FLOOD RISK
CONSULTING

RESERVOIR FLOOD RISK ASSESSMENT

PROPOSED MIXED USE REGENERATION SCHEME FOR ARNTZ BELTING COMPANY AT PENNYBURN, BUNCRANA ROAD, DERRY

FEBRUARY 2018

CHARTERED CIVIL ENGINEERS
67 Manor Park, Lisburn, Co Antrim, BT28 1EZ | Mobile +44 (0)75 6425 5696 | Email: phil@floodriskconsulting.com | Web: www.floodriskconsulting.com

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Contents

1.0 INTRODUCTION

1.1 This report has been prepared by Flood Risk Consulting. The brief for the study was to carry out a Reservoir Flood Risk Assessment (RFRA), in accordance with Policy FLD 5 of PPS 15, for the proposed regeneration of Arntz Belting Company Ltd at Pennyburn, Buncrana Road, Derry. It is Flood Risk Consulting's understanding that the requirement for this RFRA has stipulated as a planning condition for the approved development.

1.2 Rivers Agency's reservoir inundation mapping indicates that the site is partially located within the all-breach-cases floodplain of the Upper and Lower Creggan reservoirs. Therefore, this report will undertake a RFRA to assess the depth and velocity of predicted inundation flooding at the proposed site. An examination will also be carried out on the potential change in flow path as a result of the proposed development.

1.3 The proposal constitutes the replacement of the existing Arntz Belting Company development and therefore the subsection of FLD 5 regarding replacement buildings applies to the proposed site.

1.4 PPS 15 Annex D states that there are no circumstances in which the risk of flooding can be removed entirely. This report should not be considered a guarantee against future flooding events but as having the same goal as PPS 15; to prevent future development that may be at risk from flooding or that may increase the risk of flooding elsewhere.

1.5 The content of this report is © of Flood Risk Consulting 2018. Every care has been taken to ensure the accuracy of this report at the time of its preparation. Flood Risk Consulting accepts no responsibility for any documents or information supplied to Flood Risk Consulting by others. It is expressly stated that no independent verification of any documents or information supplied by others has been made.

1.6 Flood Risk Consulting has used reasonable care, skill and diligence in compiling this report and no warranty is provided as to the report's accuracy. This document has been prepared solely for the person who commissioned the report. Flood Risk Consulting accepts no responsibility or liability for any use that is made of this document other than by the commissioner of the report for the planning purpose for which it was originally commissioned and prepared.

2.0 DESCRIPTION OF SITE

2.1 *Site location*

2.1.1 Plate 2.1 presents Google mapping of the location of the proposed site, identified by the red marker, relative to Belfast, Omagh and Derry/Londonderry.

Plate 2.1: Mapping showing the location of proposed site

2.1.2 Plate 2.2 presents the location of the proposed site relative to Derry, where the site can be seen to be located within the city, close to the western bank on the River Foyle.

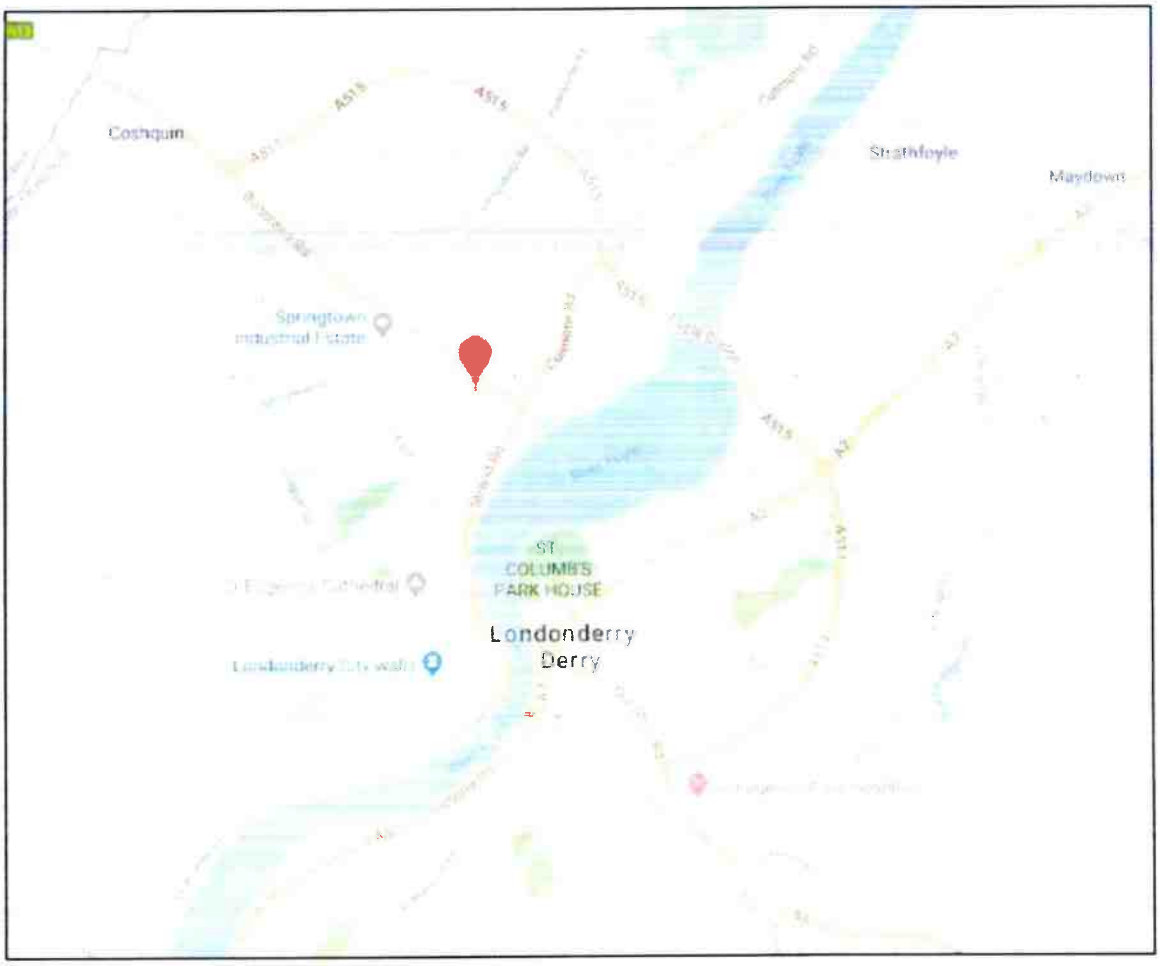


Plate 2.2: Mapping showing the location of proposed site relative to River Foyle

2.1.3 Plate 2.3 presents a site location map, where the approximately 5.5ha proposed site is outlined in red. Access to the proposed site is from the Buncrana Road via Pennyburn Pass at the site's south eastern boundary and along the Pennyburn Industrial Estate road along the north western boundary. The existing Arntz Belting factory buildings and development can be seen to be located across the site.

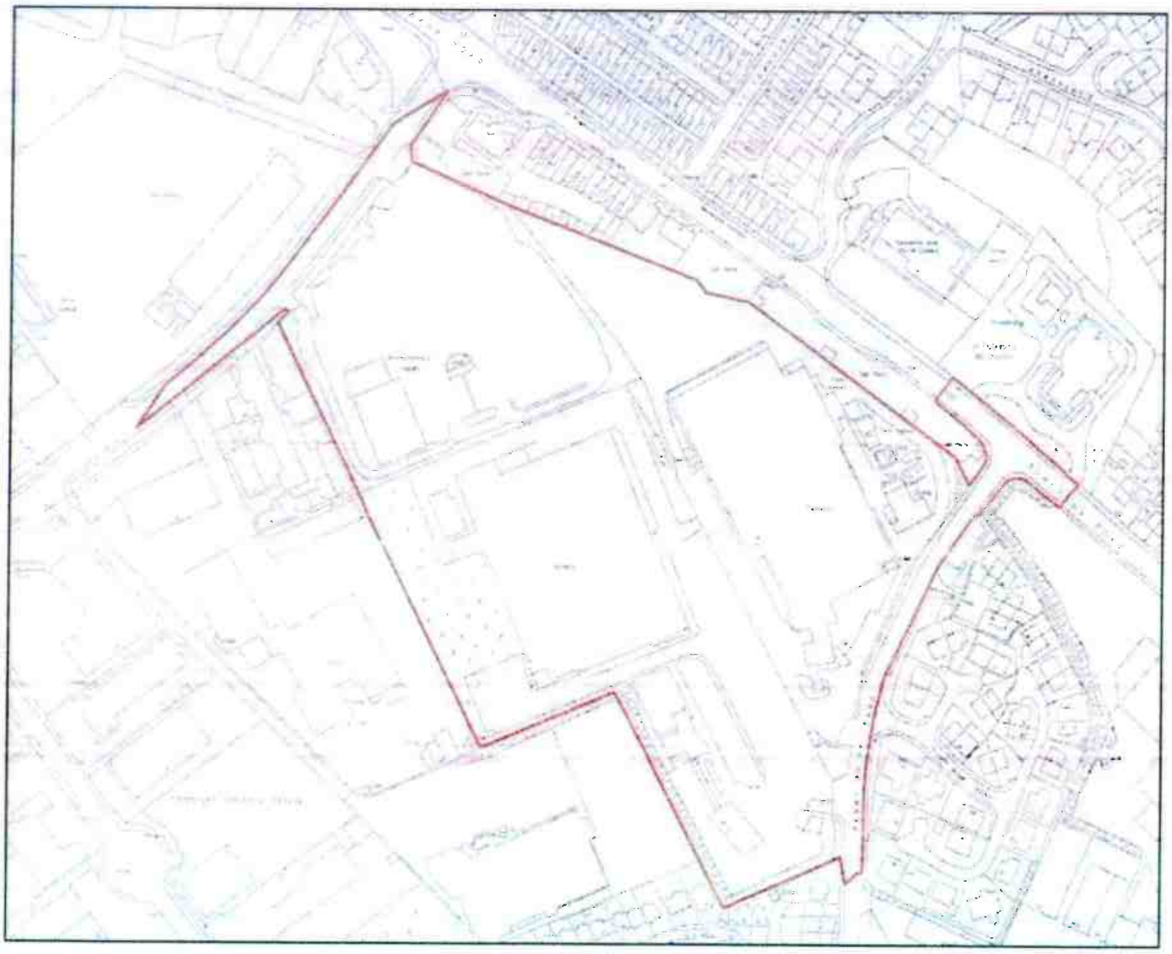


Plate 2.3: Site location map for the proposed site

2.1.4 Plate 2.4 presents Ordnance Survey mapping of the area, with the approximate extent of the proposed site highlighted in red. The site is shown on this plate to be currently mostly brownfield, where two large factory buildings can be seen within the central portion of the site.

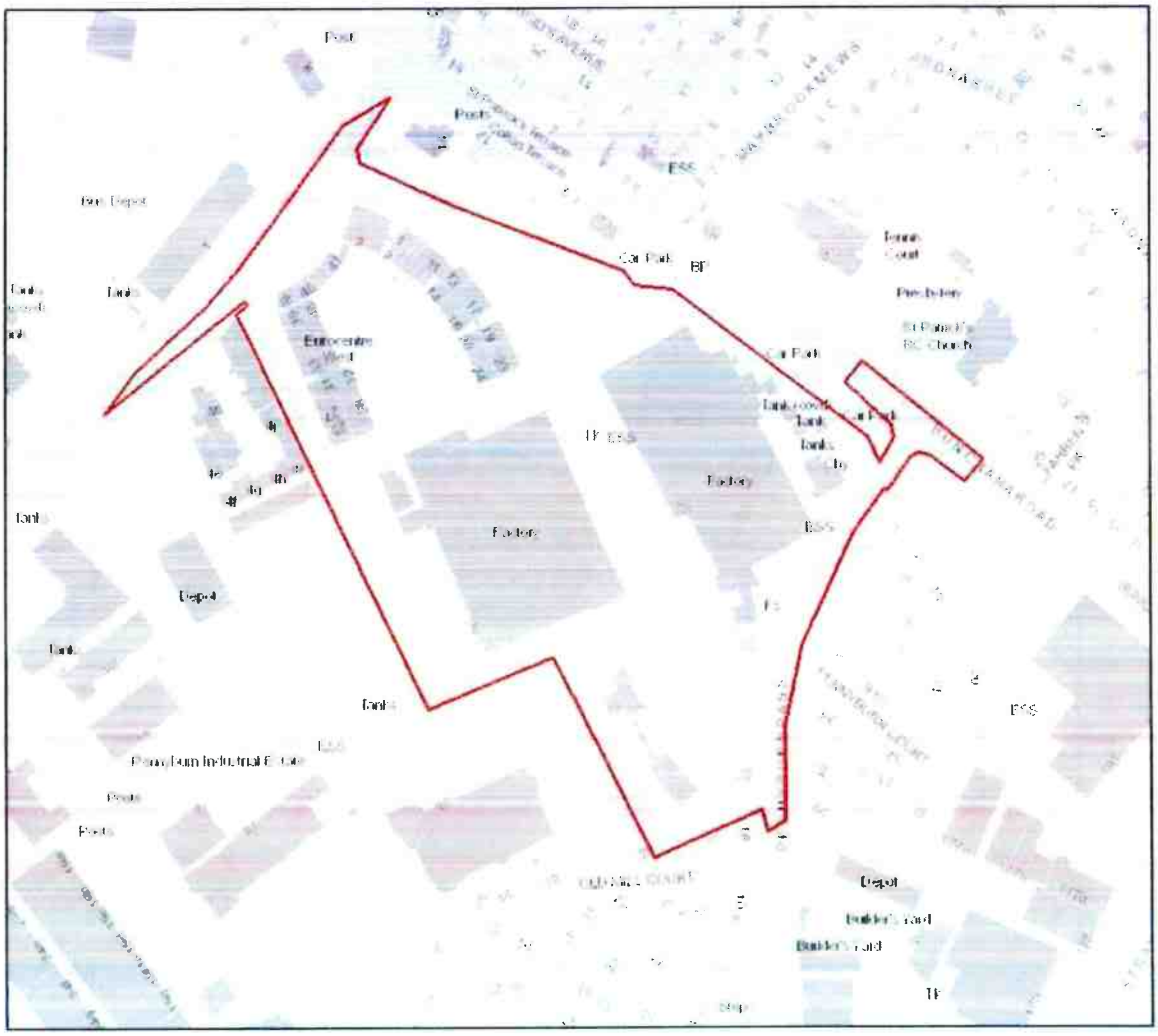


Plate 2.4: Ordnance Survey mapping of the proposed site

2.1.5 Plate 2.5 presents Ordnance Survey historical mapping of the proposed site (2nd Edition, c.1860), with the proposed site approximately identified in red. This plate shows the historic route of the Hill Stream traversing the proposed site. It is our understanding that this stream has since been culverted and diverted around the site.

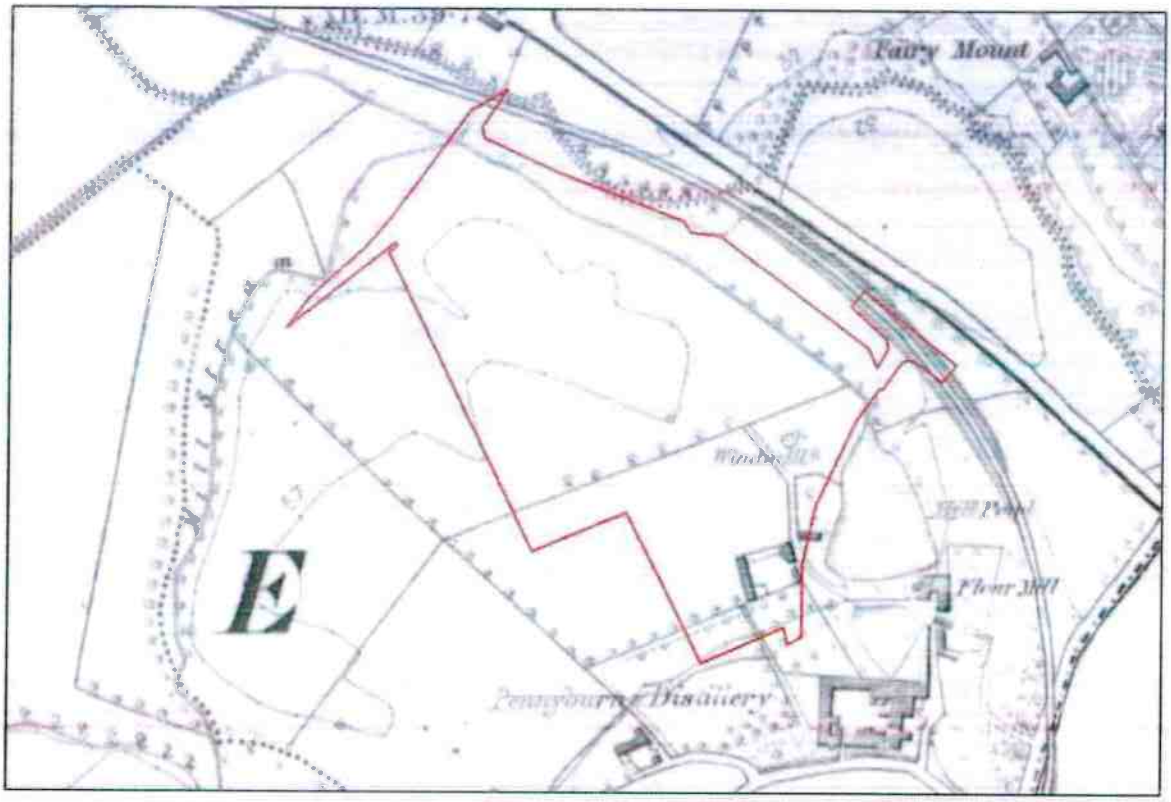


Plate 2.5: Historic Ordnance Survey mapping of the proposed site

2.1.6 Plate 2.6 presents Raster 10K mapping of the proposed site (approximately indicated by the purple circle), showing 10m contours of the area. The Upper and Lower Creggan reservoirs can be seen at the bottom left hand corner of the plate, where they can be seen to be in series. A watercourse is shown to extend downstream from the lower reservoir towards the proposed site, according to the fall of the land from south west to north east. The River Foyle can be seen along the RHS of the plate to be at a lower level than the proposed site.

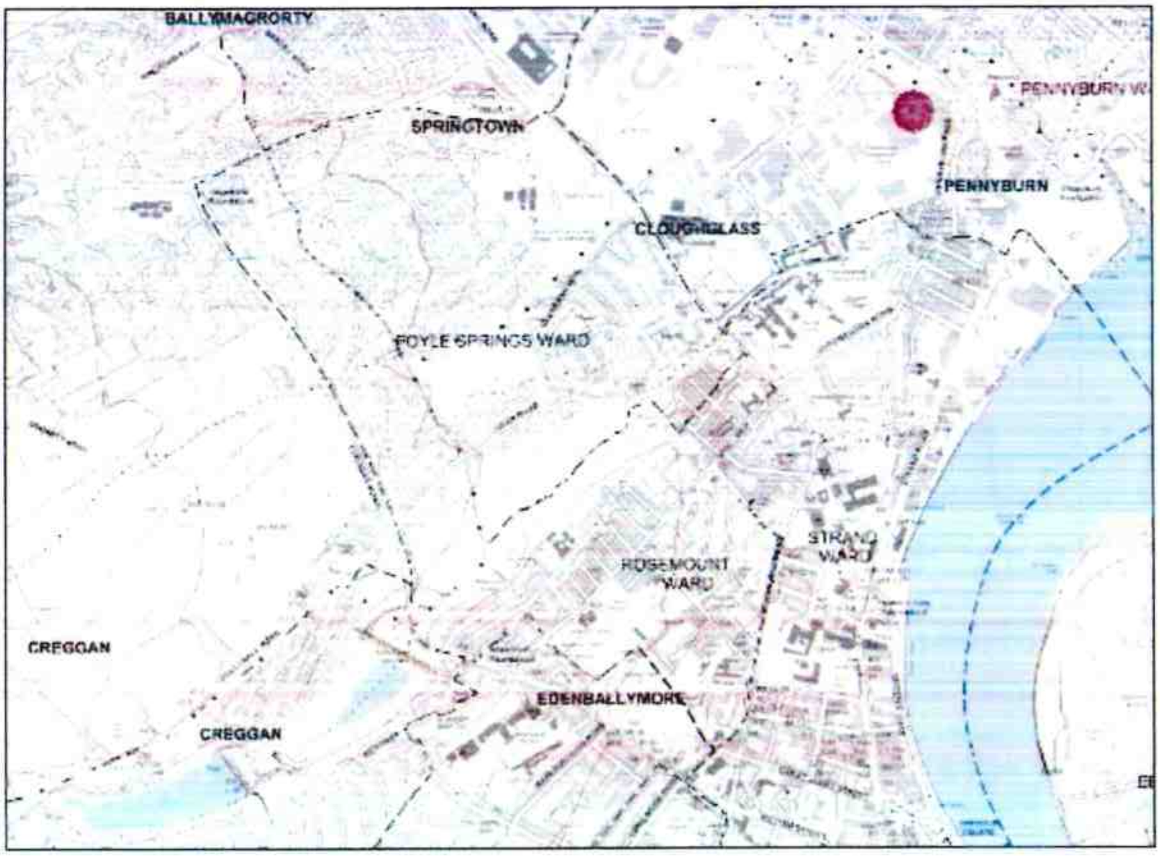


Plate 2.6: Raster 10K mapping of the proposed site

2.1.7 Plate 2.7 presents aerial photography of the proposed site, where the factory development can be seen to be extant within the central and southern portions of the site. The development within the northern area of the site is shown on this plate to have been partially demolished. The arrows on Plate 2.7 indicate the approximate location and direction of photographs presented in Section 2.2 i.e. P2.2 indicates Photograph 2.2.

Plate 2.7: Aerial photography of the proposed site

2.2 *Site visit and photographic record*

2.2.1 A site visit was undertaken in February 2018 to examine the proposed site. Photographs 2.1, 2.2 and 2.3 were recorded from Buncrana Road close to the midpoint of the site's north eastern boundary, with each subsequent photograph taken clockwise from the previous.

2.2.2 The north eastern side of the site can be seen to be located on elevated ground, where Buncrana Road can be seen falling towards the north west on the LHS of Photograph 2.1 and also falling south east on the RHS of Photograph 2.3. Photograph 2.2 shows the existing Arntz Belt factory building which is to be replaced by the proposed regeneration scheme.

Photographs 2.1, 2.2 and 2.3: Views of the proposed site from the north eastern boundary

2.2.3 Views from the proposed site's south eastern boundary along Pennyburn Pass are presented on Photograph 2.4 and 2.5 (second photograph recorded clockwise from the first). The midpoint of the site's south eastern side can again be seen to be located on higher ground, where the adjacent road is shown on both photographs to be falling northward and southward.

Photographs 2.4 and 2.5: Views from the proposed site's south eastern boundary

3.0 INFORMATION FROM RIVERS AGENCY

3.1 Plate 3.1 presents Rivers Agency's designated watercourses within the vicinity of the proposed site. The Pennyburn Stream (U21104) is shown on this plate bounding the site's northern side, and continuing downstream of the River Foyle to the south east. The urban Creggan Burn watercourse also flows within the vicinity of the proposed site, passing at a distance south of the site, and also discharging to the River Foyle.

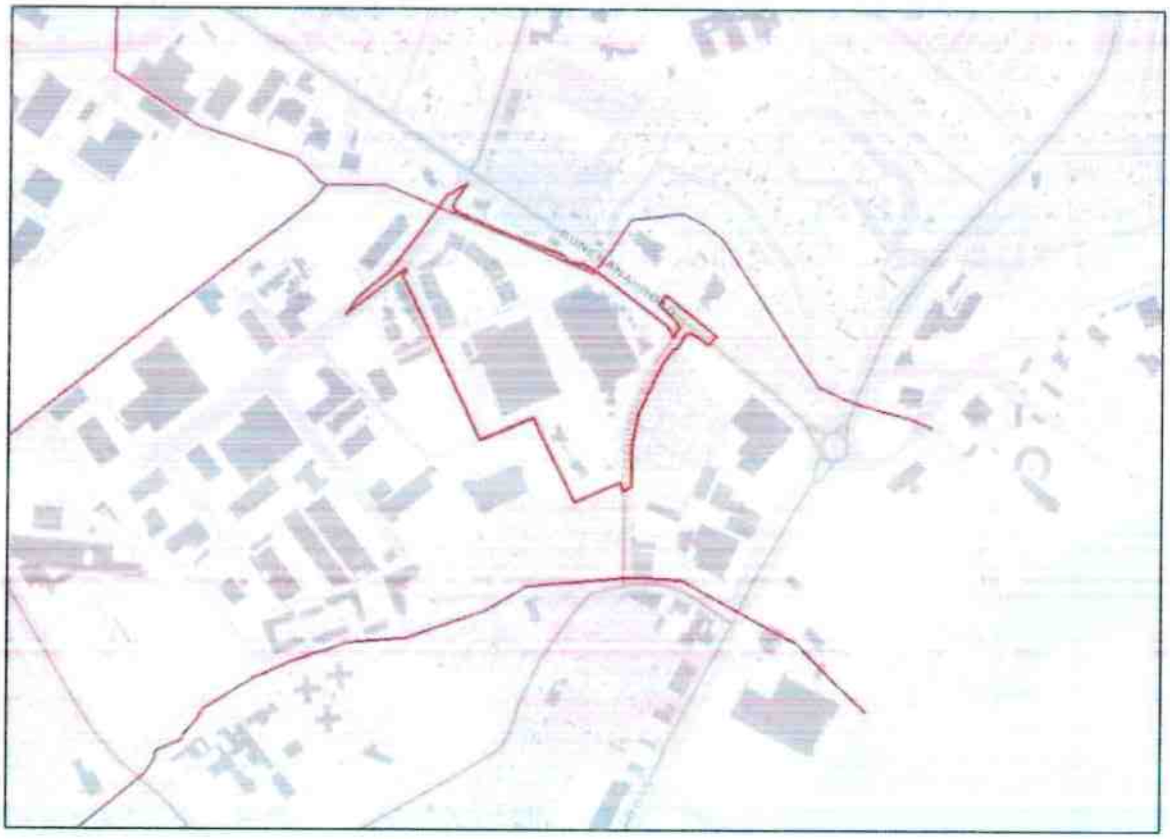


Plate 3.1: Rivers Agency's designated watercourses within the vicinity of the proposed site

3.2 Plate 3.2 presents Rivers Agency's predicted reservoir flooding in the wider area of the proposed site (approximately identified by the red circle) from an uncontrolled release of water from all possible dam failure scenarios for **both** the Upper and Lower Creggan reservoirs. This plate demonstrates that worst-case-scenario simultaneous inundation flooding from the Creggan reservoirs is predicted to almost surround the proposed site, which is located approximately 1km downstream from the lower dam. Inundation waters can be seen to flow to the River Foyle downstream of the proposed site, following the flow regimes of the Pennyburn Stream and Creggan Burn north and south of the site respectively.

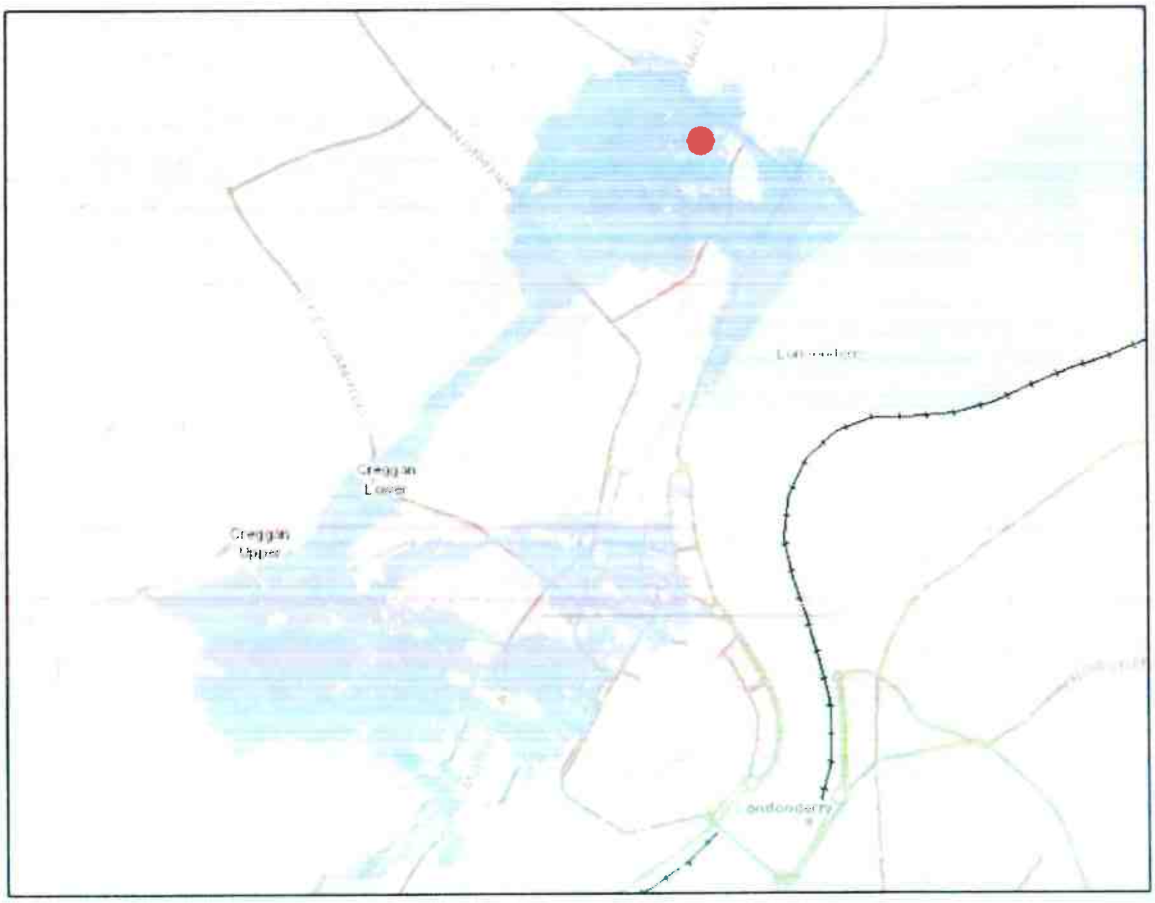


Plate 3.2: Proposed site relative to Rivers Agency's predicted reservoir flooding

3.3 Lower scale mapping of Rivers Agency's predicted reservoir inundation floodplain within the proposed site is presented on Plate 3.3. This plate confirms that the proposed site is predicted to be subject to flooding in the event of the simultaneous failures of the Upper and Lower Creggan reservoirs. Small isolated areas within the site are shown to not be located within the inundation floodplain, suggesting shallow flood water depths across the site.

Plate 3.3: Rivers Agency's predicted reservoir inundation floodplain within the proposed site

4.0 PROPOSED DEVELOPMENT

4.1 Drawing 14-112-C05-F presents the layout of the proposed development, where an extract is presented on Plate 4.1. Four buildings are proposed within the regeneration scheme, a restaurant, filling station, superstore and medical building, with associated accesses, parking and other development. The proposed FFLs of the buildings range from 11.2m OD to 9.8m OD from west to east across the site, with corresponding adjacent FGLs varying accordingly from west to east.

Plate 4.1: Proposed layout


MEDICAL BUILDING
SUPERSTORE
SERVICE YARD
TURNING CIRCLE
RESTAURANT
SELF SERVICE FILLING STATION
COURT

5.0 TOPOGRAPHICAL DATA

5.1 A topographical survey collected spot levels and contours across the proposed site; Drawing 14-112-C04 presents information from the recorded survey. Drawing 14-112-C04 confirms that the proposed site is generally falling from west to east, with levels varying across the existing development.

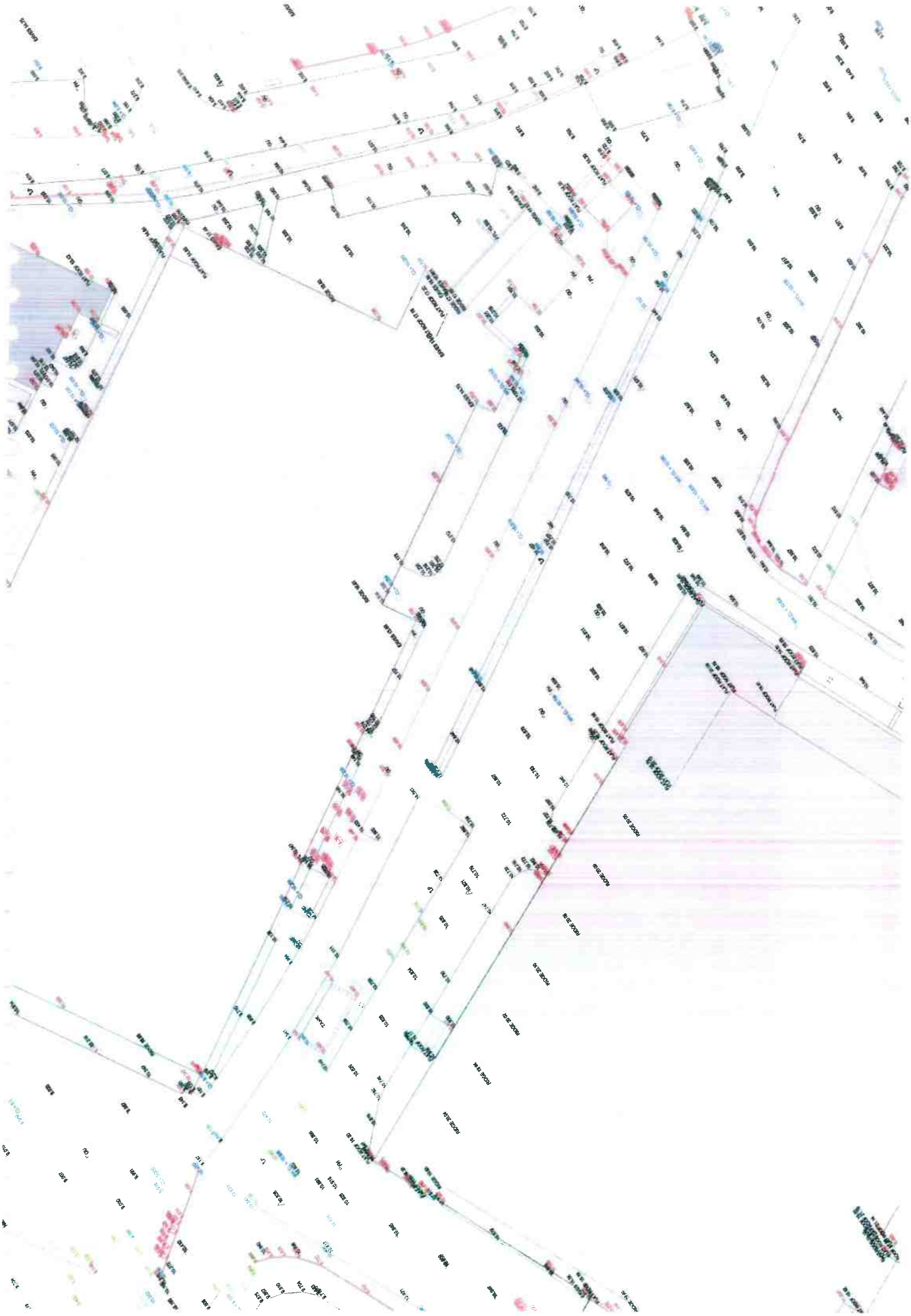
5.2 The topographical survey alone was determined to be insufficient to assess the risk of reservoir inundation to the proposed development. Hydraulic modelling of the predicted reservoir flooding was considered necessary to estimate the depth and velocity of the predicted reservoir inundation floodplain at the proposed site.

5.3 In addition to the topographical survey, Digital Terrain Model (DTM) data was acquired, providing a 1m grid of levels, for the land between the reservoir and the proposed site as well as for the area within the site. The topographical survey and DTM were utilised to examine the predicted reservoir flooding at the site.

5.4 The DTM data providing a 1m grid of terrain levels, as recorded by LiDAR, is visually represented by the ground model shown on Plate 5.1. The dark to light shading on Plate 5.1 indicates the variation of high to low ground respectively, where the Lower Creggan reservoir can be seen on the bottom left hand corner of the plate.

5.5 Plate 5.1 shows that lines of low ground are located adjacent to the site's north eastern and south eastern boundaries. This suggests that inundation waters reaching the site would be directed around the northern and southern sides of the development rather than the majority of the flood water passing through the site.

5.6 Comparison of Plate 5.1 with Plate 3.1 and 3.3 determines that the reservoir floodplain generally follows the routes of the Pennyburn Stream and Creggan Burn along lower-lying ground adjacent to the proposed site.



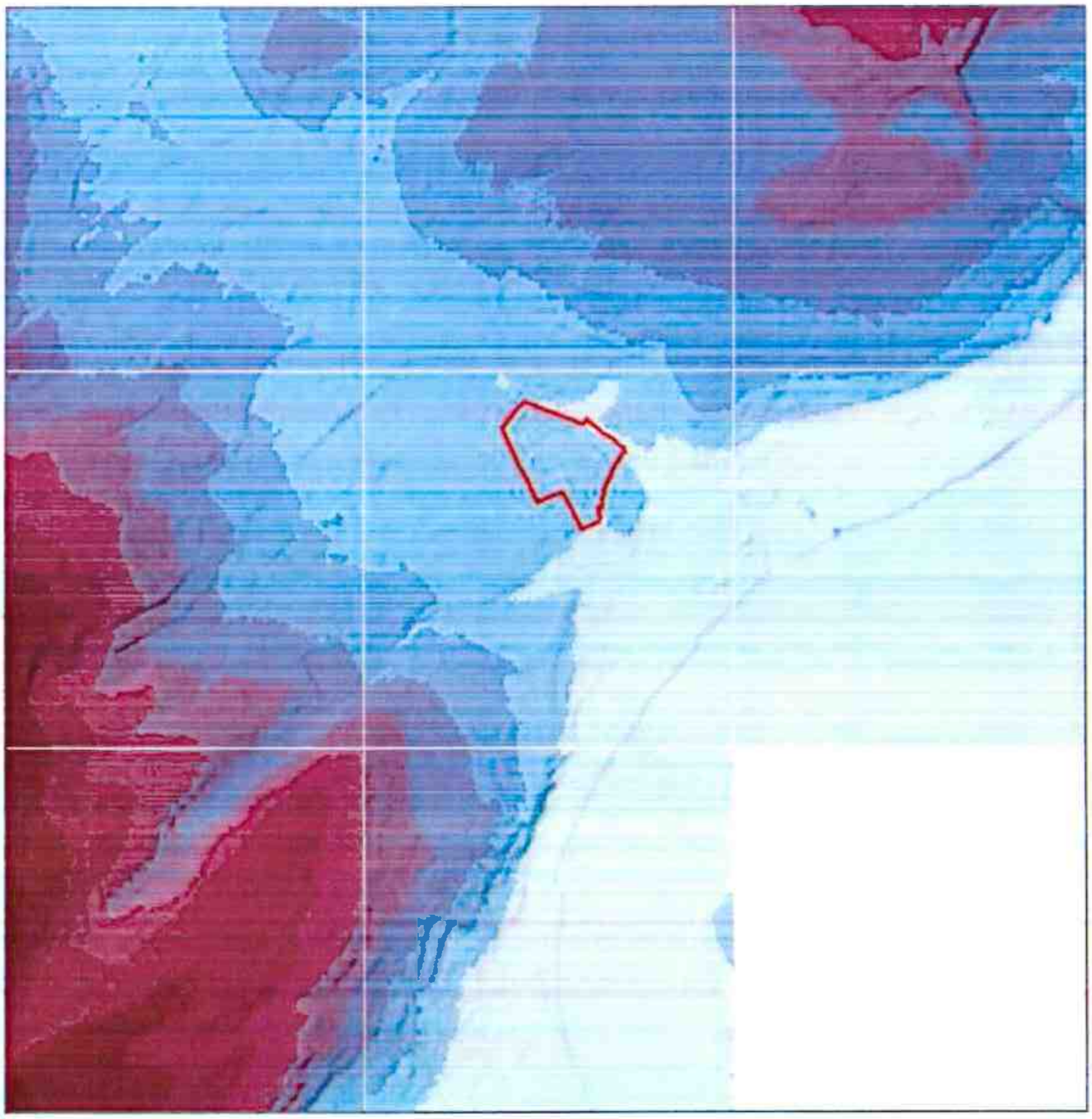


Plate 5.1: Ground model of 1m grid DTM data of the area of the site and reservoir

6.0 MANAGEMENT OF RESERVOIR

6.1 Rivers Agency's document "Reservoirs in Northern Ireland" (2014) indicates that the both the Upper and Lower Creggan reservoirs are owned by third sector bodies, where the Creggan Country Park manages the dams.

6.2 As the proposed development falls under the category of 'replacement building' in Policy FLD 5 of PPS 15 , no further information was sought regarding the present condition of these reservoirs.

7.0 LITERATURE REVIEW ON GUIDANCE FOR RESERVOIR FLOODING

7.1 *General*

7.1.1 A series of guidance manuals and booklets were examined to determine how best to evaluate reservoir flooding at the proposed site.

7.1.2 Extracts of relevant information from the guidance documents are presented below, subdivided into the manuals from which the guidance was obtained.

7.2 *Reservoir Risk Designation Guidance (August 2013, Environment Agency)*

7.2.1 There has been no loss of life from reservoir failure in the UK since reservoir safety legislation was introduced in 1930.

7.2.2 A large raised reservoir is considered a high-risk reservoir if, in the event of an uncontrolled release of water from the reservoir, human life could be endangered **and** the reservoir does not satisfy the conditions (if any) specified in regulations made by the Minister.

7.2.3 The Environment Agency considers that life could be endangered if there is a reasonable expectation that in the event of an uncontrolled release of water from a reservoir, conditions downstream will be such that persons within or in the immediate vicinity of residential, business or recreational area could be endangered or damage to infrastructure is sufficient to lead directly to human life being endangered.

7.2.4 The Environment Agency considers that human life could be endangered if, in the event of an uncontrolled release of water from the reservoir, specific technical analyses indicate that certain thresholds are exceeded. The technical analysis calculates:

- The likely loss of life downstream of a reservoir. This requires detailed computer modelling of the flood characteristics and their impact on people at risk in homes, businesses and other locations
- The rate of water flow at the property.

7.3 *Reservoir Flood Maps (RFM) Guide: Explanatory Note on Reservoir Flood Maps for local resilience Forums, Version 4 (January 2016, Environment Agency)*

7.3.1 The Environment Agency warn that reservoir flood maps were originally developed for emergency planning purposes and that while they can be used for other purposes, care should be taken to understand the limitations of the maps and the assumptions made in the modelling before using the maps for other purposes. The maps do not in any way reflect the structural integrity of the dam or the chance of it failing.

7.3.2 Two types of maps were produced:

- Outline (flood extent) maps
- Detailed maps that consider depth, velocity and hazard.

7.3.3 Dam breach flooding happens when a dam impounding a reservoir breaches, causing water stored in the reservoir to be released through the breach and flooding areas downstream of the dam. The dam breach scenario simulated on the maps is a “credible worst case” scenario. This represents a “generic” dam failure that can be adopted across the country.

7.3.4 The procedure for the development of the flood maps included the prediction of the dam breach outflow hydrograph and routing of the hydrograph downstream of the reservoir. The approach for the modelled breach scenario for an impounding reservoir assumed that the reservoir water level has risen to dam crest level plus 0.5m, leading to overtopping over the entire height of the dam.

7.3.5 Outflow hydrographs for non-impounding reservoirs assumed a water level at 0.1m above crest level and overtopping over the entire height of the dam, while a water level at crest height was applied to service reservoirs. The breach assumptions are intended to produce a single, simplified dam breach hydrograph that reflects a credible worst case scenario for a hypothetical dam breach.

7.3.6 In addition to the above addition to crest level, the calculation method of the outflow hydrographs used for the flood mapping for reservoirs with earthfill embankments identifies that a factor of safety of 1.5 is applied to the peak discharge (according to Froehlich (1995)).

7.3.7 Therefore, the modelling on an impounding reservoir assumes a crest level plus 0.5m, that flooding occurs along the full length of the dam (as opposed to an isolated breach) and that a safety factor of 1.5 is applied to the peak discharge flow.

7.2.8 The topography downstream of the reservoirs is represented in the hydraulic model by a digital terrain model (DTM), constructed using either LiDAR of IFSAR data. Floodplain features (for example road and railway embankments) are represented in the hydraulic modelling but buildings, bridges and culverts are not represented. A Manning's friction *n* value of 0.10 is set globally for the reservoir flood modelling.

7.3.9 InfoWorks-RS-2D and/or TUFLOW software is used to produce RIM Phase 2 maps for Category A reservoirs and other 'higher risk' reservoirs. Where reservoirs have a number of places where a hypothetical dam breach could occur and the breaches have significant impact on flooded areas, the flood maps have been produced showing flooding from multiple breach locations as well as a composition of all breach locations.

7.4 *The Flood Risks to People Methodology, Phase 2, Technical Report FD2321/TR1 (March 2006, Defra /Environment Agency Flood and Coastal Defence R&D Programme)*

7.4.1 Defra/EA outline initially that flood risks cannot be completely eliminated and the requirement for methods to estimate the risks to people, as well as risk of economic and environmental damage.

7.4.2 The Risks to People Methodology is explained as a form of multi-criteria assessment based on the concepts of flood hazard, area vulnerability and people vulnerability. The resulting calculated annual risk of fatality or harm is deemed 'acceptable' if it is less than the 'tolerable' value. **However, the report states that the current Government policy for flood risk management does not consider a specific threshold for tolerable risk.** Therefore, while flood hazard, area vulnerability and people vulnerability should all be considered (rather than considering flood hazard alone), current Government policy does not confirm a threshold value over which new development should not proceed.

7.4.3 Phase 1 methodology is outlined by the following equation, applied to a particular flood:

Ninj = Nz x Hazard Rating x Area Vulnerability x People Vulnerability

Where *Ninj* = number of injuries
Nz = population at risk of flooding
Hazard Rating (HR)= function of flood depth and velocity and debris factor
Area Vulnerability (AV) = function of effectiveness of flood warning, speed of onset of flooding and nature of area (including types of buildings)
People Vulnerability (PV) = function of presence of people who are very old and/or infirm/disabled/long-term sick

7.4.4 The report then expounds on each of the above variables of flood hazard rating (*HR*), area vulnerability (*AV*) and people vulnerability (*PV*), where final values are to be applied to the above equation.

7.4.5 *Flood Hazard Rating (HR)*

7.4.5.1 There is a broad consensus that the degree of hazard that floodwaters present to people (and to vehicles and property) is a function of both velocity and depth. Other factors may affect the stability of people during flooding, where a debris factor is included in the flood hazard equation.

7.4.5.2 When examining depths of flooding relating to their effect of vehicles some information is provided to give an indication of flood hazard. For example, cars will stop and/or float in shallow water (depth as low as 0.5m) while emergency vehicles may survive in slightly deeper waters (up to 1m in depth). In addition, a fire engine remains controllable in depths of 0.5m at up to 5m/sec water flows.

7.4.5.3 Section 3.5 of the report presents the final flood hazard rating formula which is based, primarily, on consideration to the direct risks of people exposed to floodwaters:

$$HR = d\,(v + 0.5) + D_F$$

Where HR = flood hazard rating

d = depth of flooding (m)

v = velocity of floodwaters (m/sec)

D_F = debris factor (= 0, 0.5 or 1 depending on the probability that debris will lead to a significantly greater hazard)

7.4.5.4 The subsequent report: *Supplementary note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose (May, 2008, Environment Agency and HR Wallingford)* presents an extended table based on a precautionary approach applying conservative debris factors and hazard classifications.

7.4.5.5 The extended flood hazard to people classification table, using the above hazard rating equation, is outlined in the guidance is presented on Plate 7.1. This table is recommended for development planning and control use.

HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03 + 0.5 = 0.53	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.13 + 0.5 = 0.63	0.15 + 1.0 = 1.15	0.20 + 1.0 = 1.20	0.25 + 1.0 = 1.25	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25
0.1	0.03 + 0.5 = 0.53	0.06 + 0.5 = 0.56	0.12 + 0.5 = 0.62	0.15 + 0.5 = 0.65	0.18 + 1.0 = 1.18	0.24 + 1.0 = 1.24	= 1.30	= 1.36	= 1.48	= 1.60	= 1.90	= 2.20	= 2.50
0.3	0.04 + 0.5 = 0.54	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.19 + 0.5 = 0.69	0.23 + 1.0 = 1.23	= 1.30	= 1.38	= 1.45	= 1.60	= 1.75	= 2.13	[illegible]	[illegible]
0.5	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.25 + 0.5 = 0.75	0.30 + 1.0 = 1.30	= 1.40	= 1.50	= 1.60	= 1.80	1.00 + 1.0 = 2.00	= 2.50	= 3.00	= 3.50
1.0	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.38 + 0.5 = 0.88	= 1.45	= 1.60	= 1.75	= 1.90	= 2.20	= 2.50	= 3.25	= 4.00	= 4.75
1.5	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	0.50 + 0.5 = 1.00	= 1.60	= 1.80	= 2.00	= 2.20	= 2.60	= 3.00	= 4.00	= 5.00	= 6.00
2.0	0.13 + 0.5 = 0.63	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	0.63 + 0.5 = 1.13	= 1.75	= 2.00	= 2.25	= 2.50	= 3.00	3.50	4.75	6.00	7.25
2.5	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.60 + 0.5 = 1.10	0.75 + 0.5 = 1.25	0.90 + 1.0 = 1.90	= 2.20	= 2.50	= 2.80	3.40	4.00	5.50	7.00	8.50
3.0	0.18 + 0.5 = 0.68	0.35 + 0.5 = 0.85	0.70 + 0.5 = 1.20	0.88 + 0.5 = 1.38	= 2.05	= 2.40	= 2.75	3.10	3.80	4.50	6.25	8.00	9.75
3.5	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	= 1.30	= 1.50	= 2.20	= 2.60	3.00	3.40	4.20	5.00	7.00	9.00	11.00
4.0	0.23 + 0.5 = 0.73	0.45 + 0.5 = 0.95	= 1.40	= 1.63	= 2.35	= 2.80	3.25	3.70	4.60	5.50	7.75	10.00	12.25
4.5	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	= 1.50	= 1.75	= 2.50	= 3.00	3.50	4.00	5.00	6.00	8.50	11.00	13.50
5.0	0.28 + 0.5 = 0.78	0.60 + 0.5 = 1.10	= 1.60	= 1.88	= 2.65	3.20	3.75	4.30	5.40	6.50	9.25	12.00	14.75

Flood Hazard Rating (HR)	Colour Code	Hazard to People Classification
Less than 0.75		Very low hazard - Caution
0.75 to 1.25		Danger for some – includes children, the elderly and the infirm
1.25 to 2.0		Danger for most – includes the general public
More than 2.0		Danger for all – includes the emergency services

Plate 7.1: Extended table to be used for hazard to people classification

7.4.5.6 The supplementary report agrees with the equation for the calculation of HR shown above. However, the reader should note that the flood hazard classifications shown on Plate 7.1 reflect the **more conservative** categorisation presented in the supplementary report (EA and HR Wallingford, May 2008) rather than those presented in the original technical report (FD2321/TR1). Therefore, the above flood hazard classifications (colour coded white, yellow, orange and red), will be applied for the following assessment.

7.4.5.7 Paragraph 2 of the supplementary report (EA and HR Wallingford, May 2008) confirms that the original report (FD2321/TR1) does not set a policy for flood hazard thresholds, but instead only provides the method of calculation.

7.4.5.8 When considering the Risks to People methodology, the Flood Hazard Rating (*HR*) (which considers depth and velocity) is only one of the three factors used. The other two factors, Area Vulnerability (*AV*) and People Vulnerability (*PV*) are considered further below.

7.4.6 *Area Vulnerability (AV)*

7.4.6.1 The Area Vulnerability concept classifies areas according to:

- flood warning
- speed of onset
- nature of area.

7.4.6.2 There will clearly be different levels of risk associated with different locations e.g. outdoor on foot compared to being indoors on the top floor of a multi-storey building. Table 4.4 of report FD2321/TR1 is presented on Table 7.1 which outlines the expression and methodology for the calculation of area vulnerability. Area vulnerability can be seen to be calculated as the sum of scores of the factors for speed of onset, nature of the area and flood warning, each scored 1, 2 or 3, for a minimum vulnerability value of 3 and maximum of 9.

Parameter	1 - Low risk area	2 - Medium risk area	3 - High risk area
Speed of onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (an hour or so)	Rapid flooding
Nature of area	Multi-storey apartments	Typical residential area (2-storey homes); commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc.
Flood warning	Score for flood warning = 3 - (P1 x (P2 + P3)) where P1 = % of Warning Coverage Target Met P2 = % of Warning Time Target Met P3 = % of Effective Action Target Met		
Area Vulnerability (*AV*) = sum of scores for 'speed of onset', 'nature of area' and 'flood warning'			

Table 7.1: Area Vulnerability scores and calculation (from Table 4.4 of FD2321/TR1)

7.4.6.3 Therefore, while the Flood Hazard Rating (*HR*) considers the hydraulic characteristics of the flood event, the Area Vulnerability (*AV*) considers the location of the development and the type of development being proposed.

7.4.7 *People Vulnerability (PV)*

7.4.7.1 Consideration of factors which could be used to characterise the 'vulnerability' of people was presented. The characteristics of old age and long-term illness were deemed to be of direct relevance when considering the direct risks of injury associated with flooding.

7.4.7.2 Section 5.3 of the technical report (FD2321/TR1) states "the very old and the infirm/disabled/long-term sick account for about 10% and 15% of the adult population respectively (and it is acknowledged that some people will fall into both categories)".

7.4.7.3 The equation below presents the method for calculation of people vulnerability (*PV*):

Y = % residents suffering from long-term illness + % residents aged 75 or over

Where *Y* = *PV* = people vulnerability expressed as a percentage

7.4.7.4 By incorporating People Vulnerability (PV) into the assessment of risk, the trifold assessment proposed in the Risk to People methodology proposed by Defra/EA considers the hydraulic conditions of the flood, the location and type of development proposed and the vulnerability of the people set who are likely to use the proposed development.

7.4.8 *Determining the Risk to People*

7.4.8.1 Section 6 of the methodology report presents the steps for the determination of the risk to people according to the equation presented in Section 7.4.3 of this report, using the methodology shown above to establish flood hazard, area vulnerability and people vulnerability factors.

7.4.8.2 It is recommended that to fully assess the risk to people, at least 5 events should be considered in order to determine the annual average individual or societal risk. The greatest impact is likely to be for more extreme events, which should therefore be included in the analysis.

7.4.8.3 The number of injuries (*Ninj*) can be determined using the following equation:

$$Ninj = 2 \times N \times HR \times (AV/100) \times PV$$

Where *Ninj* = number of injuries
N = population at risk of flooding
HR = Flood hazard rating
PV = People vulnerability

7.4.8.4 As only a proportion of those injured will suffer fatality, the number of fatalities (*Nf*) is then determined using the following equation:

$$Nf = 2 \times Ninj \times (HR/100)$$

Where *Nf* = number of fatalities
Ninj = number of injuries
HR = Flood hazard rating

7.4.8.5 After quantifying the relationships for the above factors for a single event and the annual risk of injury or fatality has been calculated, this is to be compared to the estimated acceptable risk. If the annual risk of injury or fatality is less than the 'tolerable' risk it is deemed 'acceptable'. As stated in Section 6.2.6 of the methodology report, current Government policy for flood risk management does not consider a specific threshold for tolerable risk. This tolerable risk will be considered in more detail later in this report.

7.4.9 *Damage of Buildings*

7.4.9.1 Although not directly considered within the process of calculating the risk to people, some information is provided regarding the damage of buildings due to flood waters. "Some damage can occur to buildings if the depth differential between the outside and inside water levels exceeds 0.5 metres. Severe damage can occur if the differential reaches one metre, or a differential of 0.5 metres occurs in combination with high flow velocity (greater than about 3m/s). More severe conditions can lead to irreparable damage (for example, a differential depth of one metre and a flow velocity of 6m/s, or a differential depth of two metres and a flow velocity of 3m/s). Where buildings are "floodproofed" and there is a higher level of water outside than inside, the maximum differential pressure that brickwork walls can resist is of the order of one metre."

7.5 *Flood Risks to People, Phase 2, Guidance Document FD2321/TR2 (March, 2006, Defra /Environment Agency Flood and Coastal Defence R&D Programme)*

7.5.1 This guidance document is to be read in conjunction with report FD2321/TR1 (discussed in Section 7.4 of this report) and explains how the overall method or its component parts can be applied in flood risk management, including for the application of flood plans for reservoirs.

7.5.2 General guidance, in agreement with the associated methodology report, explains that adults are unable to stand in still floodwater with a depth of about 1.5m or greater and that most people will be unable to stand when the velocity is 2m/s with an associated depth of 0.6m.

7.5.3 Guidance note 7, regarding spatial planning, is concerned with future development and states that information on flooding is required at potential development sites (where the methods apply to local scale). The methodology for the assessment of flood risk to people which is applicable to spatial planning is based upon the basic methodology report (based on factors of flood hazard and area and people vulnerability).

7.5.4 The flood hazard is to be used to identify unsafe areas, evacuation routes and guide the type and layout of buildings and infrastructure. Flood hazard results can be used to influence the selection of development sites, the type of potential development and the planning policies needed to manage the risks. The guidance on spatial planning states that people should not be located in areas of high hazard. Also, the speed of onset of flooding will provide guidance on the type of flood warning and emergency response arrangements needed for different sites. Where flood warning times are short:

- There should be safe refuge above flood level for everyone in the development site
- People in the development should be aware of the risk

7.5.5 Other development guidance that could arise from an understanding of the flood hazard at a potential development may include the avoidance of underground car parks, housing for the elderly, schools or hospitals in areas of flood risk.

7.5.6 Guidance note 8 relates to reservoir flood plans and provides methods for the calculation of flood hazard, area vulnerability and people vulnerability (according to the methodology report). The results of such analysis will provide information on locations where high flood hazard would occur in the event of a dambreak or overtopping of a dam.

7.5.7 As a dambreak can cause very high flood depths and velocities, the Area Vulnerability (*AV*) should take account of this special case. The results can be used for contingency planning and, where the risks are considered to be unacceptable, planning of mitigation measures. Such mitigation measures as the control of development, change of land use and lowering the reservoir water level are mentioned. In the context of flood from dams, the speed of onset is generally rapid and flood warning is unlikely to be available and therefore should be accounted for in the flood warning score.

7.5.8 The guidance recommends the use of several events in order to calculate the annual average number of people at risk of injury or death in a flood; events for reservoir flood plans will be very extreme. Whilst the probability of the flood might be low (perhaps in the range of 0.1% to 0.01% annual probability of occurrence), the consequences can be high and therefore the risks to people can be high.

7.5.9 The methodology for calculation of flood hazard and estimation of the speed of onset of flooding is presented. As flood hazard is a function of depth and velocity, a number of possible approaches are outlined for estimating flood depths and velocities for local mapping. The guidance outlines possible approaches to the calculation of flood depths and velocities for the calculation of *HR*, ranging from a simpler one-dimensional hydraulic model to the most complex option of two-dimensional hydraulic modelling using a triangular mesh (which can provide food velocity estimates).

7.5.10 Hydraulic modelling requires flow data (using a dambreak model or reservoir routing model to generate the flood hydrograph from the dam) and ground level data. Where Digital Terrain Models are used to provide ground data, ideally buildings should be included in the model for local applications.

7.5.11 The method for calculating flood risks to people for reservoir plans is the same as the equation presented in Section 7.4 of this report, where the risk of occurrence of the number of calculated injuries (*Ninj*) will simply be the likelihood of the given flood (probability of reservoir failure).

7.5.12 The number of injuries or deaths is also represented by:

$N(I) = N \times X \times Y$

Where *N(I)*= number of deaths/injuries

N = population within the floodplain

X= proportion of the population exposed to a risk suffering death/injury (for a given flood). The value *X* is based on *HR* and *AV* where *X = HR x AV*

Y= the proportion of those at risk who will suffer death/injury. The value of I is based on people vulnerability *(PV)*

7.5.13 The percentage of people exposed to risk (*X*) is generated by the multiplication of *HR* and *AV*. Should this score exceed 100, this is simply taken as 100. *X* is multiplied by the number of people in the floodplain to determine the number of people exposed to the flood risk *N(ZE)*. The number of people exposed to the risk is multiplied by (2 x *Y*) to obtain the number of injuries.

7.5.14 Finally, the guidance demonstrates that the fatality rate (i.e. the proportion of injured people who die) is assumed to be proportional to *HR*. Where the number of deaths is obtained by the multiplication of the number of injuries with (2 x *HR*).

7.5.15 In summary, the proportion of fatalities is calculated by the multiplication of X with 2*Y* and 2*HR*.

7.5.16 Regarding uncertainty, the guidance states "uncertainty is generally high, particularly in the number of people who will be exposed to a flood and the wide range of site specific factors that affect whether people are injured or killed".

7.6 *Flood Risk Assessment Guidance for New Development, Phase 2 – Framework and guidance for assessing and managing flood risk for new development, full documentation and tools (Defra, October 2005)*

7.6.1 The 'flood risks to people' calculator, presented above from The Flood Risk to People Methodology Technical Report (March 2006), can be used to test whether a development will increase the risks of harm or death in an extreme flood, can be used to support the consideration of outline planning applications and can be used to check or reinforce decisions made based on FRAs. **However, the guidance does not identify what should be considered as an acceptable risk for development planning, as this is the responsibility of the planning authorities, and the tool should not be used solely to determine a planning application.**

7.6.2 The method has been tested against 7 case studies and has been shown to work well, giving a reasonably realistic number of deaths compared to statistics. Despite this, some experts have still raised concerns that this method might over-estimate deaths. However, it is inevitable that a high degree of uncertainty will remain with this method, due to the few events available to calibrate against.

7.6.3 The method's application is most appropriate in comparing options. It should never be used as the sole tool in decision-making, as there are many other economic, environmental and social factors that should also be taken in consideration.

7.6.4 The calculator is designed to make broad-brush assessments of the "risks to people" at the scale of a single area or site within the floodplain e.g. the "red-line" area that forms part of a planning application.

7.6.5 As a result of the calculations, mitigation measures may be proposed. For example, these may include a mandatory constraint that developments have a "safe refuge" above the maximum flood level or raised walkways to enable safe exit.

7.6.6 The Environment Agency flood risk policy aims to reduce flood risk, but the risk of death from flooding cannot be eliminated completely. Many thousands of people already live and work in the floodplain and people are subjected to a range of risks on a day to day basis. Therefore, the concept of a "tolerable" or "acceptable risk" is useful to set on the flood risks that are unacceptable in comparison to other risks. The acceptability of residual risks is recognised, where risks with low probability but high consequences might be less acceptable that a higher probability risk but with lower consequences.

7.6.7 A summary of the risks of death in the UK, as reported in the Flood Risks to People Phase 1, is given below:

- 1 in 100 per year: Risk of dying when you are aged 60
- 1 in 1,000 per year: Risk of employee being killed in high hazard industry
- 1 in 10,000 per year: Risk of being killed in car accident
- 1 in 100,000 per year, Risk of being murdered
- 1 in 10 million per year: Risk of being killed by lightning

7.6.8 In the Risks to People Calculator, the outcome is defined as "Acceptable" or "Unacceptable" according to the following criteria related to annual average individual risk:-

- The development must not "significantly" increase the individual risk of death. Significance is taken as a greater than 1.5 increase in individual risk.
- The probability of death must be less than 0.0001% or 1 in 10,000 per year i.e. the risk of dying due to reservoir flooding must be less than the risk of being killed in a car accident.

7.6.9 If greater numbers of people are located on a floodplain, significant increases in risk are almost inevitable. However, these increased risks must be balanced against other economic, social and environmental criteria.

7.7 *Defra Flood and Coastal Defence Appraisal Guidance, Social Appraisal, Supplementary Note to Operating Authorities – Assessing and Valuing the Risk to Life from Flooding for Use in Appraisal of Risk Management Measures (May, 2008, Defra)*

7.7.1 The guidance is to supplement the Flood and Coastal Defence Project Appraisal Guidance and is based on The Flood Risk to People Methodology Technical Report (March 2006), presented in Section 7.4 of this report.

7.7.2 The Risks to People method provides an approach that allows the relative risk to life to inform the decision making process and is therefore recommended for use by operating authorities. The risk to people is useful in both a social and economic context, to calculate the possible numbers of fatalities and assign monetary values to the loss of life as indicated in the H M Treasury 'Green Book'.

7.7.3 The application of Reference Valuation is presented to quantify the economic value for the loss of life agreed by Government. Annex 1 reiterates The Flood Risks to People Methodology as presented in the report (March 2006).

7.8 *British Standard 8533:2011 Assessing and Managing Flood Risk in Development – Code of Practice*

7.8.1 The British Standard has been developed in order to bring together flood risk management guidance issued by the government and devolved administrations within the UK and to provide recommendations that can help the user to amass information for a planning application. The standard is intended to complement PPS 15 for Northern Ireland.

7.8.2 Section 4.4.6.1.2 of the standard addresses reservoir failure, outlining that the likelihood and consequence of dam failure at a reservoir should form part of an assessment. It is recommended that "for reservoirs not falling under the jurisdiction of the Reservoirs Act 1975, a risk-based approach should be taken to assess the level of detail of analysis that is appropriate for the site".

7.8.3 The following steps are presented in the code of practice:

- Where a sudden reservoir failure might result in the rapid inundation of the development with insufficient warning to allow a safe evacuation, a hydraulic assessment should be undertaken. The depth and velocity of the resulting flood wave as it approaches (and flows through) the site should be taken into consideration in this assessment.
- The structural integrity of the reservoir should be assessed in discussion with the reservoir owner or reservoir operator. Consideration should be taken of the long-term maintenance of the structure, over the lifetime of the development.
- Where the development is situated at a distance from the reservoir that it can be evacuated safely in case of a sudden structural failure, or the predicted depth of flooding through the site as a result of the structural failure of a reservoir is less than 250 mm, it is not necessary to undertake a detailed assessment.

7.8.4 BS 8533:2011 also presents a subsection on risk to public safety from fluvial flooding. While fluvial flooding will have different characteristics, the information remains useful for guidance purposes. With regards to public safety and 1 in 100 year (1%) fluvial flooding, it is recommended that the flood hazard rating for flood waters across an access route are no more than 1.25. If it is not practicable to construct an access route with a flood hazard of less than 1.25, the flood hazard rating should be less than 2.0. A development should not be proposed where the flood hazard is greater than 2.0.

7.8.5 However, when using these figures, it should be taken into consideration that the likelihood of a catastrophic reservoir failure such as that considered in this report must have a return period in excess of 1 in 100 years. Therefore, the allowable flood hazard rating should potentially be increased to take account of this lower risk of the flood event actually occurring.

7.9 *Reducing Risks, Protecting People – HSE's Decision-Making Process (HSE, 2001)*

7.9.1 The Tolerability of Risk (TOR) framework is presented and can, in principle, be applied to all hazards.

7.9.2 Regarding fatalities, for members of the public who have a risk imposed on the 'in the wider interest of society', the document states that the risk limit is judged to be at 1 in 10,000 per annum. Although, this figure is not presented within the context of reservoir failure and floodplains, it agrees with the value presented in Section 7.6.8 of this report (from Defra, October 2005) and provides confidence in the judgement of tolerable annual risk.

8.0 HYDRAULIC MODEL OF RESERVOIR FLOODING

8.1 *General*

8.1.1 In order to calculate floodwater depth and velocity at the proposed site during a breach of the dams at both the Upper and Lower Creggan reservoirs, InfoWorks ICM (Integrated Catchment Modelling) software was used.

8.1.2 A two dimensional (2D) model of the land from the downstream face of the lower reservoir to the proposed site and extending downstream was firstly produced to compare design flows with Rivers Agency's reservoir flood map. The design flows were calibrated against the extent of inundation shown on Rivers Agency's mapping, where only flood water directed north eastward were considered as was relevant to flows at the proposed site. Secondly, the 2D model was used to determine flow depths and velocities at the proposed site.

8.2 *2D InfoWorks ICM model*

8.2.1 An InfoWorks ICM 2D model was created using the 1m grid DTM data for the area between the reservoir and the proposed site. The peak design flow was calibrated against Rivers Agency's mapping (Plates 3.2 and 3.3). The 2D model provided a triangular mesh reflecting ground levels to allow the modelling of downstream flows and examination of depths and velocities, an approach outlined in Section 7.5 of this report.

8.2.2 Hydrographs of breach flows were estimated to undertake 2D modelling of the reservoir failure (where flow rates reached their peaks at 6 minutes and fell to $0m^3/s$ within an hour) to simulate the inundation caused by a rapid reservoir failure.

8.2.3 The design flows were applied to the land north east of the lower reservoir, in agreement with the inundation flow path shown on River Agency's mapping.

8.2.4 A inflow hydrograph with a peak flow of 500m³/s, applied downstream of the lower reservoir south west of the proposed site, was found to produce a flood extent in good agreement with Rivers Agency's reservoir flood map.

8.2.5 Plate 8.1 presents results from the 2D modelling of the above flows at timesteps of 4min, 12min, 18min and 24min, where the 2D model covered the area of interest downstream from the reservoir to the proposed site and extended a short distance downstream to the River Foyle. The modelled design flow can be seen to be predicted to reach the south western side of the proposed site at the approximately 18min timestep (bottom left of Plate 8.1).

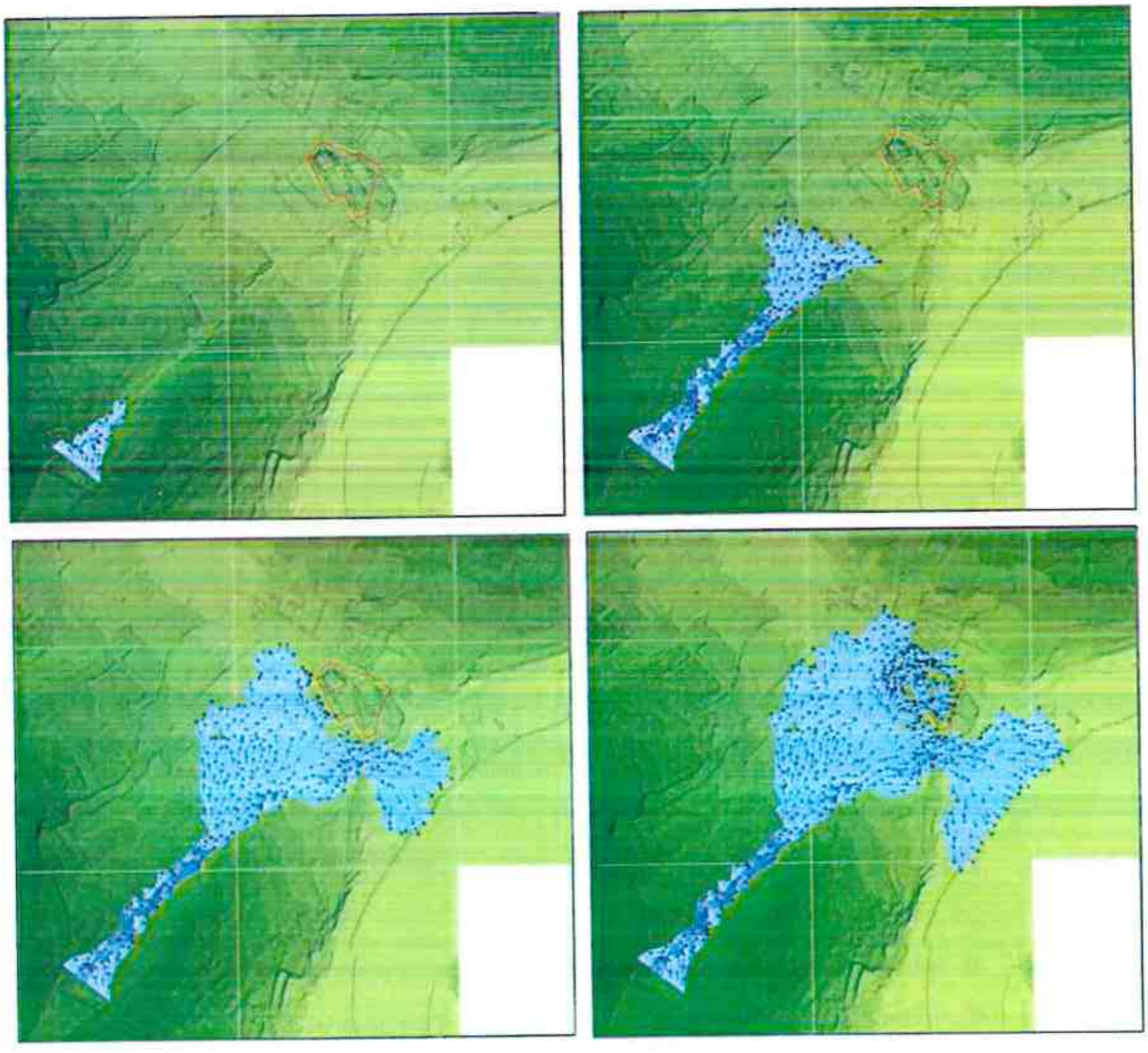


Plate 8.1: Time series (4min, 12min, 18min and 24min) of reservoir inundation flood event

8.2.6 The maximum flood extent and depths produced by the model are presented on Plate 8.2, where the site is approximately outlined in red. The blue outlines approximately indicate the extent of Rivers Agency's reservoir flood mapping. Comparison of the modelled inundation extent with that predicted by Rivers Agency identifies a generally good agreement with only a few discrepancies (small differences were to be expected due the higher resolution of 2D flood mapping produced by Rivers Agency than that shown on Plate 8.2).

8.2.7 As shown on Plate 3.3, small isolated areas within the proposed site are predicted to be above the inundation flood waters. Deeper areas of flooding are shown on Plate 8.2 adjacent to the site's north eastern boundary and south of the site, approximately following the routes of the local watercourses, the Pennyburn Stream and the Creggan Burn.

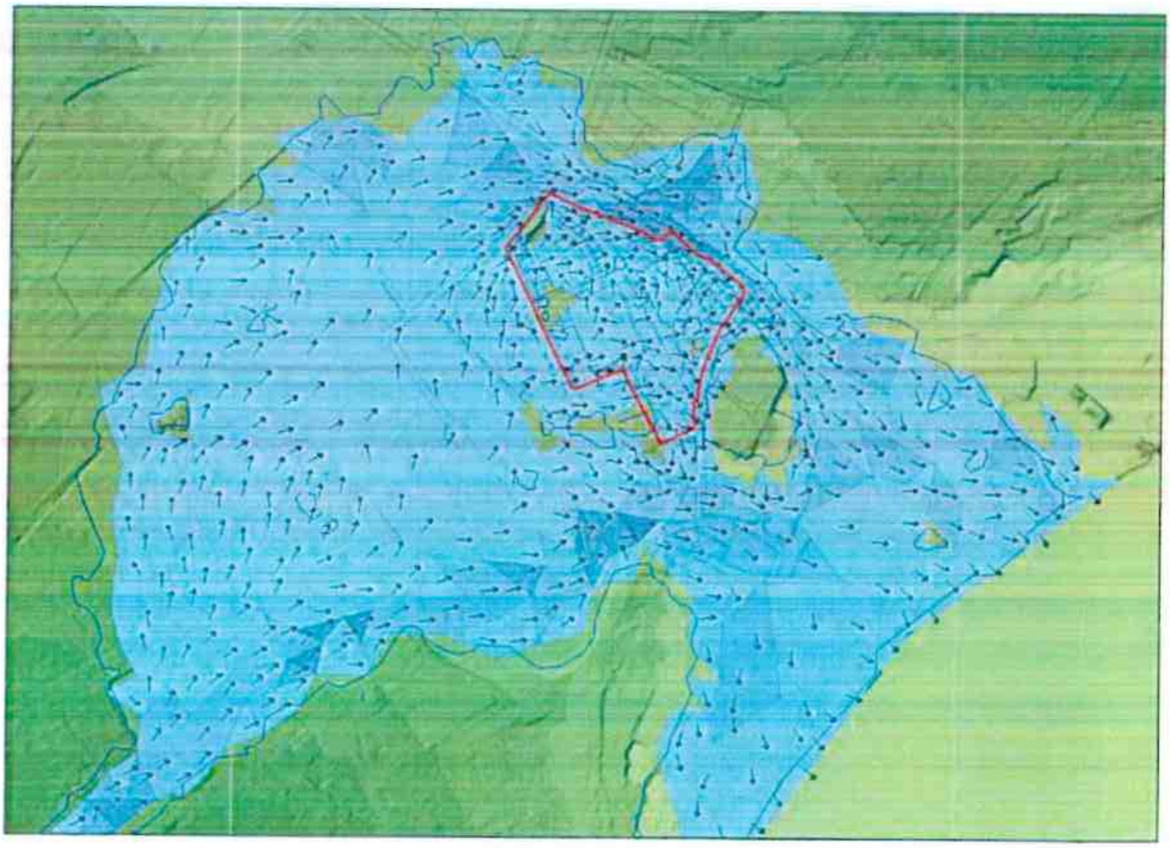


Plate 8.2: Maximum flood extent and depths resulting from a design flow with a peak of 500m^3/s

8.2.8 A slightly greater flood extent is shown on Plate 8.2 to be predicted within the proposed site. However, the design flow with a peak of 500m³/s was conservatively assumed for the following analysis. As per the methodology of reservoir inundation assumed by Rivers Agency, no structures along the watercourse were modelled in this assessment.

8.2.9 For comparison of design flows, Plate 8.3 presents the 2D results produced by an increased peak flow of 1,000m³/s, showing the maximum flood extent and depths. Comparison of the calculated flood extent with Rivers Agency's flooding (again outlined in blue) identifies that this increased flow produces a flood extent in excess of Rivers Agency's mapping, particularly within the proposed site. This therefore increases the confidence in the above modelled flow of 500m³/s, which will be assumed for the following analysis.

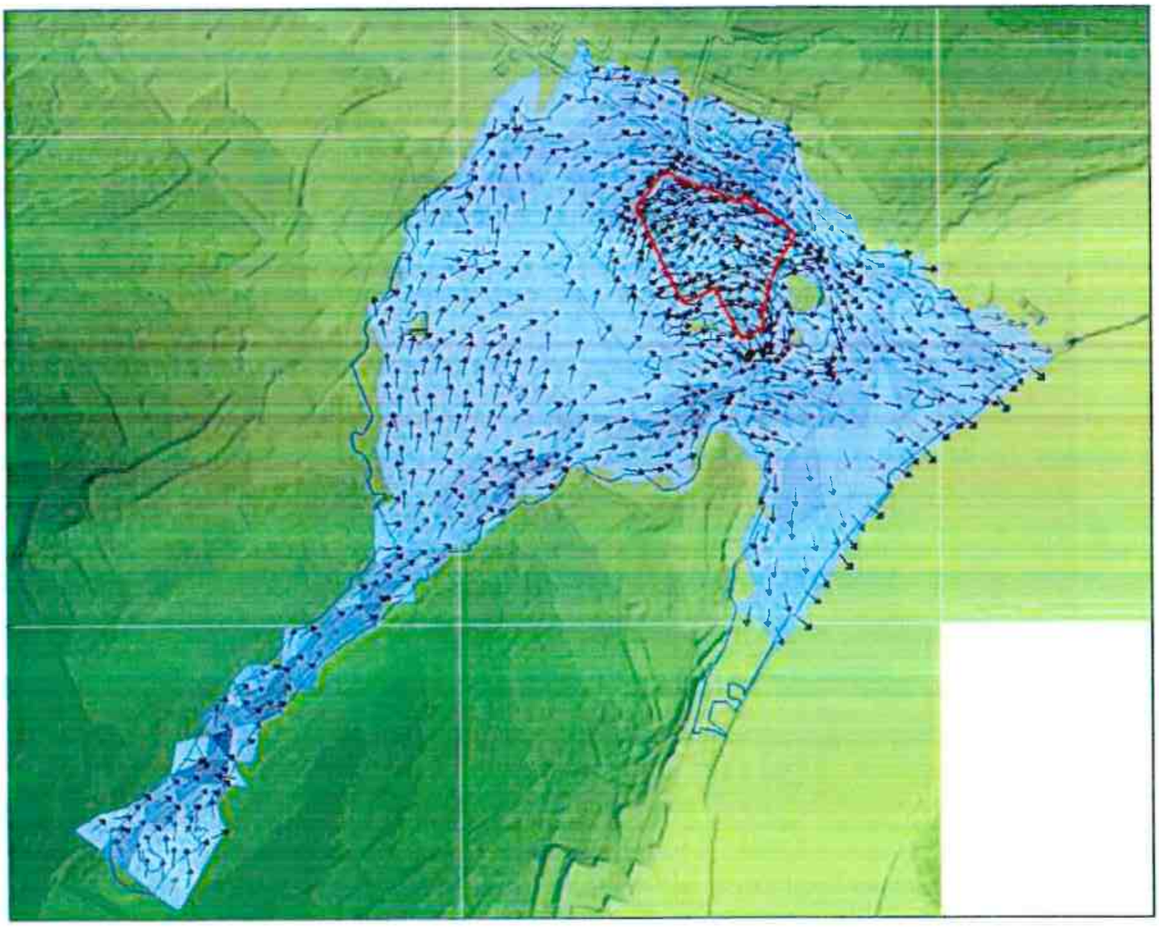


Plate 8.3: Maximum flood extent and depths resulting from a design flow with a peak of 1,000m³/s

8.2.10 The top and bottom of Plate 8.4 present mapping of the modelled maximum flood hazard ratings for the entire model and at a lower scale for the site only respectively. The flood hazard ratings shown on this plate reflect the categories presented on Plate 7.1, as recommended by Defra.

8.2.11 The results of the flood hazard modelling show that the majority of the existing site is predicted to experience low hazard inundation flooding. Deeper and faster flood waters across the northern site area and along the north eastern boundary were calculated to result in more dangerous flood hazard ratings, as indicated by the yellow, orange and red areas. As a note of caution, the presented colour coding for the flood hazard rating in Plate 8.4 considers the worst combination of depth and velocity during the entire reservoir flood event and so the majority of the flood event would produce much lower flood hazard ratings that those presented here.

8.2.12 Table 8.1 presents the peak flood hazard values at points A – C as shown on Plate 8.4, corresponding to locations of high, medium and low *HR*. The peak flood hazard calculations are shown on Table 8.1 to range from 2.13 to 0.52 across points A – C for the existing development at the proposed site.

Point	Max. Depth (m)	Max. Velocity (m/s)	Debris Factor	Max. Flood Hazard Rating
A	0.73	1.12	1	2.13
B	0.49	0.42	1	1.44
C	0.03	0.07	0.5	0.52

Table 8.1: Maximum depth, velocity and flood hazard at a selection of points at the existing site

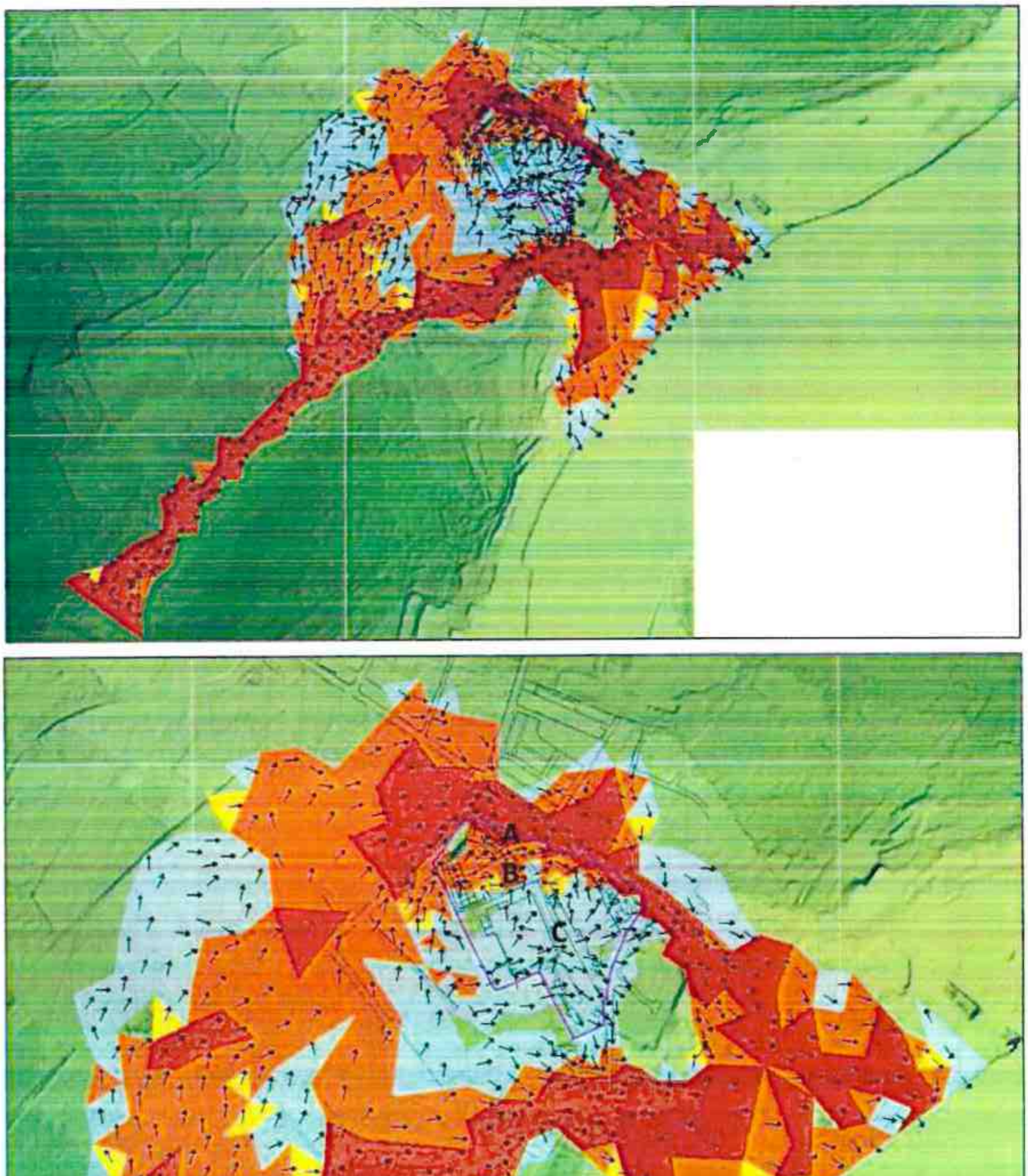


Plate 8.4: 2D model of reservoir inundation with maximum flood hazard values

8.2.12 The above analysis has presented the predicted results for inundation of the existing Arntz Belting Company facility at the existing site levels. However, the regeneration development proposes the alteration of site ground levels and the elevated FFLs of the four proposed buildings. Therefore, the above described 2D model was altered to reflect the proposed FGLs and FFLs as shown on Drawing 14-112-C05-F.

8.2.13 Plate 8.5 presents the maximum flood extent and depths for the entire model and at a lower scale at the site (top and bottom respectively) with ground levels within the site varied to reflect the proposed FGLs and FFLs of the development (red boxes identify proposed building footprints). In agreement with Rivers Agency's reservoir flood mapping procedure, the walls of the proposed buildings were not included in the 2D model.

8.2.14 Examination was undertaken of the difference in the predicted flood extent and depths resulting from the replacement development by comparison of Plate 8.5 with 8.2. It was observed that the change in site levels due to the replacement proposal did not materially change the flow paths, extent or depths. Reservoir inundation flood waters would flow post-development through the Pennyburn area, with deeper flows along the routes of the Pennyburn Stream and Creggan Burn and continuing to the River Foyle, in agreement with the current flow regime.

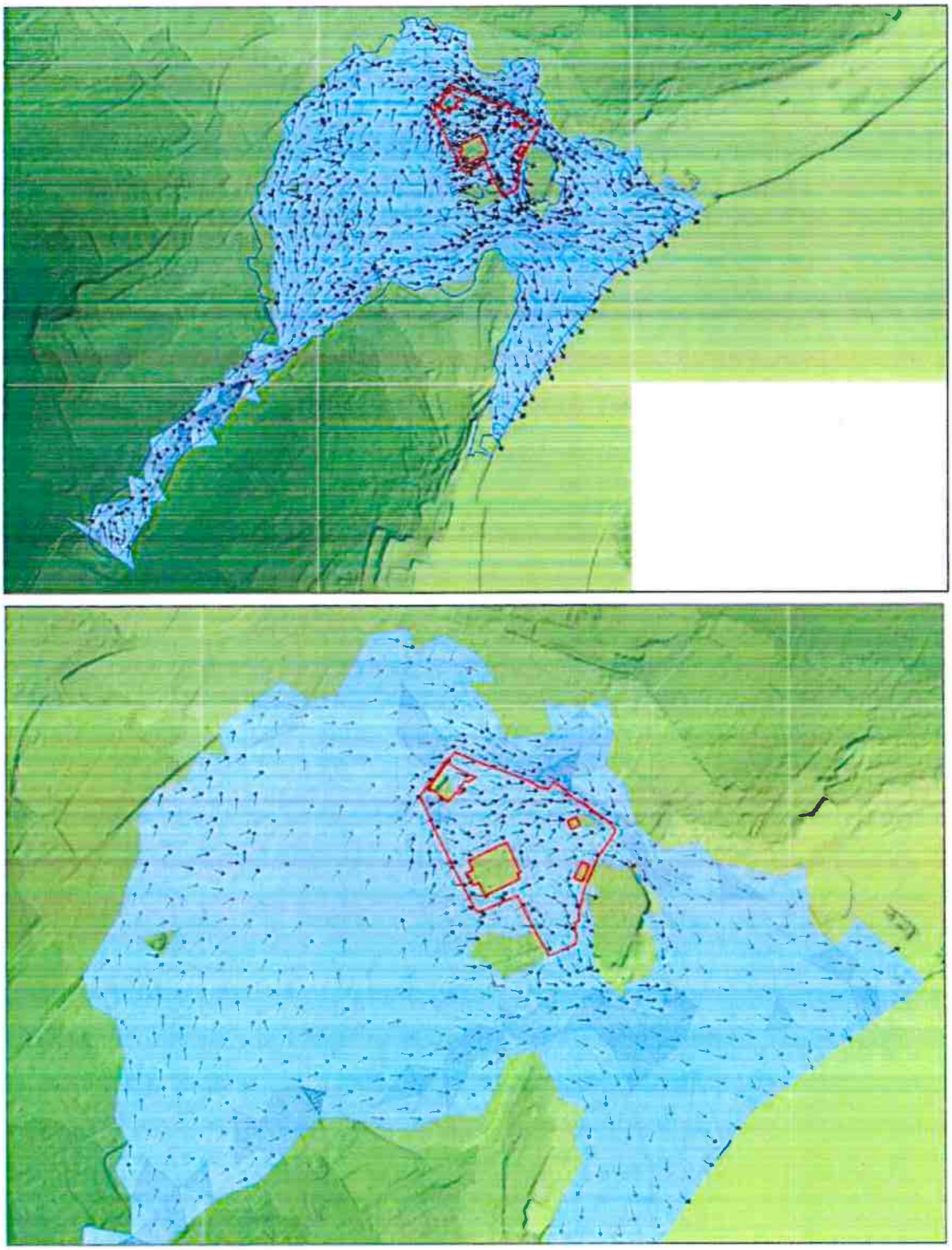


Plate 8.5: Maximum flood extent and depths post-development

8.2.15 In addition the variation in flood hazard ratings due to the introduction of the replacement development was also investigated. Plate 8.6 presents mapping of the maximum flood hazard ratings where site levels reflect those proposed for the scheme. Similar to the flood hazard mapping of the existing site (Plate 8.4), the southern portion of the site is shown on Plate 8.6 to have low, non-hazardous, *HR* ratings. Higher flood hazard is predicted within the northern portion of the site and adjacent to the site's northern boundary, in agreement with results for the site's current condition (Plate 8.4).

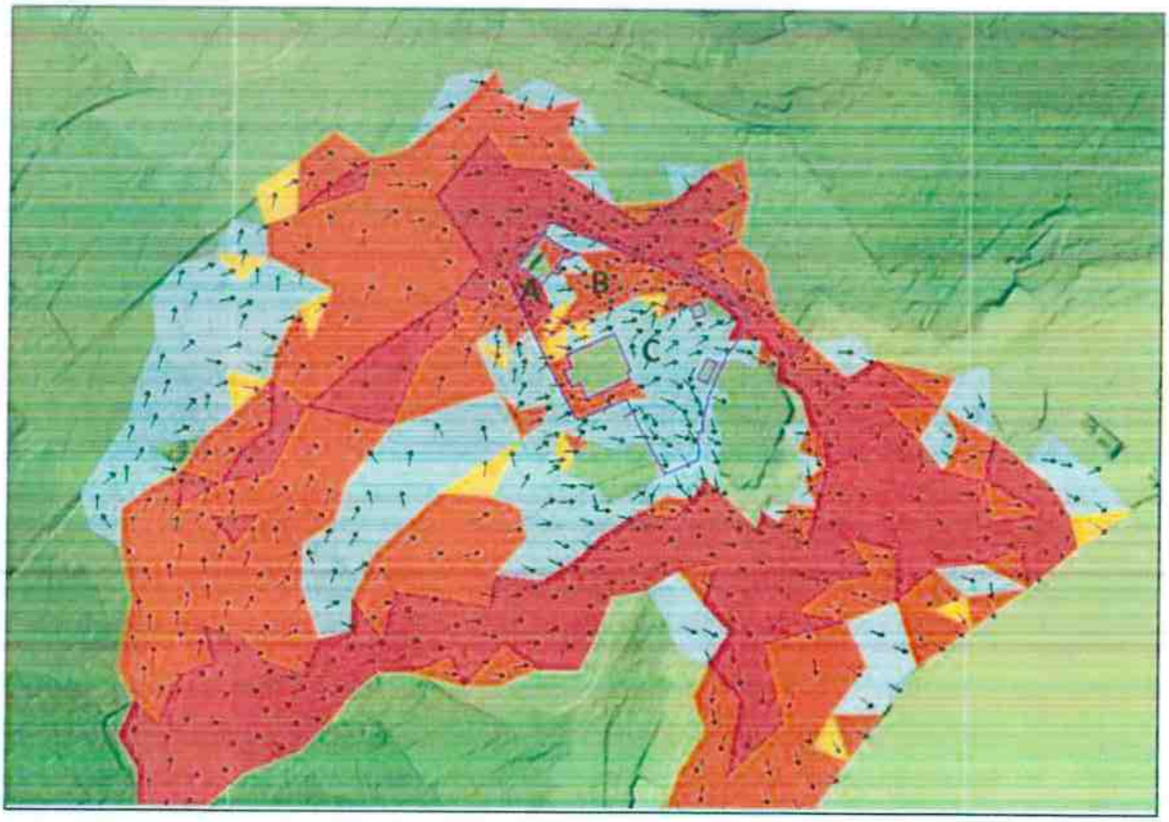


Plate 8.6: 2D model of reservoir inundation with maximum flood hazard values post-development

8.2.16 As analysed for the site at existing levels, Table 8.2 presents the maximum flood depths, velocities and hazards for points A – C as shown on Plate 8.6. Points A – C are again positioned within the site at locations of high, medium and low flood hazard respectively. Table 8.2 shows that the peak flood hazards for the replacement development closely mimic those shown on Table 8.1 for the existing development.

Point	Max. Depth (m)	Max. Velocity (m/s)	Debris Factor	Max. Flood Hazard Rating
A	1.31	0.42	1	2.20
B	0.60	1.02	1	1.83
C	0.10	0.2	0.5	0.57

Table 8.2: Maximum depth, velocity and flood hazard at a selection of points at the replacement site

8.3 *Summary*

8.3.1 Firstly, flows from uncontrolled reservoir inundation (worst case scenario) were calibrated against Rivers Agency's extents shown on their inundation mapping. The proposed site is located north east of the reservoirs and it was observed that flooding reaching the site would generally follow the routes of the Creggan Burn and Pennyburn Stream watercourses. Therefore, analysis using 2D modelling was carried out for flooding of the proposed site from the downstream face of the lower reservoir.

8.3.2 Peak depths and velocities, and resulting flood hazards were predicted to be low across a large portion of the southern site area, with higher hazards along the northern side of the existing site. The altered site levels, reflecting the FGLs and FFLs of the proposed replacement scheme were found to have minimal effects of the flood hazard within the site. No change in flow path was indicated by the 2D modelling process resulting from the proposed replacement development.

9.0 ASSESSMENT OF PROPOSED DEVELOPMENT IN LIGHT OF GUIDANCE ON RESERVOIR FLOODING

9.1 The literature review has outlined the 'flood risk to people calculator' in Section 7 of this report, as presented by EA and Defra. This method takes into account physical conditions and human parameters at the proposed site in addition to flood characteristics. The calculator can be used to assess the annual probability of an individual losing their life due to flooding. Calculations therefore include for the probability of the reservoir flood event occurring, the number of people at the proposed site, the probability of injuries and the probability of those injuries resulting in loss of life.

9.2 The risk to life is calculated based on factors of flood hazard, area vulnerability and people vulnerability. Each of these factors are calculated separately below.

9.3 *Flood Hazard Rating (HR)*

9.3.1 Section 8.0 of this report has presented the predicted velocities and depths and calculated *HR* values across the existing levels of the proposed site. These were found to be similar for the existing Arntz Belt factory and the proposed replacement development. Table 9.1 presents a comparison of the calculated *HR* ratings for the proposed site. It should be noted that only small areas within the site were predicted to experience the higher flood hazards in the 'red category' and this is conservatively not reflected in the average calculations shown on Table 9.1.

9.3.2 The average *HR* values for points A – C are shown on Table 9.1 to both be below the 'red category' (see Plate 7.1) which is considered to be dangerous to the emergency services. Note again that these averages do not account for the proportion of the site predicted to experience the high, medium and low flood hazards or the short duration of these peak values.

	Max. Flood Hazard Rating	
Point	**Existing Site**	**Proposed Replacement Development**
A	2.13	2.20
B	1.44	1.83
C	0.52	0.57
Average *HR*:	1.36	1.53

Table 9.1: Comparison of peak *HR* values from 2D hydraulic modelling

9.3.3 However, the results shown on Table 9.1 do not take into consideration the Area Vulnerability factor (*AV*), the People Vulnerability factor (*PV*), or the likelihood of complete dam failure occurring.

9.4 *Area Vulnerability (AV)*

9.4.1 The second factor to consider is the *Area Vulnerability (AV)*. A value for Area Vulnerability can be determined by adding together separate values for speed of onset of the flood, nature of the area and a flood warning score.

9.4.2 A score of 3, 2 or 1 should be assigned for speed of onset depending on the time taken for the flood event to reach the proposed site. Due to the onset of inundation from failure of the reservoirs being predicted to be less than 1hr, the highest value of 3 is designated for the proposed site.

9.4.3 When considering the nature of the area, a score of 1 can be designated for apartment blocks, a score of 2 is applied to 2 storey homes and commercial and industrial buildings and a score of 1 is used for single storey homes. Based on the above, a score of 2 was designated to the proposed replacement commercial site.

9.4.4 In order to allow for an appropriate flood warning system, the maximum score of 3 can be reduced dependent on factors such as the area's effective action plan for flooding. While scores of 2.15 and 2.23 are recommended for England and Wales, Flood Risk Consulting is not aware of any action plans being in place for Northern Ireland. Therefore, the maximum score of 3 is applied to the proposed site.

9.4.5 Based on the above three values, the Area Vulnerability (*AV*) score for the proposed site was determined to be 8.

9.5 *People Vulnerability (PV)*

9.5.1 In order to determine the number of deaths and injuries caused by a reservoir flood event, the vulnerability of the people involved must be considered. The factor known as People Vulnerability (*PV*) (also represented as *Y*) is determined by adding the percentage of people within the development with long term illnesses to the percentage of people that will be aged 75 or over. The majority of the proposed development is commercial; however, a medical building is to be located within the northern side of the site. Therefore, it shall be conservatively assumed that a total of 20% of people at the site will fall into these two vulnerability categories.

9.6 *Determining the Risk to People*

9.6.1 In order to estimate the percentage of people exposed to the risk (*X*) of reservoir flooding within the proposed site, the Flood Hazard Rating *HR* is multiplied by the Area Vulnerability *AV* value. Using the average *HR* values shown on Table 9.1 for the existing and proposed replacement site, it has been calculated that the percentages of people who will be exposed to the risk of reservoir flooding are 10.88% and 12.24% respectively.

9.6.2 The proposed replacement development would have capacity for approximately 1,000 people, and would be assumed to only be occupied less than 8 hours per day (1/3 of the time). Note that these assumptions are considered to be conservative as it is unlikely that every parking space will be filled and people remaining within the site for a third of every day.

9.6.3 To determine the proportion of people injured, the people vulnerability (*PV*) factor is accounted for (as explained in Section 7.4 of this report). Also, the proportion of fatalities is calculated, again as presented in Section 7.4).

9.6.4 The resulting probabilities of fatalities in the event of reservoir failure are 0.0012 and 0.0015 for the respective existing and replacement sites (assuming the same occupancy of people at both). While the above probabilities of 1 in 845 to 1 in 667 apply whenever an all breach conditions reservoir flood event occurs at the site, the probability of the all breach conditions reservoir flood event must also be taken into account.

9.6.5 While Northern Ireland has recently experienced several flood events with calculated return periods in excess of 100 years, no significant reservoir flooding events have occurred across the UK for nearly 100 years. Flood Risk Consulting has therefore estimated that the likelihood of an all breach conditions reservoir flood simultaneously occurring from the upper and lower reservoirs is 1 in 500 years. This value is considered to be conservative as Paragraph 7.5.8 of this report notes that Defra/EA believe the probability of such a flood event occurring probably ranges from 1 in 1,000 years to 1 in 10,000 years.

9.6.6 Therefore, the annual likelihood of a person at the proposed development experiencing an all breach conditions reservoir flood **and** dying as a result of that flood has been calculated to be 1 in 422,400 at the site at existing levels. Table 9.2 presents the probabilities of a person at the proposed development dying as a result of an all breach conditions reservoir flood event at the examined replacement development.

Annual Probability of Fatality at Site due to Reservoir Failure	
Existing Site	**Proposed Replacement Development**
1 in 422,400	1 in 333,750

Table 9.2: Comparison of annual probability of fatality at existing and proposed site levels

9.6.7 The 'flood risk to people calculator' requires than the probability of death must be less than 0.01% or 1 in 10,000 per year, which equates to the risk of dying due to reservoir flooding being less than the risk of being killed in a car accident.

9.6.8 The above calculation indicates that a person at the proposed replacement development is still more than 33 times more likely to die in a car accident than they are of dying due to reservoir failure.

9.7 *Summary*

9.7.1 Based on the final annual fatality probability, the risk is considered acceptable at both the existing site levels and at the proposed replacement development levels. In addition, the majority of the extent of the site was predicted to experience flood hazard ratings considered to be of low risk, both at the existing and replacement developments.

9.7.2 It should be noted that the hydraulic modelling was calibrated against the inundation extent shown on Rivers Agency's mapping. Section 7 of this report has presented information on the production of the mapping, which highlighted the factors of safety applied to the modelling of the reservoir failures.

9.7.3 A factor of safety of 1.5 was applied to the calculation of the peak flow from reservoirs with an earthfill embankment. In addition, a water level of 0.5m above the crest level was applied to impounded reservoirs. In reality, overtopping of the crest level would occur before the water level could reach 0.5m above the crest. The assumption that the water could build up above the crest level and then suddenly be released, as was modelled for the production of Rivers Agency's inundation maps, will therefore have resulted in conservative results.

9.7.4 Therefore, the above hydraulic assessment is judged to be very conservative due to the above conservative assumptions and the worst case scenario occurring simultaneously for both the upper and lower reservoirs was considered.

9.7.5 The 'flood risk to people calculator', which takes into account the unlikelihood of the reservoir failing, has shown that the risk of fatality due to reservoir failure is considered acceptable by both Defra/EA (Section 7.4) and HSE (Section 7.9) for the existing and replacement developments. However, despite the low probability of an extreme failure event occurring, the consequences of reservoir failure would be high at small areas within the site.

9.7.6 Reprofiling of the site according to the proposed levels of the replacement development has been shown to **reduce the risk to life at the four proposed buildings**. In addition, the proposed development has been shown to **not change the flow path of inundation flooding or increase flood hazard in the area surrounding the site.**

10.0 EVALUATION OF THE PROPOSED DEVELOPMENT IN LIGHT OF FLD 5 OF PPS 15

10.1 This section will assess whether the proposed development satisfies policy FLD 5 of PPS 15 Planning and Flood Risk (September 2014). This assessment has been undertaken by qualified professional civil engineers with experience in hydraulic engineering as required by Rivers Agency.

10.2 *Policy FLD 5: Development in Proximity to Reservoirs*

10.2.1 FLD 5 requires that the application for the proposed development is accompanied by a Flood Risk Assessment which demonstrates an assessment of the downstream flood risk in the event of:

- a controlled release of water
- an uncontrolled release of water due to reservoir failure
- a change in flow paths as a result of the proposed development.

10.2.2 Regarding replacement development, the policy states that planning permission will be granted provided it is demonstrated that there is no material increase in the flood risk to the development or elsewhere.

10.2.3 Paragraph 6.62 of the policy states that "the policy operates a presumption against bespoke development for vulnerable groups within reservoir flood inundation areas". Paragraph 6.63 continues "Any proposed development for essential infrastructure, such as for emergency services / depots, transport of utilities and also development for the storage of hazardous substances will need to demonstrate in the Flood Risk Assessment that no alternative viable sites or routes are available and that they can remain operational at times of flooding or can demonstrate appropriate contingency planning.

10.2.4 FLD 5 considers that the replacement of a building within a flood inundation area will generally be acceptable as in most cases this ought not to affect the potential future flood risk area. Continuing "Where the Flood Risk Assessment indicates that the site is located in an area susceptible to an unacceptable combination of depth and velocity, replacement opportunities located elsewhere should be considered and discussed with the planning authority".

10.2.5 Flood Risk Consulting has undertaken an assessment of an uncontrolled release of water due to an all breach conditions reservoir failure. Since an all breach conditions reservoir failure will produce more onerous flooding results than a controlled release of water, it is logical that if the proposed development can be shown to be approved for the first case, then the second case will also be acceptable.

10.2.6 FLD 5 states that there will be a presumption against development in areas where there is a likelihood of an unacceptable combination of depth and velocity. However, the policy does not prescribe 'likelihood thresholds' or the acceptability of depth and velocity combinations.

10.2.7 This report has considered Defra's 'flood risk to people calculator' which uses the factors to consider flood hazard, area vulnerability and people vulnerability. The probability of the simultaneous failure of both the Upper and Lower Creggan reservoirs was conservatively applied as 1 in 500 years. The resulting annual probability of fatality due to catastrophic reservoir failure was found to be 1 in 333,750. This risk was considered to be acceptable based on the tolerability threshold of 1 in 10,000 (specified by Defra and HSE).

10.2.8 No supporting evidence is available for the determination that the likelihood of simultaneous dam breach at the upper and lower reservoirs is 1 in 500 years. Obviously lack of historic reservoir failures can make it difficult to calculate a return period for expected failure and so engineering judgement must come into play. When applying this return period to our calculations, the assumption is based on the fact that there has been no loss of life from reservoir failure in the UK since reservoir safety legislation was introduced in 1930. Also, even if a reservoir failure did occur at either Upper or Lower Creggan, it would be unlikely for simultaneous failure to occur and resulting inundation is also unlikely to be as severe as predicted on Rivers Agency's Reservoir Flood Maps. This is because the Reservoir Flood Maps are produced with factors of safety, as explained in Section 7. Finally, the evaluation of 1 in 500 years is lower that the range of probabilities (1 in 1,000 years to 1 in 10,000 years) proposed by Defra/EA for the probability of catastrophic failure.

10.2.9 Rivers Agency's inundation mapping reflects failure of the Creggan dams for a worst case scenario of catastrophic failure along the entire impoundment structure, which is considered largely implausible. A more likely failure mode would be the gradual development of a fault at one section, where this would be expected to result in inundation flooding extents significantly smaller than that shown on Rivers Agency's Reservoir Flood Inundation Maps.

10.2.10 Despite the annual risk to life being considered to be an acceptable residual risk, a further assessment of the flood hazard factor in isolation from the wider 'flood risk to people calculator' was undertaken. The 2D InfoWorks ICM hydraulic model allowed the examination of depths and velocities.

10.2.11 The flood hazard (*HR*), a factor of the combination of depth and velocity, was found to be low risk across the majority of the proposed site with smaller areas of medium and high flood hazards. Similar extents of low, medium and high flood hazard areas were predicted for both the existing and proposed development at the site.

10.2.12 The introduction of the proposed FFLs for the proposed buildings was found to generally be sufficiently raised to the located the ground floors above the predicted inundation flood waters, with only a portion of the footprint of the north western building remaining within the floodplain (see Plate 8.6).

10.2.13 If the extent and nature of the proposed buildings is considered to be an acceptable replacement by the planners and Rivers Agency, results have shown that the proposed levels of the replacement buildings would produce flood hazard ratings less than that predicted for the existing FFLs of extant buildings at the site.

10.2.14 Despite the modelled reservoir failure reflecting the worst possible scenario with factors of safety (explained above), the annual risk to life for the proposed replacement development is 1 in 333,750. This probability is more than 33 times less likely than the Defra's maximum allowable risk of 1 in 10,000, which equates to the risk of a fatality due to a car accident.

10.2.15 Further, FLD 5 requires that emergency evacuation procedures are considered. Land outside of the inundation floodplain is located along Maybrook Mews north east of the site and Buncrana Road to the north west. This provides options for short and straight forward exit routes to higher ground in the instance of imminent reservoir failure.

10.2.16 In addition to the obvious escape routes to higher ground discussed above, Flood Risk Consulting recommends that an emergency evacuation plan be created at detailed design stage for the proposed development and occupants should be notified of the risk and procedures.

10.2.17 The plan should contain information such as an evacuee assembly point or points at safe locations on higher ground. The plan should warn people that they will need to act quickly once they become aware of the threat of flooding, that they should leave the premises immediately and proceed to the evacuee points, that they shouldn't return to the flood areas until after the flood event and the safety of the reservoir has been established. The plan should also warn people that if they have not left the buildings before the reservoir breach occurs, they should not leave the buildings but instead move up to the first floor if available and remain there until conditions are safe. The plan should also instruct people that they should cooperate with the emergency services.

10.2.18 In addition, the plan should emphasise that the risk of local reservoirs' impoundments failing has not increased or changed and that there has been no reservoir failure in the UK that has resulted in fatalities since the 1920s, but that it is important that they are prepared to respond appropriately in case of an emergency.

10.2.19 A detailed emergency evacuation plan should be created at detailed design stage. It would not be feasible to create this plan at planning stage as finalised details of the buildings would be required to create an appropriate plan.

10.2.20 The applicant should liaise with the insurance industry at an early stage to ensure that the residual risk to the site from reservoir flooding does not prevent the insurability of the development.

10.2.21 Finally, as FLD 5 raises the consideration of the nature of the development in the acceptability of a replacement site, the applicant should agree with the planners that the proposal for the medical building and filling station is permissible and does not fall into the categories of essential infrastructure or hazardous substances as mentioned in the policy.

11.0 CONCLUSIONS

11.1 The objective of the study was to carry out a Reservoir Flood Risk Assessment (RFRA) as specified by FLD 5 of *PPS15: Planning and Flood Risk* for the proposed regeneration development at Pennyburn, Buncrana Road, Derry.

11.2 The proposed site is affected by the all breach conditions reservoir flooding from the Upper and Lower Creggan reservoirs as shown on Rivers Agency's inundation mapping. The third sector Creggan Country Park manages the dams and surrounding lands.

11.3 The goal of this RFRA was to undertake hydraulic modelling to scientifically assess the risk to life from potential reservoir failure at the proposed site and examine the combination of depth and velocity (flood hazard rating) in the event of reservoir failure.

11.4 This RFRA report presented the results of 2D InfoWorks ICM hydraulic models of the area during reservoir failure, where flows were calibrated against the flood extent shown on Rivers Agency's mapping. It was shown that the InfoWorks model was in very good agreement with the Reservoir Flood Map produced by Rivers Agency.

11.5 Defra's 'flood risk to people calculator' was implemented to predict the annual risk to life of a person at the site. The annual risk to life was found to be 1 in 333,750 for the proposed development; this value was considered to be acceptable as determined by the maximum tolerable residual risk specified by HSE and Defra of 1 in 10,000. This equates to a risk of fatality **more than 33 times less likely than the risk of fatality due to a car accident**. By this assessment alone the proposed development is considered acceptable.

11.6 The above process of calculating the residual risk identified high flood hazard ratings resulting from a combination of high depths and velocities. However, these were predicted to occur at only small areas of the site. The flood hazard rating across the majority of the site were found to generally be of low and medium categories.

11.7 An assessment of the impact on flood risk of the proposed replacement site on the adjacent areas found no significant impact on the flow path, extent or hazard of the reservoir flooding.

11.8 The surrounding development area along Maybrook Mews and Buncrana Road north of the site is located outside of the predicted inundation flood area, providing a straight forward exit route in the case of an emergency. It is recommended that an emergency evacuation plan should be created for the proposed development at detail design stage, once the details of the buildings is finalised, that includes an evacuee assembly points north west and north east of the proposed site. It is worth noting for the emergency evacuation plan that the peak flows will not reach the site until 18 minutes after the reservoir failure has occurred.

11.9 In summary, Defra/EA have prepared guidance documents to consider the risk to life in the situation of a catastrophic reservoir failure. Paragraph 7.6.1 of this report states that the risk to people calculator can be used to support the considerations of planning applications and can be used to reinforce decisions made based on FRAs. If the Risk to People methodology is applied, this report has demonstrated that the risk to life within the proposed development would be acceptable for the proposed replacement development.

11.10 However, Defra/EA also state that the Flood Hazard rating (*HR*) be used by the planners to identify unsafe areas, evacuation rates and guide the type and layout of buildings and infrastructure. Flood Hazard results can be used to influence the selection of development sites, the type of development and the planning policies needed. If this Flood Hazard rating is considered to be the overriding factor, it has been demonstrated that the majority of the site is predicted to experience low flood hazard, with only a small area within the northern portion of the site calculated to have a high flood hazard rating.

11.11 FLD 5 permits the replacement of a building within a flood inundation area and it has been demonstrated that the proposal will not increase the flood risk from reservoir inundation beyond the site. In addition, apart from one small area of the north western buildings, the FFLs of the proposed buildings have been found to be above the reservoir inundation floodplain. As it has demonstrated that there will be no material increase in the flood risk to the development or elsewhere, the proposed development is considered compliant with FLD 5 of PPS 15.

[redacted]

Dr Philip Hull PhD BEng BTh CEng MICE MIEI

Director for Flood Risk Consulting Limited