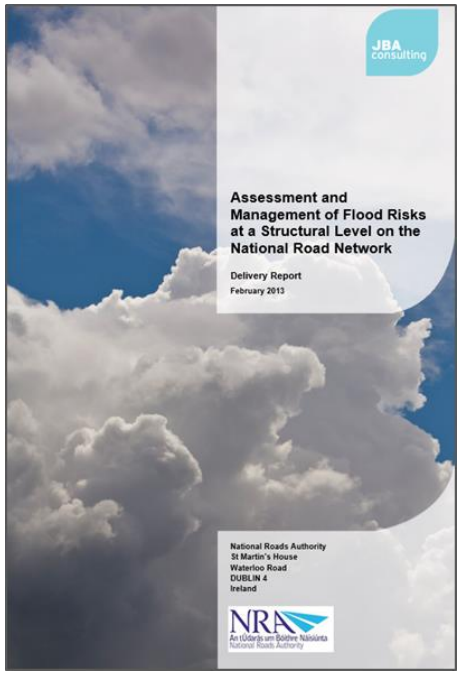
Flood Management of the Irish Road Network

Ross Bryant – JBA Consulting

Introduction

- Overview 2011-2018
- Assessment of the Irish Road Network
- Flood Risk Management Protocol
- Forecasting Flood Risk to Road Network
- Guidance on Flood Risk Assessment
- Implementation - Case Study examples



Interactive session – we encourage questions throughout

Core Objective

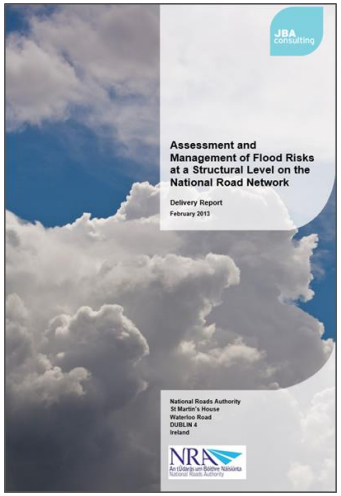
Define flood probability to the national road network, gain a more detailed understanding of which areas are at the highest risk of flooding, both now and in the future and develop management techniques to mitigate the impacts of flooding.

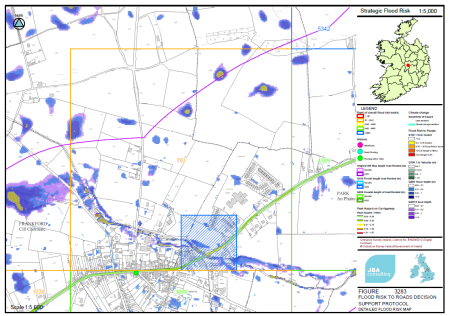
Research Questions

- How can we best model and represent flood hazard to roads, including climate change?
- How can we identify areas of greatest potential impact/risk?
- How can this information be best used to manage flooding, and mitigate damage, disruption and harm to people?
- How best can we offer advance warning of flooding to road users?

Results & Deliverables

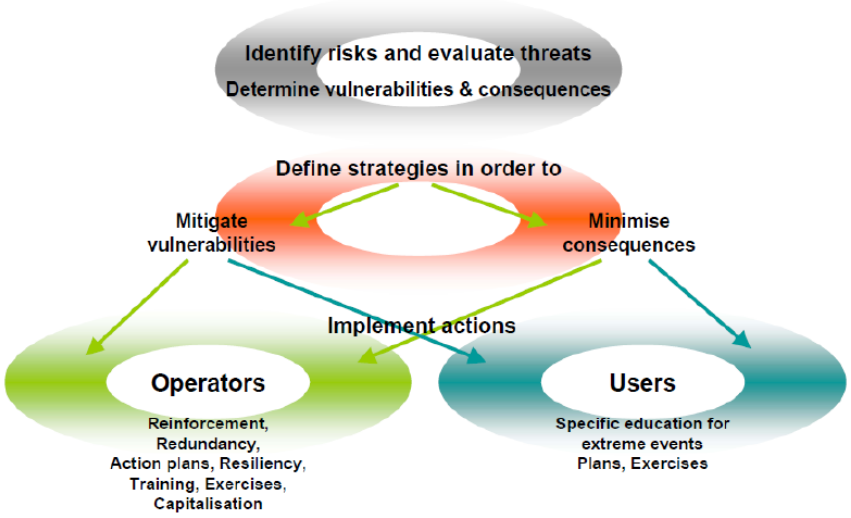
- GeoPDF Mapping – ID hotspots & culvert blockage
- Analysis Tool – investigate risk statistics
- Flood Risk Management Protocol – manage & mitigate
- Forecasting & Road Alerts – preparedness
- User Guidance & Training – specify investigations
- Site Specific Investigation – mitigation





Background

- Based on RIMMAROCC Framework (ERA-NET 2010)



- Expands on SWAMP (Larsen & Pihil 2010) which highlighted risks from surface water, using a 'depression' or 'sink' approach – Blue Spot Model.

TII Flood Mapping & Data

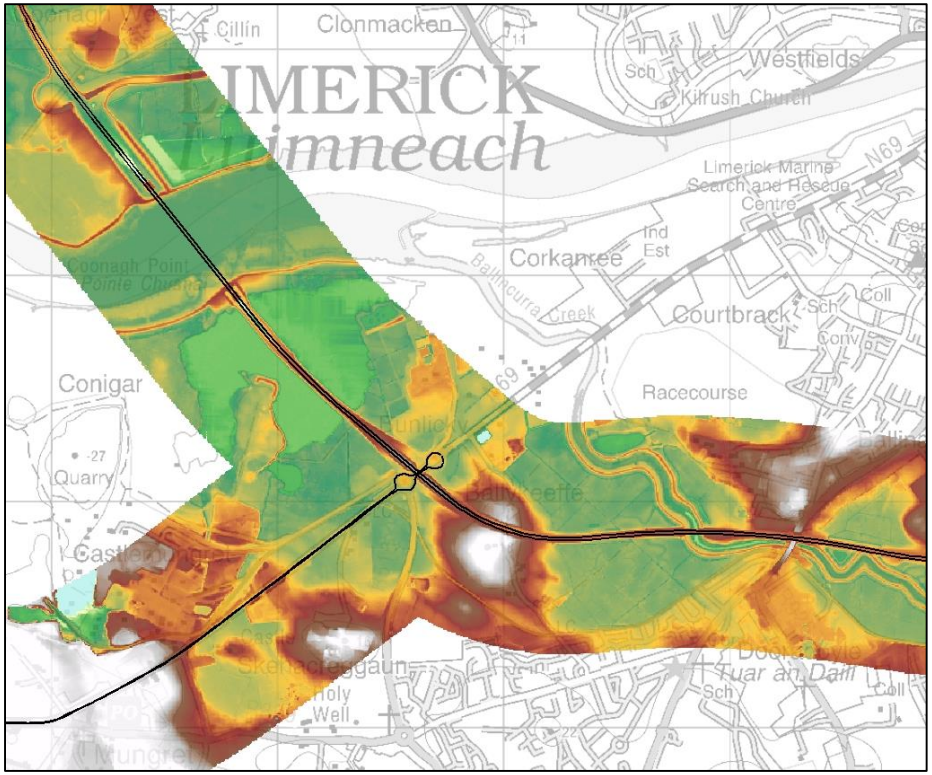
Flood Data & Mapping

- Historic Flooding
  - Floodmaps.ie + Consultation
- Fluvial
  - 1% AEP & 0.1% AEP Extent
- Coastal (Extreme Sea Levels)
  - 0.5% & 0.1% AEP Extent
- Pluvial
  - Multiple AEP
  - Depth, Velocity & Hazard

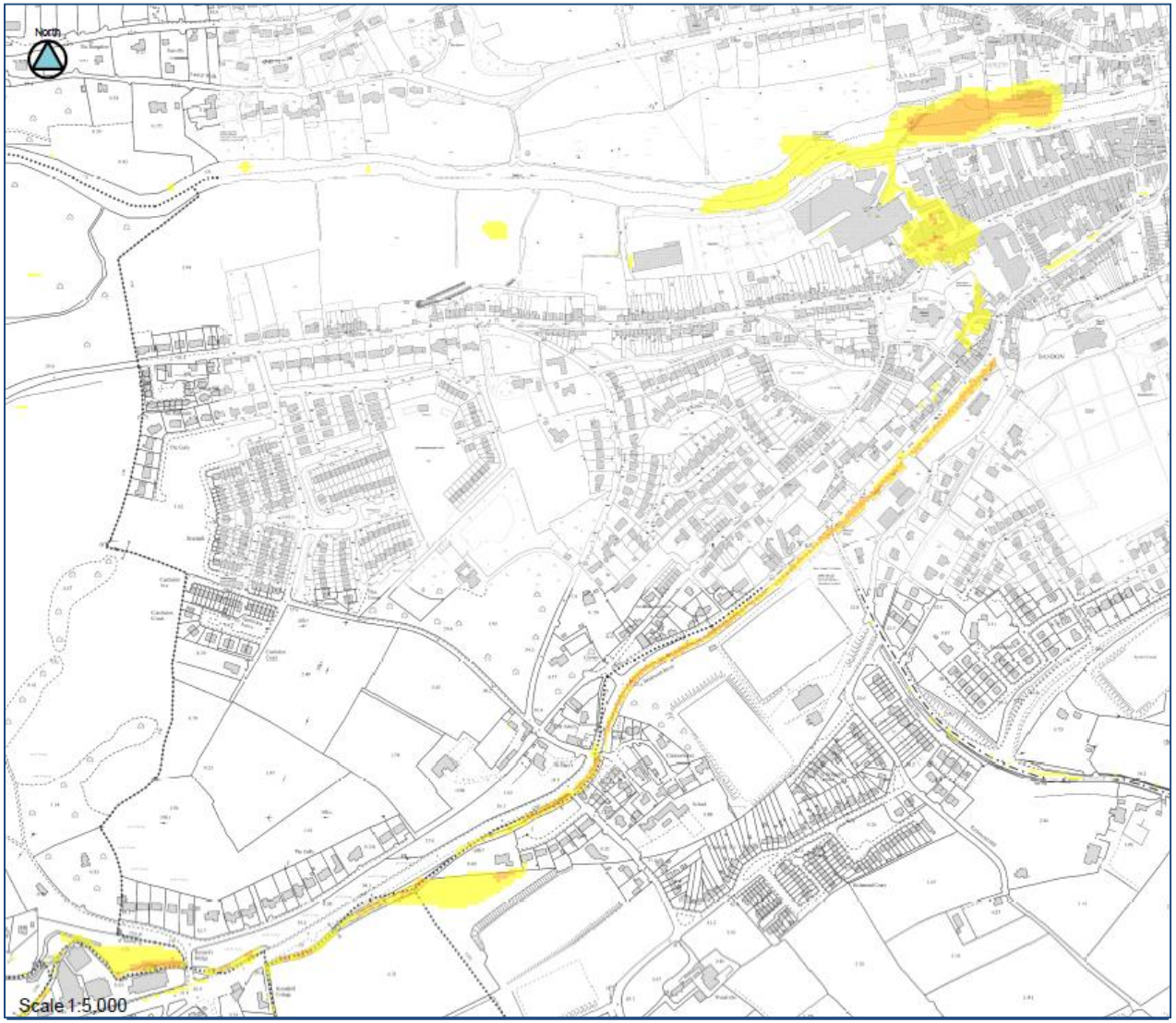
Pluvial Mapping

- Use of NRA LiDAR
- JFlow+ full 2D SWE – velocity, depth & hazard

- 1% & 0.5% AEP 1hr duration
- 1% & 0.5% AEP 6hr duration
- Variable % Runoff
- Urban Drainage 12mm p/h
- Variable Manning's grid

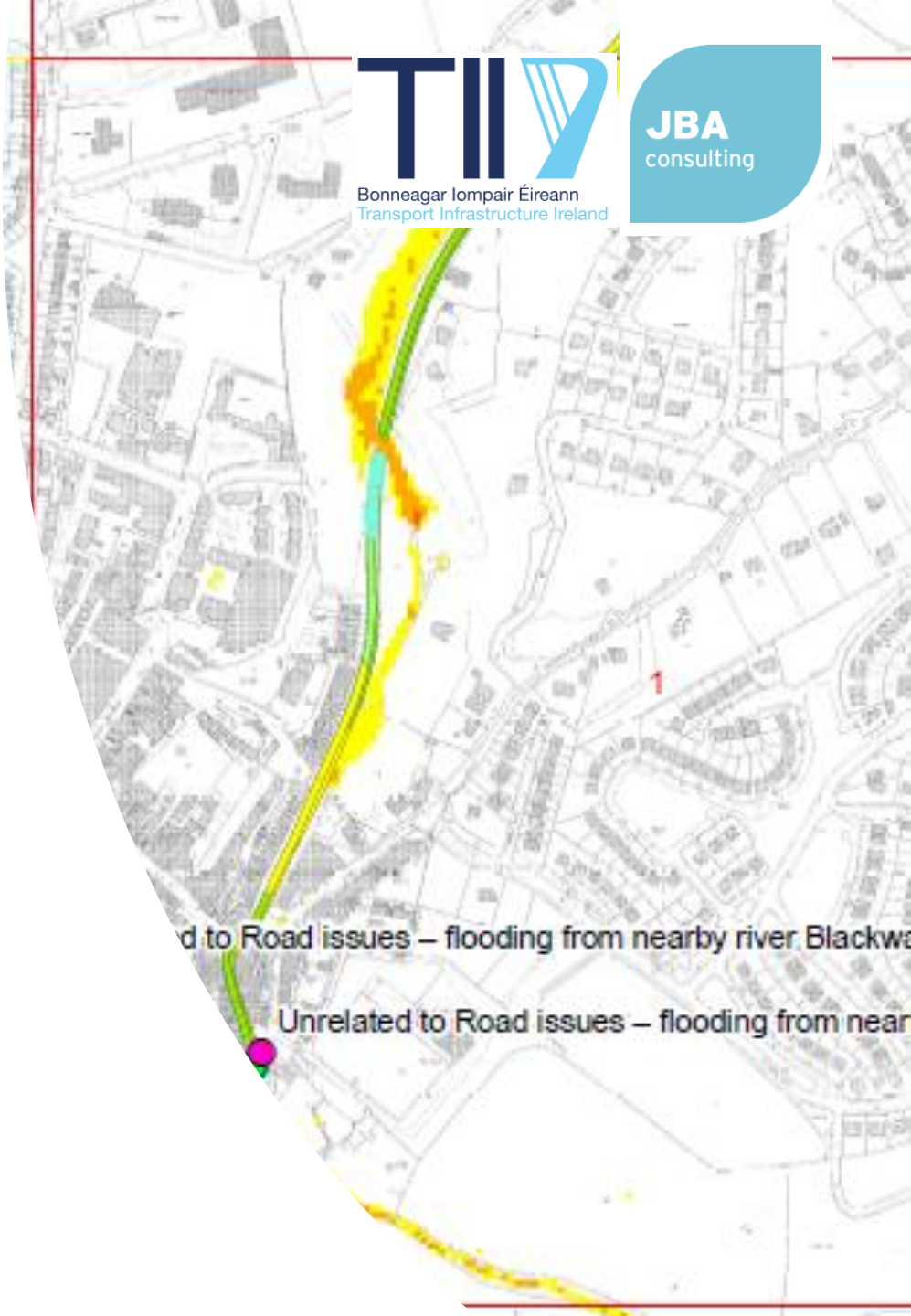


The new raster grids



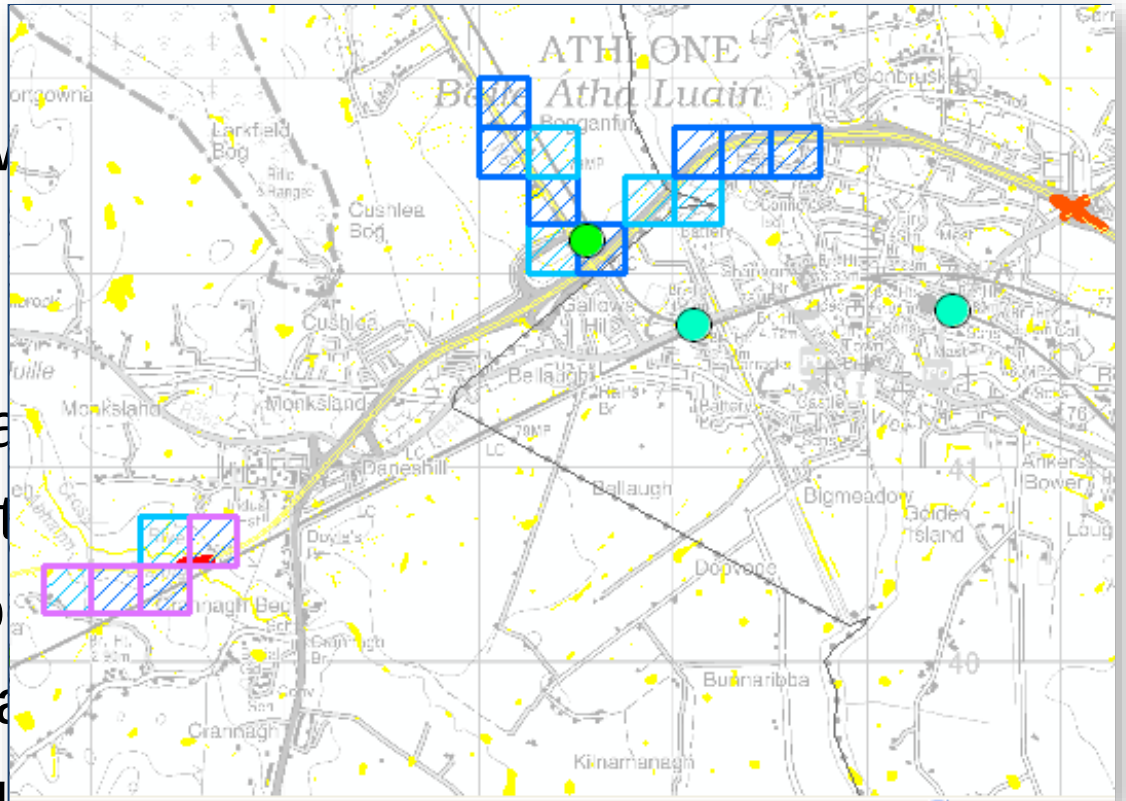
Climate change adaptation

- Identify areas that are particularly sensitive to changes in rainfall
  - Difference between 100 year and 200 year return period rainfall
  - Extent of the difference (above threshold) used to highlight sensitivity



Strategic flood risk analysis

- Receptor Data
  - 5000km carriagev
- Linear Stats
  - 100m segments a
    - Maximum Dept
    - Maximum Velo
    - Maximum Haza
    - Climate Change Sensitivity
    - Traffic Exposure (SW hazard * Mean Daily Traffic)



Strategic Tool

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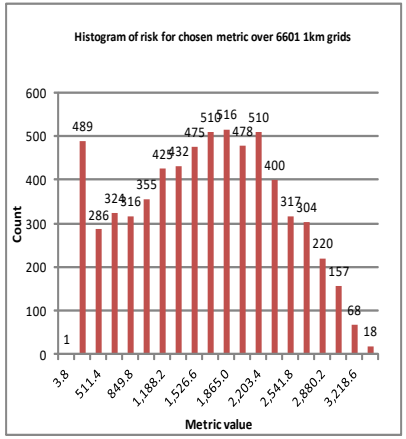
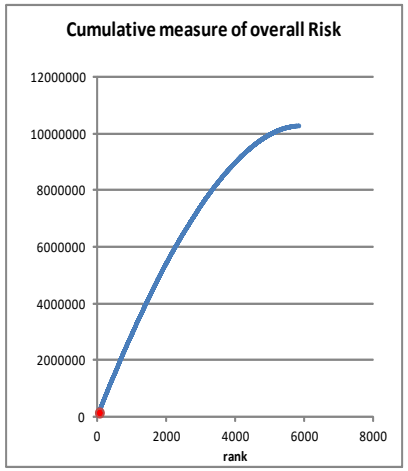
Strategic Decision Support Tool used to help prioritise 50 key sites for more detailed study described in 'High Risk Site' sheets.





Highest Risk according to your chosen flood risk metric >	Overall weighted metric		
50	< For your chosen metric, there are this many gridsquares in the worst 50 according to the Overall Risk Metric	The worst 50 grid squares sorted by your chosen metric capture this many Historic incidents >	55

Back to protocol

This only works if data sheet sorted	cumulative Overall risk	corresponding upper threshold denoting significant risk	corresponding upper percentile
50	160415	3118	1%

Rank	Index	Unique reference for 1km grid square	Overall Weighted Rank Metric	Exposure: Traffic Volume weighted by peak Hazard	Traffic Volume (AADT)	Peak Hazard	Peak Depth	Peak Velocity	Climate Change sensitivty	Historic record (recurring weighted by factor 2)?	CFM Fluvial Length flooded Q100	CFM Coastal Length flooded Q200	PFRA Fluvial length flooded Q100
1	1	X156000Y098000	3387.80	4,983	7,981	1.13	2.04	3.03	0.13	12.00	2099.46	0.00	1930.19
2	2	X148000Y054000	3375.70	6,057	4,765	1.52	1.76	2.29	0.22	2.00	1578.66	0.00	1926.29
3	3	X306000Y226000	3343.00	7,917	17,589	0.77	1.19	1.85	0.34	0.00	1396.25	0.00	347.41
4	4	X156000Y099000	3326.70	3,796	4,303	0.88	1.38	1.49	0.23	4.00	2447.78	0.00	831.93
5	5	X312000Y239000	3322.50	11,092	9,203	1.21	2.10	2.08	0.21	0.00	430.86	0.00	594.05
6	6	X163000Y067000	3318.20	11,103	12,264	0.95	0.77	1.24	0.23	4.00	1134.91	0.00	941.85
7	7	X220000Y123000	3306.90	4,424	6,969	0.63	1.15	1.58	0.14	0.00	1630.39	0.00	767.65
8	8	X318000Y241000	3295.40	11,864	71,364	0.71	0.90	0.95	0.17	0.00	928.39	0.00	1348.94
9	9	X158000Y154000	3286.00	22,709	23,473	0.97	1.93	0.93	0.08	0.00	1405.67	0.00	718.36
10	10	X147000Y053000	3269.90	2,946	4,765	1.06	2.06	3.25	0.09	0.00	710.30	0.00	982.80
11	11	X311000Y227000	3266.60	5,376	37,243	2.04	3.03	1.66	0.40	0.00	49.74	0.00	620.70
12	12	X204000Y098000	3263.90	3,216	3,337	0.96	1.92	1.99	0.25	0.00	626.26	0.00	475.04
13	13	X050000Y081000	3258.90	2,179	2,762	0.79	1.57	1.22	0.24	0.00	1679.84	652.36	574.32
14	14	X098000Y110000	3258.70	2,475	5,676	0.59	1.18	1.40	0.11	0.00	1363.61	0.00	3004.50
15	15	X267000Y335000	3249.00	5,737	9,812	0.58	1.17	0.69	0.16	1.00	1704.23	0.00	1006.70
16	16	X326000Y187000	3240.80	11,483	9,302	1.23	0.91	1.53	0.38	0.00	210.56	0.00	467.88
17	17	X314000Y237000	3239.20	1,995	9,411	1.22	1.76	2.35	0.46	2.00	233.26	0.00	405.06
18	18	X315000Y233000	3229.30	28,799	27,887	1.03	2.02	1.15	0.18	0.00	0.00	0.00	1135.89
19	19	X313000Y238000	3217.70	5,218	9,874	0.72	1.07	1.64	0.29	0.00	0.00	0.00	2285.91
20	20	X327000Y180000	3213.10	14,004	8,626	1.62	1.26	0.79	0.64	0.00	231.62	0.00	608.10
21	21	X313000Y239000	3212.80	11,092	9,203	1.21	2.10	1.33	0.22	0.00	145.30	0.00	264.02
22	22	X154000Y100000	3206.40	3,548	6,545	0.54	0.49	1.59	0.16	0.00	938.16	0.00	1285.54
23	23	X327000Y190000	3201.50	22,030	9,302	2.37	2.24	1.51	0.60	0.00	0.00	0.00	262.51
24	24	X109000Y081000	3200.30	4,472	4,970	0.99	0.96	1.26	0.27	1.00	1017.47	0.00	157.14
25	25	X165000Y349000	3199.40	7,259	5,133	1.41	1.41	1.95	0.34	0.00	320.11	0.00	157.83
26	26	X324000Y217000	3199.10	34,351	30,181	1.14	2.27	0.90	0.21	0.00	546.92	0.00	117.02
27	27	X166000Y074000	3198.50	5,007	22,851	0.95	1.87	0.68	0.08	2.00	545.30	0.00	1446.15
28	28	X291000Y261000	3193.60	4,123	10,022	0.41	0.78	1.20	0.11	0.00	853.78	0.00	673.83
29	29	X194000Y374000	3187.10	4,294	3,584	1.26	1.68	0.66	0.24	0.00	758.97	0.00	559.48
30	30	X297000Y139000	3181.40	1,420	6,002	0.48	0.69	1.14	0.12	3.00	2122.26	47.77	2145.98
31	31	X316000Y236000	3177.90	49,355	42,336	1.59	1.96	1.55	0.33	10.00	70.78	0.00	125.13
32	32	X157000Y099000	3174.40	2,614	4,303	0.61	0.47	1.41	0.15	8.00	1433.52	0.00	929.22
33	33	X224000Y410000	3167.80	11,191	11,340	0.99	1.81	0.57	0.13	0.00	771.61	0.00	365.02
34	34	X165000Y071000	3156.20	3,997	16,534	0.39	0.69	0.79	0.08	0.00	2626.88	40.78	710.67

GeoPDF Delivery (6,601)

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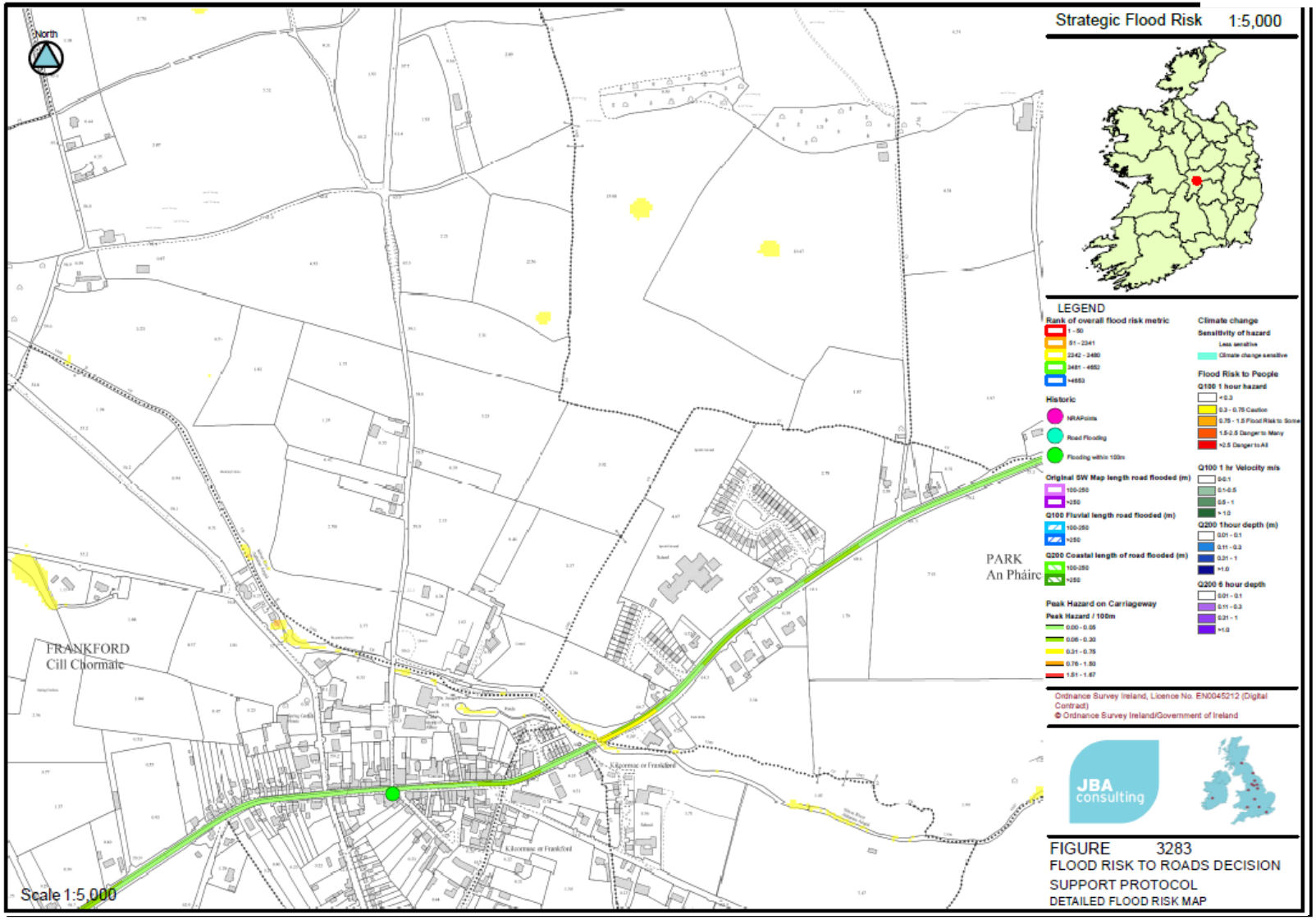
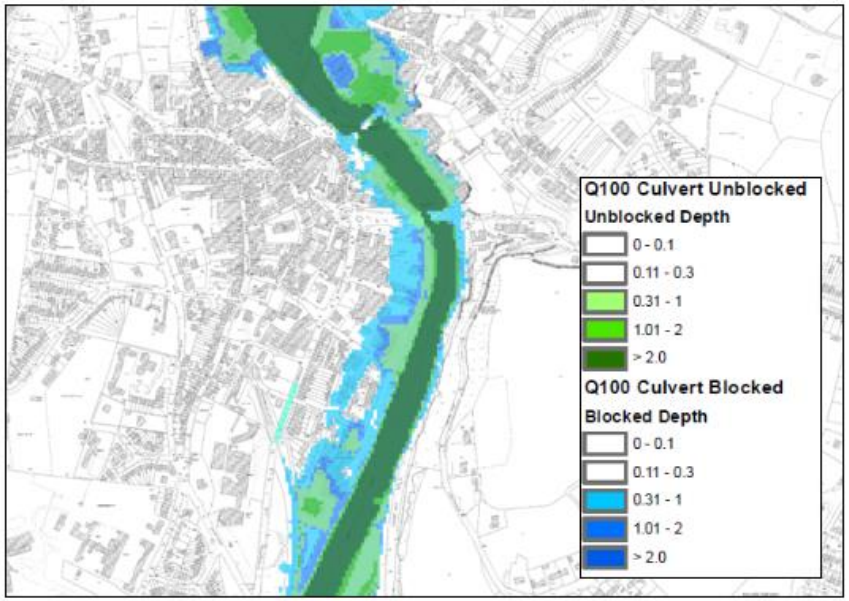
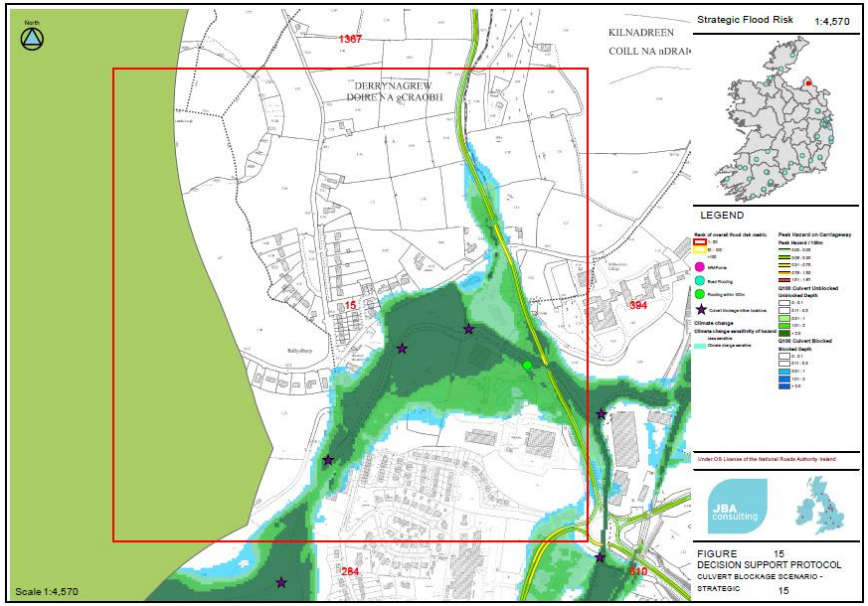


Culvert Blockage

- For 50 locations across the country, simulations were completed with major structures (bridges or culverts conveying watercourses) modelled as blocked and un-blocked.

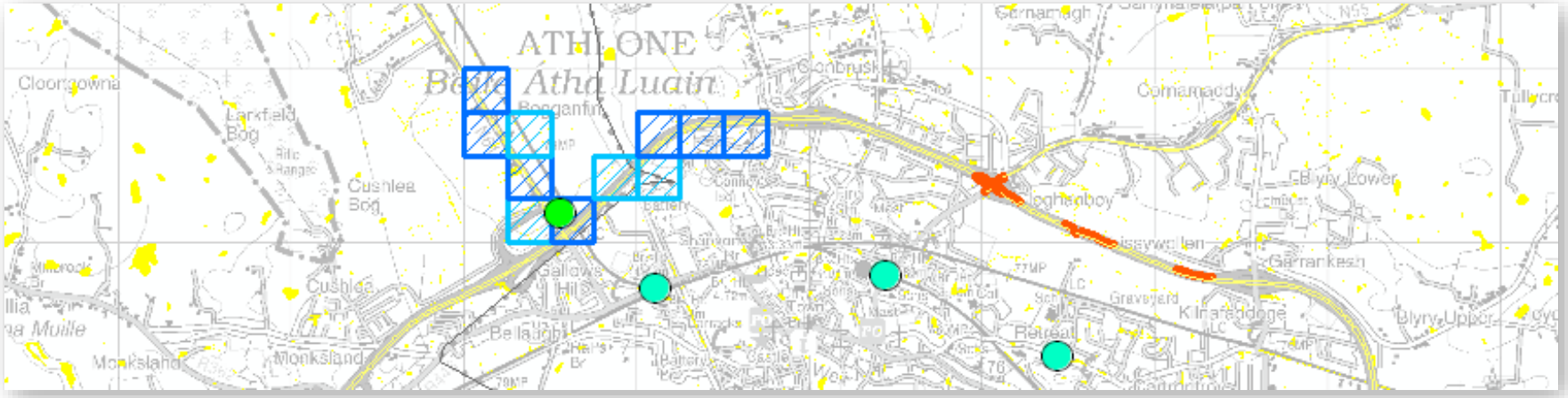




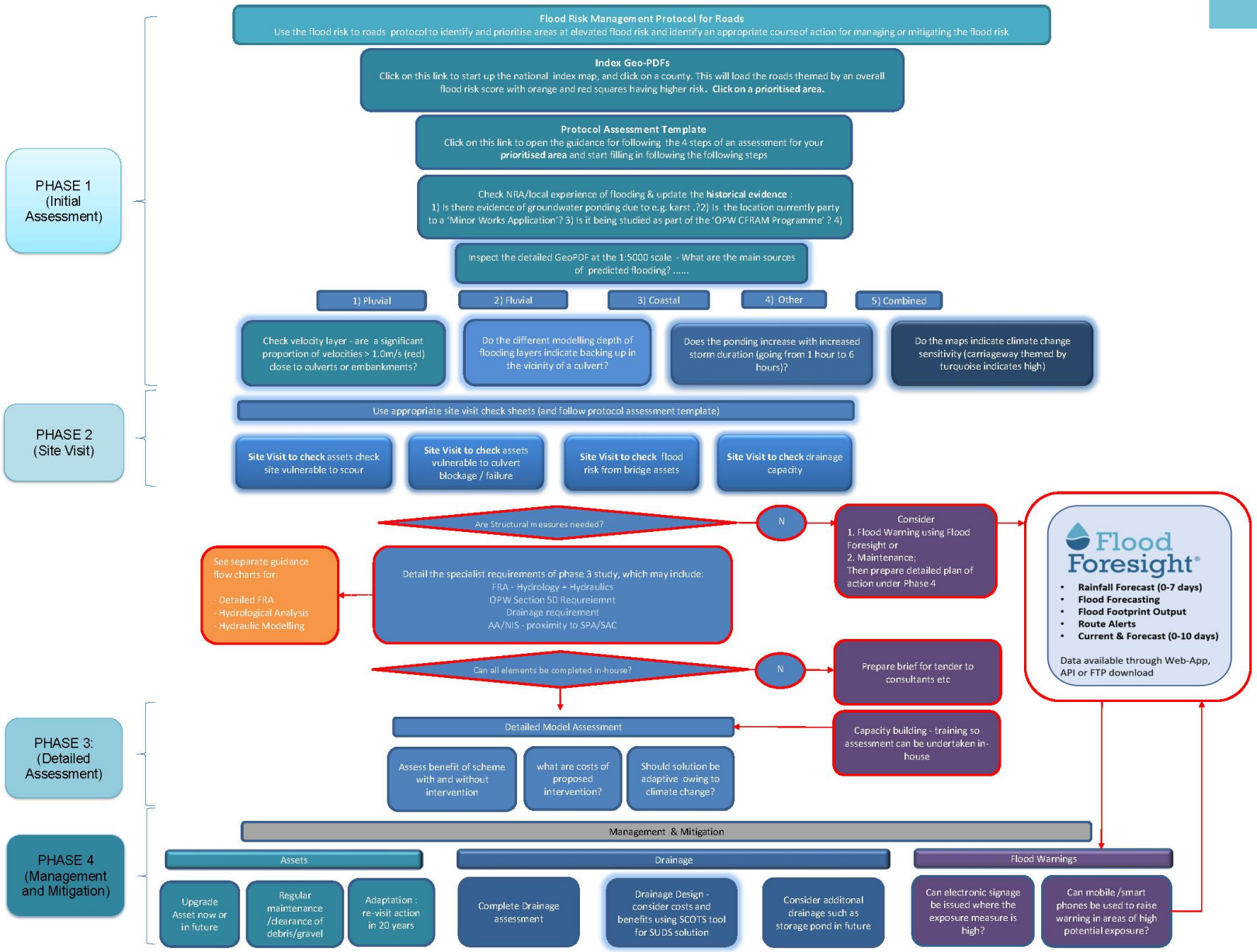
TII Flood Risk Management Protocol

Application of the Protocol

- The Protocol Assessment is initially based upon the flood risk metrics and flood history derived from the strategic tool.
- The aim is to allow an individual appraisal of sites that have been highlighted as potentially being at risk of flooding.
- Involves four phases of investigation and is centred around deriving a meaningful interpretation of the risk metrics concluding with mitigation and management options.



Flood Risk to Roads Protocol



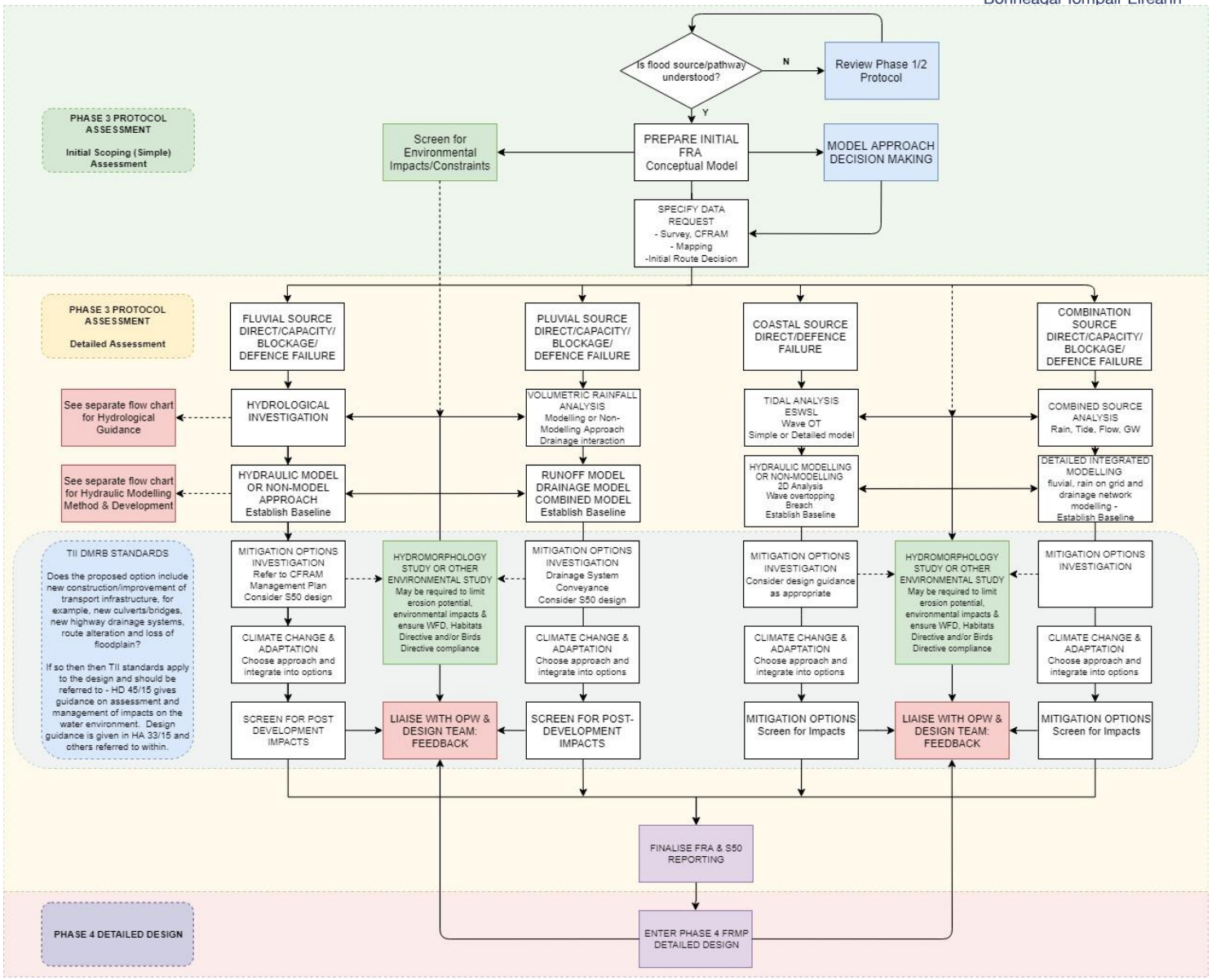
Application of the Protocol

- PHASE 1 – Initial Assessment
  - Familiarise and use all available information to understand the site and characteristics of the flooding;
- PHASE 2 – Site Visit
  - Further assess potential cause/mechanism of flooding;
  - Complete drainage, culvert or bridge assessment;
  - Trigger Detailed Assessment if required.
- PHASE 3 – Detailed Assessment
  - Bespoke assessment using appropriate methods
  - Can include detailed modelling
  - Feasibility – Benefit Cost Analysis
  - Outline Design
- PHASE 4 – Mitigation and Management
  - Clearly outline management and mitigation measures and recommendations
  - Detailed Design/Construction

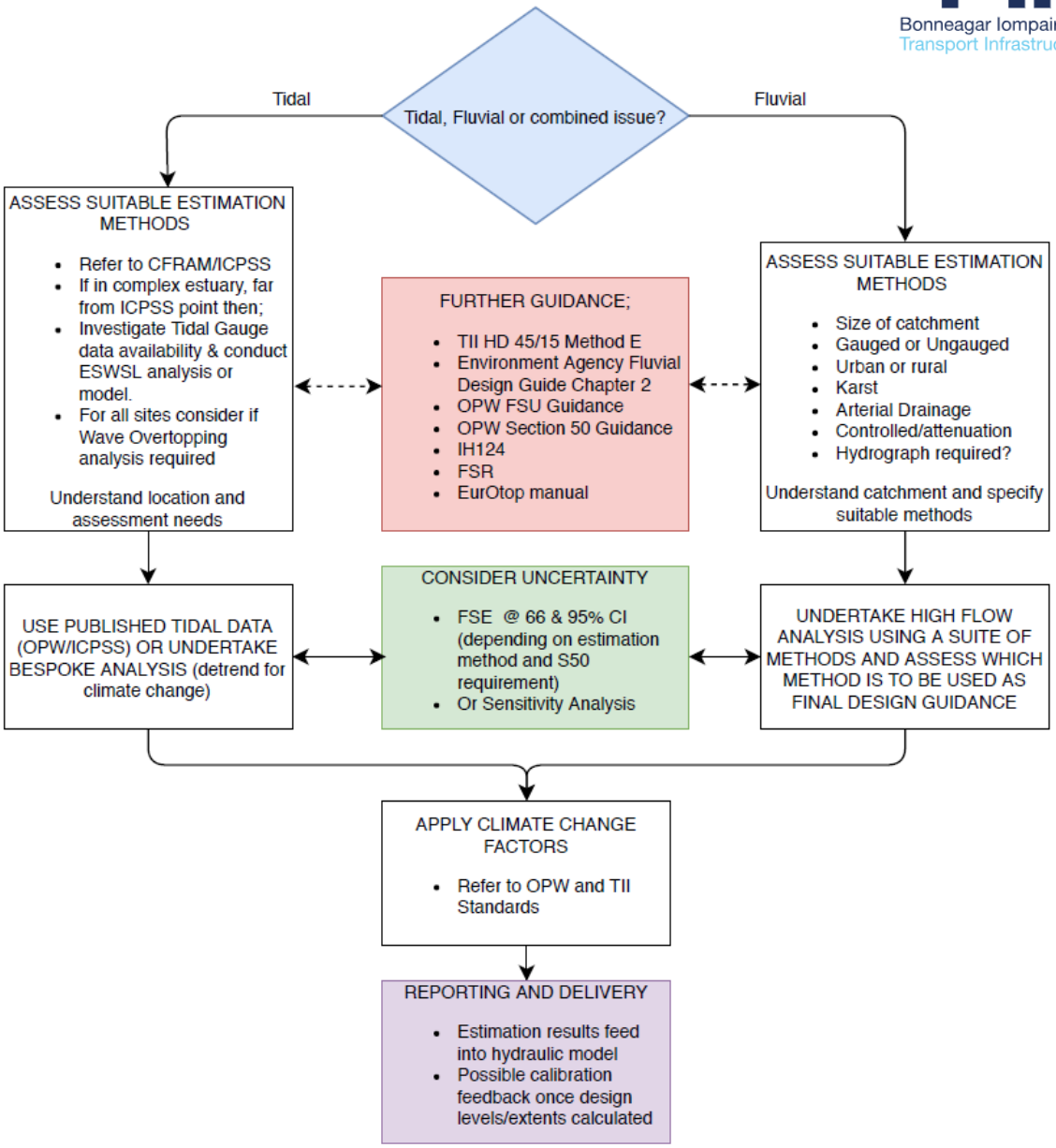
TII FRA Guidance

Flood Risk Investigation

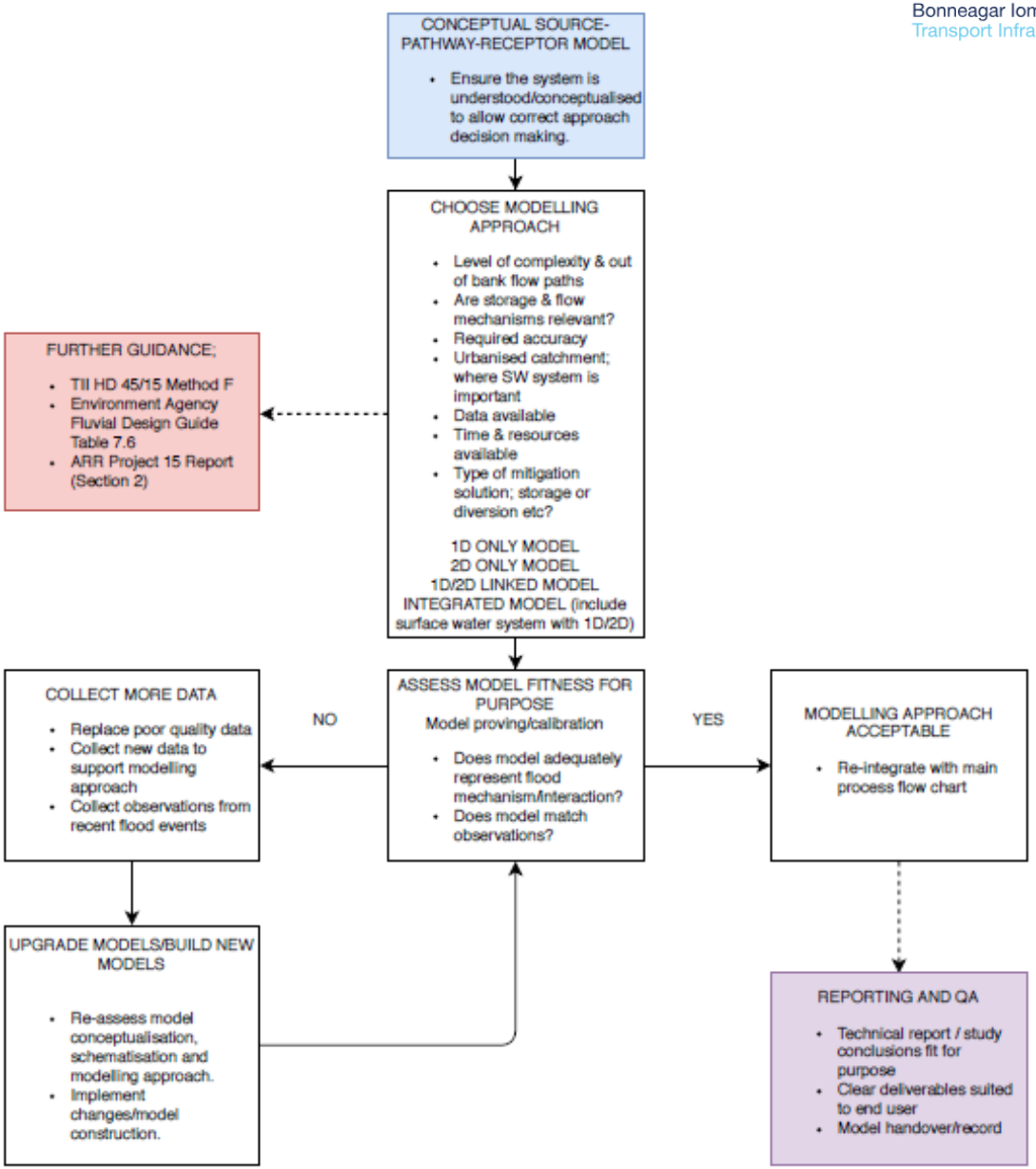
FRA Guidance – Investigation



Hydrological Estimation



Hydraulic modelling spec



Flood Foresight®

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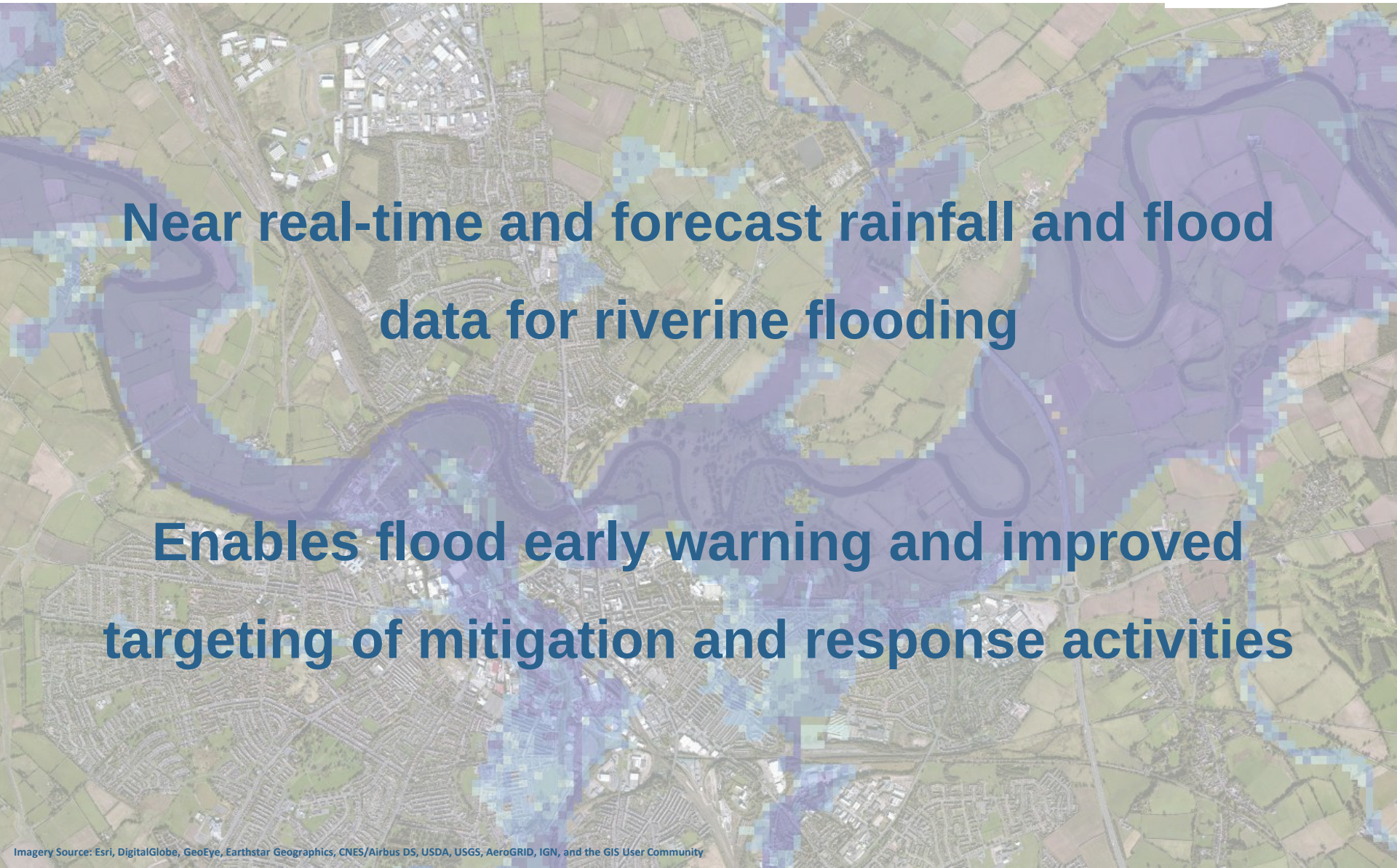


Near real-time and forecast rainfall and flood data for riverine flooding

Enables flood early warning and improved targeting of mitigation and response activities

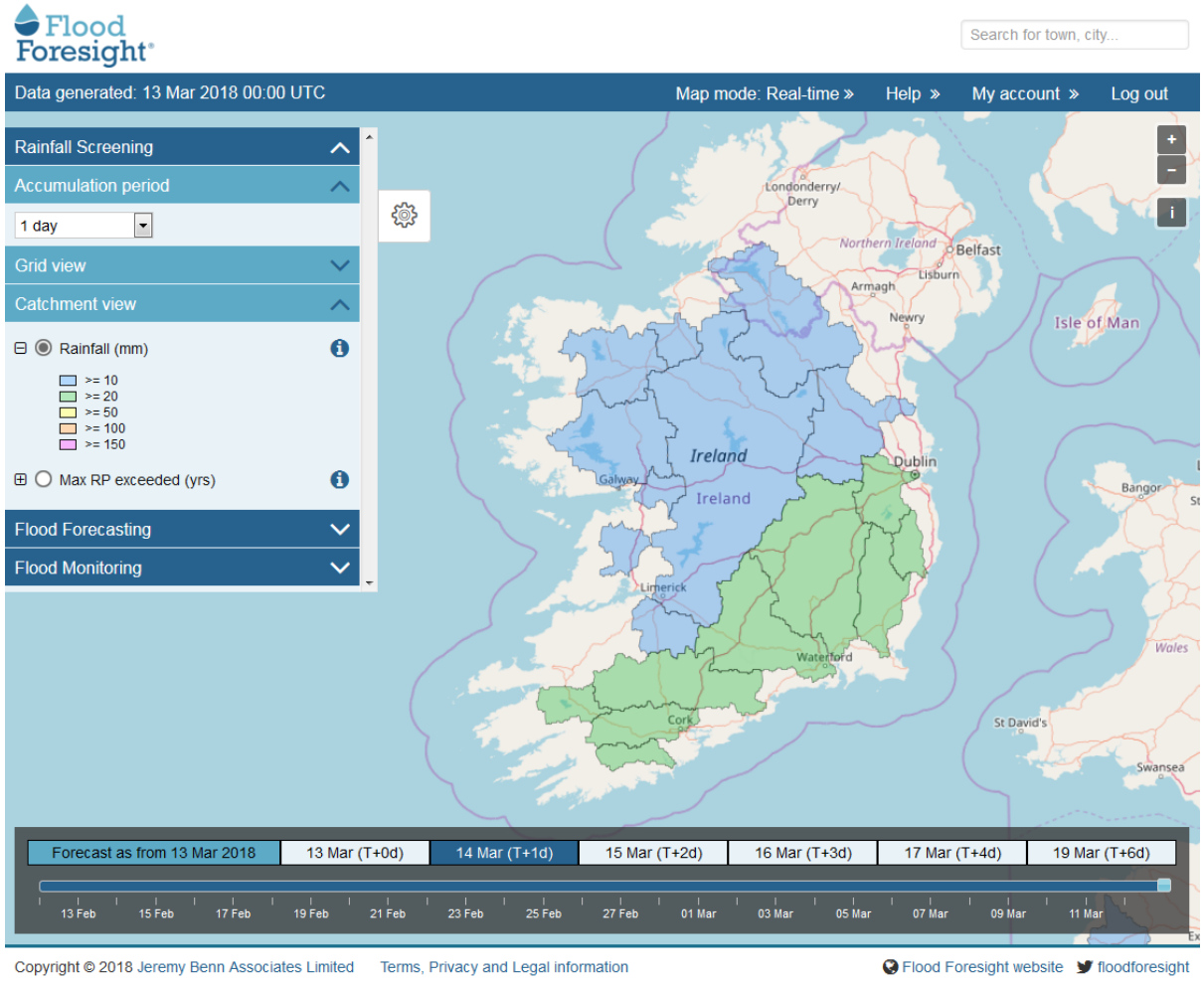
Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Rainfall Screening

13 March Forecast for the 14 March 2018

- Rainfall amounts:
  - 10-20mm N and W
  - 20-50mm S and E

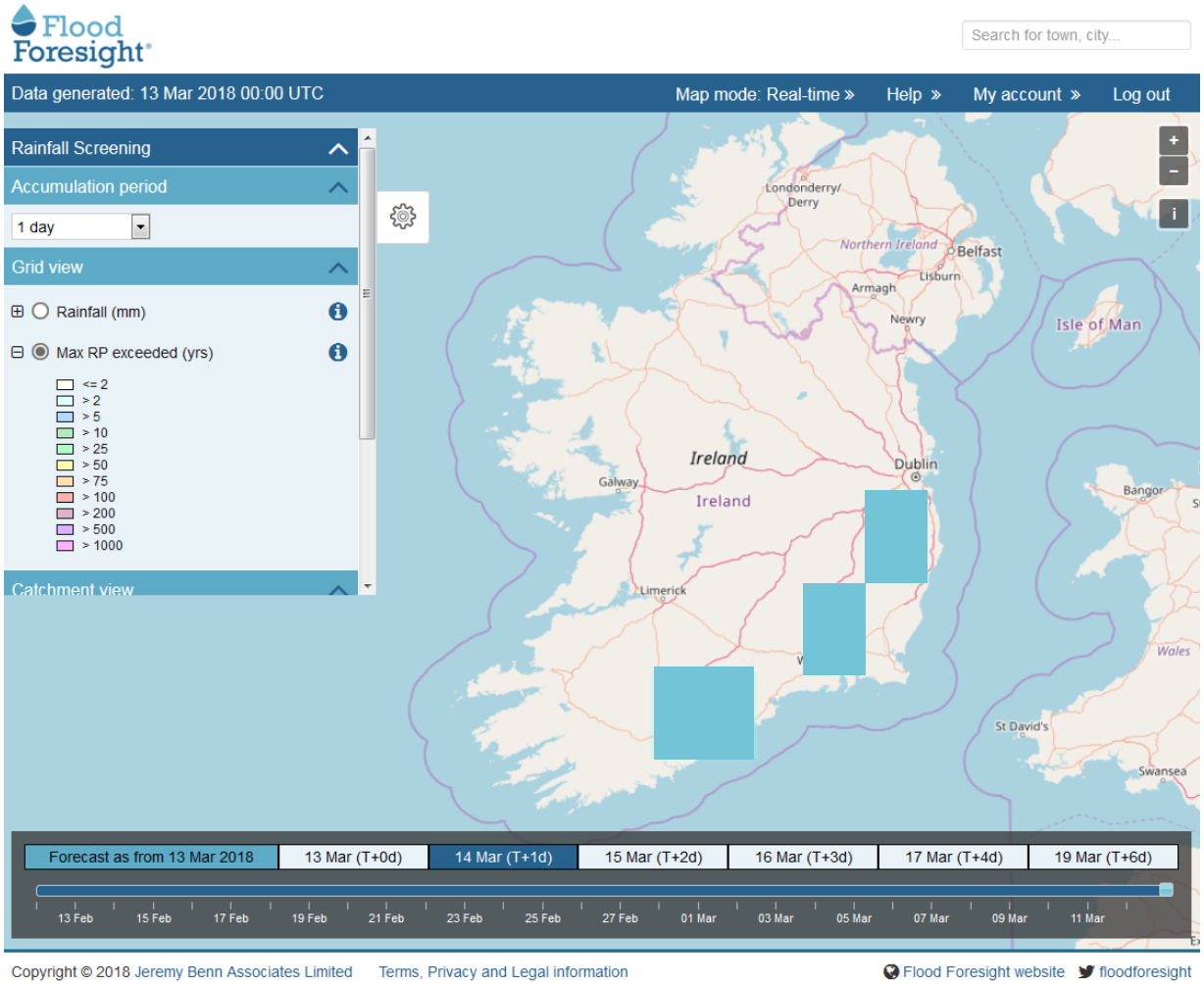
- Goes beyond rainfall forecasting
- Provides forecast flood inundation maps
- Allows custom impact forecasting
- Enables early action to reduce disruption/loss



Rainfall Rarity Screening

13 March Forecast for the 14 March 2018

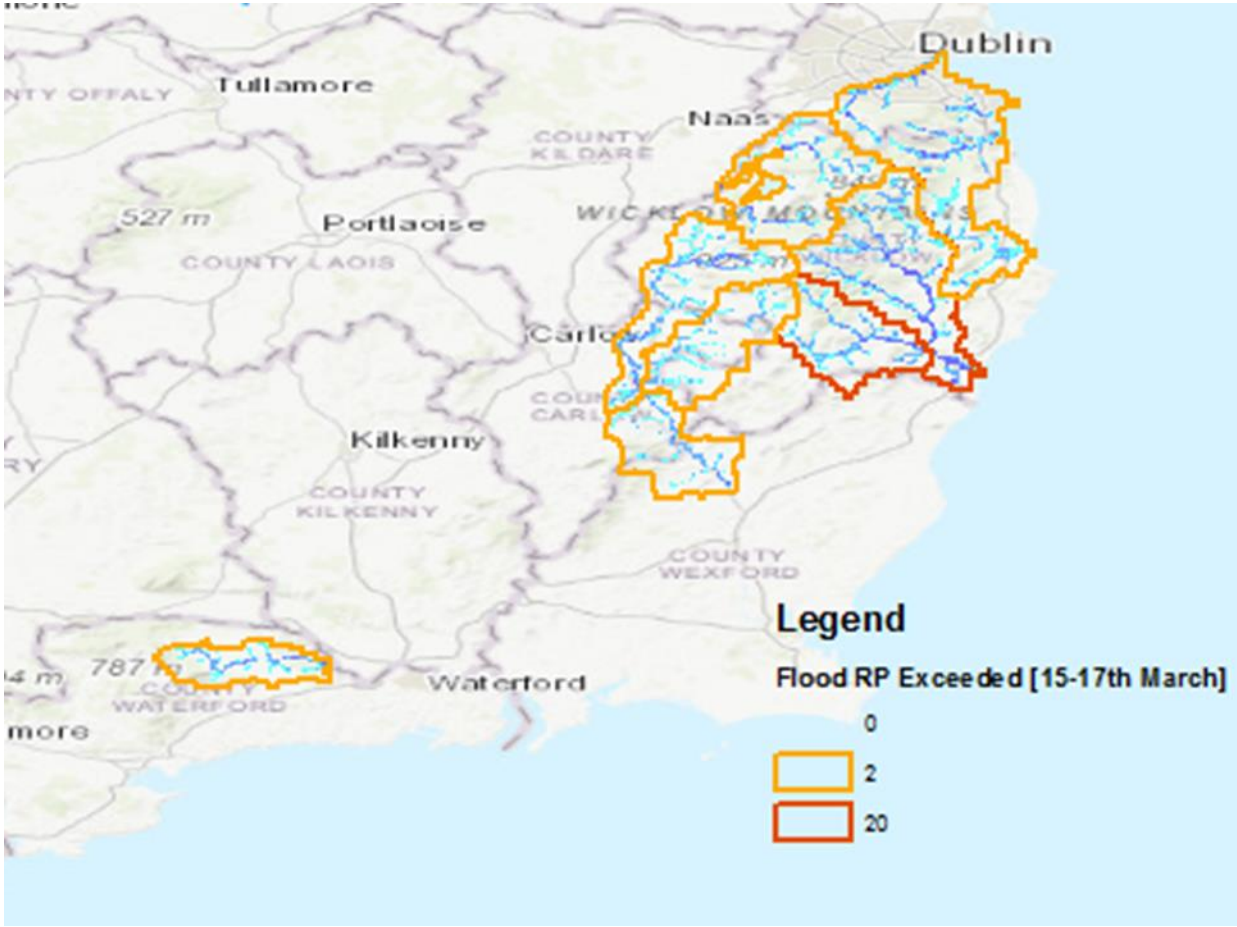
- Where is the added value?....
  - Rarity assessment
- 2-yr RP exceeded SE coast
- Dublin, Carlow and Wicklow



Forecast Flood Footprint

13 March Forecast for the 15-17 March 2018

- 2-yr RP exceeded SE coast
- 20-yr RP exceeded only for the 15th March at those basins



Potential Impacts to roads

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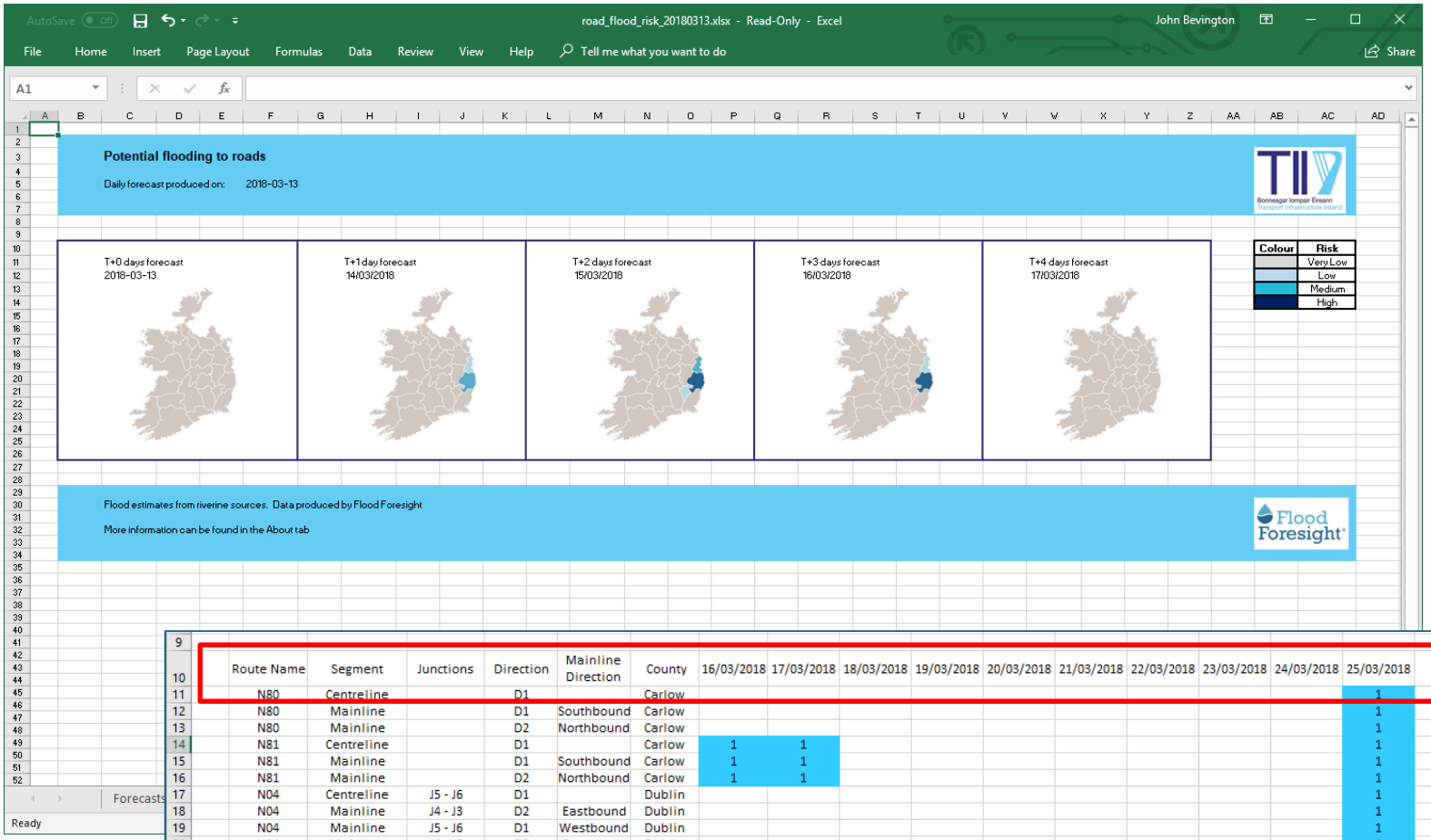


Route Name	Segment	Junctions	Direction	Mainline Direction	County	16/03/2018	17/03/2018	18/03/2018	19/03/2018	20/03/2018	21/03/2018	22/03/2018	23/03/2018	24/03/2018	25/03/2018
N80	Centreline		D1		Carlow										1
N80	Mainline		D1	Southbound	Carlow										1
N80	Mainline		D2	Northbound	Carlow										1
N81	Centreline		D1		Carlow	1	1								1
N81	Mainline		D1	Southbound	Carlow	1	1								1
N81	Mainline		D2	Northbound	Carlow	1	1								1
N04	Centreline	J5 - J6	D1		Dublin										1
N04	Mainline	J4 - J3	D2	Eastbound	Dublin										1
N04	Mainline	J5 - J6	D1	Westbound	Dublin										1
N04	Mainline	J6 - J5	D2	Eastbound	Dublin										1
N07	Centreline	J2 - J3	D1		Dublin										1
N07	Entry/Exit Ramp		D1		Dublin										1
N07	Entry/Exit Ramp		D2		Dublin										1
N07	Mainline	J2 - J3	D1	Westbound	Dublin										1
N07	Mainline	J3 - J2	D2	Eastbound	Dublin										1
N11	Centreline		D1		Dublin	1	1								1
N11	Entry/Exit Ramp		D1		Dublin	1	1								1
N11	Entry/Exit Ramp		D2		Dublin										1
N11	Entry/Exit Ramp		D2		Dublin										1

Potential Flooding	1
Not Flooded	

Forecast floods | County Maps | About

Ready

Display Settings

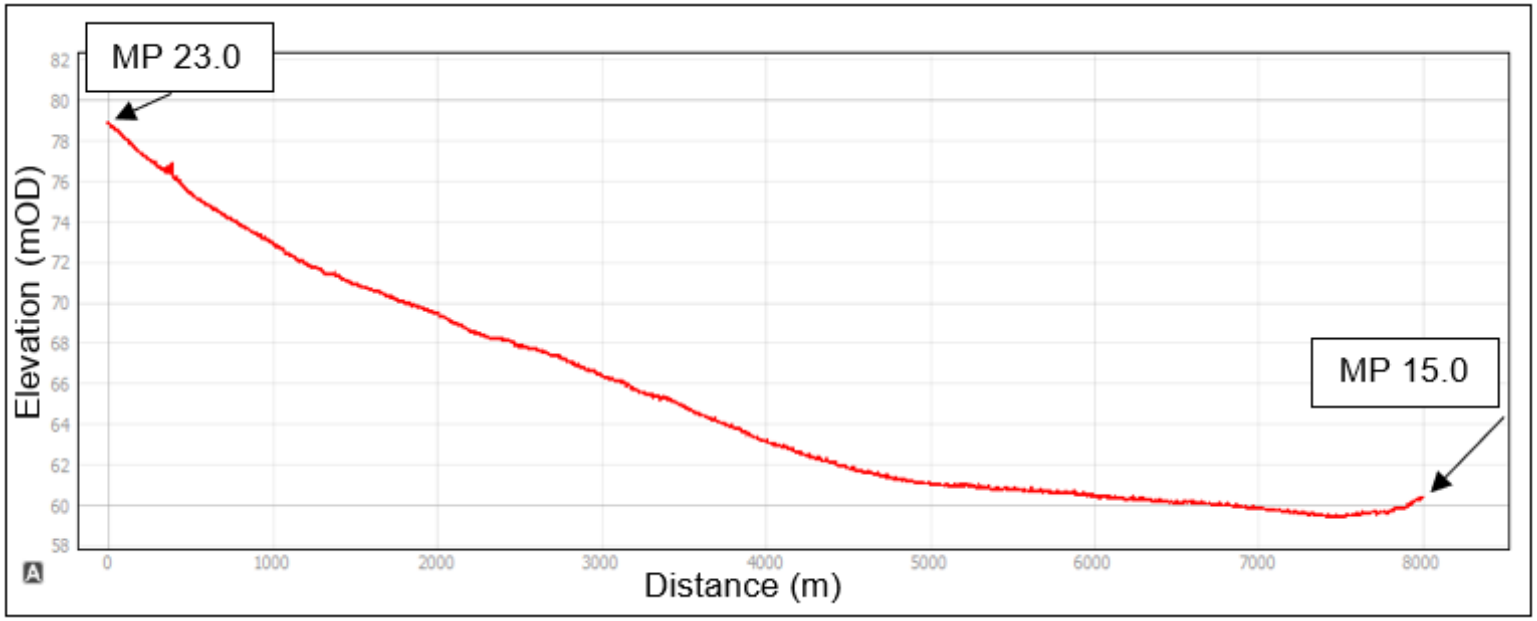
Summary

- Research & Case Studies disseminated
  - Conferences for OPW & TII
  - Training for Road Design Offices
  - Peer reviewed paper in Journal of Infrastructure & Asset Management
- All National Road Design Offices in receipt of data
  - Use in planning for strategic improvements
- Linking with Climate Action Regional Offices (CAROs)
  - Use in maintenance and operations
- Foresight integration with operational web apps - TII
- Focus on implementation – site specific studies

Case Study
M4 Kilcock/Maynooth

M4 Kilcock/Maynooth - 2018

- Flood risk and options review M4 Kilcock - Maynooth.
- Ranked in top 5% national routes at risk of flooding. Sensitive to fluvial, pluvial and therefore climate change.
- This study aims to;
  - Quantify to TII the flood risks to the M4 between Kilcock and Maynooth Towns.
  - Investigate potential mitigation measures to increase network resilience



M4 Historic Flooding

- Driver for the study was the 21-22 November 2017 rainfall event.
- 50mm rain depth over 10hrs – circa 5% AEP (20yr)

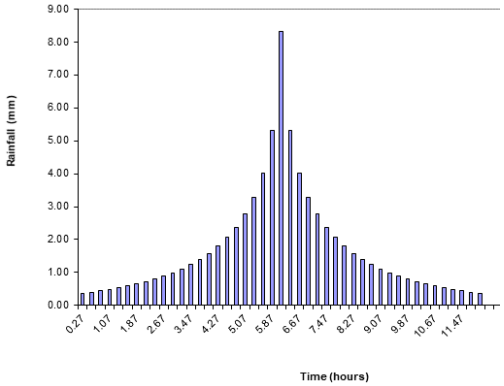
M4 Detailed Assessment

- Further detailed fluvial and pluvial modelling required

- Study split into two investigative areas;
  - Kilcock – Pluvial source, 2D TuFLOW model with conduits (culverts) under M4
  - Maynooth – Fluvial and Pluvial sources, 1D/2D linked model (ESTRY/TuFLOW)

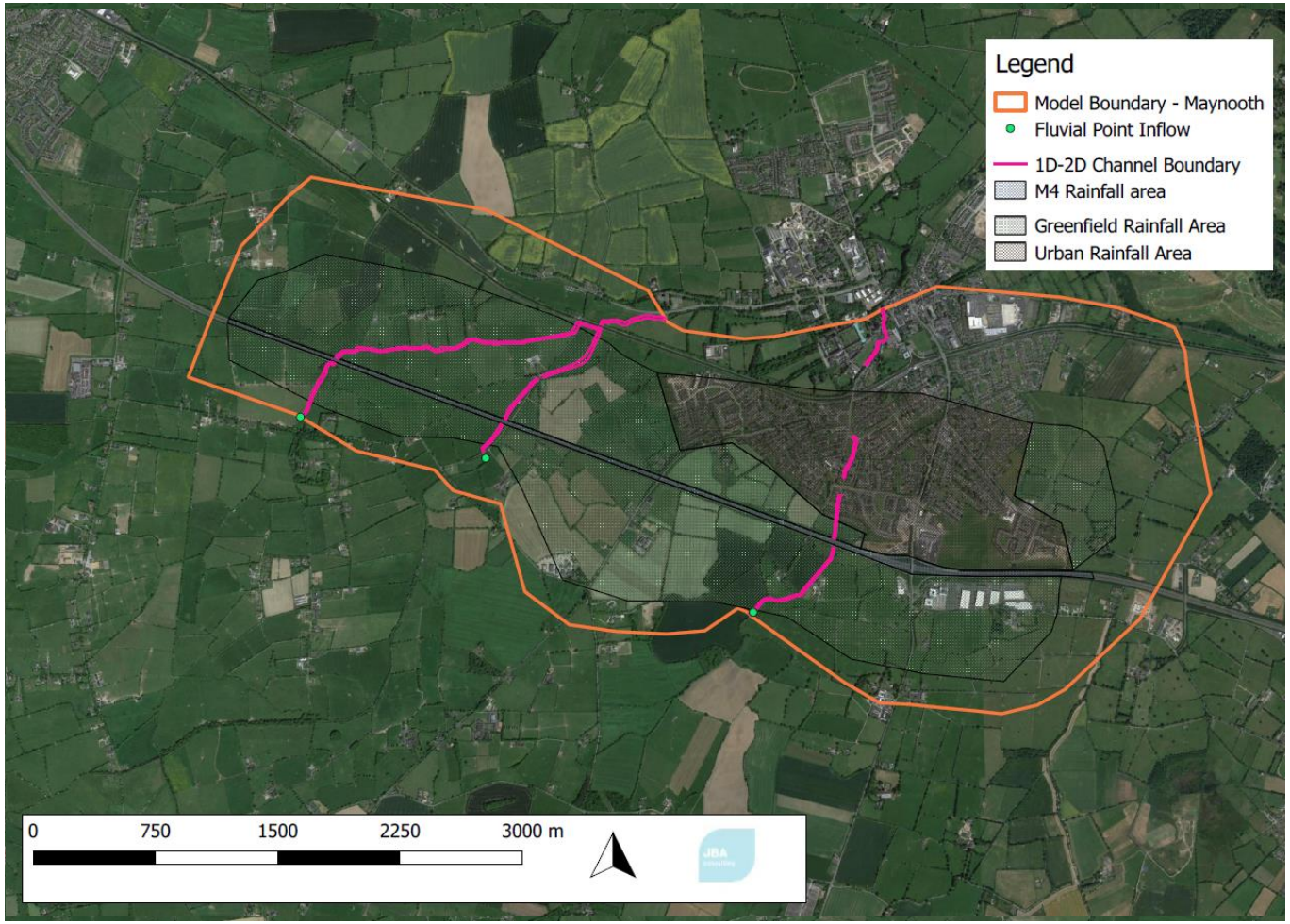
- Rainfall 12hr duration 5% AEP - 52mm (Met Eireann DDF)
- Hydrology – Flows taken from CFRAM (FSU)

Annual Exceedance Probability (%)	Peak Flow (m^3/s) Roestown	Peak Flow (m^3/s) Lyreen	Peak Flow (m^3/s) Roosk / Meadowbrook
Qmed (2yr)	2.49	7.77	1.49
5% (20yr)	5.43	16.21	3.25
2% (50yr)	6.92	20.32	4.14
1% (100yr)	8.27	27.44	5.05
0.1% (1000yr)	14.71	40.95	8.82



M4 Detailed Assessment

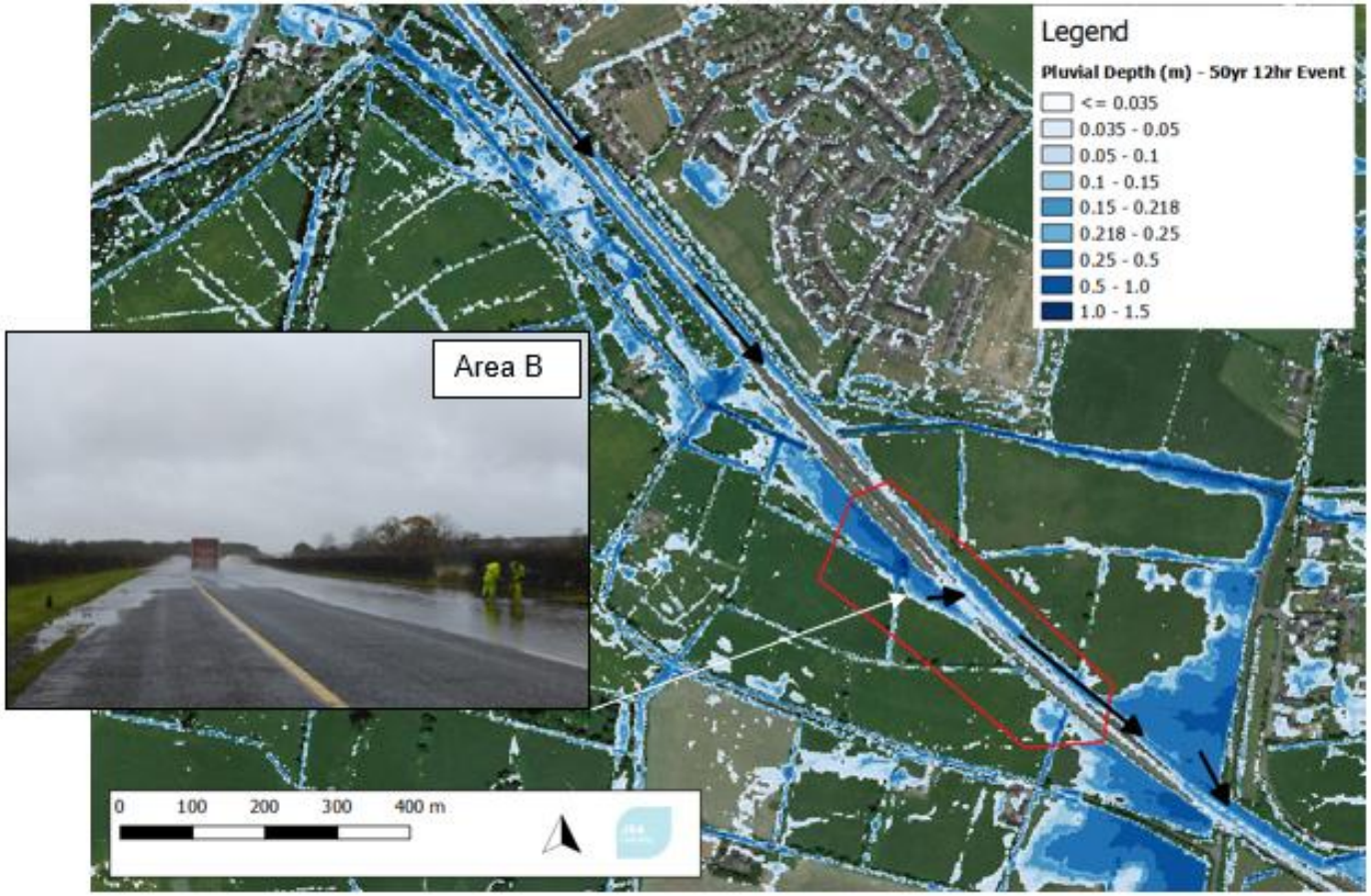
- Model Setup – 2D Rain on Grid & rain + 1D/2D Linked Model



M4 Detailed Assessment

KILCOCK

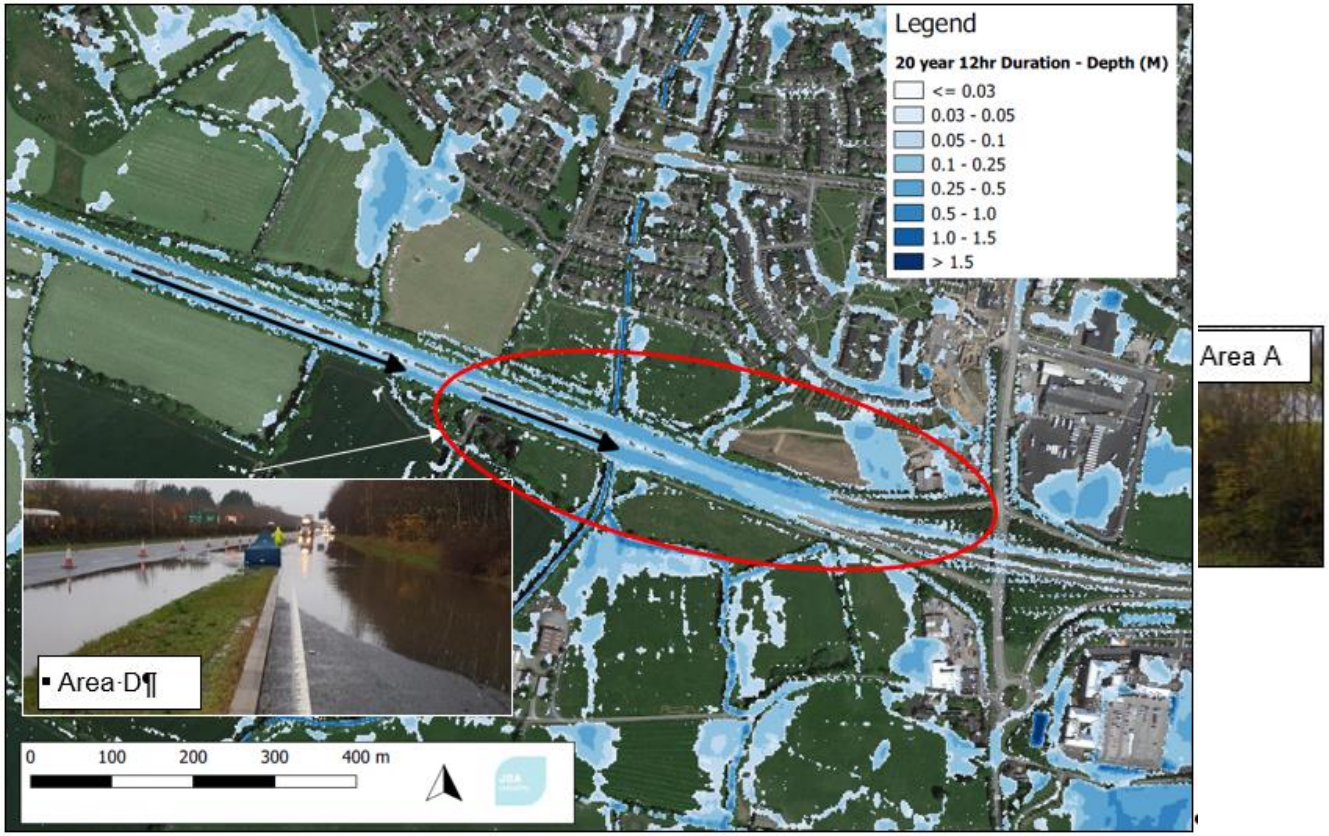
- Pluvial runoff from third party lands onto the highway.
- Local field drainage culverts are under capacity & spill onto highway.



M4 Detailed Assessment

MAYNOOTH

- Fluvial risk from Lyreen is primary source – culvert capacity & overland flow onto highway.
- Secondary source is pluvial runoff from third party lands.



M4 Mitigation - Ongoing

Screening of Flood Risk Management Options	Comments
Existing	• Planning System and Flood Risk Management Guidelines • Channel / flood defence maintenance works / programme
Non-Structural Measures	• Carry out targeted public awareness and preparedness campaign • Early warning system (Flood Foresight) & Flood Emergency Response Plan
Structural Measures	• **Flood Storage – Lyreen catchment** • **Natural Flood Management Measures – Lyreen & Kilcock** • Flood Storage – Kilcock catchment • Re-instatement of culvert @ MP 17.24 • Upstream Storage – Lyreen catchment • Re-size critical structures – Lyreen upstream catchment • Re-size critical structures – Kilcock catchment

M4 Mitigation – Initial Results

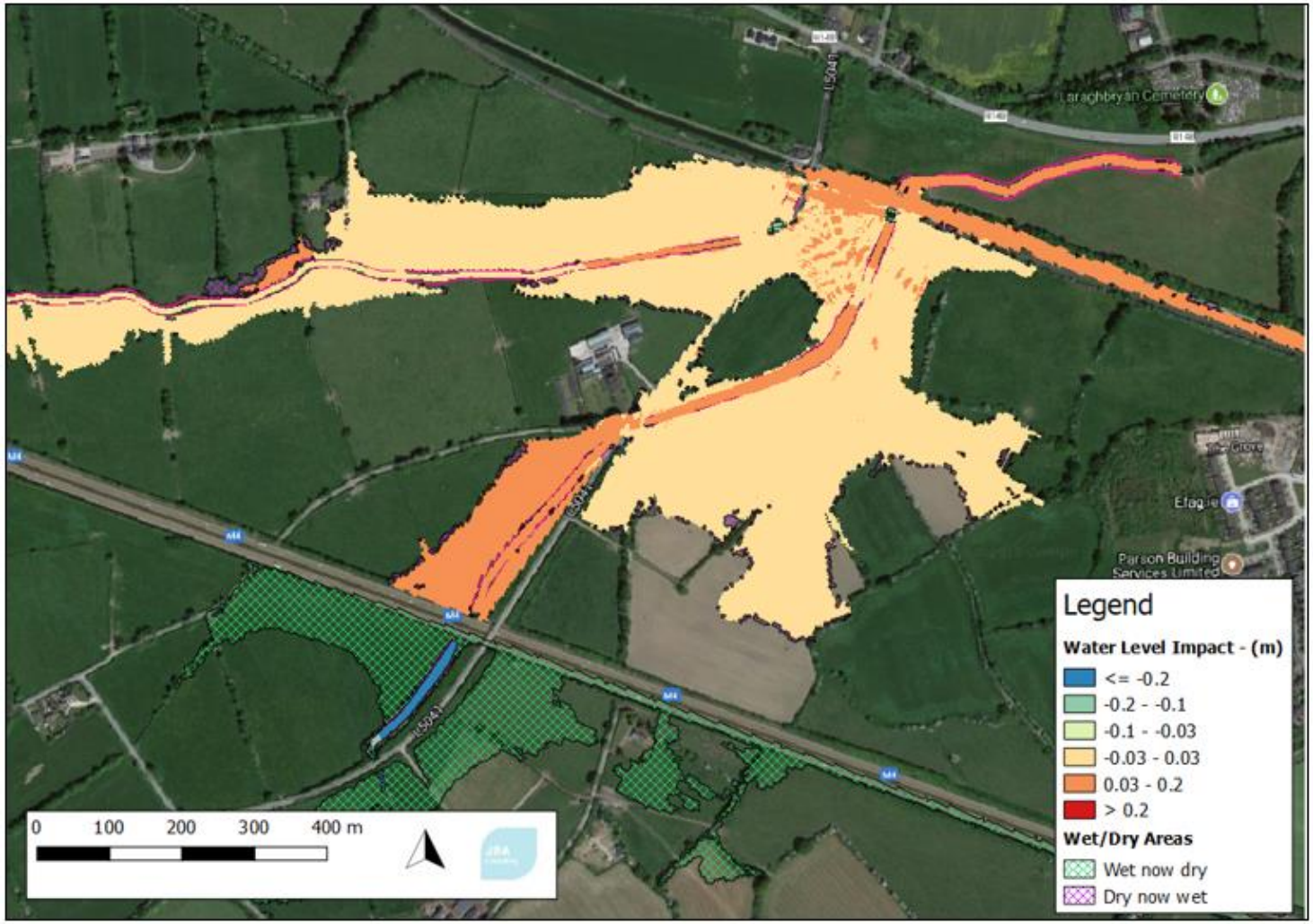


Figure 6-2: Flood Impacts - 50year Fluvial Event - Resizing critical structures Lyreen

M4 Summary

- Problem not just related to carriageway drainage.
- Initial solutions prevent flooding to M4 but increase extent either upstream or downstream.
- National FRA data must be supplemented by detailed modelling to fully understand mechanism and investigate mitigation options.
- Other local factors need to be considered;
  - Pluvial inputs from third party lands
  - Culverts
  - Outfalls and network operation
  - Holistic approach – reduction of flow is important
- Mitigation will involve third parties – OPW and Local Authority.
- Natural Flood Management may play an important role.

Case Study
N85 – New Route FRA & Section 50

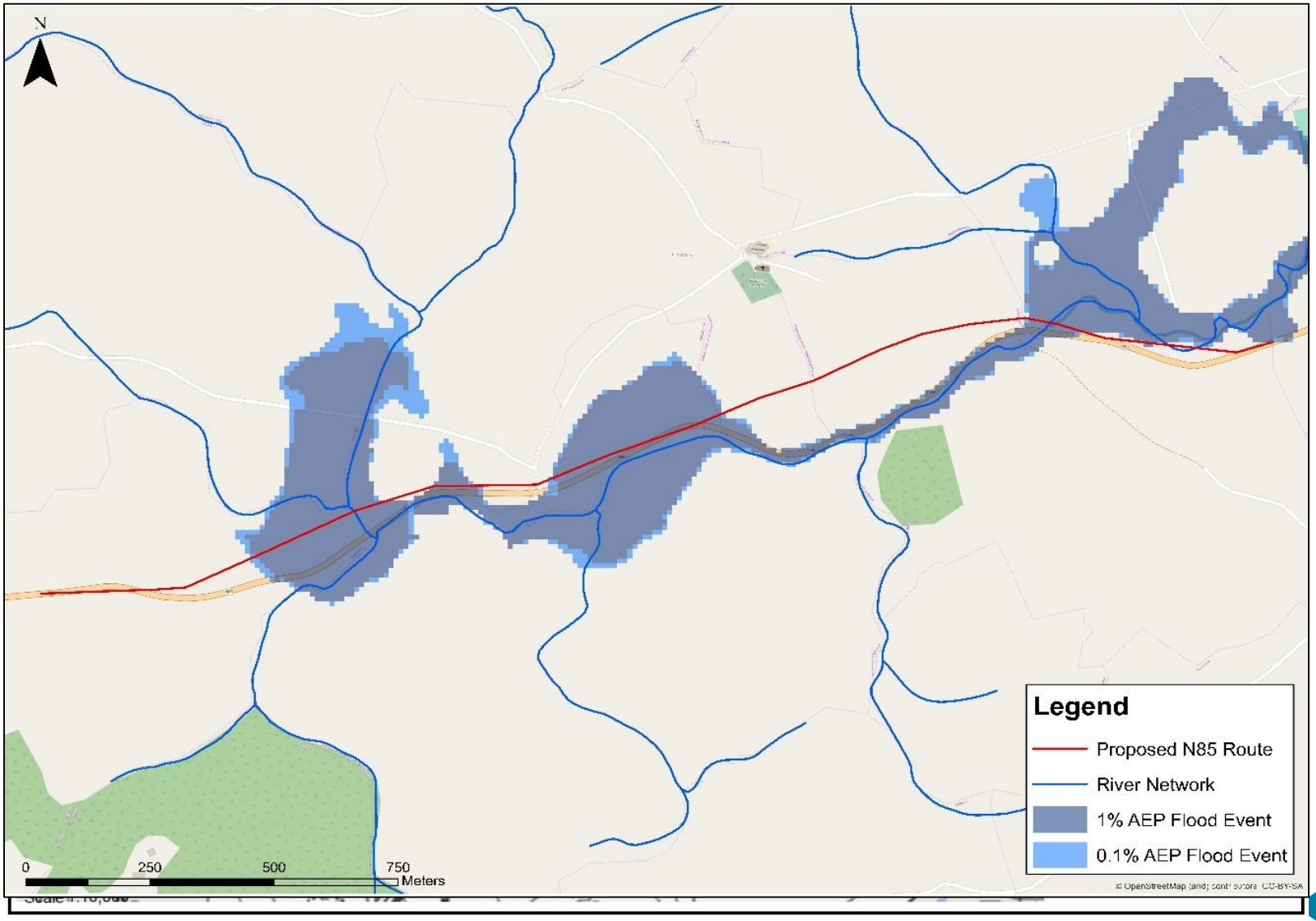
N85 Road Improvement

- 2nd ranked section of N85 for flood risk
- Historic flooding (fluvial), poor adaptive capacity, erosion risk

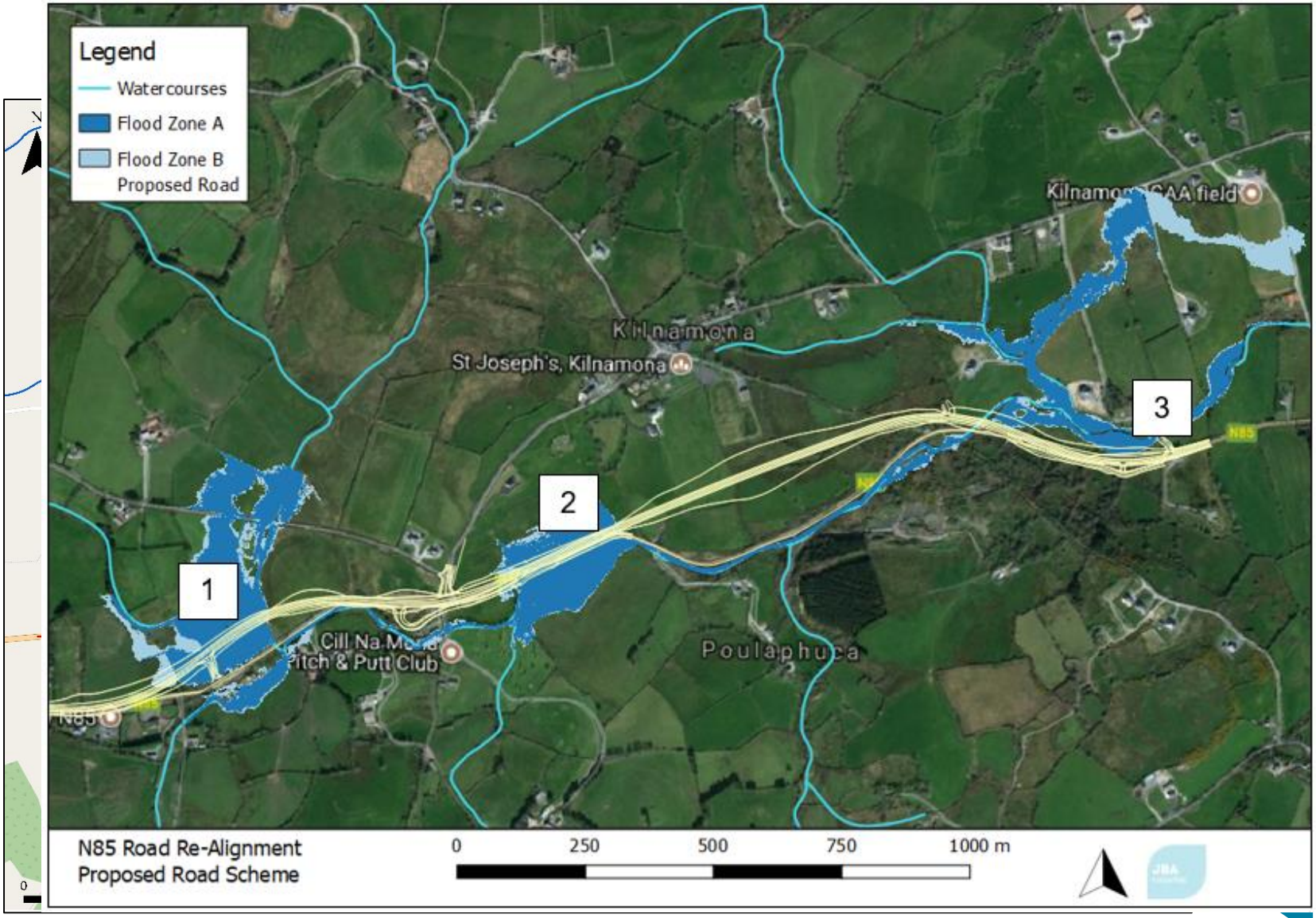
- JBA instructed in November 2017
- New road alignment and mitigation for flood risk

- The objectives of this FRA are to:
  - Identify potential sources of flood risk;
  - Confirm the level of flood risk and identify key hydraulic features;
  - Provide Section 50 design guidance for new structures;
  - Assess the impact that the proposed development has on flood risk.

N85 Initial Investigation

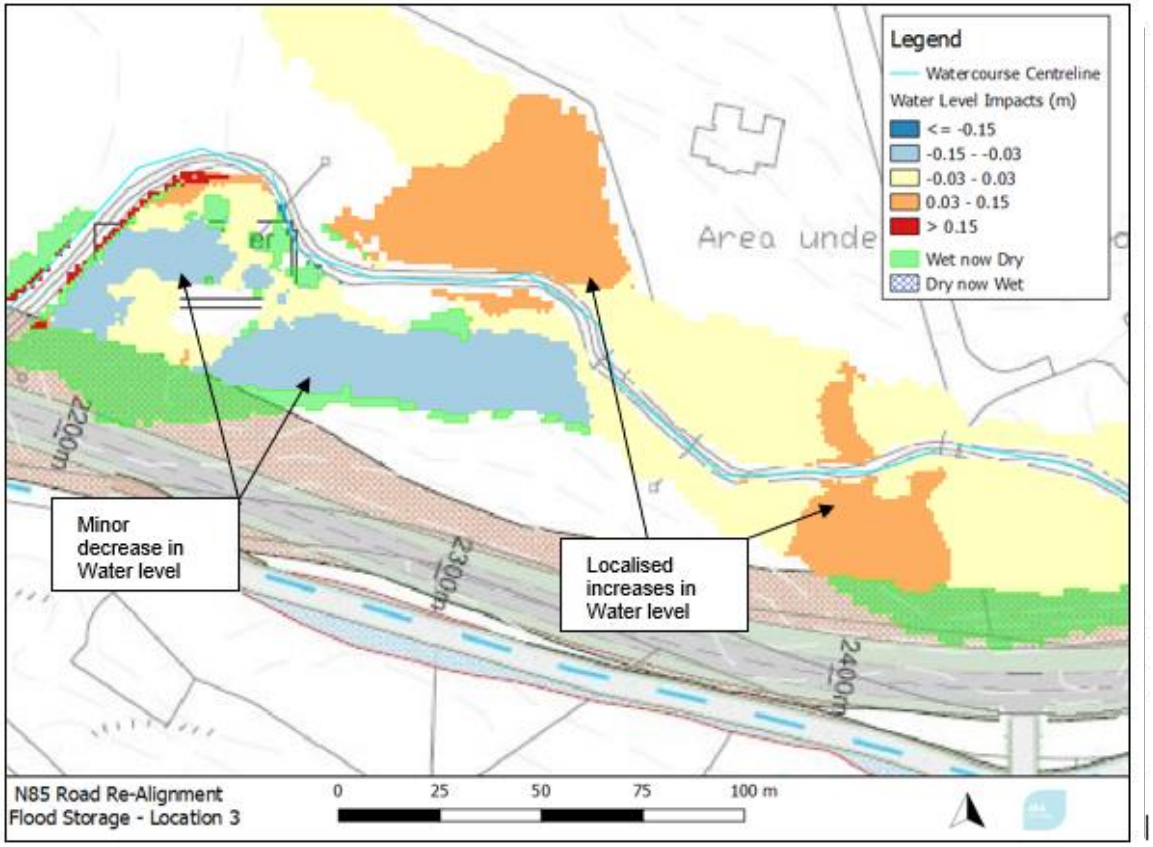


N85 Baseline Results



N85 Mitigation

- Location 1 – raise road between chainage 680-700m, new culvert
- Location 2 – maintain connections, raise at chainage 1400m
- Location 3 – Levels are appropriate, new culvert required



N85 Summary

- Significant risk to existing road.
- Proposed new route interacts with Shallee floodplain.
- Resilience increased by Assumptive Approach for climate change and culvert design.
- Approach is over-adaptive and costly.
- There are alternative approaches to assessing adaptive capacity.
- Recommendations are now with designer - feasibility assessment.

Case Study
N65 Carrigahorig

N65 Carrigahorig Flooding

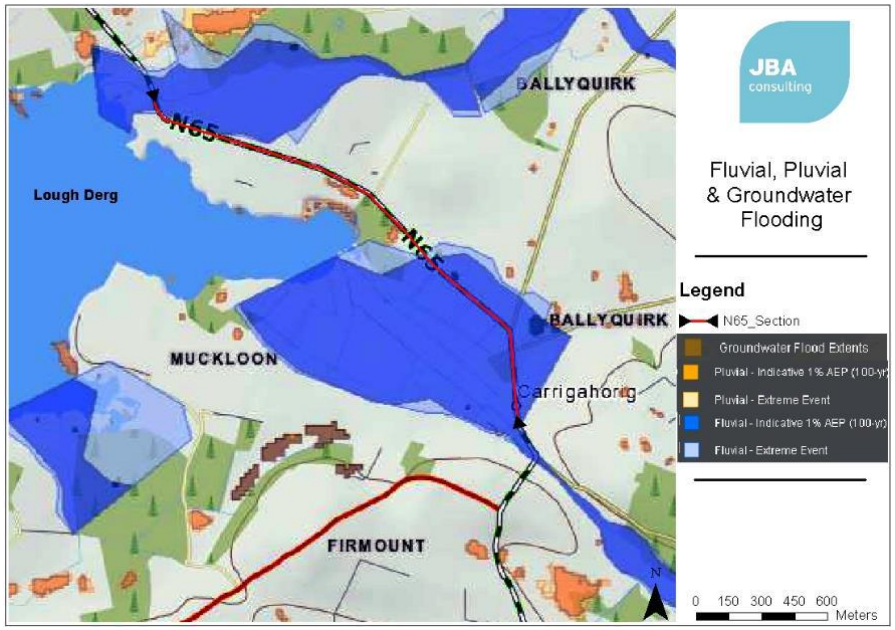
- MWRDO & Tipperary County Council
- Study conducted between Nov 2016 to Feb 2017
- 650m of N65 flooded at Carrigahorig for 6 weeks ‘15/16

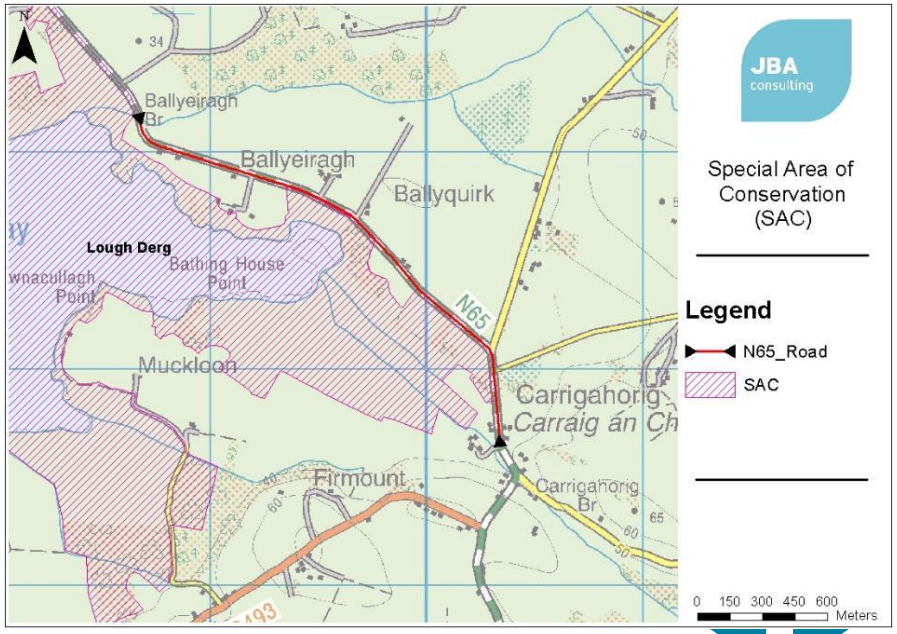
- Flood risk investigation & mitigation study

- Objectives:
  - Identify potential sources of flood risk;
  - Examine existing flood outlines for the location and, if possible, improve upon their accuracy;
  - Inform decisions relating to the detailed design of the road;
  - Develop appropriate flood risk mitigation and management measures which will allow for the long term improvement of the site.

N65 Carrigahorig Flooding

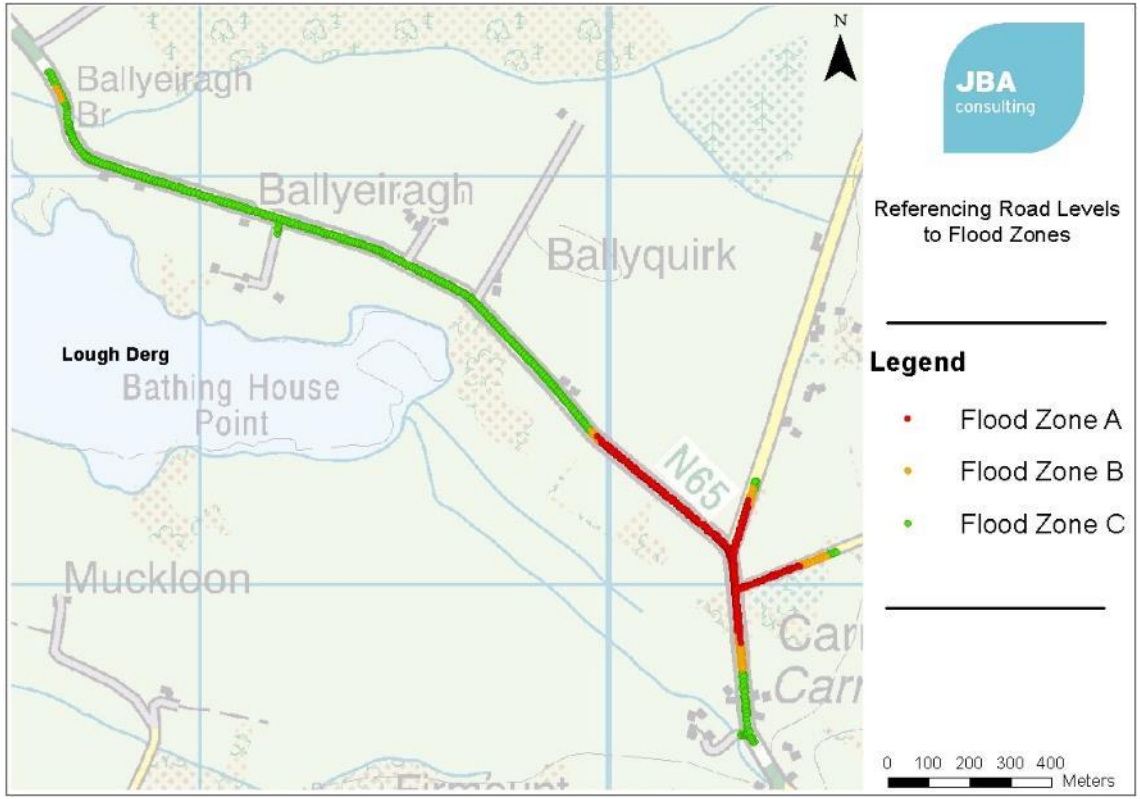
- Source is lacustrine (lake) flooding from Lough Derg
- Groundwater is close to the surface in the project area
- Flooded in 2009 (32.05mOD) and 2015/16 (31.97mOD, long duration
- Road forms boundary with SAC and this forms a large constraint
- Existing flood mapping is not fit for purpose





N65 Carrigahorig Flooding

- Level analysis from Portumna gauge
- Fitted GEV distribution and estimated extreme lake levels
- Mapped road hazard to identify vulnerable sections



N65 Mitigation

- Standard of Protection to consider adaptive capacity / cost benefit;
- Use in decision making for route alignment or raising option;
- Road level (inc FB) not to exceed 32.8mOD (500mm less than FFL);

- SAC proximity will invoke the requirement for full Stage 2 Appropriate; Assessment, CEMP and a more onerous planning route;
- Existing culverts under road can convey Lough Derg volumes;
- However, additional high level culverts should be installed.

Overview

- Understanding of how TII is;
  - Identifying flooding hotspots
  - Using forecasting data & route alerts
  - Manage & mitigating flooding to the road
  - Undertaking/specifying FRA for:
    - Road Design – Section 50 culverts & bridges
    - Road Route – assessment of impacts, levels, design
    - Investigation & mitigation of existing flooding problems

Thank you

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