A5 Western Transport Corridor

Flood Risk Assessment Report 2

Hydraulic Model Build Report

A5 Western Transport Corridor

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July 2016

Produced for

Prepared by

Project Office:
Shorefield House
30 Kinnegar Drive
Holywood
County Down
Northern Ireland
BT18 9JQ

T 028 9042 4117
F 028 9042 7039

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Executive Summary

Introduction

This report is Part Two of the A5 Western Transport Corridor (A5 WTC) Flood Risk Assessment (FRA) Report and provides a summary of the hydraulic models developed to facilitate detailed flooding assessments for the Proposed Scheme. This report summarises the development of hydraulic models, software utilised, key parameters, hydrology, model results and model validation.

Additional information pertaining to route development and route selection of the Proposed Scheme is available on the A5 WTC website (www.a5wtc.com) in the form of the Preliminary Options Report and Preferred Options Report.

Route Development

A5 WTC Preferred Route

The selection of a Preferred Route has involved the assessment of a number of alternative Route Options; information pertaining to these assessments is contained within the *Preferred Options Report - Scheme Assessment Report 2* available on the A5 WTC website. The executive summary is within the A5WTC *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment*.

In July 2009 the A5 WTC Preferred Route was announced to the public. A description of the Preferred Route along with drawings providing an overview of this route can be seen in *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment*.

A5 WTC Route Development Overview

Since the announcement of the Preferred Route, the route has been developed and some amendments have been implemented. As a result of this, the alignment has changed both horizontally and vertically at a number of locations.

Details of the various changes to the Preferred Route alignment can be seen in the *Preferred Options Report*, *Alternatives Discussion Report* and *Report on the Choice of Route for the A5 WTC at Ballymagorry* (http://www.a5wtc.com/).

A5 WTC Proposed Scheme

Over a number of years, the A5 WTC has progressed through a number of stages which are detailed in *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment*.

Drawings 718736-0500-D-00184 to 718736-0500-D-00193 in Appendix A of this report provide a detailed overview of the Proposed Scheme.

Reviewed Flood Model Requirements

Due to changes to the horizontal alignment through the various stages of route development, some of the flood models outlined in *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment* are no longer required. A summary of these flood models can be seen in the following table.

Summary of Watercourses No Longer Required for A5 WTC Flood Risk Assessment

Section	Watercourse	Hydraulic Model ID
3	Ranelly Creamery Drain	M.K
	Ranelly Drain	M.J

The remaining models detailed in FRA Report 1 have been developed and information pertaining to these models can be seen within this report. The following table provides a summary of the floodplains that are impacted by the A5 WTC Proposed Scheme:

Summary of Watercourses Required for A5 WTC Flood Risk Assessment

Section	Watercourse	Hydraulic Model ID
1	Gortin Hall Drain	M.A
	Blackstone Burn	M.B
	River Foyle, River Finn, Mourne River, Deele River, Swilly Burn, Glenmornan & Burndennet Rivers	M.1, M.2 and M.3
2	Ranelly Drain	M.L
	Undesignated	M.D
	River Derg	M.5
	Coolaghy Burn	M.E
	Back Burn	M.F
	Undesignated	M.G
	Tully Drain	M.H
	Omagh (including Fairy Water, Aghnamoyle Drain, Coneywarren Drain, and Tully Drain and Strule River)	M.4
	Fireagh Lough Drain	M.I
	Drumragh River	M.6

Summary of Watercourses Required for A5 WTC Flood Risk Assessment

Section	Watercourse	Hydraulic Model ID
3	Letfern Watercourse	M.M
	Undesignated Watercourse	M.N
	Undesignated Watercourse	M.O
	Routing Burn	M.P, M.Q
	Undesignated Watercourse (Newtownsaville)	M.R
	Undesignated Watercourse (Kilgreen)	M.S
	Roughan River	M.T
	Ballygawley River	M.U
	Tullyvar	M.V
	Ravella	M.W
	Undesignated	M.X
	Lisadavil	M.Y

Detailed Hydraulic Modelling Extents

Site inspections of all proposed modelling locations were undertaken to confirm the location and nature of the various watercourses, gain an appreciation of catchment characteristics (steepness, land use, etc), confirm model extents and determine the appropriate channel and floodplain roughness (Manning's n) coefficients to be applied in the hydraulic models.

A specification for the topographical survey was developed after the site visits; this included detailing model cross sections and any hydraulic control structures to be surveyed (bridges, culverts, etc).

Generally, model extents were determined in consideration of the following factors:

- The floodplain extents identified in the preliminary floodplain assessments,
- The downstream boundary was located sufficiently far downstream as not to significantly influence conditions at the location of interest,
- The upstream boundary was located to ensure that any significant impacts propagating upstream (backwater effects) were noted, and
- In some locations model extents included nearby gauges to aid model calibration.

With regards to the choice of 1D or 2D models, in areas where extensive and complex floodplains were anticipated, 2D models were developed. Within 2D models LiDAR data has been typically used to define the ground topography of large floodplain areas.

Model Data Collection

Flood Risk Assessment Report 1 – *Assessment Parameters and Preliminary Flood Risk Assessment* provides details of all data collected pre hydraulic model development stage. This was used to identify likely sources of flooding and determine flood risk assessment requirements, this information included:

- Consultations with statutory bodies including Rivers Agency, Transport NI (formally Roads Service), NI Water, Loughs Agency and Londonderry/Derry Port and Harbour Commissioners,
- Field work assessments,
- Historical flooding data,
- Drift geology mapping,
- Detailed aerial surveys
- Existing flood risk assessments / models.

FRA Report 1 provides details of preliminary flood plain identification; information / data collated during that assessment has been used to define hydraulic modelling requirements.

Specific information in relation to the collation of watercourse cross-sectional data, survey of model structures (bridges, culverts, flap valves, etc) and miscellaneous information pertaining to hydraulic models is contained within this report.

Survey Methods and Equipment

Watercourse cross sections and structures for flood modelling were surveyed primarily using a combination of Global Position System (GPS) and Total Station, with control being provided by GPS. Manual measurements using tapes and staffs were also undertaken to record dimensions of structures. With regards to deeper stretches of water; depths were recorded using an Acoustic Doppler Current Profiler combined with onboard GPS.

Surveyed Detail

Watercourse cross sections and structures were surveyed according to briefs supplied by flood modelling specialists. Site visits were used to establish the optimum survey method for various rivers and site conditions.

Cross sections were surveyed from left to right banks (facing downstream) and perpendicular to the direction on flow; then labelled accordingly. The top and bottom of banks of the channel at each cross section were surveyed carefully to reflect the general nature of the watercourse.

All significant features across the flood plain and main channels were surveyed. Relevant structures along the watercourse, such as bridges or culverts, were surveyed in detail.

Data Processing

Completed surveys were downloaded from the instruments and processed where necessary using appropriate software. Data was also exported to Mapinfo GIS software to check content and quality.

Data was delivered to flood modelling teams in the requested format with accompanying drawings, sketches and photographs to illustrate structures. MapInfo tables were also provided showing all topographical information gathered on site.

Specification and Accuracy

Surveys were completed to within acceptable levels of accuracies; representing site conditions as faithfully as possible. Good survey practice was followed when recording detail and establishing control. Redundancy of data was maintained where possible and tie points were surveyed with GPS to confirm reliability of data. Real time quality control measures, such as a cut off mask, coupled with extended observation times were used to improve the relative accuracy of surveyed points.

Co-ordinate and Reference System

Data was translated as necessary between global and local datums. All survey points were ultimately referenced in Irish Grid to Ordnance Datum Belfast Lough.

LiDAR Data

DTM/LiDAR data typically supplements surveyed data in floodplain areas and is typically used for flood mapping purposes. It is also used where floodplains are modelled in 2D, as the key component of any 2D model is a detailed 3D ground model.

DTM / LiDAR data was gathered from a number of sources to cover the areas of interest and levels of accuracy may vary between individual datasets.

Hydrological Assessments

Hydrological assessments were undertaken based primarily on Flood Estimation Handbook (FEH) techniques, OS mapping, and DTM data. The appropriate hydrological catchments for the various modelled watercourses were identified.

The industry standard Flood Estimation Handbook (FEH) provides two main approaches to flood frequency estimation: the statistical analysis of peak flows, and the rainfall-runoff method. Where applicable, a hybrid method may also be used. The methods where utilised as appropriate and more information is available as required.

The hydrological assessments were completed for each identified model. Data is provided in relation to the catchment details, existing hydrological data and design flow estimation.

Model Software and Boundary Conditions

A summary of the model details and the principal boundary conditions used within each of the models is provided.

Model Details

A number of industry standard computer packages were used in the river modelling activities for the A5 WTC study: HEC-RAS (Version 4.0), ISIS (Version 3.6), MIKE FLOOD incorporating MIKE 11 (Version 2014), TUFLOW (Version 2012-05-AE-iSP-w32), InfoWorks RS (Version 11) and Infoworks ICM (Version 5.5).

The following watercourses / floodplains were modelled as 1D-2D coupled models: M.1, M.2 and M.3 – Foyle River System, M.4 - Omagh, M.U – Ballygawley Water, M.V Tullyvar and M.Y – Lisadavil; all other watercourses / floodplains are modelled as 1D.

Model Boundary Conditions

Model boundary conditions are provided in relation to Manning's roughness coefficients, channel descriptions and upstream and downstream boundary conditions. It is noted that determination of Manning roughness coefficients are based on site visits and photographs obtained at time of survey.

Hydraulic Modelling Results

Through detailed hydraulic modelling, flood levels and associated flood extents were determined for the identified model locations.

Modelling also allowed an assessment of the likely effects resulting from the crossing of the watercourses, and floodplains with the proposed road. This information was then used for developing possible flood mitigation measures, and ensuring the design complies with the recommendations set out in the DMRB. Further information on this can be seen in FRA Report 3 – *Impacts and Mitigation Assessment Report*.

Water levels along the watercourses were calculated for a range of return periods for the existing scenario. For the requirements of this report, the 100 year [1% Annual Exceedance Probability (1% AEP)] flood outline for each of the flood models is detailed within this report. For tidal floodplain the 200 year [0.5% AEP] is assessed for tidally dominant scenarios. These are the ‘design’ events for fluvial and tidal floodplain areas.

Model Calibration/Sensitivity Analysis

Model Calibration/Verification

The calibration of a hydraulic model is usually completed using water levels for a recorded event of known peak flow. The model coefficients are then adjusted to obtain a reasonable fit with the recorded data. Where peak flow recorded information existed for a particular model, calibration was undertaken. Where data is anecdotal, sparse or of uncertain quality, this data can also be used to ‘sense check’ or verify results, however, caution needs to be exercised to ensure that model output is not ‘force fitted’ to uncertain data.

Model output was also sense checked against Rivers Agencies strategic flood-mapping, historical flood information and some other anecdotal information including site visits.

Model Sensitivity Testing

In addition to model calibration, and particularly in the absence of reliable calibration data, sensitivity testing was undertaken. Sensitivity testing allows an assessment of model sensitivity to variations in key model parameters.

For each of the models numerous model runs were undertaken with varying boundary conditions to test the sensitivity of the models to parameter variations and ensure consistency and confidence in the numerical results. The key sensitivity tests undertaken for all model were for variations in friction, downstream water levels and flows.

Summary

This flood risk assessment is number two of three reports. This report provides a summary of the proposed model build strategy and design flow estimations for the identified hydraulic models along the Proposed Scheme.

This report also provides information in relation to the model data collection methods through on-site surveying and obtaining LiDAR information. Following the data collection process, boundary conditions such as Manning's 'n' values and channel descriptions were determined and are also provided within this report.

This report provides predicted Q_{100} flood outlines for floodplains along the route of the proposed A5 WTC. Information pertaining to the assessment of impacts arising from the proposed A5 WTC and mitigation proposals can be found in Flood Risk Assessment Report 3 – *Impact and Mitigation Assessment Report*.

1 Introduction

This report is Part Two of the A5 Western Transport Corridor (A5 WTC) Flood Risk Assessment (FRA) Reports and provides a summary of the hydraulic models developed to facilitate detailed flooding assessments for the Proposed Scheme. This report summarises the development of hydraulic models, software utilised, key parameters, hydrology, model results and model validation.

Information relating to flood risk assessment parameters, the study area and the preliminary flood risk assessments is contained in A5 WTC *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment.*

Additional information pertaining to route development and route selection of the Proposed Scheme is available on the A5 WTC website (www.a5wtc.com) in the form of the Preliminary Options Report and Preferred Options Report.

1.1 Flood Model Locations

The locations of the flood models based on the Emerging Preferred Route for the Proposed Scheme are specified in *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment*. Any changes to those locations will be discussed in Section 2.4.

2 Route Development

2.1 A5 WTC Preferred Route

The selection of a Preferred Route has involved the assessment of a number of alternative Route Options; information pertaining to these assessments is contained within the *Preferred Options Report - Scheme Assessment Report 2* available on the A5 WTC website. The executive summary is within the A5WTC *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment*.

In July 2009 the A5 WTC Preferred Route was announced to the public. A description of the Preferred Route along with drawings providing an overview of this route can be seen in *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment*.

2.2 A5 WTC Route Development Overview

Since the announcement of the Preferred Route, the route has been developed and some amendments have been implemented. As a result of this, the alignment has changed both horizontally and vertically at a number of locations. The main changes from Preferred Route to the Proposed Scheme were at the following locations:

- At the beginning of Section 1, the alignment has shifted slightly to the west from the point where Victoria Road meets Woodside Road to the point where the Proposed Route crosses Gortin Hall Drain, keeping to the east of the River Foyle
- Close to Drumgauty, there the road has been re-aligned to the east of Victoria Road, between Donagheady Road and Ash Avenue
- In the proximity of Cloghcor, the alignment has moved horizontally to the east, while remaining on the west side of Victoria Road from the Ballydonaghy Road to Leckpatrick
- From the Greenlaw Road to Spruce Road, the alignment has been re-aligned to the west and traverses Ballymagorry Burn
- At the Mourne River, the alignment is re-aligned slightly to the west, whilst keeping to the east of the River Finn
- From Urney Road to the end of Section 1, the alignment has been re-alighted slightly to the west
- In the vicinity of Clady Blair, the Proposed Route has been re-aligned slightly to the west

- From Upper Deerpark to the Grange Road, the horizontal alignment has been re-aligned slightly south; keeping to the south of Newtownstewart
- The Proposed route has been re-aligned to the east from Gillygooly Road to Botera Road; remaining to the west of Mullaghmena Road
- In the proximity of Beagh, the route has been re-aligned slightly to the east
- From the Seskinore Road to Ranelly the route has been re-aligned to the south of Tattykeel and Doogary Road
- In the vicinity of Tullanafoile the route has been re-aligned considerably to the north of the Newtownsaville Road
- To the south of Kilgreen Lower, the route has been re-aligned very slightly to the north
- Close to the Feddan Road, route has been re-aligned to the south of Tullywinny and Tullyvar
- At Derrycreevy, the route has been re-aligned to the south until the route intersects Loughans Road
- Approaching the River Blackwater, and the end of Section 3, the route is re-aligned slightly to the west

Details of the various changes to the Preferred Route alignment can be seen in the *Preferred Options Report*, *Alternatives Discussion Report* and *Report on the Choice of Route for the A5 WTC at Ballymagorry* (http://www.a5wtc.com/).

2.3 A5 WTC Proposed Scheme

Over a number of years, the A5 WTC has progressed through a number of stages which are detailed in *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment*.

The following section provides a description of the Proposed Scheme alignment for Section 1, Section 2 and Section 3 of the Proposed Scheme. Drawings 718736-0500-D-00184 to 718736-0500-D-00193 in Appendix A of this report also provide a detailed overview of the Proposed Scheme.

2.3.1 Section 1 Route Description

The northern terminal point of the Proposed Scheme is located to the northwest of New Buildings, close to Woodside road. Here the Proposed Route crosses its first minor watercourse, New Buildings stream.

The road continues southwest, located between the River Foyle and the existing A5. After 2km the proposed road passes over the watercourse Gortin Hall Drain. The road then travels southwest bypassing the village of Magheramason. In this area it crosses another watercourse Blackstone Burn.

The Proposed Scheme continues south intersecting the existing A5 east of the Cloghboy road. The road travels for a further 2.7km to the east of the existing A5, bypassing Bready. It once again crosses the existing A5 150m south of the Grangefoyle Road, and continues to the west of the existing A5.

At 10.5km from the starting point of the Proposed Scheme, the road bridges its first major watercourse; the Burn Dennet. The road travels to the west of the existing A5 for a further 2.2km where it then crosses another major watercourse; the Glenmornan River.

The route maintains its course between the River Foyle and A5 passing to the west of Ballymagorry and to the west of Strabane. The Proposed Scheme bridges the Mourne River 100m downstream from the existing A5 bridge.

The road course continues to the southwest travelling between the Glen Finn and Urney Road. A junction is proposed 240m to the southwest of Glenfinn View, with the intention of future development with the N14/N15 Letterkenny link. The proposed road then travels south, bypassing Sion Mills to the west of the existing A5.

2.3.2 Section 2 Route Description

The route continues south to the west of the existing A5, and crosses a number of minor watercourses. It bridges the River Derg 420m upstream from the existing A5 Bridge. A further 2.1km south, the route crosses Coolaghy Burn. The Proposed Scheme passes to the south of Newtownstewart and continues towards the existing A5. It then proceeds south, passing a number of watercourses including Tully Drain.

As the proposed road approaches Omagh, it traverses the Fairy Water; 370m upstream from the existing A5 Bridge and to the west of the Omagh Rugby Club grounds. The Proposed Scheme then bypasses Omagh to the west of the town, crossing over three more main watercourses; Aghnamoyle drain, Fireagh Lough Drain and Loughmuck.

As the Proposed Scheme reaches the end of Section 2, the route crosses the Drumragh River at a point 190m southeast of the Ballynahatty road and 580m south of the Shanley road.

2.3.3 Section 3 Route Description

At the beginning of Section 3, the Proposed Scheme continues southeast; west of the existing A5. After Drumconnelly road, the distance between the existing A5 gradually increases and the route crosses the Tullyrush road and Ranelly Drain. The road travels southeast crossing the Moyleagh Road and Augherpoint Road. The route also traverses the watercourse, Letfern.

The Proposed Scheme continues southeast for 3km where it crosses Routing Burn; 445m to the south of Greenmount Road and 320m to the east of Killadroy Road. A further 2km south, the route passes the Springhill Road and an undesignated watercourse.

The Proposed Scheme travels southeast for a further 3.6km, crossing minor watercourses, then changes direction and continues east.

After 4km the Proposed Scheme traverses the Roughan River and 2km further, it approaches the existing A4. It is proposed that there will be a junction at this location.

The Proposed Scheme will then bridge the Ballygawley River. After 4.7km in a south easterly direction, the proposed road changes direction in order to bypass Aughnacloy. When the Proposed Scheme is to the east of Aughnacloy, the road crosses another main watercourse, Lisadavil. The road then travels south towards the Blackwater River. The Proposed Scheme ends where it intersects the Monaghan road with the potential for future development towards Dublin.

2.4 Reviewed Flood Model Requirements

Due to changes to the horizontal alignment through the various stages of route development, some of the flood models outlined in *FRA Report 1 - Assessment Parameters and Preliminary Flood Risk Assessment* (Tables 8-1, 8-2 and 8-3) are no longer required. A summary of these flood models can be seen in table 2.3.3-1:

Table 2.3.3-1- Summary of Watercourses No Longer Required for A5 WTC Flood Risk Assessment

Section	Watercourse	Hydraulic Model ID
3	Ranelly Creamery Drain	M.K
	Ranelly Drain	M.J

The remaining models detailed in FRA Report 1 have been developed and information pertaining to these models can be seen in the following sections.

Table 2.3.3-2 provides a summary of the floodplains that are impacted by the A5 WTC Proposed Scheme:

Table 2.3.3-2 - Summary of Watercourses Required for A5 WTC Flood Risk Assessment

Section	Watercourse	Hydraulic Model ID
1	Gortin Hall Drain	M.A
	Blackstone Burn	M.B
	River Foyle, River Finn, Mourne River, Deele River, Swilly Burn, Glenmornan & Burndennet Rivers	M.1, M.2 and M.3
2	Undesignated	M.D
	River Derg	M.5
	Coolaghy Burn	M.E
	Back Burn	M.F
	Undesignated	M.G
	Tully Drain	M.H
	Omagh (including Fairy Water, Aghnamoyle Drain, Coneywarren Drain, Tully Drain and Strule River)	M.4
	Fireagh Lough Drain	M.I
	Drumragh River	M.6
3	Ranelly Drain	M.L
	Letfern Watercourse	M.M
	Undesignated Watercourse	M.N
	Undesignated Watercourse	M.O
	Routing Burn	M.P, M.Q
	Undesignated Watercourse (Newtownsaville)	M.R
	Undesignated Watercourse (Kilgreen)	M.S
	Roughan River	M.T
	Ballygawley River	M.U
	Tullyvar	M.V
	Ravella	M.W
	Undesignated	M.X
	Lisadavil	M.Y

Since the last issue of this report, the models have been reviewed and updated where appropriate, and are considered suitable for the purpose of this FRA. Each model has been discussed with Rivers Agency and model build approach agreed.

3 Detailed Hydraulic Modelling Extents

The focus of this chapter is to provide information on the locations and the extents of hydraulic models that were developed based on the identification of potential floodplains contained in Table 2.3.3-2.

Site inspections of all proposed modelling locations were undertaken to confirm the location and nature of the various watercourses, gain an appreciation of catchment characteristics (steepness, land use, etc), confirm model extents and determine the appropriate channel and floodplain roughness (Manning's n) coefficients to be applied in the hydraulic models.

A specification for the topographical survey was developed after the site visits, detailing model cross sections and any hydraulic control structures to be surveyed (bridges, culverts, etc) was developed subsequent to site visits.

Generally, model extents were determined in consideration of the following factors:

- The floodplain extents identified in the preliminary floodplain assessments,
- The downstream boundary was located sufficiently far downstream as not to significantly influence conditions at the location of interest,
- The upstream boundary was located to ensure that any significant impacts propagating upstream (backwater effects) were noted,
- In some locations model extents extended to nearby gauges to aid model calibration.

With regards to choice of 1D or 2D models; in areas where extensive and complex floodplains were anticipated, 2D models were developed with LiDAR data typically used to define the associated ground topography in extensive floodplain areas.

The following information outlines brief details of the watercourses to be modelled and the associated modelling extents.

3.1 Proposed Scheme Section 1 – Watercourse Details and Model Extents

3.1.1 Model M.A – MW1127 Gortin Hall Drain

The Gortin Hall Drain is located between the towns of New Buildings and Maghermason. The source of the watercourse is located approximately 5km east in the uplands areas of Gortmonely Hill and Clondermot, at an elevation of 200m AOD and 150m AOD respectively. A number of undesignated tributaries discharge to the Gortin Hall Drain. The watercourse flows generally in a westerly direction and ultimately discharges to the River Foyle near Tully Bridge (Grid Reference (GR) 239825, 411371). The catchment of the watercourse is predominantly rural.

Figure 3.1.1-1 below illustrates the proposed model extents. The length of the modelled reach is approximately 225m. There were no structures or culverts identified within the area of the Proposed Scheme. A 1D model was considered appropriate for Gortin Hall Drain.

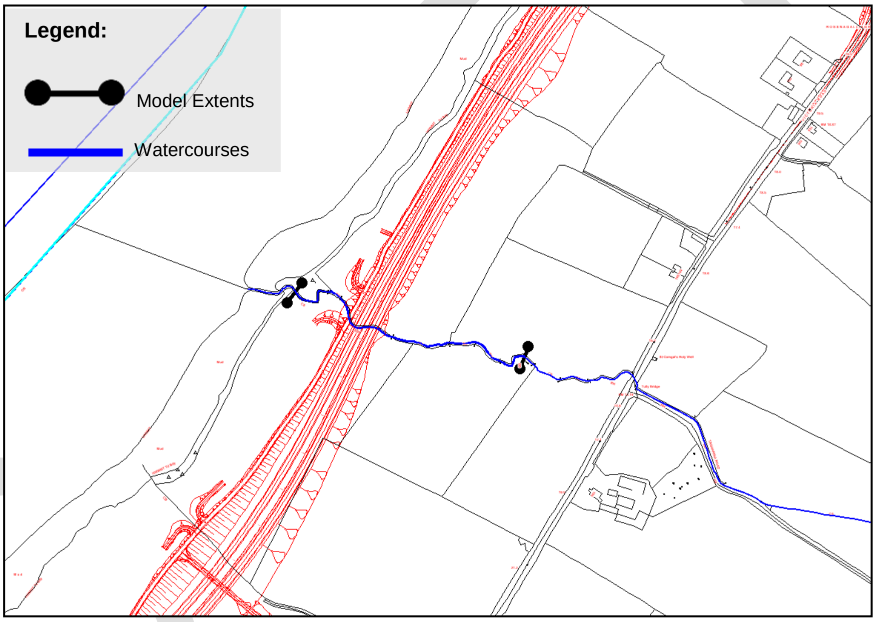


Figure 3.1.1-1 - Model M.A Extents – Gortin Hall Drain

The Gortin Hall Drain has an approximate channel width between the tops of banks of around 7m. Within the model extents, the gradient of the watercourse varies from around 1:27 upstream of Hulg Well to 1:57 downstream of Tully Bridge.

Within the model extents the watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep. The bed is partially weeded.

Site inspections identified that the downstream extents of the watercourse would likely be affected by water levels in the River Foyle. It was further identified that the River Foyle is subject to tidal influence at this location. It was considered that the influence of the River Foyle would extend up the Gortin Hall Drain to some degree.

Photograph 3.1.1-1 and 3.1.1-2 shown below illustrate the nature of this watercourse and immediate environs.

Photograph 3.1.1-1 – Gortin Hall Drain, Downstream of the Existing A5 WTC

Photograph 3.1.1-2 – Gortin Hall Drain in Vicinity of Tully Bridge

3.1.2 Model M.B – U21109 Blackstone Burn

The Blackstone Burn is located in the vicinity of Maghermason. The source of the watercourse is located approximately 3.1km east in the upland areas of Gortmonely Hill, at an elevation of around 112m AOD. A number of tributaries discharge to the Blackstone Burn including U21109A Coolmaghery Burn and other undesignated watercourses. The watercourse flows generally in a north westerly direction and ultimately discharges to the River Foyle north west of Magheramason (GR 239110 411150). The catchment of the watercourse is predominantly rural, although also includes some of the urban area of Magheramason.

Figure 3.1.2-1 below illustrates the proposed model extents. The length of the modelled reach is approximately 136m. There were six existing culverts along the proposed modelled reaches. A 1D model was considered appropriate for Blackstone Burn.

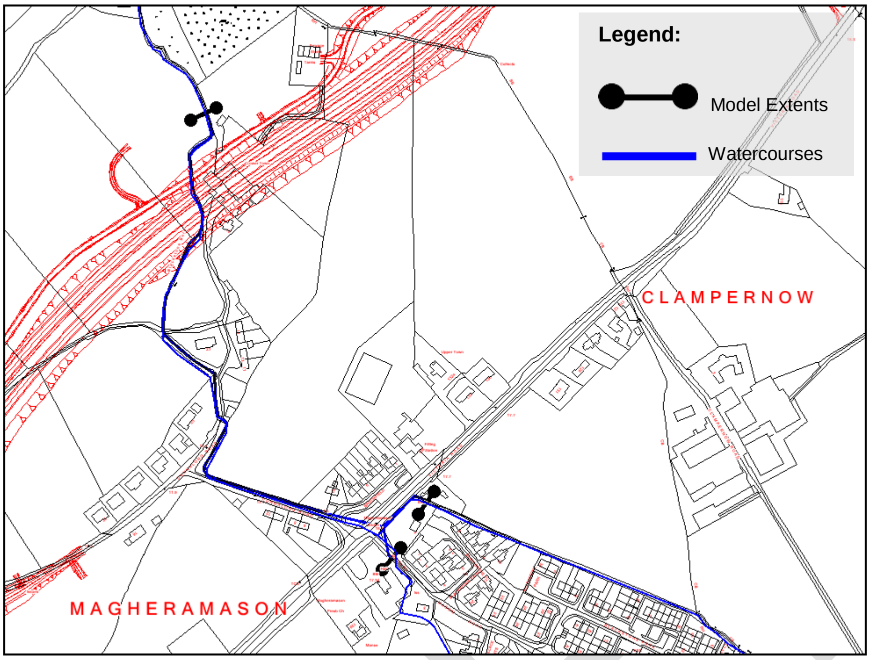


Figure 3.1.2-1 - Model M.B Extents – Blackstone Burn

The Blackstone Burn has an approximate channel width between tops of banks of around 8m. Within the model extents, the gradient of the watercourse varies from around 1:52 upstream to 1:24 downstream.

Within the model extents the watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep. The bed comprises some small and medium sized stones and is partially weeded.

Site inspections identified that the downstream extents of the watercourse would likely be affected by water levels in the River Foyle. It was further identified that the River Foyle is subject to tidal influence at this location. It was considered that the influence of the River Foyle would extend up the Blackstone Burn to some degree.

Photographs 3.1.2-1 to 3.1.2-4 shown below illustrate the nature of this watercourse and immediate environs.

Photograph 3.1.2-1 – Blackstone Burn downstream of the Proposed Scheme

Photograph 3.1.2-2 – Blackstone Burn upstream of the Proposed Scheme

Photograph 3.1.2-3 – Culvert inlet upstream of Victoria Road

Photograph 3.1.2-4 – Culvert inlet at Mason Road

3.1.3 Model M.1, M.2 and M.3 – Foyle River System (including River Foyle, River Mourne, River Finn, Ballymagorry, Burn Dennet, Deele River, Swilly Burn)

The River Foyle and the lower reaches of the River Mourne and River Finn are located within Section 1 of the Proposed Scheme. This section provides a short summary of the site and watercourse inspection in relation to the Foyle River System model; further details with regards to the hydraulic model build can be seen in document *718736/0500/R/004 Draft Model Build and Hydrology Report – Foyle River System* .

The River Foyle starts at the confluence of the River Mourne and the River Finn. The width of the main river channel of the Foyle varies from 90m to 550m. The Deele River, Swilly Burn, Burn Dennet, Glenmornan River and a number of other small tributaries discharge to the River Foyle. The modelled reach extends as far downstream as Londonderry/Derry Lough Foyle with an average gradient of around 1:1750.

The River Finn arises in Donegal and generally flows in an easterly direction. The modelled reach commences at Killygordon, with a river bed elevation of approximately 12.45m AOD and an average gradient of around 1:1500. The typical channel width is approximately 50m.

The River Mourne/Mourne - Strule commences south of Omagh, at the confluence of the Drumragh and Camowen rivers and flows north. The modelled reach extends as far upstream as Drumnabouy (downstream of Sion Mills). The river bed elevation is 3.6m AOD at the upstream boundary of the model with a typical channel width of 60m.

The Glenmornan River starts to the north of Owenreagh Hill and then flows in a westerly direction. The modelled reach commences at approximately 400m upstream of the Ballinderry bridge. The river bed elevation at the start of the modelled reach is about 7.15m AOD and slopes down to the confluence with the Foyle at an average gradient of around 1:400. The typical channel width is around 20m.

The Burn Dennet's source is located on the hills of Mullaghclogha. The modelled reach commences just upstream of the Burndennet bridge. The Burn Dennet flows in a westerly direction with a bed elevation at the upstream start of the modelled reach around 2.3m AOD with an average gradient of 1:900 and a typical channel width between top of banks of 40m.

The Deele River flows generally in an easterly direction and starts in the Cark mountains. The modelled reach starts approximately 2km upstream of the Ballindrait Bridge with a bed elevation of around 0.6m AOD and an approximate gradient of 1:3500. The typical channel width is around 50m between banks.

The Swilly Burn flows in a easterly direction with its source at Raphoe. The modelled reach starts upstream of the Swilly Bridge with an average gradient of around 1:1200 and a bed elevation at the start of the reach modelled around -0.76m AOD. The Swilly Burn has a typical channel width of 20m between top of the banks.

It can be seen that the main rivers emanating from Co. Donegal (Finn, Swilly, Deele) are very flat and sluggish in nature, in comparison to the rivers joining the Foyle from the Northern Ireland side. The proposed reach lengths to be modelled are shown in Table 3.3.3-1.

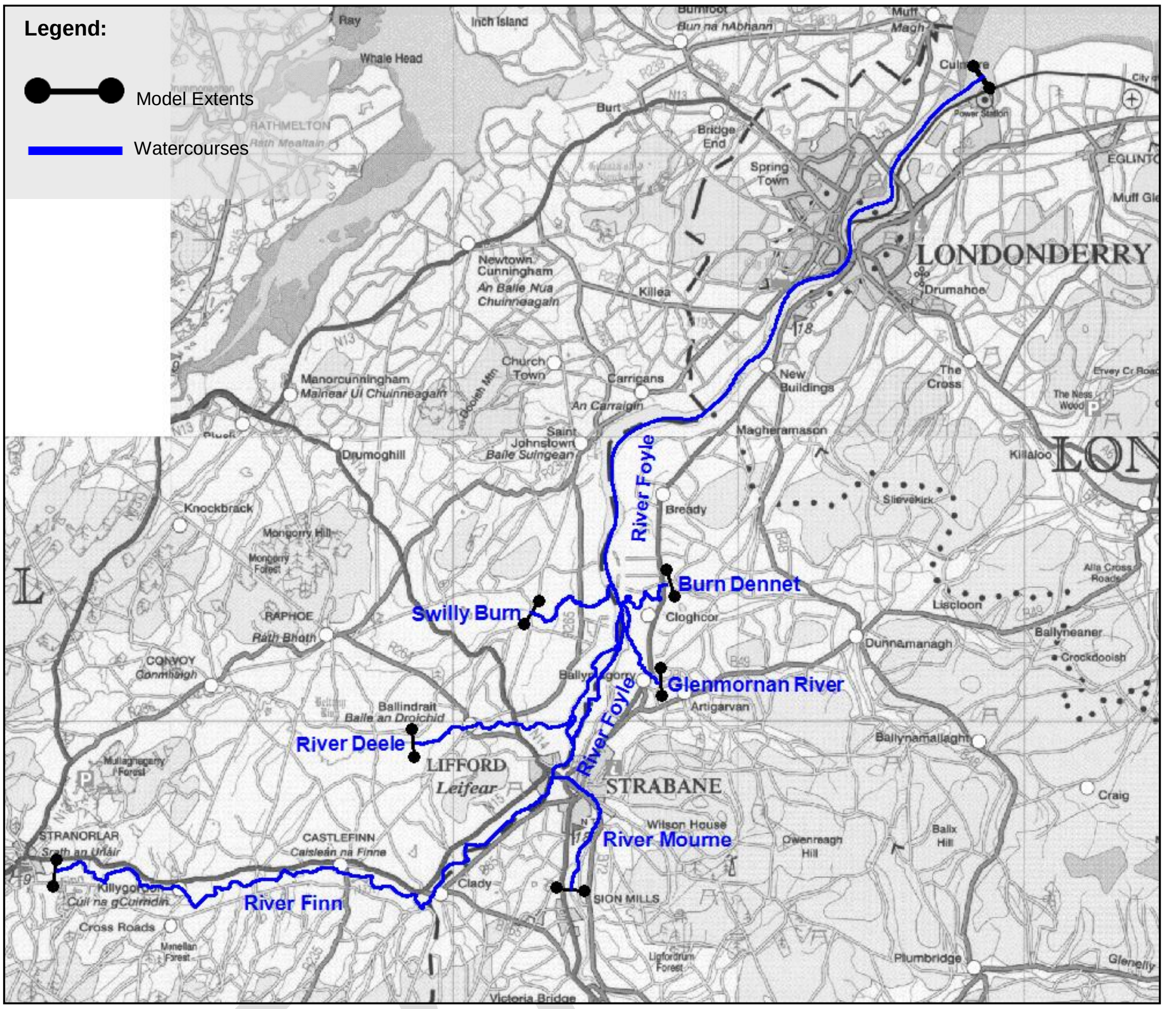


Figure 3.1.3-1 - Model M.1, M.2, M.3 Extents – Foyle River System

Table 3.1.3-1 Modelled Reach Lengths

Watercourse	Length of Modelled Reaches (km)
Foyle River	32.1
River Mourne	5.2
River Finn	24.6
Glenmornan	3.6
Burn Dennet	3.6
Deele River	6.4
Swilly Burn	3.8

Initial investigations (including some preliminary 1D modelling in HEC-RAS) showed that flooding around the Foyle system in the vicinity of the Proposed Scheme was complex and included substantial over-bank spilling into large floodplain areas. Both, fluvial and tidal components are present. There are large flood embankments running along most of the rivers and therefore floodplain flooding occurs when these embankments are overtopped or if any embankments fail. The prevailing hydraulic conditions indicated that a fully dynamic and linked 1D / 2D model was required to be developed that could more accurately assess these complex flooding patterns. The seven key rivers comprising the Foyle system are contained in a single integrated model. This allows flood risk, impact appraisal and mitigation optioneering to be assessed across the various extensive Route Options and watercourses in a fully joined up way.

Details of the watercourses were recorded and photographs taken to assist in the model build and also to correlate field and modeller estimation of Manning's n friction values. A number of structures are present in the area. These include the Lifford Bridge on the River Foyle, three bridges on the River Finn, the two bridges on the River Mourne in Strabane, Ballymagorry Bridge on the Glenmornan, Burn Dennet Bridge on the Burn Dennet, two bridges in the Deele and two bridges in the Swilly. Photographs of all the modelled rivers which depict the general nature of these rivers are shown below in Photographs 3.1.3-1 to 3.1.3-7.

Photograph 3.1.3-1 – River Foyle

Photograph 3.1.3-2 – Mourne River

Photograph 3.1.3-3 – River Finn

Photograph 3.1.3-4 – Burn Dennet

Photograph 3.1.3-5 – Glenmornan

Photograph 3.1.3-6 – Deele River

Photograph 3.1.3-7 – Swilly Burn

3.2 Proposed Scheme Section 2 – Watercourse Details and Model Extents

3.2.1 Model M.D – Undesignated Watercourse (Upstream of Seein Bridge)

This undesignated watercourse is located approximately 0.5 km upstream of Seein Bridge. The source of the watercourse is approximately 2.7km west in the upland areas of Urney, Glentimon and Whisker Hill at elevations of 120m AOD, 110m AOD and 160m AOD respectively. The watercourse discharges to the 094 Mourne – Strule (Extension) close to the village of Seein Bridge (GR 234310, 391126) and in general, flows in an easterly direction. The catchment area of the watercourse is predominantly rural.

This undesignated watercourse has an approximate channel width, between the top of banks of around 4m. The average gradient of the watercourse is 1:50. There were no structures or culverts identified within the proposed model extents. It is proposed that a 1D model is appropriate for this undesignated watercourse. Figure 3.2.1-1 below illustrates the proposed model extents. The length of the modelled reach is approximately 417m.

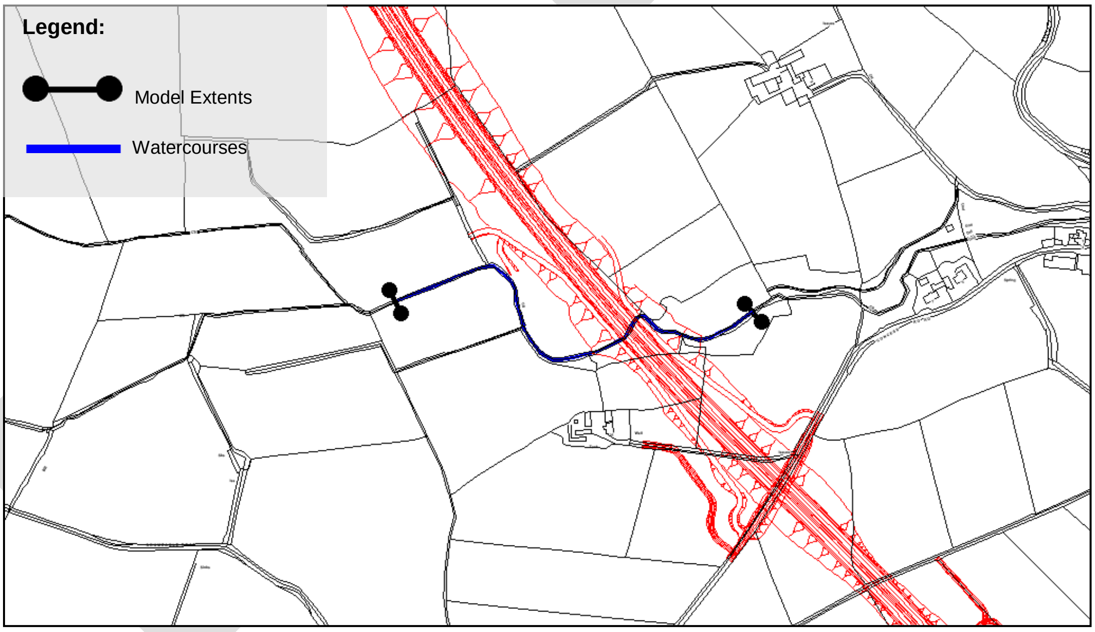


Figure 3.2.1-1 - Model M.D Extents – Undesignated Watercourse (Upstream Seein Bridge)

Within the study area the watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep but slightly meandering through the prevailing topography. The bed comprises some small stones and is partially weeded. Photographs 3.2.1-1 and 3.2.1-2 below depict the watercourse.

Photograph 3.2.1-1 – Undesignated Watercourse Downstream of Proposed Scheme

Photograph 3.2.1-2 – Undesignated Watercourse Upstream of Proposed Scheme

3.2.2 Model M.5 – 101 River Derg

The River Derg is located approximately 4km north of Newtownstewart, with the Proposed Scheme crossing the river between Ardstraw and Millbrook. The source of the river is in the upland areas of Ardnamona along the Co. Tyrone / Co. Donegal border at an elevation of approximately 260m AOD. The most significant of the tributaries are the Mourne-Beg River, the source of which is Lough Mourne, Co. Donegal, and the Glendergan River.

The River Derg discharges to the 094 Mourne – Strule (Extension) in the vicinity of Millbrook (GR 236760, 387920) and in general, flows in an easterly direction. The catchment area of the river is predominantly rural incorporating agricultural grassland (40%), upland heath (50%) and coniferous forest (10%), the catchment area also includes the small urban area of Castlederg.

In the vicinity of the Proposed Scheme River Derg crossing the river has an approximate channel width between tops of banks of around 40-50m. The gradient of the watercourse varies from around 1:1160 upstream of Ardstraw to 1:100 downstream of Milbrook.

Within the vicinity of the Proposed Scheme the river banks are dominated by weeds, shrubs, bushes and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is very flat upstream and slightly steeper downstream. The river meanders slightly through the prevailing topography. The bed comprises a range of stone sizes, large and small, and is partially weeded. Photographs 3.2.2-1 and 3.2.2-2 below depict the river.

Photograph 3.2.2-1 – Derg River Downstream of Strabane Road

Photograph 3.2.2-2 – Derg River Upstream of Old Bridge Road

In June 2008, Rivers Agency provided Mouchel with an existing hydraulic model of the Mourne Strule Extension which extended from GR 236100 389700 to GR 241300 386500 and incorporated the downstream reach of the River Derg from GR 234704 387209 to its confluence with the Mourne – Strule (Extension) (refer to FRA Report Volume 1).

The existing Rivers Agency model was reviewed by Mouchel and deemed to be a suitable platform from which to develop the River Derg hydraulic model. Site visits by Mouchel confirmed that the Derg model should be extended to upstream of Ardstraw Bridge. The existing Mourne Strule (Extension) model reach would be cropped with a suitable reach retained. Figure 3.2.2-1 shows the proposed model extents. The modelled reaches include approximately 2.5km of the River Derg and 5.8km of the Mourne-Strule River.

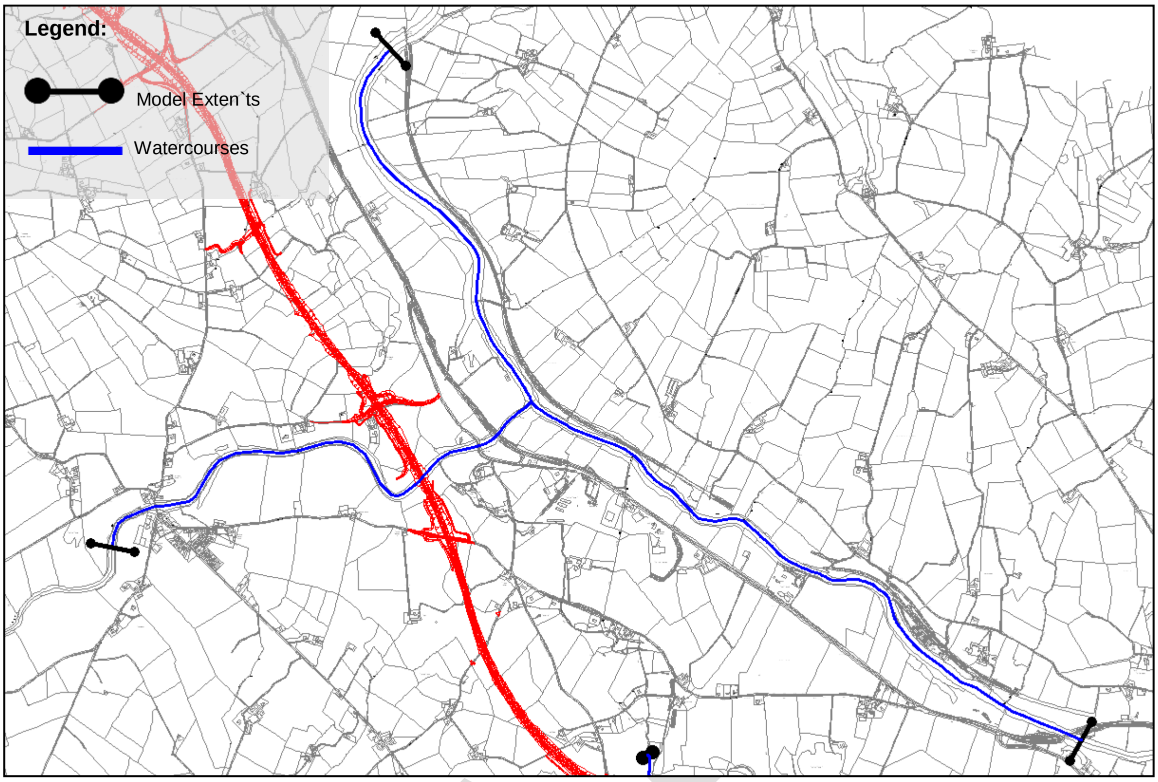


Figure 3.2.2-1 - Model M.5 Extents – River Derg

Mouchel site visits identified three significant structures crossing the River Derg within the proposed extents of the model; these being a bridge structure at Ardstraw and two bridge structures at Millbrook, Photographs 3.2.2-3 to 3.2.2-5 depict these structures.

Photograph 3.2.2-3 – Strabane Road Bridge at Millbrook

Photograph 3.2.2-4 – Old Bridge at Mill Brook

Photograph 3.2.2-5 – Ardstraw Bridge

It is proposed that a 1D model will be appropriate for the River Derg. At the time of receipt, the River Agency Mourne-Strule River model was also a 1D model.

3.2.3 Model M.E – Coolaghy Burn (Undesignated)

The Coolaghy Burn is an undesignated tributary of the River Derg. The Proposed Scheme crossing of this watercourse is located approximately 2.5km upstream of its confluence with the River Derg, between Coolaghy and Woodbrook. The source of the watercourse is Bessy Bell approximately 6.5km south-west of the Proposed Scheme crossing, at an elevation of approximately 350m AOD. The upstream catchment includes Lough Fanny and Lough Catherine. In general, the Burn flows in a northerly direction through a predominately rural catchment.

The Burn has an approximate width from tops of banks of approximately 6m and the average gradient of the modelled reach is approximately 1:257.

Figure 3.2.3-1 illustrates the proposed model extents. The length of the modelled reach is approximately 788m. A single bridge structure was identified within the proposed model extents. It was further identified that a 1D model is appropriate for the undesignated Coolaghy Burn.

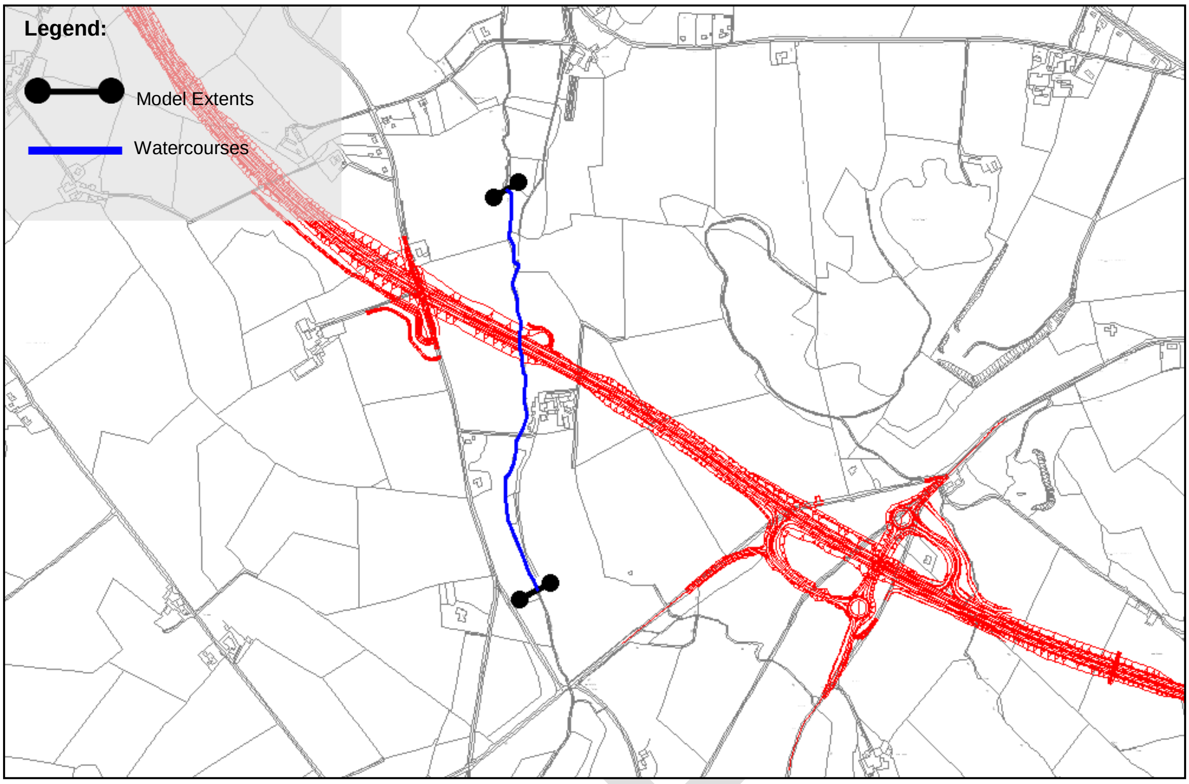


Figure 3.2.3-1 - Model M.E Extents – Coolaghy Burn

Within the study area the watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively flat. The bed comprises some small stones and is partially weeded.

Photographs 3.2.3-1 to 3.2.3-4 below illustrate Coolaghy Burn and associated floodplain areas.

Photograph 3.2.3-1 – Potential Floodplain Area Coolaghy Burn (Watercourse Along Line of Trees)

Photograph 3.2.3-2 – Potential Floodplain Area Coolaghy Burn (Watercourse Along Line of Trees)

Photograph 3.2.3-3 – Coolaghy Burn

Photograph 3.2.3-4 – Coolaghy Burn

3.2.4 Model M.F – U1704 Ext Back Burn Extension, Newtownstewart (undesignated upper reach)

On the basis of alluvium mapping, historical mapping and Rivers Agency flood mapping, the Back Burn watercourse was not identified as a location of potential flood risk. However, Rivers Agency advised Mouchel that there were some localised flooding issues associated with this watercourse and specifically highlighted this watercourse in terms of ensuring no exacerbation of flood risk post scheme. Consequently, this watercourse was included for modelling to assess the likely flows and water levels but also to allow any proposed crossings / culverts to be modelled.

This undesignated upper reach of the U1704 Back Burn is located south-west of Newtownstewart, with the Proposed Scheme crossing of the watercourse being approximately 0.8 km upstream of the town. The source of the watercourse is approximately 1.6km southwest at Bessy Bell, which rises to an elevation of approximately 300m AOD. The U1704 Back Burn ultimately discharges to the 094 Mourne – Strule (Extension). In general, the watercourse flows in a north-easterly direction. The catchment area of the watercourse is predominantly steep upland and rural. Lower reaches (downstream of Proposed Scheme crossing) include some urbanised sub-catchment areas of Newtownstewart.

The watercourse has an approximate channel width between tops of banks of around 8m and the average gradient of the modelled reach is around 1:14. Figure 3.2.4-1 below illustrates the proposed model extents. The length of the modelled reach is approximately 320m. There were no culverts identified within the proposed model extents. Glen Road runs parallel to the watercourse on the upstream part of the modelled reach and sits at a significantly higher elevation. It is proposed that a 1D model is appropriate for the Back Burn watercourse.

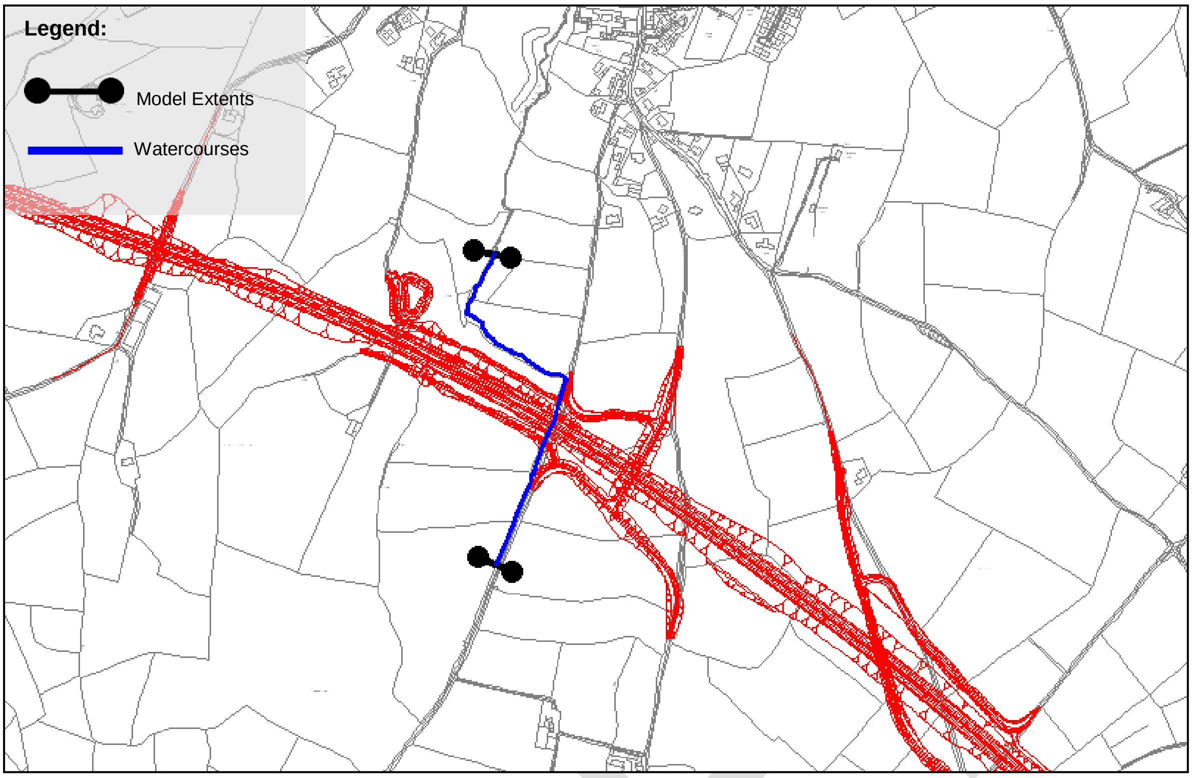


Figure 3.2.4-1 - Model M.F Extents – Back Burn

Within the study area the watercourse banks are dominated by weeds, shrubs and a very few isolated trees and bushes, extending further from the steep banks, the land is predominately agricultural grassland. The watercourse channel is very steep and the bed mainly comprises stones and is partially weeded. Photographs 3.2.4-1 to 3.2.2-3 depict the watercourse.

Photograph 3.2.4-1 – Back Burn in Vicinity of Proposed Scheme

Photograph 3.2.4-2 – Back Burn

Photograph 3.2.4-3 – Back Burn

3.2.5 Model M.G – Undesignated Watercourse

This undesignated watercourse flows from in a southerly direction near to the village of Mountjoy. The Proposed Scheme would cross the watercourse at GR 241519, 378536. The source of the watercourse lies in the hills to the northwest, at an elevation of approximately 195m AOD. The watercourse discharges into Strule River to the east of Mountjoy at GR 242809, 378214. The area is predominantly rural and the main land use is agricultural.

This undesignated watercourse has an approximate channel width, from the top of banks of around 3-4m. The average bed slope within the study area is approximately 1 in 135. Figure 3.2.5-1 below illustrates the proposed model extents. A 1D model was considered appropriate for this undesignated watercourse.

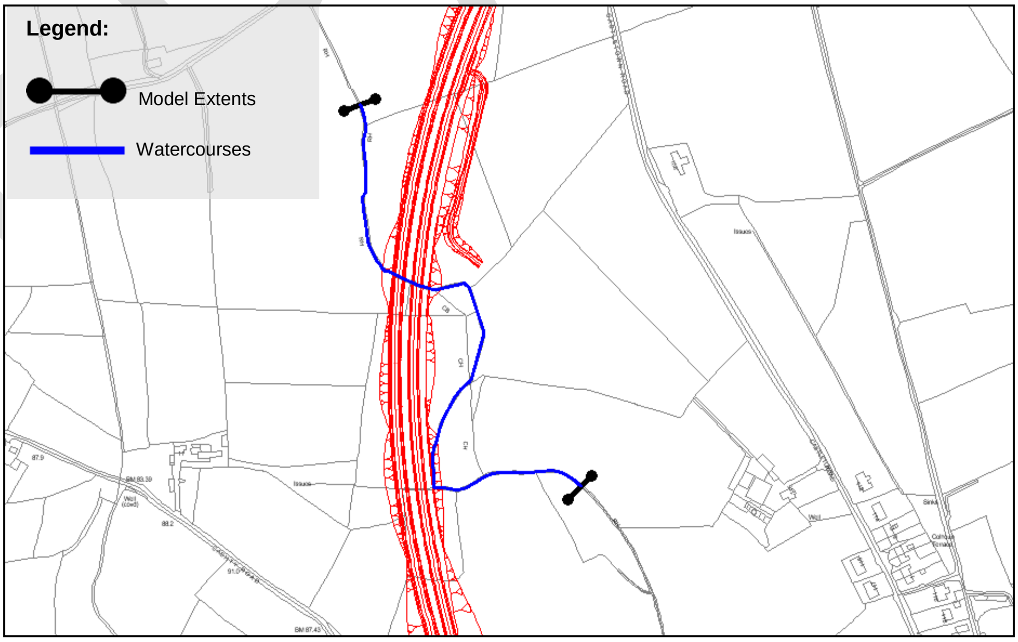


Figure 3.2.5-1 - Model M.G Extents – Undesignated Watercourse

The length of the modelled reach is approximately 700m. One structure was identified within the extent of the model which may impact on flooding. This is a 450mm diameter circular concrete culvert (GR 241572, 378339) and is shown in Photograph 3.2.5-1:

Photograph 3.2.5-1 – Culvert 1 (GR 241572, 378339)

Within the study area the watercourse banks are dominated by weeds, shrubs and trees. Extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep but slightly meandering through the prevailing topography. The bed comprises some stones and is partially weeded. Photographs 3.2.5-2 and 3.2.5-3 below depict the watercourse

Photograph 3.2.5-2 – Upstream of Proposed Scheme

Photograph 3.2.5-3 – Downstream of Proposed Scheme

3.2.6 Model M.H – Tully Drain (Undesignated Reach – Mountjoy)

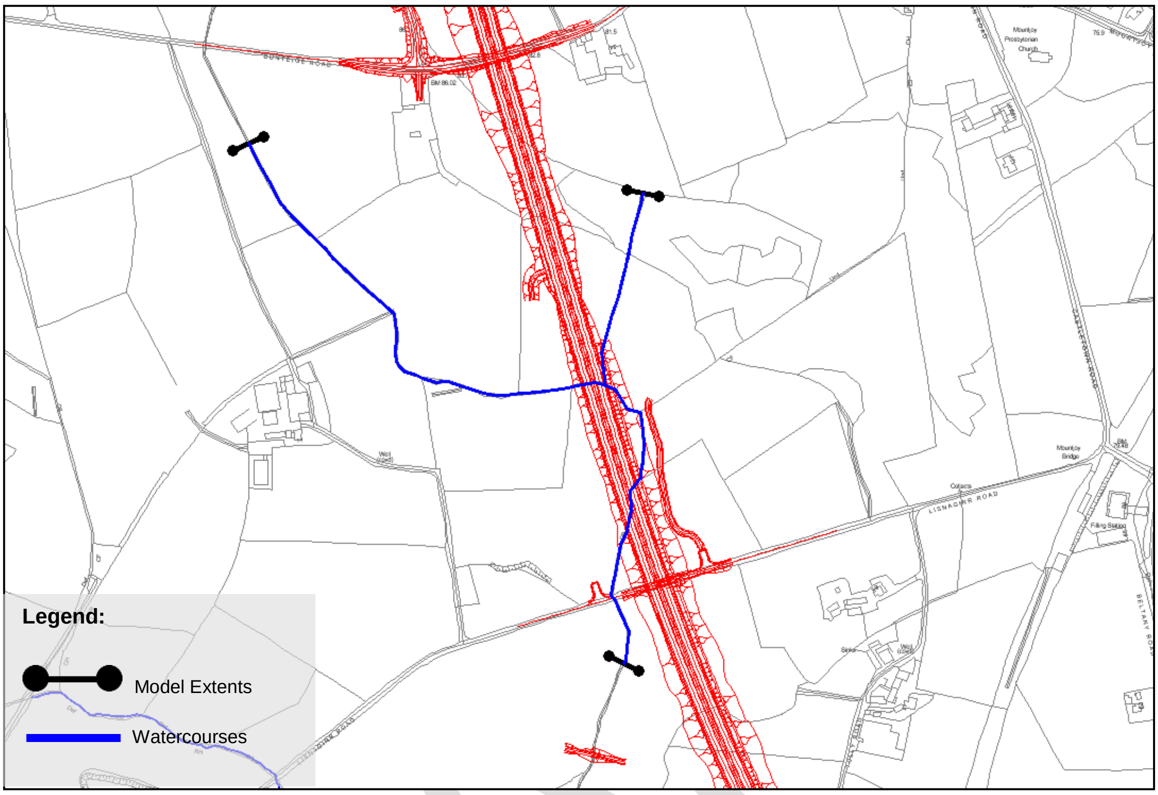


Figure 3.2.6-1 - Model M.H Extents – Tully Drain (Undesignated)

The Tully Drain (undesignated) is located southwest of Mountjoy between the Dunteige and Lisnagirr Roads and is an upstream reach of the designated MW1609 Tully Drain. Bessy Bell's south-eastern slopes are the source of the watercourse, approximately 3.5 km upstream of the Proposed Scheme crossing at an elevation of approximately 190m. The watercourse discharges to the 094 Mourne-Strule (Extension) north of Omagh and in general, flows in a south-easterly direction. The catchment area of the watercourse is predominantly rural.

The Tully Drain (undesignated) has an approximate channel width between tops of banks of around 6m. The average gradient of the modelled reach is around 1:142. Figure 3.2.6-1 below illustrates the proposed model extents. The length of the modelled reach is approximately 1390m, with two structures being identified at Lisnagirr Road and Dunteige Road. A 1D model was considered appropriate for Tully Drain (undesignated).

Within the study area the watercourse banks are dominated by weeds, shrubs, bushes and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep. The bed comprises some small stones and is quite weeded. Photographs 3.2.6-1 to 3.2.6-3 depict the watercourse.

Photograph 3.2.6-1 – Tully Drain (Undesignated) Upstream of Lisnagirr Road Bridge

Photograph 3.2.6-2 – Tully Drain (Undesignated) Downstream of Dunteige Road Bridge

Photograph 3.2.6-3 – Lisnagirr Road Bridge

3.2.7 Model M.4 – Omagh (including Fairy Water, Aghnamoyle Drain, Coneywarren Drain, Tully Drain and Strule River)

The Proposed Scheme would cross the Fairy Water, Aghnamoyle Drain and Tully Drain to the west of Omagh.

The Fairy Water flows eastwards from its source at the foot of the Bolaght Mountain in West Tyrone to meet the Strule River west of Omagh, approximately 450m downstream of the Proposed Scheme Fairy Water crossing (GR 242778, 374962). The Fairy Water Valley, upstream of the Proposed Scheme, includes the broad, marshy Fairy Water Valley and the undulating branching valley of the Drumquin River to the south. The catchment geology consists mainly of Carboniferous Limestone with extensive areas of till and alluvium drift deposits on both banks of the river. The catchment is predominantly grassland with some shrub heath, bog and coniferous woodland.

The Proposed Scheme would cross the Aghnamoyle Drain approximately 1km south of the Fairy Water (GR 242558, 374013). The Aghnamoyle Drain discharges into the Conneywarren Drain which in turn discharges into the Fairy Water immediately downstream of the Proposed Scheme Fairy Water crossing.

The Proposed Scheme would cross the Tully Drain approximately 800m north of the Fairy Water (GR 242553, 375723). The Tully Drain discharges into the Strule River 1km east of the Proposed Scheme Fairy Water crossing.

The Strule River begins at the confluence of the Camowen and Drumragh Rivers in the centre of Omagh at Strule Bridge. The Camowen River rises from the granite outcrop of Cregganconroe and flows predominantly in a westerly direction towards Omagh. The Drumragh River has two main tributaries, Ballynahatty Water and Quiggery Water which combine to form Drumragh River approximately 6 km upstream of Omagh.

Initial investigations identified that flooding has occurred around Omagh and in the vicinity of the Proposed Scheme; earthen embankments align the Fairy Water, however, these are not considered to provide flood defence protection for the design event (1 in 100 year).

It is also identified that there are a number of hydraulic control structures within the wider catchment that may potentially influence flooding dynamics in the vicinity of the Proposed Scheme. These include: flood defences through the centre of the town, a number of bridge and weir structures along the Strule and Fairy Water Rivers including proposals for a new bridge crossing the Strule River at Strathroy, a control structure at the divergence between Hunters Crescent and the Coneywarren Drain, the Hunter's Crescent culverted watercourse, flood defence walls at Hunter's Crescent, a culvert between Coneywarren Drain and Fairy Water and various flap valve controls throughout the system.

The prevailing hydraulic conditions indicated the need for a fully dynamic and linked 1D / 2D model. This being required to properly assess the potentially complex flooding patterns. Key watercourses and structures in the vicinity of Omagh would be contained in the same single model; enabling flood risk, impact appraisal and mitigation optioneering to be assessed compositely.

Figure 3.2.7-1 illustrates the proposed model extents. The reach lengths and average gradients of the principal watercourses within the extents of the proposed Omagh model are presented in Figure 3.2.7-1.

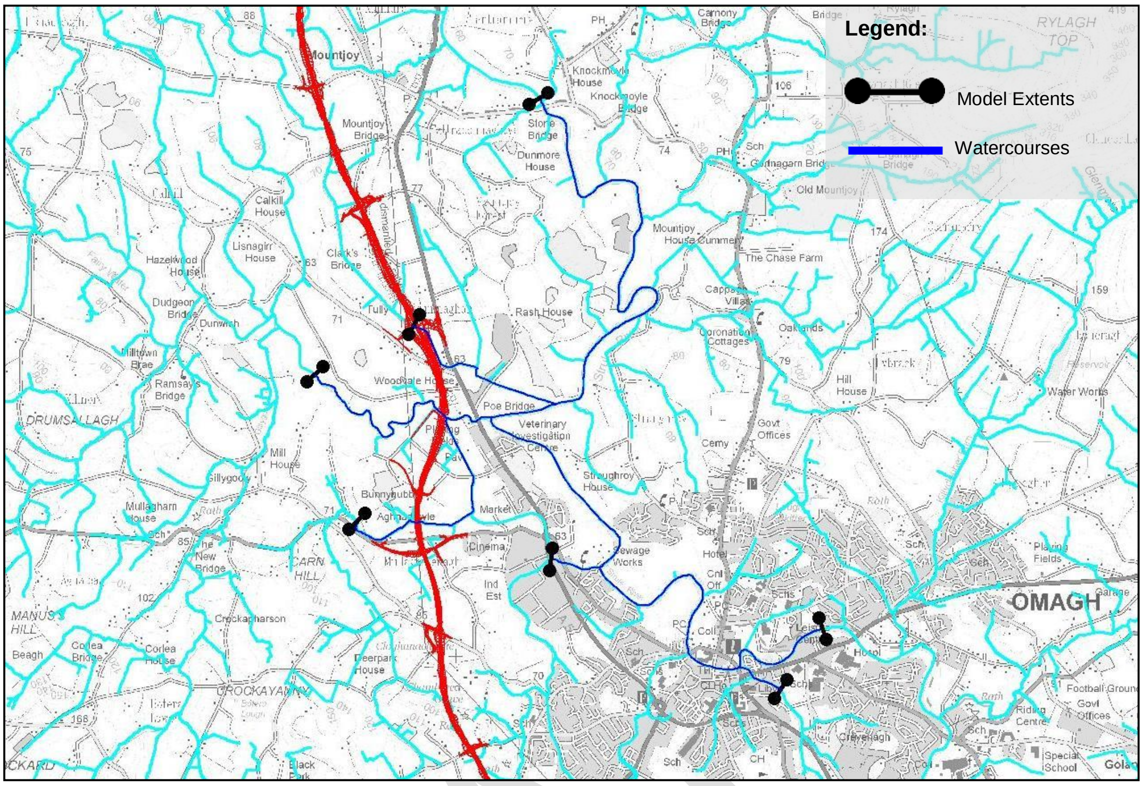


Figure 3.2.7-1 - Model M.4 Extents – Omagh Model

Table 3.2.7-1 - Omagh Model Extents

Watercourse	Upstream NGR	Downstream NGR	Approx reach length	Average Gradient
Drumragh River	245710 372575	245390 372756	0.4 km	1 in 580
Camowen River	246060 373057	245390 372756	1.0 km	1 in 248
Strule River	245390 372756	243588 377772	9.4 km	1 in 1575
Coneywarren Drain	243763 372856	242806 374934	3.1 km	1 in 475
Fairy Water	241795 375211	243179 374935	2.1 km	1 in 3442
Aghnamoyle Drain	242127 373892	243037 374102	1.0 km	1 in 323
Tully Drain	242167 376048	243731 375043	2.0 km	1 in 515

Details of the various watercourses were recorded and photographs taken to assist in the model build and to facilitate estimation of Manning's n friction values.

Photographs 3.2.7-1 to 3.2.7-6 below depict the key watercourses and associated structures.

Photograph 3.2.7-1 – Confluence of the Fairy Water with the River Strule

Photograph 3.2.7-2 – Outfall of Tully Drain at confluence with River Strule

Photograph 3.2.7-3 – Tully Drain upstream of confluence with River Strule

Photograph 3.2.7-4 – Aghnamoyle Drain upstream of confluence with Conneywarren Drain

Photograph 3.2.7-5 – Outfall of Hunters Crescent Stream into River Strule

Photograph 3.2.7-6 – Downstream model boundary at Tattraconnaghty stone bridge

In January 2009 consultations were held with Rivers Agency; during consultations it was identified that Rivers Agency were progressing a pilot model build study for Omagh town and surrounding flood plain areas including the Fairy Water. The model under development by Rivers Agency was identified as a 1D – 2D Infoworks RS model, the extents being similar to that as identified for the assessment of the Proposed Scheme.

It was agreed that Rivers Agency would extend its pilot study to incorporate all reaches as required for the Proposed Scheme; Rivers Agency provided a base model to TransportNI for subsequent development and assessment of flood risk in relation to the A5 WTC.

Following receipt of the base InfoWorks RS model for the Omagh catchment a detailed model review incorporating some model refinements was completed to provide a suitable basis for the development of the A5 WTC Flood Risk Assessment.

In 2014 the Omagh InfoWorks RS model was converted to Infoworks ICM to enable the more accurate quantification of river flooding.

InfoWorks ICM has been developed for the main purpose of enabling 1D-2D coupling, through both point and linear coupling. InfoWorks RS is limited to point coupling, which reduces the model accuracy and quantification of flow over river banks.

The Infoworks RS model was converted to Infoworks ICM through an import process. As a consequence of slight differences in the software packages all structures within the model were re-built including the proposed Strathroy Bridge. Other changes made to the ICM model included:

- Rebuilding the river reaches to represent bank lines,

- River confluences were represented using inline banks,
- Representation of weirs on the Camowen and Strule rivers were improved,
- The lateral watercourses were rebuilt as river reaches,
- Incorporation of Hunter's Crescent Flood Defences,
- Representation of a closed link between Beltany Road / Watson Park drainage culvert and Coneywarren,
- Coefficients were altered to improve river bank model stability.

The InfoWorks RS model extents were evaluated as appropriate, therefore remained the same in ICM. The upstream limits were set by the lower reaches of the Drumragh and Camowen Rivers, proximal to the urban boundary of Omagh town. The eastern extents were set by the Hunters Crescent, Aghnamoyle and Fairywater Rivers, and the northern extent defined by Stone Bridge with representation of the bridge structure being included in the model.

Once model improvements had been made, inflow hydrographs were run through the model for the 10 year and 100 year return period events and for the 2011 historical flood event. The resultant prediction of flooding extents was then compared against the River Agency Flood Maps (NI). Water levels in the river at certain 'break nodes' were also compared.

Following model calibration, for the baseline existing scenario, model results were found to be within acceptable margins of the River Agency Flood Maps (for depth, velocity and flow), for those areas potentially influenced by the Proposed Scheme.

3.2.8 Model M.I – MW1545 Fireagh Lough Drain

Fireagh Lough Drain is located west of Omagh between the A32 Clanabogan Road and the Brookmount Road. The source of the watercourse is approximately 2.0km southwest at Fireagh Lough. The elevation of the Lough is approximately 110m AOD. The watercourse discharges to the 094 Mourne – Strule (Extension) via the U1602 Hunter's Crescent Stream in the vicinity of the Gortrush Industrial Estate, Omagh. In general the watercourse flows in a north-easterly direction and the catchment area is predominantly rural.

The watercourse has an approximate channel width between tops of banks 2.5m. The average gradient of the modelled reach is 1:131. It is proposed that a 1D model is appropriate for Fireagh Lough Drain. The length of the modelled reach is approximately 800m.

Figure 3.2.8-1 below illustrates the proposed model extents.

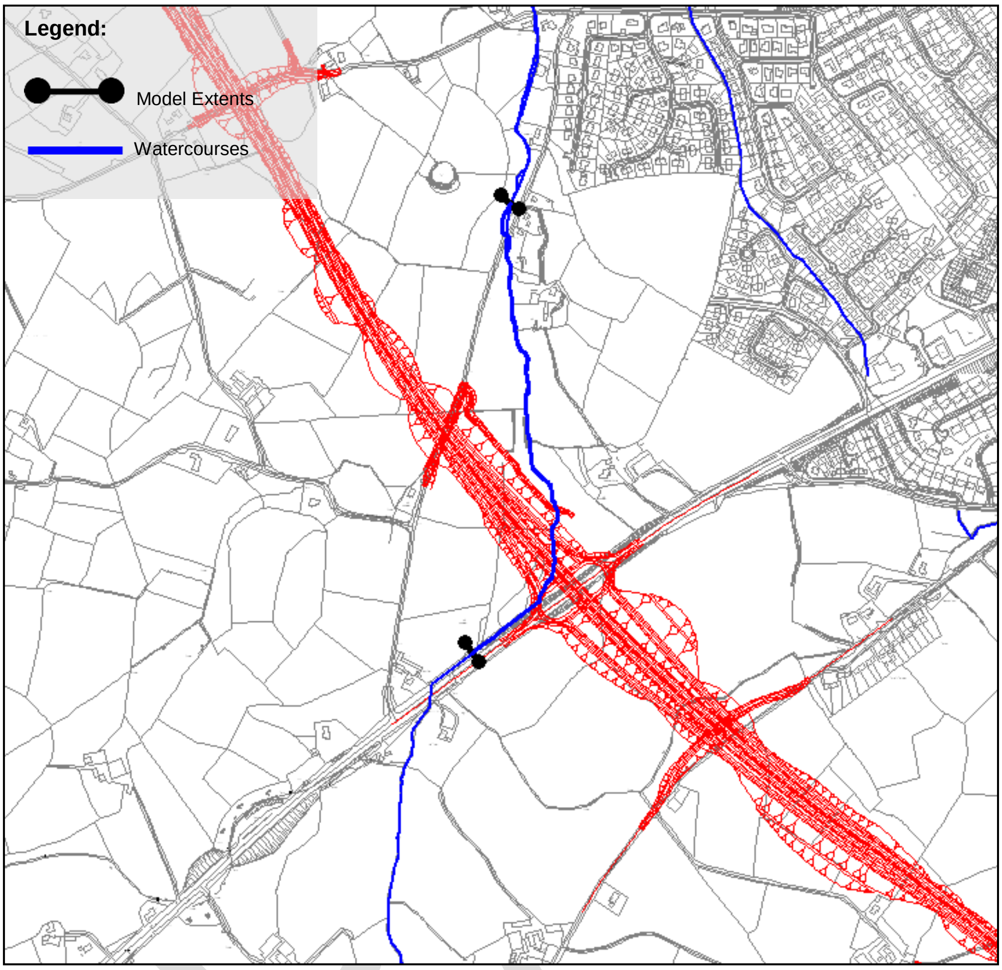


Figure 3.2.8-1 - Model M.I Extents – Fireagh Lough Drain

The watercourse banks are dominated by heavy weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep. The bed comprises some small stones and is partially weeded. Photographs 3.2.8-1 to 3.2.8-4 depict the watercourse.

Photograph 3.2.8-1 – Fireagh Lough Drain; West of Gleninue House

Photograph 3.2.8-2 – Fireagh Lough Drain; West of Gleninue House

Photograph 3.2.8-3 – Fireagh Lough Drain; North of Clanabogan Road

Photograph 3.2.8-4 – Fireagh Lough Drain; North of Clanabogan Road

One structure was identified within the proposed model extents at Brookmount Road. Photograph 3.2.8-5 illustrates this structure.

Photograph 3.2.8-5 – Fireagh Lough Drain at Brookmount Road

3.2.9 Model M.6 – 121 Drumragh River (Extension)

The Drumragh River is located approximately 2.5 km south-west of Omagh, with the Proposed Scheme crossing between Drumragh Bridge and Drumshanly. Approximately 2.3km upstream of the Proposed Scheme crossing at Relaghdooey, two major rivers combine to form the Drumragh River; the Owenreagh River (also referred to on maps as the Ballynahatty Water) and the Quiggery Water.

The Quiggery Water runs from south to north and is formed from Glennamuck River (whose source is near Fintona at an elevation of approximately 150mAOD) and Routing Burn (whose source is near Garvaghy at an elevation of approximately 180m AOD). The catchment of Quiggery Water has a U-shaped valley with relatively gentle sloped sides of pasture land with few trees. The average bed slope of Quiggery Water is approximately 1:800 near the confluence with the Ballynahatty Water.

The Ballynahatty Water runs from south west to north east and is formed from Owenreagh River whose source is near Dromore at an elevation of approximately 110m AOD. The catchment of Ballynahatty Water has similar characteristics to Quiggery Water, and the average bed slope is also approximately 1:800 near the confluence with Quiggery Water.

The Drumragh River discharges to the Mourne – Strule (Extension) in the vicinity of Drumragh Avenue within Omagh town (GR 245370, 372760) and in general the river flows in a north-easterly direction. The catchment area of the river is predominantly rural incorporating agricultural grassland, upland heath and coniferous forest. The catchment area upstream of the Proposed Scheme also includes the small urban catchments of Seskinore, Fintona, Garvagh and Dromore.

In the vicinity of the Proposed Scheme the Drumragh River the river has an approximate channel width between tops of banks of around 20-30m. The average gradient of the watercourse is approximately 1:800 in that reach. The length of the modelled reach is approximately 6.4km, extending from the upstream Drumshanley gauging station to the Campsie Bridge gauging station. Figure 3.2.9-1 illustrates the proposed model extents. A 1D model was considered appropriate for floodplain identification along the Drumragh River.

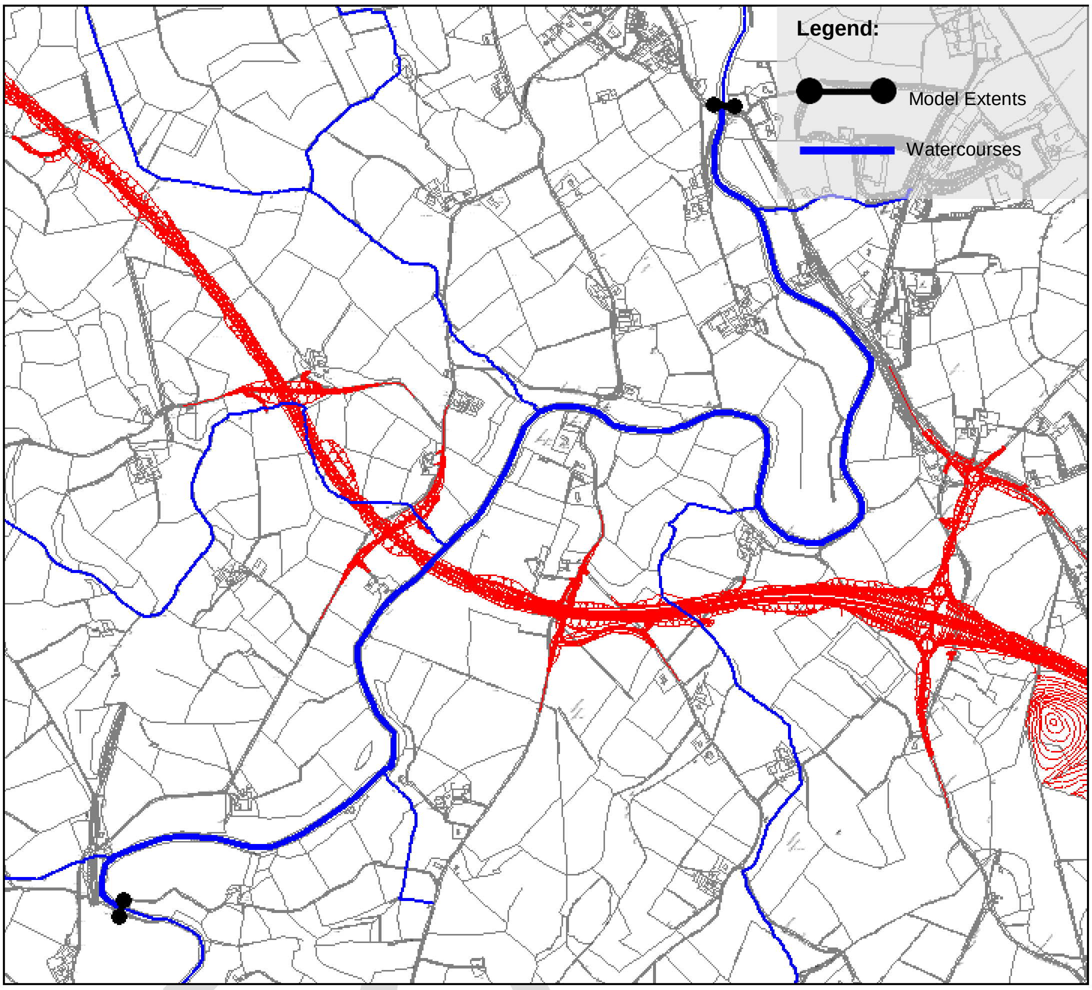


Figure 3.2.9-1 - Model M.6 Extents – Drumragh River

Within the vicinity of the Proposed Scheme the river banks are dominated by weeds, shrubs and trees, extending further from the bank the land is predominately agricultural grassland. Photographs 3.2.9-1 and 3.2.9-2 depict the river. There are four bridge structures also identified within the model extents; a steel footbridge at Drumshanley gauging station, the Drumragh Bridge, the Lissan Bridge and the Campsie Bridge, it is further noted that there is a small weir on the downstream side of the Lissan Bridge. Photographs 3.2.9-3 and 3.2.9-4 illustrate the Drumragh and Lissan Bridges.

Photograph 3.2.9-1 – Typical Vegetation on Banks of Drumragh River

Photograph 3.2.9-2 – Tributary (Loughmuck) Joining the Drumragh River

Photograph 3.2.9-3 – Drumragh Bridge and Flood Relief Arches

Photograph 3.2.9-4 – Lissan Bridge and Downstream Weir

3.3 Proposed Scheme Section 3 – Watercourse Details and Model Extents

3.3.1 Model M.L – MW1410 Ranelly Drain

The Proposed Scheme would cross the upstream extents of the Ranelly Drain in the vicinity of the Doogary / Tullyrush Roads, southeast of Omagh.

Within the study area the watercourse has an approximate channel width, from the top of either bank, of 2 – 4 m. The average gradient of the watercourse within the study area is approximately 1 in 400.

Figure 3.3.1-1 illustrates the proposed model extents. The length of the modelled reach is approximately 3km. It is proposed that a 1D model is appropriate for Ranelly Drain.

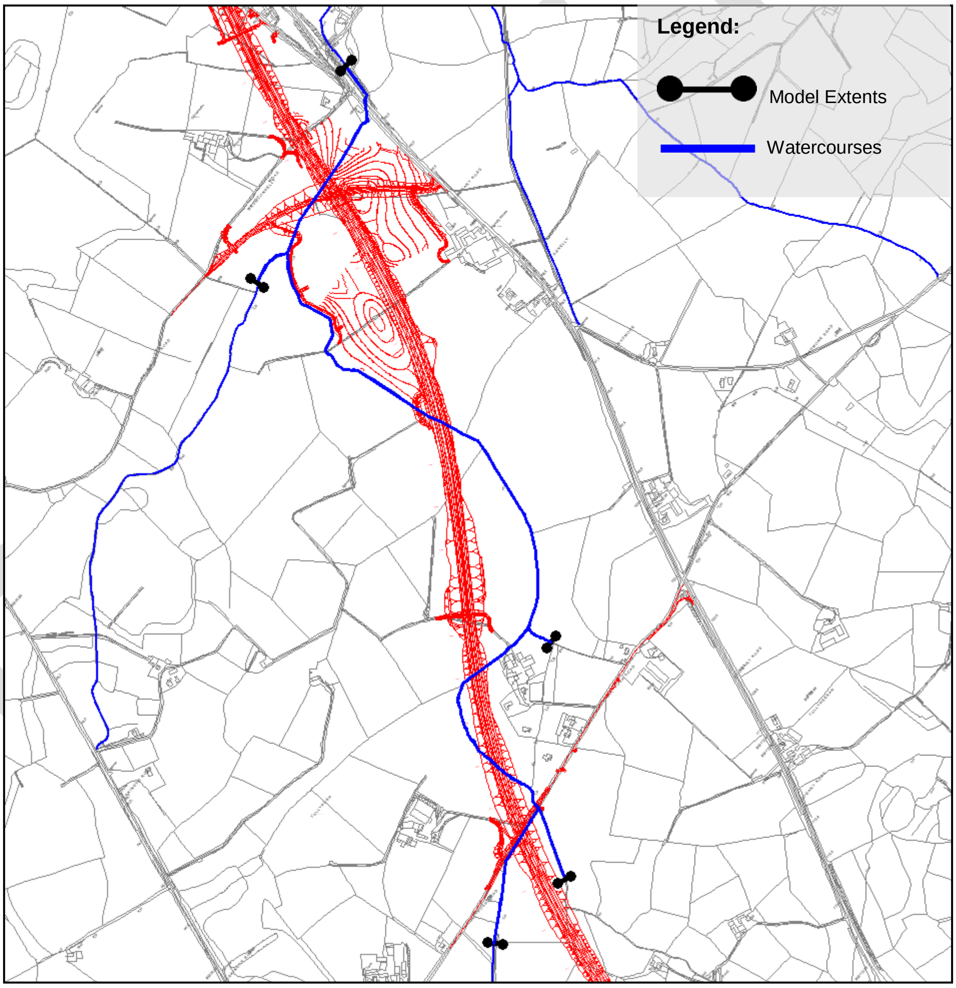


Figure 3.3.1-1 - Model M.L Extents – Ranelly Drain

Three structures have been identified within the extents of the model; twin 900mm diameter pipe culverts at a crossing point for the Tullyrush Road, twin 1.25m diameter pipe culverts at a crossing point for an access track (GR 248331 367303) and at the downstream extents, a 1.5m high by 3.0m wide box culvert at a crossing point for Doogary Road.

The watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. Photographs 3.3.1-1 to 3.3.1-5 below depict the watercourse and some associated structures.

Photograph 3.3.1-1 - Ranelly Drain Typical Channel

Photograph 3.3.1-2 - Ranelly Drain Typical Channel

Photograph 3.3.1-3 – Tullyrush Road Culverts on the Ranelly Drain - (GR 248818 366252)

Photograph 3.3.1-4 – Access Track Culverts on the Ranelly Drain - (GR 248331 367303)

Photograph 3.3.1-5 – Doogary Road Culverts on the Ranelly Drain - (GR 248425 367872)

3.3.2 Model M.M – MW1401 Letfern Watercourse

The Letfern watercourse is located approximately 2km east of the village of Seskinore, in the locality of the junction of Augher Point Road and B46 Moylagh Road. The source of the watercourse is approximately 5.6km southeast in the vicinity of the upland area of Roscavey, at an elevation of approximately 180m.

The Letfernburn Branch is a tributary of the Letfern watercourse. The watercourse discharges to the Seskinore watercourse approximately 2.2km downstream of the Proposed Scheme, in the vicinity of Letfern. In general, the watercourse flows in a westerly direction and the principal upstream land use is agricultural.

Within the study area the watercourse has an approximate channel width, from the top of either bank, of around 4-5m. The average gradient of the watercourse within the study area is approximately 1:200.

Figure 3.3.2-1 below illustrates the proposed model extents. The length of the modelled reach is approximately 2.5km and four structures have been identified within the extents of the model; three structures at crossing points for the Augher Point Road and a bridge under the Moylagh Road. It is noted that only two of the Augher Point Road structures will be included within the model; the third structure being a narrow width flat deck footbridge with no head wall and as such is considered to have no significant hydraulic impact on the watercourse. It is proposed that a 1D model is appropriate for Letfern.

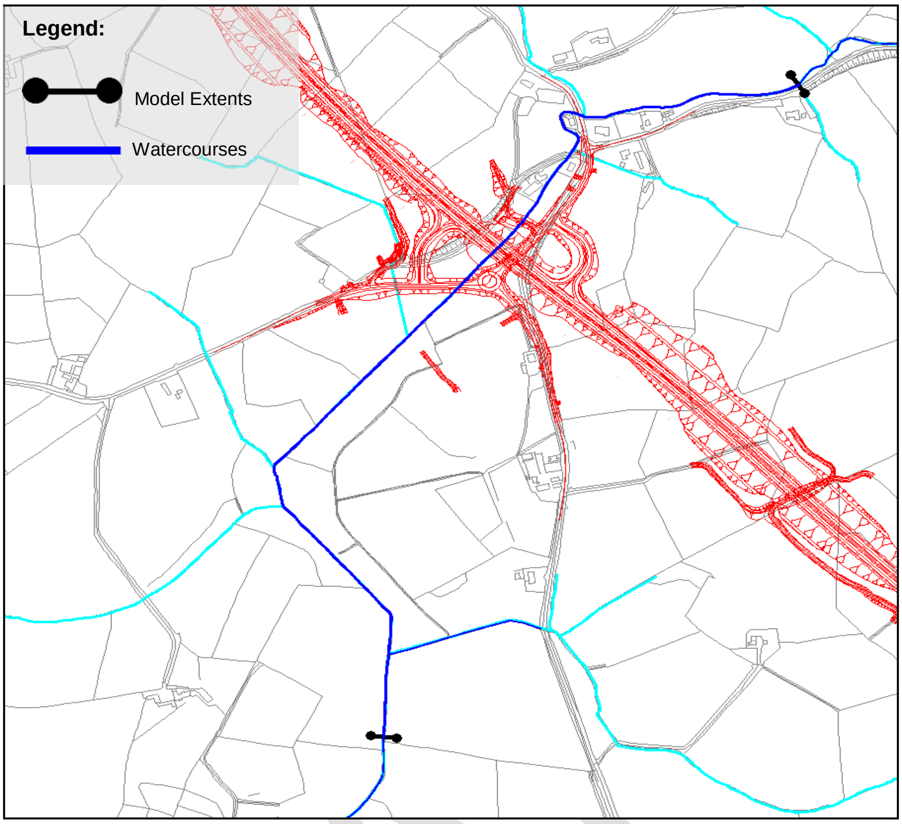


Figure 3.3.2-1 - Model M.M Extents – Letfern Watercourse

The watercourse banks are dominated by shrubs and trees; extending further from the bank the lands are a combination of residential and agricultural grassland. The bed comprises mainly large stones with some smaller stones. Photographs 3.3.2-1 to 3.3.2-3 below depict the watercourse and some associated structures.

Photograph 3.3.2-1 - Augher Road Bridge (North) on the River Letfern - Upstream View (GR 250601, 364275)

Photograph 3.3.2-2 - Moylagh Road Bridge on the River Letfern - Upstream View (GR 250595, 364205)

Photograph 3.3.2-3 - Augher Road Bridge (North) on the River Letfern - Upstream view (GR 250601, 364275)

3.3.3 Model M.N – Undesignated Watercourse (Upstream of MW1402 Letfernburn Branch)

This undesignated watercourse is an upstream tributary of the MW1402 Letfern Burn Branch and is located between the B46 Moylagh Road and Greenmount Road, approximately 2.8km southeast of the village of Seskinore. The source of the watercourse is approximately 1.2km east of the Proposed Scheme crossing, at an elevation of approximately 130m AOD.

The MW1402 Letfernburn Branch is a tributary of the Letfern watercourse. The watercourse discharges to the Letfern watercourse approximately 1.0km downstream of the proposed hydraulic model. In general, the watercourse flows in a westerly direction and the main land use upstream of the Proposed Scheme is agricultural grassland.

Within the study area the watercourse has an approximate channel width, from the top of either bank, of around 2m. The gradient of the watercourse varies through the study area and is approximately 1:37 on the north tributary and approximately 1:48 on the south tributary.

Figure 3.3.3-1 illustrates the proposed model extents. The length of the modelled reach is approximately 380m and it was confirmed that there is one structure within the extents of the model; a 200mm dia pipe on the northern tributary. It is proposed that a 1D model is appropriate for this undesignated watercourse.

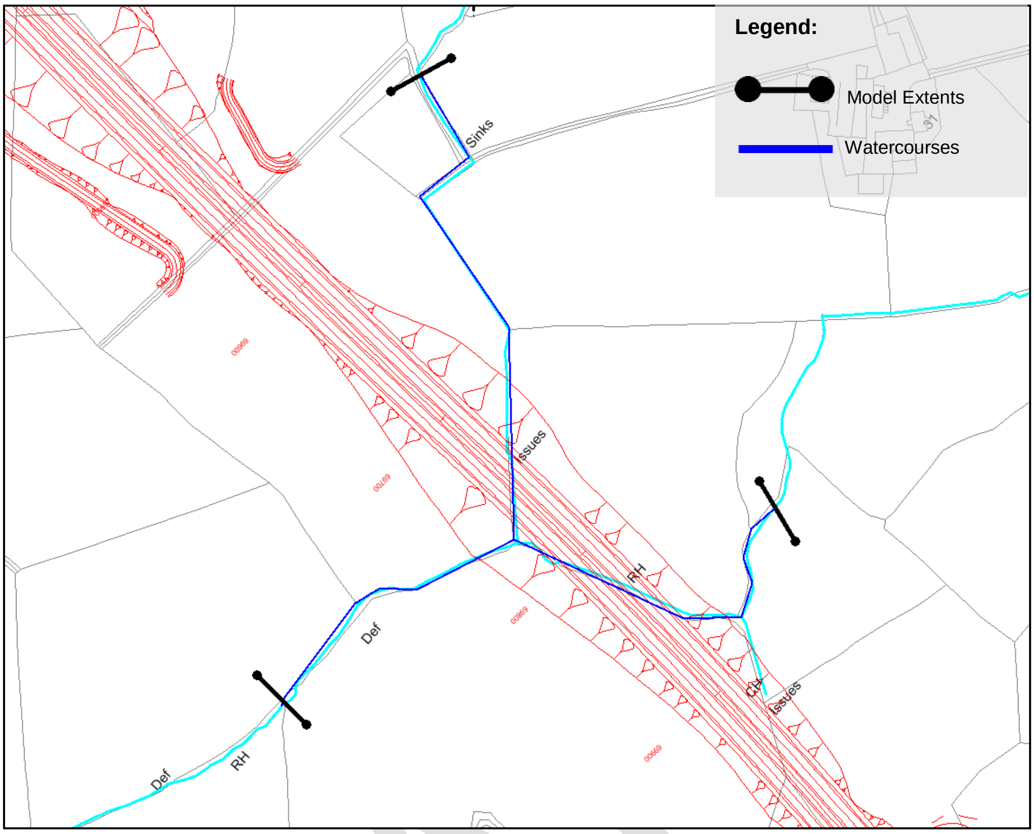


Figure 3.3.3-1 - Model M.N Extents – Undesignated Watercourse

The watercourse banks are dominated by shrubs, trees and agricultural grassland. The bed comprises some small stones and is partially weeded. Photographs 3.3.3-1 to 3.3.3-3 below depict the watercourse and associated structure.

Photograph 3.3.3-1 - Undesignated Watercourse Immediately Downstream of Proposed Scheme Crossing

Photograph 3.3.3-2 - East Tributary of Undesignated Watercourse 600m Upstream of Proposed Scheme Crossing

Photograph 3.3.3-3 – 200mm dia pipe culvert located in the Northern tributary

3.3.4 Model M.O – Undesignated Watercourse

This undesignated watercourse flows in a south-westerly direction and is made up of two tributaries whose confluence is approximately 300m downstream of the crossings with the Proposed Scheme. This watercourse then discharges into Routing Burn approximately 2km downstream. The Proposed Scheme would cross the watercourses at GR 251527, 363014 and 251668, 362840. The two tributaries originate in the hills approximately 1km to the east of the proposed crossings at an approximate elevation of 130m AOD at the source. The area is predominately rural and the main land use is agricultural grassland.

Within the study area each tributary has an approximate channel width, from the top of either bank, of around 1.5m. The gradient of the watercourse varies through the study area and is approximately 1:45 on the north tributary and approximately 1:32 on the south tributary.

Model O is modelled as two separate reaches; the north tributary reach is approximately 230m and the south tributary reach is approximately 390m. Figure 3.3.4-1 below illustrates the proposed model extents. It is proposed that a 1D model is appropriate for this watercourse.

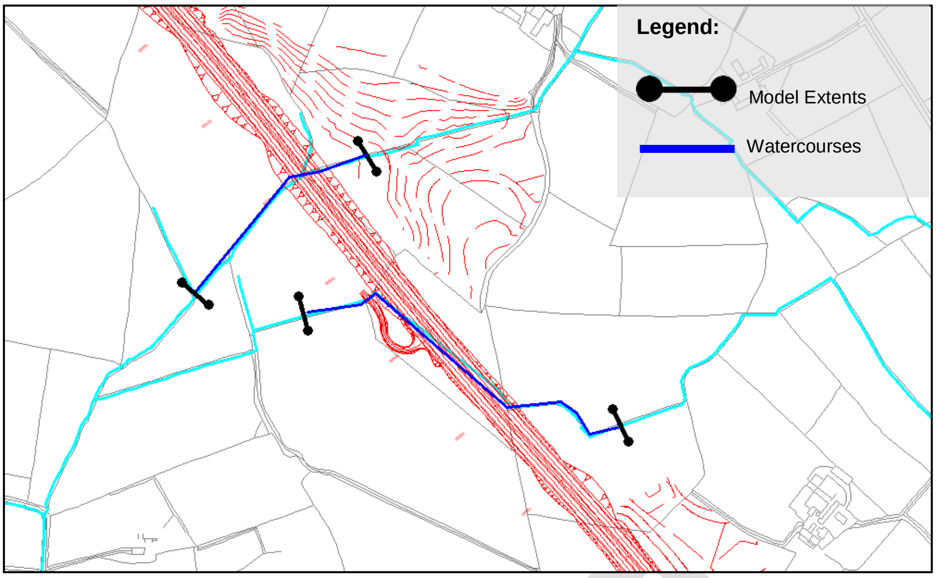


Figure 3.3.4-1 - Model M.O Extents – Undesignated Watercourses

Within the study area the watercourse banks are dominated by weeds, shrubs and trees. Extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep but slightly meandering through the prevailing topography. The bed comprises some stones and is partially weeded. Photographs 3.3.4-1 and 3.3.4-2 below depict the watercourses:

Photograph 3.3.4-1 - North Tributary

Photograph 3.3.4-2 - South Tributary

3.3.5 Model M.P / M.Q - 144 Routing Burn and Undesignated Tributary

The Routing Burn watercourse including, an undesignated tributary, are located in the vicinity of the Greenmount, Killadroy and Routing Burn Roads approximately 2km northwest of the village of Newtownsaville. The source of the Routing Burn watercourse is approximately 8km east in the upland area of Slievedivena / Slievemore, at an elevation of approximately 260m AOD. The undesignated tributary of the Routing Burn drains a small local area, and incorporates areas draining north of Springhill Road.

The Routing Burn combines with the Eskragh and the Agharonan Drain in the vicinity Milltown to form the Seskinore River. In general, the Routing Burn watercourse flows in a westerly direction and the main land use upstream of the Proposed Scheme is agricultural grassland.

Within the study area the Routing Burn has an approximate channel width, from the top of either bank, of around 6m. The gradient of the watercourse varies through the study area but is approximately 1:83.

Figure 3.3.5-1 illustrates the proposed model extents. The length of the proposed modelled reach is approximately 1.3km. Two structures have been identified within the extents of the model; these are small bridges associated with the Killadroy Road where it crosses the undesignated tributary and the Routing Burn watercourse. It is proposed that a 1D model is appropriate for the Routing Burn model.

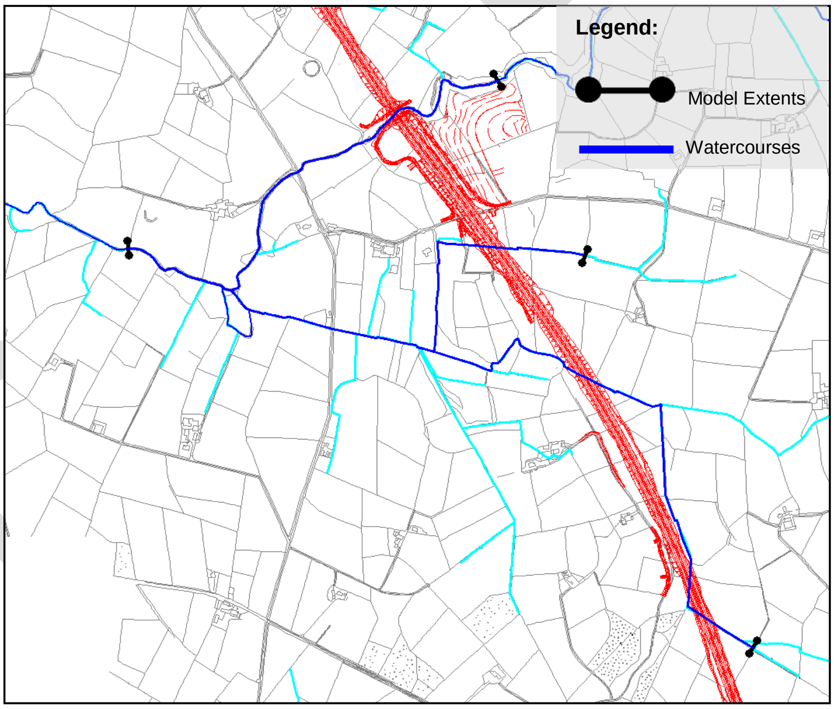


Figure 3.3.5-1 - Model M.P/M.Q Extents – Routing Burn and Undesignated Tributary

The watercourse banks are dominated by grasses, shrubs and small trees, extending further from the bank the land is predominately agricultural grassland. The bed comprises stones and is partially weeded. Photographs 3.3.5-1 to 3.3.5-4 depict the watercourse.

Photograph 3.3.5-1 - Routing Burn at the Location of Proposed Scheme Crossing

Photograph 3.3.5-2 - Routing Burn Downstream of the Existing bridge (approx. 265 m downstream of Proposed Scheme Crossing)

Photograph 3.3.5-3 - Undesignated Watercourse Downstream of Proposed Scheme Crossing (GR 252770, 361230)

Photograph 3.3.5-4 - Undesignated Watercourse at Proposed A5 WTC Scheme (GR 253110, 360600)

3.3.6 Model M.R – Undesignated Watercourse (Newtownsaville)

This undesignated watercourse is located immediately east of Newtownsaville in the vicinity of the Springhill Road.

The source of the undesignated watercourse is approximately 4km south-east in the upland area of Tullanafoile Hill, at an elevation of approximately 185m AOD. The undesignated watercourse discharges to the MW1409 Cormore River in the vicinity of Dunbiggan approximately 2.4km downstream of the Proposed Scheme, which in turn discharges to the MW1408 Eskragh River. In the locality of the Proposed Scheme the undesignated watercourse generally flows in a north-westerly direction and the main land use upstream is agricultural grassland.

Within the study area the undesignated watercourse has an approximate channel width, from the top of either bank, of around 3m, the gradient of the watercourse varies significantly through the study area, from around 1:88 at the upstream extent of the model to 1:420 at the downstream extent of the model.

Figure 3.3.6-1 below illustrates the proposed model extents.

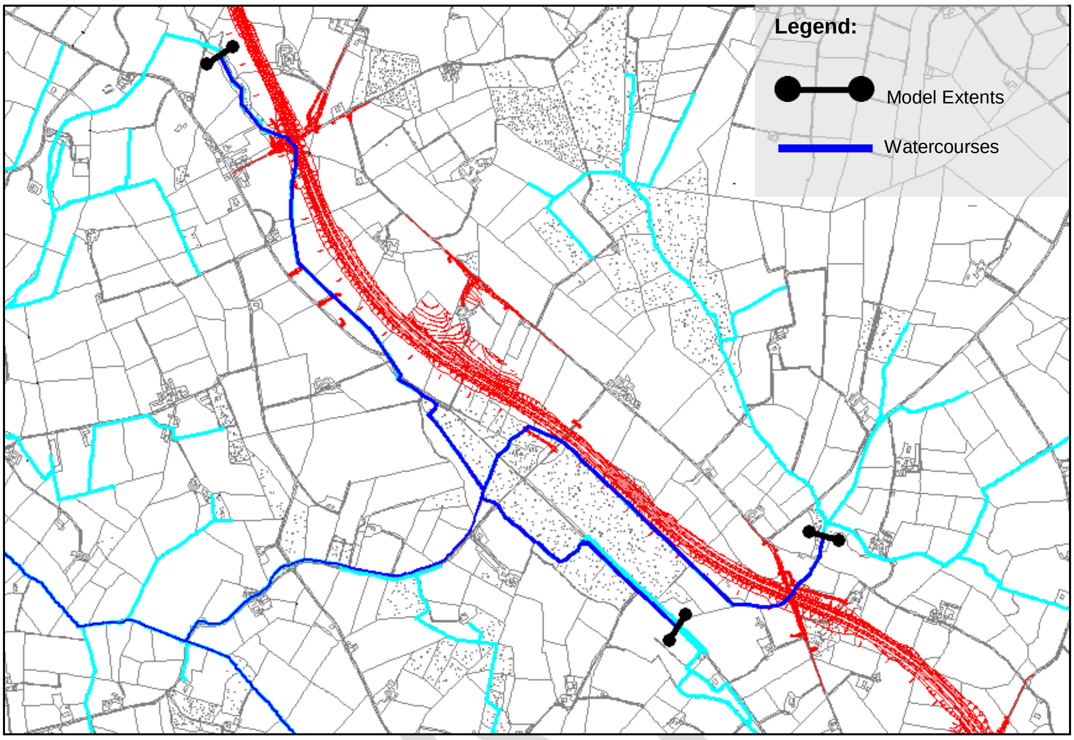


Figure 3.3.6-1 - Model M.R Extents –Undesignated Watercourse

The length of the proposed modelled reach is approximately 1.5 km. There were two structures identified within the extents of the proposed model, these structures comprise single stone arch bridges at crossings associated with the Newtownsaville Road and Springhill Road.

There are also three smaller pipes within the extents of the model. Two existing pipes have been included within our model at GR 254165 359088 and GR 253974. There is also a 900mm diameter pipe at GR 253890, 358820; this pipe has previously been discussed with Rivers Agency and they explained that there have been some flooding issues in the vicinity of this culvert. To be conservative at this stage of the design process, we have assumed this culvert to be completely blocked and our assessment has been based on a worst case scenario.

It is proposed that a 1D is appropriate for this undesignated watercourse.

The watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The bed comprises some small stones and is partially weeded. Photographs 3.3.6-1 and 3.3.6-2 depict the watercourse and associated structures.

Photograph 3.3.6-1 - Culvert under Newtownsaville Road

Photograph 3.3.6-2 - Bridge under Springhill Road

3.3.7 Model M.S – Undesignated Watercourse (Kilgreen)

This undesignated watercourse is located in the vicinity Kilgreen, County Tyrone. The source is approximately 2km north in the upland area associated with Glennageeragh, Tycanny Hill, Rarogan Hill and Black Hill, at an elevation of approximately 210m AOD. The main land use, upstream of the Proposed Scheme, is upland agricultural grassland.

The undesignated watercourse discharges to the Roughan River in the vicinity of Keady, approximately 2.5km downstream of the Proposed Scheme. In the locality of the Proposed Scheme the undesignated watercourse generally flows in a south-easterly direction.

Within the study area the undesignated watercourse has an approximate channel width, from the top of either bank, of around 7m, the gradient of the watercourse varies through the study area, from around 1:8 within its upstream reaches to 1:60 at the downstream reach. In the locality of the Proposed Scheme, the watercourse gradient is approximately 1:40.

Figure 3.3.7-1 below illustrates the proposed model extents. The length of the proposed modelled reach is approximately 2.4km. It is also identified that there are two structures identified within the extents of the proposed model, these structures comprise a single stone arch bridges at the Newtownsaville Road and a culvert under the Tycanny Road.

It was further noted that although no formal structural defences existed within the proposed model extents, raised ground and embankments were evident along the river and where surveyed, these embankments will be included with the model. It is proposed that a 1D model is appropriate for this undesignated watercourse.

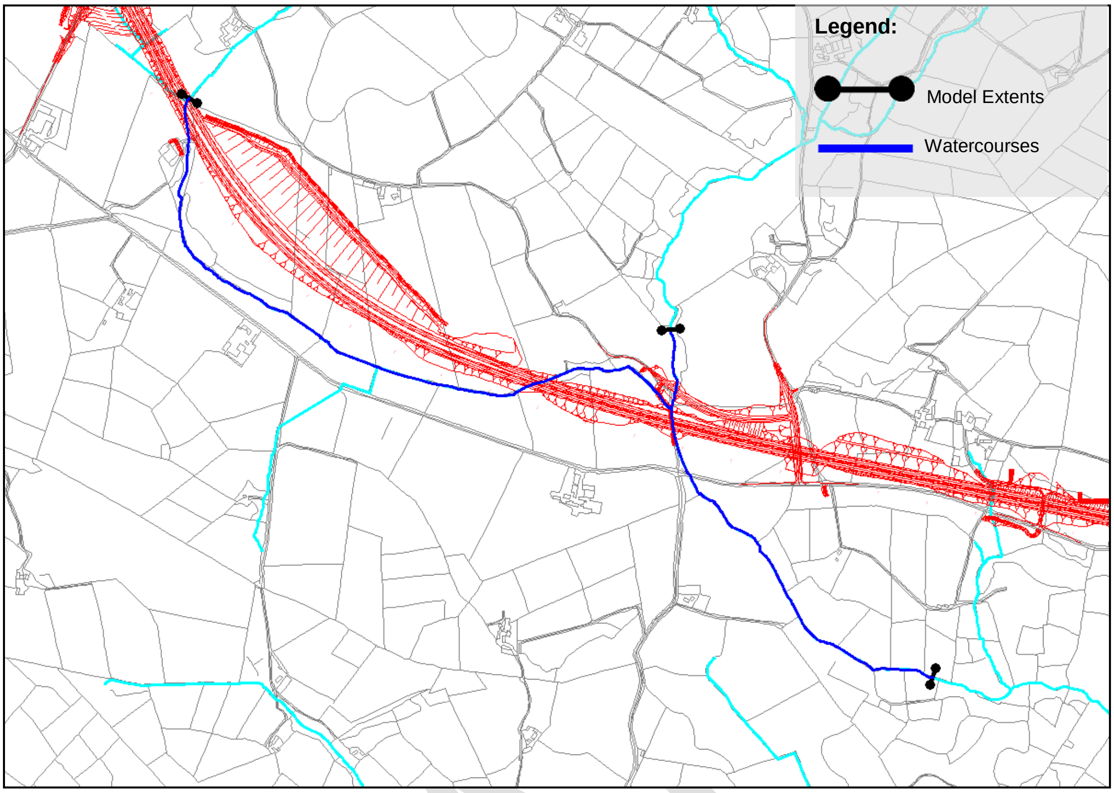


Figure 3.3.7-1 - Model M.S Extents – Undesignated Watercourse

The watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The bed comprises some small stones and is partially weeded. Photographs 3.3.7-1 to 3.3.7-4 below depict the watercourse and associated structures.

Photograph 3.3.7-1 - River Channel Upstream of Tycanny Road Bridge

Photograph 3.3.7-2 - U-Shaped Valley with Grass Pasture Land

Photograph 3.3.7-3 - Tycanny Road Bridge

Photograph 3.3.7-4 - Arch of Newtonsaville Road Bridge

3.3.8 Model M.T – MW4105 Roughan River

The Roughan River is located between Ballynasaggart and Rattling Ford. The source of the river is approximately 5km north in the upland area associated with Slievemore, Knockbrack and Tullyglush, at an elevation of approximately 230m AOD. The main land use, upstream of the Proposed Scheme, is agriculturally grassland but includes the small settlements at Ballynasaggart and Ballymackilroy.

The Roughan River discharges to the Blackwater River in the vicinity of Caldrum, approximately 4.5km downstream of the Proposed Scheme. In the locality of the Proposed Scheme the Roughan River generally flows in a westerly direction.

Within the study area the river has an approximate channel width, from the top of either bank, of around 5-10m. At the source of the river the catchment is relatively steep with an average river bed slope of 1 in 15. The Roughan River then traverses through a 'U' shaped valley which is relatively flat with an average river bed slope gradient being 1 in 70. At the Proposed Scheme crossing, the valley is wide and flat with an approximate bed slope of 1 in 200.

Figure 3.3.8-1 below illustrates the proposed model extents. The length of the proposed modelled reach is approximately 1.9km. It is also identified that there are two structures identified within the extents of the proposed model. These structures comprise a single stone arch bridge with flood relief arch on the left bank at the Ballynasaggart Road and a culvert under the Glenhoy Road.

It was further noted that although no formal structural defences existed within the proposed model extents, raised ground and embankments were evident along the river and where surveyed, these embankments will be included with the model. It is proposed that a 1D model is appropriate for this model.

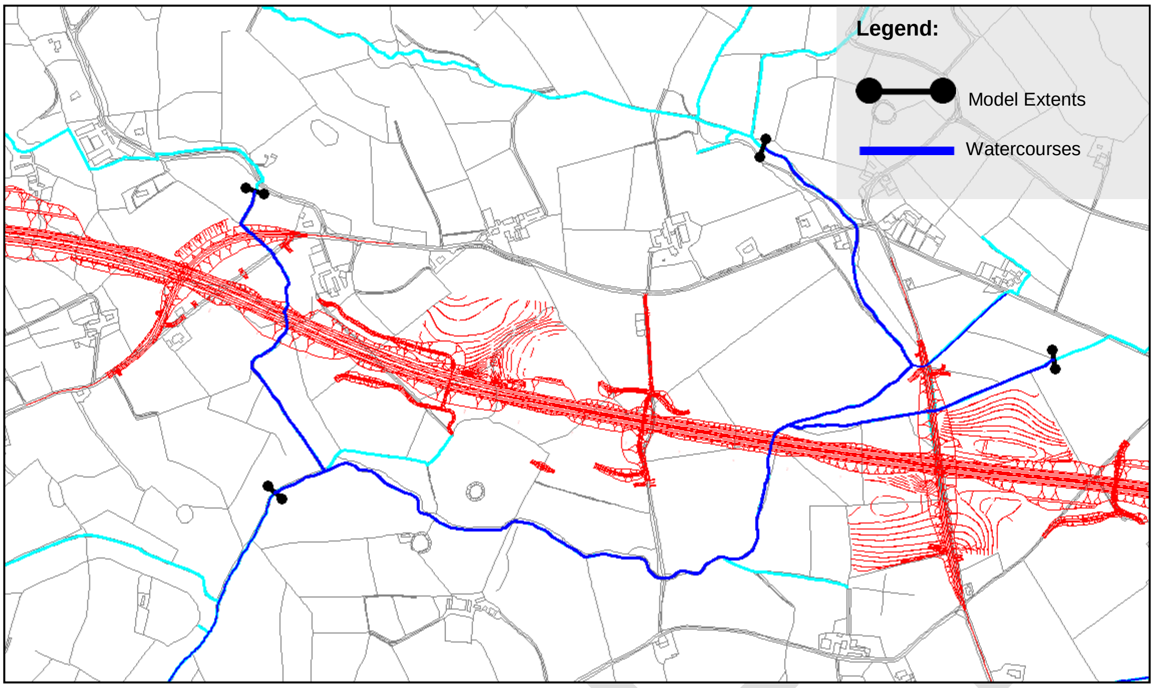


Figure 3.3.8-1 - Model M.T Extents – Roughan River

The watercourse banks are dominated by weeds, shrubs and trees, extending further from the bank the surrounding land is mainly agricultural grassland and residential. The bed mainly comprises large stones and is partially weeded. Photographs 3.3.8-1 to 3.3.8-4 below depict the watercourse and associated structures.

Photograph 3.3.8-1 - U-shaped Valley with Grass Pasture Land and Typical Vegetation Next to Watercourse Along Verge

Photograph 3.3.8-2 – Grassland on Banks of Roughan River and Flood Relief Arch of Ballynasaggart Bridge

Photograph 3.3.8-3 - Ballynasaggart Bridge

Photograph 3.3.8-4 - Arch of Ballynasaggart Bridge

3.3.9 Model M.U – Ballygawley Water

The section of Ballygawley Water in the vicinity of the Proposed Scheme is located between the village of Ballygawley and Lisdoart Bridge.

The source of the Ballygawley Water is located on the Western side of the Eshmore Hill. The catchment area of the watercourse, upstream of the Proposed Scheme, is predominately rural.

The Ballygawley Water ultimately discharges to the River Blackwater at (GR 263116, 352930), approximately 3.3km west of the village of Aughnacloy. In the locality of the Proposed Scheme the Ballygawley Water flows in a southerly direction.

Within the study area the river has an approximate channel width, from the top of either bank, of around 8-12 m. In the area of the Proposed Scheme crossing, the river flows through wide and relatively flat area with an approximate bed slope of 1 in 350.

Figure 3.3.9-1 below illustrates the proposed model extents. The length of the proposed modelled reach is approximately 2km but includes approximately 100m of the Feddan Watercourse which is a tributary of the Ballygawley Water, joining just west of St Ciaran's High School. There are five structures identified within the extents of the proposed model. Three bridges (Tullybryan Bridge, Annaghilla Road Bridge, and Lisdoart Bridge) were identified which will likely exert some hydraulic controls over the modelled reaches. Also, a 900mm culvert underneath Annaghilla Road, and 1.5m culvert underneath Richmond Lane have been identified. An undesignated tributary to the Ballygawley Water has been diverted due to the location of the newly constructed A4 road.

Also, further to the above mentioned, Rivers Agency has completed a flood defence scheme in the locality of Ballygawley. The scheme incorporates improvements to flood defences at Main Street / Grange Road, Ballygawley, from Ballygawley sewage treatment works and St. Ciaran's High School to the Tullybryan Bridge along the Tullybryan Road and at a single site along the Tullybryan Road. The Rivers Agency scheme will be incorporated into the flood model to represent the flood defence scheme.

Other than the above mentioned defences, raised ground and some smaller flood embankments were evident along some sections of the river. Due to the extent of the known floodplains, the existence of some small embankments and the potential for the A5 WTC alignment to sit, in part, within these floodplain extents, it is proposed that a 1D/2D model is appropriate for the Ballygawley Water.

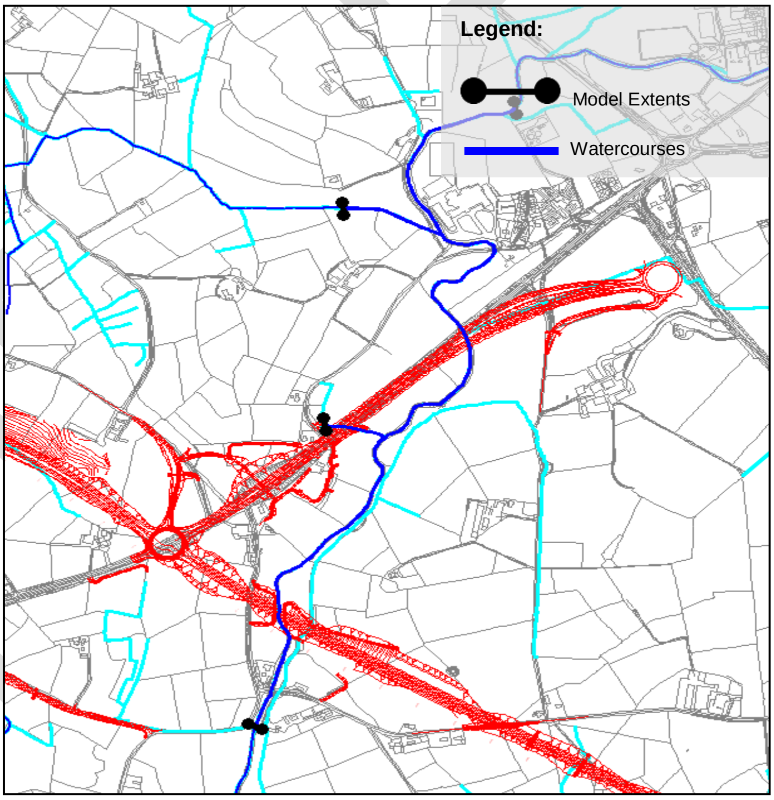


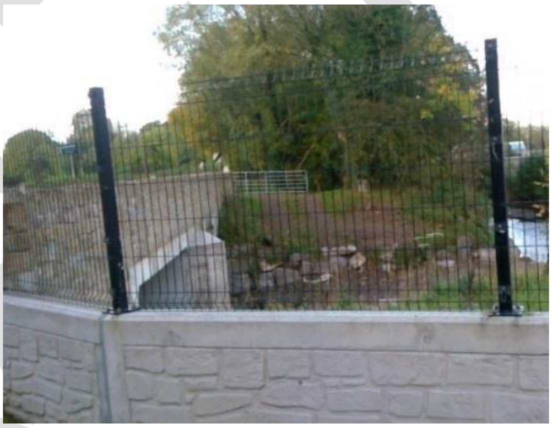
Figure 3.3.9-1 - Model M.U Extents – Ballygawley Water

The watercourse banks are dominated by weeds, shrubs and trees, extending further from the bank the surrounding land is mainly agricultural grassland. The bed mainly comprises some stones, gravel and is partially weeded. Photographs 3.3.9-1 to 3.3.9-6 below depict the watercourse and associated structures.

Photograph 3.3.9-1 - Grass Pasture Land and Typical Vegetation Upstream of Annaghilla Road Bridge

Photograph 3.3.9-2 - Tullybryan Road Bridge

Photograph 3.3.9-3 - Tullybryan Road Bridge adjacent flood defences



Photograph 3.3.9-4 - Tullybryan Road Bridge upstream flood defences

Photograph 3.3.9-5 - Annaghilla Road Bridge

Photograph 3.3.9-6 - 900 mm Culvert Underneath Annaghilla Road

Photograph 3.3.9-7 - Grass Pasture Land and Typical Vegetation Upstream of Lisdoart Bridge

Photograph 3.3.9-8 - Lisdoart Bridge

3.3.10 Model M.V – MW4230 Tullyvar Drain

The Tullyvar Drain is a designated watercourse located between Cavankilgreen and the Lismore Bridge near the Lisginny Road.

The source of the watercourse is approximately 2.7km northeast at the base of the upland area associated with Ivy Hill and the Burnt Hill, at an elevation of approximately 130m AOD. The main land use, upstream of the Proposed A5 scheme, is agricultural grassland.

The Tullyvar Drain discharges to the Ballygawley River approximately 1.8km downstream of the Proposed Scheme. In the locality of the Proposed Scheme the watercourse generally flows in a westerly direction.

Within the study area the river has an approximate channel width, from the top of either bank, of around 1.5 – 2m. The average gradient of the watercourse within the study area is around 1:350.

The watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep but slightly meandering through the prevailing topography. The bed comprises some small stones and is partially weeded. Photographs 3.3.10-1 to 3.3.10-4 below depict the watercourse.

Photograph 3.3.10-1 - Tullyvar Drain and Surrounding Grassland

Photograph 3.3.10-2 - Tullyvar Drain in Vicinity of Proposed Scheme

Photograph 3.3.10-3 - Tullyvar Drain

Photograph 3.3.10-4 - Tullyvar Drain

Following initial site visits to assess the watercourse and identify potential model extents; access restrictions in the vicinity of the Tullyvar Drain prevented direct access to the watercourse and the collection of cross-sectional survey data by topographical survey staff.

Review of aerial photography and OS mapping for the proposed model identified that there were no structures or flood defences within the extents of the proposed model. As no watercourse cross-sectional data is currently available for the Tullyvar Drain it is proposed that a 2D model is appropriate for this watercourse, based on LiDAR data. This is considered a robust and conservative approach in the absence of survey data. The length of the proposed modelled reach is approximately 1.5km. Figure 3.3.10-1 below illustrates the proposed model extents.

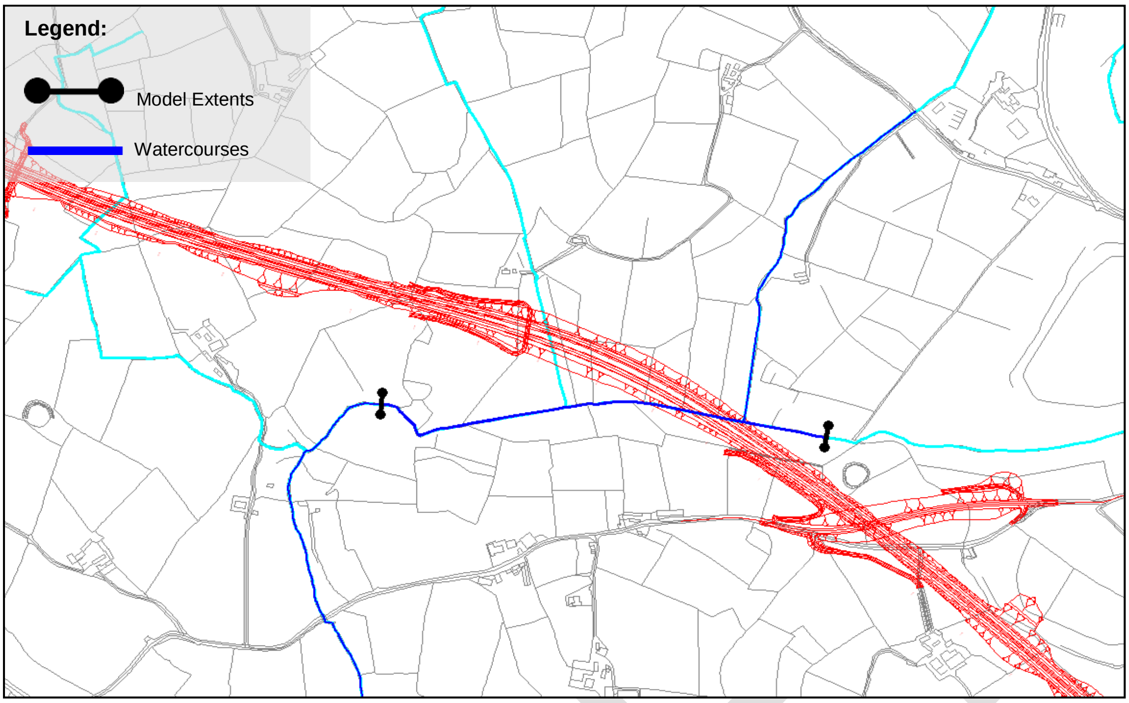


Figure 3.3.10-1 - Model M.V Extents – Tullyvar Drain

3.3.11 Model M.W – MW4226 Ravella Drain

The Ravella Drain is a designated watercourse located near Lissenderry between the A5 Tullyvar Road and the A28 Favor Royal Road.

A number of undesignated tributaries combine to form the Ravella Drain. Upstream of the Proposed Scheme the watercourse originates in the vicinity of Cavankilgreen, at an elevation of approximately 90m. The main land use, upstream of the Proposed Scheme, is agricultural grassland. In the locality of the Proposed Scheme the land type is predominately marshland.

The Ravella Drain discharges to the River Blackwater approximately 3.5km downstream of the Proposed Scheme. In the locality of the Proposed Scheme the watercourse generally flows in a southerly direction.

Within the study area the river has an approximate channel width, from the top of either bank, of around 2m. The gradient of the watercourse varies through the study area, from around 1:33 upstream of the Proposed Scheme to 1:125 downstream. Figure 3.3.11-1 below illustrates the proposed model extents. The length of the proposed modelled reach is approximately 325m. No structures were identified within the extents of the proposed model. It is proposed that a 1D model is appropriate for this watercourse.

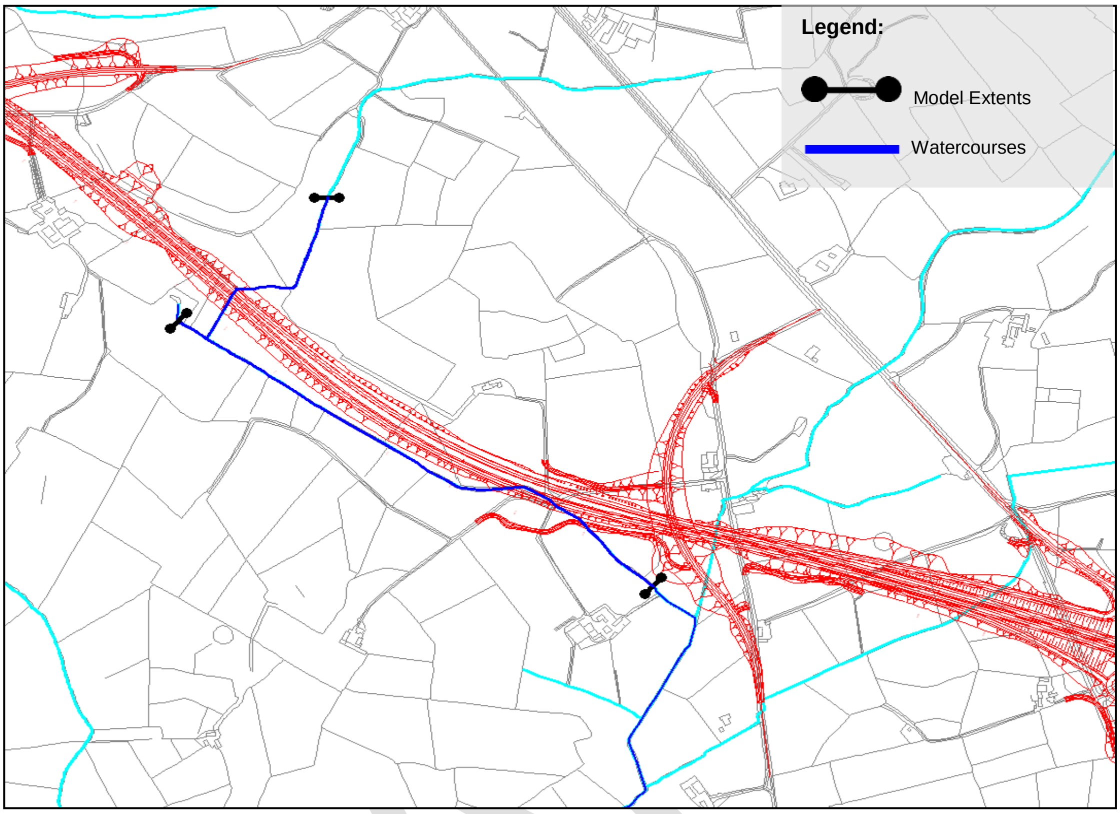


Figure 3.3.11-1 - Model M.W Extents – Ravella Drain

The watercourse banks are dominated by weeds, shrubs and trees, extending further from the bank the land are predominately agricultural grassland. Photographs 3.3.11-1 to 3.3.11-3 depict the watercourse:

Photograph 3.3.11-1 - Right Bank of Ravella Drain at Proposed Scheme Location

Photograph 3.3.11-2 - Ravella Drain at Proposed Scheme Location

Photograph 3.3.11-3 - Surrounding Land at Ravella Drain

3.3.12 Model M.X – Undesignated Watercourse (Upstream Tributary of MW4201 Ext Aughnacloy Urban Ext)

This undesignated watercourse is located in the vicinity of Glack, approximately 1.2km north of Aughnacloy.

The watercourse generally flows in a southerly direction towards Aughnacloy and becomes the designated Aughnacloy Urban Extension approximately 500m south of the Proposed Scheme.

The watercourse originates in the in the upland area associated with the Burnt Hill, at an elevation of approximately 160m. The main land use, upstream of the Proposed Scheme, is agricultural grassland.

The Aughnacloy Urban Extension discharges to the Aughnacloy River approximately 1.6km downstream of the Proposed Scheme at the town of Aughnacloy.

Within the study area the river has an approximate channel width, from the top of either bank, of around 3.5 m. The gradient of the watercourse varies through the study area, from around 1:57 upstream of Glack to 1:63 downstream of Glack.

Figure 3.3.12-1 below illustrates the proposed model extents. The length of the proposed modelled reach is approximately 440m. No structures were identified within the extents of the proposed model.

It is proposed that a 1D model is appropriate for this watercourse

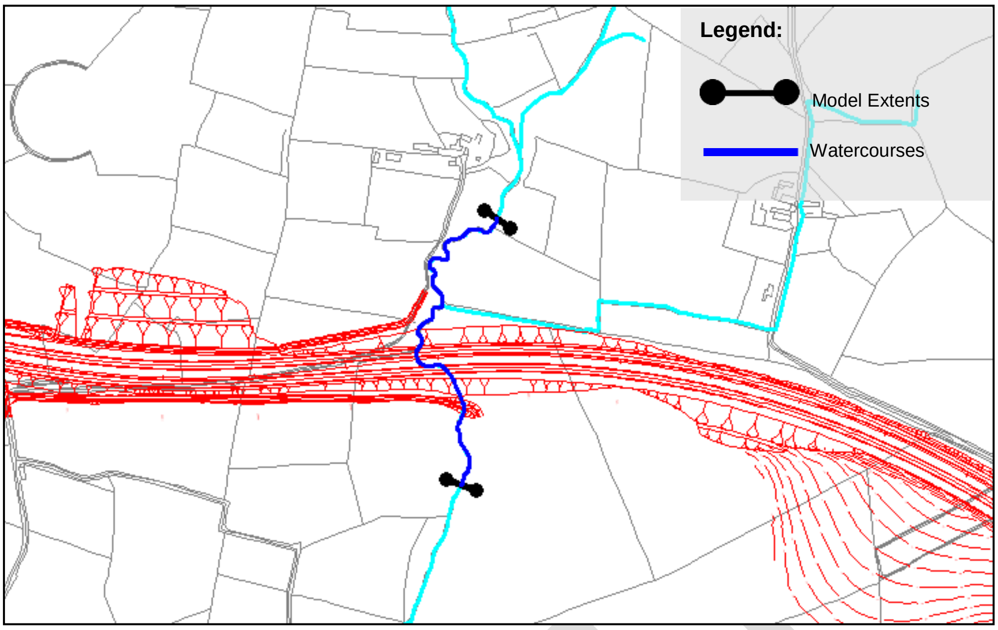


Figure 3.3.12-1 - Model M.X Extents – Undesignated Watercourse

The watercourse banks are dominated by weeds, shrubs and a few isolated trees, extending further from the bank the land is predominately agricultural grassland. The watercourse channel is relatively steep but slightly meandering through the prevailing topography. The bed comprises some small stones and is partially weeded. Figures 3.3.12-1 to 3.3.12-4 depict the watercourse.

Photograph 3.3.12-1 Undesignated Watercourse (Upstream Tributary Aughnacloy Urban Extension)

Photograph 3.3.12-2 Undesignated Watercourse (Upstream Tributary Aughnacloy Urban Extension)

Photograph 3.3.12-3 Undesignated Watercourse (Upstream Tributary of Aughnacloy Urban Extension)

Photograph 3.3.12-4 Undesignated Watercourse (Upstream Tributary of Aughnacloy Urban Extension), Surrounding Banks Area

3.3.13 Model M.Y – MW4222 Lisadavil River

The Lisadavil River is located east and south of the town of Aughnacloy. The river generally flows in a south-westerly direction towards Aughnacloy and becomes the Aughnacloy River at Aughnacloy. A number of undesignated tributaries combine to form the Lisadavil River.

The river originates in the upland area and valley areas associated with the Burnt Hill and Kenaghy Mountain, at an elevation of approximately 150m AOD.

Within the study area it is identified that there is a main river reach and two tributaries. The predominant land use is agricultural grassland. Tributaries combine with the river north and south of the main channel. The Lisadavil River / Aughnacloy River discharges to the River Blackwater south-west of Aughnacloy.

Within the study area the main river has an approximate channel width, from the top of either bank, of around 4m. The gradient of the watercourse is approximately 1:100.

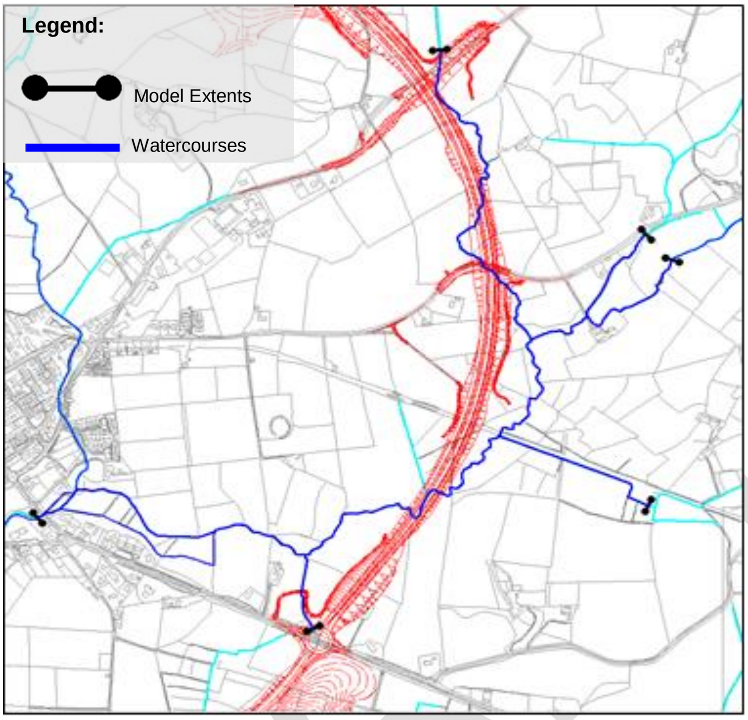


Figure 3.3.13-1 - Model M.Y Extents – Lisadavil River

Figure 3.3.13-1 illustrates the proposed model extents. The length of the proposed modelled reach is approximately 4.5km. Site inspections further identified that there are five structures within the proposed model extents. Three structures were identified along the main channel; a stone masonry spring arch at Carnteel Road, a stone masonry arch at Rehaghy road and a concrete box culvert at Monaghan Road. A brick masonry bridge crosses the northern tributary at a field access track and a stone masonry arch crosses the southern tributary at a field access track. Due to the anticipated extent of the floodplains and potential for the A5 WTC alignment to sit, in part and obliquely, within these floodplain extents, it is proposed that a 1D/2D model is appropriate for the Lisadavil River.

The watercourse banks are dominated by weeds, shrubs and some trees, extending further from the bank the land is predominately agricultural grassland. The bed comprises some stones and is partially weeded. Photographs 3.3.13-1 to 3.3.13-7 depict the watercourse and associated structures.

Photograph 3.3.13-1 - Lisadavil River Upstream of Proposed Scheme

Photograph 3.3.13-2 - Lisadavil River Downstream of the Proposed Scheme

Photograph 3.3.13-3 - Main Channel Stone Masonry Spring Arch at Carnteel Road

Photograph 3.3.13-4 - Main Channel Stone Masonry Arch at Rehaghy Road

Photograph 3.3.13-5 - Main Channel Concrete Culvert at Monaghan Road

Photograph 3.3.13-6 - North Tributary Brick Masonry Bridge at Field Access Track

Photograph 3.3.13-7 South Tributary Stone Masonry Arch at Field Access Track

4 Model Data Collection

The following section provides a summary of the data collected to undertake hydraulic modelling for the Proposed Scheme.

Flood Risk Assessment (FRA) Report 1 – Assessment Parameters and Preliminary Flood Risk Assessment, provides details of all data collected pre hydraulic model development to identify likely sources of flooding and determine flood risk assessment requirements, this information includes:

- Consultations with statutory bodies including Rivers Agency, Transport NI, NI Water, Loughs Agency and Londonderry/Derry Port and Harbour Commissioners,
- Field work assessments,
- Historical flooding data,
- Drift geology mapping,
- Detailed aerial surveys
- Existing flood risk assessments / models.

FRA Report 1 also identifies data utilised for preliminary floodplain identification and hydraulic modelling requirements.

The following provides specific information in relation to the collation of watercourse cross-sectional data, survey of model structures (bridges, culverts, flap valves, etc) and miscellaneous information pertaining to hydraulic models.

4.1 Survey Methods and Equipment

Watercourse cross sections and structures for flood modelling were surveyed primarily using a combination of Global Position System (GPS) and Total Station, with control being provided by GPS. Manual measurements using tapes and staffs were also undertaken to record dimensions of structures. Reflectorless Total Station was used to survey large structures or in locations where access proved difficult.

Where required river channels were surveyed using a small boat with GPS onboard and depths recorded using a staff. With regards to deeper stretches of water, depths were recorded using an Acoustic Doppler Current Profiler combined with onboard GPS where appropriate.

Cross section locations were confirmed on site using plans and drawings and by setting out known co-ordinates.

4.2 Surveyed Detail

Watercourse cross sections and structures were surveyed according to briefs supplied by in-house flood modelling specialists. Site visits were used to establish the optimum survey method for various rivers and site conditions.

Cross sections were surveyed from left to right banks (facing downstream) and labelled accordingly. The top and bottom of banks of the channel at each cross section were surveyed carefully to reflect the general nature of the watercourse.

The cross sections were surveyed perpendicular to the direction of flow. All significant features across the flood plain and main channels were surveyed.

In some places, it was necessary to slightly relocate some cross sections due to site obstructions or land access agreements/restrictions; this was achieved through consultation with the relevant flood modelling specialist.

Relevant structures along the watercourse, such as bridges or culverts, were surveyed in detail. A full cross section was taken immediately upstream and downstream of the structure. The soffits, springing and deck levels were surveyed for each structure on both the upstream and downstream face, as well as any abutments or parapets present. Invert and crown levels were taken at culverts.

4.3 Data Processing

Completed surveys were downloaded from the instruments and processed where necessary using N4ce, Geosite or Trimble Geomatics Office survey software. Data was also exported to Mapinfo GIS software to check content and quality.

Data was delivered to flood modelling teams in the requested format, usually in Excel spreadsheets with accompanying drawings, sketches and photographs to illustrate structures. MapInfo tables were also provided showing all topographical information gathered on site.

4.4 Specification and Accuracy

Detail was surveyed to sufficient accuracies to represent site conditions as faithfully as possible. Good survey practice was followed when recording detail and establishing control. Redundancy of data was maintained where possible and tie points were surveyed with GPS to confirm reliability of data. Real time quality control measures, such as a cut off mask, coupled with extended observation times were used to improve the relative accuracy of surveyed points.

Traverses and check shots taken using total station were required to gain accuracies of 15mm in plan and 25mm in height, but accuracies greater than this were routinely achieved.

GPS was used in both Real Time Kinematic (RTK) and Network Real Time Kinematic (NRTK) modes. Achievable accuracies are approximately 10-20mm horizontally and 15-30mm vertically for NRTK and slightly better than this using RTK and post processing with OS Rinex data.

4.5 Co-ordinate and Reference System

Data was translated as necessary between global and local datums. It should be noted that surveys extend across the Irish border in several areas, requiring the use of different Geoid Models to provide orthometric heights.

All survey points were ultimately referenced in Irish Grid to Ordnance Datum Belfast Lough.

4.6 LiDAR Data

DTM/LiDAR data typically supplements surveyed data in floodplain areas (saving time and cost) and is typically used for flood mapping purposes. It is also used where floodplains are modelled in 2D as the key component of any 2D model is a detailed 3D ground model.

DTM / LiDAR data was gathered from a number of sources to cover the areas of interest and the accuracies vary for the particular data used. The ground model data sets used were:

- A5 WTC procured DTM Data
    - 10m grid,
    - general vertical accuracy +/- 1000mm
- A5 WTC procured LiDAR Data (filtered)
    - 2m grid
    - soft ground vertical accuracy +/- 70mm
    - hard ground vertical accuracy +/- 35mm
- Rivers Agency Strabane LiDAR data
    - 1m grid,
    - vertical accuracy +/- 100mm
- NEXTMap Ireland IfSAR DTM
    - 5m grid,

  - vertical accuracy +/- 500mm

- National Roads Design Office (Donegal) Contour Data
  - vertical accuracy +/- 250mm

5 Catchment Analysis and Design Flows

The following section provides a summary of the catchment details for the identified watercourses and the associated hydrological analyses as part of this study.

5.1 Hydrological Assessment

Hydrological assessments were undertaken based primarily on Flood Estimation Handbook (FEH) techniques, OS mapping, and DTM data. The appropriate hydrological catchments for the various modelled watercourses were identified.

The industry standard Flood Estimation Handbook (FEH) provides two main approaches to flood frequency estimation: the statistical analysis of peak flows, and the rainfall-runoff method. Where applicable, a hybrid method may also be used. The methods were utilised as appropriate and more information is available as required.

For the purposes of design flow estimation, no reliance has been placed upon any restrictions caused by upstream structures. This is considered a robust and conservative approach as it is possible that during extreme storm events any upstream structures which may currently serve to restrict flows could be overtopped and bypassed.

The FEH Statistical Approach uses QMED as the 'index flood' which is the median of the annual maxima and has a return period of 1:2, or a '2 year' event. Where the Statistical Approach is used QMED (2yr) is typically cited. Where the Rainfall Runoff method is utilised, QBAR (mean annual flood) has been used; referred to as the 'annual' return period. The frequency of the mean annual flood is 1/2.33.

Where climate change is added to the 100 year flow for the purposes of the sensitivity checks, this is an uplift of the flow value by 20%, in accordance with current guidance.

5.1.1 Rainfall-Runoff Method

The Rainfall Runoff Method converts rainfall input into a flow output using a model of catchment response. Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model. The three main parameters in the model are unit hydrograph time to peak, percentage runoff and base-flow. FEH software generates descriptors for any catchment in the UK of greater than $0.5km^2$. Where catchments sizes are relatively small (and thus poorly represented in the FEH gauge database) and/or no gauged data exists, the Rainfall Runoff Method is typically the most appropriate method.

5.1.2 Statistical Approach

The Statistical Approach is generally the first choice method where there are long records of gauged floods at or near the site of interest and utilises the FEH WIN-FAP software suite. The Statistical Approach is more suited to larger catchments as the concept of a catchment wide design storm becomes less realistic the larger the catchment.

The Statistical Approach consists of two main stages; the estimation of the index flood (QMED) and the derivation of a growth curve that is applied to the QMED value to estimate higher return period flows.

The following summarises the typical key steps followed using the FEH Statistical Approach:

- QMED is either calculated using recorded flows for gauged catchments or estimated from FEH catchment descriptors for ungauged catchments. If using ‘donor’ catchments to inform QMED estimation, these should ideally be located within the same catchment and the catchment area should not differ by more than a factor of 5.WINFAP-FEH software is used to calculate a growth curve that is applied to the QMED estimate for a site to define higher return period flows.

- A ‘single site’ growth curve analysis is carried out but the results from this exercise should not be used to derive flows for return period events exceeding the record period

- A ‘pooling group’ analysis is undertaken to derive a growth curve to estimate flows for higher return periods. Pooling groups are constructed in WINFAP-FEH and contain hydrologically similar sites to the site of interest. Pooling groups are created for the 100 year return period, therefore, stations with a total record length of 500 years are selected (i.e. 5 times the target return period). The stations comprising the pooling group are carefully analysed in order to remove stations with:

    - FARL values (FEH index of flood attenuation due to reservoirs and lakes) smaller than 0.95.

    - URBEXT 2000 values (FEH catchment descriptor defining urban extent) greater than 0.03.

    - SPRHOST values (standard percentage runoff based on HOST soil types) less than 20

    - High discordancy due to other stated reasons.

- The heterogeneity of the pooling group is also checked in order to obtain as homogeneous a group as possible.

- The growth curve derived using the pooling group is applied to the QMED value for the site of interest to estimate flows for a range of return periods. Where no acceptable distribution / 'goodness of fit' can be obtained from the pooling group then the Statistical Approach is not considered suitable.

5.1.3 FEH Hybrid Method

Where full flow hydrographs are required rather than just the peak flow value (such as 2D models), a hybrid FEH method has been used. This is where the hydrograph generated using the Rainfall-Runoff Method is scaled to fit the peak derived from the Statistical Approach, i.e. a combination of FEH statistical and rainfall runoff techniques has been utilised:

- FEH Rainfall Runoff method with the catchment descriptors from the FEH CD-ROM will be used to produce full hydrographs (in conjunction with the ISIS FEH software module) for the following range of return periods; the 100 year is the 'design' return period utilised for the flood risk assessment whilst the annual, 25 year, 100 year + climate change were utilised for sensitivity checks.

- FEH statistical pooling group analyses were undertaken with the FEH WINFAP software to determine the peak flow estimates for a range of return periods.

- The FEH Rainfall Runoff Method provides the shape of the hydrograph with it then scaled to match the peak flow obtained through the FEH Statistical Approach.

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5.2 Section 1 – Catchment Analysis and Design Flows

5.2.1 Model M.A – MW1127 Gortin Hall Drain

Catchment Details

The Gortin Hall Drain is defined within FEH software and is a tributary of the River Foyle. The hydrological catchment of the Gortin Hall Drain to the point GR 239825, 411371 covers an area of approximately 3.4 km^2

Hydrological Data

At the time of this assessment no recorded flow data was available for the Gortin Hall Drain.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for the Gortin Hall Drain. Peak design flows were estimated for one location at the model downstream extents. Figure 5.2.1-1 and Table 5.2.1-1 below shows the hydrological catchment boundary and a summary of the estimated design flows.

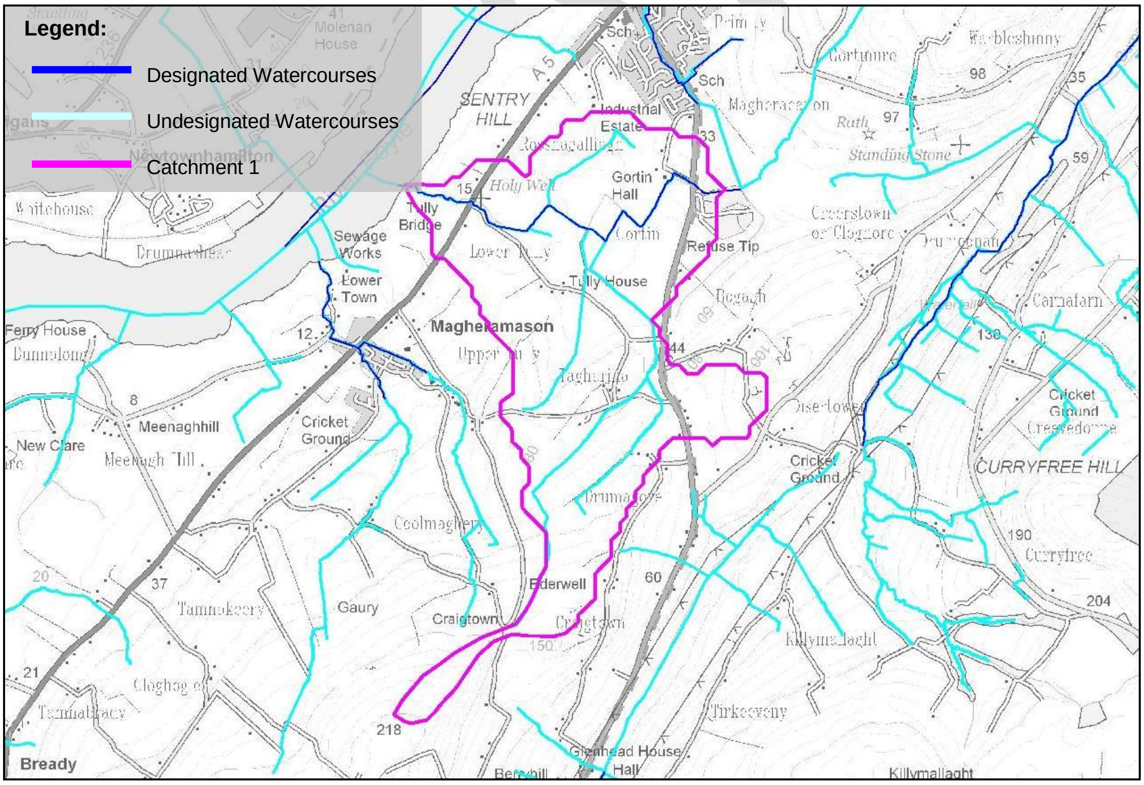

Figure 5.2.1-1 - Model M.A Gortin Hall Drain - Hydrological Catchment Outline

Table 5.2.1-1- Model M.A MW1127 Gortin Hall Drain Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	3.44	1.42	3.19	4.58	5.49

5.2.2 Model M.B – U21109 Blackstone Burn

Catchment Details

The Blackstone Burn is defined within FEH software. For assessment purposes, design flows have been estimated for four sub-catchments within the model extents. The hydrological catchment of the Blackstone Burn, to the point GR 239261 410835 is approximately 3.11km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for the Blackstone Burn.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for the Blackstone Burn. Peak design flows were estimated for four locations within the local study extents. Figure 5.2.2-1 and Table 5.2.2-1 shows the four hydrological sub-catchment boundaries and a summary of the estimated design flows.

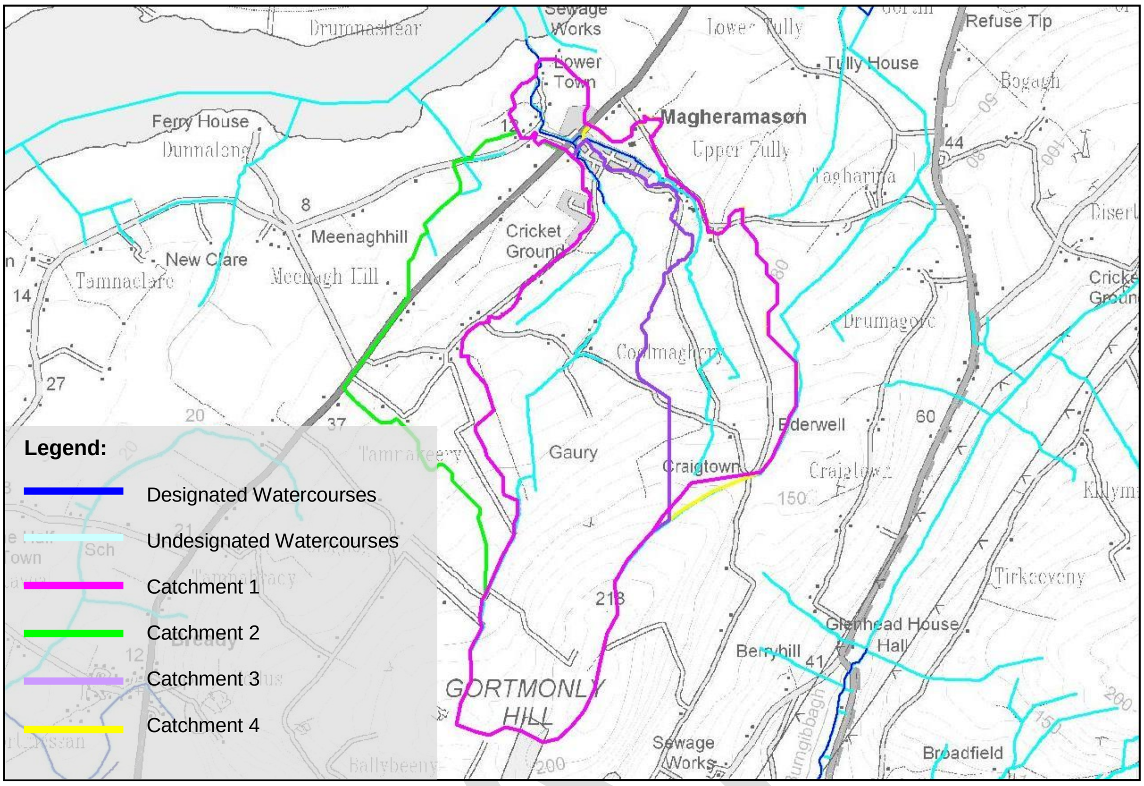

Figure 5.2.2-2 - Model M.B Blackstone Burn - Hydrological Catchment Outline

Table 5.2.2-1- Model M.B U21109 Blackstone Burn Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	3.11	1.74	3.93	5.68	6.82
2	1.08	0.74	1.76	2.52	3.02
3	0.89	0.52	1.18	1.71	2.06
4	2.08	1.23	2.80	4.04	4.84

5.2.3 Model M.1, M.2 and M.3 – Foyle River System (including River Foyle, River Mourne, River Finn, Ballymagorry, Burn Dennet, Deele River, Swilly Burn)

This section provides a short summary of the hydrological catchment analysis and design flow estimation in relation to the Foyle River System model; further details with regards to this model can be seen in in document *718736/0500/R/004 Draft Model Build and Hydrology Report – Foyle River System.*

Catchment Details

The principal hydrological catchments contributing to the Foyle system are listed in Table 5.2.3-1 and Figure 5.2.3-1 illustrates the catchment areas of the principal rivers comprising the Foyle system.

Table 5.2.3-1 - Key Foyle System River Catchments

Watercourse	Catchment Size (km^2)
River Foyle	2895
River Mourne	1961
River Finn	495
Glenmornan	31
Burn Dennet	147
Deele River	133
Swilly Burn	58
Liberly River	44

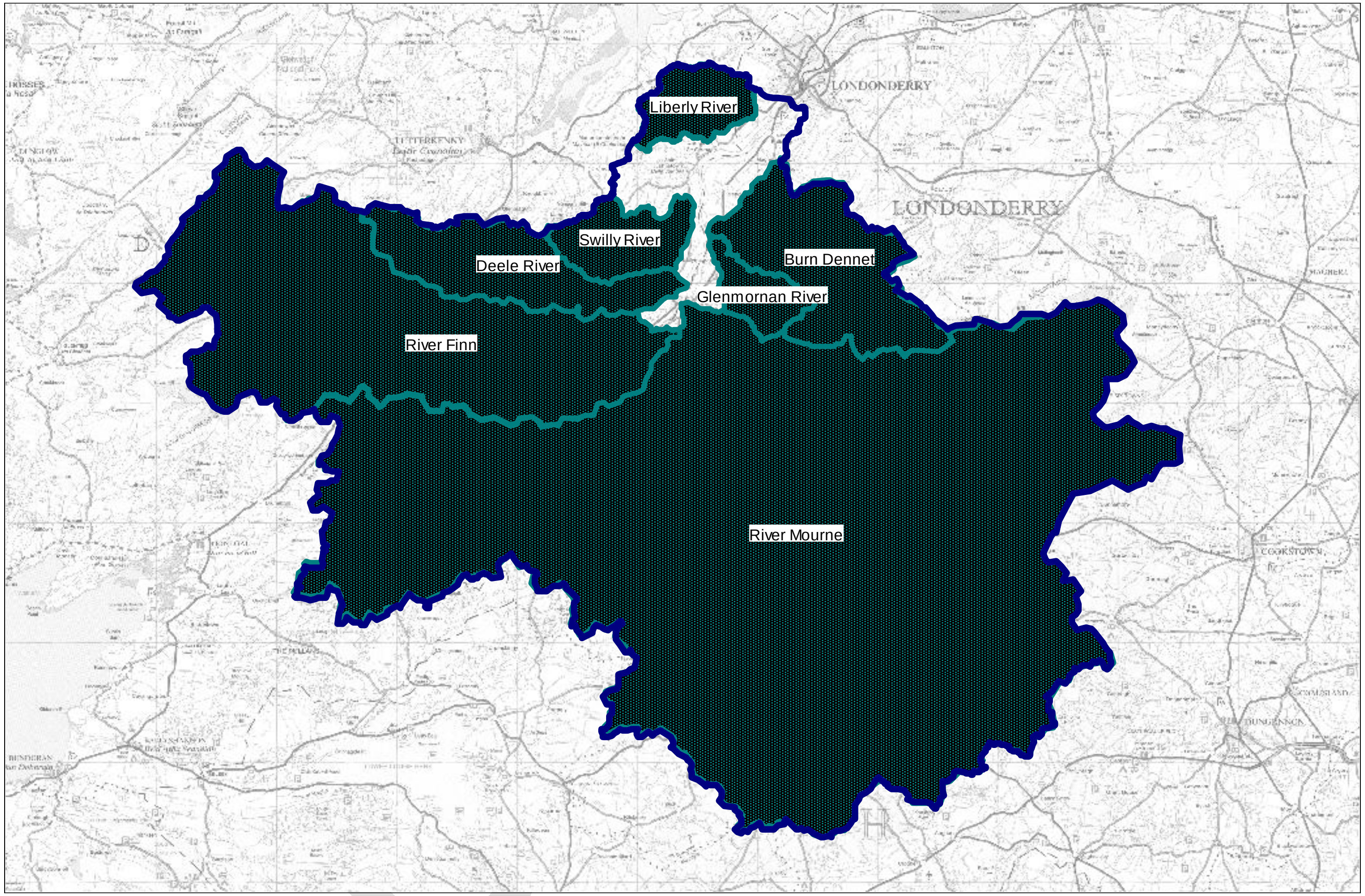

Figure 5.2.3-1 - Model M.1, M2, M.3 – River Foyle Key Hydrological Catchments

Hydrological Data

A review of existing available hydrometric data was completed relating to the Foyle system. Several flow and rainfall gauge stations were identified and data gathered. This hydrometric information was utilised as part of the hydrological assessment. The majority of river flow data came from Rivers Agency, with rainfall data coming from the MET Office.

Design Flow Estimation

Design flows were derived using the FEH procedure, whereby, the Statistical Approach was principally used to derive peak design flows using relevant river gauging data, where available. Hydrographs were generated for all the required model inflow locations using the Rainfall Runoff Method for various return periods. The peaks of the hydrographs were then scaled to the peak flows derived using the Statistical Approach.

Peak design flows (and associated hydrographs) were estimated for a range of return periods for the principal feeder rivers to the Foyle system. A summary of these peak flows can be seen in Table 5.1.3 2.

Hydrograph shapes were adjusted (calibrated) using rainfall and flow data information for two key recorded storm events (October 1987 and September 2008).

Table 5.1.3 2 – Foyle Model Peak Design Flows

Grid Reference	River	Return Period Estimated Peak Flow (m^3/s)			
		2 Yrs	25 Yrs	100 Yrs	100 Yrs + CC
IH 33750 98050	River Mourne	602.94	932.74	1152.21	1382.65
IH 31250 95850	River Finn	304.35	512.53	19.66	23.59
IC 37200 01400	Glenmornan	17.28	31.78	40.98	49.18
IC 37250 04750	Burn Dennet	81.80	142.90	81.83	98.20
IH 33850 99850	Deele River	89.59	149.35	179.27	215.12
IC 34400 04100	Swilly Burn	31.91	58.94	72.15	86.58
IC 36450 11750	Liberly River	21.76	41.29	51.12	61.34

Apart from the Burndennet and Glenmornan rivers, all flow estimates are associated with the most downstream point of the river prior to discharge to the Foyle. Flow estimates for the Burndennet and Glenmornan rivers are associated with the locations of the Rivers Agency gauging stations. It was not considered necessary to recalculate these peak flows for locations further downstream as extensive embankments largely prevent any additional flows entering these rivers prior to discharge into the Foyle.

As the focus of these studies is associated with the floodplains in the vicinity of the Foyle, for simplicity and robustness, peak flows would be conservatively applied to the most upstream cross section of the corresponding modelled reach as a hydrological inflow boundary condition.

The River Foyle and tributaries (including the River Mourne and the River Finn) are subject to tidal influence. Consequently, consideration needs to be given to this tidal influence as part of any flooding assessment for rivers. A full tidal analysis was undertaken including joint probability analyses to account for tidal effects in the flooding appraisal. Further detail regarding this tidal appraisal can be seen in document *718736/0500/R/004 Draft Model Build and Hydrology Report – Foyle River System.*

5.3 Section 2 – Catchment Analysis and Design Flows

5.3.1 Model M.D – Undesignated Watercourse (Upstream of Seein Bridge)

Catchment Details

The undesignated watercourse is defined within FEH software. The hydrological catchment to the point GR 233600 391100 is approximately 5.74km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for this undesignated watercourse.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for this undesignated watercourse. Peak design flows were estimated for one location at the model downstream extents. Figure 5.3.1-1 and Table 5.3.1-1 below shows the hydrological catchment boundary and a summary of the estimated design flows.

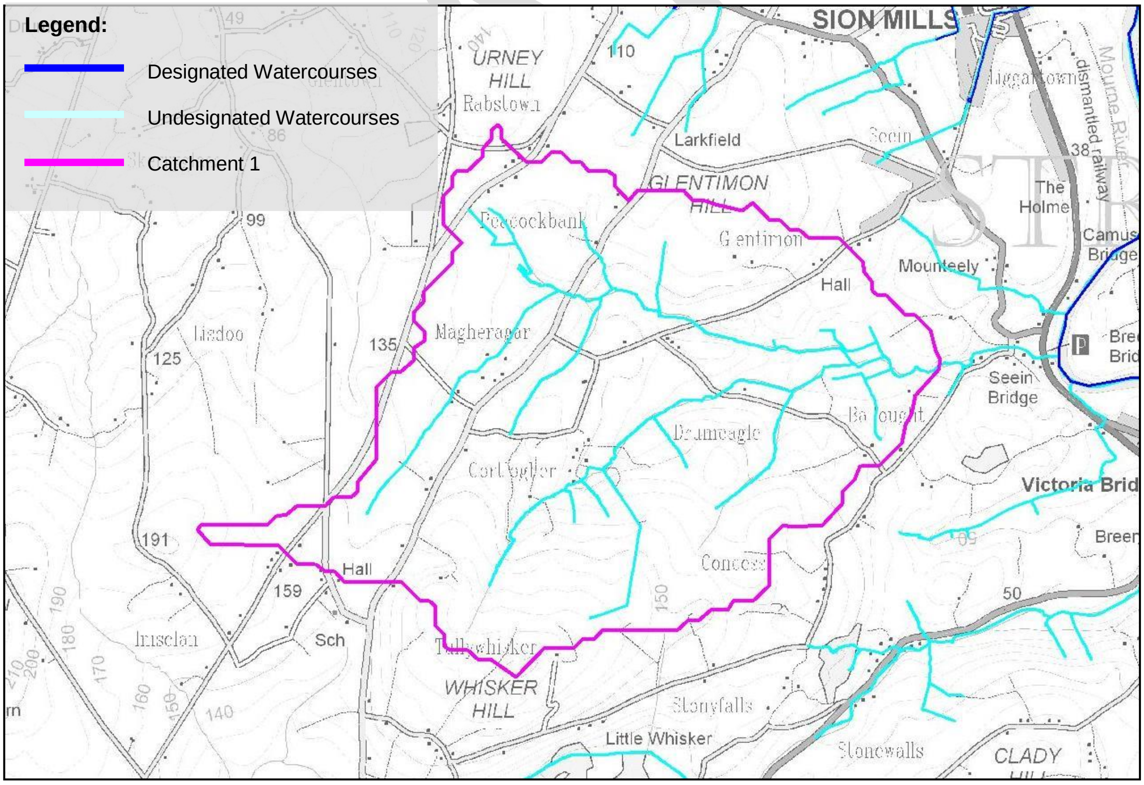

Figure 5.3.1-1 - Model M.D Undesignated Watercourse - Hydrological Catchment Outlines

Table 5.3.1-1- Model M.D Undesignated Watercourse (Upstream of Seein Bridge) Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	5.74	2.71	5.75	8.05	9.66

5.3.2 Model M.5 – 101 River Derg

This section provides a short summary of the hydrological analysis and design flow estimation in relation to the Derg / Strule Rivers. Catchment analyses and design flow estimation were undertaken based on Flood Estimation Handbook (FEH) techniques.

Catchment Details

The River Derg is a tributary of Strule River. The hydrological catchment of the entire River Derg as defined using FEH software is approximately 437.96km^2 (to GR 234693 387213). A nominal reach of the Strule River is included in the model as a downstream boundary to the Derg model. The hydrological catchment of the Strule River to a point on the downstream end of the River Derg (to GR 236371 390101) is approximately 1810.27km^2.

Hydrological Data

Table 5.3.2-1 below provides a summary of river gauging stations with hydrological relevance to the Derg modelling. The Castlederg Station started recording flows in 1976 and the Drumnabouy Station in 1982. The annual maxima (AM) and peak-over-threshold (POT) data contained within the FEH database was updated with information from the Hi-Flows website and information from Rivers Agency.

Table 5.3.2-1 – Summary of River Gauging Stations Model 5 - Derg

Station Number	Watercourse	Location	Easting	Northing	Body Responsible
01304	Mourne - Strule	Stone Bridge	243700	377500	Rivers Agency [NI]
01008	Derg	Castlederg	226500	384200	Rivers Agency [NI]

Design Flow Estimation

Due to catchment size and the availability of gauge data, peak design flows were derived using the FEH Statistical method for the River Derg and Mourne-Strule reaches within Model 5. Figure 5.3.2-1 and Table 5.3.2-1 show the hydrological sub-catchment boundaries and a summary of the estimated design flows.

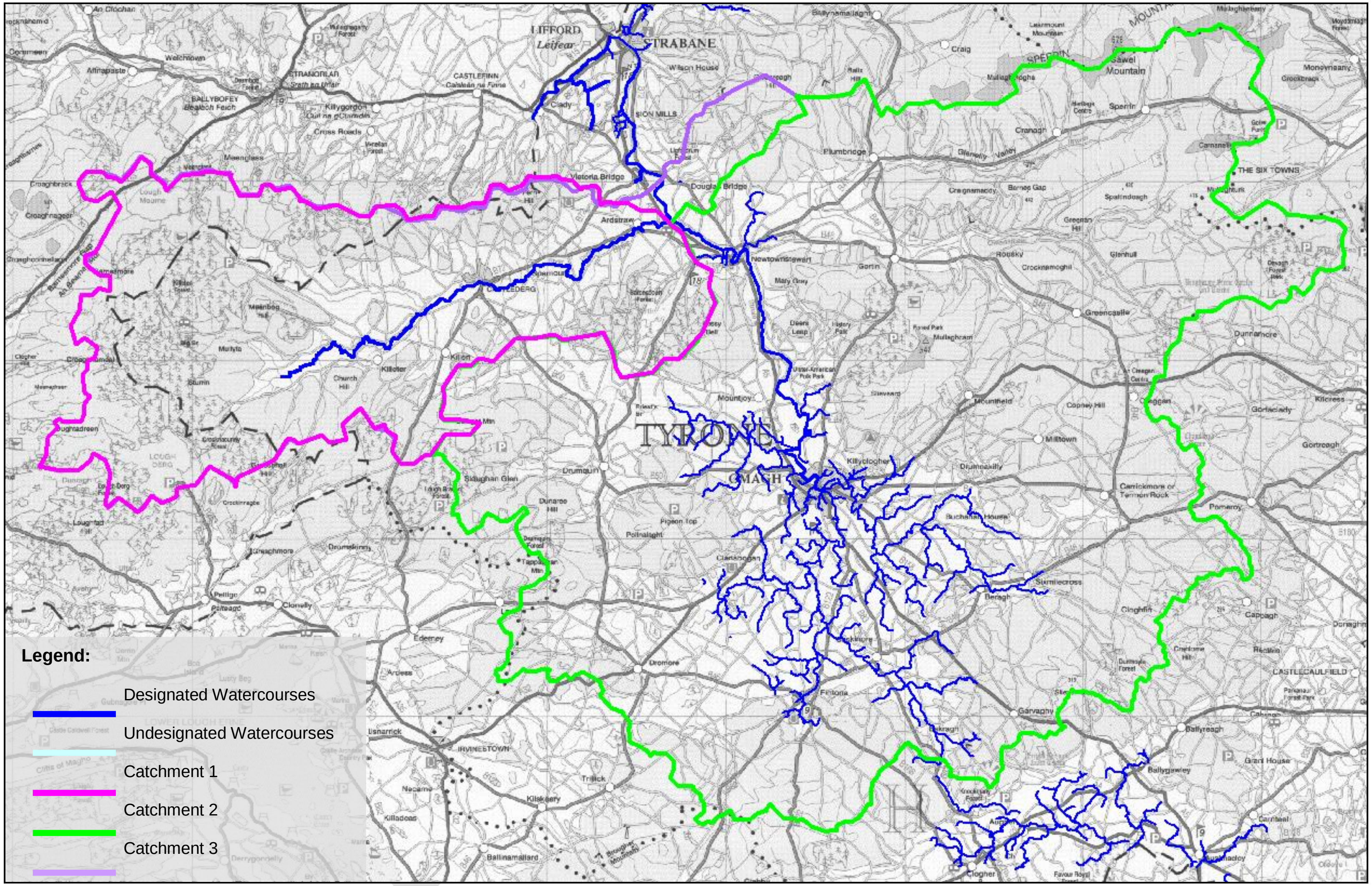

Figure 5.3.2-1 - Model M.5 River Derg - Hydrological Catchment Outlines

Table 5.3.2-2- Model M.5-101 River Derg Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		2 Yrs	25 Yrs	100 Yrs	100 Yrs + CC
River Derg	437.98	223.97	277.27	303.03	363.64
Upstream Strule	1340.60	475.17	794.01	1004.98	1205.98
Downstream Strule	1810.27	591.73	988.78	1251.51	1501.81

5.3.3 Model M.E – Coolaghy Burn (Undesignated)

Catchment Details

The Coolaghy Burn is defined within FEH software and is a tributary of the River Derg. The hydrological catchment of the Coolaghy Burn to the point GR 237350 386000 is approximately 28.5km^2.

Hydrological Data

There are no flow monitoring stations along the Coolaghy Burn, and consequently no recorded flow data.

Design Flow Estimation

Due to catchment size, peak design flows were derived using both the FEH Rainfall Runoff Method and Statistical Approaches for the Coolaghy Burn. Peak design flows were estimated for three locations within the model extents. Figure 5.3.3-1 and Table 5.3.3-1 show the three hydrological sub-catchment boundaries and a summary of the estimated design flows. The Rainfall Runoff Method yielded higher flows than the Statistical Approach. Therefore these flows have been used within the model to be conservative. It should be noted that the flow estimates derived using the Rainfall Runoff method did not increase from upstream to downstream along the watercourse due to changes in the catchment descriptors at each of the flow estimation points and a relatively small increase in catchment size downstream. This decrease in flows from upstream to downstream has not been incorporated into the hydraulic model.

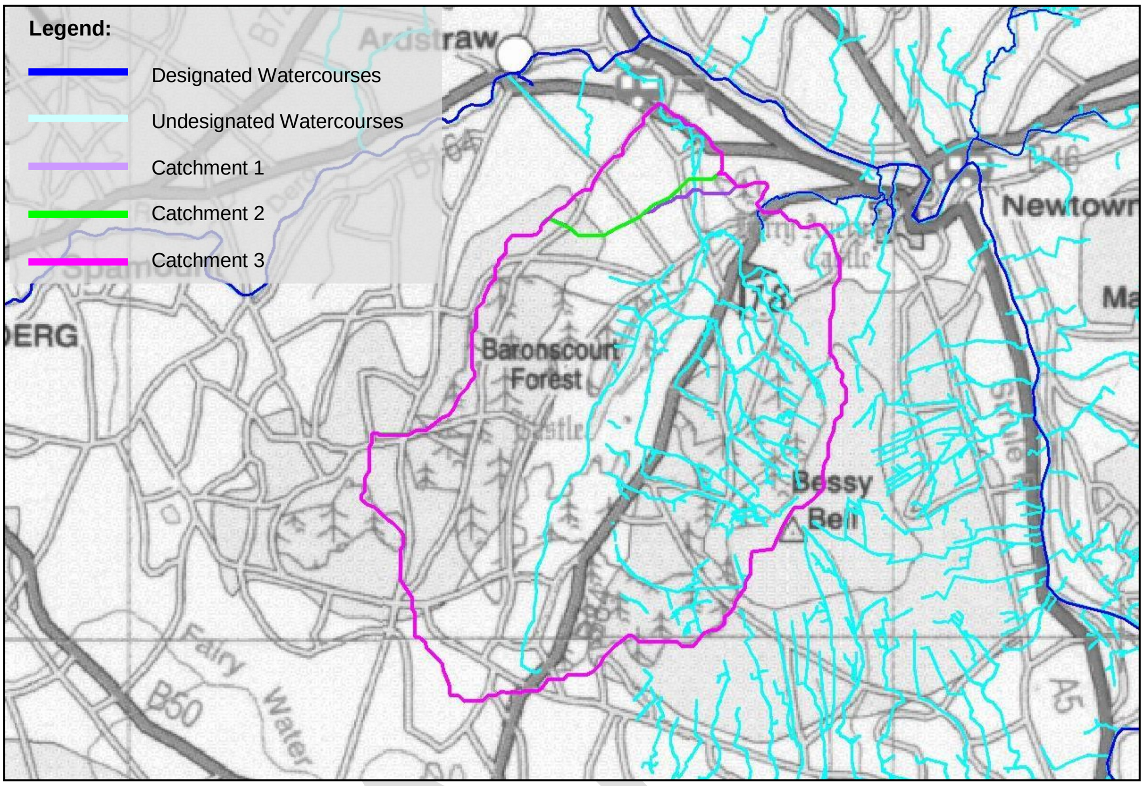

Figure 5.3.3-1 - Model M.E Coolaghy Burn - Hydrological Catchment Outlines

Table 5.3.3-1- Model M.E Coolaghy Burn Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	28.39	11.586	23.294	32.57	39.084
2	28.55	11.51	23.729	32.34	38.808
3	30.32	11.276	23.165	31.57	37.884

5.3.4 *Model M.F – U1704 Ext Back Burn Extension, Newtownstewart*

Catchment Details

The Back Burn is defined within FEH software and is an upstream tributary of Mill Stream, which in turn discharges to the Mourne-Strule Extension. The hydrological catchment of the Back Burn to the point GR 239768 384976 is approximately 0.77km^2.

Hydrological Data

At the time of this study there was no recorded flow data available for the Back Burn Watercourse.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for the Back Burn Extension. Peak design flows were estimated for one location at the model downstream extents. Figure 5.3.4-1 and Table 5.3.4-1 shows the hydrological catchment boundary and a summary of the estimated design flows.

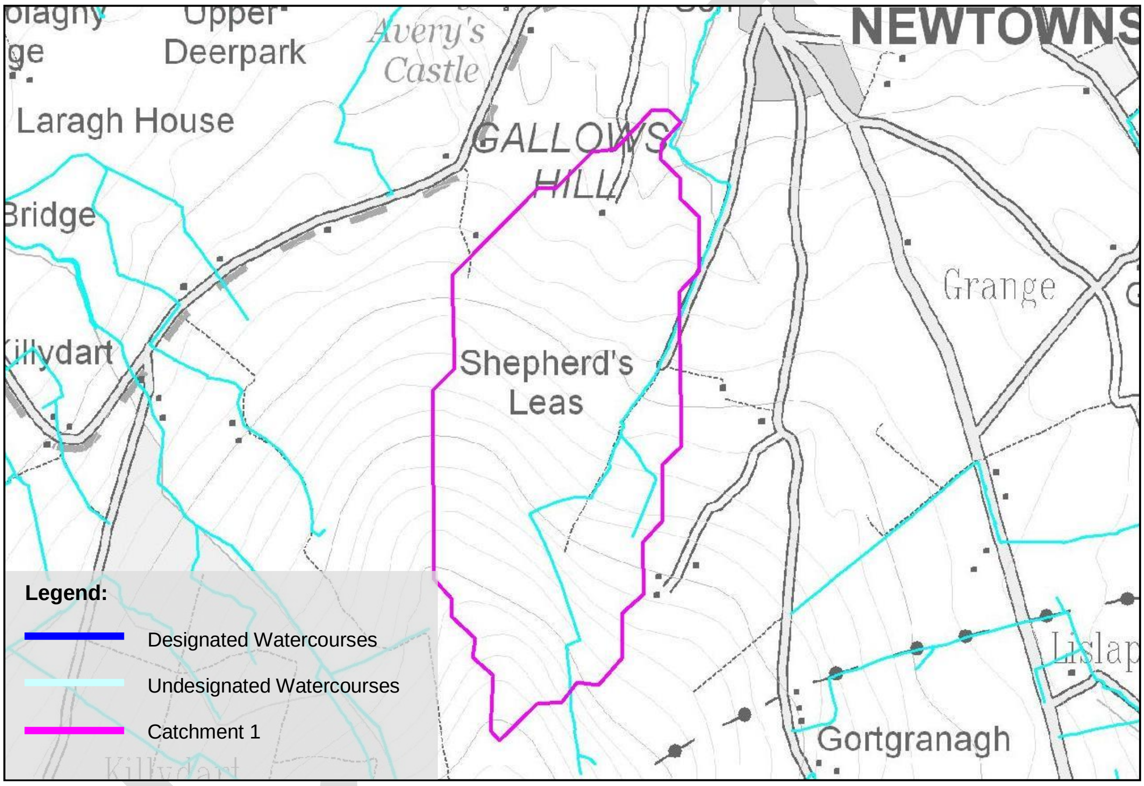

Figure 5.3.4-1 - Model M.F Back Burn - Hydrological Catchment Outlines

Table 5.3.4-1- Model M.F U1704 Back Burn Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	0.77	0.50	1.13	1.55	1.86

5.3.5 *Model M.G – Undesignated Watercourse*

Catchment Details

This undesignated watercourse is defined within FEH software and is a tributary of the Mourne - Strule (Extension). The hydrological sub-catchment of this undesignated watercourse to GR 241460, 378730 covers the area of approximately 1.48km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for this undesignated watercourse.

Design Flow Estimation

Peak design flows were derived using both the FEH Statistical method and the rainfall runoff method. The FEH Statistical method produced higher peak flows than the rainfall runoff method and therefore this method was used to define the design inflows to the model. The hydrographs produced using the rainfall runoff method have been scaled to the FEH Statistical peak flows to produce the model inflow boundaries. Peak design inflows were estimated at the upstream and downstream model extents. Table 5.3.5-1 below provides a summary of the peak design flows calculated. There is one lateral inflow from a low-lying area of land to the west of the Proposed Scheme within Model M.G considered as representative of the difference between the upstream and downstream FEH Statistical flow estimates along the watercourse.

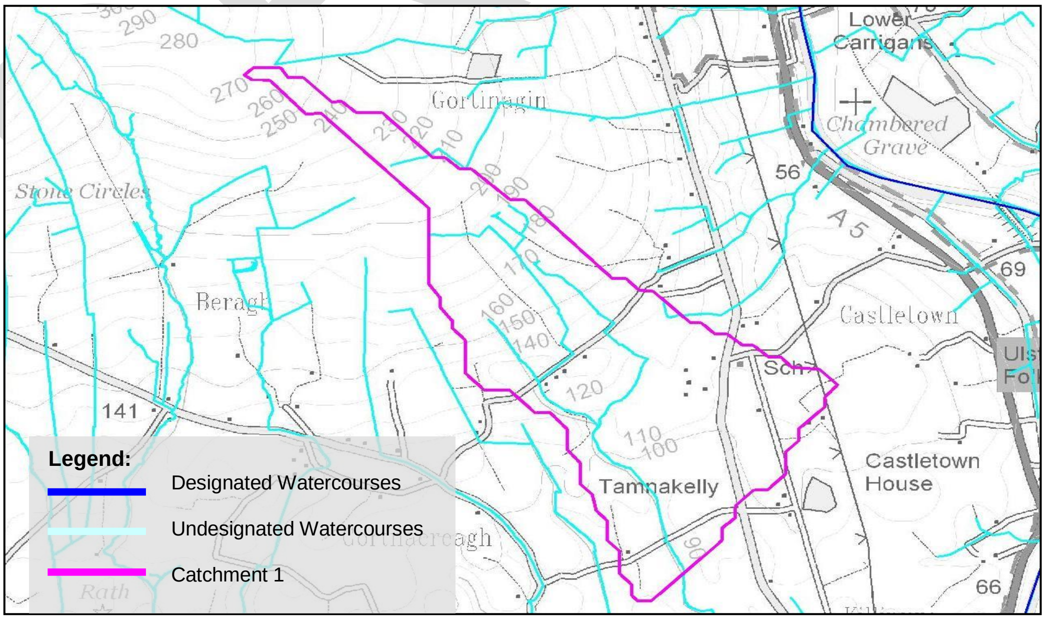

Figure 5.3.5-1 - Model M.G Undesignated Watercourse - Hydrological Catchment Outlines

Table 5.3.5-1- Model M.G, Undesignated Watercourse Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	1.48	1.40	2.92	4.10	4.92

5.3.6 Model M.H – Tully Drain (Undesignated Reach – Mountjoy)

Catchment Details

The Tully Drain is defined within FEH software and is an upstream tributary of the Strule River. The hydrological sub-catchment of the Tully Drain to the point GR 241889 376434 is approximately 3.06km^2.

Hydrological Data

There are no flow monitoring stations on Tully Drain, and consequently no recorded flow data.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for Tully Drain. Peak design flows were estimated for the three locations within the model extents. Figure 5.3.6-1 and Table 5.3.6-1 show the three hydrological sub-catchment boundaries and a summary of the estimated design flows.

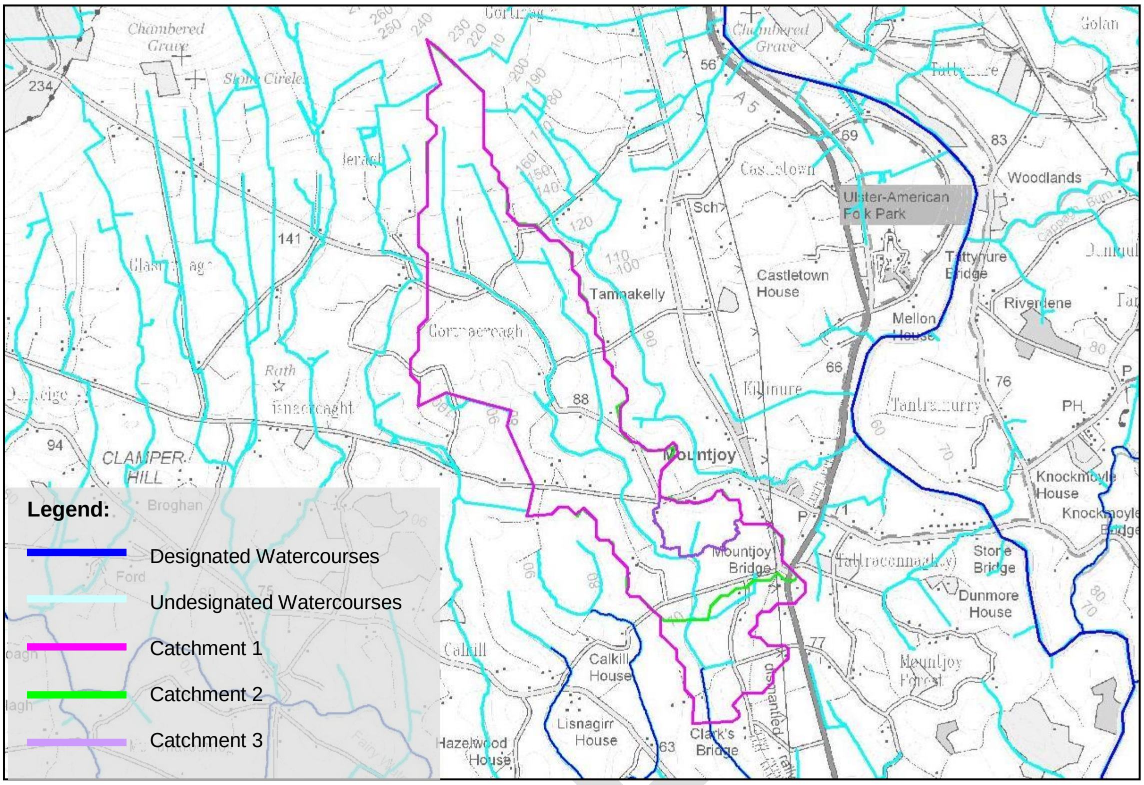

Figure 5.3.6-1 - Model M.H Tully Drain - Hydrological Catchment Outlines

Table 5.3.6-1- Model M.H, Tully Drain Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	3.07	1.08	2.26	3.20	3.84
2	2.65	1.01	2.12	2.99	3.59
3	0.15	0.06	0.13	0.18	0.22

5.3.7 Model M.4 – Omagh (including Fairy Water, Aghnamoyle Drain, Coneywarren Drain, Tully Drain and Strule River)

The Omagh model contains a number of watercourses which are tributaries of the Strule River. This section provide a short summary of the hydrological analysis and design flow estimation in relation to the Omagh model.

<u>Catchment Details</u>

The Strule River and associated tributaries are defined within FEH software. The hydrological sub-catchment of the Strule River to the point GR 243600, 377750 is approximately 819km^2. The principal hydrological catchments contributing to the Strule River within our model extents are:

Table 5.3.7-1 – Omagh Model Watercourse Catchment Sizes

Sub-catchment	Sub-catchment Area (km^2)
Drumragh River	320.5
Camowen River	276.4
Coneywarren Drain	4.7
Fairy Water	173.3
Aghnamoyle Drain	3.0
Tully Drain	3.7

Hydrometric Data

There are three river gauges within the Omagh model extents in each of the principal sub-catchments as detailed in Table 5.3.7-2. Data from the three gauges within the model extents was supplied by Rivers Agency in June 2014. All of the gauges have relatively long records and record good quality data. Mean daily flow and level data at each gauge from October 2007 to June 2014 was supplied along with the Annual Maximum (AMAX) series for each gauge from 2007 to 2014. In addition to the three gauges within the modelled area, AMAX data was also supplied for the Drumnabuoy gauge on the Mourne-Strule River approximately 23km downstream of the modelled extent of the Strule.

Information about the gauges from which data has been used in this study is provided in Table 5.3.7-2. Data from the gauges was reviewed as part of this study and used within the assessment.

Table 5.3.7-2 - Model M.04, Rivers Agency Gauging Stations					
Station Number	**Watercourse**	**Location**	**Easting**	**Northing**	**Length of gauge record used in analysis**
201005	Camowen River	Camowen Terrace	246070	373050	42 years (1972 – 2014)
201006	Drumragh River	Campsie Bridge	245940	372190	42 years (1972 – 2014)
201002	Fairy Water	Dudgeon Bridge	240580	375810	43 years (1971 – 2014)
201010	Mourne-Strule	Drumnabuoy House	234800	396150	32 years (1982 – 2014)

Flows were estimated at 14 points along the modelled watercourses as shown on Figure 5.3.7-1. The 14 sub-catchments to each flow estimation point were extracted from the FEH CD-ROM and checked against OS mapping and DTM data.

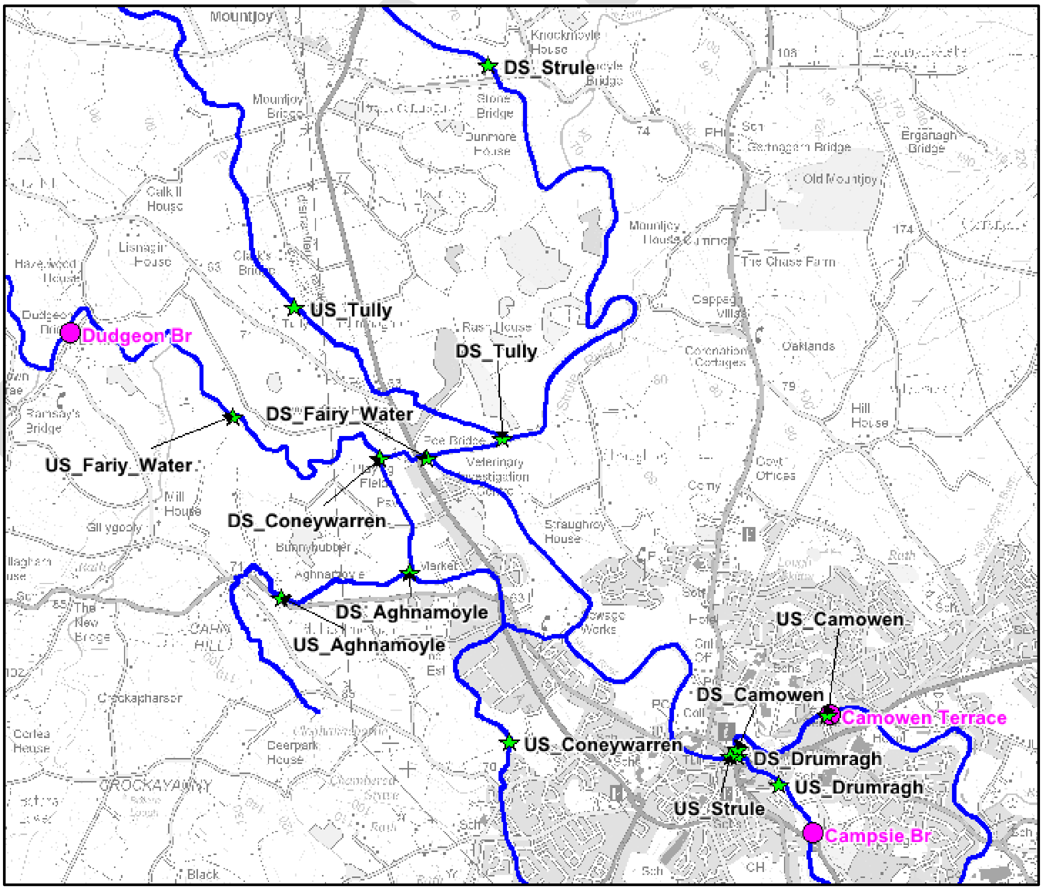

Figure 5.3.7-1 - Model M.4 Omagh - Hydrological Catchment Locations

Design Flow Estimation

The FEH Statistical method was used to derive flows for the larger watercourses within the study area, these are the Camowen, Drumragh, Fairywater and Strule rivers. The size of these catchments and availability of good quality gauge data means that the statistical method is the most appropriate hydrological approach for the flow estimation points on the four large watercourses. There are two stages to the FEH statistical method; QMED estimation and development of a growth curve to define higher return period flows.

AMAX data was used to refine QMED estimates for the flow estimation points on the main gauged watercourses within the modelled extent (Camowen, Drumragh, Fairywater and Strule). Where a flow estimation point was not at a gauge, the QMED at the gauge has been used to adjust the calculated QMED. The QMED was calculated using catchment descriptors at the flow estimation point and application of a standard adjustment formula; this formula takes into account the distance of the gauge from the flow estimation point. Table 5.3.7-3 shows the QMED values calculated at the three main inflows to the model (Camowen, Drumragh and Fairywater) and at the downstream extent of the model on the Strule.

Table 5.3.7-3- QMED Estimation

Flow Estimation Point	QMED calculated from catchment descriptors (m^3/s)	QMED adjusted using gauge data – taken forward for analysis (m^3/s)
US_Camowen	82.43	**88.69**
US_Drumragh	122.82	**106.88**
US_Fairywater	86.37	**72.03**
DS_Strule	257.56	**260.82**

Once the QMED values had been estimated, growth curves developed using WINFAP-FEH v3 software were applied to them in order to estimate the higher return period flows on the large watercourses within the model. Pooling groups were compiled in WINFAP for each of the four watercourses. For a given watercourse, the gauge on that watercourse was included in the pooling group in order to inform the design flow estimation.

The design flows calculated using the statistical method for the three main inflows to the Omagh model and at the downstream extent of the model on the Strule are shown in Table 5.3.7-4.

As well as the three main inflows to the Omagh model, there are ten smaller tributary inflows within the model. The peak flows on these watercourses are considerably less than those on the Camowen, Drumragh and Fairywater due to their smaller catchment sizes. There are no gauges on any of the tributary catchments and as a result, the FEH Statistical method is not appropriate to estimate flows on these watercourses. Instead the FEH rainfall-runoff method has been used, which calculates a design hydrograph and peak flow for a given flow estimation point based on the catchment descriptors extracted from the FEH CD-ROM.

The peak flows calculated for the smaller tributaries within the model are shown in Table 5.3.7-4.

Table 5.3.7-4- Model M.4, Omagh Model Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		2 Yrs	50 Yrs	100 Yrs	100 Yrs + CC
Drumragh River	320.5	106.88	191.20	214.61	257.53
Camowen River	276.4	88.69	176.31	202.82	243.39
Coneywarren Drain	4.7	1.75	4.19	4.74	5.69
Fairy Water	173.3	72.03	128.00	143.20	171.84
Aghnamoyle Drain	3.0	1.08	2.61	2.97	3.56
Tully Drain	3.7	1.06	2.57	2.92	3.50
Tributary of Tully Drain	0.6	0.19	0.47	0.54	0.65
McConnell's	1.2	0.57	1.16	1.35	1.62
Strathroy	0.7	0.25	0.62	0.70	0.84
Killybrack	4.8	1.89	4.50	5.09	6.11
Mountjoy	0.6	0.24	0.57	0.64	0.77
Gortnagern	3.5	1.58	3.74	4.23	5.08
Carnorny Burn	9.3	4.07	9.68	10.93	13.12
Model Downstream Boundary (River Strule)	818.5	260.82	554.51	643.97	772.76

Design hydrographs were required for each model inflow locations in the model.

For the ten smaller tributaries within the model, hydrographs calculated using the FEH rainfall-runoff method have been used to define the inflows.

The FEH Statistical approach was used to define the peak flows for the three main inflows to the model but this approach does not calculate hydrographs. In 2009, Atkins analysed the hydrology of the Strule catchment through Omagh as part of a flood mapping pilot study[1]. Part of their review involved analysing the hydrograph shapes on the Camowen, Drumragh and Fairywater rivers using the available gauge data on these watercourses. Through their analysis, a standardised hydrograph was derived for each of the watercourses based on a number of recorded flood events. These standardised hydrographs have been used to define the inflow hydrographs on the Camowen, Drumragh and Fairywater rivers within the Omagh model. The standardised hydrographs have been scaled to fit the peak flows derived using the FEH Statistical method for these watercourses.

In order to account for runoff from intervening catchment areas along the Strule River, not covered by the tributary inflow catchments, three lateral inflows have been incorporated into the model along the Strule. The hydrographs for the lateral inflows have been defined using the FEH rainfall-runoff method. The storm duration has been configured to ensure that the peak flow coincides with the timing of the peak flow on the Strule as defined by the Camowen and Drumragh inflows. The rainfall-runoff hydrographs have then been scaled appropriately to ensure that the FEH Statistical flow calculated at the downstream extent of the model on the Strule is matched.

5.3.8 Model M.I – MW1545 Fireagh Lough Drain

Catchment Details

The Fireagh Lough Drain is defined within FEH software and is an upstream tributary of Coneywarren Drain. The hydrological catchment of the Fireagh Lough Drain to the point GR 243449 371932 is approximately 3.29km^2.

Hydrological Data

There are no flow monitoring stations on the Fireagh Lough Drain, and consequently no recorded flow data.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for Fireagh Lough Drain. Peak design flows were estimated for the three locations within the model extents. Figure 5.3.8-1 and Table 5.3.8-1 below shows the three hydrological sub-catchment boundaries and a summary of the estimated design flows.

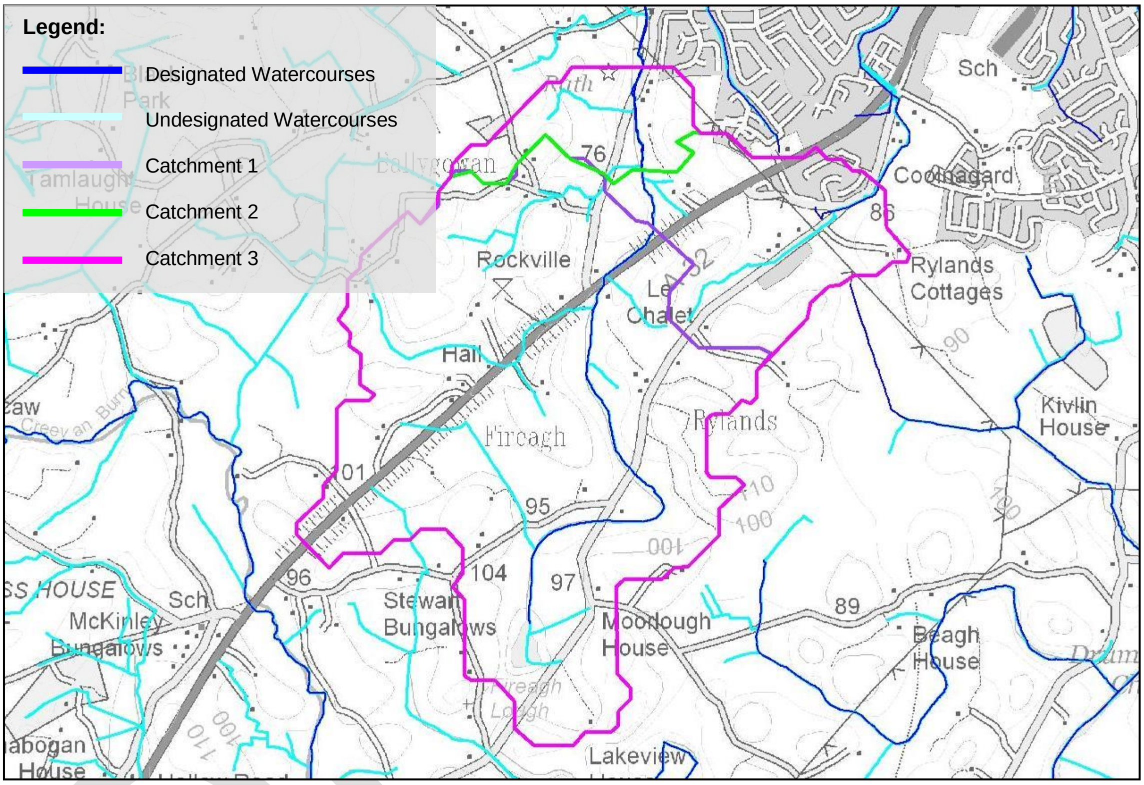

Figure 5.3.8-1 – Model M.I Fireagh Lough Drain - Hydrological Catchment Outlines

Table 5.3.8-1- Model M.I, Fireagh Lough Drain Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	2.42	1.14	2.48	3.50	4.20
2	3.05	1.57	3.27	4.67	5.60
3	3.29	1.73	3.57	5.12	6.14

5.3.9 *Model M.6 – 121 Drumragh River*

This section provides a short summary of the hydrological analysis and design flow estimation in relation to the Drumragh River. Catchment analyses and design flow estimation were undertaken based on Flood Estimation Handbook (FEH) techniques.

Catchment Details

The Drumragh River is defined within FEH software. The hydrological catchment of the Drumragh River to the point GR 245800 371100 is approximately 318.8km^2.

Hydrological Data

There are two Rivers Agency gauging stages on the Drumragh River which are detailed in Table 5.3.9-1 below:

Table 5.3.9-1 - Model M.6, Drumragh Rivers Agency Gauging Stations

Station Number	Watercourse	Location	EASTING	NORTHING
201013	Drumragh River	Drumshanly	244470	368450
201006	Drumragh River	Campsie Bridge	245800	371100

These river gauge locations will form the upstream and downstream boundaries of the modelled reach. The data from both gauges will be used to verify / calibrate the hydraulic model of Drumragh River.

Drumshanly Gauging Station

Drumshanly river level gauge, maintained by the Rivers Agency, measures water levels every 15 minutes and has been operational since 1990. The gauging station is not listed on the Hi-Flows UK website. Data was requested and the full data record has been provided by the Rivers Agency. The Drumshanly gauge hut and gauge board are shown in Photograph 5.3.9-1 and the steel footbridge immediately downstream is shown in Photograph 5.3.9-2.

Photograph 5.3.9-1 – Drumshanly gauging station

Photograph 5.3.9-2 – Drumshanly steel footbridge

Campsie Bridge Gauging Station

A river level gauge maintained by the Rivers Agency is located 600m upstream of Campsie Bridge and measures water levels every 15 minutes and has been operational since 1973. The gauge board is shown in Photograph 5.3.9-3 and the gauge hut in Photograph 5.3.9-4.

The gauging station is listed on the Hi-Flows UK website. A rating curve based on the gauged flows and a best-fit equation is also provided on the Hi-Flows UK website, however an update to the rating at the gauge was made in 2014. The rating shown on Hi-Flows is valid for water levels up to 0.83m recorded at the gauge, above this level the new rating has been applied. The river overtops the channel banks at a stage of 2.8m. The maximum gauged flow is Q = 149m^3/s and stage h = 3.82m. The maximum recorded stage was 4.929m on 22nd October 1987; the associated flow is Q = 231.89m^3/s based on the updated extrapolated rating curve.

Photograph 5.3.9-3 – Campsie Bridge gaugeboard

Photograph 5.3.9-4 – Campsie Bridge gauging station

Peak Flood Events

Annual peak flow data is provided on the Hi-Flows UK website for Campsie Bridge gauging station and the following five peak flood events have been identified as possible events for verification / calibration of the model. Mouchel were provided with 15-minute interval level data from the Rivers Agency for these specific events for both Drumshanly and Campsie Bridge gauging stations.

- 21 December 1991
- 25 October 1995
- 28 November 1999
- 3 December 1999
- 21 January 2008
- 25 October 2011

Design Flow Estimation

The FEH Statistical Approach was principally used to derive peak design flows for Drumragh River using relevant river gauging data. For some smaller tributaries, flows were derived using FEH catchment descriptors and an associated rainfall runoff model. Design flows were estimated for the six locations within the model extents. Figure 5.3.9-1 and Table 5.3.9-2 below shows the six hydrological sub-catchment boundaries and a summary of the estimated design flows within the model extents.

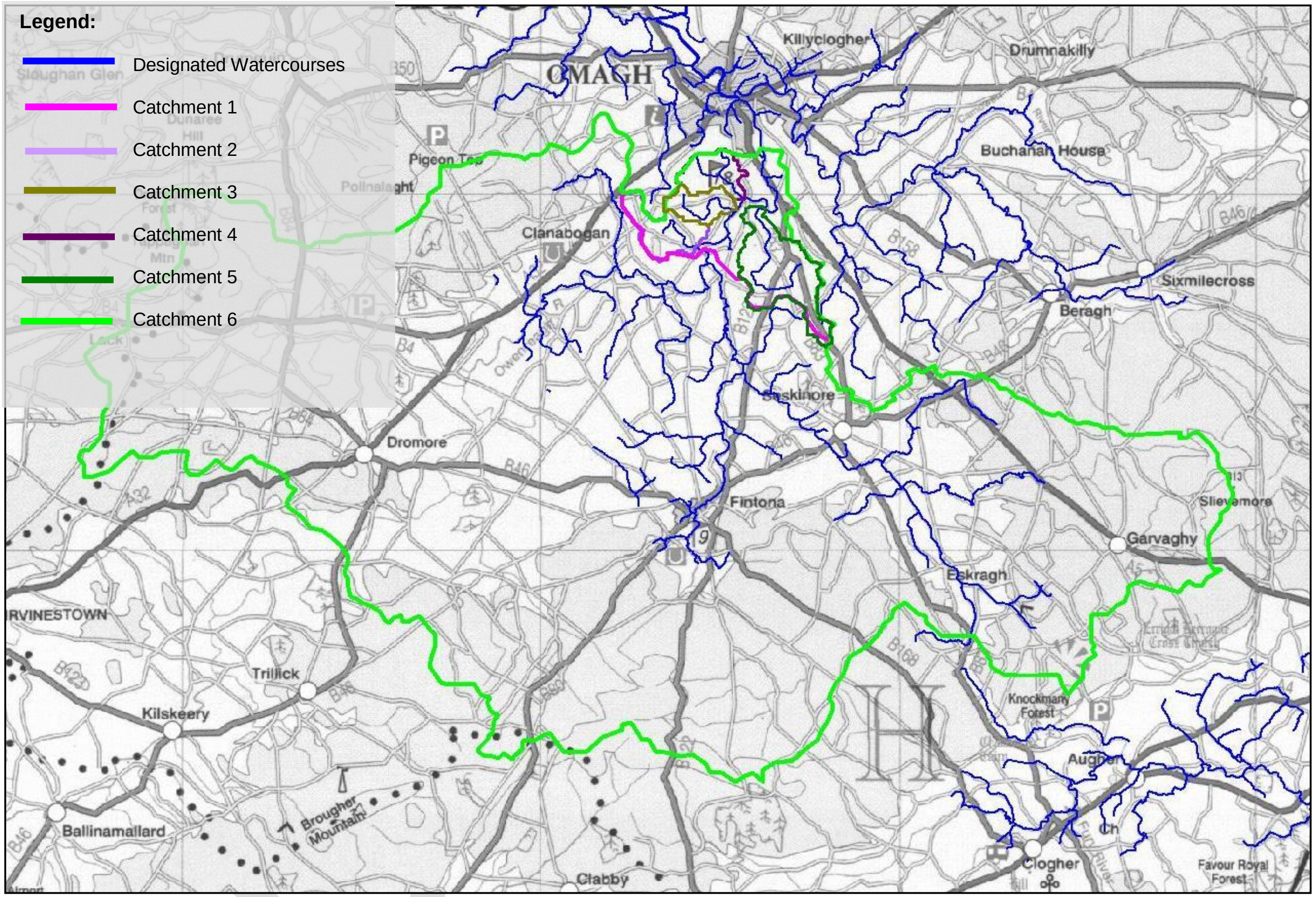

Figure 5.3.9-1 – Model M.6 Drumragh River - Hydrological Catchment Outlines

Table 5.3.9-2- Model M.6, Drumragh River Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		2 Yrs	25 Yrs	100 Yrs	100 Yrs + CC
1 - Drumshanly gauging station	304.71	105.80	168.76	212.45	254.94
2 - Lough Muck tributary	2.18	0.77	1.64	2.23	2.67
3 - Beagh House tributary	1.40	0.58	1.23	1.65	1.97
4 - Kivlin Burn tributary	1.76	0.61	1.31	1.77	2.12
5 - Freughmore Drain tributary	4.65	1.4	3.0	4.05	4.87
6 - Campsie Bridge gauging station	318.8	106.30	169.55	213.45	256.14

5.4 Section 3 – Catchment Analysis and Design Flows

5.4.1 Model M.L – MW1410 Ranelly Drain

Catchment Details

The Ranelly Drain is defined within FEH software and is an upstream tributary of the Camowen (Extension). The hydrological sub-catchment of Ranelly Drain to the point GR 248400 367850 is approximately 5.5km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for the Ranelly Drain.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for Ranelly Drain. Peak design flows were estimated at three locations within the model extent. Figure 5.4.1-1 and Table 5.4.1-1 below show the hydrological sub-catchment boundary at the downstream boundary and a summary of the estimated design flows at this location.

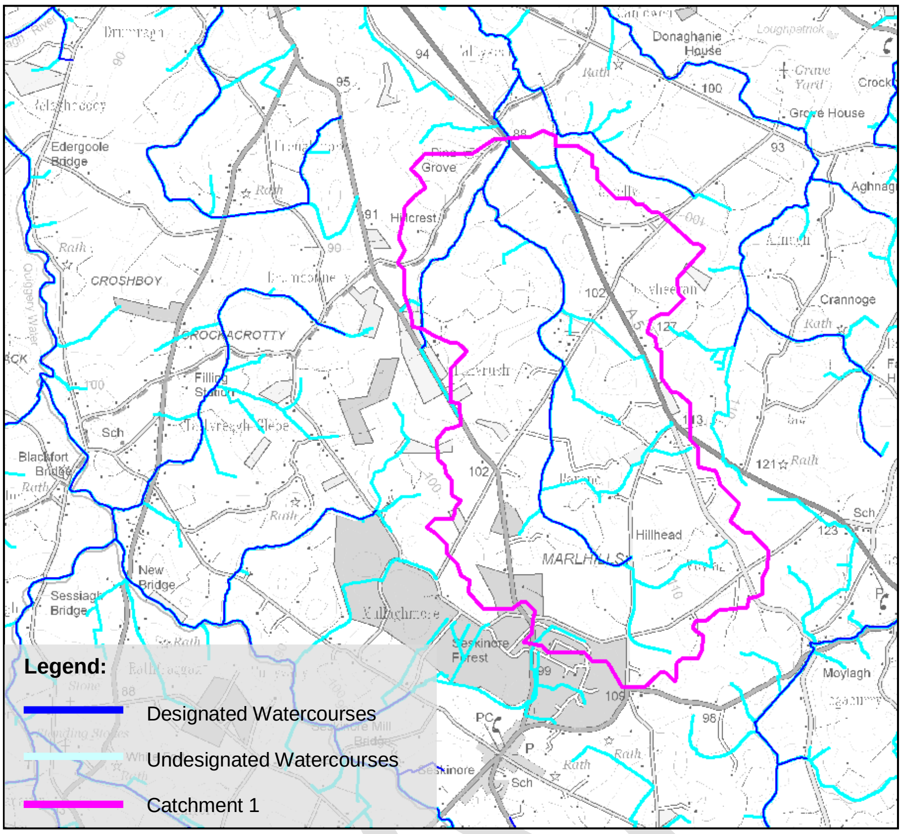

Figure 5.4.1-1 Model M.L Ranelly Drain - Hydrological Catchment Outline

Table 5.4.1-1- Model M.L, Ranelly Drain Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	5.45	2.31	4.94	6.93	8.32

5.4.2 Model M.M – MW1401 Letfern Watercourse

Catchment Details

The Letfern Watercourse is defined within FEH software and is an upstream tributary of the Seskinore. The hydrological subcatchment of Letfern to the point GR 250337 363271 is approximately 7.60km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for the River Letfern or any associated tributaries.

Table 5.4.2-1- Model M.M, Letfern Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
Letfern upstream boundary	4.96	2.50	4.40	6.10	7.30
Letfern downstream boundary	7.60	3.80	6.70	9.20	11.10

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for the Letfern. Peak design flows were estimated for two locations within the model extents. Figure 5.4.2-1 and Table 5.4.2-1 below show the hydrological sub-catchment boundaries and a summary of the estimated design flows.

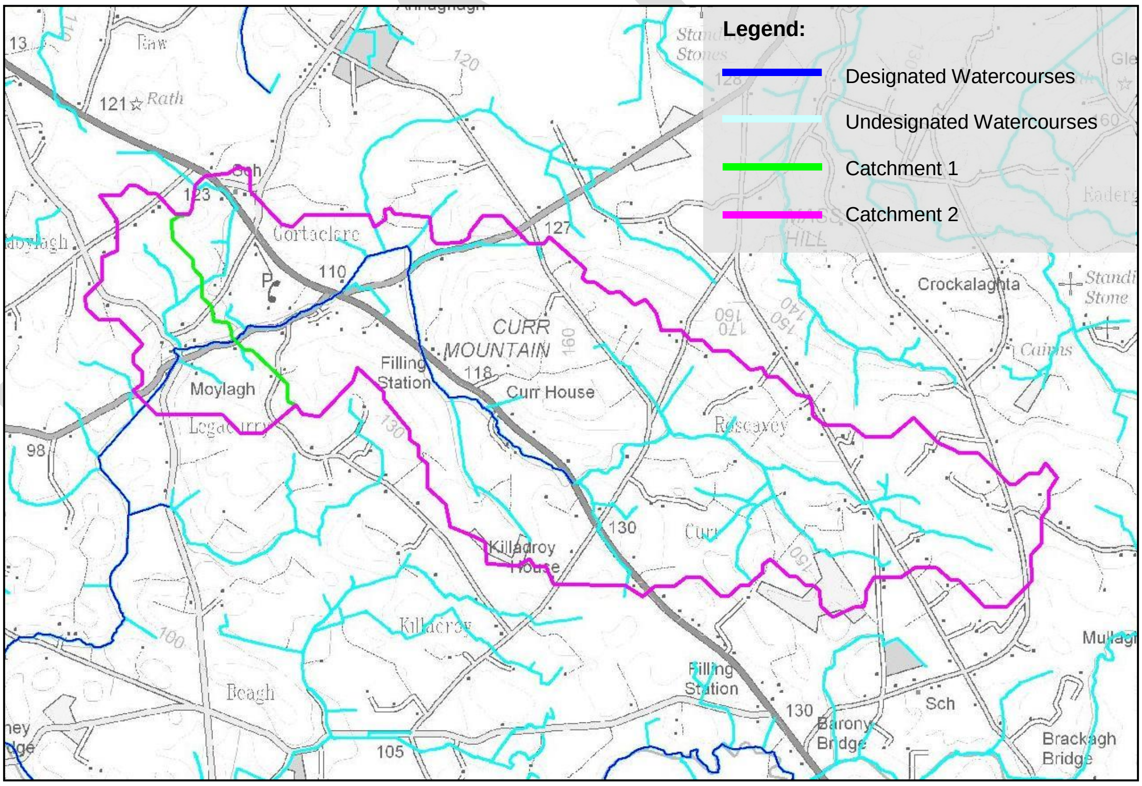

Figure 5.4.2-1 – Model M.M Letfern Watercourse - Hydrological Catchment Outlines

Table 5.4.2-2- Model M.M, Letfern Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
Letfern upstream boundary	4.96	2.50	4.40	6.10	7.30
Letfern downstream boundary	7.60	3.80	6.70	9.20	11.10

5.4.3 Model M.N – Undesignated Watercourse (Upstream of MW1402 Letfern Burn Branch)

Catchment Details

This undesignated watercourse is defined within FEH software and is an undesignated tributary of the Letfern. The hydrological catchment to the point GR 251110 363309 is approximately 0.65km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for this undesignated watercourse.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model. However, the two tributaries which meet to form this undesignated watercourse are individually too small to be defined on the FEH CD ROM. The upstream boundaries of the model lie on these tributaries. Consequently, the flow derived from the catchment descriptors at the downstream boundary are proportioned across each of the upstream boundaries based on their catchment areas (from OS map). 40% of the peak flow will be applied at the west tributary upstream boundary and 60% at the east.

Figure 5.4.3-1 shows the hydrological sub-catchment for the downstream boundary derived from FEH and Table 5.4.3-1 below shows a summary of the estimated design flows.

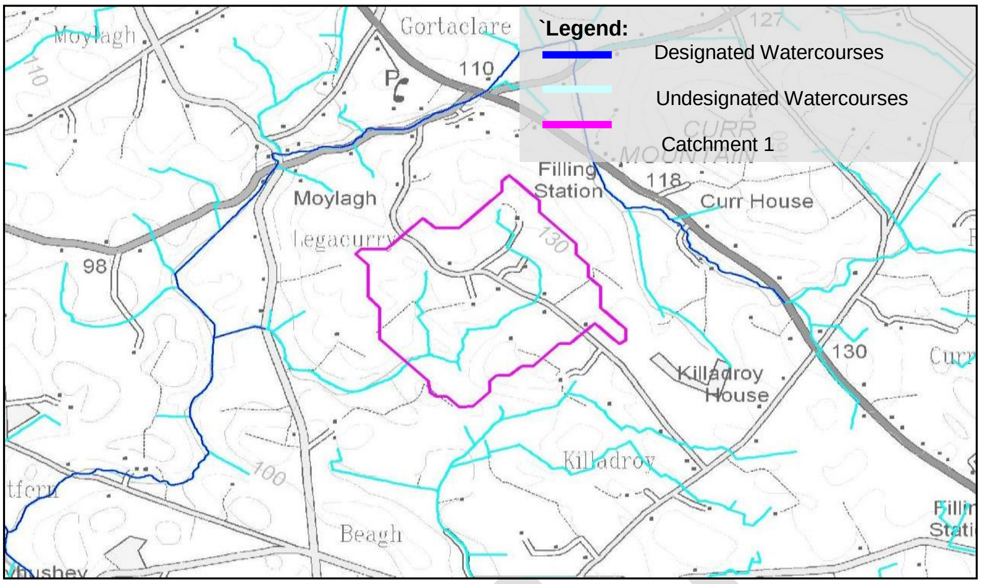

Figure 5.4.3-1 – Model M.N – Undesignated - Hydrological Catchment Outlines

Table 5.4.3-1- Model M.N, Undesignated Watercourse Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
Downstream Boundary	0.65	0.46	0.99	1.37	1.64

5.4.4 Model O – Undesignated Watercourse

Catchment Details

This undesignated watercourse is defined within FEH software and is an undesignated tributary of the Routing Burn. The hydrological catchment to the point GR 251850 362700 is approximately 0.53km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for this undesignated watercourse.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model. The catchment area extracted from the FEH CD-ROM has been checked against the OS background and the FEH defined catchment only included one of the tributaries making up this undesignated watercourse. The catchment area of the north tributary is approximately 0.5km^2 and the south tributary is approximately 0.4km^2. The approach taken to estimate a range of design flows at each boundary is to use the catchment descriptors, and adjust the area in accordance with the measured catchment areas.

Figure 5.4.4-1 shows the hydrological sub-catchment for the downstream boundary derived from FEH and Table 5.4.4-1 shows a summary of the estimated design flows.

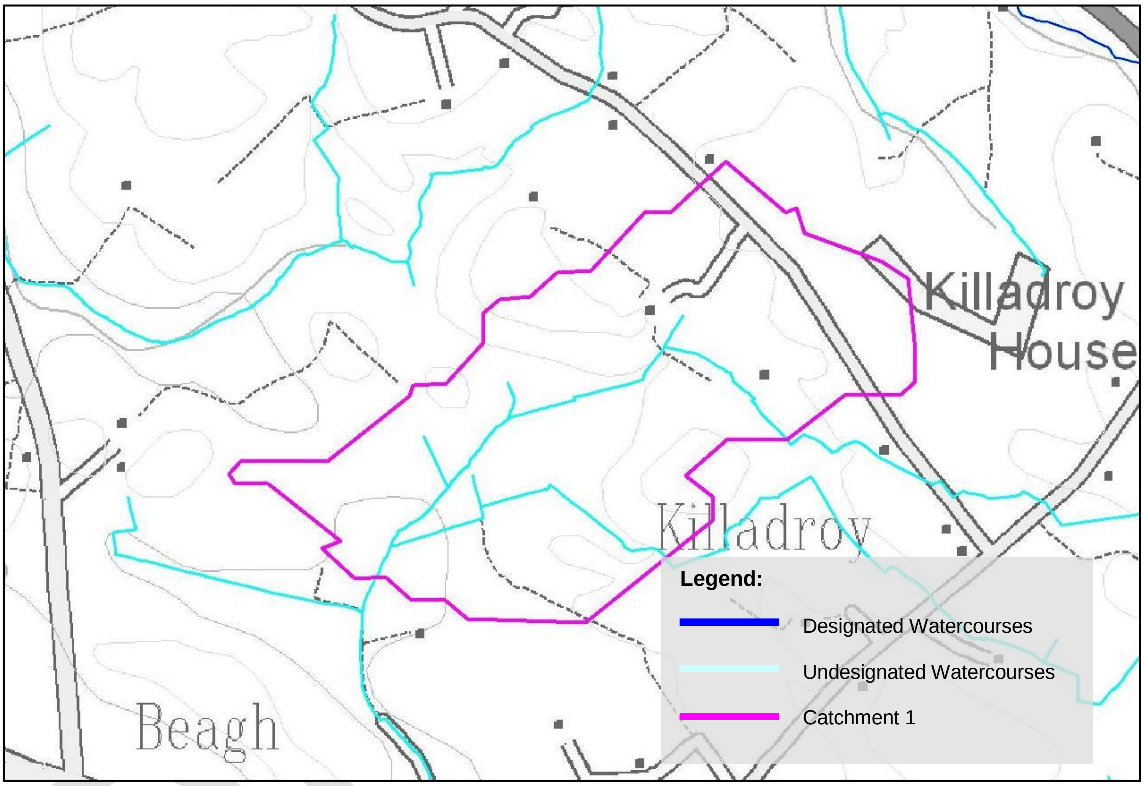

Figure 5.4.4-1 – Model M.O – Undesignated Watercourse - Hydrological Catchment Outlines

Table 5.4.4-1- Model M.O, Undesignated Watercourse Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1 - North Tributary	0.5	0.35	0.74	1.04	1.24
1 - South Tributary	0.4	0.26	0.56	0.78	0.94

5.4.5 Model P / Q - 144 Routing Burn, MW1424 Routing Burn Ext and Undesignated Tributary

Catchment Details

The Routing Burn, Routing Burn Ext and undesignated tributary are defined within FEH software and ultimately flow into the Seskinore River. The hydrological catchment to the point GR 251750 361500 is approximately 23.9km^2, the catchment area was revised based on 10k OS mapping and contours from what was extracted from the FEH CD-ROM (original area 28.55km^2). The individual sub-catchments of the Routing Burn Ext and the associated undesignated tributary are approximately 20km^2 and 3km^2 at the confluence of the two watercourses.

Hydrological Data

At the time of this assessment no recorded flow data was available for the Routing Burn or associated upstream tributaries.

Design Flow Estimation

Due to catchment size, peak design flows were derived using the FEH Statistical Approach. Peak design flows were estimated at the upstream and downstream model extents. Inflow hydrographs were derived using the Rainfall-Runoff method and were then scaled to match the FEH Statistical peak flows calculated for the catchment. Figure 5.4.5-1 and Table 5.4.5-1 below show the hydrological catchments and a summary of the estimated design flows.

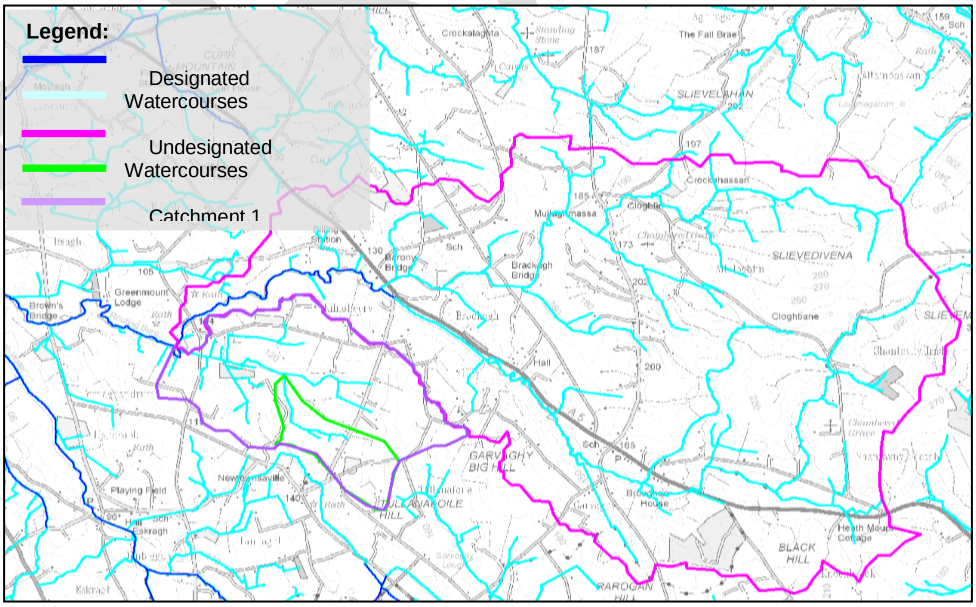

Figure 5.4.5-1 – Model M.P / M.Q – Routing Burn and Undesignated Tributaries - Hydrological Catchment Outlines

5.4.6 Model M.R – Undesignated Watercourse (Newtownsaville)

Table 5.4.5-1- Model M.P / M.Q, Routing Burn, MW1424 Routing Burn Ext and Undesignated Tributary Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
Model M.P Location (GR 252000 361400)	19.95	8.82	15.05	18.79	22.55
Model M.Q Tributary Location (GR 253050 361100)	0.7	0.29	0.63	0.86	1.03
Model M.Q Inflow D Lateral Inflow (GR 252060 361360)	2.89	1.15	2.47	3.36	4.03

Catchment Details

The undesignated watercourse is defined within FEH software and is an upstream tributary of the Cormore River. The hydrological catchment to the point GR 253136 360260 is approximately 5.3km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for this undesignated watercourse.

Design Flow Estimation

Due to catchment size, peak design flows were derived using the FEH Statistical Approach. Peak design flows were estimated at the upstream and downstream model extents. Inflow hydrographs were derived using the Rainfall-Runoff method and were then scaled to match the FEH Statistical peak flows calculated for the catchment. Figure 5.4.6-1 and Table 5.4.6-1 below show the hydrological catchments and a summary of the estimated design flows.

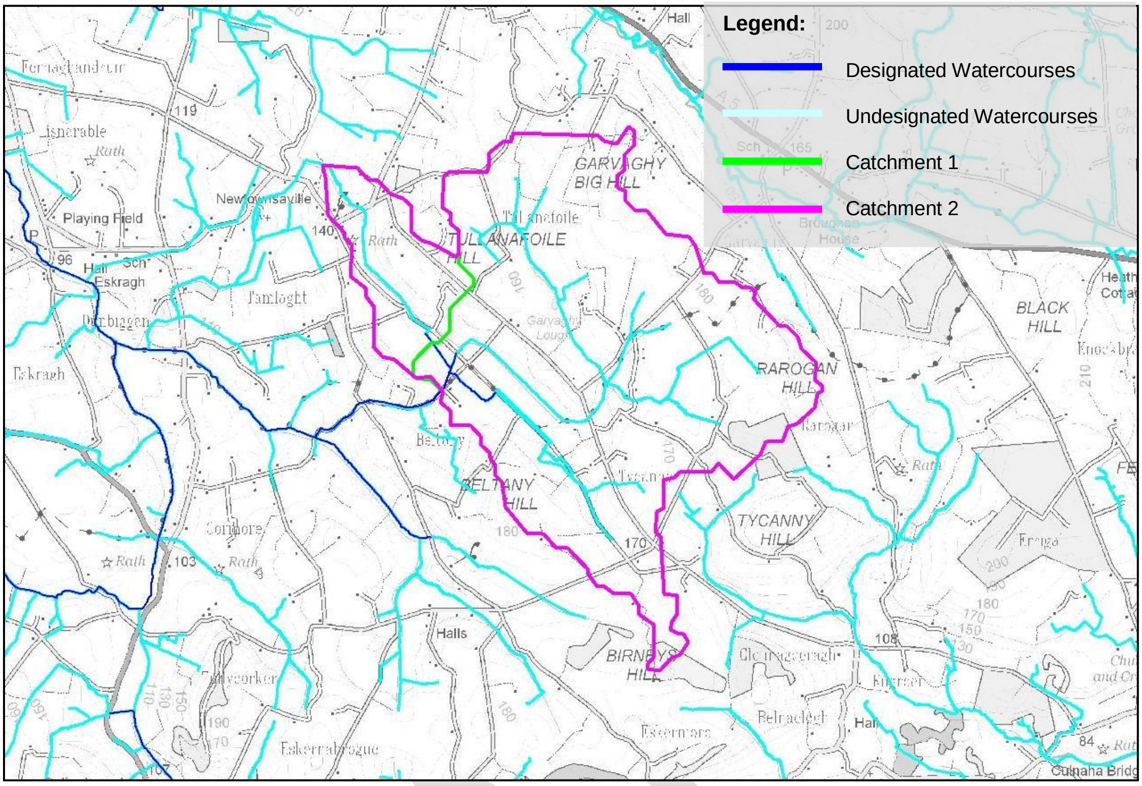

Figure 5.4.6-1 – Model M.R - Hydrological Catchment Outlines

Table 5.4.6-1- Model M.R, Undesignated Watercourse Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	3.62	1.57	3.4	4.86	5.83
2	5.3	2.26	4.91	7.05	8.46

5.4.7 Model M.S – Undesignated Watercourse (Kilgreen)

Catchment Details

This undesignated watercourse and associated unnamed, undesignated tributary are defined within FEH software and are upstream tributaries of the Roughan River. The hydrological catchment to the point GR 257110 356726 is approximately 4.19km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for this undesignated watercourse or the unnamed tributary.

Design Flow Estimation

Peak design flows were derived using the FEH Statistical Approach. Peak design flows were estimated at the upstream and downstream model extents. Inflow hydrographs were derived using the Rainfall-Runoff method and were then scaled to match the FEH Statistical peak flows calculated for the catchment. Due to the nature of this model, full hydrographs have not be simulated for this watercourse and steady model runs with the peak flows Figure 5.4.7-1 and Table 5.4.7-1 below show the hydrological catchment and a summary of the estimated design flows.

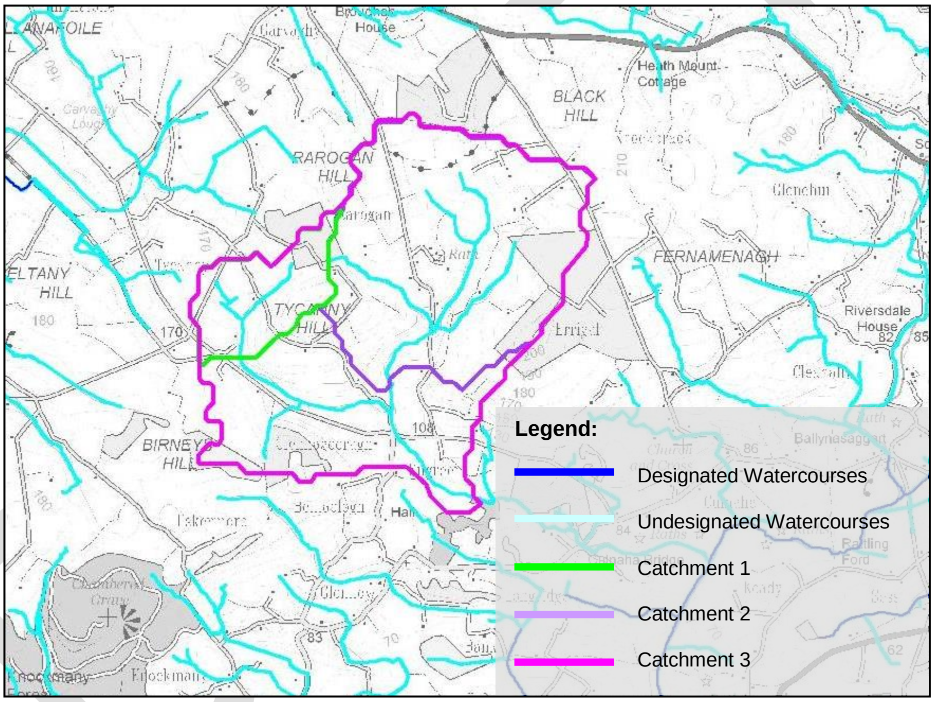

Figure 5.4.7-1 – Model M.S - Hydrological Catchment Outlines

Table 5.4.7-1- Model M.S, Undesignated Watercourse Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1 - Upstream Boundary (GR 255620 357890)	2.27	0.42	0.91	1.30	1.56
2 - Upstream Boundary (GR 256588 357470)	0.53	1.23	2.66	3.80	4.56
3 - Downstream boundary (GR 257110 356726)	4.19	2.05	4.43	6.34	7.61

5.4.8 *Model M.T – MW4105 Roughan River*

Catchment Details

The Roughan River and an associated undesignated tributary flowing in from the direction of Culnaha are defined within FEH software and are upstream tributaries of the Blackwater (Extension No.2). The hydrological catchment of Roughan River to the point GR 258785 356505 is approximately 12.68km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for the Roughan River or undesignated tributaries.

Design Flow Estimation

Due to catchment size, peak design flows were derived using both the FEH Rainfall Runoff Method and Statistical Approaches for the Roughan River. Design flows were estimated for three locations within the model extents. Figure 5.4.8-1 and Table 5.4.8-1 below show the hydrological catchment and a summary of the estimated design flows. It should be noted that the Statistical Approach yielded slightly higher flows than the Rainfall Runoff Method. Consequently, to be conservative, the higher Statistical Approach flows have been adopted for design purposes.

The undesignated (Culnaha) tributary contributes approximately 10% of the Roughan flow and enters near the downstream end of the proposed model reach. The difference between the upstream and downstream model boundary peak flows (FEH pooled group Statistical Approach) was applied for the lateral inflow of this tributary.

Due to the small catchment size of the Crew Hill tributary, flows on this watercourse were estimated using the rainfall runoff method.

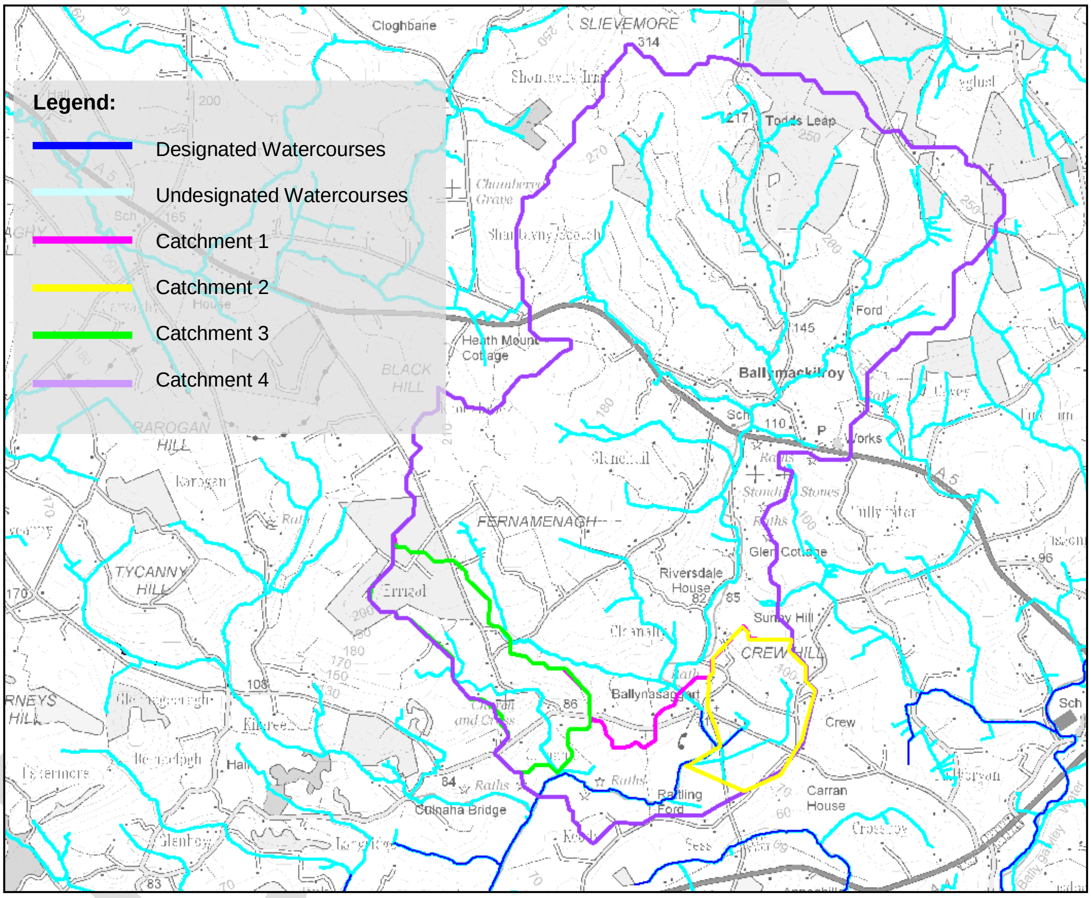

Figure 5.4.8-1 – Model M.T - Hydrological Catchment Outlines

Table 5.4.8-1- Model M.T, Roughan River Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		2 Yrs	25 Yrs	100 Yrs	100 Yrs + CC
1 - Upstream Roughan boundary	10.64	6.65	13.81	19.38	23.26
2 - Undesignated Tributary (Crew Hill)	0.65	0.26	0.54	0.73	0.88
3 - Undesignated Tributary (Culnaha)	0.90	0.63	1.30	1.83	2.20
4 - Downstream Roughan boundary	12.68	7.72	16.03	22.50	27.00

5.4.9 Model M.U – Ballygawley Water

This section provides a short summary of the hydrological analysis and design flow estimation in relation to the Ballygawley River. Catchment analyses and design flow estimation were undertaken based on Flood Estimation Handbook (FEH) techniques.

Catchment Details

The Ballygawley Water is defined within FEH software. The hydrological catchment of the Ballygawley Water to the point GR 261862 355462 is approximately 45.8km^2.

Hydrological Data

A Rivers Agency river gauging station is situated within the proposed model extents. Tullybryan hydrometric gauging station (Station Ref: 203041) is located 70m upstream of Annaghilla Road Bridge. Recorded flow data from this station exists from 1981. However, during the late 1980's the Ballygawley Water (and Blackwater River System) were subject to extensive re-alignment, bed slope re-grading and channel re-sectioning which changed the watercourse from a natural river system to a canalised trapezoidal channel. These drainage works were carried out to improve and increase agricultural production.

Consequently, data from the gauging station pre-1990 has not been used in the hydrological analysis due to the impact of these agricultural drainage works on watercourse flows. Only the flow data from 1991 onwards was used in the design flow estimation, as recommended by Rivers Agency. Data from this station were not available on the Hi-Flows website.

Design Flow Estimation

Design flows were derived using the FEH procedure, whereby, the Statistical Approach was used to derive peak design flows using relevant river gauging data. Hydrographs were generated using the Rainfall Runoff Method for various return periods. The peaks of the hydrographs were then scaled to the peak flows derived using the Statistical Approach.

Peak design flows (and associated hydrographs) were estimated for a range of return periods for two locations within the model extents. Figure 5.4.9-1 and Table 5.4.9-1 below show the hydrological catchments and a summary of the estimated design flows.

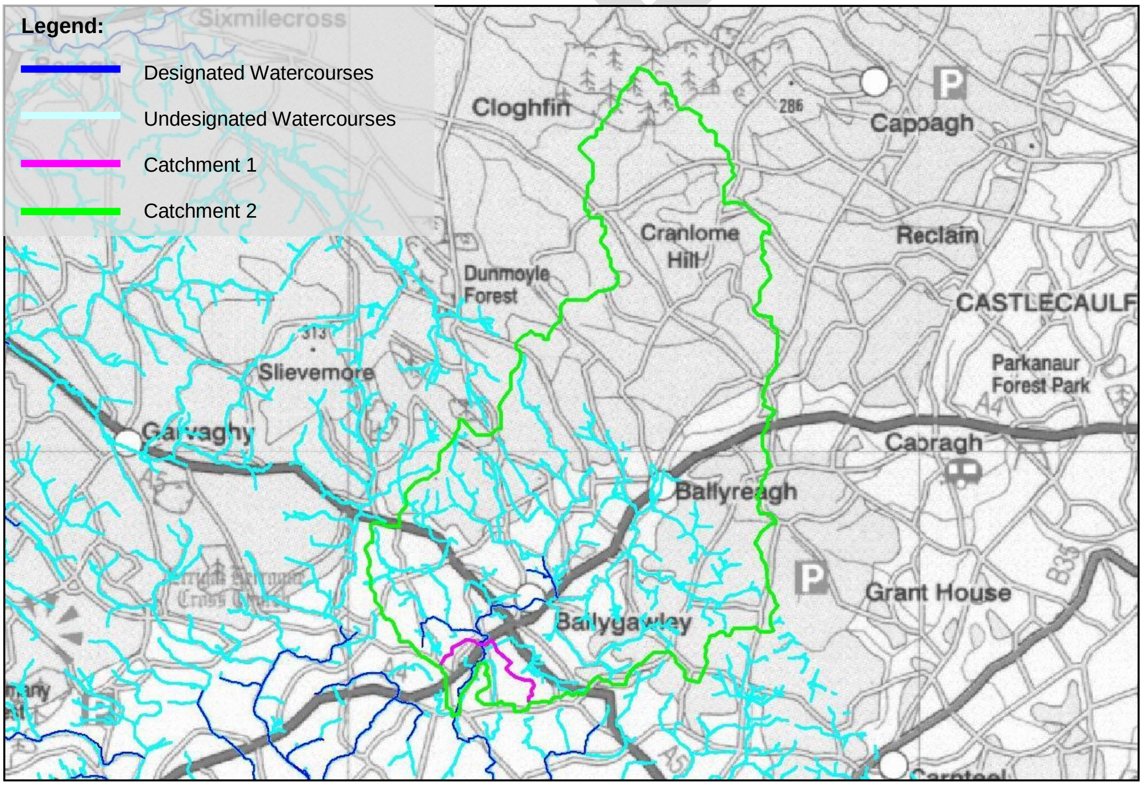

Figure 5.4.9-1 – Model M.U - Hydrological Catchment Outlines

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Table 5.4.9-1- Model M.U, Ballygawley River Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		2 Yrs	25 Yrs	100 Yrs	100 Yrs + CC
Flows at Tullybryan Gauge	44.7	26.78	39.15	47.27	56.72
Downstream boundary (at Lidoart)	45.8	26.99	39.46	47.63	57.16

5.4.10 Model M.V – MW4230 Tullyvar Drain

Catchment Details

The Tullyvar Drain is defined within FEH software and is a tributary of the Ballygawley River. The hydrological catchment to the point GR 263612 354745 is approximately 2.62km^2.

Hydrological Data

There are no flow monitoring stations on Tullyvar Drain, and consequently no recorded flow data.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for Tullyvar Drain. Peak design flows were estimated for one location. Figure 5.4.10-1 and Table 5.4.10-1 below shows the hydrological catchment boundary and a summary of the estimated design flows.

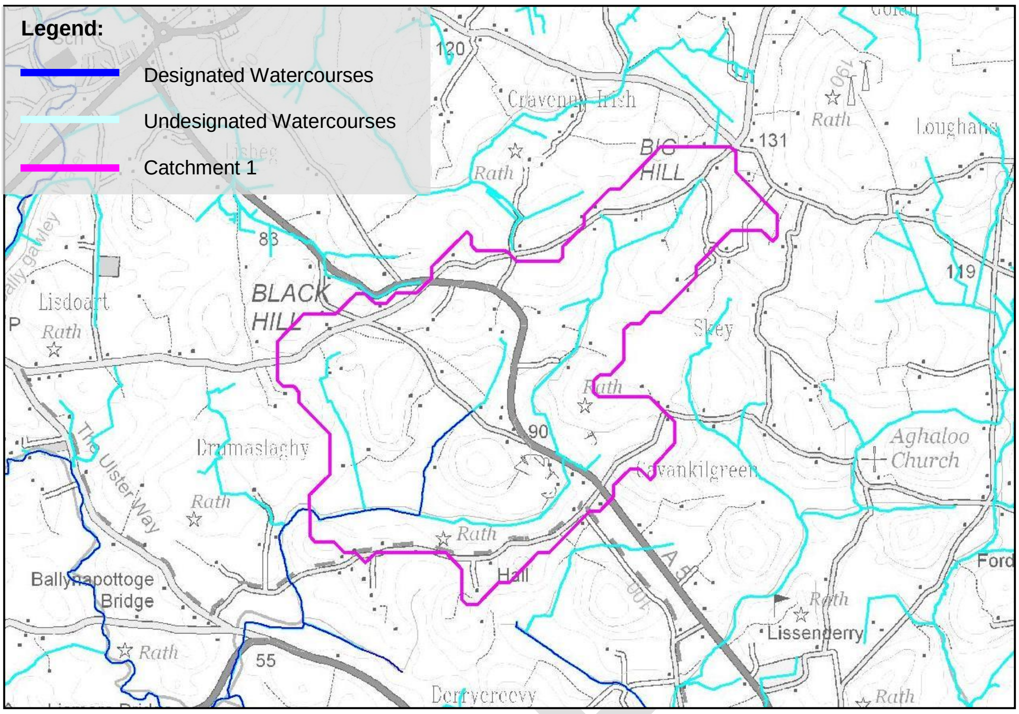

Figure 5.4.10-1 – Model M.V - Hydrological Catchment Outlines

Table 5.4.10-1- Model M.V, Tullyvar Drain Watercourse Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	2.62	1.38	2.93	4.10	4.92

5.4.11 Model M.W – MW4226 Ravella Drain

Catchment Details

The Ravella Drain is defined within FEH software and is a tributary of the River Blackwater. The hydrological catchment of the Ravella Drain to the point GR 251850 362700 is approximately 0.69km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for the Ravella Drain.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model for Ravella Drain. Peak design flows were estimated for one location at the downstream extent of the catchment and were applied at the upstream model extent in order to be conservative. Figure 5.4.11.1 and Table 5.4.11-1 below shows the hydrological catchment boundary and a summary of the estimated design flows.

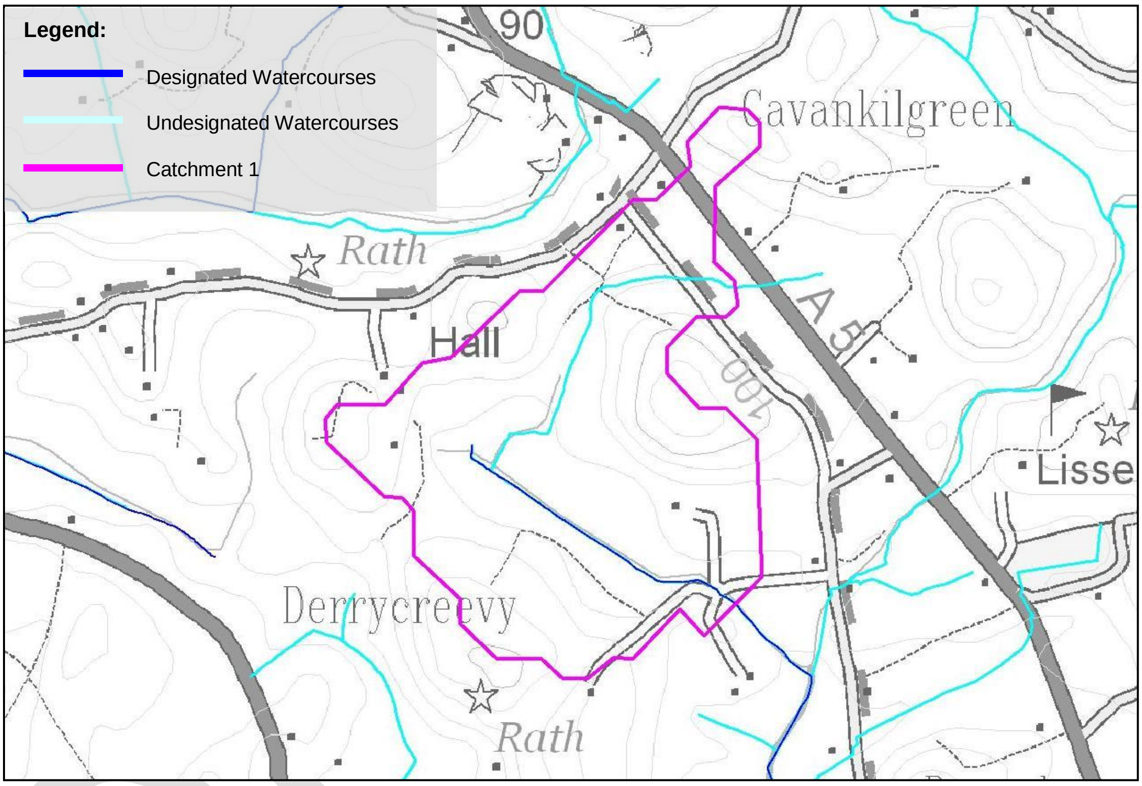

Figure 5.4.11-1 – Model M.W – Undesignated- Hydrological Catchment Outlines

Table 5.4.11-1- Model M.W, Undesignated Watercourse Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
1	0.69	0.63	1.03	1.31	1.57

5.4.12 Model M.X – Undesignated Watercourse (Upstream reach of MW4201 Aughnacloy Urban Ext)

Catchment Details

This upper reach of the Aughnacloy Urban Ext watercourse is defined within FEH software. The hydrological catchment to the point GR 266719 353606 is approximately 4.24km^2.

Hydrological Data

At the time of this assessment no recorded flow data was available for this undesignated watercourse.

Design Flow Estimation

Design flow hydrographs were derived using FEH catchment descriptors and an associated rainfall runoff model. Peak design flows were estimated for one location. Figure 5.4.12-1 and Table 5.4.12-1 below shows the hydrological catchment boundary and a summary of the estimated design flows.

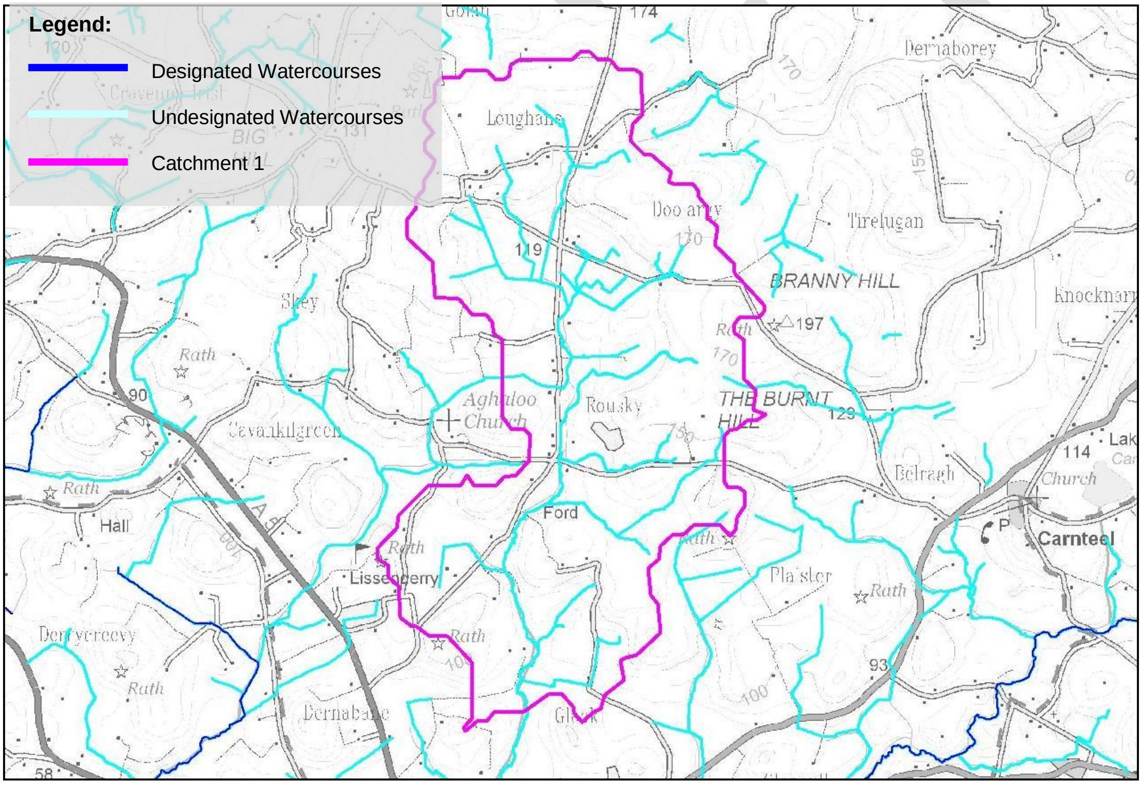

Figure 5.4.12-1 – Model M.X - Hydrological Catchment Outlines

Table 5.4.12-1- Model M.X, Upper reach of Aughnacloy Urban Ext Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
Upstream Boundary	4.24	2.34	4.70	6.73	8.07

5.4.13 Model M.Y – MW4222 Lisadavil River

Catchment Details

The Lisadavil River and associated tributaries are defined within FEH software. It is an upstream tributary of the Aughnacloy River, and the hydrological catchment at the downstream extent of the proposed hydraulic model (GR 266800 357000) covers an area of approximately 15km^2.

Hydrological Data

There are no river level/flow gauges installed along the Lisadavil River and its tributaries within the study reach.

Design Flow Estimation

The hydrological inputs to the proposed hydraulic model will consist of one inflow from each of the seven sub-catchments listed below:

- The upstream catchment area of the River Lisadavil.
- The catchment area of the north branch of the main tributary on the left bank of the River Lisadavil, referred to as 'North – Trib 1' in this report.
- The catchment area of the south branch of the main tributary on the left bank of the River Lisadavil, referred to as 'South – Trib 1' in this report.
- The catchment of the next downstream tributary on the left bank of the River Lisadavil, referred to 'Trib 2' in this report.
- The catchment of the next downstream tributary on the left bank of the River Lisadavil, referred to 'Trib 3' in this report.
- The catchment of the right bank tributary entering between Tributary 2 and Tributary 3. This tributary is referred to as 'Trib 4' in this report.

- The catchment of the next downstream tributary on the right bank of the River Lisadavil, referred to 'Trib 5' in this report. This tributary is situated just upstream of the Monaghan Road Bridge and is the Aughnacloy River.

Due to downstream catchment size, peak design flows were derived using the FEH Statistical method for the Lisadavil River and in order to be consistent this approach was also used to derive peak flows on the tributaries within the model reach. The peak design flows estimated for the eight locations are shown in Table 5.4.13-1. Figure 5.4.13-1 shows the corresponding hydrological catchment boundaries.

Table 5.4.13-1- Model M.Y, Lisadavil River Peak Design Flows

Sub-catchment	Sub-catchment Area (km2)	Return Period Estimated Peak Flow (m3/s)			
		Annual	25 Yrs	100 Yrs	100 Yrs + CC
Upstream Lisadavil	1.04	0.59	1.11	1.47	1.76
North – Trib 1	0.89	0.64	1.21	1.59	1.91
South – Trib 1	4.96	2.54	4.79	6.31	7.57
Trib 2	0.72	0.37	0.70	0.93	1.12
Trib 3	0.72	0.47	0.89	1.17	1.40
Trib 4	0.41	0.35	0.65	0.86	1.03
Trib 5	6.04	3.64	6.87	9.05	10.86
Downstream boundary of the model	14.6	7.11	13.42	17.68	21.22

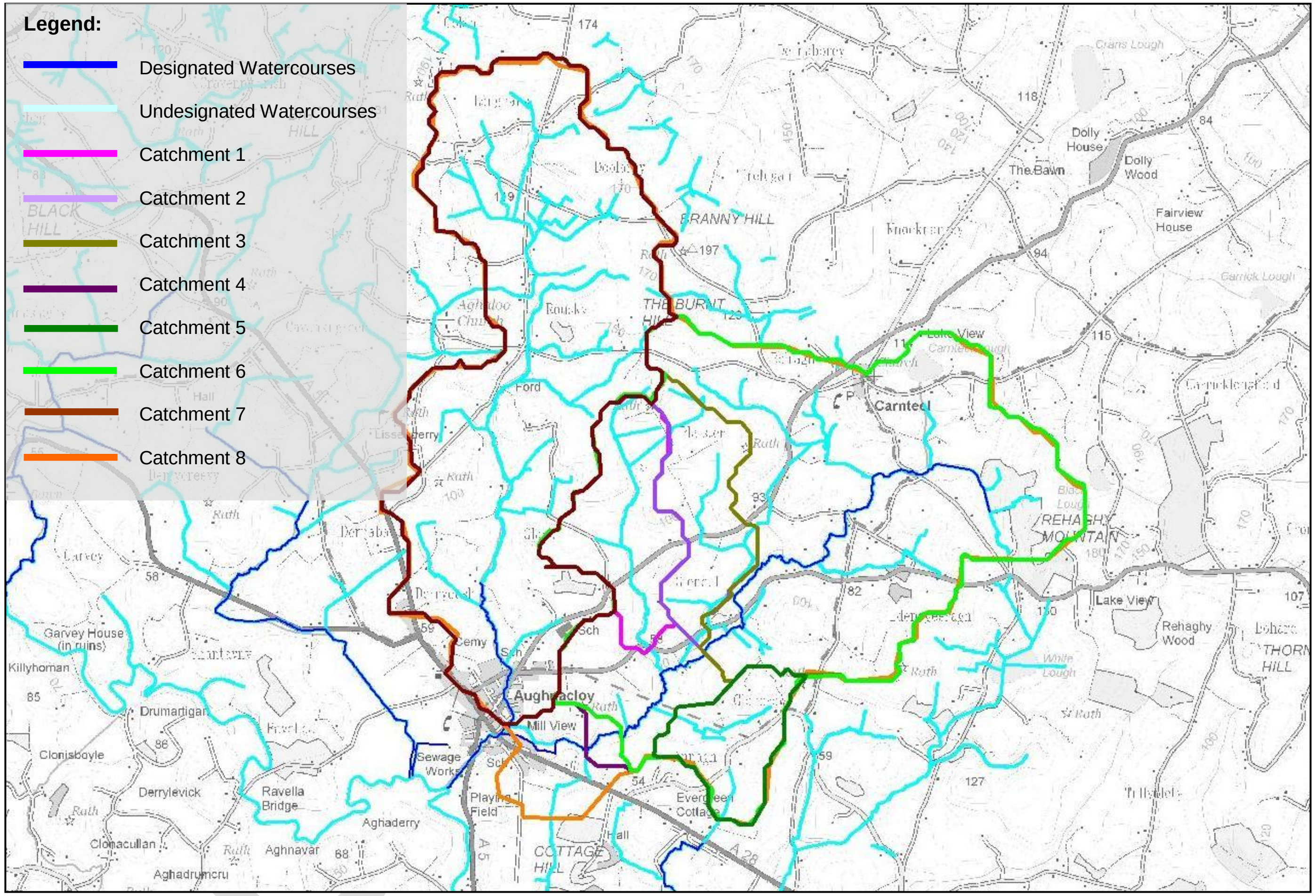

Figure 5.4.13-1 – Model M.Y - Lisadavil River Hydrological Catchment Outlines

6 Model Software and Boundary Conditions

This chapter provides a summary of the model details and the principal boundary conditions used within each of the models. It is noted that determination of Manning roughness coefficients are based on site visits and photographs obtained at time of survey.

6.1 Model Details

A number of industry standard computer packages were used in the river modelling activities for the A5 WTC study:

- HEC-RAS (Version 4.0), US Army Corps of Engineers
- ISIS (Version 3.6), Halcrow Group Limited
- MIKE FLOOD, Danish Hydraulic Institute, incorporating MIKE 11 (Version 2014) and MIKE 21 (Version 2009), Service Pack 5
- TUFLOW (Version 2012-05-AE-iSP-w32), Halcrow Group Limited & BMT WBM Group
- INFOWORKS RS (Version 11), Innovyze
- INFOWORKS ICM (Version 5.5 64 Bit), Innovyze

As detailed in Section 3 of this report, all of the models were modelled in 1D apart from M.1, M.2 and M.3 – Foyle River System, M.4 - Omagh, M.U – Ballygawley Water, M.V - Tullyvar and M.Y - Lisadavil.

6.2 Section 1 - Model Boundary Conditions

6.2.1 Model M.A – MW1127 Gortin Hall Drain

Model boundary conditions are displayed in Table 6.2.1-1 below:

Table 6.2.1-1 - Model M.A, Gortin Hall Drain, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.043	Winding, some pools & shoals, some weeds and stones	-
Left Overbank	0.045	Scattered brush, some weeds.	-
Right Overbank	0.045	Scattered brush, short grass, some weeds	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	4.58 m^3/s	Peak 100 year flow	-
	0.0381	Upstream slope for normal depth calculation	-
Downstream Boundary	2.42 mAOD	Peak Foyle 'design' flood level (from Foyle model)	-

6.2.2 Model M.B – U21109 Blackstone Burn

Model boundary conditions are displayed in Table 6.2.2-1 below:

Table 6.2.2-1 - Model M.B, Blackstone Burn, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.043	Clean, winding, some pools & shoals, some weeds and stones	-
Left Overbank	0.045	Scattered brush, short grass, some weeds	-
Right Overbank	0.045	Scattered brush, short grass, some weeds	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	5.68 m^3/s	Peak 100 year flow	-
	0.0165	Upstream slope for normal depth calculation	-
Downstream Boundary	2.42 mAOD	Peak Foyle 'design' flood level (from Foyle model)	-

6.2.3 Model M.1, M.2 and M.3 – Foyle River System (including River Foyle, River Mourne, River Finn, Ballymagorry, Burn Dennet, Deele River, Swilly Burn)

The Foyle System comprises seven key rivers in a single hydraulic model. Due to tidal influences, a number of model boundary permutations have been applied. This is where combinations of tide levels and river flows with a given chance of occurrence are assessed (joint probability). Tables 6.2.3-1 to 6.2.3-7 below illustrate the typical model boundary conditions for a 100 year fluvial dominant scenario. This information is also contained within document *718736/0500/R/004 Draft Model Build and Hydrology Report – Foyle River System*

Table 6.2.3-1 – Model M.1, Foyle System Model Boundary Conditions (Finn)

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.030	Clean, straight, some pools & shoals. Mud, stones and gravel	-
Left Over-bank	0.045 0.044	Floodplain – open fields	1D domain upstream of Clady Bridge 2D domain downstream of Clady Bridge
Right Over-bank	0.045 0.030-0.044	Floodplain – open fields	1D domain upstream of Clady Bridge 2D domain downstream of Clady Bridge
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	619/66 m^3/s	100 year fluvial flow hydrograph	-
	-	Upstream slope for normal depth calculation	MIKE model applies automatically
Downstream Boundary	Foyle	Confluence with Foyle / Mourne	-

Table 6.2.3-2 – Model M.1, Foyle System Model Boundary Conditions (Mourne)

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.031	Clean, straight, some pools & shoals, some weeds and stones	-
Left Over-bank	0.048 0.025-0.044	Floodplain – open fields and some urban areas	1D domain upstream of Milltown Bridge, 2D domain downstream of Milltown Bridge (urban Strabane not flooding)
Right Over-bank	0.048 0.025-0.046	Floodplain – open fields and some urban areas	1D domain upstream of Milltown Bridge 2D domain downstream of Milltown Bridge (urban Strabane not flooding)
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	1152.21 m3/s	100 year fluvial flow hydrograph	-
	-	Upstream slope for normal depth calculation	MIKE model applies automatically
Downstream Boundary	Foyle	Junction Foyle / Finn	-

Table 6.2.3-3 – Model M.1, Foyle System Model Boundary Conditions (Foyle)

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.027-0.030	Clean, straight, wide. Mud, stones and gravel.	-
Left Over-bank	0.045	Floodplain – open fields, pasture, some localised urban areas / roads	2D domain
Right Over-bank	0.045	Floodplain – open fields, pasture, some localised urban areas / roads	2D domain
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	-	100 year fluvial flow hydrographs from other connecting rivers	various
	-	Conditions across confluence of all connecting rivers	MIKE model applies automatically
Downstream Boundary	Tide	Tidal levels	dynamic

Table 6.2.3-3 – Model M.1, Foyle System Model Boundary Conditions (Foyle)

Watercourse Feature	Manning's 'n' Value	Description	Comments

Table 6.2.3-4 – Model M.2, Foyle System Model Boundary Conditions (Burn Dennet)

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Clean, winding, some pools & shoals, some weeds and stones	Burn Dennet
Left Over-bank	0.0375	Floodplain – Open fields, pasture	2D domain
Right Over-bank	0.0375	Floodplain – Open fields, pasture	2D domain
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	181.83 m3/s	100 year fluvial flow hydrograph	-
	-	Upstream slope for normal depth calculation	MIKE model applies automatically
Downstream Boundary	Foyle	Downstream Foyle water level	-

Table 6.2.3-5 – Model M.3, Foyle System Model Boundary Conditions (Glenmornan)

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Clean, straight, some pools & shoals, some weeds and stones	-
Left Over-bank	0.0375	Floodplain – Open fields, pasture	2D domain
Right Over-bank	0.0375	Floodplain – Open fields, pasture	2D domain
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	40.98 m3/s	100 year fluvial flow hydrograph	-
	-	Upstream slope for normal depth calculation	MIKE model applies automatically
Downstream Boundary	Foyle	Foyle water level	-

Table 6.2.3-6 – Model M.1, Foyle System Model Boundary Conditions (Deele)

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Clean, winding, some pools & shoals, some weeds and stones	-
Left Over-bank	0.0375	Floodplain – Open fields, pasture	2D domain
Right Over-bank	0.0375	Floodplain – Open fields, pasture	2D domain
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	179.27 m3/s	100 year fluvial flow hydrograph	-
	-	Upstream slope for normal depth calculation	MIKE model applies automatically
Downstream Boundary	Foyle	Foyle water level	-

Table 6.2.3-7 – Model M.1, Foyle System Model Boundary Conditions (Swilly)

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Clean, winding, some pools & shoals, some weeds and stones	-
Left Over-bank	0.0375	Floodplain – Open fields, pasture.	2D domain
Right Over-bank	0.0375	Floodplain – Open fields, pasture.	2D domain
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	72.15 m3/s	100 year fluvial flow hydrograph	-
	-	Upstream slope for normal depth calculation	MIKE model applies automatically
Downstream Boundary	Foyle	Foyle water level	-

6.3 Section 2 - Model Boundary Conditions

6.3.1 Model M.D – Undesignated Watercourse (Upstream of Seein Bridge)

Model boundary conditions are displayed in Table 6.3.1-1 below:

Table 6.3.1-1 - Model M.D, Undesignated Watercourse, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.047	Winding, some weeds, stones.	-
Left Overbank	0.050	Scattered brush, heavy weeds, high grass.	-
Right Overbank	0.050	Scattered brush, heavy weeds, high grass.	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	8.05 m^3/s	Peak 100 year flow	-
	0.0089	Upstream slope for normal depth calculation	-
Downstream Boundary	0.03	Downstream slope for normal depth calculation	-

6.3.2 Model M.5 – 101 River Derg

Model boundary conditions are displayed in Table 6.3.2-1 below:

Table 6.3.2-1 - Model M.5, River Derg, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.0351	Channel - Major Rivers- clean, straight, some stone and weeds	Strule and Derg
Left Overbank	0.044	Floodplain – pasture, scattered brush and weeds	Strule and Derg
	0.05	Floodplain – pasture, scattered brush and weeds with a few trees	Strule and Derg
Right Overbank	0.044	Floodplain – pasture, scattered brush and weeds	Strule and Derg
	0.05	Floodplain – pasture, scattered brush and weeds with a few trees	Strule and Derg
	0.0551	Floodplain – pasture, scattered brush and weeds with a few trees	Strule and Derg
Watercourse Feature	**Value**	**Description**	**Comments**

Upstream Boundary	303.03 m³/s	Peak 100 year flow	Derg
	0.00086	Upstream slope for normal depth calculation	Derg
	956.77 m³/s	Peak 100 year flow	Strule
	0.0015	Upstream slope for normal depth calculation	Strule
Downstream Boundary	0.0025	Downstream slope for normal depth calculation	Strule

6.3.3 Model M.E – Coolaghy Burn (Undesignated)

Model boundary conditions are displayed in Table 6.3.3-1 below:

Table 6.3.3-1 - Model M.E, Coolaghy Burn, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.040	Channel clean, straight, no deep pools, more stone or weeds	-
Left Overbank	0.043	Floodplain – pasture, mature field crops, grass, light brush	-
Right Overbank	0.043		-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	$32.57\ m^3/s$	Peak 100 year flow	-
	0.0043	Upstream slope for normal depth calculation	-
Downstream Boundary	0.00355	Downstream slope for normal depth calculation	-

6.3.4 Model M.F – U1704 Ext Back Burn Extension, Newtownstewart

Model boundary conditions are displayed in Table 6.3.4-1 below:

Table 6.3.4-1 - Model M.F, Ext Back Burn Extension, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.0045	Clean, winding, some pools & shoals, some weeds and stones	
Left Overbank	0.050	Scattered brush, heavy weeds	-
	0.035	Short Grass	-
	0.06	Short Grass	-
Right Overbank	0.050	Scattered brush, heavy weeds	-
	0.035	Short Grass	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	1.55 m^3/s	Peak 100 year flow	-
	0.105	Upstream slope for normal depth calculation	-
Downstream Boundary	0.1006	Downstream slope for normal depth calculation	-

6.3.5 Model M.G – Undesignated Watercourse

Model boundary conditions are displayed in Table 6.3.5-1 below:

Table 6.3.5-1 - Model M.G, Undesignated Watercourse, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.03	Clean channel, no rifts or deep pools	-
Left Overbank	0.05	Scattered brush, heavy weeds	-
Right Overbank	0.05	Scattered brush, heavy weeds	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	4.10 m^3/s	Peak 100 year flow	-
	0.0026	Upstream slope for normal depth calculation	-
Downstream Boundary	0.001	Downstream slope for normal depth calculation	-

6.3.6 Model M.H – Tully Drain (Undesignated Reach – Mountjoy)

Model boundary conditions are displayed in Table 6.3.6-1 below:

Table 6.3.6-1 - Model M.H, Tully Drain, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.050	Winding, some stones, weeds	-
Left Overbank	0.055	Scattered brush, cultivated area	-
Right Overbank	0.055		-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	3.2 m³/s	Peak 100 year flow	-
	0.00193	Upstream slope for normal depth calculation	
Downstream Boundary	0.003	Downstream slope for normal depth calculation	-

6.3.7 Model M.4 – Fairy Water, Omagh (including Aghnamoyle Drain, Tully Drain, Camowen River, Drumragh River and Strule River)

Table 6.3.7-1 - Model M.4, Fairy Water (Omagh), Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.030	Channel – Major Rivers - clean, straight with some stones and weeds	Fairy Water downstream of cross section FAIR01_1920; Strule River upstream of cross section STRU01_4398; Drumragh River and Camowen River.
	0.045	Channel – Major Rivers - clean, winding with more stones and weeds	Fairy Water upstream of cross section FAIR01_1920; Strule River downstream of cross section STRU01_4398;
Minor Channel	0.035	Channel – Minor Rivers - clean, winding with more stones and weeds	Anaghmoyle Drain,Tully Drain, Conneywarren.
Left Overbank	0.050	Floodplain – scattered brush and weeds with a few trees	Fairy Water downstream of cross section FAIR01_1920; Strule River upstream of cross section STRU01_4398; Drumragh River and Camowen River.

Table 6.3.7-1 - Model M.4, Fairy Water (Omagh), Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
	0.06	Floodplain – medium to dense brush and weeds with more trees	Fairy Water upstream of cross section FAIR01_1920; Strule River downstream of cross section STRU01_4398;
	0.035	Floodplain – medium to dense brush and weeds with more trees	Anaghmoyle Drain and Tully Drain, Conneywarren.
Right Overbank	0.050	Floodplain – scattered brush and weeds with a few trees	Fairy Water downstream of cross section FAIR01_1920; Strule River upstream of cross section STRU01_4398; Drumragh River and Camowen River.
	0.06	Floodplain – medium to dense brush and weeds with more trees	Fairy Water upstream of cross section FAIR01_1920; Strule River downstream of cross section STRU01_4398;
	0.035	Floodplain – medium to dense brush and weeds with more trees	Anaghmoyle Drain and Tully Drain, Conneywarren.
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	202 m^3/s	Peak 100yr flow	Camowen River
	0.007	Upstream slope	Camowen River
Upstream Boundary	143 m^3/s	Peak 100yr flow	Fairy Water
	0.003	Upstream slope	Fairy Water
Upstream Boundary	214 m^3/s	Peak 100yr flow	Drumragh River
	0.003	Upstream slope	Drumragh River
Upstream Boundary	2.92 m^3/s	Peak 100yr flow	Tully Drain

Table 6.3.7-1 - Model M.4, Fairy Water (Omagh), Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Upstream Boundary	0.004	Upstream slope	Tully Drain
	2.97 m^3/s	Peak 100yr flow	Aghnamoyle Drain
	0.008	Upstream slope	Aghnamoyle Drain
Downstream Boundary	644 m^3/s	Peak 100yr flow	Strule River
	0.0009	Downstream slope	

6.3.8 Model M.I – MW1545 Fireagh Lough Drain

Model boundary conditions are displayed in Table 6.3.8-1 below:

Table 6.3.8-1 - Model M.I, MW1545 Fireagh Lough Drain, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.04	Straight, some stones and weeds	-
Left Overbank	0.04	Scattered brush, pasture, low to medium high grass	-
	0.045	Scattered brush, high grass	-
Right Overbank	0.04	Scattered brush, pasture, low to medium high grass	-
	0.045	Scattered brush, high grass	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	4.67 m^3/s	Peak 100 year fluvial flow	-
	0.0625	Upstream slope for normal depth calculation	-
Downstream Boundary	0.00495	Downstream slope for normal depth calculation	-

6.3.9 Model M.6 – 121 Drumragh River (Extension)

Model boundary conditions are displayed in Table 6.3.9-1 below:

Table 6.3.9-1 - Model M.6, 121 Drumragh River (Extension), Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.032	Straight channel with vegetation.	-
Left Overbank	0.055	Light to medium brush	-
Right Overbank	0.045 - 0.055	Light to medium brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	212.45 m³/s	Peak 100 year flow	Drumragh River
	0.001	Upstream slope for normal depth calculation	Drumragh River
Upstream Boundary	2.23 m³/s	Peak 100 year flow	Lough Muck Tributary
Upstream Boundary	1.65 m³/s	Peak 100 year flow	Beagh House Tributary
Upstream Boundary	1.77 m³/s	Peak 100 year flow	Kivlin Burn Tributary
Upstream Boundary	4.05 m³/s	Peak 100 year flow	Freaghmore Drain tributary
Downstream Boundary	0.001	Downstream slope for normal depth calculation	Drumragh River

6.4 Section 3 - Model Boundary Conditions

6.4.1 Model M.L – MW1410 Ranelly Drain

Model boundary conditions are displayed in Table 6.4.1-1 below:

Table 6.4.1-1 - Model M.L, MW1410 Ranelly Drain, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.030	Clean silt and gravel bed channel with short grass to banks.	-
Left Overbank	0.040	Field with short to medium height grass.	-
Right Overbank	0.040	Field with short to medium height grass.	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	3.17 m^3/s	Peak 100 year flow	-
	0.004	Upstream slope for normal depth calculation	-
Upstream Tributary	1.73 m^3/s	Peak 100 year flow	-
	0.005	Upstream slope for normal depth calculation	-
Lateral Inflow	3.28 m^3/s	Peak 100 year flow	-
Downstream Boundary	0.011	Downstream slope for normal depth calculation	-

6.4.2 Model M.M – MW1401 Letfern Watercourse

Model boundary conditions are displayed in Table 6.4.2-1 below:

Table 6.4.2-1 - Model M.M, MW1401 Letfern Watercourse, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Natural channel with medium size cobbles	-
Left Overbank	0.050	Floodplain with light brush	-
Right Overbank	0.050	Floodplain with light brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	6.10 m^3/s	Peak 100 year flow	-
	0.012	Upstream slope for normal depth calculation	-
Downstream Boundary	0.003	Downstream slope for normal depth calculation	-

6.4.3 Model M.N – Undesignated Watercourse (Upstream of MW1402 Letfernburn Branch)

Model boundary conditions are displayed in Table 6.4.3-1 below:

Table 6.4.3-1 - Model M.N, Undesignated Watercourse, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Irregular channel with cobble bed. Minimum vegetation on banks.	-
Left Overbank	0.055	Light to medium brush	-
Right Overbank	0.055	Light to medium brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	0.55 m³/s	Peak 100 year flow	West Tributary
	0.035	Upstream slope for normal depth calculation	West Tributary
Upstream Boundary	0.82 m³/s	Peak 100 year flow	East Tributary
	0.022	Upstream slope for normal depth calculation	East Tributary
Downstream Boundary	0.028	Downstream slope for normal depth calculation	-

6.4.4 Model M.O – Undesignated Watercourse

Model boundary conditions are displayed in Table 6.4.4-1 below:

Table 6.4.4-1 - Model M.O, Undesignated Watercourse, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Irregular channel with cobble. Minimum vegetation on banks.	-
Left Overbank	0.055	Light to medium brush	-
Right Overbank	0.055	Light to medium brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary (North Tributary)	1.04 m³/s	Peak 100 year flow	-
	0.032	Upstream slope for normal depth calculation	-
Upstream Boundary (South Tributary)	0.78 m³/s	Peak 100 year flow	-
	0.013	Upstream slope for normal depth calculation	-
Downstream Boundary	0.019	Downstream slope for normal depth calculation	-

6.4.5 Model M.P/M.Q - 144 Routing Burn, MW1424 Routing Burn Ext and Undesignated Tributary

Model boundary conditions are displayed in Table 6.4.5-1 below:

Table 6.4.5-1 - Model M.P/M.Q, 144 Routing Burn, MW1424 Routing Burn Ext and Undesignated Tributary, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	clean, straight channel with cobble and short grass	-
Left Overbank	0.035	Floodplain – pasture, short grass	-
	0.050	Floodplain – light brush	-
Right Overbank	0.035	Floodplain – pasture, short grass	-
	0.050	Floodplain – light brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary (model M.P)	18.79 m^3/s	Peak 100 year flow	Routing Burn
	0.018	Upstream slope for normal depth calculation	Routing Burn
Upstream Boundary (model M.Q Inflow A)	0.86 m^3/s	Peak 100 year flow	Undesignated
	0.037	Upstream slope for normal depth calculation	Undesignated
Upstream Boundary (model M.Q Inflow B)	1.28 m^3/s	Peak 100 year flow	Undesignated
	0.011	Upstream slope for normal depth calculation	Undesignated
Upstream Boundary (model M.Q Inflow C)	0.41 m^3/s	Peak 100 year flow	Undesignated
	0.014	Upstream slope for normal depth calculation	Undesignated
Upstream Boundary (model M.Q Inflow D)	0.82 m^3/s	Peak 100 year flow	Undesignated
	0.011	Upstream slope for normal depth calculation	Undesignated
Downstream Boundary	0.0036	Downstream slope for normal depth calculation	Routing Burn

6.4.6 Model M.R – Undesignated Watercourse (Newtownsaville)

Model boundary conditions are displayed in Table 6.4.6-1 below:

Table 6.4.6-1 - Model M.R, Undesignated Watercourse, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.03	Clean silt and gravel bed channel with short grass to banks.	Downstream reach of model
	0.04	Channel with heavy vegetation.	Upstream reach of model
Left Overbank	0.050	Floodplain – Light Brush	-
Right Overbank	0.050	Floodplain – Light Brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	3.79 m³/s	Peak 100 year flow	-
	0.012	Upstream slope for normal depth calculation	-
Downstream Boundary	0.022	Downstream slope for normal depth calculation	-

6.4.7 Model M.S – Undesignated Watercourse (Kilgreen)

Model boundary conditions are displayed in Table 6.4.7-1 below:

Table 6.4.7-1 - Model M.S, Undesignated, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.03	Clean silt and gravel bed channel with short grass to banks.	-
Left Overbank	0.050	Floodplain – light brush	-
Right Overbank	0.050	Floodplain – light brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Tributary	3.8 m³/s	Peak 100 year flow	Main Undesignated Watercourse
	0.033	Upstream slope for normal depth calculation	-
Upstream Boundary (unnamed tributary)	1.30 m³/s	Peak 100 year flow	Undesignated Tributary
	0.028	Upstream slope for normal depth calculation	-
Downstream Boundary	0.021	Downstream slope for normal depth calculation	-

6.4.8 Model M.T – MW4105 Roughan River

Model boundary conditions are displayed in Table 6.4.8-1 below:

Table 6.4.8-1 - Model M.T, MW4105 Roughan River, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.030 – 0.032	Clean silt and gravel bed channel with short grass to banks.	-
Left Overbank	0.050 – 0.055	Floodplain – light to medium brush	-
Right Overbank	0.050 – 0.055	Floodplain – light to medium brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	19.38 m^3/s	Peak 100 year flow	Roughan River
	0.0080	Upstream slope for normal depth calculation	Roughan River
Upstream Boundary (Crew Hill)	0.73 m^3/s	Peak 100 year flow	Undesignated tributary
	0.007	Upstream slope for normal depth calculation	Undesignated tributary
Lateral Inflow	0.57 m^3/s	Peak 100 year flow	Undesignated tributary
	0.007	Upstream slope for normal depth calculation	Undesignated tributary
Upstream Boundary (Culnaha)	1.83 m^3/s	Peak 100 year flow	Undesignated tributary
	0.039	Upstream slope for normal depth calculation	Undesignated tributary
Downstream Boundary	0.0033	Downstream slope for normal depth calculation	Roughan River

6.4.9 Model M.U – Ballygawley Water

Model boundary conditions are displayed in Table 6.4.9-1 below:

Table 6.4.9-1 - Model M.U, Ballygawley Water, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.040	Straight, no deep pools, some weeds and gravel.	Modelled in 1D domain
Left Overbank	0.013	Roads and pavements	Modelled in 2D domain
	0.040	Short to medium grass	
	0.050	Long grass and bushes	
Right Overbank	0.013	Roads and pavements	Modelled in 2D domain
	0.040	Short to medium grass	
	0.050	Long grass and bushes	
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	47.27 m³/s	Peak 100 year flow	-
	0.0023	Upstream slope for normal depth calculation	-
Downstream Boundary	0.001	Downstream slope for normal depth calculation	-

6.4.10 Model M.V – MW4230 Tullyvar Drain

Model boundary conditions are displayed in Table 6.4.10-1 below:

Table 6.4.10-1 - Model M.V, Tullyvar Drain, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	-	No main channel in the model	Modelled in 2D domain only (using LiDAR) due to lack of survey access
Left Overbank	0.040	Floodplain – Open fields, short grass	No survey data
	0.045	Floodplain – vegetated, bushes or high grass	No survey data
Right Overbank	0.040	Floodplain – Open fields, short grass	No survey data
	0.045	Floodplain – vegetated, bushes or high grass	No survey data
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	4.1 m^3/s	Peak 100 year flow	-
Downstream Boundary	57.5 m AOD	Fixed water level at d/s end of 2D model (beyond influence of study area).	-

6.4.11 Model M.W – MW4226 Ravella Drain

Model boundary conditions are displayed in Table 6.4.11-1 below:

Table 6.4.11-1 - Model M.W, MW4226 Ravella Drain, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.035	Irregular channel with slight vegetation on banks.	-
Left Overbank	0.055	Light to medium Brush	-
Right Overbank	0.055	Light to medium Brush	-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	1.31 m^3/s	Peak 100 year flow	-
	0.027	Upstream slope for normal depth calculation	
Downstream Boundary	0.025	Downstream slope for normal depth calculation	-

6.4.12 Model M.X – Undesignated Watercourse (Upstream Tributary of MW4201 Ext Aughnacloy Urban Ext)

Model boundary conditions are displayed in Table 6.4-12-1 below:

Table 6.4.12-1 - Model M.X, Undesignated Watercourse, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.040	Drain is clean, straight, no deep pools, some stones and weeds	-
Left Overbank	0.045	Floodplain – Light brush & trees	-
Right Overbank	0.045		-
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	6.73 m^3/s	Peak 100 year flow	-
	0.01758	Upstream slope for normal depth calculation	-
Downstream Boundary	0.01587	Downstream slope for normal depth calculation	-

6.4.13 Model M.Y – MW4222 Lisadavil River

Model boundary conditions are displayed in Table 6.4.13-1 below:

Table 6.4.13-1 - Model M.Y, MW4222 Lisadavil River, Model Boundary Conditions

Watercourse Feature	Manning's 'n' Value	Description	Comments
Main Channel	0.033	Irregular channel with cobble and short grass on the banks	Modelled in 1D Domain
Left Overbank	0.05	Light brush	Modelled in 2D Domain
Right Overbank	0.05	Light brush	Modelled in 2D Domain
Watercourse Feature	**Value**	**Description**	**Comments**
Upstream Boundary	1.47 m3/s	Peak 100 year flow	Lisadavil River
	0.029	Upstream slope for normal depth calculation	Lisadavil River
Upstream Boundary	1.59 m3/s	Peak 100 year flow	Tributary 1 North
Upstream Boundary	6.31 m3/s	Peak 100 year flow	Tributary 1 South
Upstream Boundary	0.93 m3/s	Peak 100 year flow	Tributary 2
Upstream Boundary	1.17 m3/s	Peak 100 year flow	Tributary 3
Upstream Boundary	0.86 m3/s	Peak 100 year flow	Tributary 4
Upstream Boundary	9.05 m3/s	Peak 100 year flow	Tributary 5
Downstream Boundary	0.001	Downstream slope for normal depth calculation	Lisadavil River

7 Hydraulic Modelling Results

Through hydraulic modelling, flood levels and associated flood extents were determined for the watercourses / model locations outlined in previous chapters.

Water levels along the watercourses were calculated for a range of return periods up to and including the 100 year [1% Annual Exceedance Probability (1% AEP)] plus climate change for the existing scenario. An estimation of the flood outline for various return periods is determined by comparing projected water levels against the prevailing site topography. For the requirements of this report, this section illustrates the 1% AEP flood outline for each of the flood models associated with the Proposed Scheme. This is considered the ‘design’ event. For tidal floodplain the 200 year [0.5% AEP] was also assessed for tidally dominant scenarios. Each of the flood outlines can be seen in the figures under the headings for the relevant flood model. The flood outlines are within in model extents detailed in Section 3 of this report.

Hydraulic modelling also allowed an assessment of the likely effects resulting from the crossing of the watercourses, and floodplains with the Proposed Scheme. This information was then used for developing possible flood mitigation measures, and ensuring the design complies with the recommendations set out in the DMRB. Further information on this aspect can be seen in FRA Report 3 – *Impacts and Mitigation Assessment Report*.

7.1 Section 1 – Flood Extents

7.1.1 Model M.A – MW1127 Gortin Hall Drain

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.1.1-1 below:

Figure 7.1.1-1 - Model M.A Gortin Hall Drain Q100 Floodplain (Scale 1:5000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI).

7.1.2 Model M.B – U21109 Blackstone Burn

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.1.2-1 below:

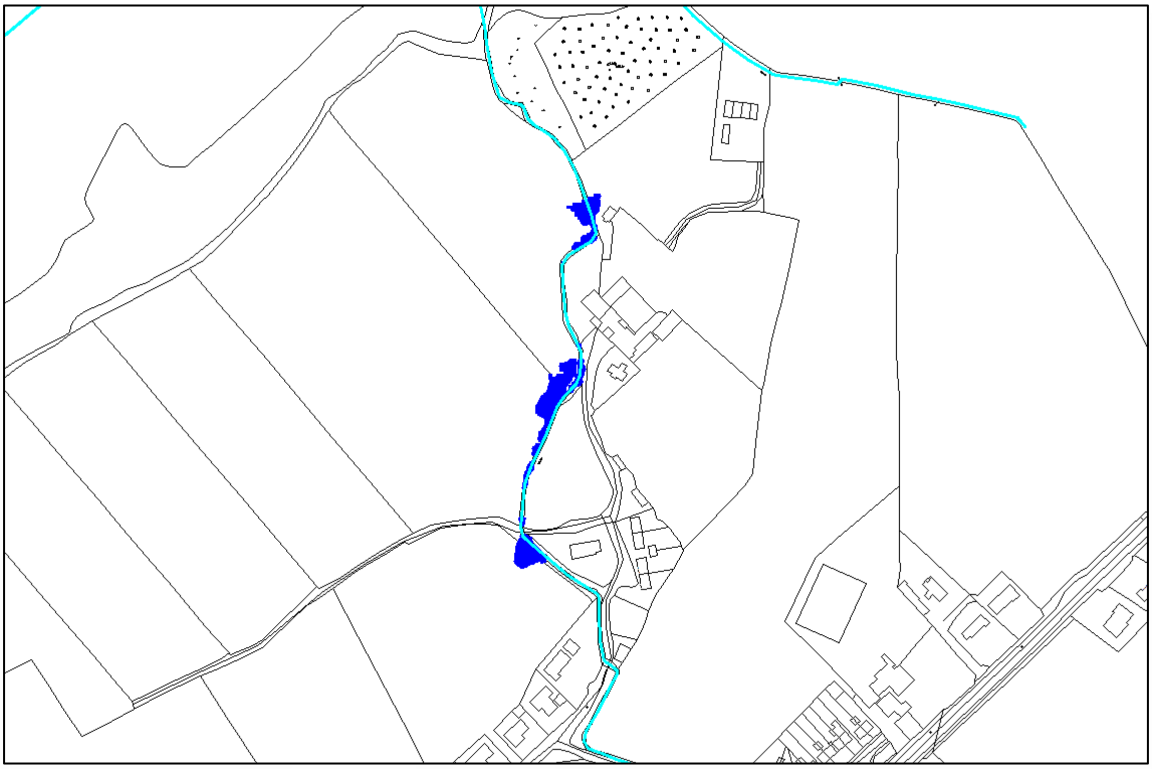

Figure 7.1.2-1 - Model M.B Blackstone Burn Q100 Floodplain (Scale 1:5000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI).

7.1.3 Model M.1, M.2 and M.3 – Foyle River System (including River Foyle, River Mourne, River Finn, Ballymagorry, Burn Dennet, Deele River, Swilly Burn)

An estimation of the flood outline for various return periods is determined by comparing predicted water levels with site topography. It is observed that flooding within the Foyle model arises as a consequence of both tidal inundation, fluvial inundation and inundation at an inter-tidal zone which is mainly around Ballymagorry / Burndennet River. Flood extents for the two design event scenarios: 100 year fluvial flows with an annual (plus climate change) tidal boundary and the 200 year (plus climate change) tide with annual fluvial inflows are illustrated in Figure 7.1.3-1. More details on the model results can be seen in document *718736/0500/R/004 Draft Model Build and Hydrology Report – Foyle River System.*

The red floodplain areas shown in Figure 7.1.3-1 illustrate where the 200 year tidal dominant design event (including an allowance for climate change) yields higher levels than the 100 year fluvial dominant design event. The blue floodplain shows where the fluvial dominant 100 year design event yields higher design levels. Although the red / blue areas indicate which joint probability scenario yields the highest flood level, there is still a significant tidal component present within the upstream fluvial dominant peak levels shown in blue.

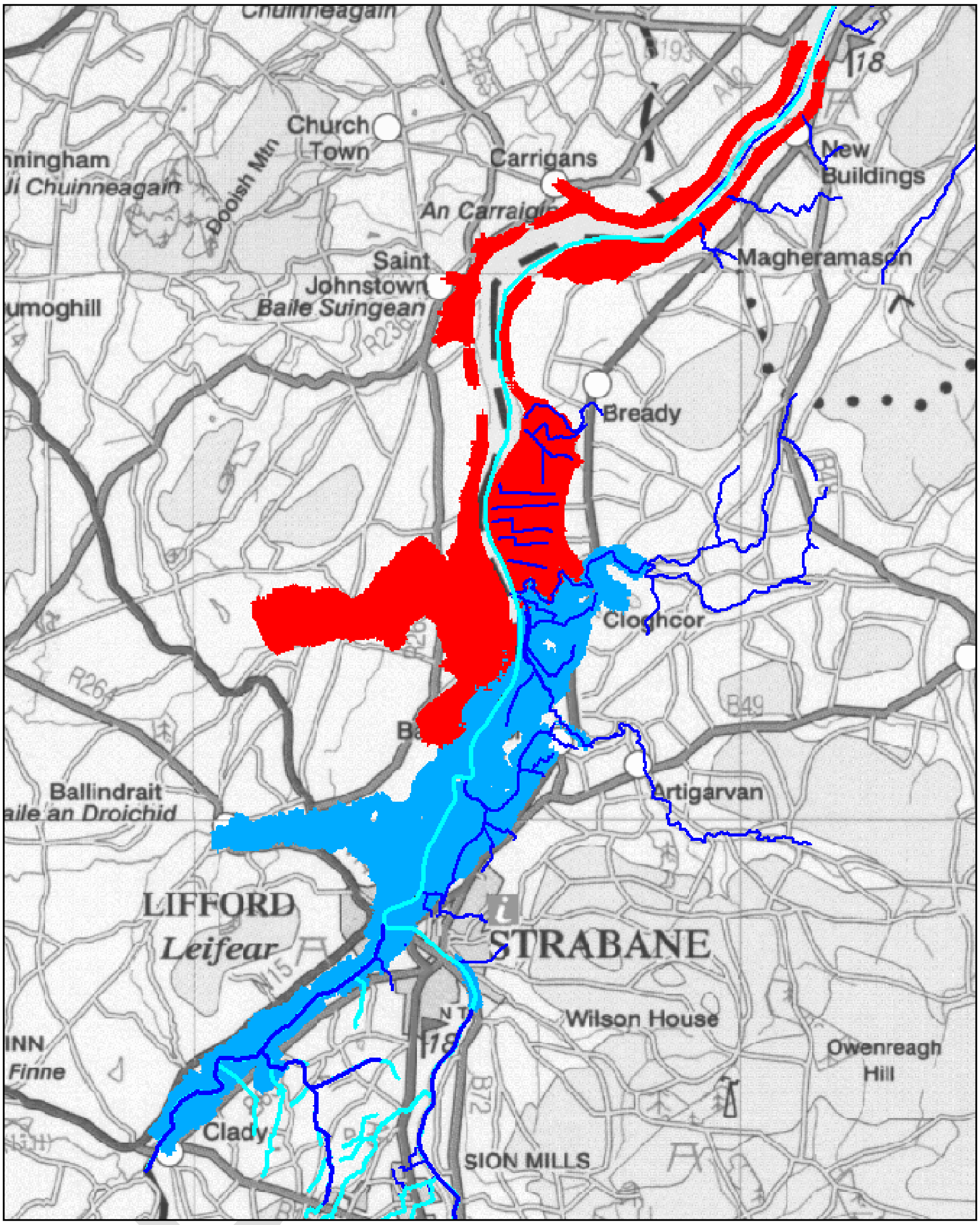

Figure 7.1.3-1 - Model M.1, M.2 and M.3 - River Foyle Joint Q_{100} (fluvial) / Q_{200} (tidal) Floodplains

It is observed that in comparing with Flood Maps (NI), the above illustrated floodplains are more extensive for both the fluvial and tidal scenarios. In reviewing the tidal component it is identified that modelling for the Proposed Scheme includes an allowance for climate change for the Proposed Scheme's design life. It is highlighted that assessments for the Proposed Scheme have taken a conservative approach, further reviews may be undertaken during value engineering phases which will incorporate any scientific updates as they occur.

7.2 Section 2 – Flood Extents

7.2.1 Model M.D – Undesignated Watercourse (Upstream Seein Bridge)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.2.1-1 below:

Figure 7.2.1-1 - Model M.D Undesignated Watercourse Q_{100} Floodplain (Scale 1:5000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that there are some minor differences in relation to the predicted 100 year. However, it is noted that within Flood Maps (NI) the watercourse is modelled strategically and a Strategic floodplain is indicated.

7.2.2 Model M.5 – 101 River Derg

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.2.2-1 below:

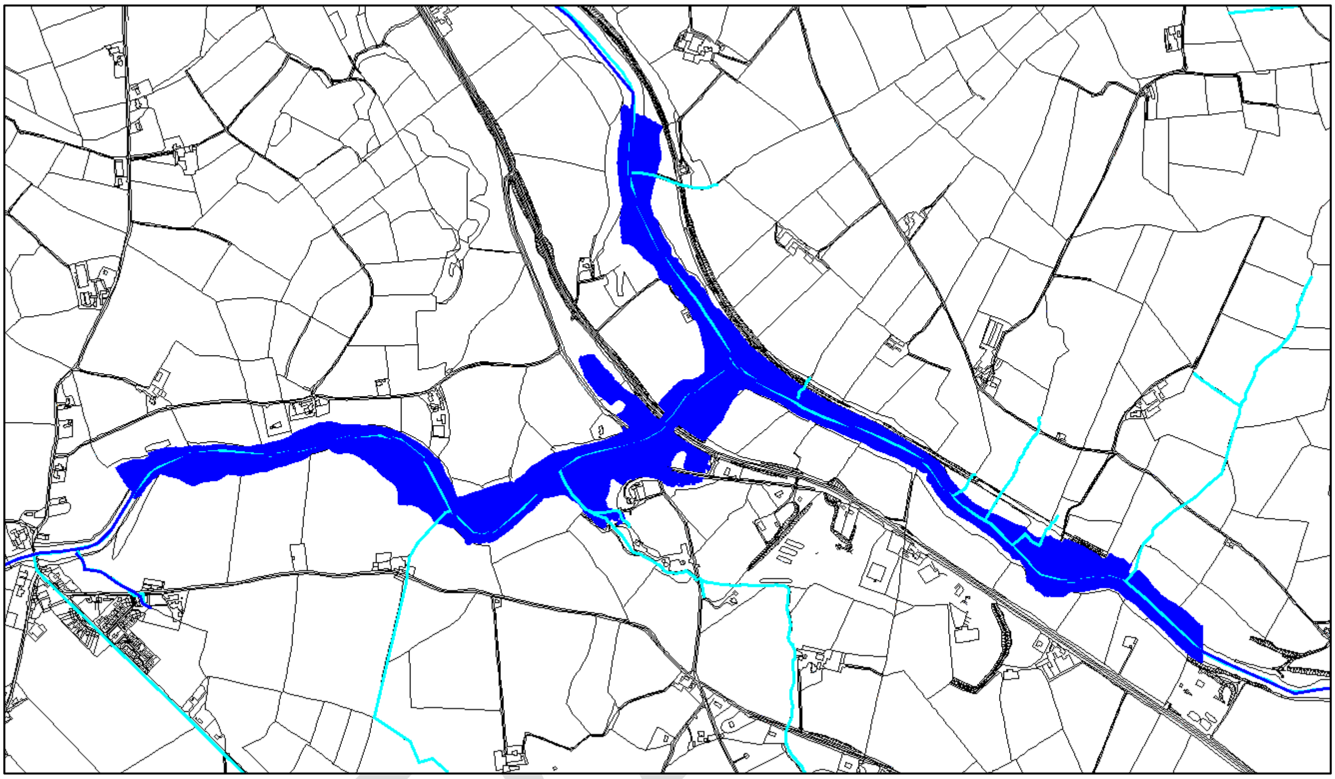

Figure 7.2.2-1 - Model M.5 River Derg Q_{100} Floodplain (Scale 1:20000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI).

7.2.3 Model M.E – Coolaghy Burn (Undesignated)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.2.3-1 below:

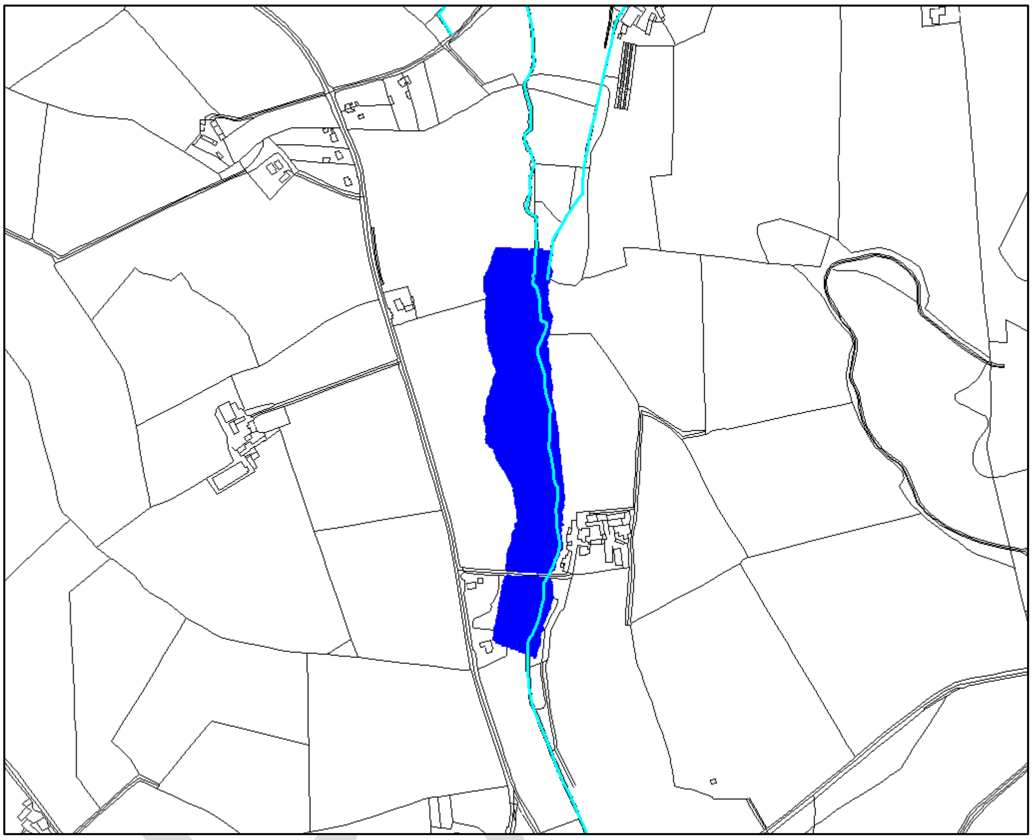

Figure 7.2.3-1 - Model M.E Coolaghy Burn Q_{100} Floodplain (Scale 1:10000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI).

7.2.4 Model M.F – U1704 Ext Back Burn Extension, Newtownstewart

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.2.4-1 below:

Figure 7.2.4-1 - Model M.F Back Burn Q_{100} Floodplain (Scale 1:5000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI).

7.2.5 Model M.G – Undesignated Watercourse

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.2.5-1 below:

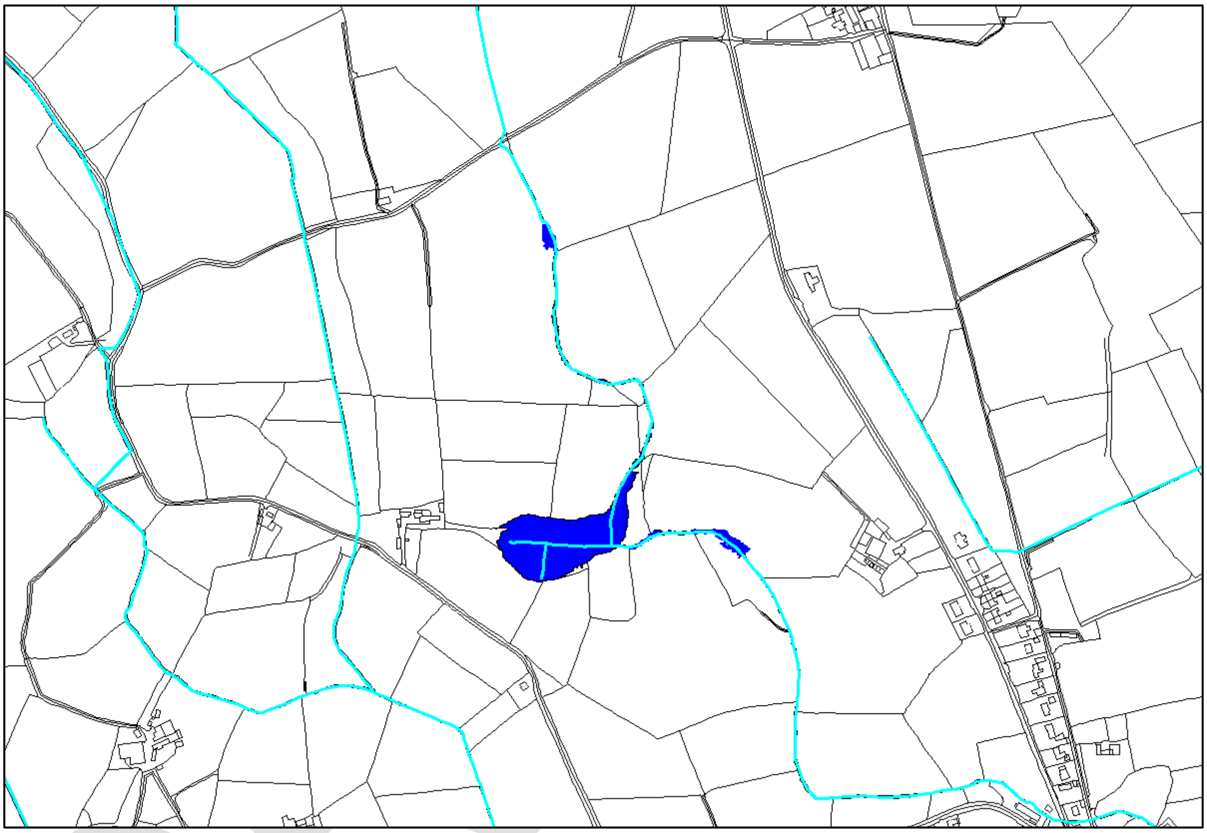

Figure 7.2.5-1 - Model M.G Undesignated Watercourse Q_{100} Floodplain (Scale 1:10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that Flood Maps (NI) do not indicate floodplain at this location. However, it is noted that within Flood Maps (NI) the watercourse is modelled strategically, hydraulic modelling for the Proposed Scheme has identified an undersized culvert along the modelled section of watercourse which causes upstream predicted flooding for the 100 year event.

7.2.6 Model M.H – Tully Drain (Undesignated Reach – Mountjoy)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.2.6-1 below:

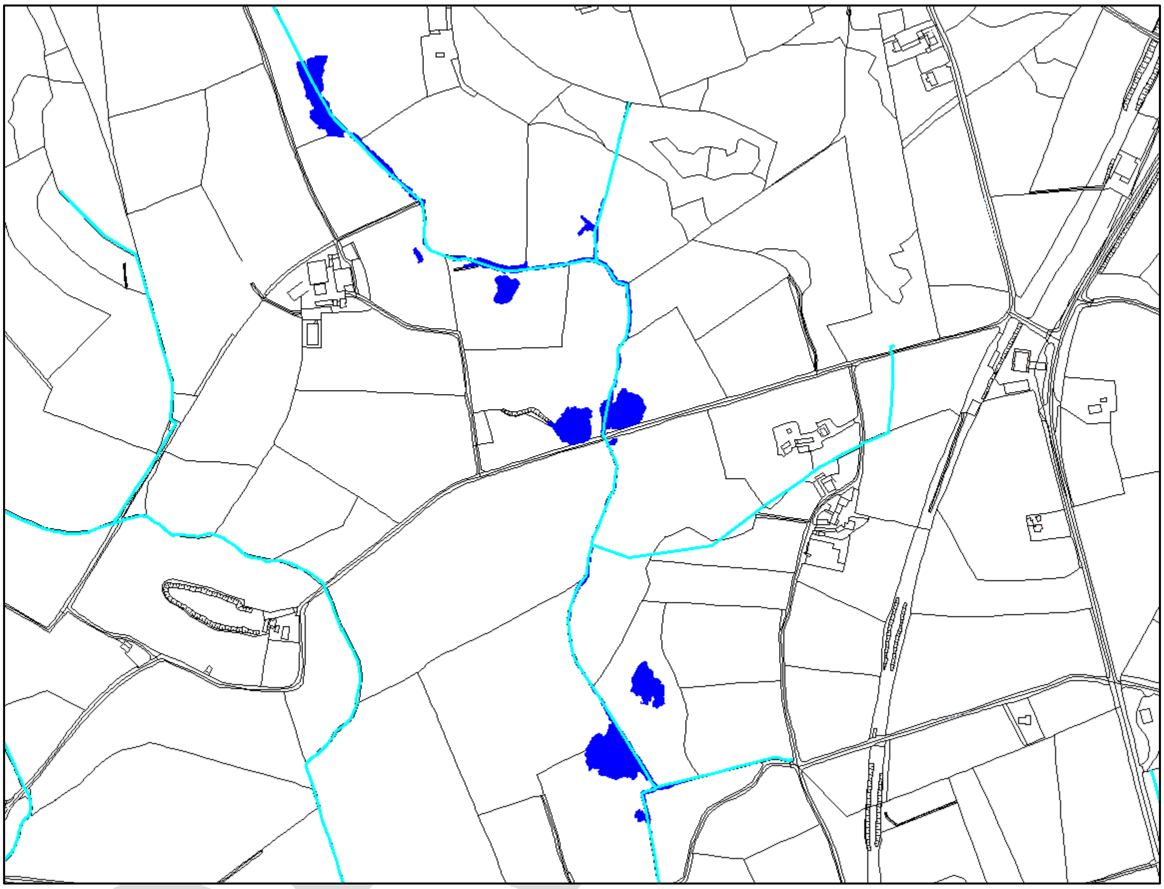

Figure 7.2.6-1 - Model M.H Tully Drain Q_{100} Floodplain (Scale 1:10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that Flood Maps (NI) indicate a more extensive floodplain at this location. It is noted that within Flood Maps (NI) the watercourse and associated floodplain are modelled strategically.

7.2.7 Model M.4 – Fairy Water, Omagh

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figures 7.2.7-1 and 7.2.7-2:

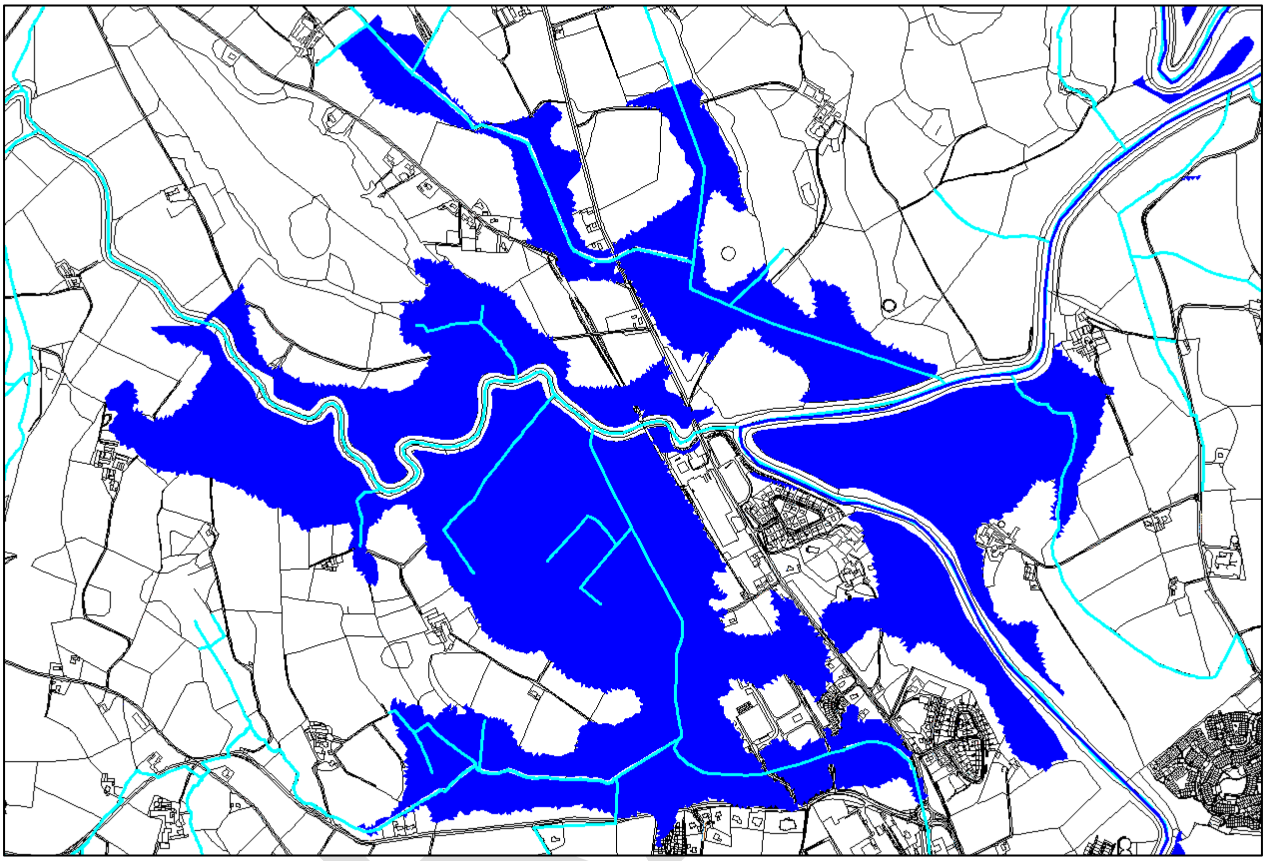

Figure 7.2.7-1 - Model M.4 Fairy Water Q_{100} Floodplain – North (Scale 1:20000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that there are some slight differences in relation to the predicted 100 year floodplain, however, it is considered that, given the scale of the floodplain and extents of the modelled area, this is minor.

7.2.8 Model M.I – MW1545 Fireagh Lough Drain

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.2.8-1 below:

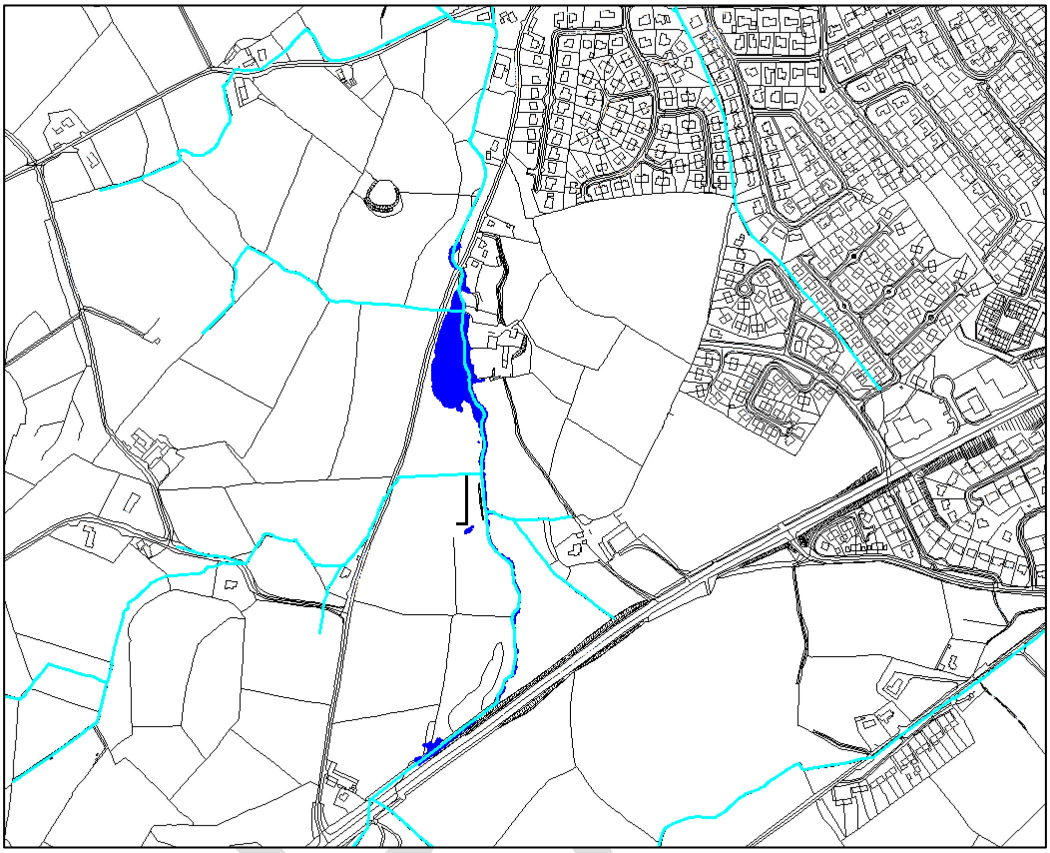

Figure 7.2.8-1 - Model M.I Fireagh Lough Drain Q_{100} Floodplain (Scale 1:10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that there are some minor differences in relation to the predicted 100 year. However, it is noted that within Flood Maps (NI) the watercourse is modelled strategically and a Strategic floodplain is indicated.

7.2.9 Model M.6 – 121 Drumragh River (Extension)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figures 7.2.9-1:

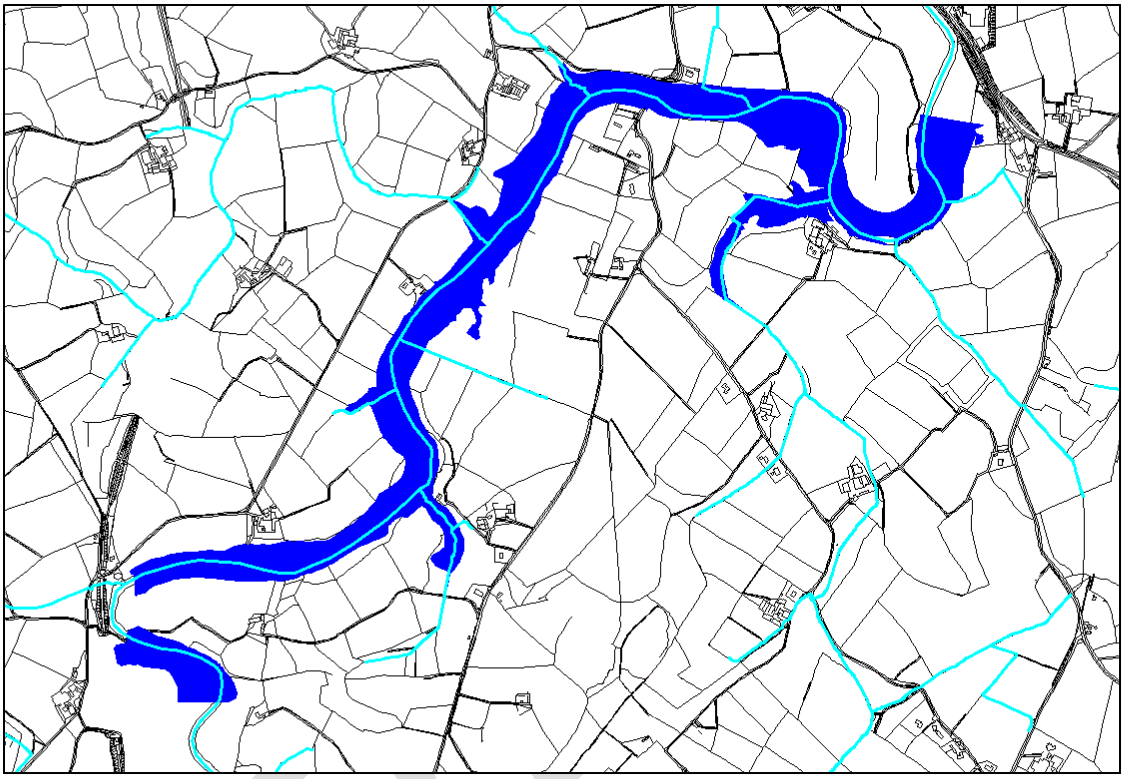

Figure 7.2.9-1 - Model M.6 Drumragh River Q_{100} Floodplain (Scale 1:20000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that there are some slight differences in relation to the predicted 100 year floodplain with the floodplain identified within Flood Maps (NI) being slightly more extensive. However, it is considered that the identified differences are minor.

7.3 Section 3 – Flood Extents

7.3.1 Model M.L – MW1410 Ranelly Drain

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.1-1 below:

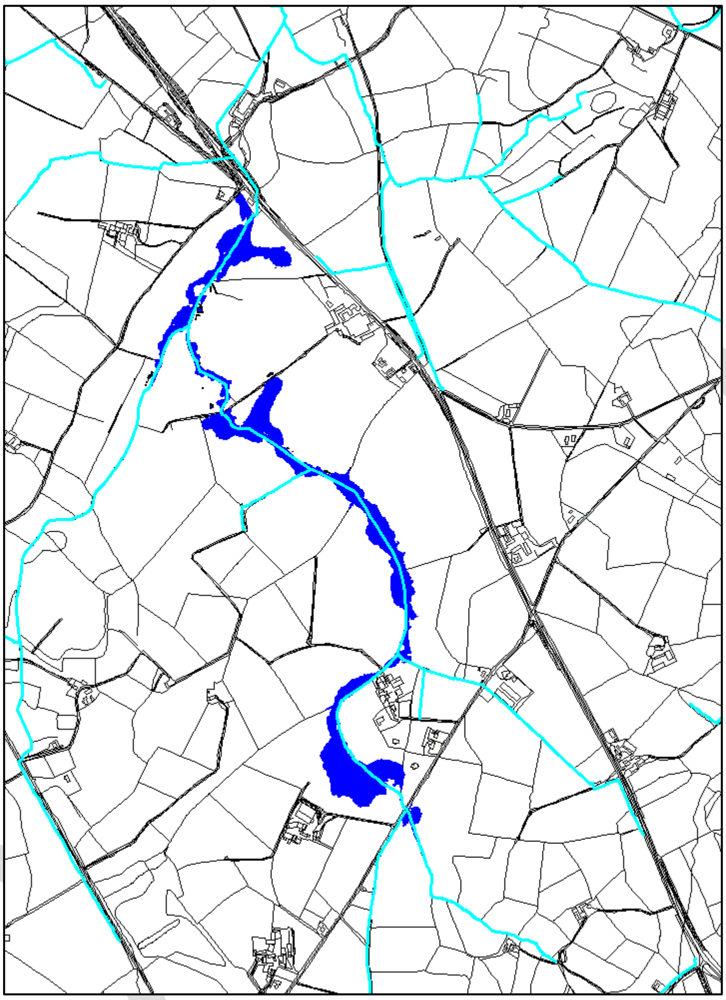

Figure 7.3.1-1 - Model M.L Ranelly Drain Q_{100} Floodplain (Scale 1:20000)

In comparing the above with the Rivers Agency Flood Maps (NI) it is observed that there are some slight differences. Generally, it being seen that Flood Maps (NI) indicate a slightly more extensive floodplain within downstream reaches but no floodplain at the upstream extents. It is noted that within Flood Maps (NI) the watercourse and associated floodplain for the downstream extents are modelled strategically and that upstream extents of the watercourse are unmodelled; consequently, it is considered that the differences in predicted outlines are minor.

7.3.2 Model M.M – MW1401 Letfern Watercourse

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.2-1 below:

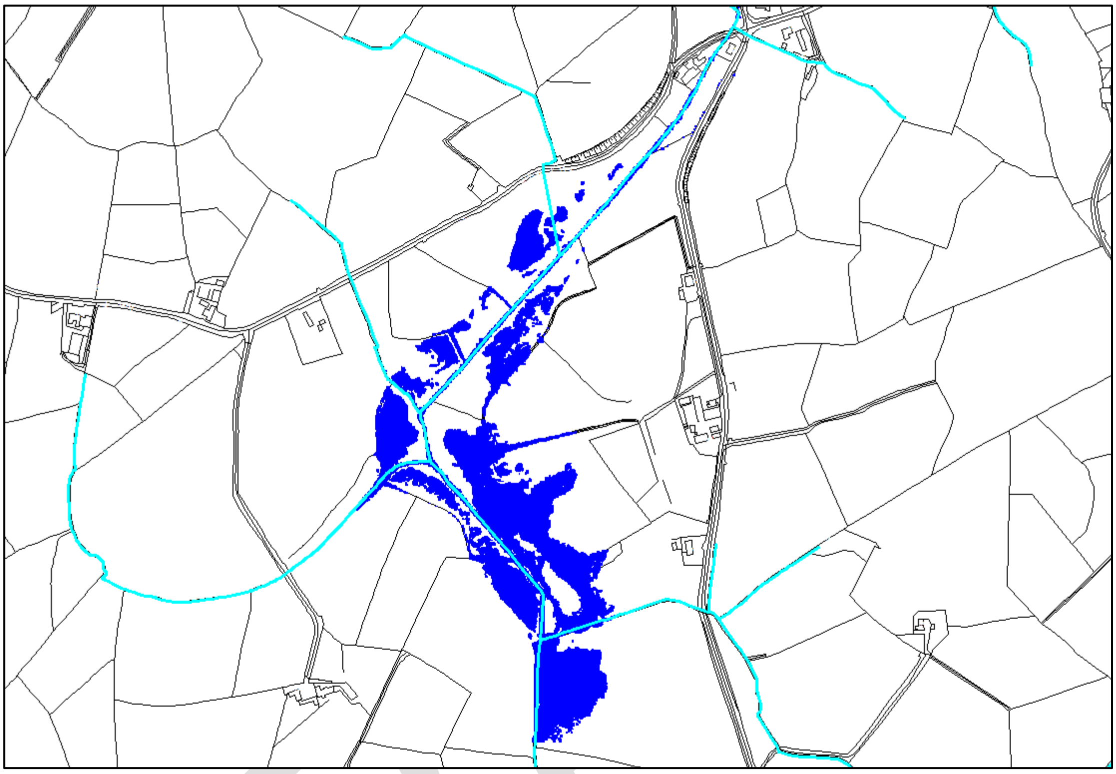

Figure 7.3.2-1 - Model M.M Letfern River Q_{100} Floodplain (Scale 1:10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that the indicated floodplain is not as extensive as that illustrated above, however, differences are considered to be minor.

7.3.3 Model M.N – Undesignated Watercourse (Upstream of MW1402 Letfernburn Branch)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.3-1 below:

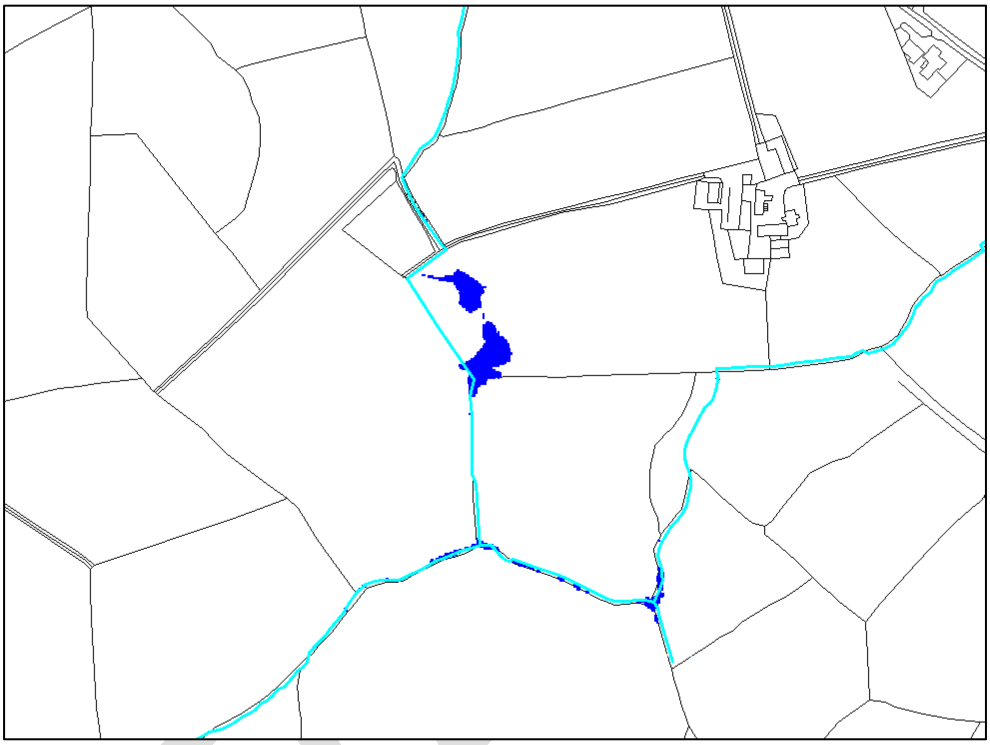

Figure 7.3.3-1 - Model M.N Undesignated Watercourse Q_{100} Floodplain (Scale 1:5000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that this undesignated watercourse has not been included in the Flood Maps (NI).

7.3.4 Model M.O – Undesignated Watercourse

The flood model did not predict any flooding for the Q_{100} flood event (within the model extents) as illustrated in Figure 7.3.4-1 below:

Figure 7.3.4-1- Model M.O Undesignated Watercourse Q100 Floodplain (Scale 1:1000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that this undesignated watercourse has not been included in the Flood Maps (NI)

7.3.5 Model M.P/M.Q - 144 Routing Burn and Undesignated Tributary

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.5-1 below:

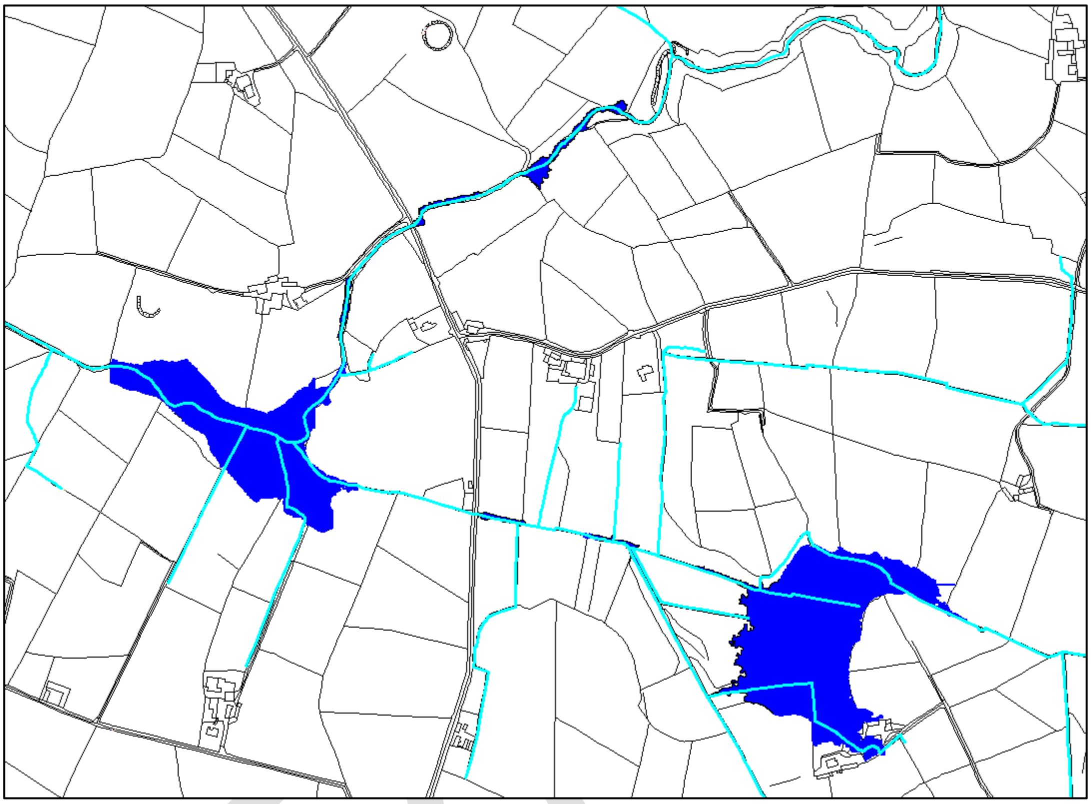

Figure 7.3.5-1 - Model M.P Routing Burn and Undesignated Tributary Q_{100} Floodplain (Scale 1: 10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that along the northern tributary, predicted 100 year floodplains are as indicated above. It is also observed that Flood Maps (NI) indicate a more extensive floodplain along the southern tributary. It is noted that within Flood Maps (NI) the watercourse and associated floodplain are modelled strategically, furthermore, the southern tributary of the Flood Maps (NI) modelled reach does not extend as far as that assessed for the Proposed Scheme.

7.3.6 Model M.R – Undesignated Watercourse (Newtownsaville)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.6-1 below:

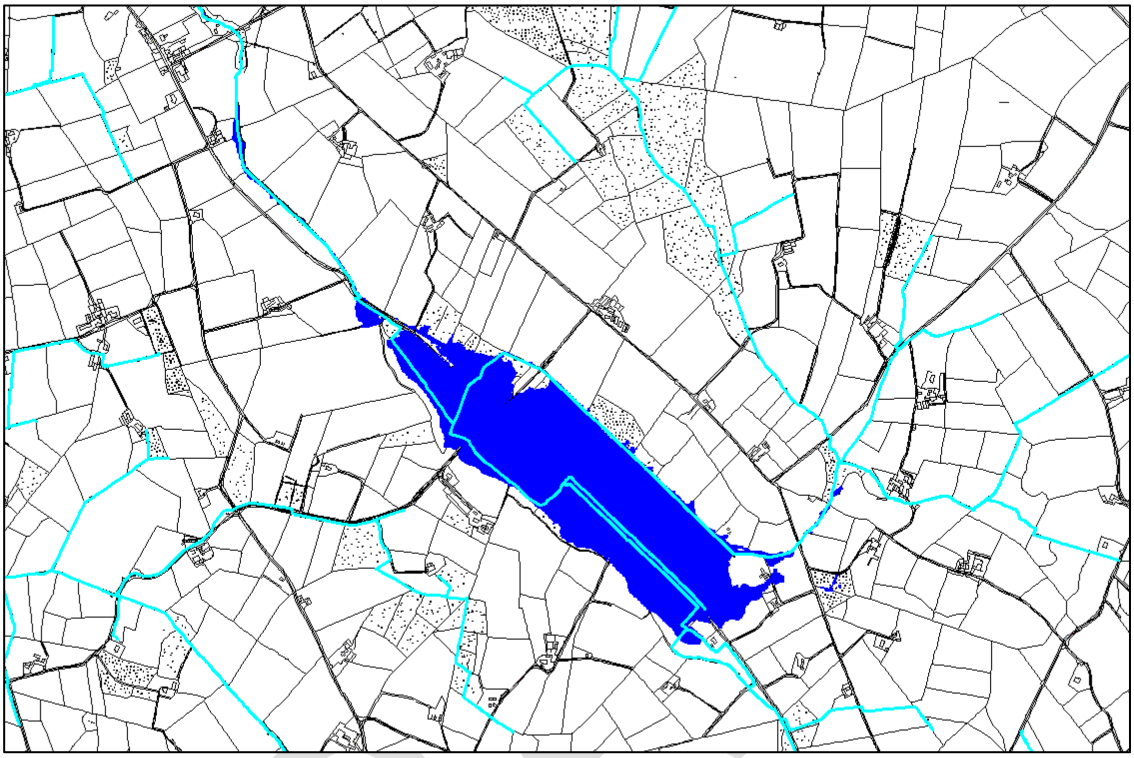

Figure 7.3.6-1 - Model M.R Undesignated Watercourse Q_{100} Floodplain (Scale 1:20000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that the indicated floodplain is not as extensive as that illustrated above, however, differences are considered to be minor.

7.3.7 Model M.S – Undesignated Watercourse (Kilgreen)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.7-1 below:

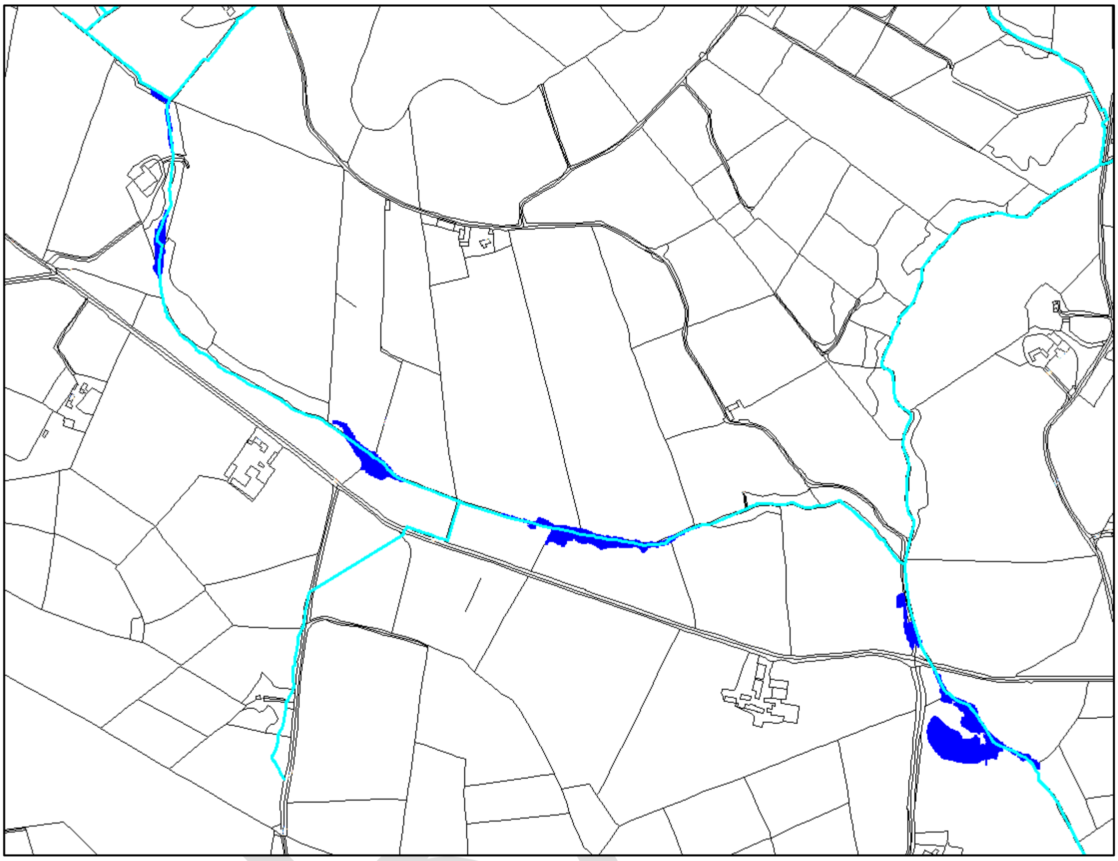

Figure 7.3.7-1 - Model M.S Undesignated Watercourse Q_{100} Floodplain (Scale 1:10000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI).

7.3.8 Model M.T – MW4105 Roughan River

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.8-1 below:

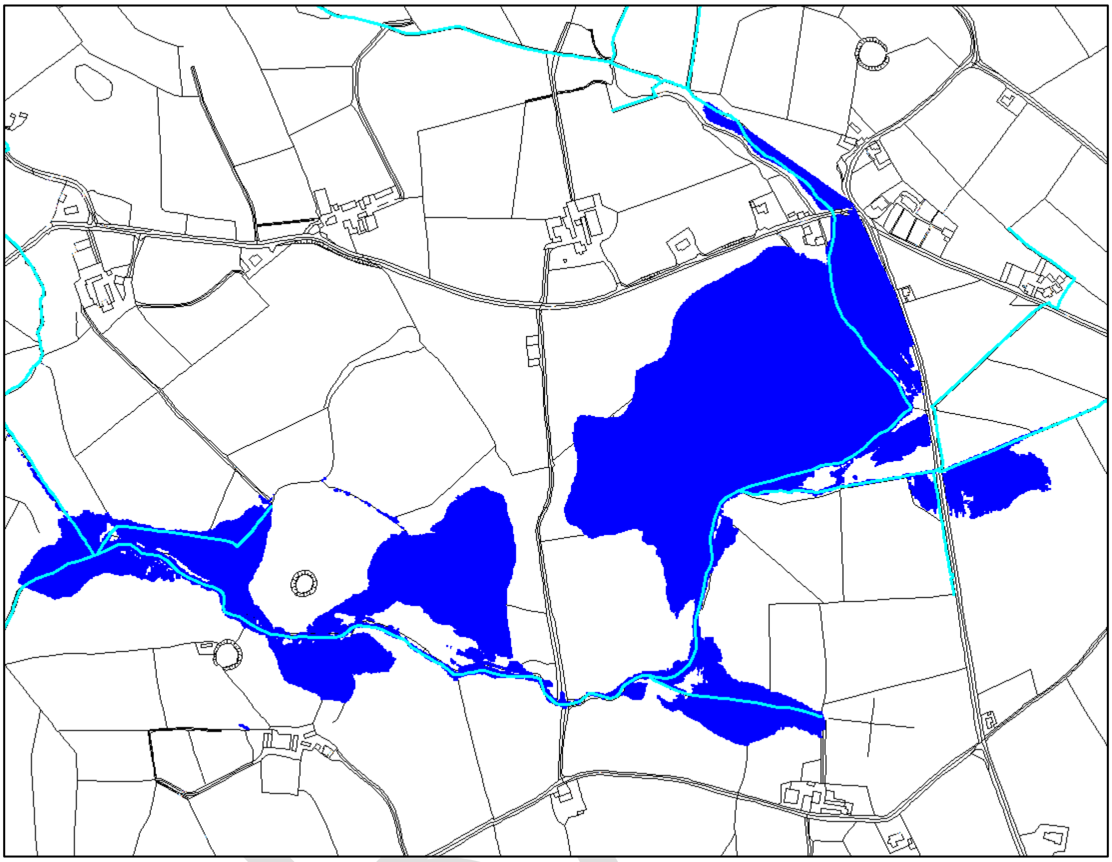

Figure 7.3.8-1 - Model M.T Roughan River Q_{100} Floodplain (Scale 1:10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that the indicated floodplain is not as extensive as that illustrated above. It is noted that Flood Maps (NI) advise that the level of modelling detail associated with the watercourse is strategic, therefore, the detailed hydraulic modelling associated with the Proposed Scheme may be a truer reflection of the floodplain extents.

7.3.9 Model M.U – Ballygawley Water

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.9-1 below:

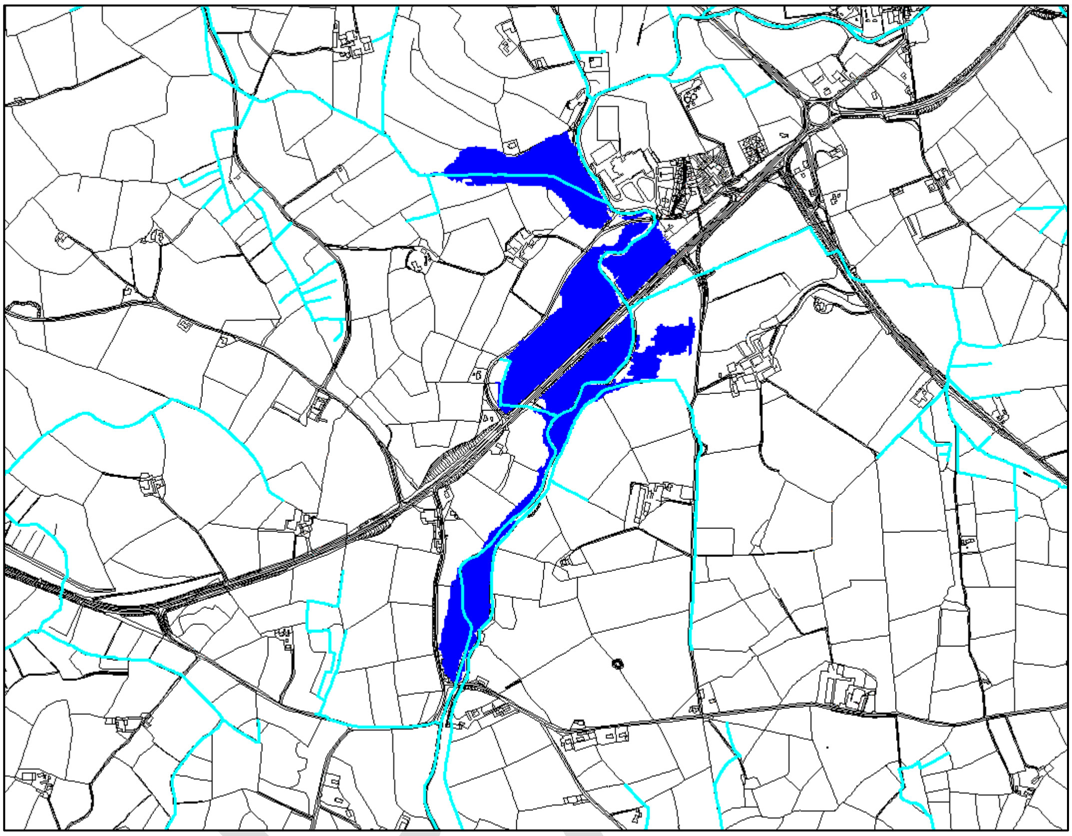

Figure 7.3.9-1 - Model M.U Ballygawley Water Q100 Floodplain (Scale 1:20000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that the indicated floodplain is not as extensive as that illustrated above. It is noted that Flood Maps (NI) advise that the level of modelling detail associated with the watercourse is strategic, therefore, the detailed hydraulic modelling associated with the Proposed Scheme may be a truer reflection of the floodplain extents.

7.3.10 Model M.V – MW4230 Tullyvar Drain

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.10-1 below:

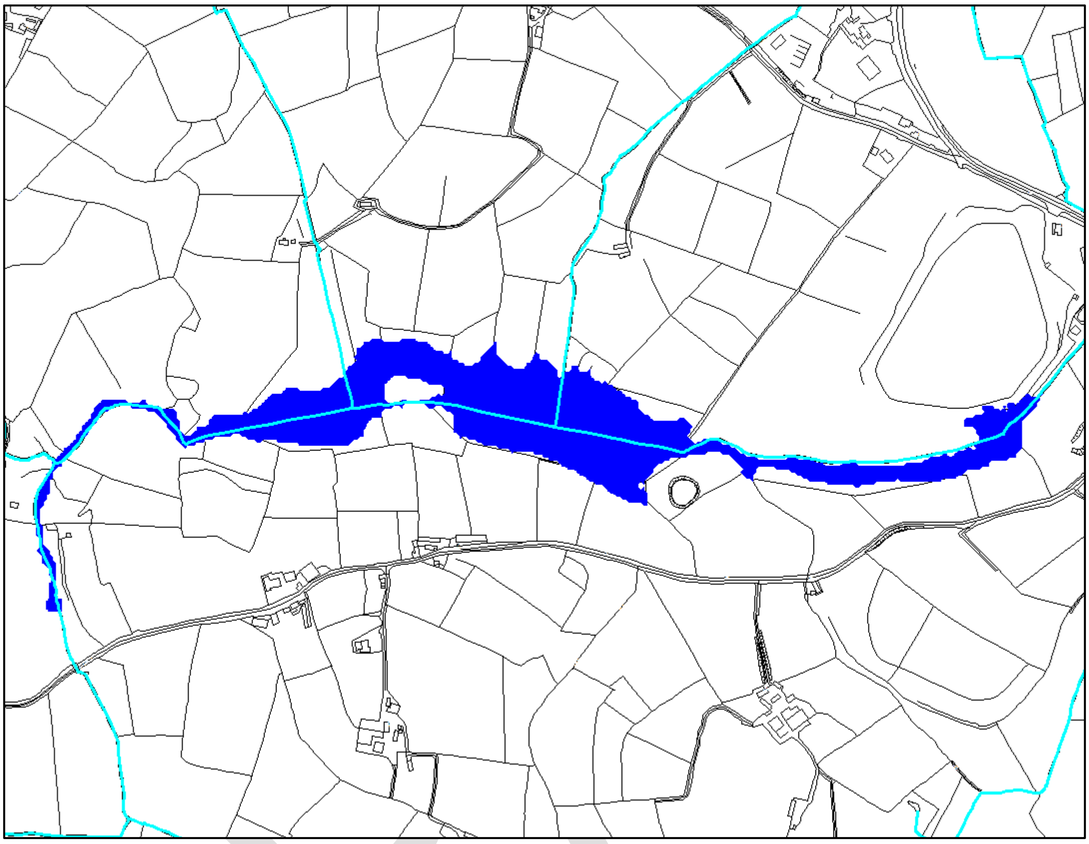

Figure 7.3.10-1 - Model M.V Tullyvar Drain Q_{100} Floodplain (Scale 1:10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that the indicated floodplain is not quite as extensive as that illustrated above. It is considered that the differences are minor.

7.3.11 Model M.W – MW4226 Ravella Drain

The flood model did not predict any flooding for the Q_{100} flood event (within the model extents) as illustrated in Figure 7.3.11-1 below:

Figure 7.3.11-1 - Model M.W Ravella Drain Q_{100} Floodplain (Scale 1:10000)

In comparing with the Rivers Agency Flood Maps (NI) it is observed that in contrast to the above a small area of floodplain is identified. It is considered that the differences are minor. It is noted that within Flood Maps (NI) the watercourse and associated floodplain are modelled strategically.

7.3.12 Model M.X – Undesignated Watercourse (Upstream Tributary of MW4201 Ext Aughnacloy Urban Ext)

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.12-1 below:

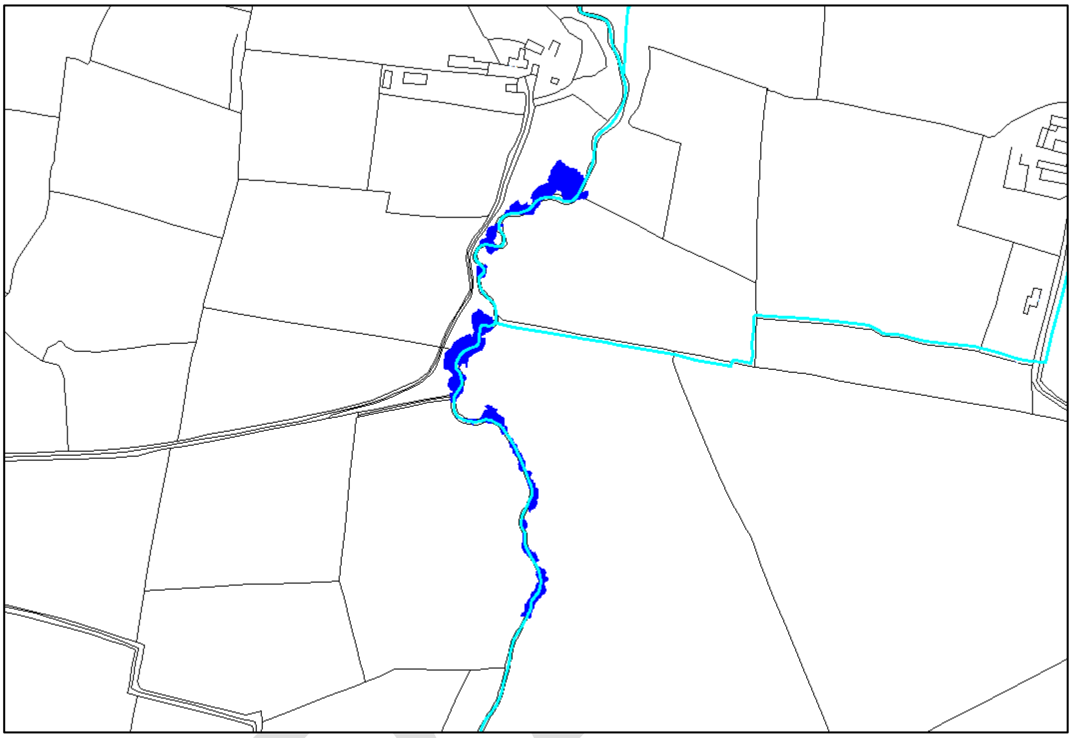

Figure 7.3.12-1 - Model M.X Undesignated Watercourse Q_{100} Floodplain (Scale 1:5000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI).

7.3.13 Model M.Y – MW4222 Lisadavil River

The flood outline for the Q_{100} flood event (within the model extents) is illustrated in Figure 7.3.13-1 below:

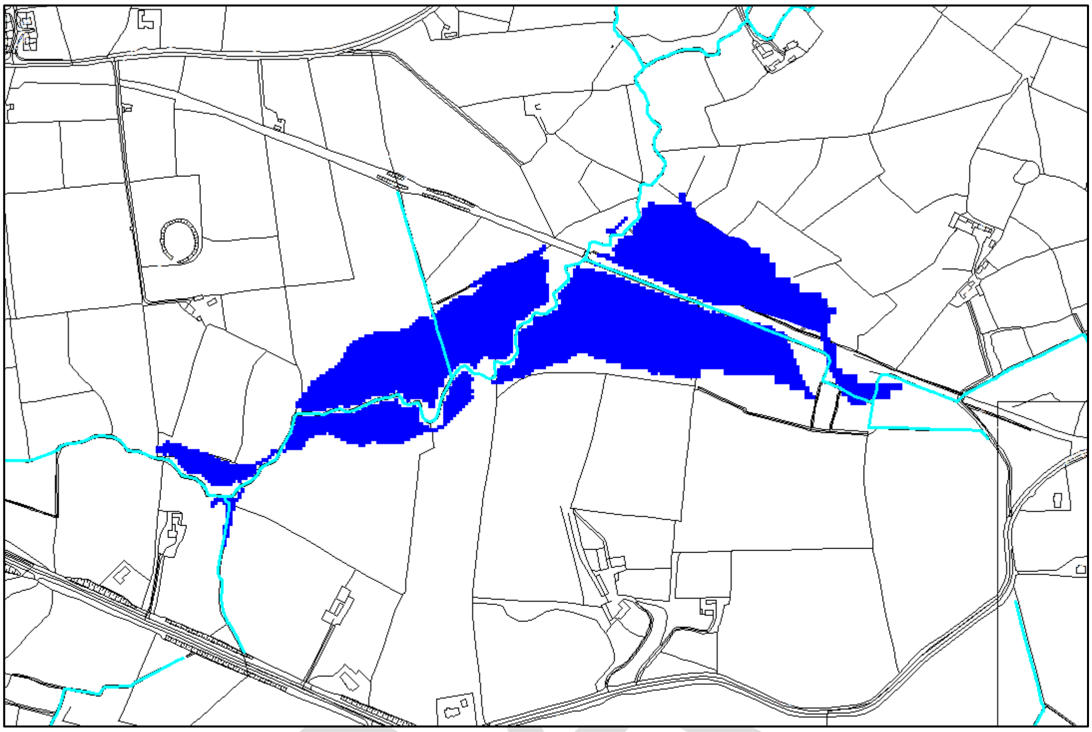

Figure 7.3.13-1 - Model M.Y Lisadavil River Q_{100} Floodplain (Scale 1:10000)

It is observed that the predicted 100 year flood plain corresponds approximately with that indicated within Rivers Agency Flood Maps (NI). However, it is seen that along upstream reaches flooding indicated above is less extensive than that indicated on Flood Maps (NI). It is noted that within Flood Maps (NI) the watercourse and associated floodplain are modelled strategically.

8 Model Calibration/Sensitivity Analysis

8.1 Model Calibration / Verification

The calibration of a hydraulic model is usually completed using water levels for a recorded event of known peak flow. The model coefficients are then adjusted to obtain a reasonable fit with the recorded data. Where peak flow recorded information existed for a particular model, calibration was undertaken. This typically involved adjustments of friction values to obtain a good correlation with the depth / flow relationship at a particular gauge. Where data is anecdotal, sparse or of uncertain quality, this data can also be used to 'sense check' or verify results however, caution needs to be exercised to ensure that model output is not 'force fitted' to uncertain data. In most cases the models could not be calibrated as there was not sufficient recorded flow data. However, the following flow information was used in the calibration of hydraulic models for the A5 WTC.

- Burndennet River gauge at Burndennet Bridge (Ref: 201007)
- Mourne-Strule River gauge at Drumnabouy House (Ref: 201010)
- Glenmornan River gauge at Ballymagorry (Ref: 201015)
- Camowen River gauge at Camowen Terrace (Ref: 201005)
- Drumragh River gauge at Campsie Bridge (Ref: 201006)
- Drumragh River gauge at Drumshanly (Ref: 201013)
- Ballygawley River gauge at Tullybryan (Ref: 203041)

Model output was also sense checked against Rivers Agency Flood Maps (NI), historical flood information and some other anecdotal information including site visits.

8.2 Model Sensitivity Testing

In addition to model calibration, and particularly in the absence of reliable calibration data, sensitivity testing was undertaken. Sensitivity testing allows an assessment of model sensitivity to variations in key model parameters.

For each of the models outlined in previous chapters, numerous model runs were undertaken with varying boundary conditions to test the sensitivity of the models to parameter variations and ensure consistency and confidence in the numerical results. The key sensitivity tests undertaken for all model were for variations in friction, downstream water level and flows. The following sensitivity test were undertaken:

- Testing a range of flows; the Annual, 25 years, 100 years and 100 years including 20% climate change return periods to determine the water levels for each event and therefore to ensure consistency in the results.

- Manning's 'n' friction values were generally varied by +/- 20% in order to check the model stability / response to variations in the chosen friction values.

- Stability of the model was checked against changes in downstream boundary condition. This was to ensure that the reach of interest was sufficiently far upstream from the downstream boundary that it wouldn't materially affect the results in the area of interest.

Information in relation to specific models can be requested as required.

9 Summary

This flood risk assessment is number two of three reports. This report provides a summary of the proposed model build strategy and design flow estimations for the identified hydraulic models along the Proposed Scheme.

This report outlines amendments in route development and provides reference documents in relation to this development. Additional information will be published in the *Scheme Assessment Report 3.*

This report also provides information in relation to the model data collection methods through on-site surveying and obtaining LiDAR information. Following the data collection process, boundary conditions such as Manning's 'n' values and channel descriptions were determined and are also provided within this report.

The chapters in relation to the hydraulic model extents, design flows and the boundary conditions provide details of the information utilised in each of the hydraulic models.

Finally, this report provides Q_{100} flood outlines for the hydraulic models. As identified previously, the Proposed Scheme potentially interacts with a number of modelled floodplain locations. It is a recommendation of this report that these areas are explored in more detail. Information pertaining to further assessment can be found in Flood Risk Assessment Report 3 – *Impact and Mitigation Assessment Report*.