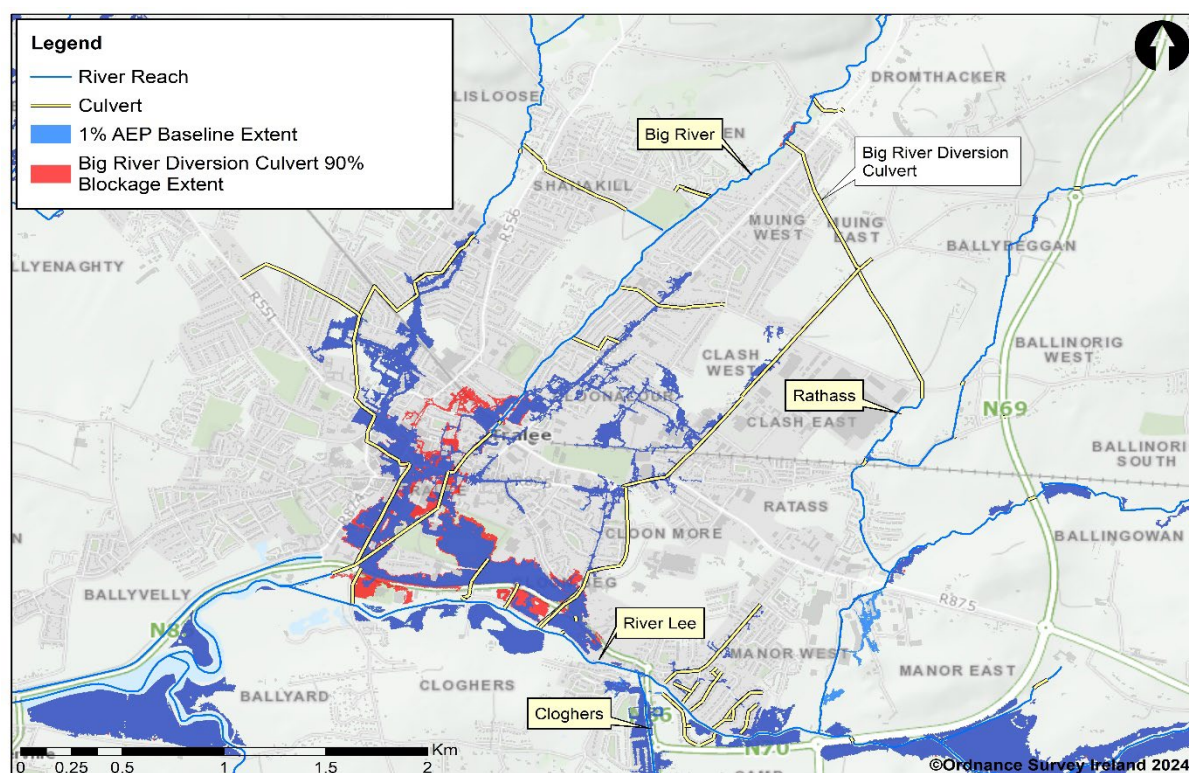


Figure 3.71: Blockage to Big River Diversion Culvert

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

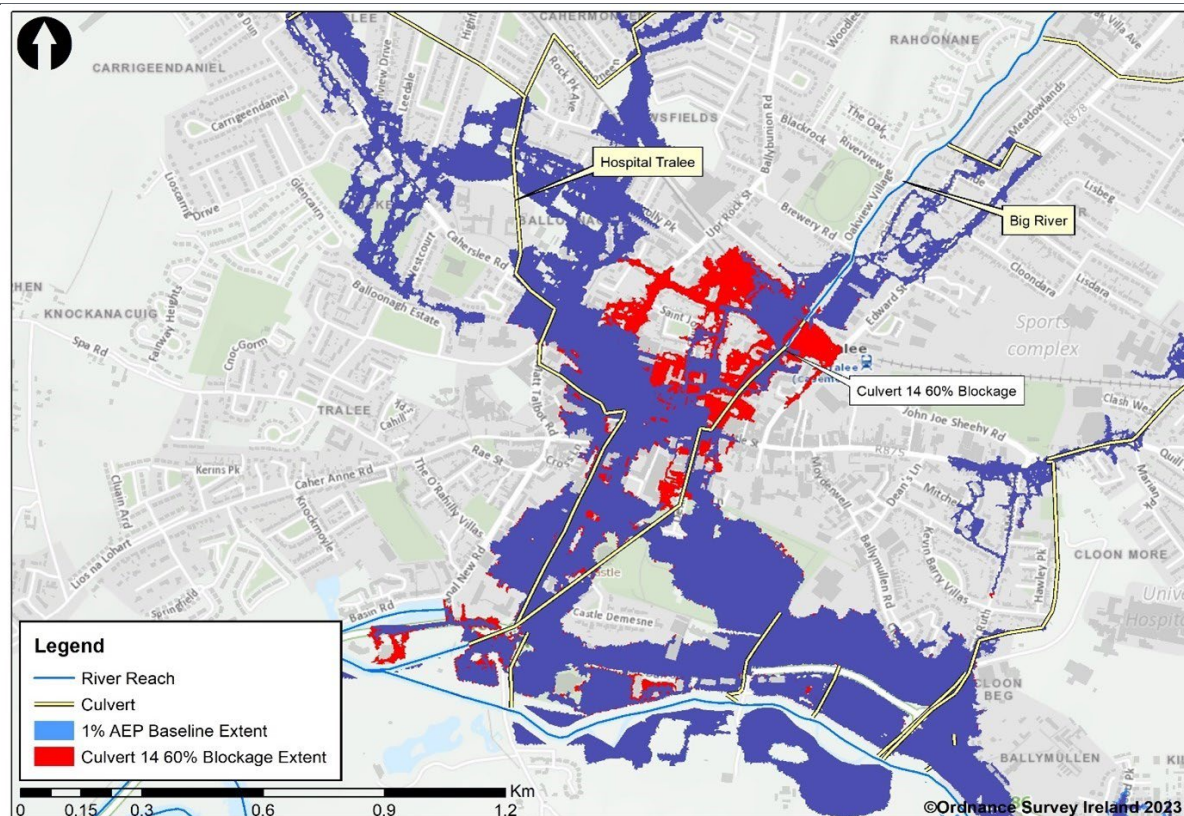


Figure 3.72: Blockage to Big River Long Culvert (Cul14_IN)

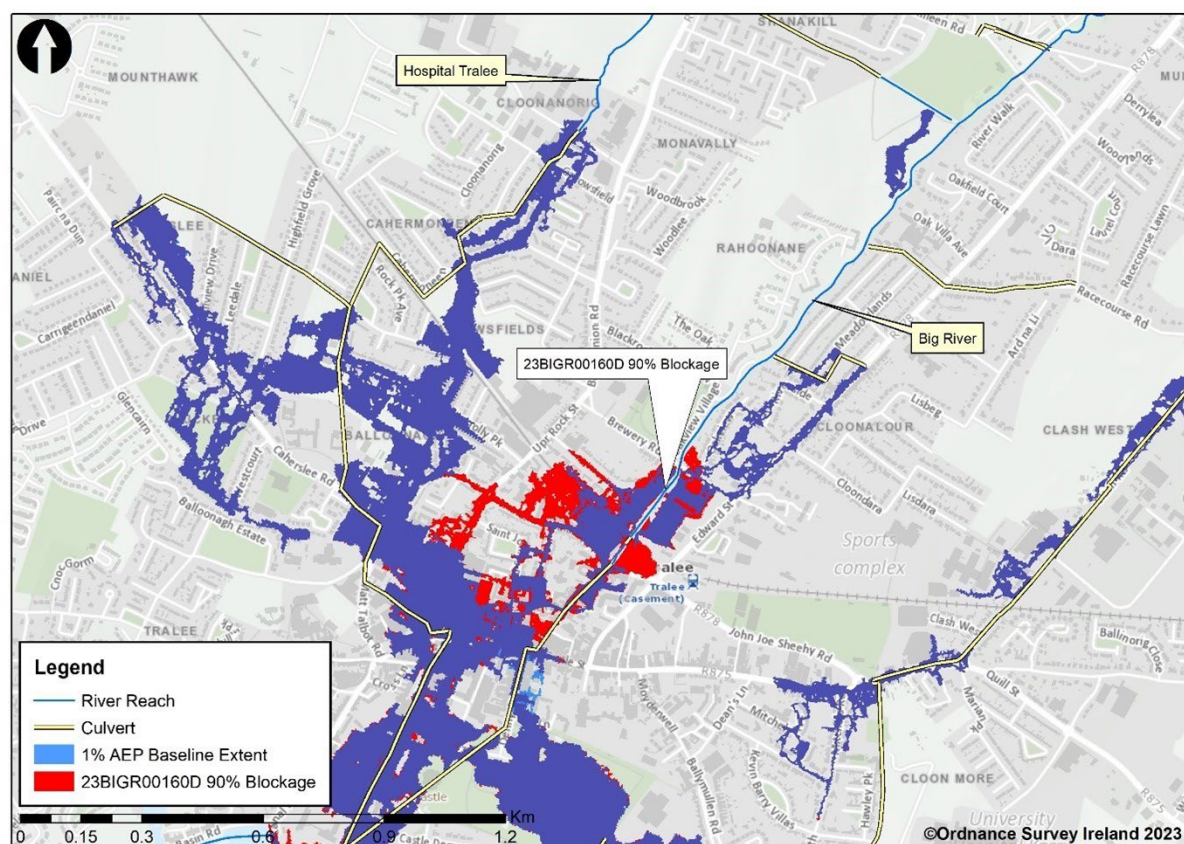


Figure 3.73: Blockage to Big River Bridge (23BIGR00160D)

3.9.6 Sensitivity Analysis Conclusions

The purpose of sensitivity analysis is to test the model's sensitivity to various parameter changes. The outcomes are flagged to inform the development of the options, robustness of business case and detailed design of the Tralee FRS. It may be used to make recommendations regarding adjustments to freeboard or other design considerations to ensure a 'no-regrets' approach.

The Tralee model was shown to be most sensitive to change in flows and blockage scenarios. Areas in the model that were most sensitive to changes in flood risk were along the River Lee, Cloghers, Big River and Balloonagh River. Changes in flood risk were based on a review of extent only. However, as stubby buildings with threshold levels are represented within the model, any additional properties flooded due to increased depths would have been considered in the economic damage assessment.

Some moderate sensitivity was shown to the increased 1D roughness combined with the decreased 2D roughness. The increase in flood extents has an impact upon properties located close to the Killerisk Road, Glen Castle and Prince's Street.

3.10 Coastal Model

The basis of deriving design coastal water levels at Tralee is the coastal level dataset from Phase 1 of the Irish Coastal Wave and Water Level Study (ICWWS) 2018⁶ which is an update of the original Irish Coastal Protection Strategy Study (ICPSS)⁷ undertaken by RPS on behalf of the OPW. Further details of the coastal modelling undertaken and the derivation of the coastal design water levels are included in Chapter 5 of the Tralee Flood Relief Scheme – Hydology Report (MCW1082-RPS-03-ZZ-RP-Z-0003 S3P03).

3.11 Model Performance

RPS have undertaken a mass balance check on the 1% AEP model to ensure that the total volume of water entering and leaving the model at the upstream and downstream boundaries balances the quantity of water remaining in the model domain at the end of a simulation. This will be a further indication of how the model is performing. Generally mass errors should be less than 2%. If the mass error is greater than 2%, the cause and location of the mass error within the model schematisation should be identified and the consequence of this error assessed with improvements to the model considered. If the mass error is greater than 5%, then it suggests that the model schematisation is not robust and needs to be reviewed (Environment Agency⁸).

⁶ RPS, 2020. Irish Coastal Wave and Water Level Modelling Study 2018: Phase 1 – Extreme Water Levels. Available at: https://s3-eu-west-1.amazonaws.com/docs.floodinfo.opw/floodinfo_docs/ICWWS-2018/Phase-1/IBE1505_ICWWS_Ph1_Rp01_F02.pdf

⁷ RPS 2013. Irish Coastal Protection Strategy Study: Phase 4 - South West Coast: Work Packages 2,3 & 4A - Technical Report. Available at: <https://www.gov.ie/en/collection/572115-irish-coastal-protection-strategy-study-phase-4-south-west-coast/>

⁸ (Environment Agency, 2021)

TRALEE FLOOD RELIEF SCHEME**HYDRAULICS REPORT**

The mass error of the Tralee FRS model during the 1% AEP simulation was calculated as -0.0083% therefore the model is deemed to be robust. The volume balance report from the 1% AEP simulation is shown below in Figure 3.74.

Volume balance report		

2d Zone name :	TRALEE_2D	
IV -> Initial volume (m3) :	0.0000	
IVC -> Initial volume 2D conduits (m3) :	0.0000	
FV -> Final volume (m3) :	1068967.5715	
FVC -> Final volume 2D conduits (m3) :	0.0000	
Inflows :		
I1D2DN -> 1d-2d Nodes (m3) :	177152.8180	1.06
I1D2DB -> 1d-2d Banks (m3) :	16587736.2254	98.94
IT -> Inflow total (m3) :	16764889.0433	100.00
Outflows :		
O1D2DN -> 1d-2d Nodes (m3) :	203946.9360	1.30
I1D2DB -> 1d-2d Banks (m3) :	10801832.0595	68.83
OBN -> Normal boundaries (m3) :	4688752.8956	29.88
OT -> Outflow total (m3) :	15694531.8910	100.00
Net inflows :		
N1D2DN -> 1d-2d Nodes (m3) :	-26794.1180	
N1D2DB -> 1d-2d Banks (m3) :	5785904.1659	
NBN -> Normal boundaries (m3) :	-4688752.8956	
NT -> Net inflow total (m3) :	1070357.1523	
Volume balance summary :		
VBE -> Volume balance error (m3) :	-1389.5808	
VBE = FV+FVC-IT-IV-IVC+OT		
VBEP -> Volume balance error % :	-0.0083	
VBEP = VBE*100/(IV+IVC+IT)		
VBEP10 -> VBE as % of inflow + outflow :	-0.0043	
VBEP10 = VBE*100/(IT+OT)		
VBEPNI -> VBE as % of inflow - outflow :	-0.1298	
VBEPNI = VBE*100/(IT-OT)		
Effective area (ha) :	7394.4641	100.00
Flooded area at the end of the simulation (ha) :	375.6856	5.08
Maximum flooded area (ha) :	585.3491	7.92

Figure 3.74 1% AEP Fluvial Simulation Volume Balance Report

4 QUALITY ASSURANCE

RPS have carried out internal reviews of the model. The hydraulic model lead has reviewed model set up at 1D and 2D development and reviewed calibration and design simulation outputs to ensure the model meets expectations. Quality assurance sheets are in the form of RPS' internal model log which will accompany the hydraulic model.

5 CONCLUSIONS

RPS have undertaken a comprehensive review of existing information including historical flood event data, reports and models from previous studies and survey information. Additional topographical and culvert survey information has been procured for the purposes of the Tralee FRS.

An Infoworks ICM model was developed to undertake the numerical modelling of watercourses affecting the study area. The 1D domain of the model incorporates all hydraulic structures and connects with the 2D domain to provide an accurate assessment of both the in-channel flow regime and floodplain flow paths.

Following the Tralee CFRAM Study, updates were made to the hydrological analysis, as discussed in the Tralee FRS Hydrology Report. The updates resulted in a hydrological conclusion that the methodologies for understanding the flood frequency and deriving the design flows presented in this report are considered the most robust possible utilising all available data.

Tralee has suffered extensive flooding throughout its history with five of those being used to calibrate the model. The five events occurred in January 2014, September 2015, December 2015, February 2020, and December 2021. These flood events were calibrated to a high degree of accuracy in the Tralee FRS hydraulic model.

The model is moderately well anchored to hydrological estimates and where there are significant discrepancies this is explained by the hydraulic mechanisms captured within the model. The model is well calibrated to five recent flood events and has a mass balance error of 0.034%. The model is deemed robust and reliable.

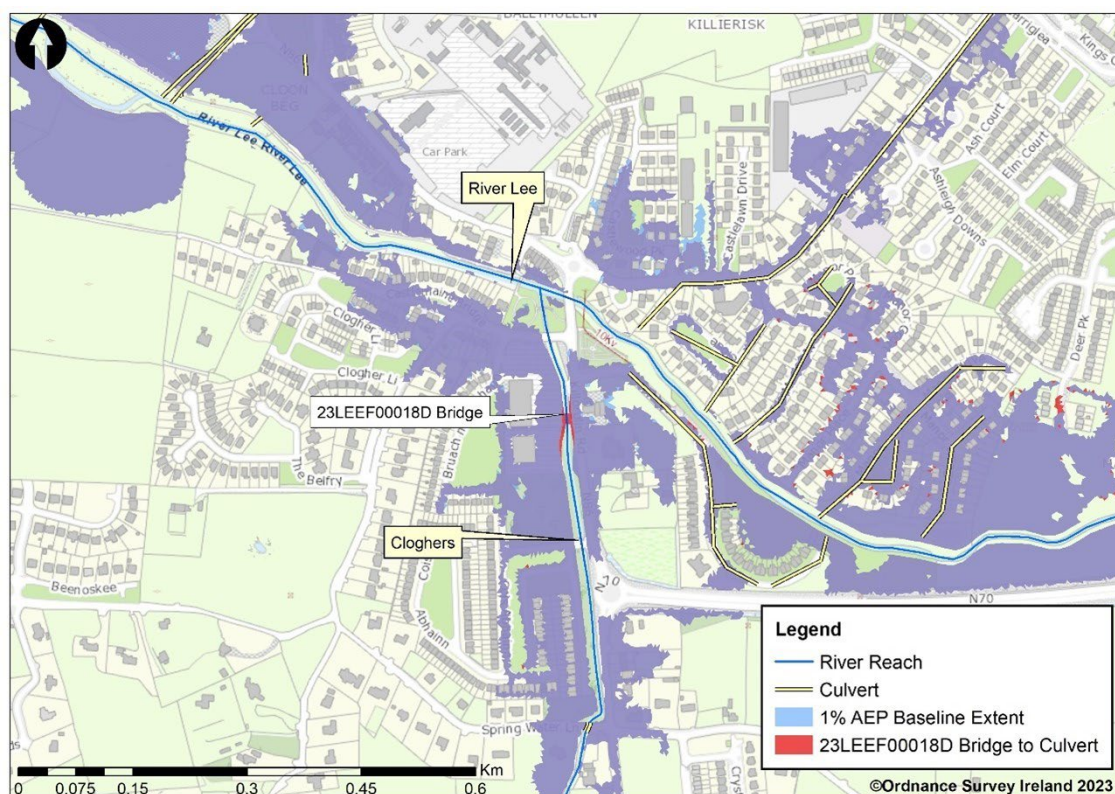
Sensitivity and blockage assessments have also been undertaken as part of the Tralee FRS model assessment. Sensitivity simulations were conducted to test the model's sensitivity to various parameter changes. The model is particularly sensitive to the climate change flow scenarios and the blockage scenarios. Outputs of the analysis will inform the development of the options and detailed design of the Tralee FRS, particularly in making recommendations regarding adjustments to freeboard or other design considerations to ensure a 'no-regrets' approach.

The hydraulic model and its spatial data outputs are considered robust and suitable for the progression of the Scheme Analysis and Development phase of the project.

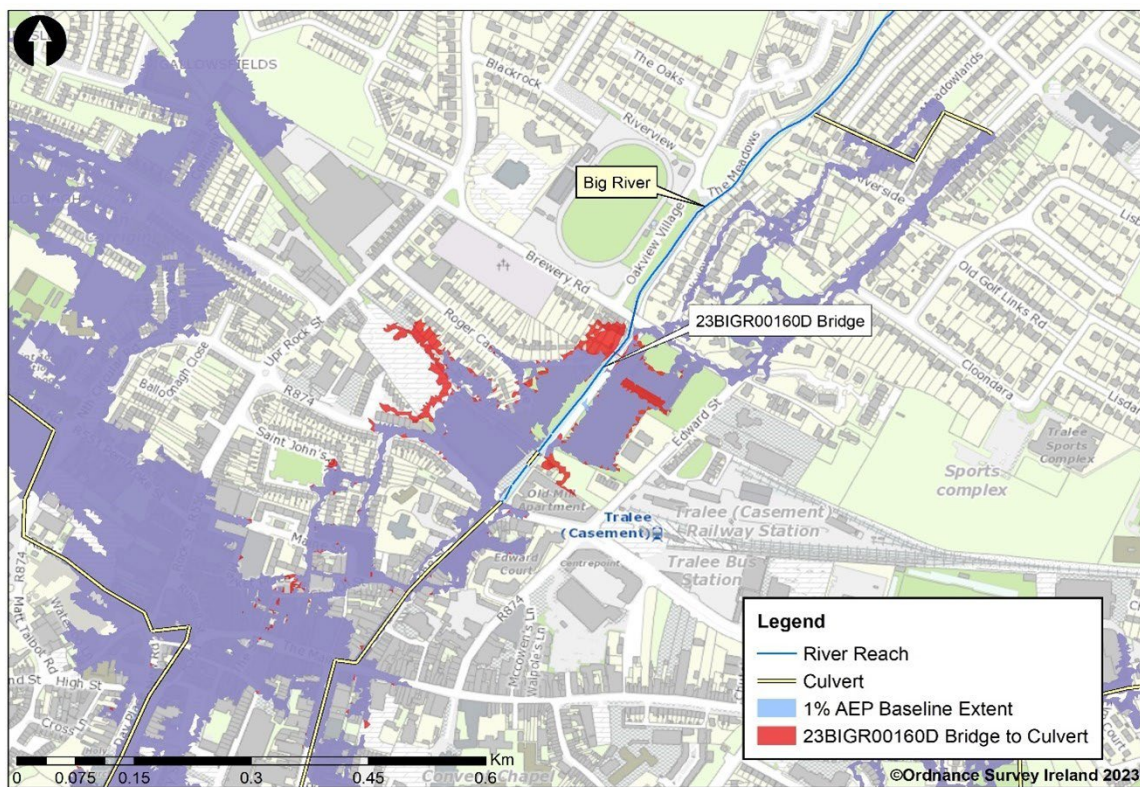
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3. North Western – Neagh Bann CFRAM Study UOM 1 Hydraulics Report, OPW, 2014.
 - Available at: https://s3-eu-west-1.amazonaws.com/docs.floodinfo.opw/floodinfo_docs/NWNB_CFRAM/_UOM_01/02_Hydraulics/IBE0700Rp0011_HA01_Hydraulics_Report_F05.pdf
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8. Mott MacDonald. 2013. CFRAM Guidance Note 24 – Breach Analysis, OPW.
9. Environment Agency, 2021. *Hydraulic Modelling: Best Practice (model approach)*, Bristol: Environment Agency.

Appendix A – Sensitivity Analysis Figures



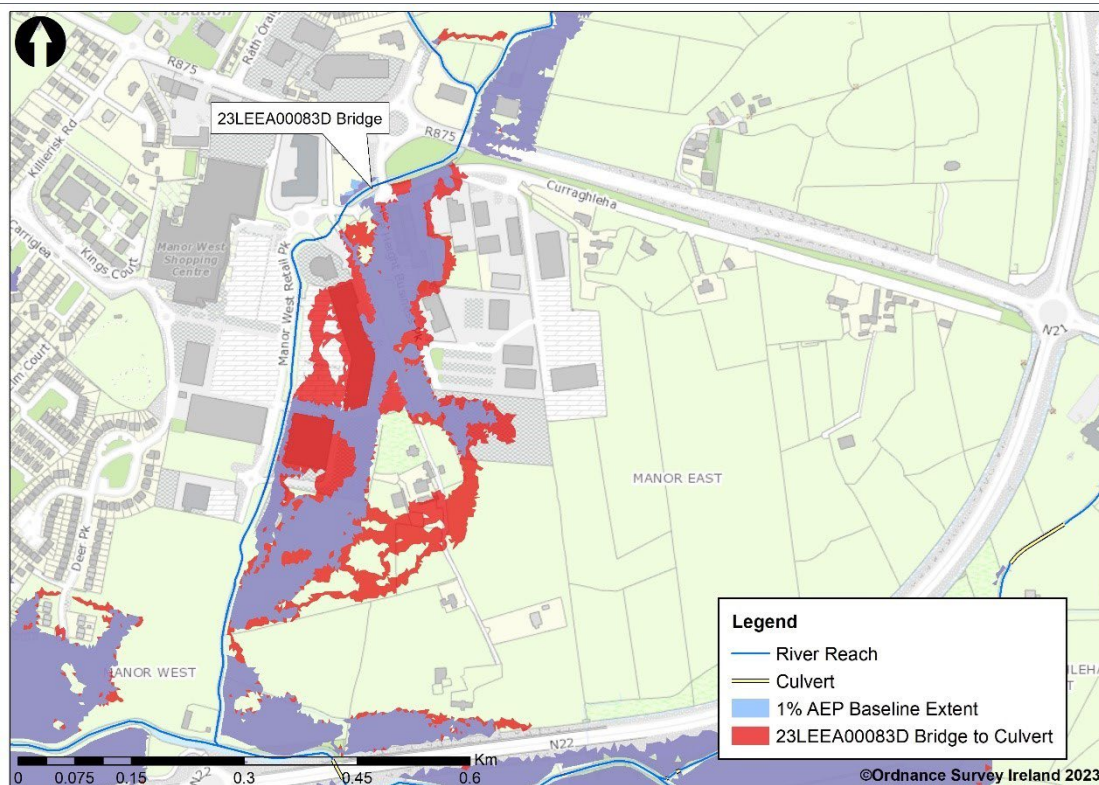
Appendix A - Figure 1: Change to Structure 23LEEF00018D



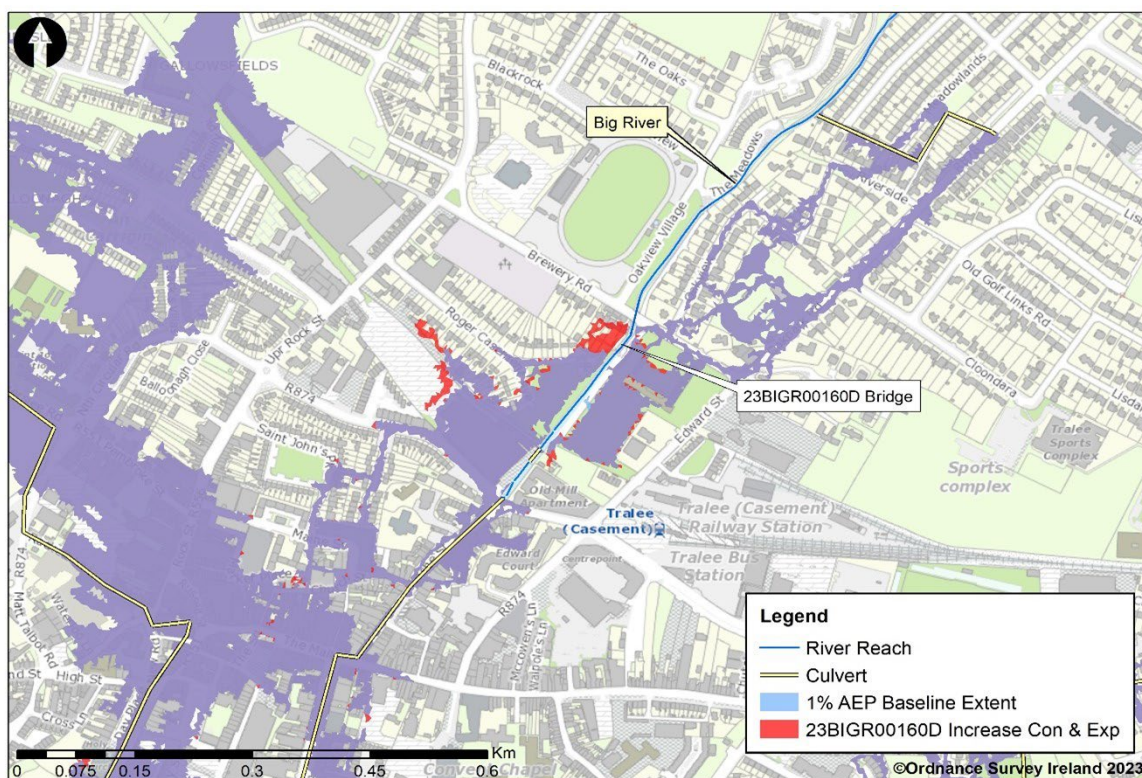
Appendix A - Figure 2: Change to Structure 23BIGR00160D

TRALEE FLOOD RELIEF SCHEME

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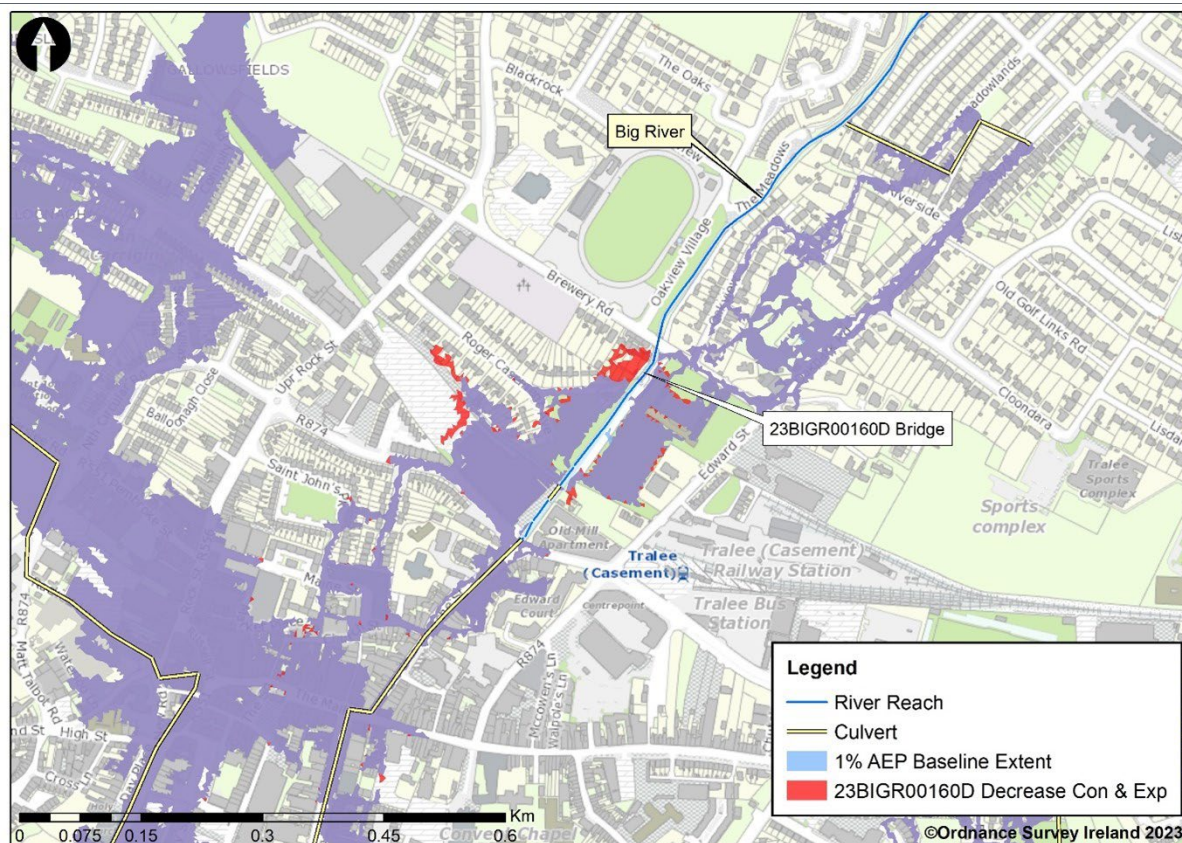
Appendix A - Figure 3: Change to Structure 23LEEA00083D



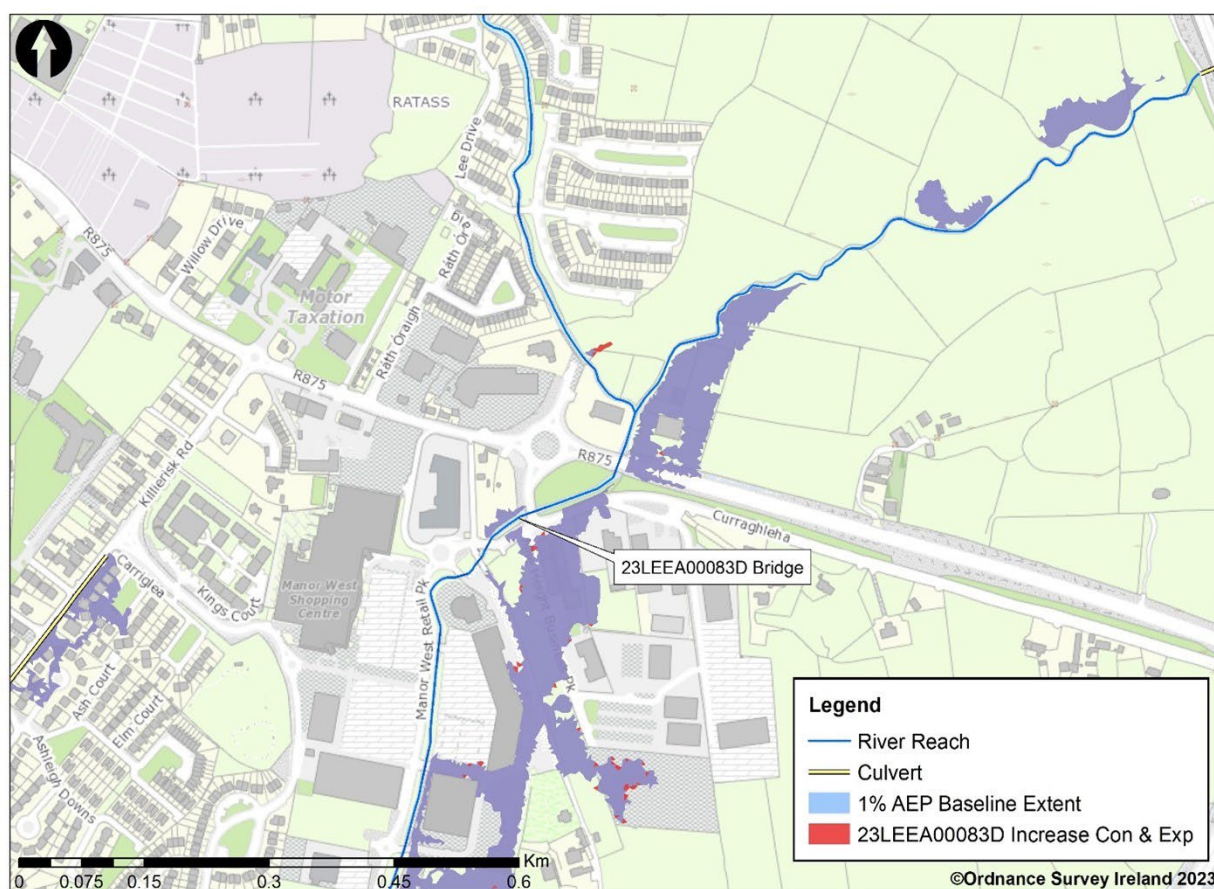
Appendix A - Figure 4: Increased contraction and expansion on structure 23BIGR00160

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT



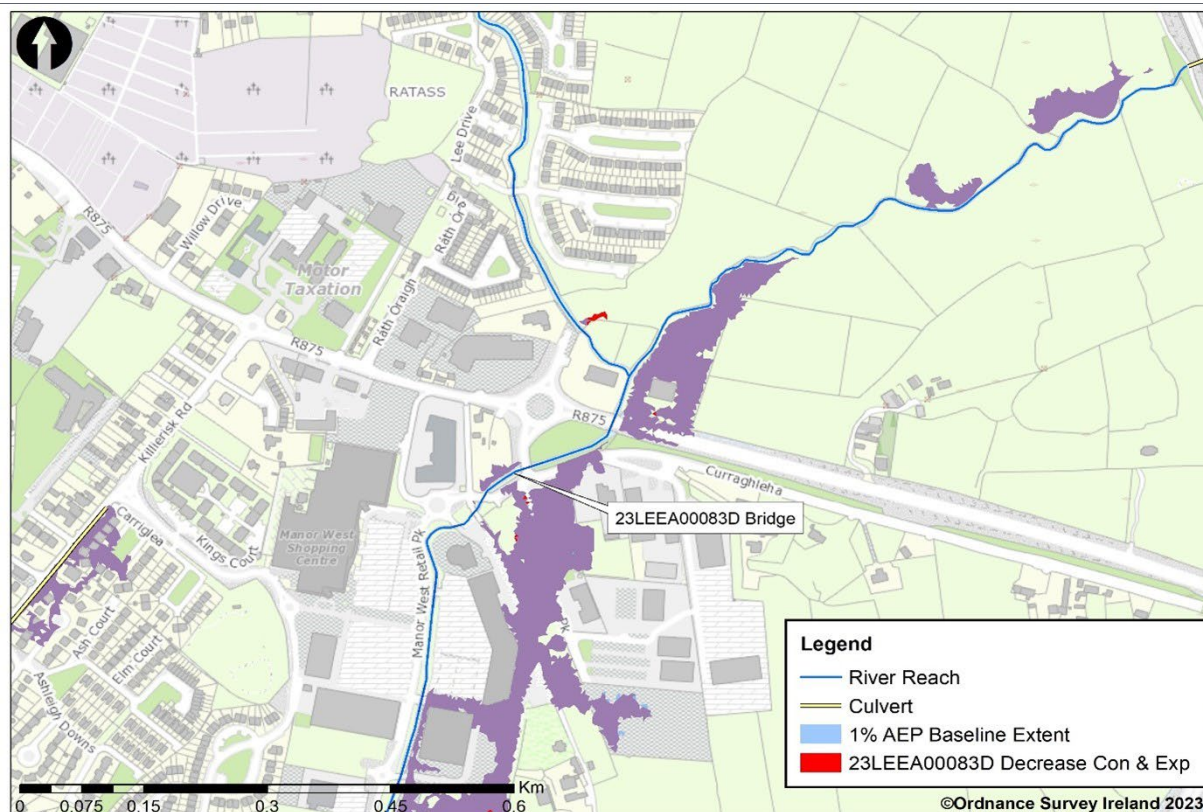
Appendix A - Figure 5: Decreased contraction and expansion on structure 23BGR00160



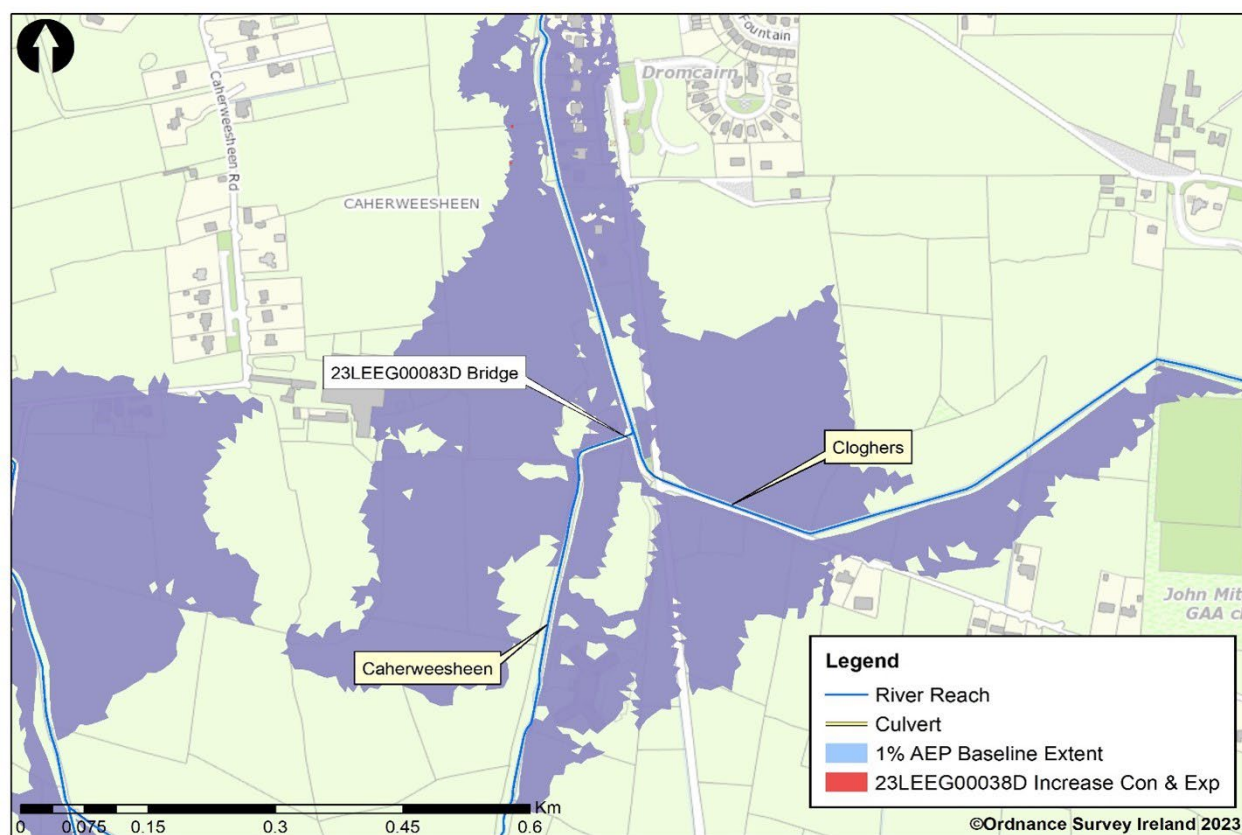
Appendix A - Figure 6: Increased contraction and expansion on structure 23LEE00083D

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT



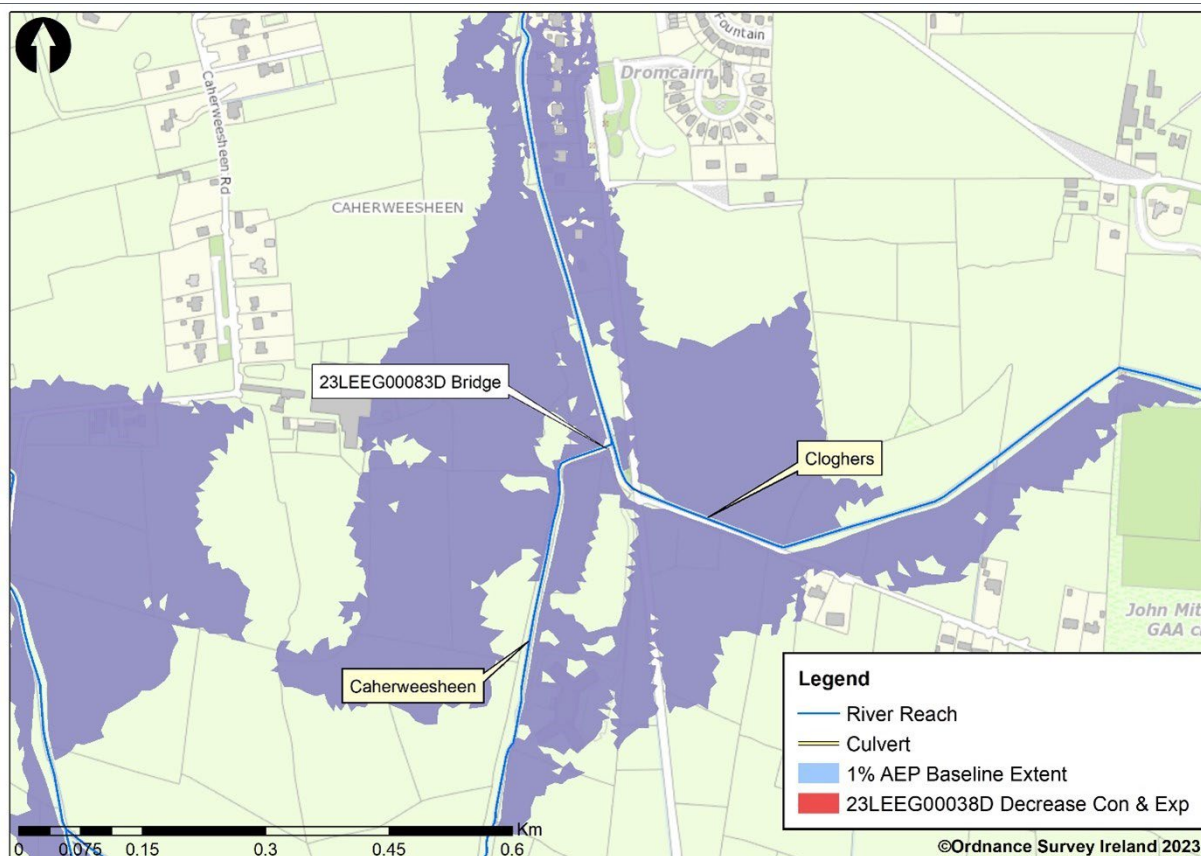
Appendix A - Figure 7: Decreased contraction and expansion on structure 23LEEA00083D



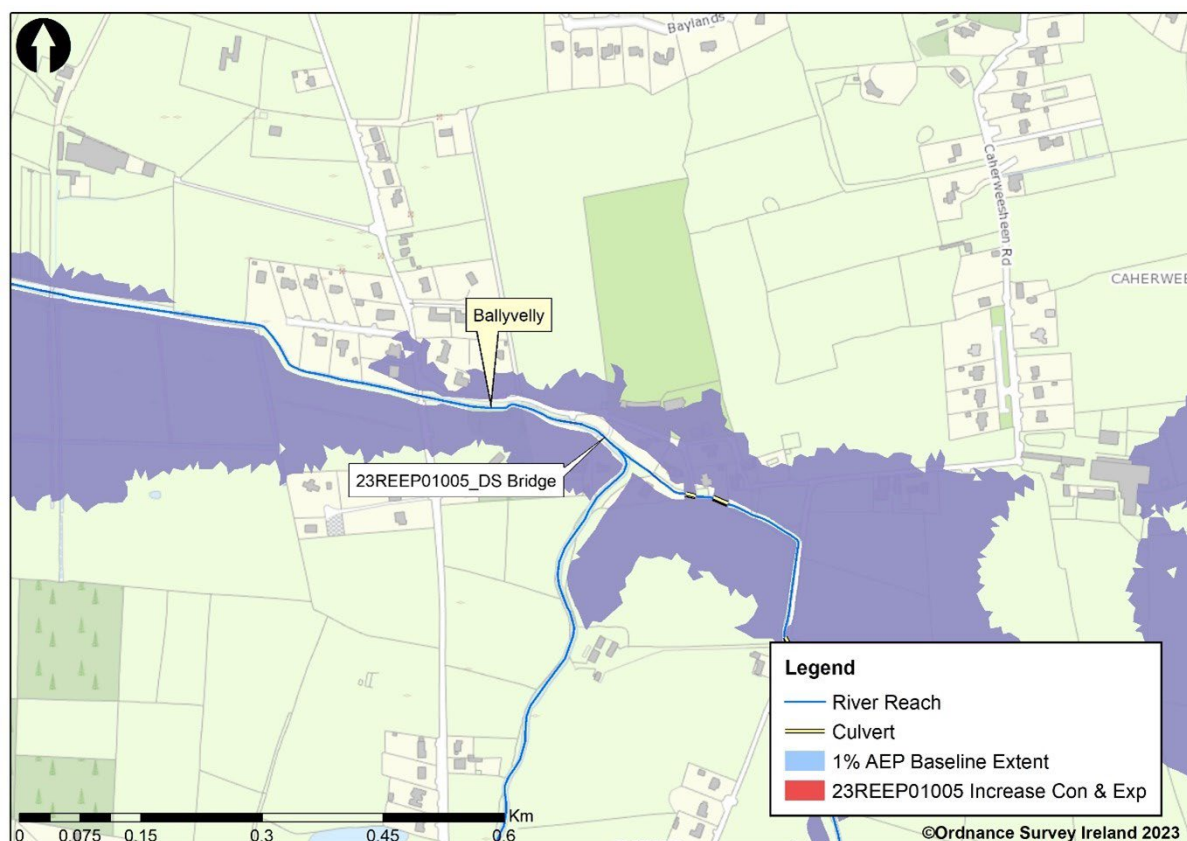
Appendix A - Figure 8: Increased contraction and expansion on structure 23LEEG00038D

TRALEE FLOOD RELIEF SCHEME

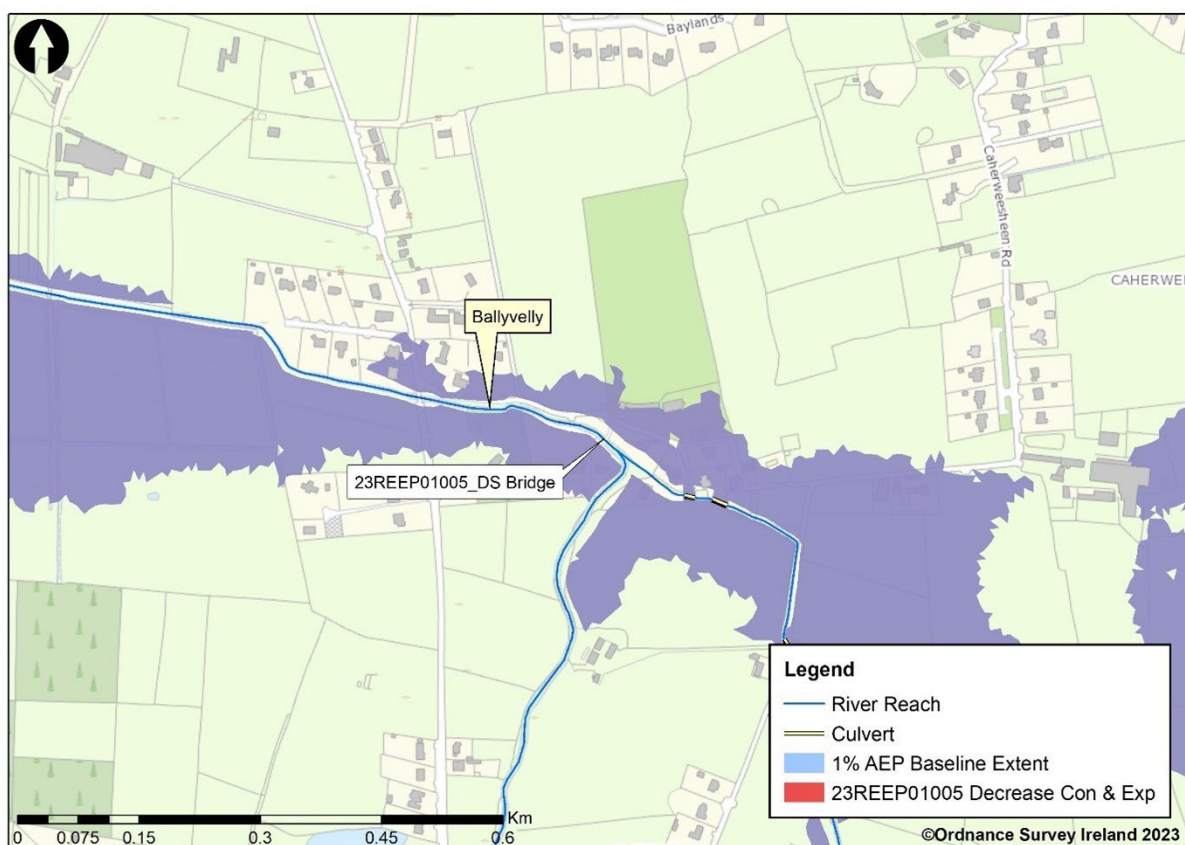
HYDRAULICS REPORT



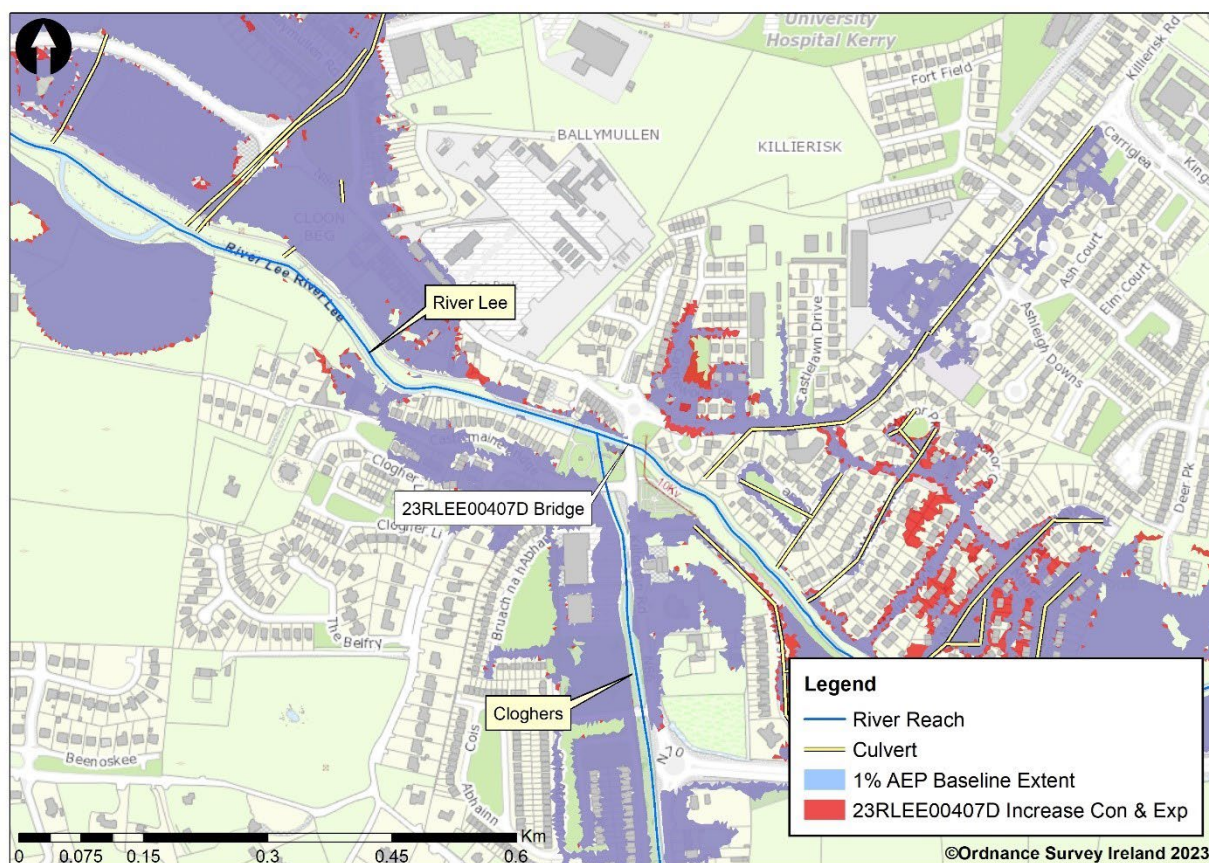
Appendix A – Figure 9: Decreased contraction and expansion on structure 23LEEG00038D



Appendix A - Figure 10: Increased contraction and expansion on structure 23REEP01005_2022



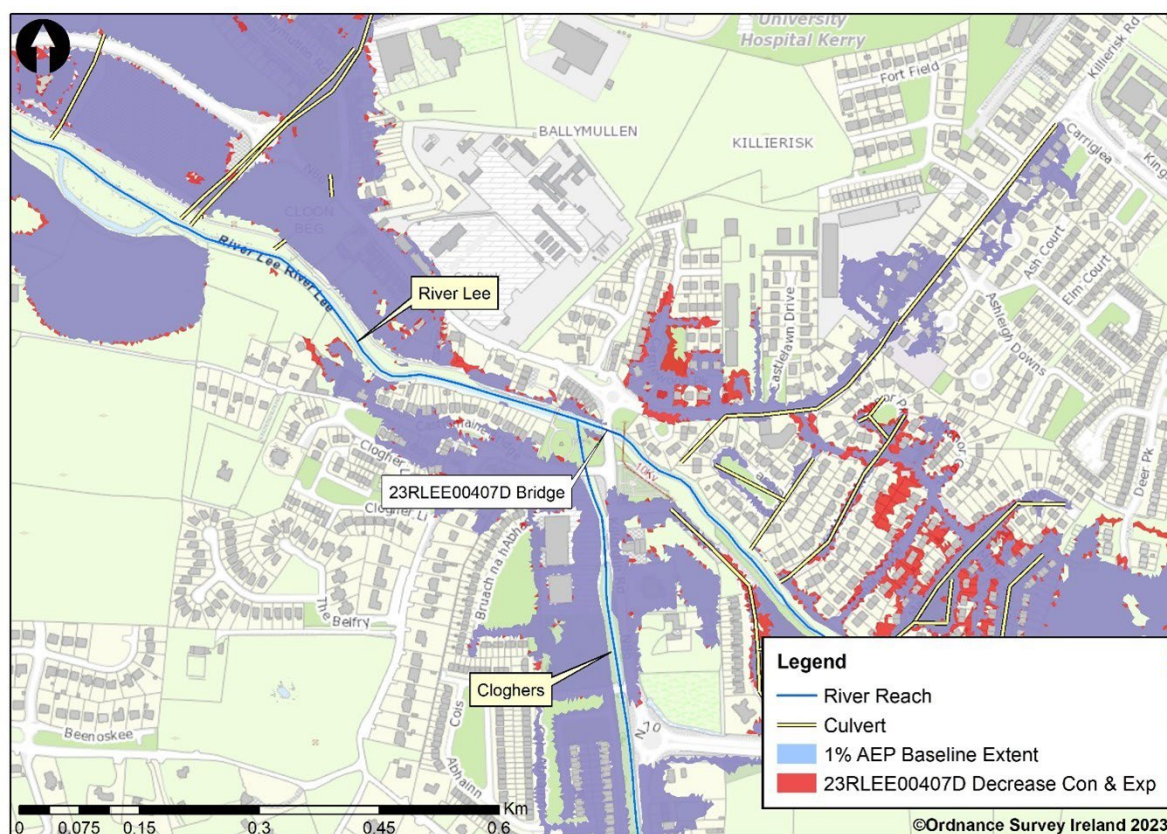
Appendix A - Figure 11: Decreased contraction and expansion on structure 23REEP01005_2022



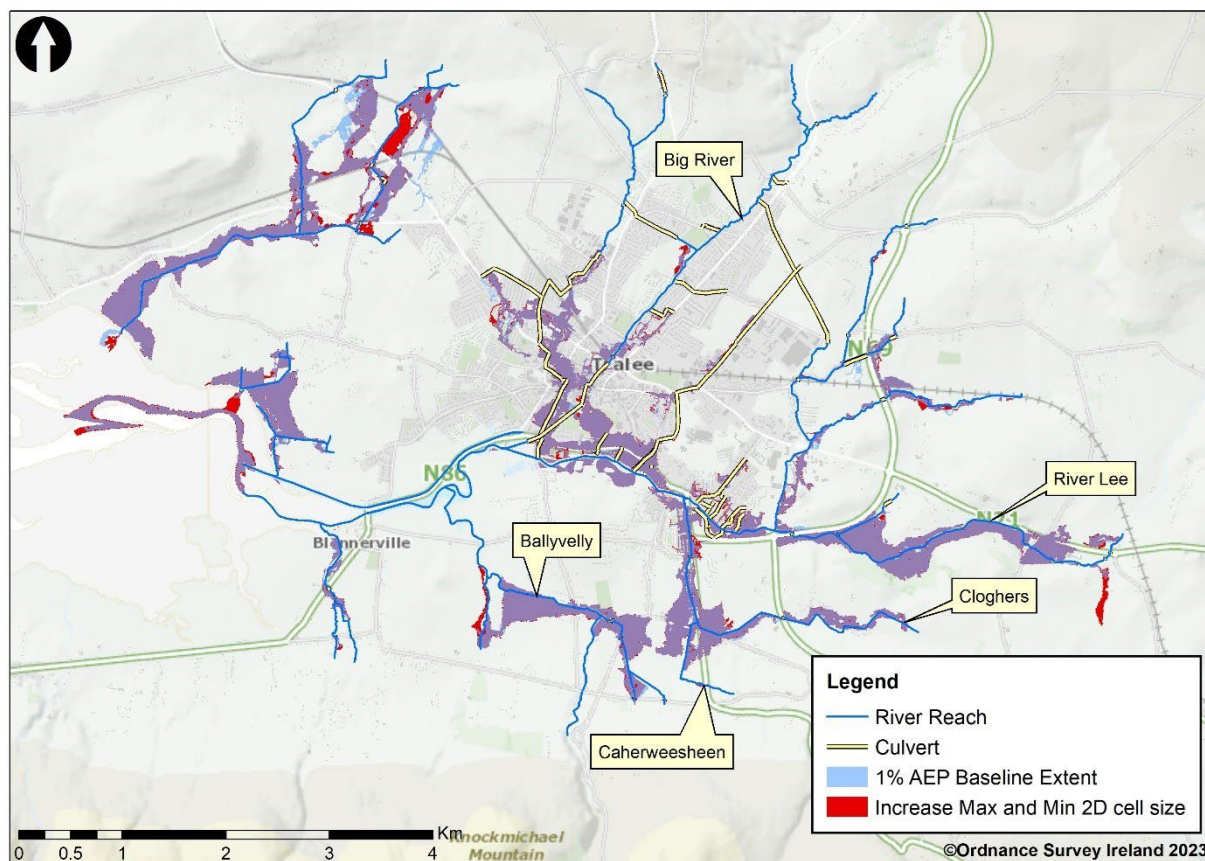
TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

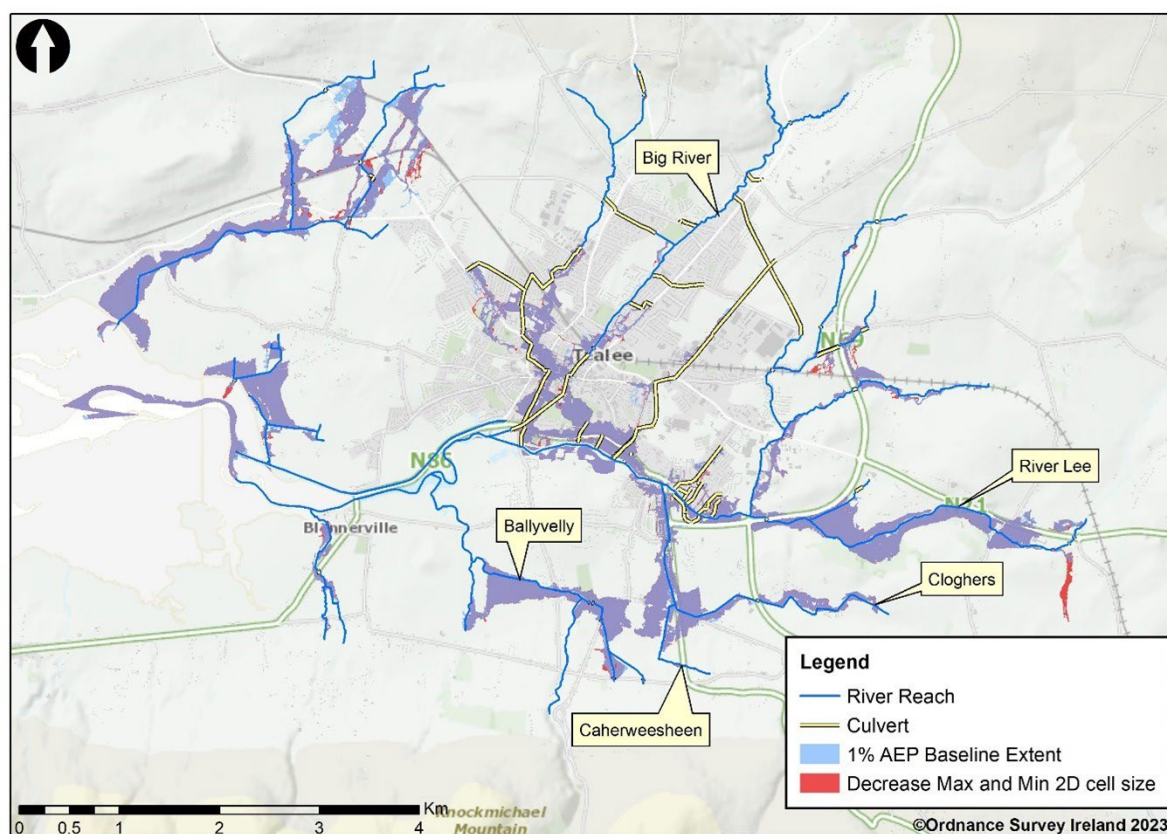
Appendix A - Figure 12: Increased contraction and expansion on structure 23RLEE00407D



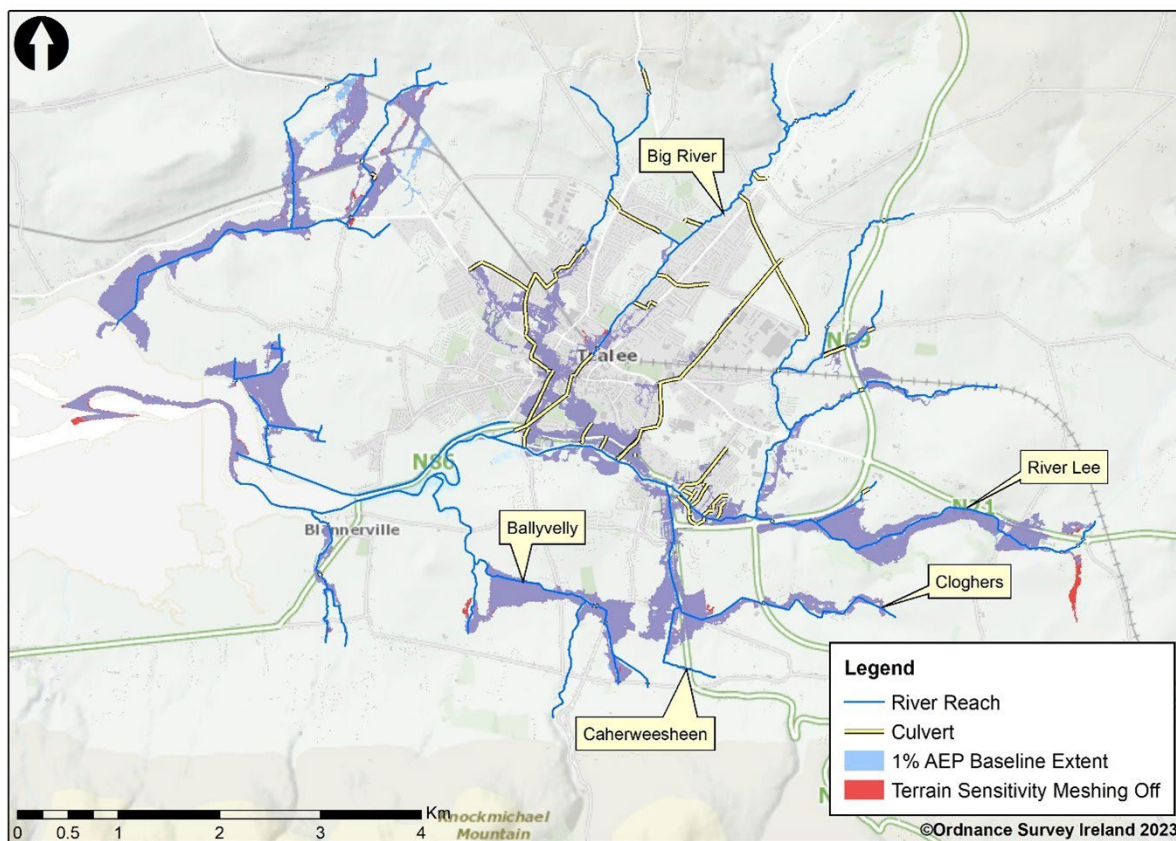
Appendix A - Figure 13: Decreased contraction and expansion on structure 23RLEE00407D



Appendix A - Figure 14: Increased 2D Cell Size



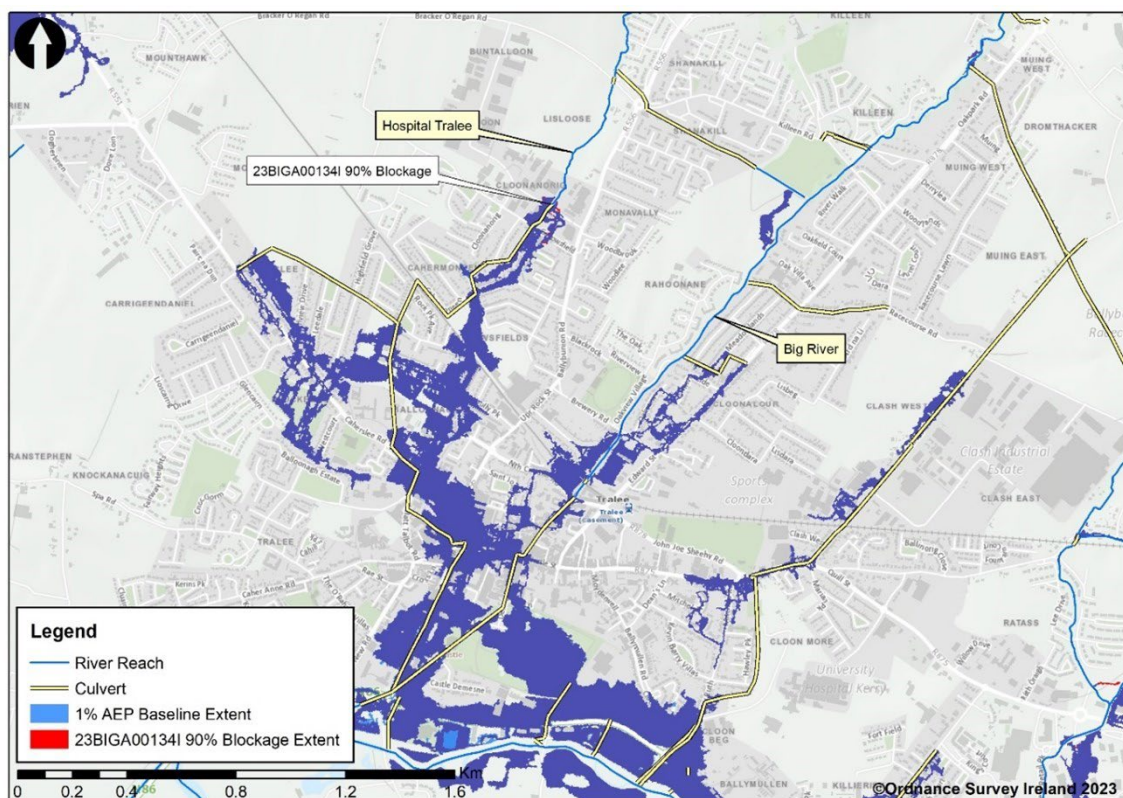
Appendix A - Figure 15: Decreased 2D Cell Size



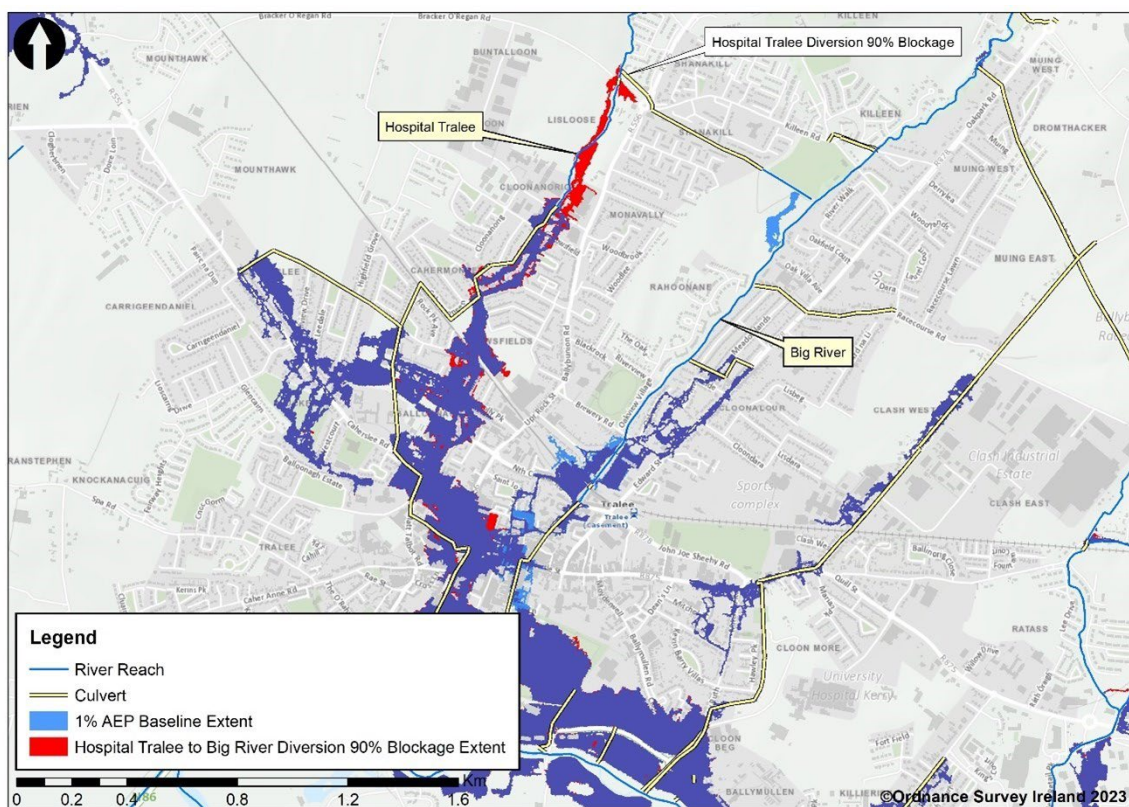
Appendix A - Figure 16: Terrain Sensitive Meshing Off

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT



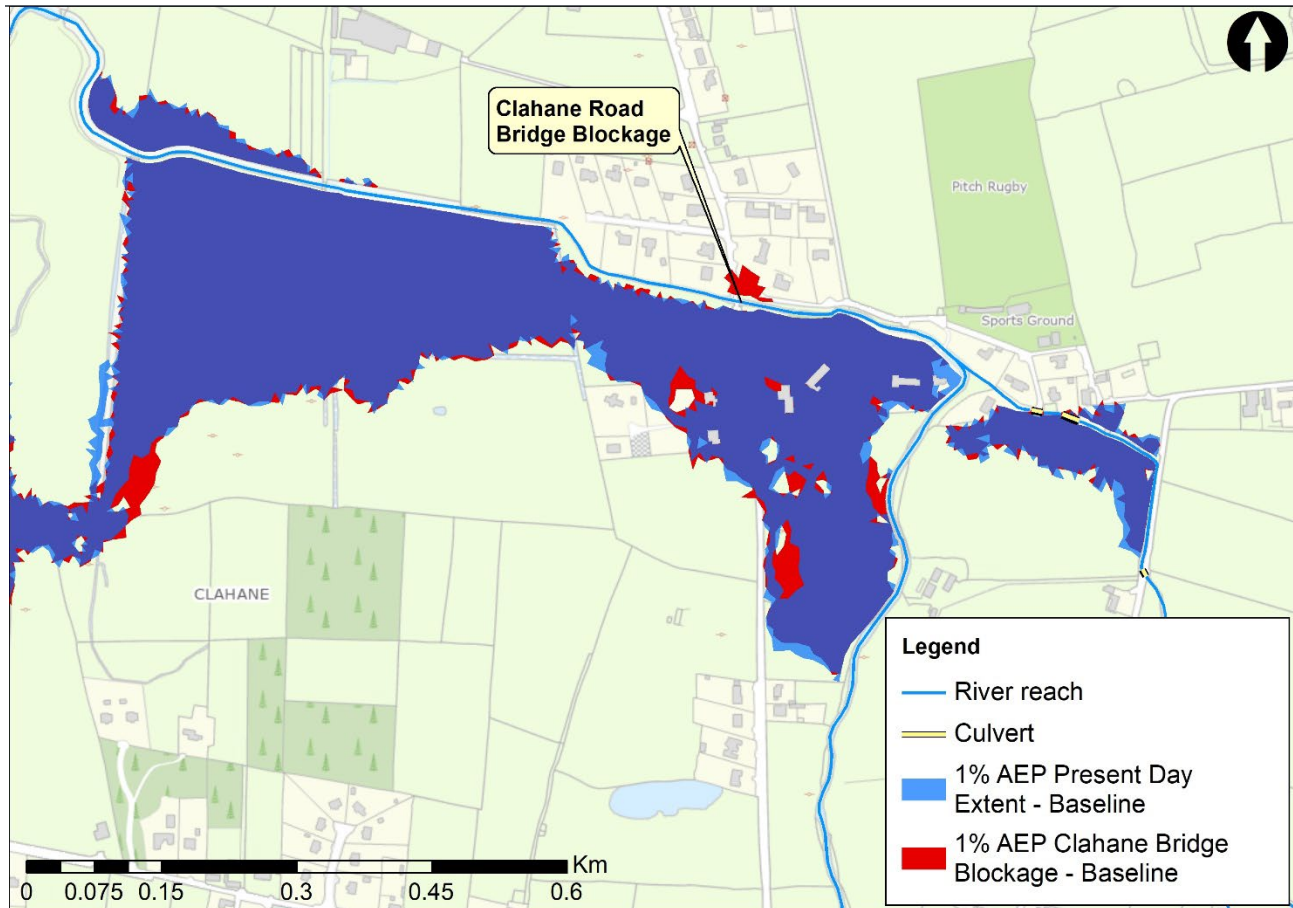
Appendix A - Figure 17: 90% blockage to 23BIGA00134I



Appendix A - Figure 18: 90% blockage to 23ALLO00083I

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT



Appendix A - Figure 19: 90%/60% blockage to Clahane Road Bridge

Appendix B – Hydrological Anchoring

Internal validation checks using modelled flows against hydrological estimations have ensured that the model is anchored to the hydrological estimates of flow. Based upon these reviews, there is confidence the model is replicating the expected hydrological flow regime as set out in the Hydrological Analysis, within tolerance. The location of the HEPs is outlined in the Hydrology Report Section 3.1.

HEP	Peak Flow			
	AEP (%)	Check Flow (m ³ /s)	Model Flow (m ³ /s)	Difference (%)
LEE_02	50	16.6	15.3	-8%
	10	23.2	22.9	-1%
	1	37.3	35.9	-4%
	0.1	64.1	59.1	-8%
LEE_03	50	16.8	15.4	-8%
	10	23.6	22.8	-3%
	1	37.9	36.0	-5%
	0.1	65.0	59.1	-9%
LEE_05	50	0.2	2.7	1250%
	10	0.3	15.5	5067%
	1	0.4	19.6	4800%
	0.1	0.6	36.0	5900%
LEE_06	50	17.2	16.0	-7%
	10	24.3	25.0	3%
	1	37.9	36.9	-3%
	0.1	61.5	65.6	7%
LEE_08	50	4.2	4.3	2%
	10	5.8	6.0	3%
	1	8.2	8.4	2%
	0.1	11.3	11.6	3%
LEE_09	50	4.7	2.4	-49%
	10	6.5	3.2	-51%
	1	9.1	4.3	-53%
	0.1	12.6	5.9	-53%
LEE_12	50	5.1	2.5	-51%
	10	7.0	3.2	-54%

TRALEE FLOOD RELIEF SCHEME

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	1	9.9	4.3	-57%
	0.1	13.7	6.0	-56%
LEE_14	50	0.1	7.9	7800%
	10	0.2	10.4	5100%
	1	0.2	14.2	7000%
	0.1	0.3	19.9	6533%
LEE_15	50	5.3	10.1	91%
	10	7.3	13.3	82%
	1	10.3	17.5	70%
	0.1	14.3	22.6	58%
LEE_16	50	5.3	10.1	91%
	10	7.3	13.4	84%
	1	10.3	17.6	71%
	0.1	14.2	21.9	54%
LEE_18	50	2.7	2.9	7%
	10	3.7	3.9	5%
	1	5.3	5.5	4%
	0.1	7.3	7.5	3%
LEE_19	50	3.1	3.3	6%
	10	4.3	4.5	5%
	1	6.0	6.3	5%
	0.1	8.3	8.2	-1%
LEE_20	50	8.6	13.3	55%
	10	11.9	17.8	50%
	1	16.7	23.7	42%
	0.1	23.1	27.2	18%
LEE_21	50	9.0	13.4	49%
	10	12.4	18.1	46%
	1	17.4	23.9	37%
	0.1	24.1	32.7	36%
LEE_22	50	24.1	23.4	-3%
	10	34.1	31.2	-9%
	1	53.2	48.4	-9%
	0.1	86.2	78.2	-9%
LEE_29	50	24.2	23.2	-4%

TRALEE FLOOD RELIEF SCHEME

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	10	34.2	31.0	-9%
	1	53.4	48.4	-9%
	0.1	86.6	73.9	-15%
LEE_31	50	5.6	5.7	2%
	10	7.9	8.0	1%
	1	11.5	11.0	-4%
	0.1	16.7	16.9	1%
LEE_32	50	6.4	6.2	-3%
	10	8.9	8.5	-4%
	1	13.0	12.9	-1%
	0.1	18.9	17.6	-7%
LEE_33	50	6.6	5.4	-18%
	10	9.2	8.5	-8%
	1	13.4	12.4	-7%
	0.1	19.5	18.3	-6%
LEE_35	50	5.3	5.3	0%
	10	7.5	7.3	-3%
	1	10.9	11.0	1%
	0.1	15.8	16.7	6%
LEE_36	50	9.2	6.7	-27%
	10	12.8	9.9	-23%
	1	18.6	14.2	-24%
	0.1	27.1	19.0	-30%
LEE_37	50	9.5	7.4	-22%
	10	13.3	11.2	-16%
	1	19.3	16.8	-13%
	0.1	28.1	24.7	-12%
LEE_38	50	9.8	7.8	-20%
	10	13.7	11.4	-17%
	1	19.9	16.4	-18%
	0.1	29.0	24.4	-16%
LEE_39	50	30.3	31.0	2%
	10	42.7	42.4	-1%
	1	66.7	61.4	-8%
	0.1	108.1	92.2	-15%

TRALEE FLOOD RELIEF SCHEME

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LEE_45	50	32.7	31.5	-4%
	10	46.2	42.5	-8%
	1	72.1	58.0	-20%
	0.1	116.9	87.2	-25%
LEE_47	50	33.0	33.3	1%
	10	46.5	43.8	-6%
	1	72.6	58.2	-20%
	0.1	117.7	77.5	-34%
LEE_49	50	3.7	3.9	5%
	10	5.2	5.5	6%
	1	7.4	7.7	4%
	0.1	10.1	10.6	5%
LEE_51	50	3.0	3.1	3%
	10	4.2	4.3	2%
	1	6.0	6.1	2%
	0.1	8.1	8.3	2%
LEE_52	50	6.7	7.0	4%
	10	9.5	9.9	4%
	1	13.4	14.0	4%
	0.1	18.3	19.1	4%
LEE_55	50	7.4	7.8	5%
	10	10.4	10.9	5%
	1	14.6	15.4	5%
	0.1	20.0	21.0	5%
LEE_56	50	7.5	1.9	-75%
	10	10.5	3.5	-67%
	1	14.9	6.7	-55%
	0.1	20.3	11.7	-42%
LEE_59	50	8.6	4.1	-52%
	10	12.1	6.9	-43%
	1	17.0	11.2	-34%
	0.1	23.3	17.4	-25%
LEE_61	50	8.7	4.3	-51%
	10	12.2	7.1	-42%
	1	17.2	11.5	-33%

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

	0.1	23.5	17.9	-24%
LEE_63	50	9.3	4.9	-47%
	10	13.1	7.8	-40%
	1	18.5	21.1	14%
	0.1	25.2	21.3	-15%
LEE_64	50	9.4	5.0	-47%
	10	13.3	7.9	-41%
	1	18.7	11.1	-41%
	0.1	25.6	15.1	-41%
LEE_66	50	0.9	0.9	0%
	10	1.2	1.3	8%
	1	1.8	1.8	0%
	0.1	2.4	2.4	0%
LEE_68	50	0.5	0.5	0%
	10	0.7	0.7	0%
	1	1.0	1.0	0%
	0.1	1.4	1.3	-7%
LEE_69	50	1.5	1.6	7%
	10	2.1	2.4	14%
	1	3.0	3.3	10%
	0.1	4.1	4.6	12%
LEE_70	50	1.5	1.7	13%
	10	2.2	2.4	9%
	1	3.1	3.4	10%
	0.1	4.3	4.7	9%
LEE_71	50	1.7	0.5	-71%
	10	2.4	0.6	-75%
	1	3.4	1.2	-65%
	0.1	4.7	2.1	-55%
LEE_72	50	2.5	0.9	-64%
	10	3.5	0.9	-74%
	1	5.0	0.9	-82%
	0.1	6.9	0.9	-87%
LEE_74	50	0.5	0.5	0%
	10	0.7	0.7	0%

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

	1	1.0	1.0	0%
	0.1	1.4	1.4	0%
LEE_75	50	3.3	1.8	-45%
	10	4.7	2.0	-57%
	1	6.6	2.4	-64%
	0.1	9.1	2.8	-69%
LEE_76	50	4.7	3.5	-26%
	10	6.8	4.7	-31%
	1	9.6	8.6	-10%
	0.1	13.2	14.8	12%
LEE_77	50	14.6	8.4	-42%
	10	20.6	12.1	-41%
	1	29.0	14.8	-49%
	0.1	39.7	15.6	-61%
LEE_78	50	42.7	39.6	-7%
	10	60.3	51.2	-15%
	1	94.0	68.1	-28%
	0.1	152.4	92.0	-40%
LEE_79	50	42.7	45.7	7%
	10	60.3	60.4	0%
	1	94.0	101.0	7%
	0.1	152.4	123.5	-19%
LEE_81	50	1.2	1.2	0%
	10	1.8	1.9	6%
	1	2.9	2.9	0%
	0.1	4.4	4.4	0%
LEE_82	50	1.8	1.7	-6%
	10	2.6	2.4	-8%
	1	4.1	3.9	-5%
	0.1	6.2	5.9	-5%
LEE_84	50	8.0	5.3	-34%
	10	12.0	5.4	-55%
	1	18.5	6.0	-68%
	0.1	28.3	6.5	-77%
LEE_85	50	9.5	6.5	-32%

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

	10	14.2	7.8	-45%
	1	21.9	10.1	-54%
	0.1	33.5	12.8	-62%
LEE_86	50	9.6	10.1	5%
	10	14.3	14.6	2%
	1	22.1	22.2	0%
	0.1	33.8	31.9	-6%
LEE_87	50	10.0	8.6	-14%
	10	14.9	9.6	-36%
	1	23.1	14.2	-39%
	0.1	35.3	21.9	-38%
LEE_89	50	4.6	4.7	2%
	10	6.9	6.5	-6%
	1	10.7	9.6	-10%
	0.1	16.3	14.3	-12%
LEE_90	50	4.6	4.7	2%
	10	6.8	6.6	-3%
	1	10.6	9.7	-8%
	0.1	16.1	13.9	-14%
LEE_91	50	13.7	10.1	-26%
	10	20.3	13.0	-36%
	1	31.5	18.8	-40%
	0.1	48.1	28.3	-41%
LEE_92	50	13.7	11.3	-18%
	10	20.3	12.6	-38%
	1	31.5	18.8	-40%
	0.1	48.1	28.7	-40%
LEE_93	50	13.7	-16.2	-218%
	10	20.3	-16.3	-180%
	1	31.5	19.7	-37%
	0.1	48.1	26.8	-44%
LEE_94	50	54.9	53.0	-3%
	10	77.6	84.4	9%
	1	121.0	105.0	-13%
	0.1	196.2	127.0	-35%

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

LEE_96	50	1.0	1.1	10%
	10	1.5	1.6	7%
	1	2.3	2.5	9%
	0.1	3.6	3.8	6%
LEE_98	50	0.1	0.1	0%
	10	0.1	0.2	100%
	1	0.2	0.4	100%
	0.1	0.3	0.6	100%
LEE_99	50	1.1	1.2	9%
	10	1.6	1.8	13%
	1	2.5	2.6	4%
	0.1	3.9	3.6	-8%
LEE_102	50	0.1	0.1	0%
	10	0.1	0.1	0%
	1	0.2	0.2	0%
	0.1	0.3	0.3	0%
LEE_103	50	0.4	0.6	50%
	10	0.7	0.9	29%
	1	1.1	1.5	36%
	0.1	1.6	2.7	69%
LEE_105	50	0.5	0.6	20%
	10	0.8	0.8	0%
	1	1.3	1.2	-8%
	0.1	2.0	2.2	10%
LEE_108	50	0.4	0.4	0%
	10	0.7	0.6	-14%
	1	1.1	1.0	-9%
	0.1	1.6	1.4	-13%
LEE_110	50	0.5	0.2	-60%
	10	0.8	0.1	-88%
	1	1.2	0.2	-83%
	0.1	1.8	0.2	-89%
LEE_111	50	0.8	0.8	0%
	10	1.3	1.2	-8%
	1	2.0	1.6	-20%

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

	0.1	3.0	1.7	-43%
LEE_113	50	1.6	1.7	6%
	10	2.5	2.5	0%
	1	4.0	3.6	-10%
	0.1	6.5	5.8	-11%
LEE_114	50	2.9	2.7	-7%
	10	4.3	4.0	-7%
	1	7.0	6.3	-10%
	0.1	11.4	8.5	-25%
LEE_115	50	3.6	4.0	11%
	10	5.4	5.7	6%
	1	8.7	11.0	26%
	0.1	14.1	16.9	20%
LEE_118	50	1.5	1.5	0%
	10	2.2	2.3	5%
	1	3.5	3.6	3%
	0.1	5.8	5.2	-10%
LEE_119	50	1.7	1.8	6%
	10	2.5	2.7	8%
	1	4.1	4.0	-2%
	0.1	6.7	6.2	-7%
LEE_120	50	2.0	1.3	-35%
	10	3.0	1.6	-47%
	1	4.8	2.4	-50%
	0.1	7.7	4.6	-40%
LEE_122	50	2.6	2.0	-23%
	10	3.8	2.6	-32%
	1	6.2	4.1	-34%
	0.1	10.1	7.0	-31%
LEE_123	50	5.9	6.1	3%
	10	8.9	8.5	-4%
	1	14.4	15.0	4%
	0.1	23.4	23.2	-1%
LEE_124	50	5.9	6.3	7%
	10	8.9	8.4	-6%

TRALEE FLOOD RELIEF SCHEME			HYDRAULICS REPORT	
	1	14.4	15.1	5%
	0.1	23.4	24.3	4%
LEE_125	50	6.7	7.1	6%
	10	10.1	10.4	3%
	1	16.2	17.9	10%
	0.1	26.4	24.6	-7%

To demonstrate anchoring of the hydraulic model to the design flow estimation it is important that modelled flows at check points are either within tolerances or where there is a hydraulic reason for the discrepancy, this is explained. Where the hydraulic model flow and hydrological estimation are within 10% of each other it is considered that modelled flows are anchored within tolerances unless the check point HEP represents a flood flow gauging station where much lower (tighter) tolerances are required. The most important return period for anchoring of the hydrology, especially at gauging stations, is the 50% AEP. This is an event that occurs often and is therefore well-documented when compared with lower probability events. Those HEPs which have matched for all four return periods are listed below.

- LEE_02, LEE_03, LEE_06, LEE_08, LEE_18, LEE_19, LEE_22, LEE_31, LEE_32, LEE_35, LEE_49, LEE_51, LEE_52, LEE_55, LEE_66, LEE_68, LEE_69, LEE_70, LEE_74, LEE_81, LEE_82, LEE_86, LEE_96, LEE_99, LEE_102, LEE_105, LEE_118, LEE_119, LEE_123, LEE_124 and LEE_125.

Those HEPs which are not anchored to all four return periods are listed below with an explanation as to why this has not been possible.

- LEE_05 – This HEP is not anchored to the hydrology for any of the return periods. This is due to a large flow path from the River Lee that significantly increases the peak flow in the Manor East watercourse. The flow expected down the Manor East watercourse is very small compared with the River Lee flows which leads to these flows being significantly out.
- LEE_09 – This HEP is not anchored to the hydrology for any of the events. The reason for this is the N22 bypass channel located upstream of this HEP. This bypass channel takes approximately 50% of the flow away from the HEP meaning the peak flow is always lower.
- LEE_12 – This HEP is not anchored to the hydrology for any of the events. The reason for this is the N22 bypass channel located upstream of this HEP. This bypass channel takes approximately 50% of the flow away from the HEP meaning the peak flow is always lower.

TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

- LEE_14, LEE_15, LEE_16, LEE_20 and LEE_21 – These HEPs are not anchored to any of the four events. The reason for this is the additional flow coming down the diversion culvert from the Big River and the N22 bypass which increases the flow throughout the Rathass/Ballinorig watercourses. For example, during the 50% AEP event this diversion culvert conveys a peak flow of 6m³/s. Without this additional flow the HEPs would be much better matched.
- LEE_29 - This HEP is anchored to the 50%, 10% and 1% AEP events, however, it is not anchored to the 0.1% AEP event. The reason for this is floodplain attenuation upstream and around this node. As the event becomes larger the more floodplain attenuation occurs. This leads to the 0.1% event falling just outside the criteria to be considered anchored.
- LEE_33 – This HEP is anchored to the 10%, 1% and 0.1% AEP events but not to the 50% AEP event. The reason for this is floodplain attenuation at the upstream side of the bridge where the flooding cannot get across a road. This HEP is located just downstream of the bridge at the other side of this road. The HEP is then anchored to the 10%, 1% and 0.1% AEPs because during these larger events flooding can get across the road. Therefore, this flow contributes to the peak flow rather than being stored.
- LEE_36 - This HEP is not anchored to any of the four events. The reason for this is floodplain attenuation and flow paths that bypass this HEP. There is significant out of bank flooding from the Caherweesheen watercourse upstream which floods the adjacent fields and reduces the overall peak at the HEP.
- LEE_37 - This HEP is not anchored to any of the four events. The reason for this is floodplain attenuation and flow paths that bypass this HEP. There is significant out of bank flooding from the Caherweesheen and Cloghers watercourses upstream which floods the adjacent fields and reduces the overall peak at the HEP.
- LEE_38 - This HEP is not anchored to any of the four events. The reason for this is floodplain attenuation and flow paths that bypass this HEP. There is significant out of bank flooding from the Caherweesheen and Cloghers watercourses upstream which floods the adjacent fields and reduces the overall peak at the HEP.
- LEE_39 - This HEP is anchored to the 50%, 10% and 1% AEP events, however, it is not anchored to the 0.1% AEP event. The reason for this is floodplain attenuation upstream and around this node. As the event becomes larger the more floodplain attenuation occurs. This leads to the 0.1% event falling just outside the criteria to be considered anchored.
- LEE_45 - This HEP is only anchored to the 50% and 10% AEP events. The reason for this is floodplain attenuation upstream and around this node. As the event becomes larger the more floodplain attenuation occurs.
- LEE_47 - This HEP is only anchored to the 50% and 10% AEP events. The reason for this is floodplain attenuation from the River Lee upstream and around this node. As the event becomes larger the more floodplain attenuation occurs.

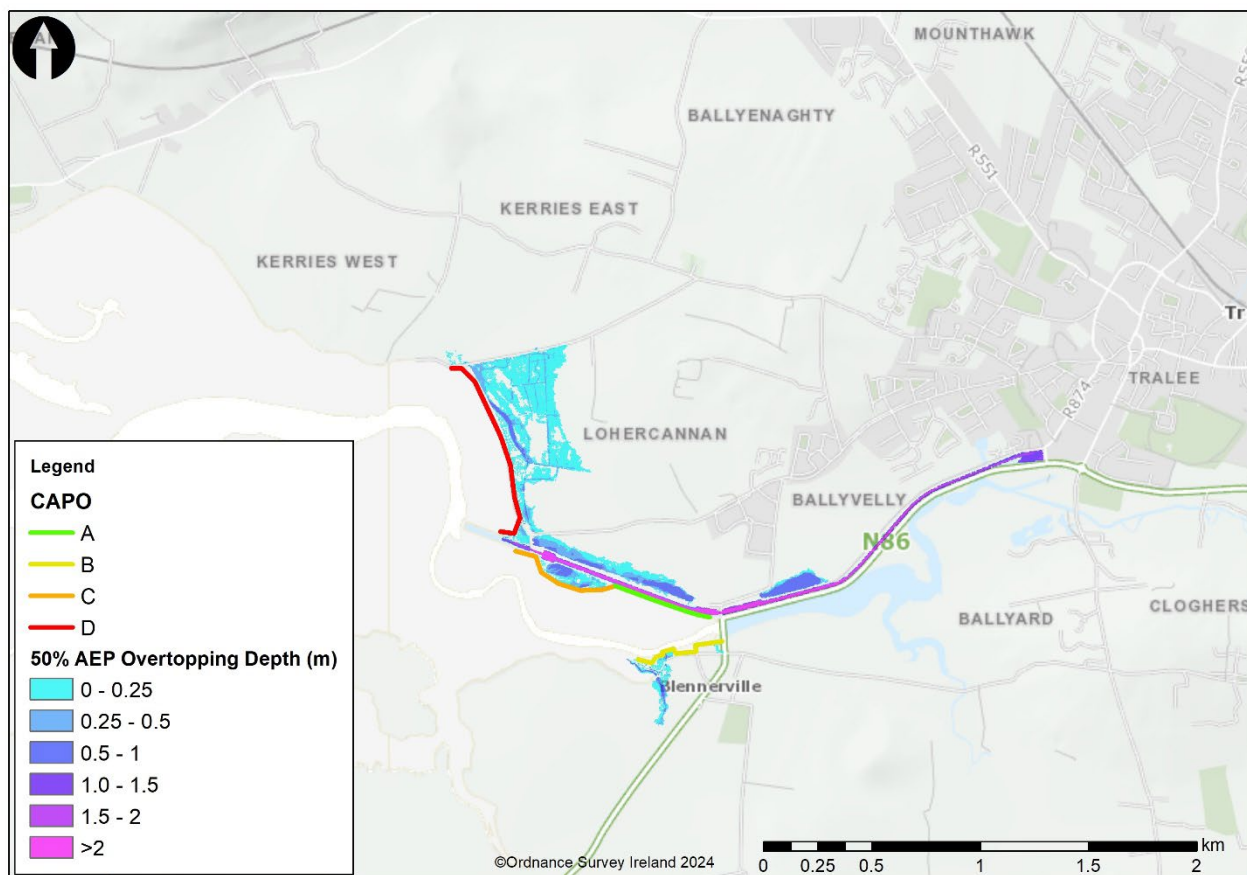
TRALEE FLOOD RELIEF SCHEME**HYDRAULICS REPORT**

- LEE_56, LEE_59 and LEE_61 - These HEPs are not anchored to any of the four events. The reason for this is the diversion culvert that takes flow from the Big River to the Rathass watercourse. This decreases the flow by approximately 6m³/s in the 50% AEP. If that was added to the HEPs for this event then it would be matched more closely.
- LEE_63 - This HEP is not anchored to any of the four events. The reason for this is the diversion culvert that takes flow from the Big River to the Rathass watercourse. Additionally, during the larger return periods there is significant out of bank flooding with several flow paths that bypass this HEP.
- LEE_64 - This HEP is not anchored to any of the four events. The reason for this is the diversion culvert that takes flow from the Big River to the Rathass watercourse. Additionally, during the larger return periods there is significant out of bank flooding with a number of flow paths that bypass this HEP. It is difficult to determine which flow paths are only related to the Big River as there is also significant flooding out of the Balloonagh River which overlaps this flooding throughout the town.
- LEE_71 and LEE_72 - These HEPs are not anchored to any of the four events. The reason for this is the diversion culvert that takes flow from the Balloonagh River to the Big River. During the 50% AEP event this diversion takes approximately 1.3m³/s of flow away from the watercourse. If this was added to the HEP then this would be closer matched.
- LEE_75, LEE_76, LEE_77 and LEE_78 - These HEPs are not anchored to any of the four events. The reason for this is the diversion culvert that takes flow from the Balloonagh River to the Big River. During the 50% AEP event this diversion takes approximately 1.3m³/s of flow away from the watercourse. If this was added to the HEP then this would be closer matched. Furthermore, during the larger return periods there are significant flow paths which bypass these HEPs. It is difficult to determine which flow paths belong to the Balloonagh River due to the Big River also flooding out and overlapping.
- LEE_79 - This HEP is anchored to the 50%, 10% and 1% AEP events, however, it is not anchored to the 0.1% AEP event. The reason for this is floodplain attenuation upstream of this node.
- LEE_84 – This HEP is not anchored for any of the events. This is due to a significant flow path upstream that bypasses the HEP and reduces the peak flow.
- LEE_85 – This HEP is not anchored for any of the events. This is due to a significant flow path upstream that bypasses the HEP and reduces the peak flow.
- LEE_87 - This HEP is not anchored for any of the events. This is due to attenuation in the fields upstream of this HEP.
- LEE_89 - This HEP is anchored to the 50% and 10% AEP events. The reason for this is flooding out of the channel for the other events that bypasses the HEP and makes its way into the Ballyvelly watercourse.

TRALEE FLOOD RELIEF SCHEME**HYDRAULICS REPORT**

- LEE_90 - This HEP is anchored to the 50%, 10% and 1% AEP events. The reason for this is flooding out of the channel for the 0.1% AEP event that bypasses the HEP and makes its way into the Ballyvelly watercourse.
- LEE_91, LEE_92 and LEE_93 - These HEPs are not anchored to any of the events. The reason for this is significant floodplain attenuation upstream of HEP_87 along the Ballyvelly watercourse. There is also an impact of the tidal levels on the LEE_93 which causes it to have negative peak flows for some of the events.
- LEE_94 - This HEP is only anchored to the 50% and 10% AEP events. The reason for this is the significant amount of floodplain attenuation upstream of this HEP along the River Lee and a number of its tributaries in the larger return period events.
- LEE_98 - This HEP not anchored to any of the four events. The reason for this is additional flow coming from the adjacent watercourse which enters this watercourse and increases the peak flow.
- LEE_103 - This HEP not anchored to any of the four events. The reason for this is additional flow coming from the adjacent watercourse which enters this watercourse and increases the peak flow.
- LEE_108 - This HEP is anchored to the 50%, 10% and 1% AEP events. The reason this HEP being slightly out for the 0.1% AEP is due to a flowpath that takes flooding out and into the channel to the north.
- LEE_110 and LEE_111 - These HEPs are not anchored to any of the four events. The reason for this is that a large flow path comes out of the right bank of the Lohercannon watercourse and travels towards the Farrenstephen watercourse. Therefore, this flow never makes it to the HEP.
- LEE_113 and LEE_114 - These HEPs are anchored to the 50% and 10% AEP events, however, they are not anchored to the 1% and 0.1% AEP events. The reason for this is a large flow path that occurs further upstream and flows through adjacent fields rather than passing the HEPS.
- LEE_115 – This HEP is not anchored to any of the events. The reason for this is flooding out of the Pinure watercourse travels west and increases the peak flow in this watercourse for all the events.
- LEE_120 and LEE_122 - These HEPs are not anchored to any of the four events. The reason for this is that a flow path that comes out of the right bank and enters the adjacent watercourse rather than flowing past these HEPS.

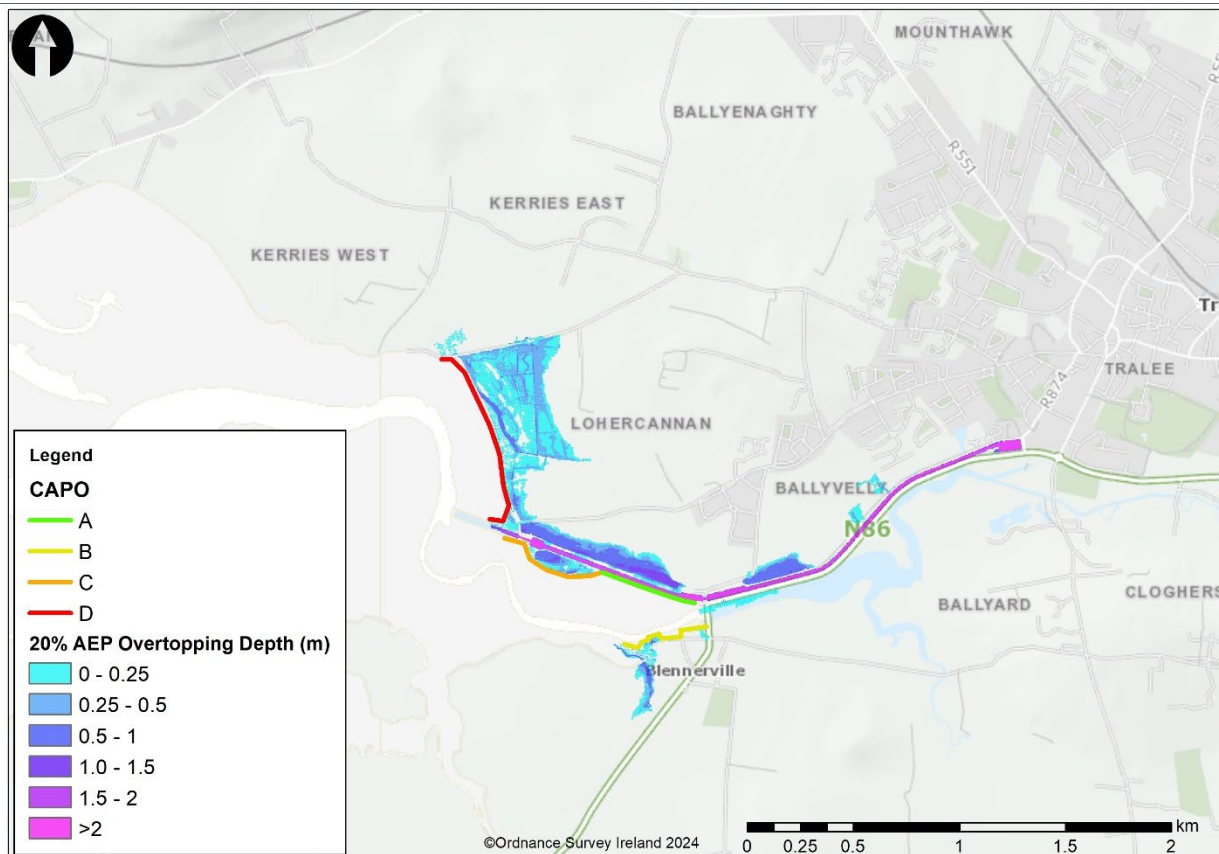
Appendix C – Overtopping Depth Figures



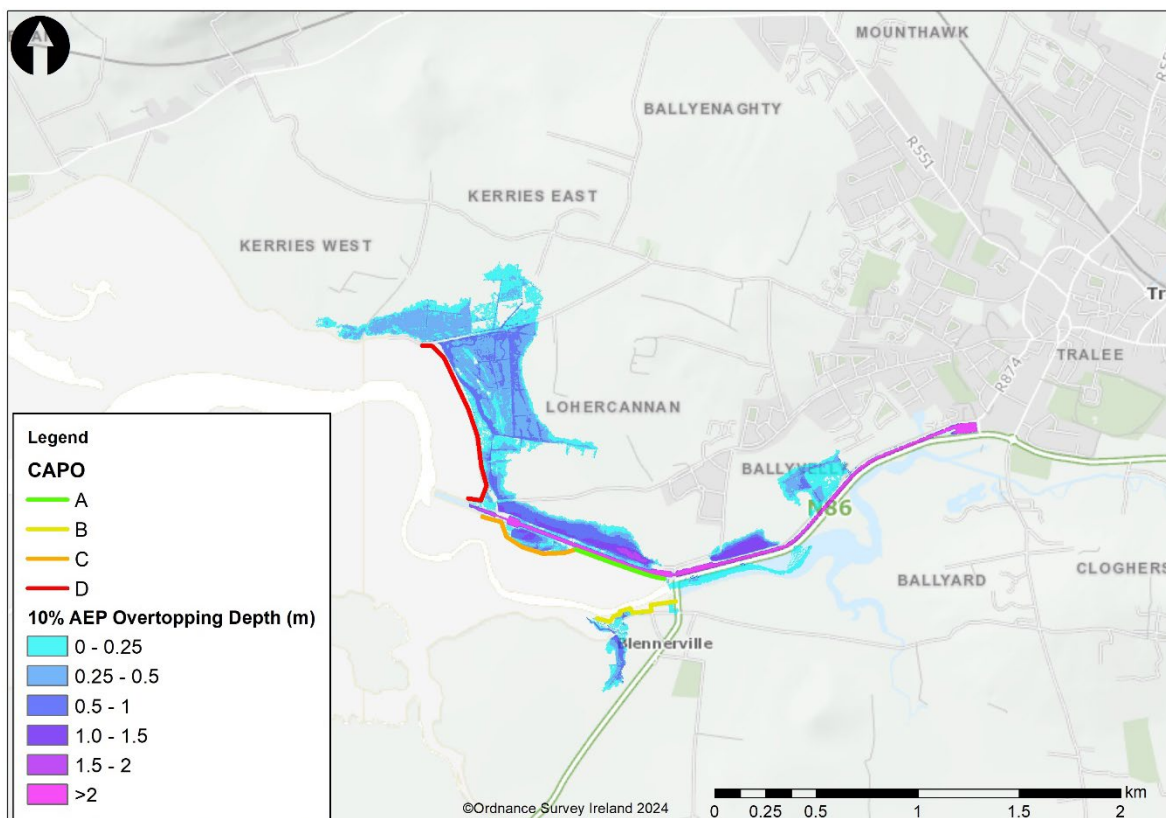
Appendix C – Figure 1 – 50% AEP Overtopping Depth

TRALEE FLOOD RELIEF SCHEME

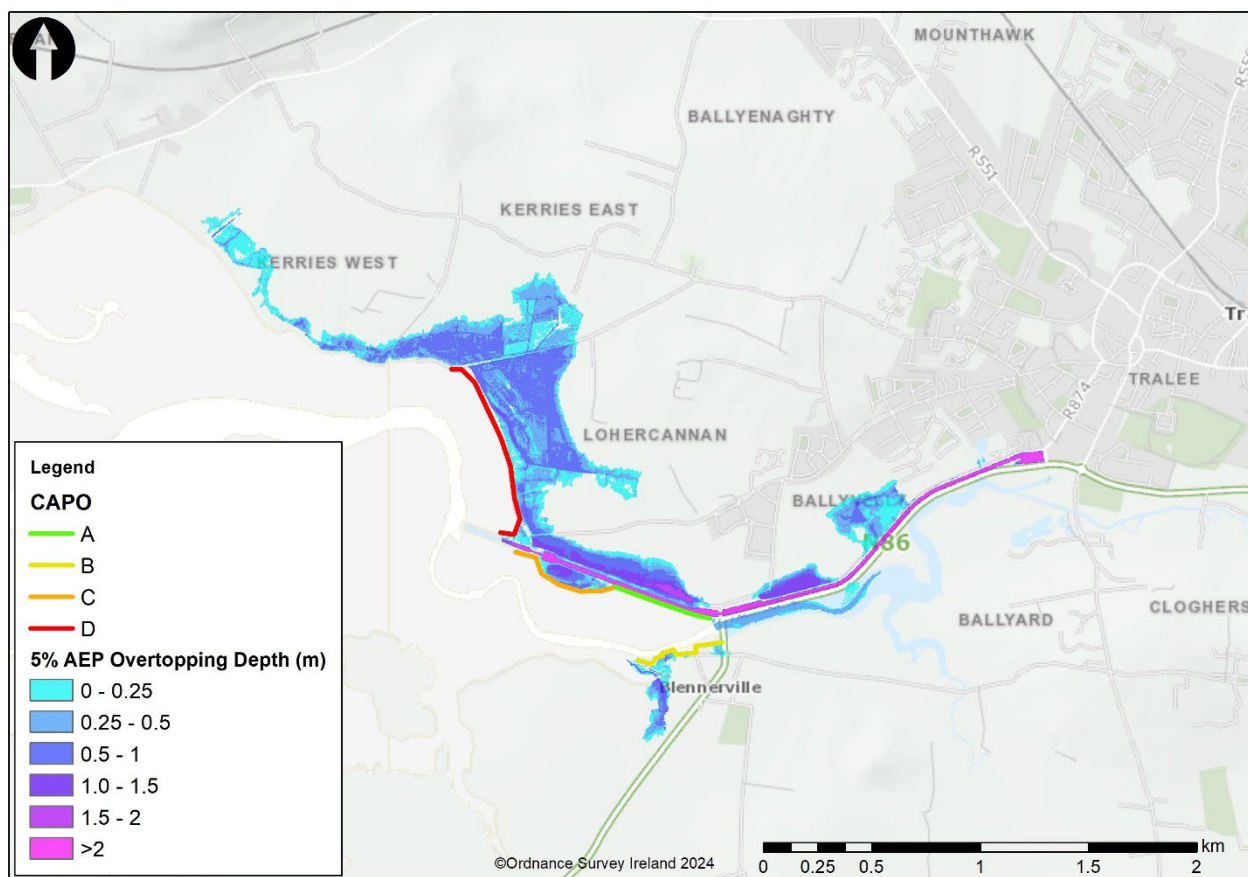
HYDRAULICS REPORT



Appendix C – Figure 2 – 20% AEP Overtopping Depth



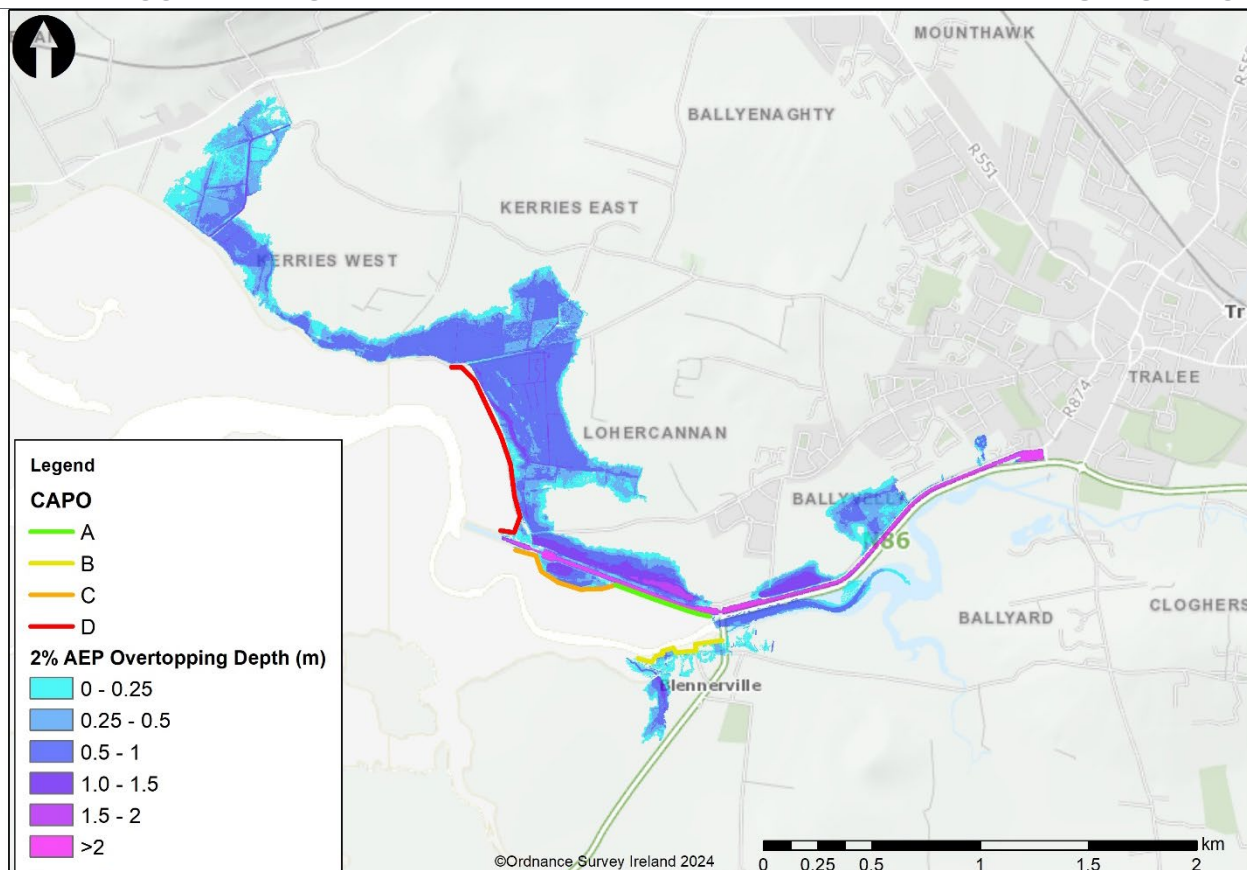
Appendix C – Figure 3 – 10% AEP Overtopping Depth



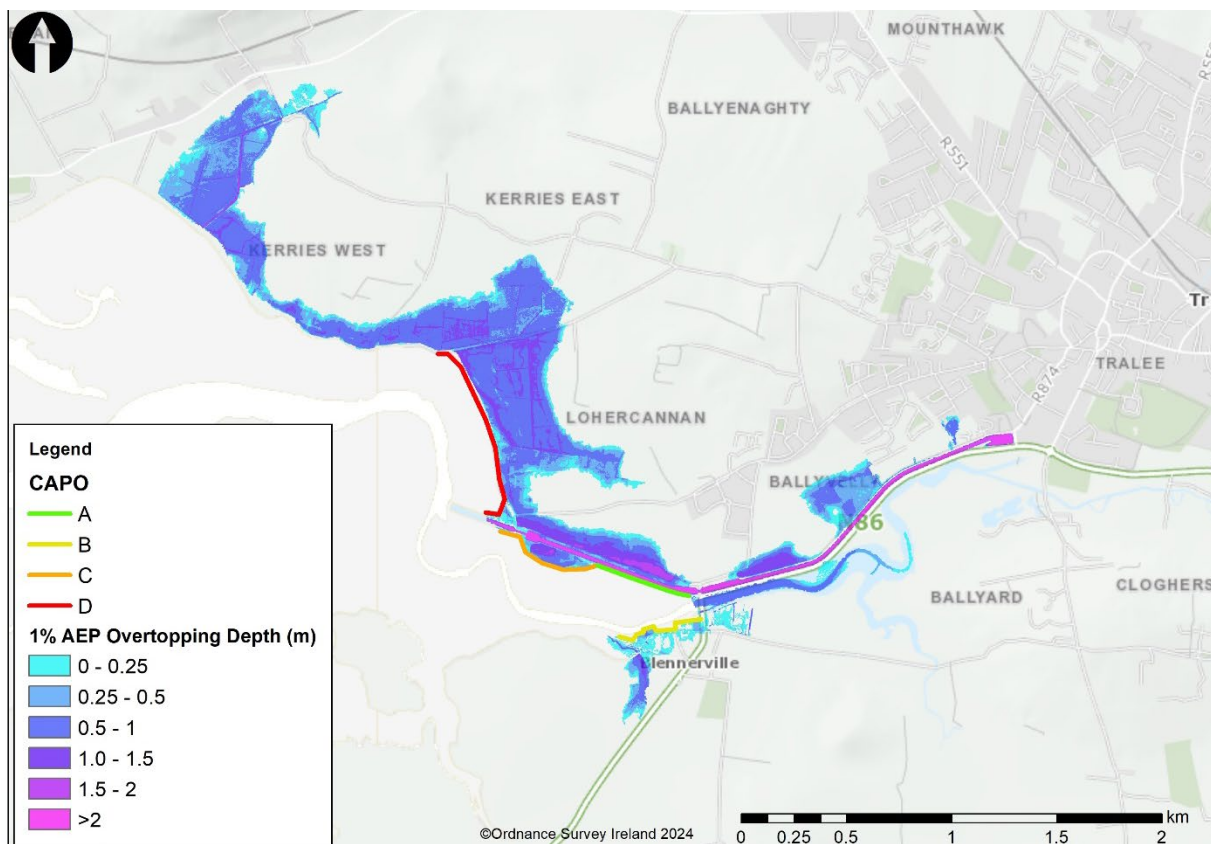
Appendix C – Figure 4 – 5% AEP Overtopping Depth

TRALEE FLOOD RELIEF SCHEME

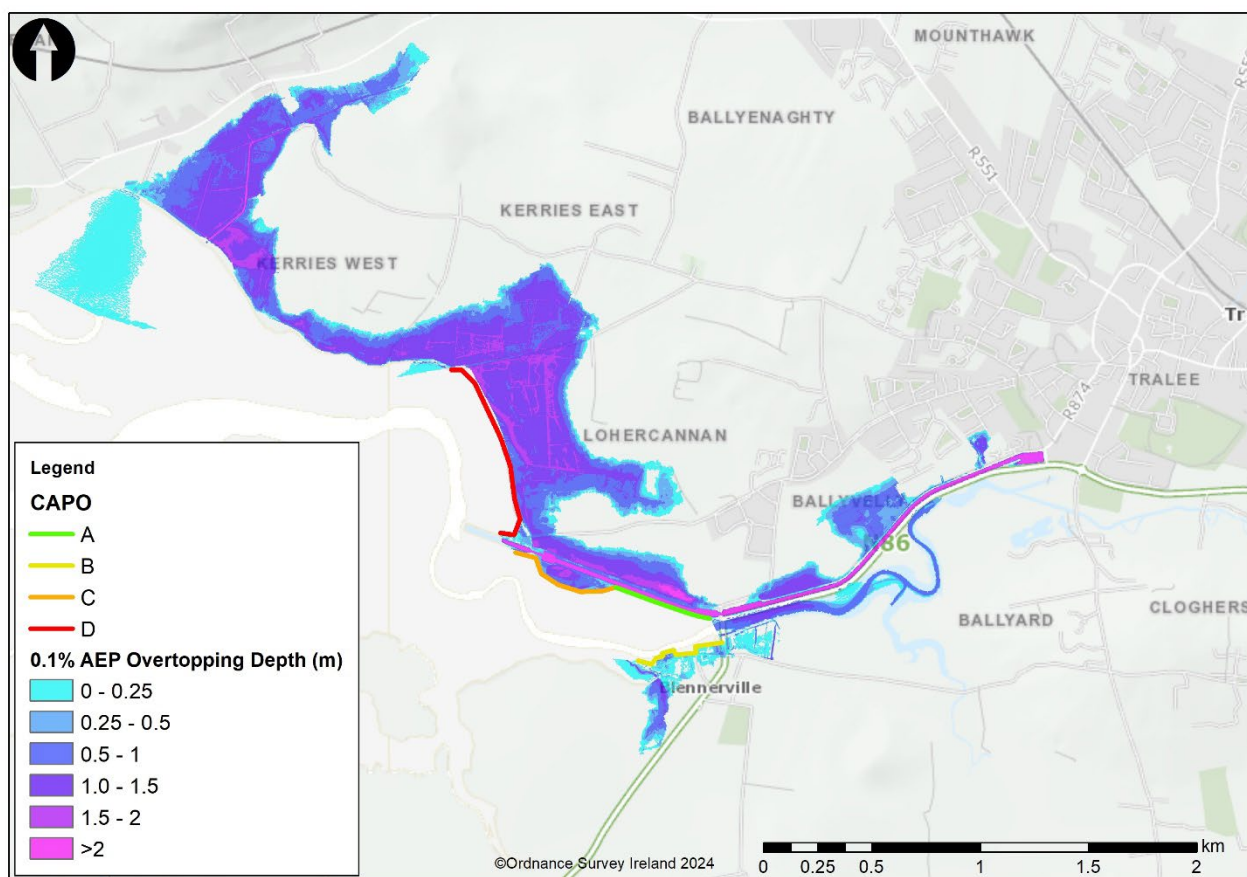
HYDRAULICS REPORT



Appendix C – Figure 5 – 2% AEP Overtopping Depth



Appendix C – Figure 6 – 1% AEP Overtopping Depth



Appendix C – Figure 7 – 0.1% AEP Overtopping Depth

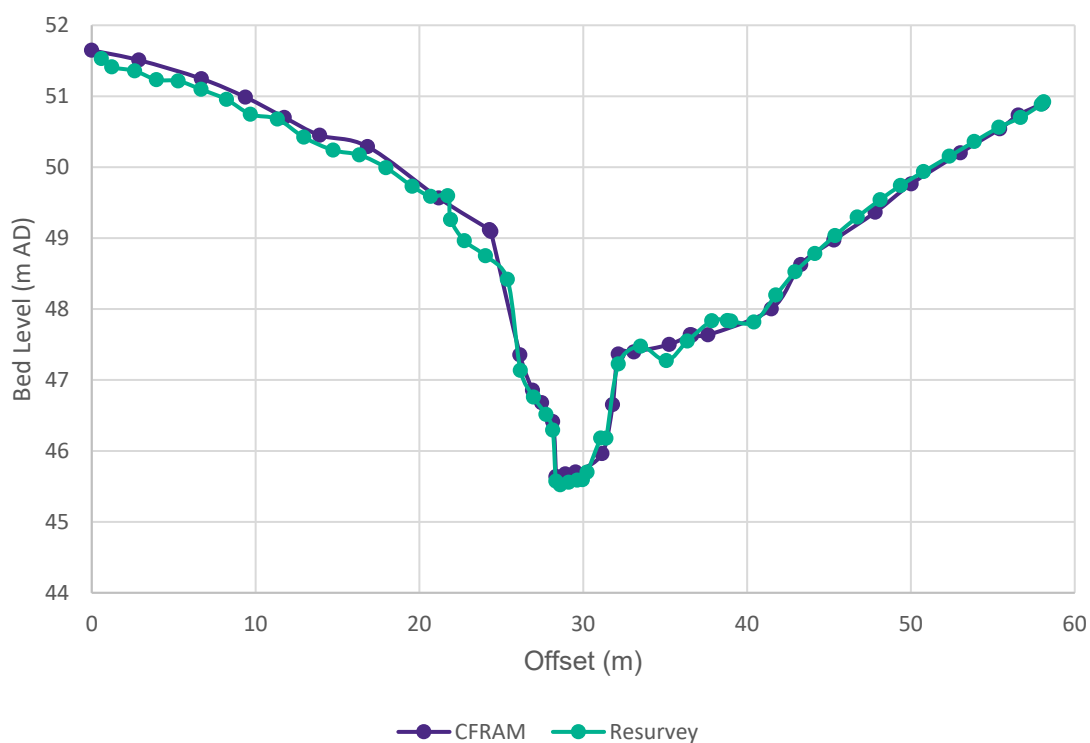
All cross sections compared between CFRAMS and the Tralee FRS are shown below.



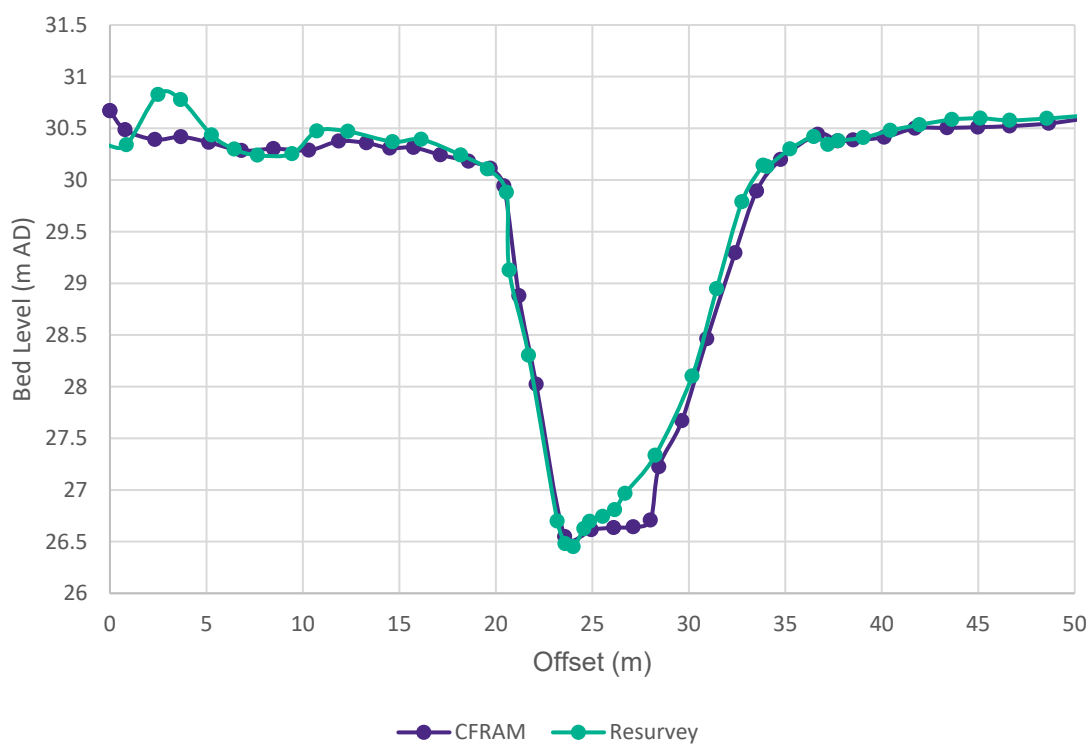
TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT

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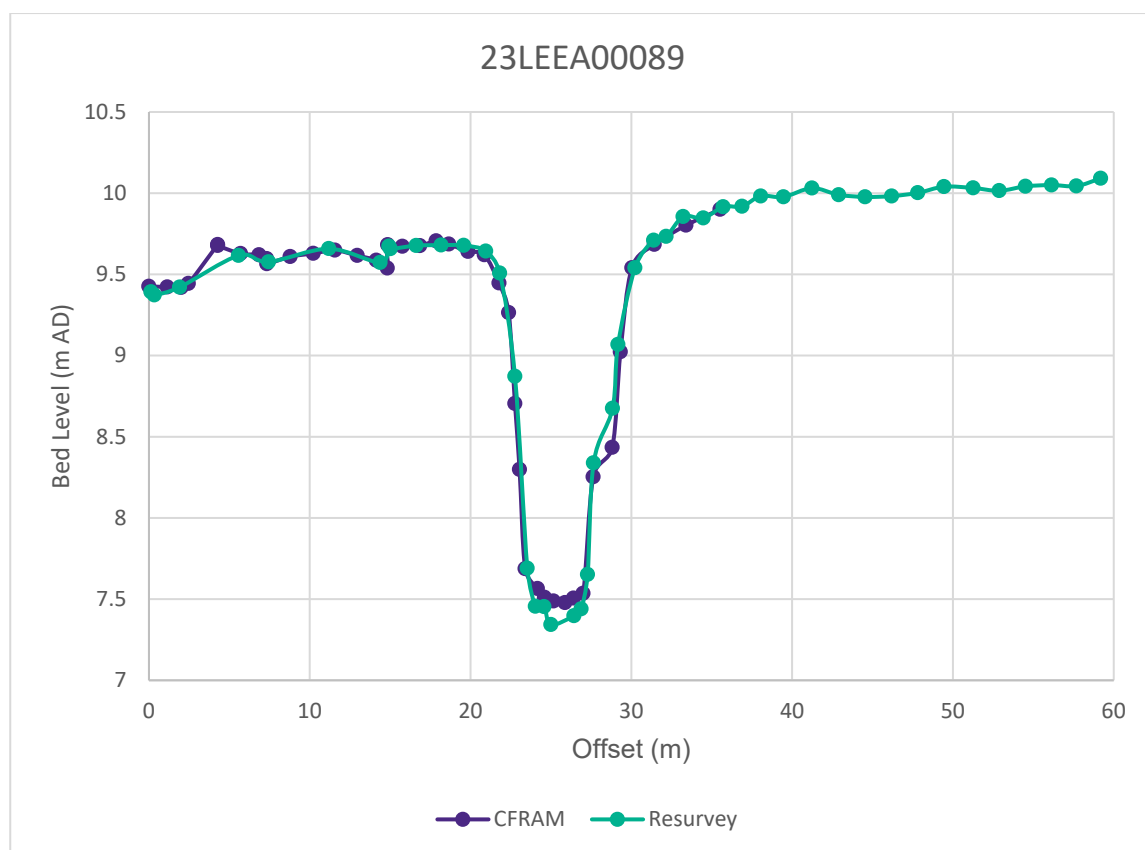
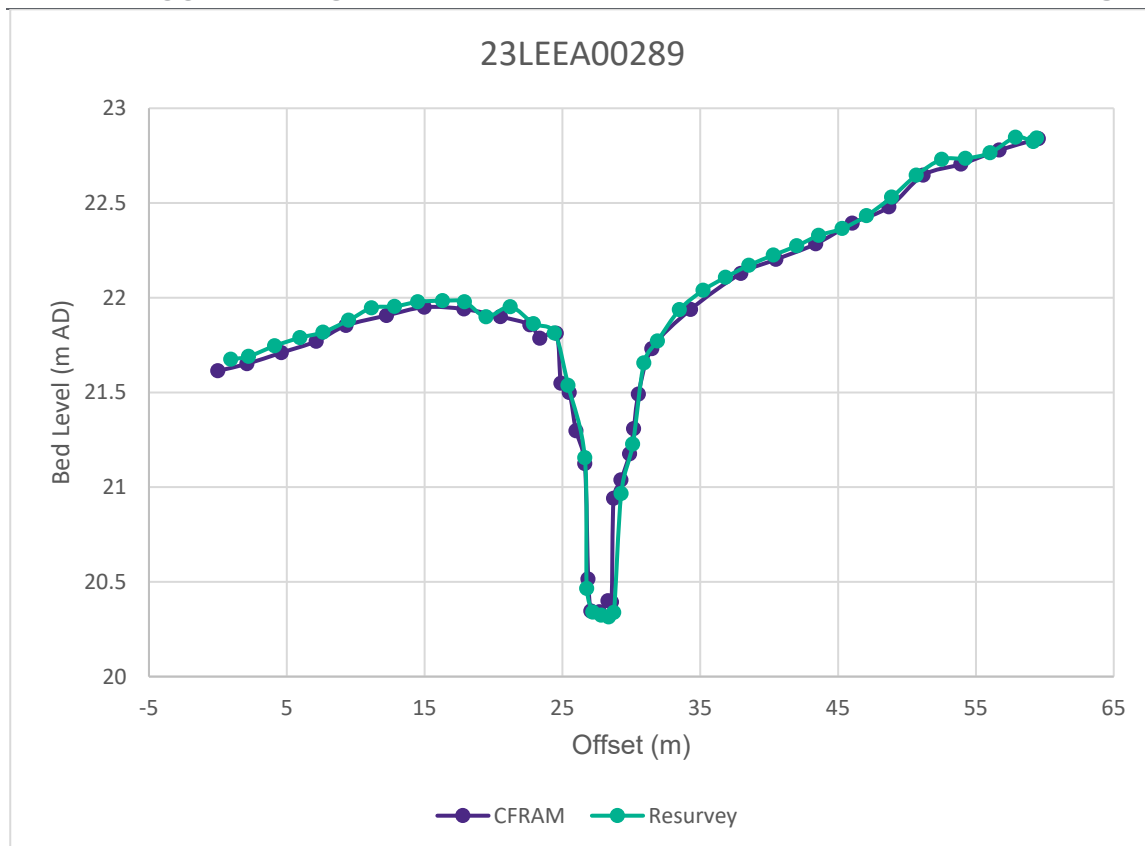


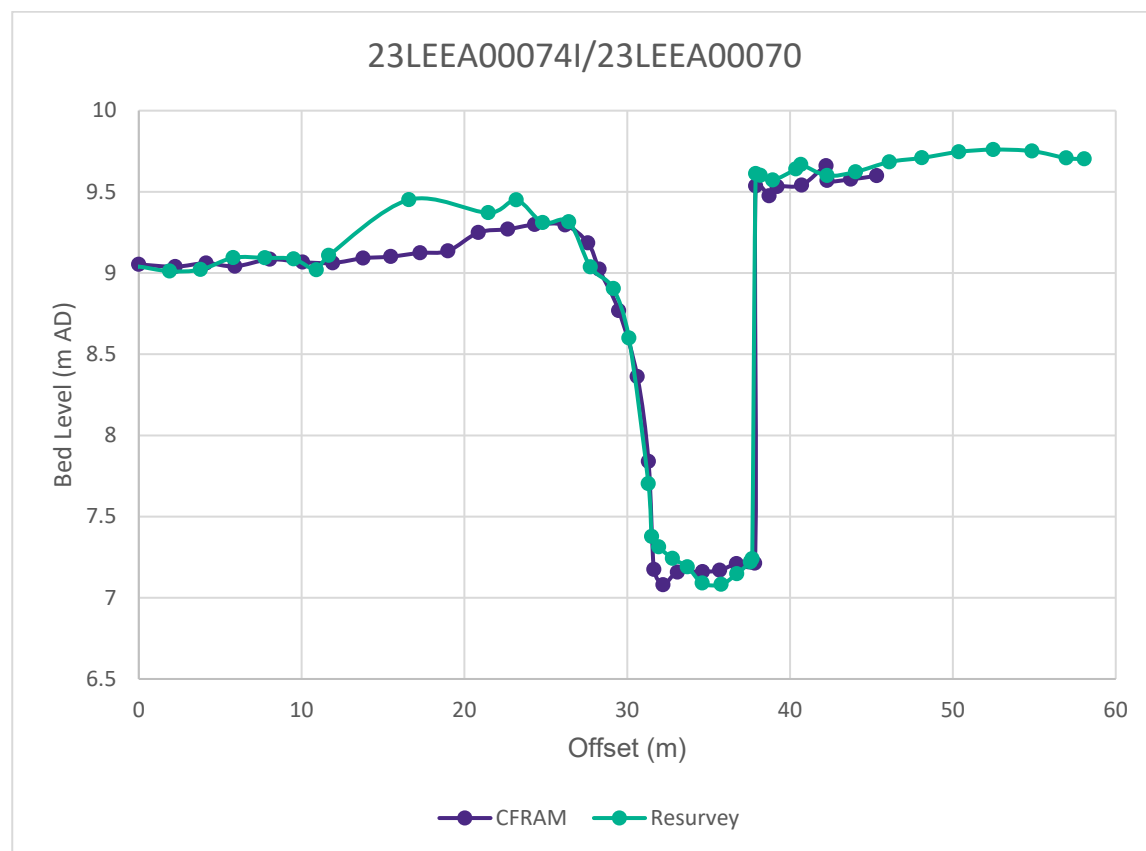
23BIGR00323



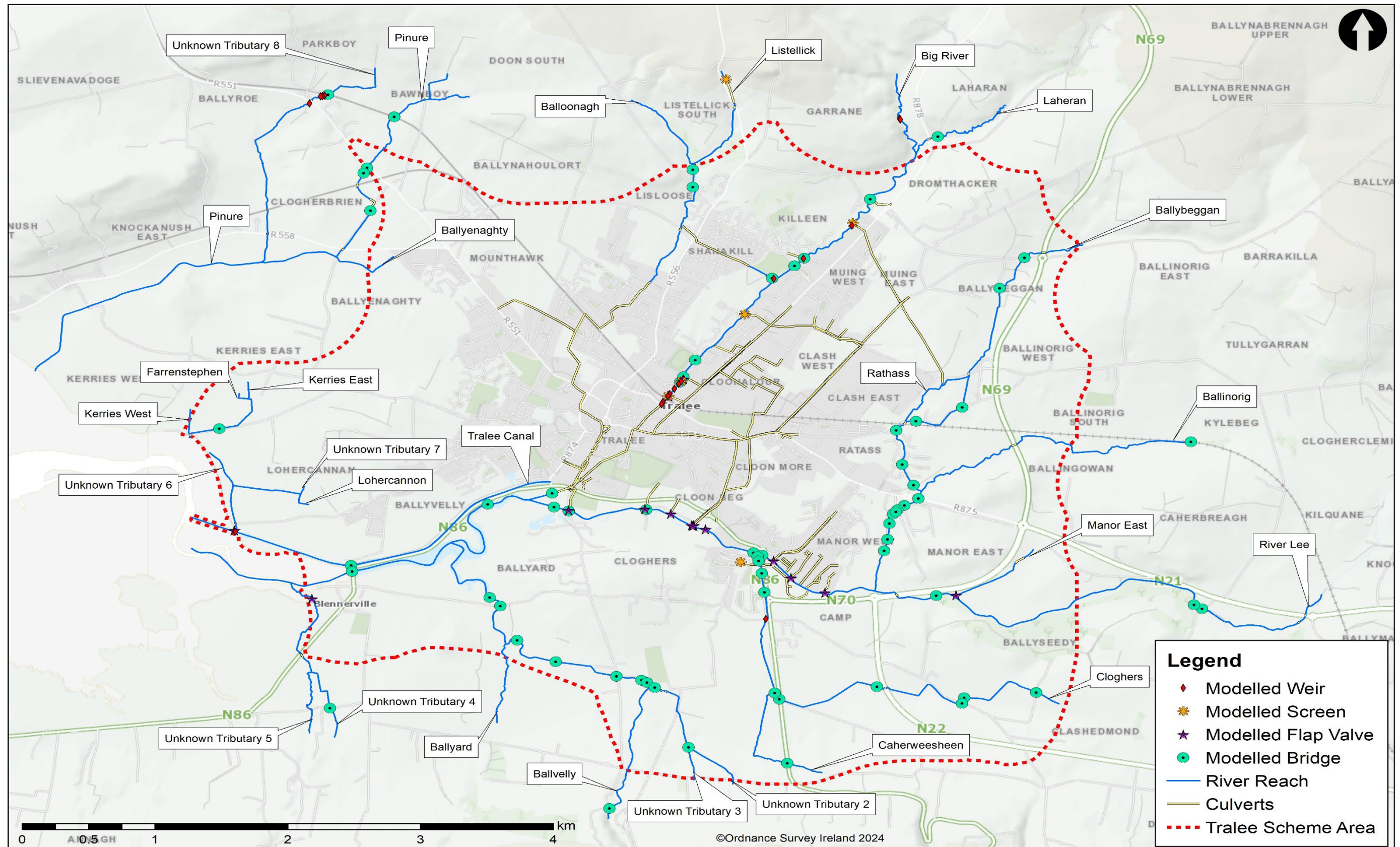
TRALEE FLOOD RELIEF SCHEME

HYDRAULICS REPORT





Appendix E - Location of Modelled Structures



Appendix F – Coastal Flood Extent Maps

The flood extent and depth mapping contained in these appendices have been produced as per the Joint Probability Analysis undertaken in Section 7 of the Tralee Flood Relief Scheme Hydrology report with existing flood defences structures included as per Section 3.1.4.4 of this report.

- 0.1% AEP Coastal Extent
- 0.5% AEP Coastal Extent
- 1% AEP Coastal Extent
- 2% AEP Coastal Extent
- 5% AEP Coastal Extent
- 10% AEP Coastal Extent
- 20% AEP Coastal Extent
- 50% AEP Coastal Extent
- Tralee Current Coastal Flood Extents

Appendix G– Fluvial Flood Extent Maps

The flood extent and depth mapping contained in these appendices have been produced as per the Joint Probability Analysis undertaken in Section 7 of the Tralee Flood Relief Scheme Hydrology report with existing flood defences structures included as per Section 3.1.4.4 of this report.

- 0.1% AEP Fluvial Extent
- 0.5% AEP Fluvial Extent
- 1% AEP Fluvial Extent
- 2% AEP Fluvial Extent
- 5% AEP Fluvial Extent
- 10% AEP Fluvial Extent
- 20% AEP Fluvial Extent
- 50% AEP Fluvial Extent
- Tralee Current Fluvial Flood Extents

Appendix H – Coastal Flood Depth Maps

The flood extent and depth mapping contained in these appendices have been produced as per the Joint Probability Analysis undertaken in Section 7 of the Tralee Flood Relief Scheme Hydrology report with existing flood defences structures included as per Section 3.1.4.4 of this report.

- 0.1% AEP Coastal Depth
- 0.5% AEP Coastal Depth
- 1% AEP Coastal Depth
- 2% AEP Coastal Depth
- 5% AEP Coastal Depth
- 10% AEP Coastal Depth
- 20% AEP Coastal Depth
- 50% AEP Coastal Depth

Appendix I– Fluvial Flood Depth Maps

The flood extent and depth mapping contained in these appendices have been produced as per the Joint Probability Analysis undertaken in Section 7 of the Tralee Flood Relief Scheme Hydrology report with existing flood defences structures included as per Section 3.1.4.4 of this report.

- 0.1% AEP Fluvial Depth
- 0.5% AEP Fluvial Depth
- 1% AEP Fluvial Depth
- 2% AEP Fluvial Depth
- 5% AEP Fluvial Depth
- 10% AEP Fluvial Depth
- 20% AEP Fluvial Depth
- 50% AEP Fluvial Depth

Appendix J– Flood Zone Mapping

- Flood Zones Baseline Extents
- Flood Zones Extents + 20% AEP Pluvial
- Flood Zones Extents No Pluvial