# Tidal Flood Risk Transport Modelling

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## 1.0 Introduction

### 1.1 Overview

CH2M have been commissioned by Bristol City Council (BCC) to undertake transport modelling and monetary impacts analysis associated with four flood risk scenarios to support BCC's Avon Tidal Flood Risk Management Strategy project being undertaken by AECOM.

The four scenarios that have been modelled relate to varying likelihood of occurrence and / or mitigation measures. Each scenario is defined in terms of the road closures that would be required due to the flooding. The scenarios are as depicted in Appendix A, as provided by AECOM, where the road closures are indicated by red lines.

AECOM have advised the scenarios have associated likelihoods in terms of annual chance present day tidal flood as shown in Table 1. The table also include a brief description of each scenario.

| Scenario | Likelihood | Description |
|---|---|---|
| 1 | 1 in 5 | Closures include sections of A4 Portway, A369 Rownham Hill, limited roads around Cumberland Basin and Clarence Road. |
| 2 | 1 in 20 | As above plus Albert Road. |
| 3 | 1 in 200 | As above plus further closures in the vicinity of Cumberland basin, Cumberland Road, roads in the vicinity of Welshback and Redcliffe St, roads in the vicinity of Bedminster Parade and East St and further roads in the St Philip's Marsh area. |
| 4 | 1 in 200 | This scenario is the same likelihood as Scenario 3 but assumes flood walls are in place. Closures are as Scenario 3 but without some sections of Cumberland Road / Avon Crescent and Cattlemarket Road. |

Table 1 – Scenario descriptions

This Technical Memo reports the modelling and monetary impact analysis undertaken.

The monetary impact of a closure of Avon Fixed Bridge is also included in this Technical Memo based on previous modelling undertaken for the Department for Transport (DfT) Highway Maintenance Challenge Fund work in 2015.

# 2.0 Methodology

## 2.1 Overview

The GBATS4M transport model of the Greater Bristol area has been used to test the flood impact scenarios. Scenarios have been modelled in the AM peak, inter-peak (IP) and PM peak models with a forecast year of 2036. This model contains assumptions about planned developments and schemes within the model area, in accordance with DfT guidance.

The main infrastructure schemes included in the future year networks are shown in Table 2.

| Scheme | Description |
|---|---|
| 20mph speed limits | Roll out of 20mph speed limits across Bristol |
| CPNN Off-site Works Package | A38 Filton roundabout. Capacity and safety improvements on 3-arms.<br>Widening of M5 J16 motorway off-slips, A38 North and circulatory carriageway.<br>Signing & lining changes on M5 J17 southbound off-slip. Widening of Merlin Road exit from roundabout and Highwood Lane entry to Merlin Road junction.<br>Widening of southbound approach at A38 Aztec West Rbt.<br>A4018 Bus Corridor. Crow Lane, Charlton Road, Greystoke Avenue junction improvements.<br>Local bus service enhancements. |
| MetroBus | Rapid transit from Ashton Vale to Temple Meads via Bristol city centre.<br>North Fringe to Hengrove Package.<br>New highway link and bus route between A370 and Hengrove Park |
| Temple Circus Project | Redesign of Temple Circus roundabout. Related changes to the end of Victoria Street, The Friary, Temple Way, Temple Gate, connection with Redcliffe Way, Bath Bridge Roundabout |
| Managed Motorway Scheme | M4 Junctions 19-20 & M5 Junctions 15-17 |
| Cribbs Patchway MetroBus Extension | Extending the NFHP MetroBus route from The Mall back to Parkway |
| M5 Junction 19 | Replacement of left turn off the south bound exit slip, with a two lanes |
| London Paddington – South Wales Rail Electrification | Extra services between Bristol Temple Meads and London Paddington via Bristol Parkway included |

Table 2 Additional Infrastructure included in MetroWest Future Year Do Minimum

Table 3 details the total additional homes/jobs explicitly assumed in the future year Reference Case models (excluding smaller sites less than 1 hectare for employment sites less than 50 homes for housing). The forecasts are also controlled to Tempro growth in line with DfT guidance. Car trips are forecast to increase by around 20% by 2036.

| Year | Additional New Homes | Additional New Jobs |
|---|---|---|
| 2013-2021 | 27,719 | 34,621 |
| 2021-2036 | 7,656 | 16,937 |
| 2013- 2036 | 35,375 | 51,559 |

Table 3 Additional Planned Development included in Do Minimum

Further information on the model development is contained in GBATS4M MetroWest Do Minimum Forecasting Report, February 2016.

To identify monetary impacts, TUBA[1] software was used which incorporates the DfT's Transport Appraisal Guidance (TAG) economic parameters issued in December 2015.

## 2.2 Transport Modelling

To assess the road closure impacts, the relevant modelled highway links were closed to general traffic. The model was then re-assigned using a fixed demand highway assignment. Since the road closures would be likely to occur at short notice, a full multi-modal test was not considered appropriate, as such a test is more representative of longer term effects where travel decisions adapt to changed circumstances over a longer timescale.

Bus routes were not altered in the model as impacts on public transport were not assessed.

Where some areas will experience complete severance from road closures due to flooding, it has not been possible to reflect the full economic impacts of such an occurrence as this is outside the scope of a network based transport model.

## 2.3 Monetary Impacts

Monetary impacts have been identified for a single day using the DfT TUBA software. This was undertaken through modelling of a single assessment year for AM, IP and PM modelled hours, with no expansion undertaken to calculate annual results. Expansion factors were applied based on local data to calculate peak period and inter-peak period impacts from the modelled hours as follows:

- AM : 2.55
- IP : 6
- PM : 2.56

TUBA uses value of time (VOT) parameters in line with DfT guidance which vary by trip purpose and traveller income group. Car driver 2015 values are as follows:

- Employers' business: £26.54 / hour
- Non-work low income: £5.31 / hour
- Non-work medium income: £6.76 / hour
- Non-work low income: £8.54 / hour

[1] Transport User Benefits Assessment version 1.9.6

VOT values are forecast by DfT to increase by between 1% and 2% per year up to the forecast year of 2036. A discount rate of 3.5% per year is applied to adjust 2036 monetary impacts to 2015 values. Over the 21 years combined this results in a reduction of 53% due to discounting of benefits. Whilst values of time (VOTs) increase through time it is at a rate of 1 to 2% per year so the discounting outweighs the VOT increases by about two-fold.

Appendix B gives further details of the TUBA guidance 'consumer surplus' calculations which have been employed, albeit with disbenefits being identified in this case as opposed to benefits which are normally associated with transport schemes.

# 3.0 Flood Impacts

## 3.1 Traffic plots

Figures 3.1 to 3.4 indicate the traffic re-routing impacts of the road closures for the AM peak hours. Note, red and green bars represent forecast traffic flow decreases and increases on the road network respectively compared to a Reference Case scenario that does not contain any flood related road closures.

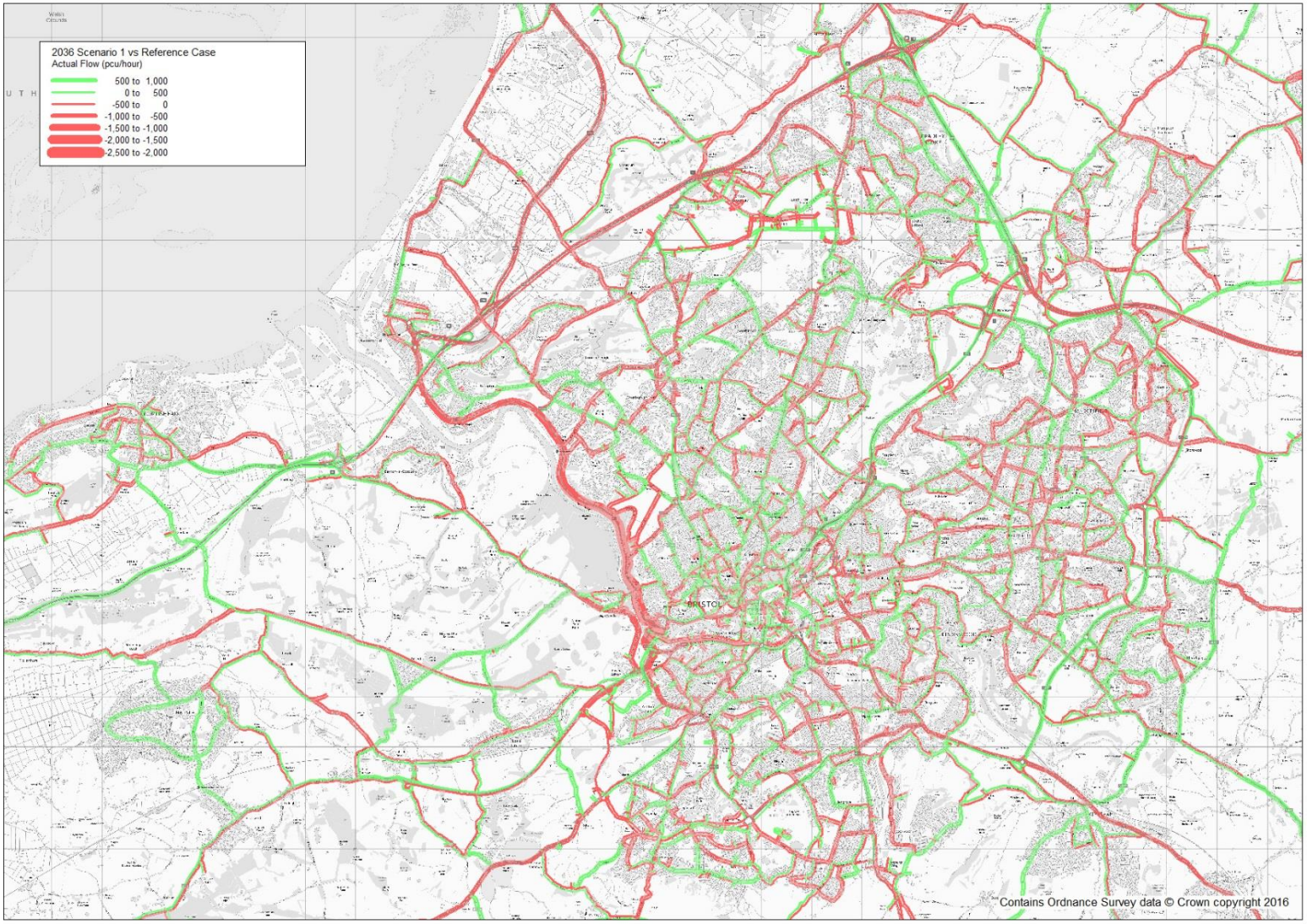



**Figure 3.1 Scenario 1 Traffic Flow Impacts**

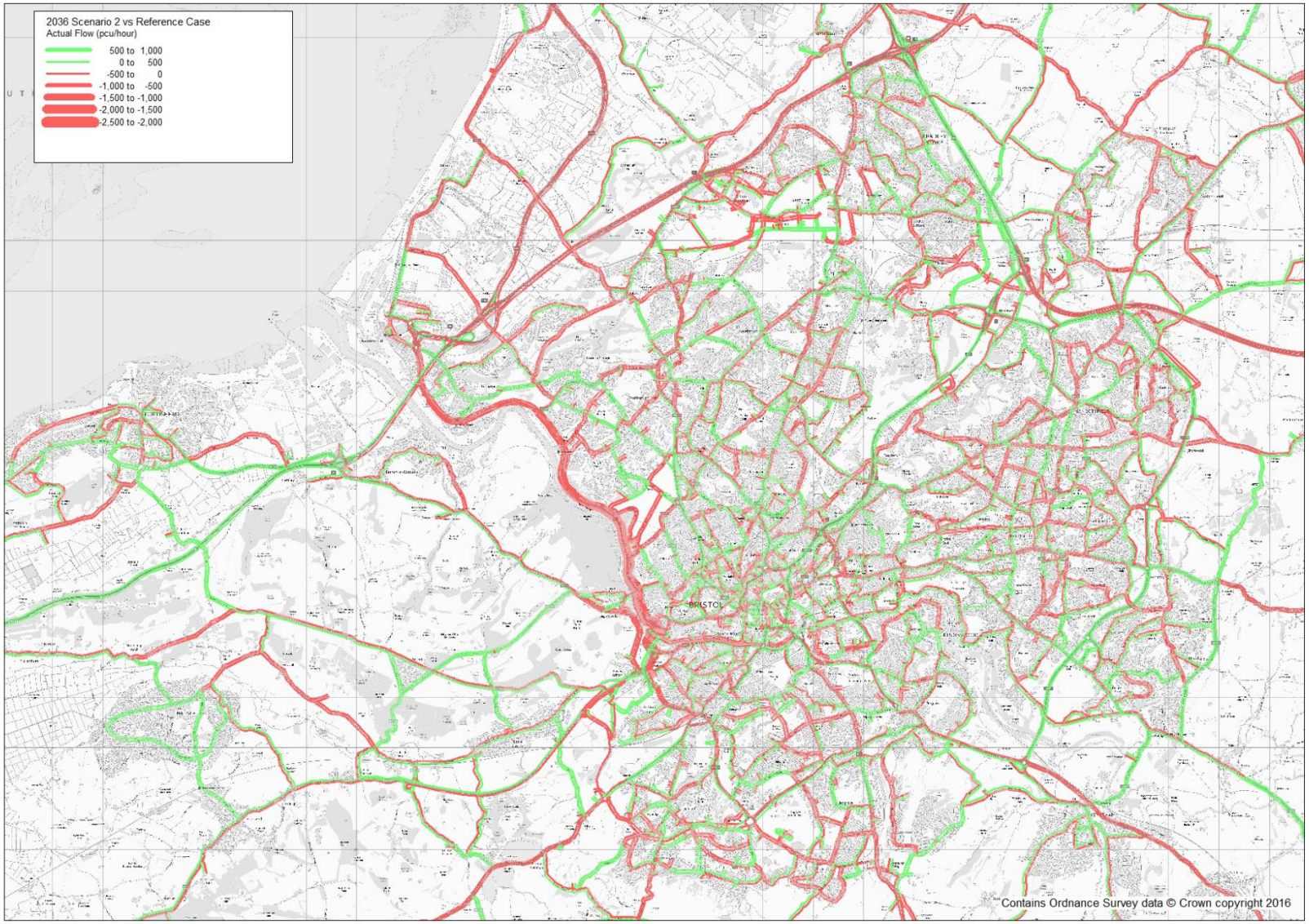



**Figure 3.2 Scenario 2 Traffic Flow Impacts**

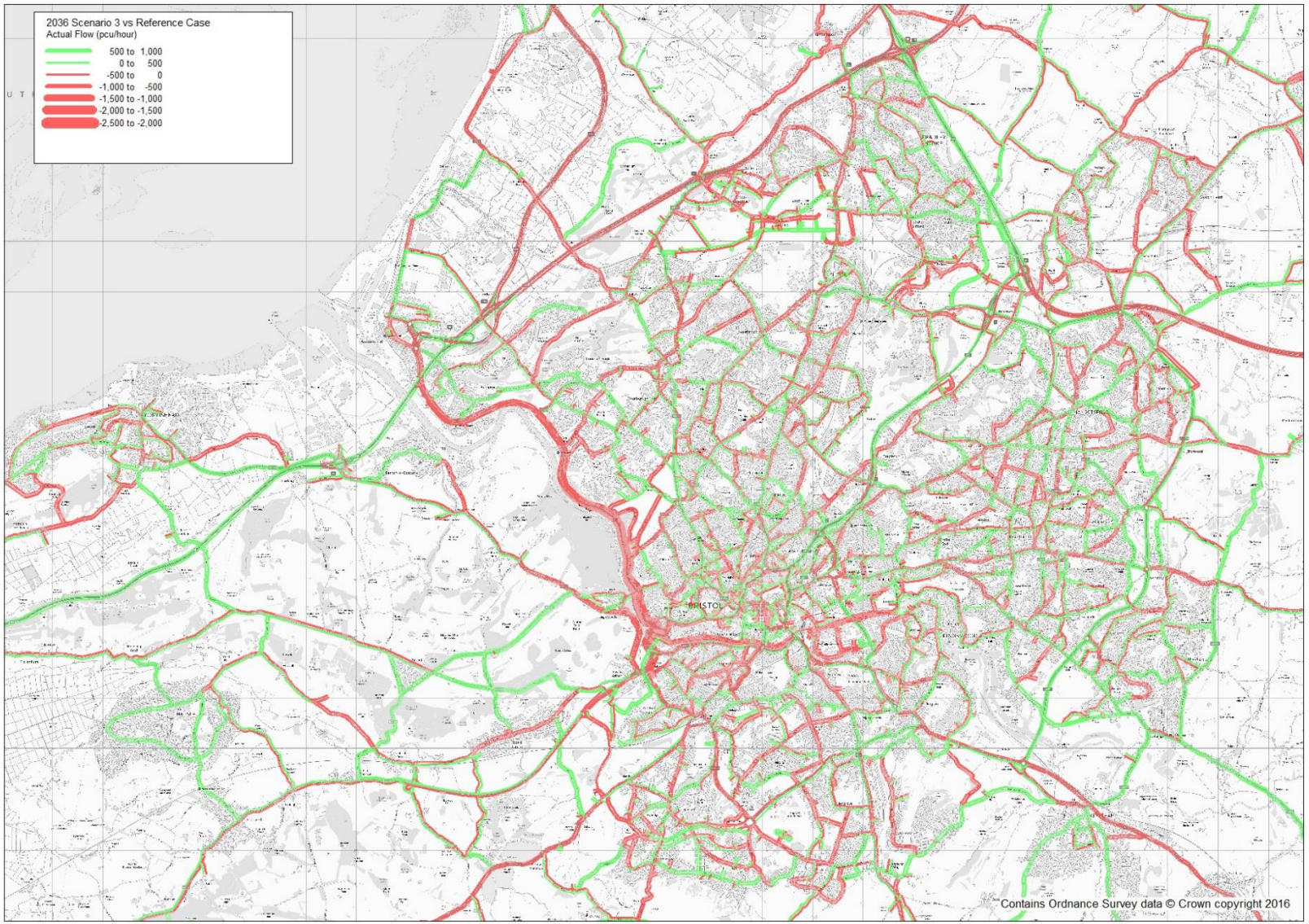



**Figure 3.3 Scenario 3 Traffic Flow Impacts**

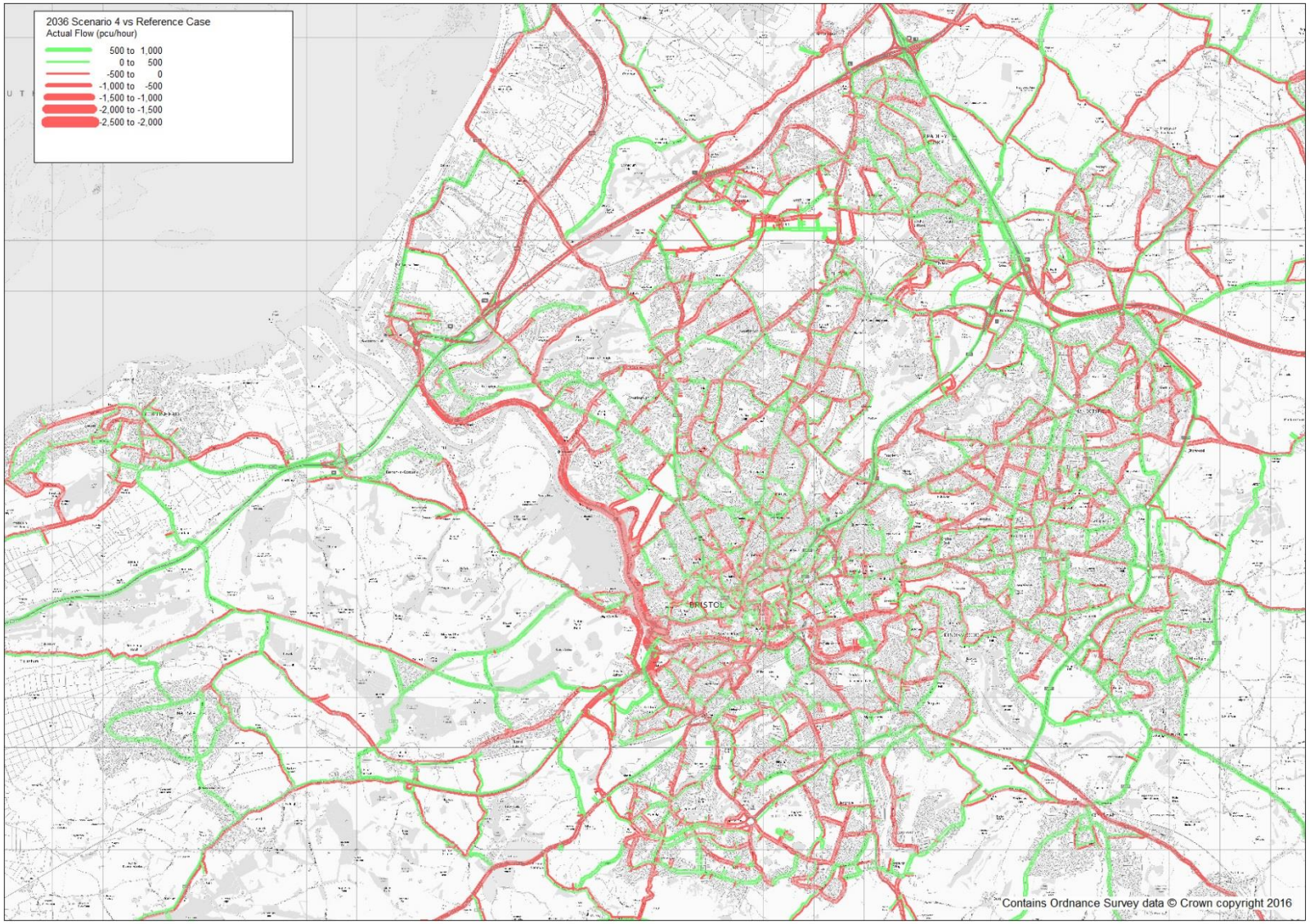



**Figure 3.4 Scenario 4 Traffic Flow Impacts**

## 3.2 Description of impacts

For each scenario, reductions in traffic flows can be seen on the affected roads. Common to all scenarios, the displaced traffic is predicted to transfer to a large number of widespread alternative routes rather than simply transfer to a few alternative routes. Some further commentary is provided below for each scenario:

Scenario 1

- Large traffic reduction in both directions on A4 Portway between Hotwell Rd and the M5 J18
- Traffic reduction on A369 from M5 J19 to A370. Increase in traffic along B3128 and B3129
- Trip reductions in both directions of M5 between Jn 18 and M5/M4 interchange
- Trip increase on A370 and B4054 towards Bristol
- Traffic increase on M32

Scenario 2, as above plus

- Localised decreases in the St Philip's Marsh area

Scenario 3, as above plus

- Further decreases on Cumberland Road, Malago Road / East St and Feeder Road
- Associated displaced increases on local roads

Scenario 4

- Similar to Scenario 3 with lesser impacts on Cumberland Road

Impacts on bus routes have not been modelled, however, a number of bus routes would be affected by road closures in the various scenarios considered, and in particular:

All scenarios:

- Portway: Park and Ride service
- A369: X2/3 services

Scenarios 3/4:

- Malago Rd / East St: A1 Airport service / 75, 76, 90 services

Table 4 gives network impacts in terms of change in average speed and over-capacity queues for the AM peak hours due to the closures modelled in each scenario compared to the Reference Case without the closures. Over-capacity queues relate to vehicles that are still held in queues at the end of the simulation period.

| Scenario | Average speed | Over-capacity queues |
|---|---|---|
| 1 | -6.3% | 42.1% |
| 2 | -7.0% | 49.6% |
| 3 | -23.0% | 221.5% |
| 4 | -22.8% | 219.1% |

Table 4 Speed and queue network impacts

This shows significant operational impacts across the whole model area due to the flood related closures, particularly for scenarios 3 and 4 which relate to the 1 in 200 likelihood flood risk events.

### 3.3 Monetary impacts

Table 5 gives the monetary impacts for each scenario, assessed for a single day. TUBA uses a base year of 2010. Monetary impacts have been adjusted to a base year of 2015 for consistency with the Avon Tidal Flood Risk Management Strategy project, via a price base and discounting adjustment in line with TAG.

| Time period | Scenario 1 (1 in 5) | Scenario 2 (1 in 20) | Scenario 3 (1 in 200 no flood walls) | Scenario 4 (1 in 200 flood walls) |
|---|---|---|---|---|
| AM | 46,579 | 47,329 | 174,391 | 159,697 |
| IP | 82,448 | 90,843 | 252,894 | 246,219 |
| PM | 39,336 | 46,747 | 196,691 | 186,886 |
| **Total** | **168,363** | **184,920** | **623,976** | **592,802** |

Table 5 Daily monetary impacts (£ 2015 values and prices)

Table 6 gives the equivalent monetary impacts with undiscounted 2036 values (but retaining a 2015 price base).

| Time period | Scenario 1 (1 in 5) | Scenario 2 (1 in 20) | Scenario 3 (1 in 200 no flood walls) | Scenario 4 (1 in 200 flood walls) |
|---|---|---|---|---|
| AM | 98,428 | 100,013 | 368,511 | 337,460 |
| IP | 174,224 | 191,963 | 534,398 | 520,294 |
| PM | 83,121 | 98,783 | 415,634 | 394,915 |
| **Total** | **355,773** | **390,760** | **1,318,543** | **1,252,669** |

Table 6 Daily monetary impacts (£ 2036 values / 2015 prices)

## 4.0 Limitations and Assumptions

### 4.1 Overview

Impacts that have not been assessed include:

- Bus and rail public transport impacts, such as cancellation or re-routing of bus services
- Economic impacts of severance of areas of housing or employment, such as productivity, Gross Value Added (GVA) etc.

## 5.0 Avon Bridge

### 5.1 Monetary Impacts

Previous modelling work was undertaken using the GBATS3 model in 2015 to support the DfT Highway Maintenance Challenge Fund submission which include testing of the impacts of a closure to the Avon Fixed Bridge, Brunel Way across the River Avon.

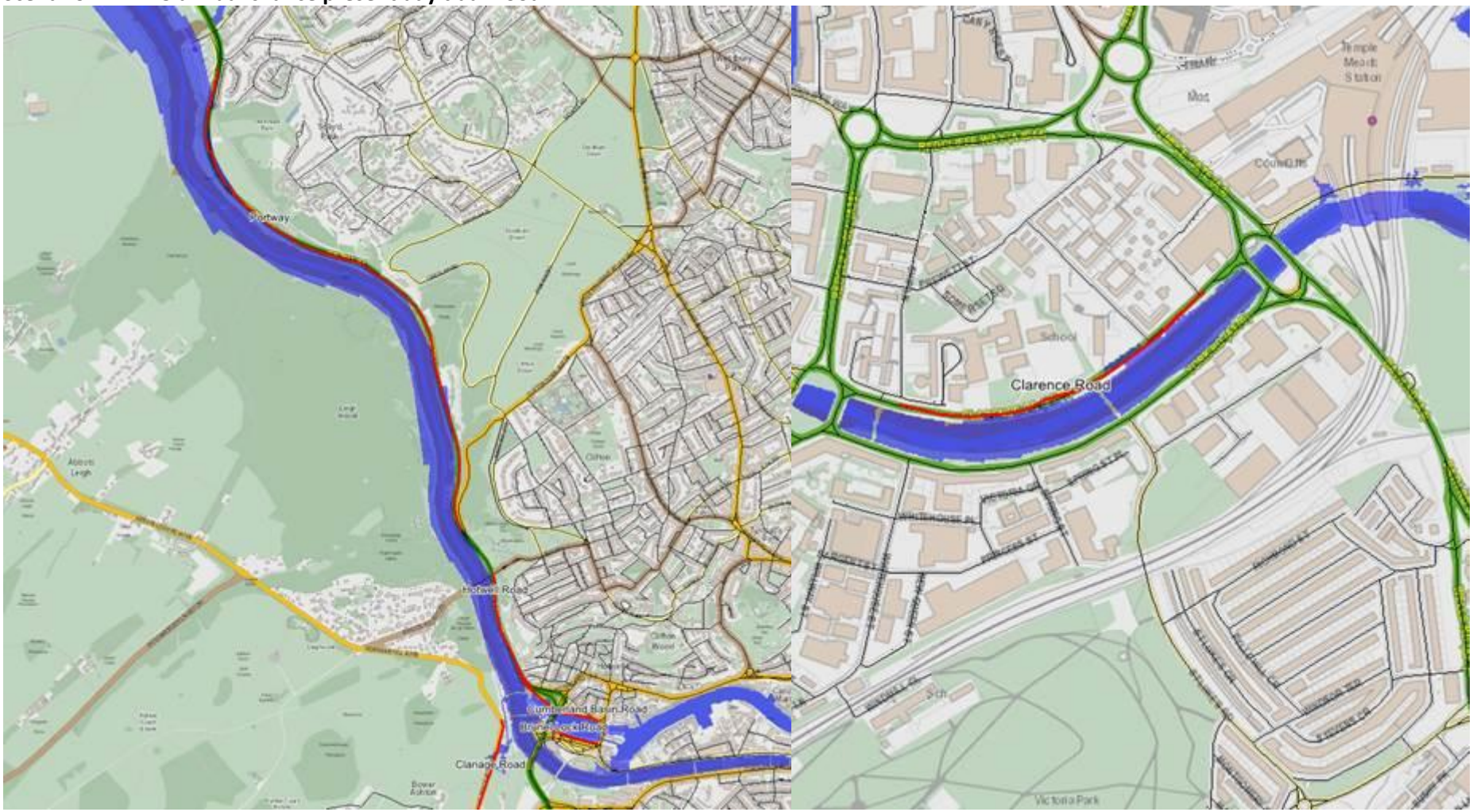
The bridge closure impacts identified in the DfT Highway Maintenance Challenge Fund submission included a likelihood-weighted assessment of different levels of restrictions, monetised over a 60 year period. The TUBA results have been further interrogated to extract the relevant values to identify the monetised daily impact of a full bridge closure in 2036.

The monetised daily impact has been calculated accordingly as £125,223 (2015 values and prices). The annual average daily traffic (AADT) on the Avon Fixed Bridge is estimated at around 30,000 vehicles. Hence this equates to around £4 per vehicle, although it should be noted this values has been

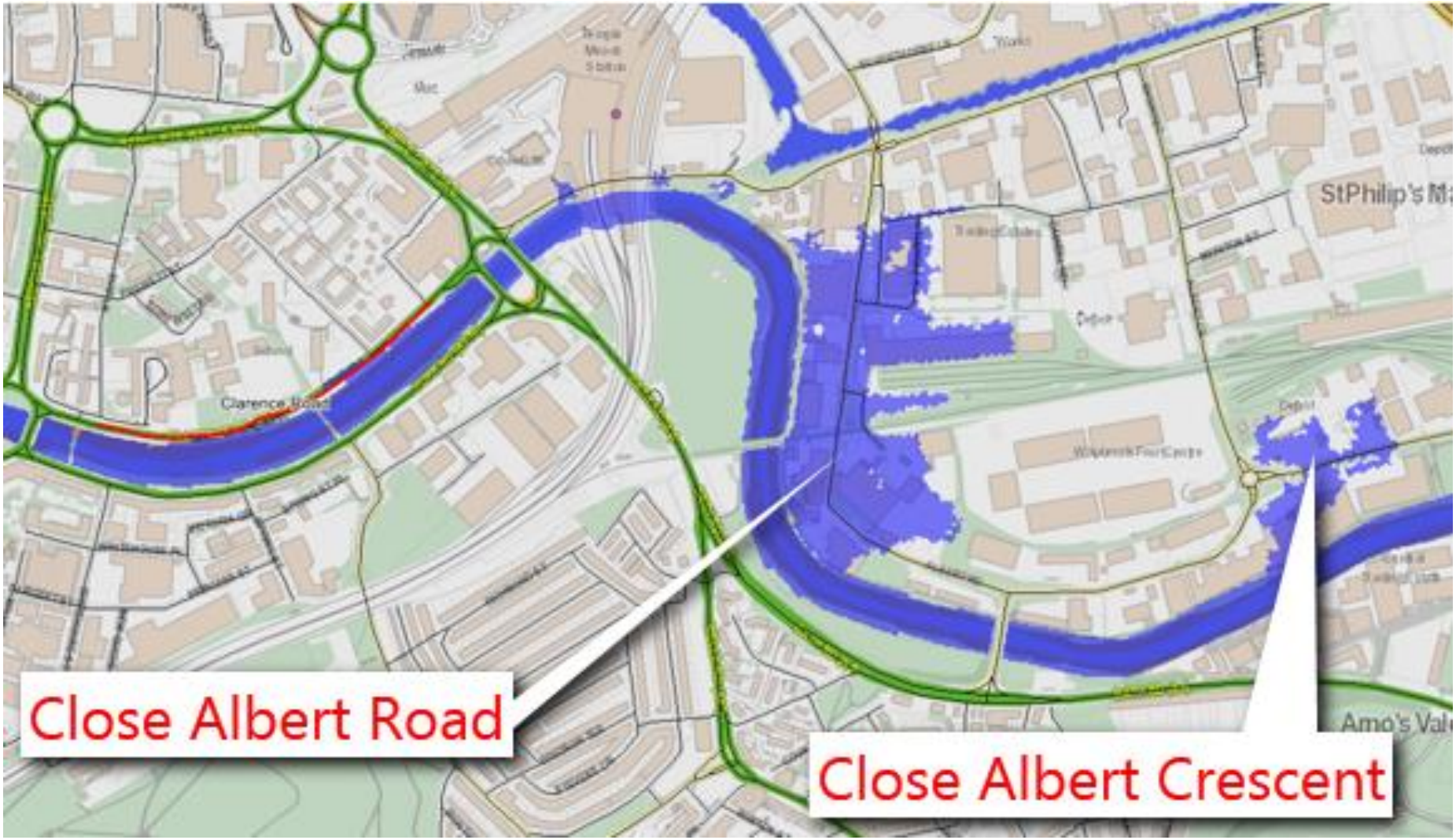
discounted at a rate of 3.5% per year over the 21 years from 2015 to 2036 (a 53% reduction in total). The undiscounted equivalent value for 2036 for monetised daily impact is £264,613.

# Appendix A – Modelled Scenarios

**Scenario 1 : 1 in 5 annual chance present day tidal flood**

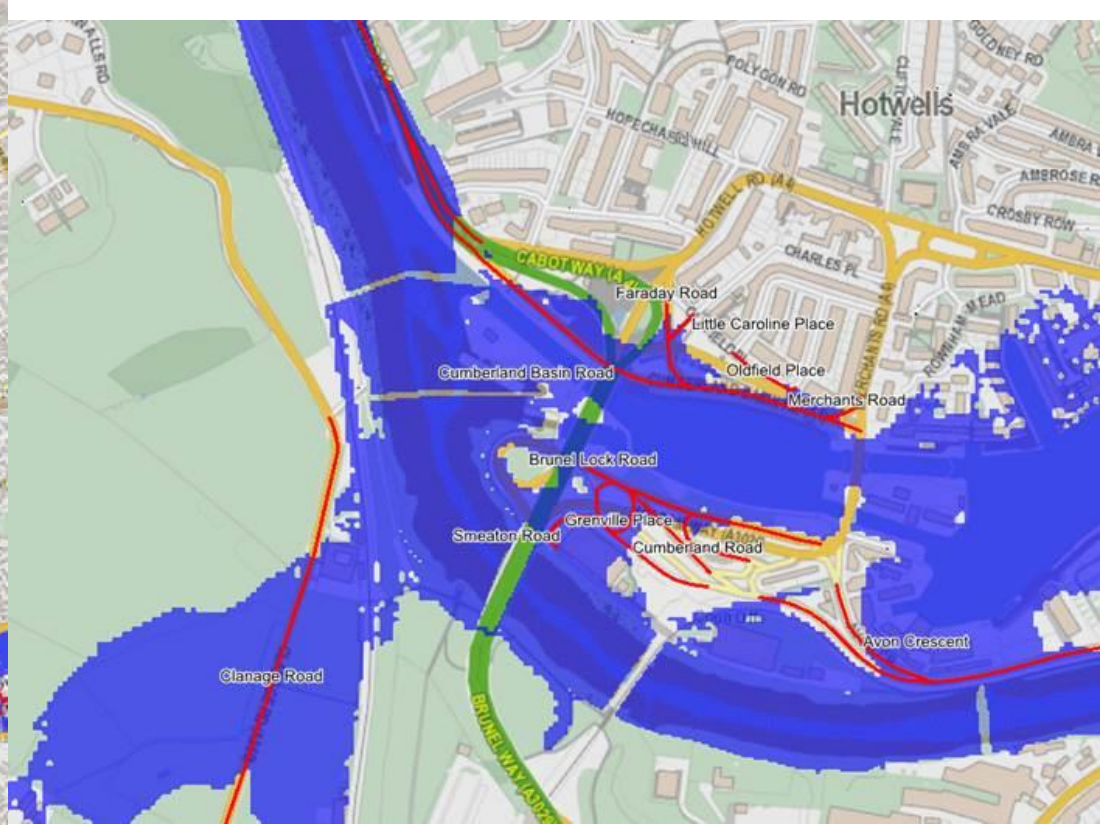


**Scenario 2 : 1 in 20 annual chance present day tidal flood** – as 1 plus

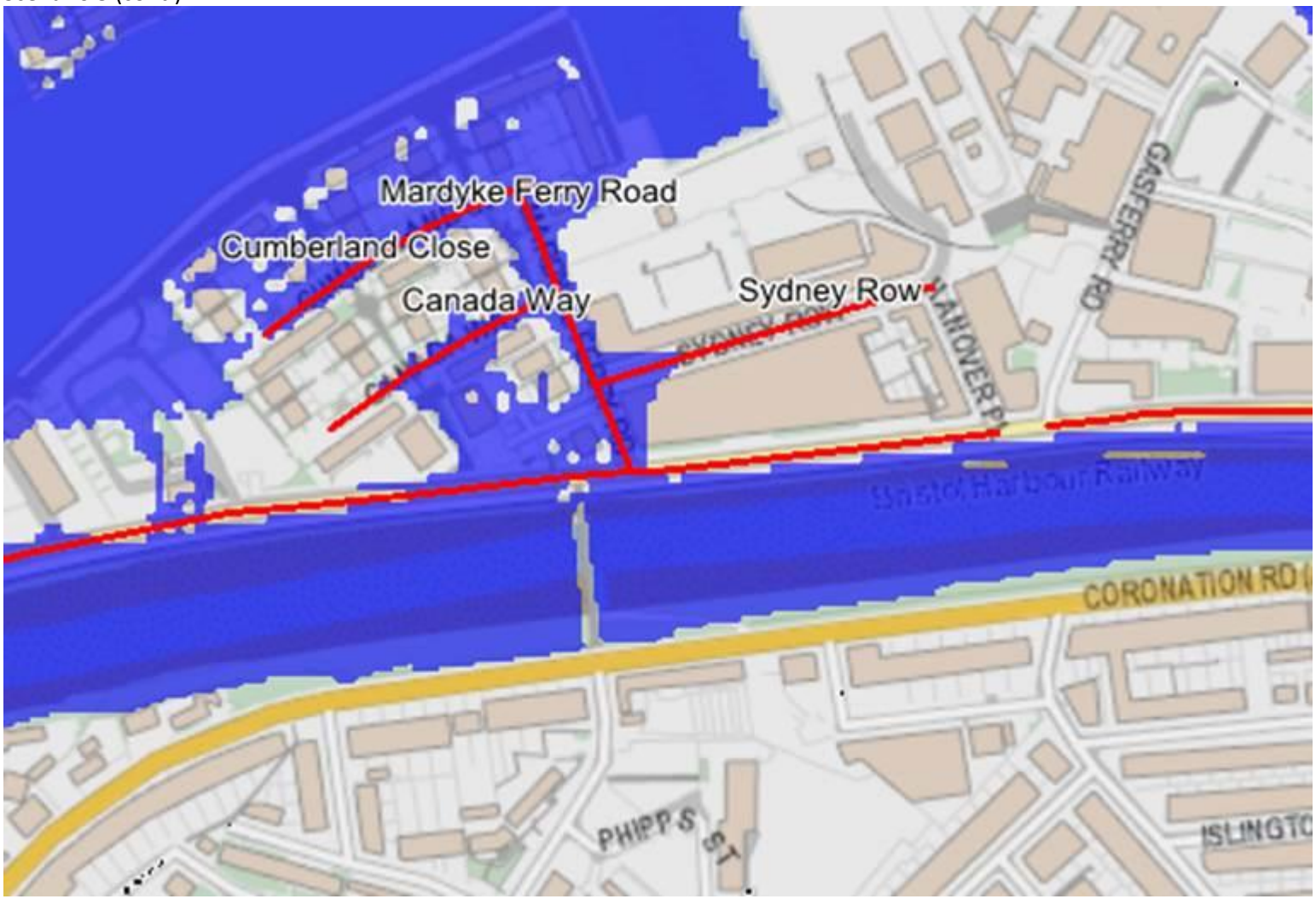



Note: Albert Crescent should read Albert Road

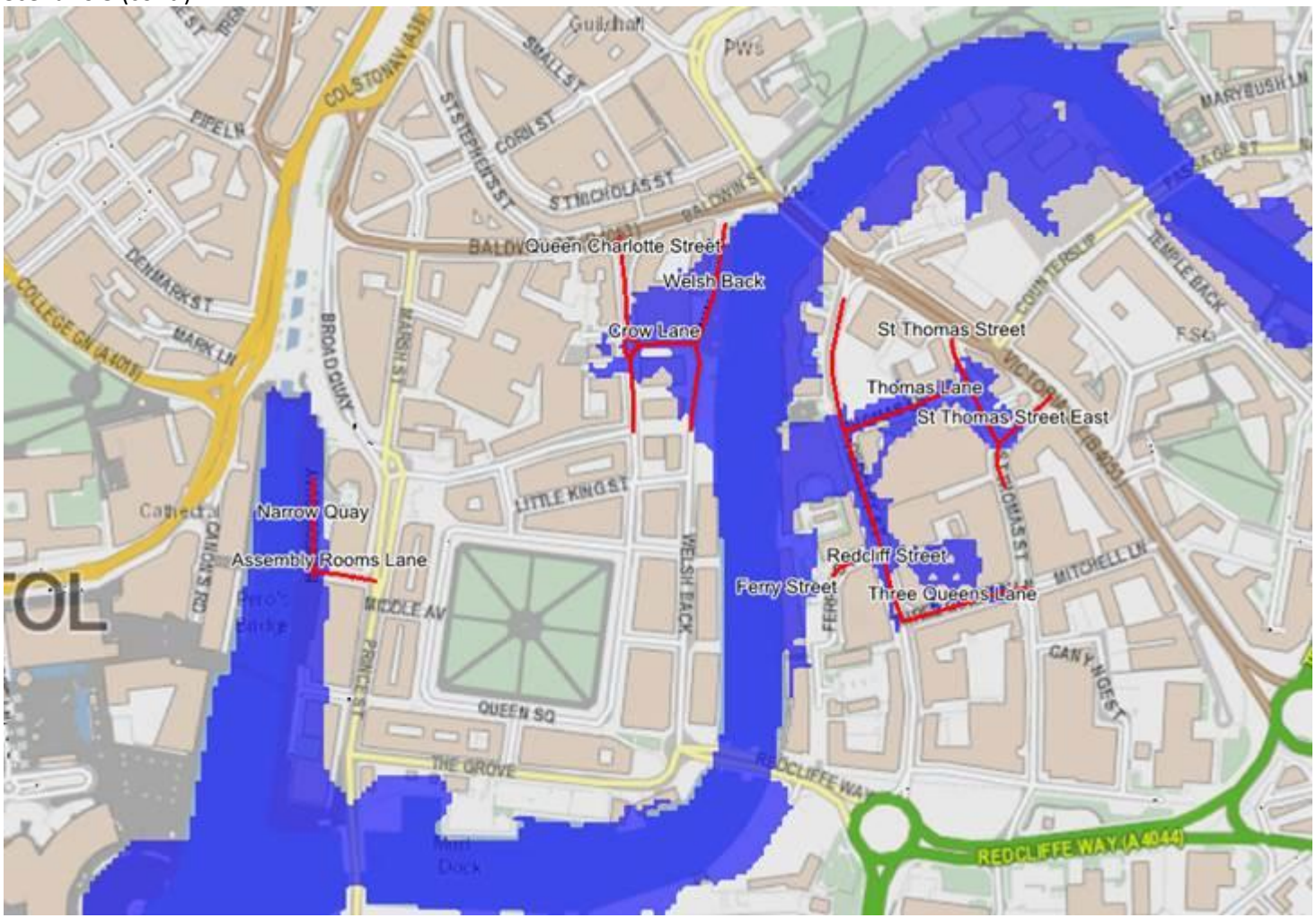
**Scenario 3 : 1 in 200 annual chance present day tidal flood (no flood walls)**

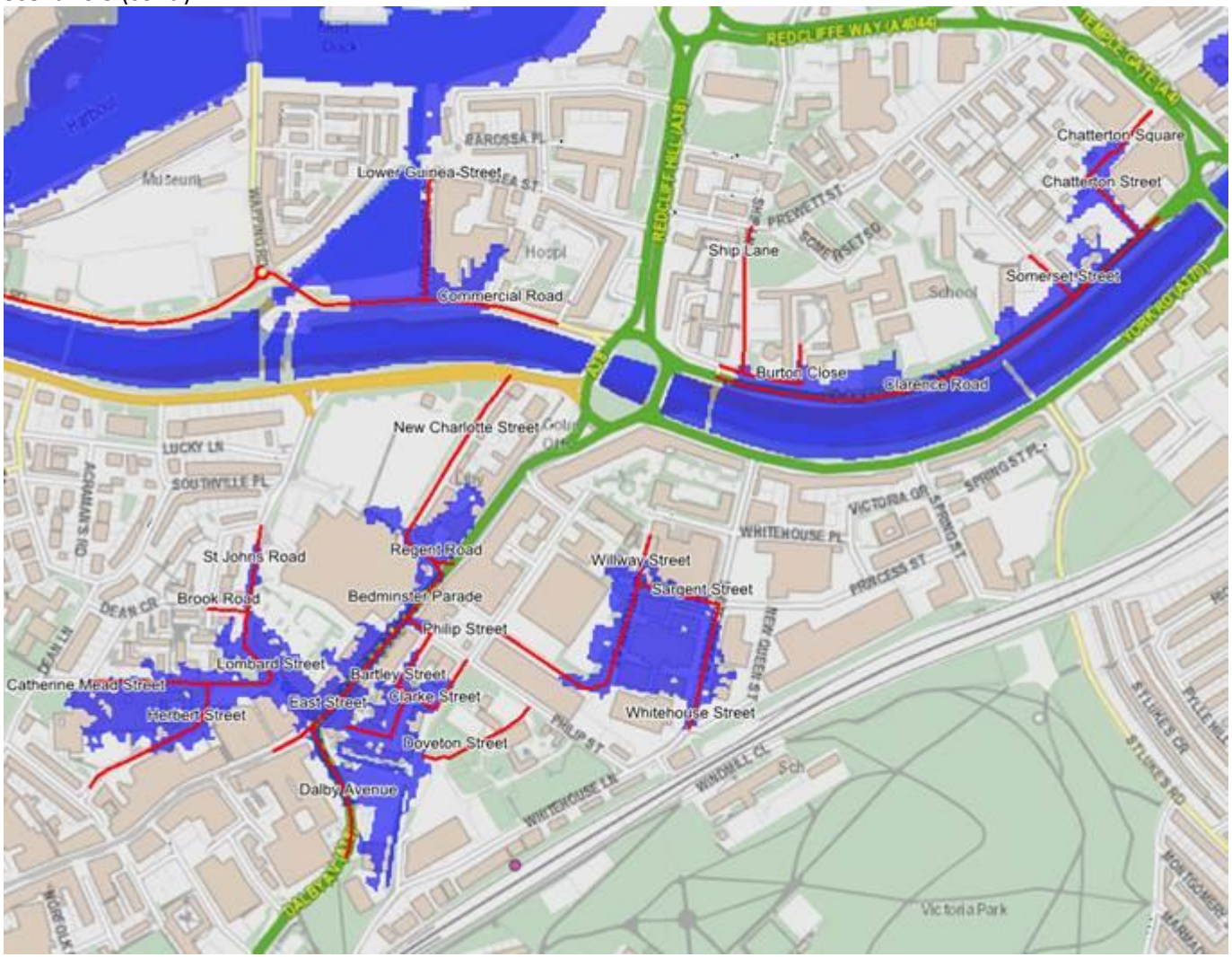
Scenario 3 (cont.)



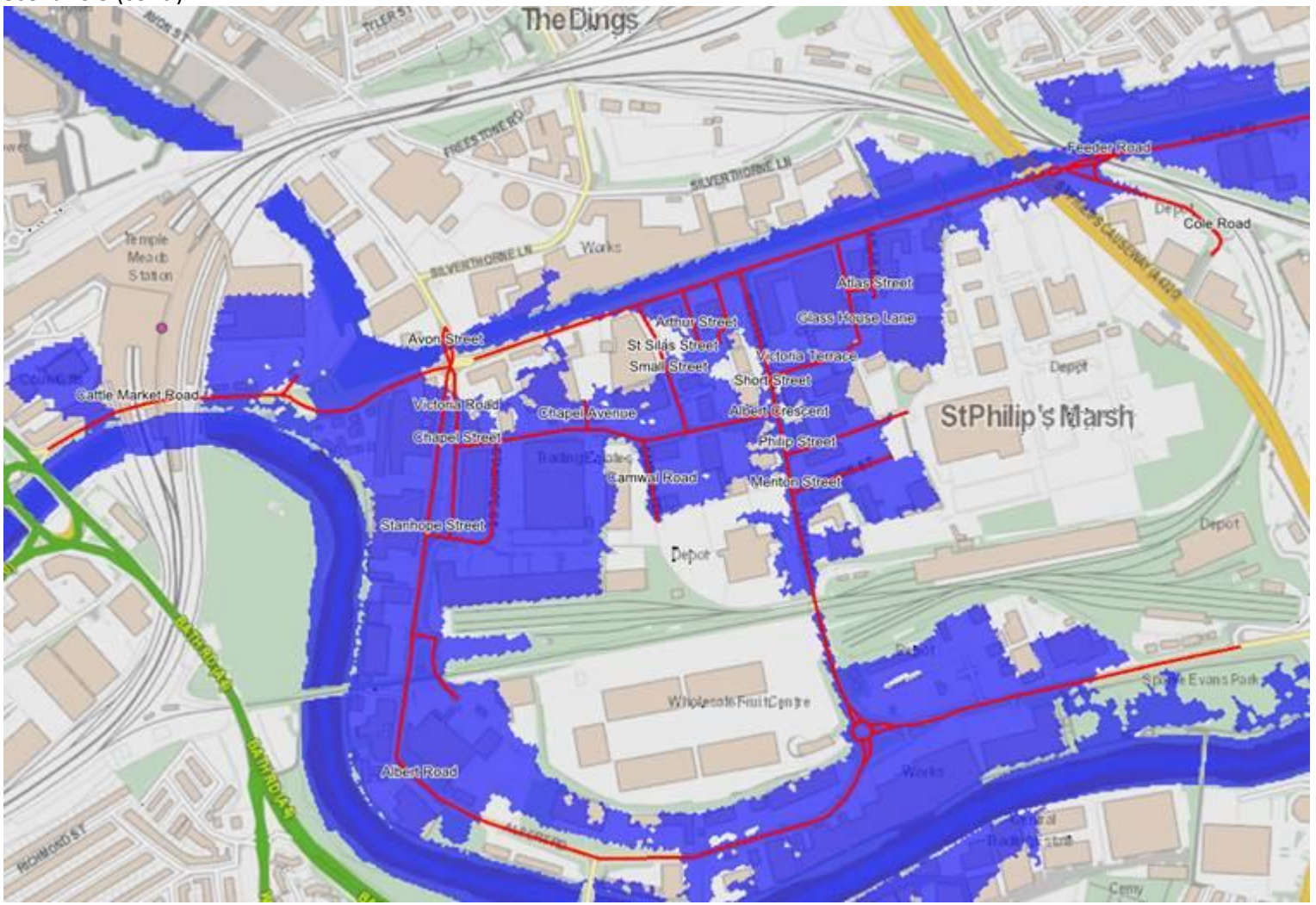
Scenario 3 (cont.)



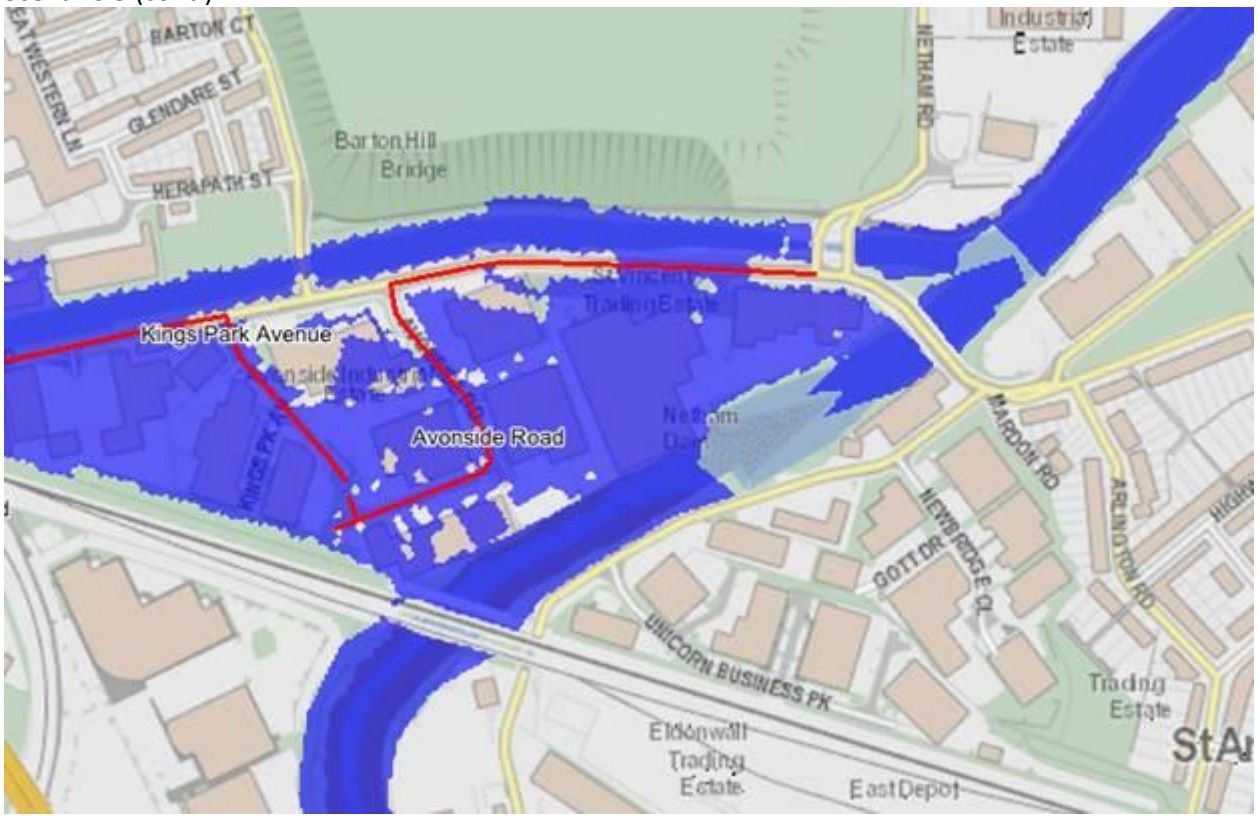
Scenario 3 (cont.)



Scenario 3 (cont.)

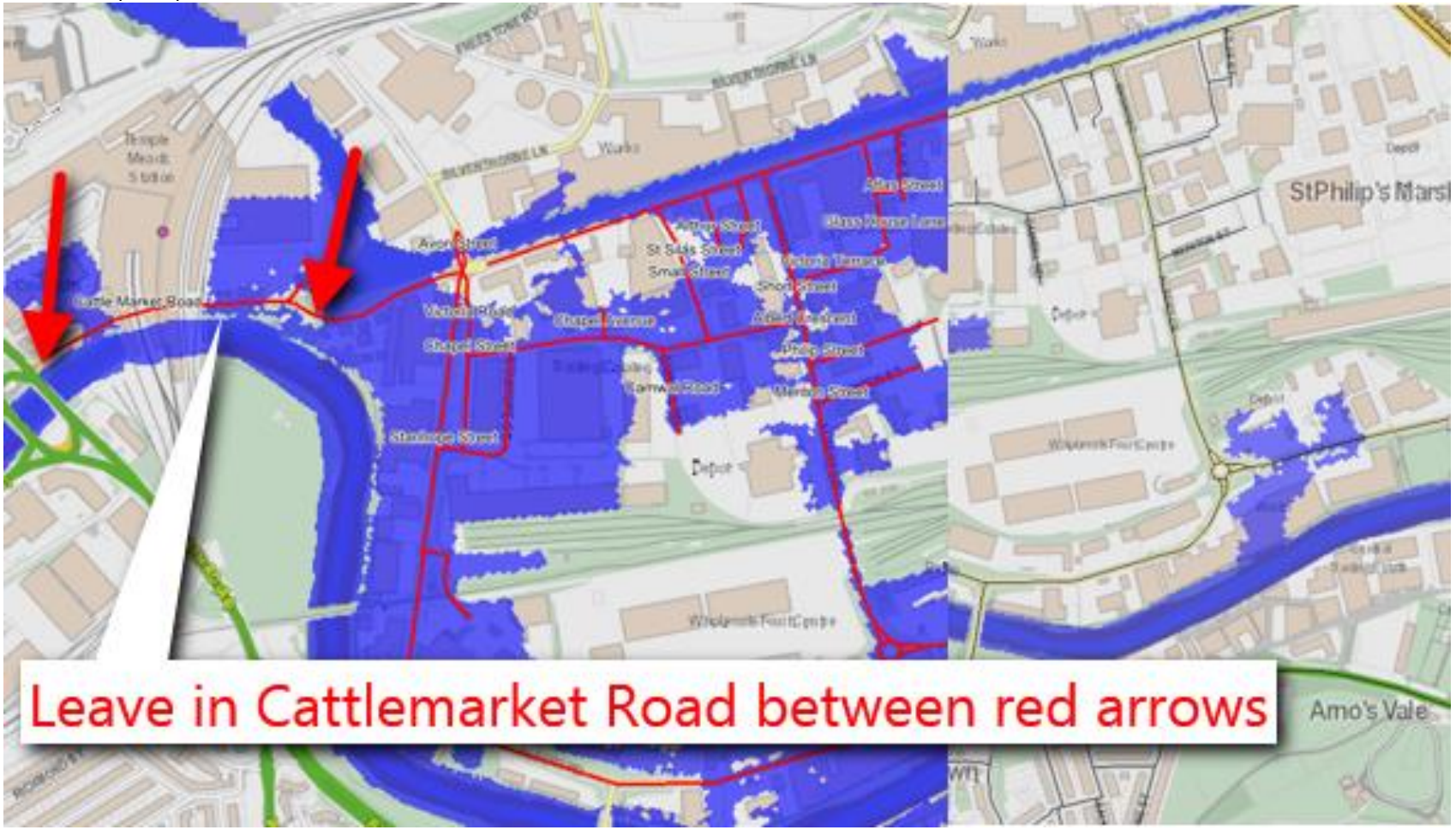


Scenario 3 (cont.)



**Scenario 4 : 1 in 200 annual chance present day tidal flood (with flood walls)** – as 3 but

Scenario 4 (cont.)

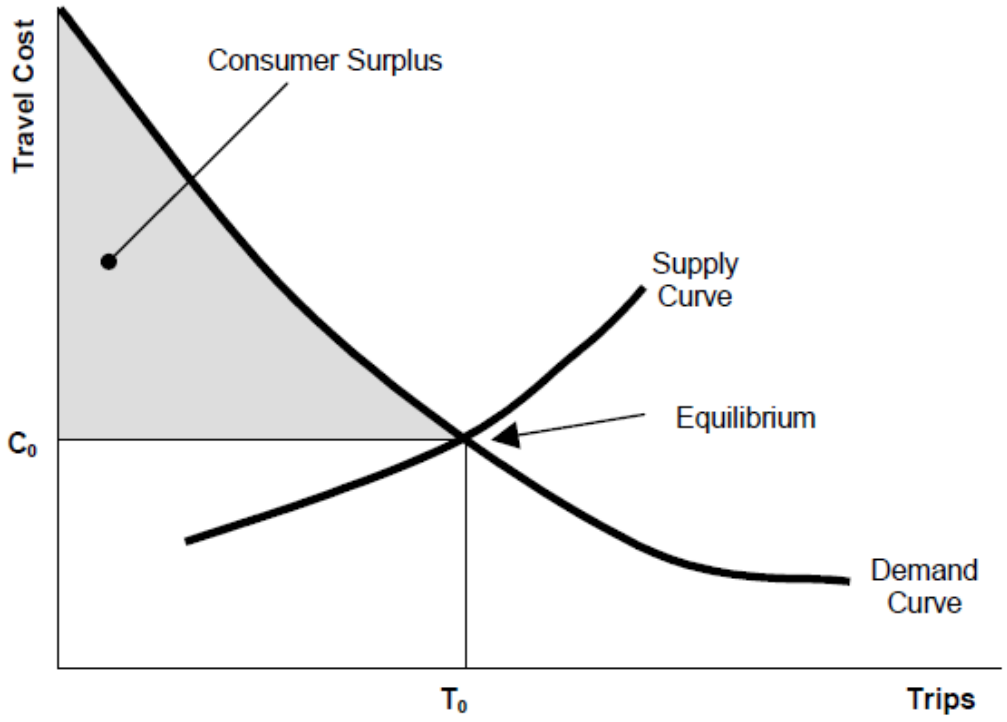


# Appendix B – TUBA Calculations

## Theory

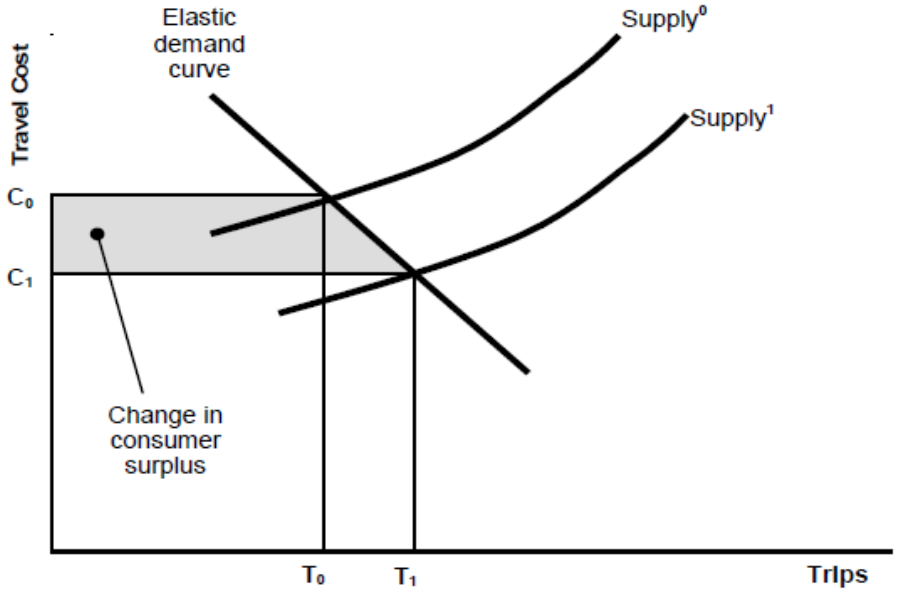
The appraisal of economic benefits relies on the transport system equilibrium being correctly assessed by the transport model(s). That is to say that the numbers of trips $T_0$ (demand) and system performance (supply) are in balance producing an average trip cost $C_0$. Figure 3.1 shows this equilibrium point between notional curves of demand and supply.

**Figure 3.1: Supply/demand equilibrium showing consumer surplus**




At this equilibrium point there are benefits to the consumer over and above the actual trip costs, that is, there is a difference between what they would be willing to pay and what they actually pay. This difference is the consumer surplus. Figure 3.2 shows the consumer surplus diagrammatically by the shaded area above the equilibrium trip cost.

**Figure 3.2: Change in consumer surplus**

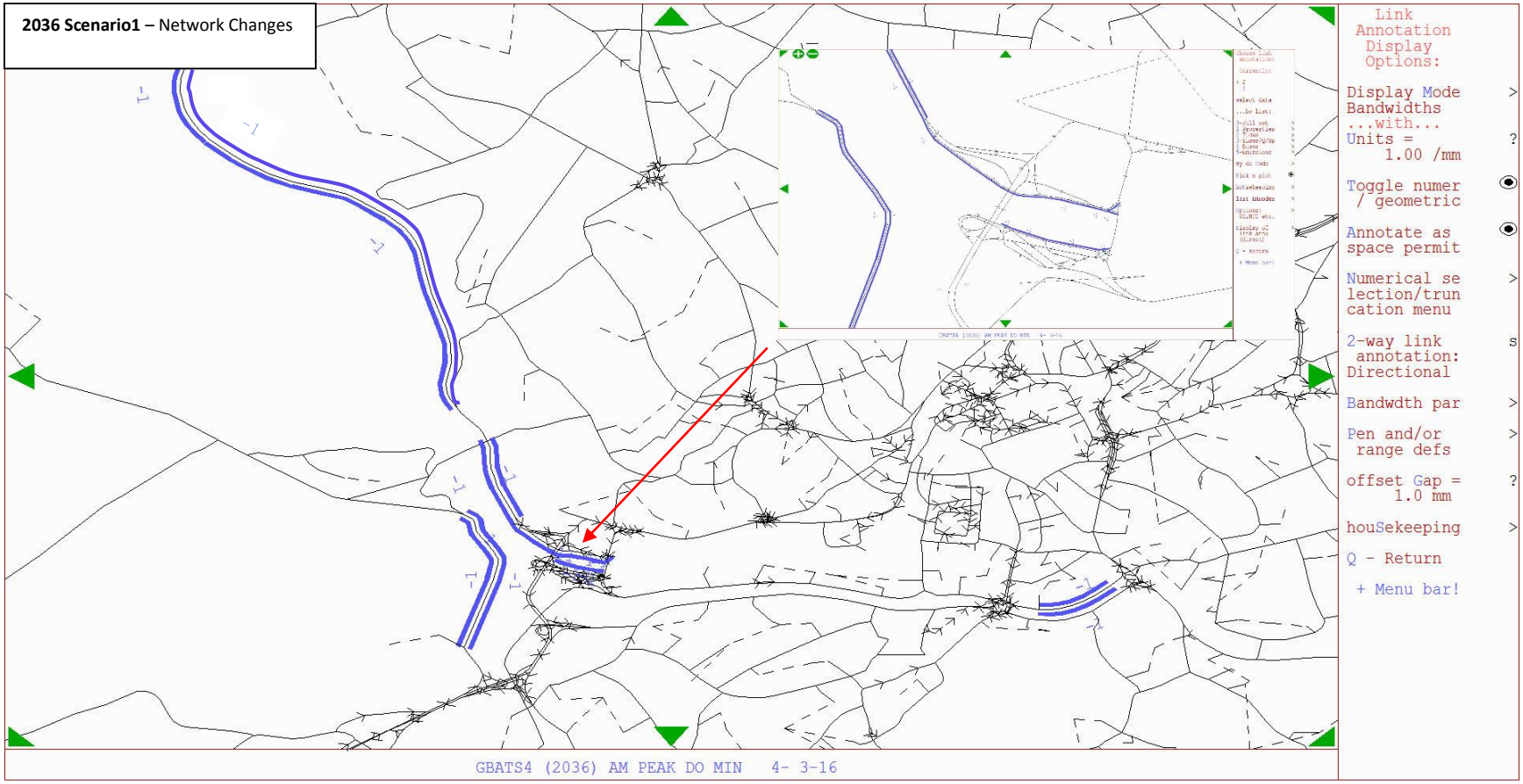



We now consider the case where a transport scheme (the do something (DS) – the former situation is the do-minimum (DM)) is proposed that will reduce travel costs. This shifts the supply curve down as shown in Figure 3.2 and a new system equilibrium is found at the point where the demand is $T_1$ and the supply cost is $C_1$. The user benefits of the scheme are given by change in consumer surplus. This is shown by the shaded area on the graph. If we assume that the demand curve is linear between $T_1$ and $T_0$ then the change in consumer surplus is given by:

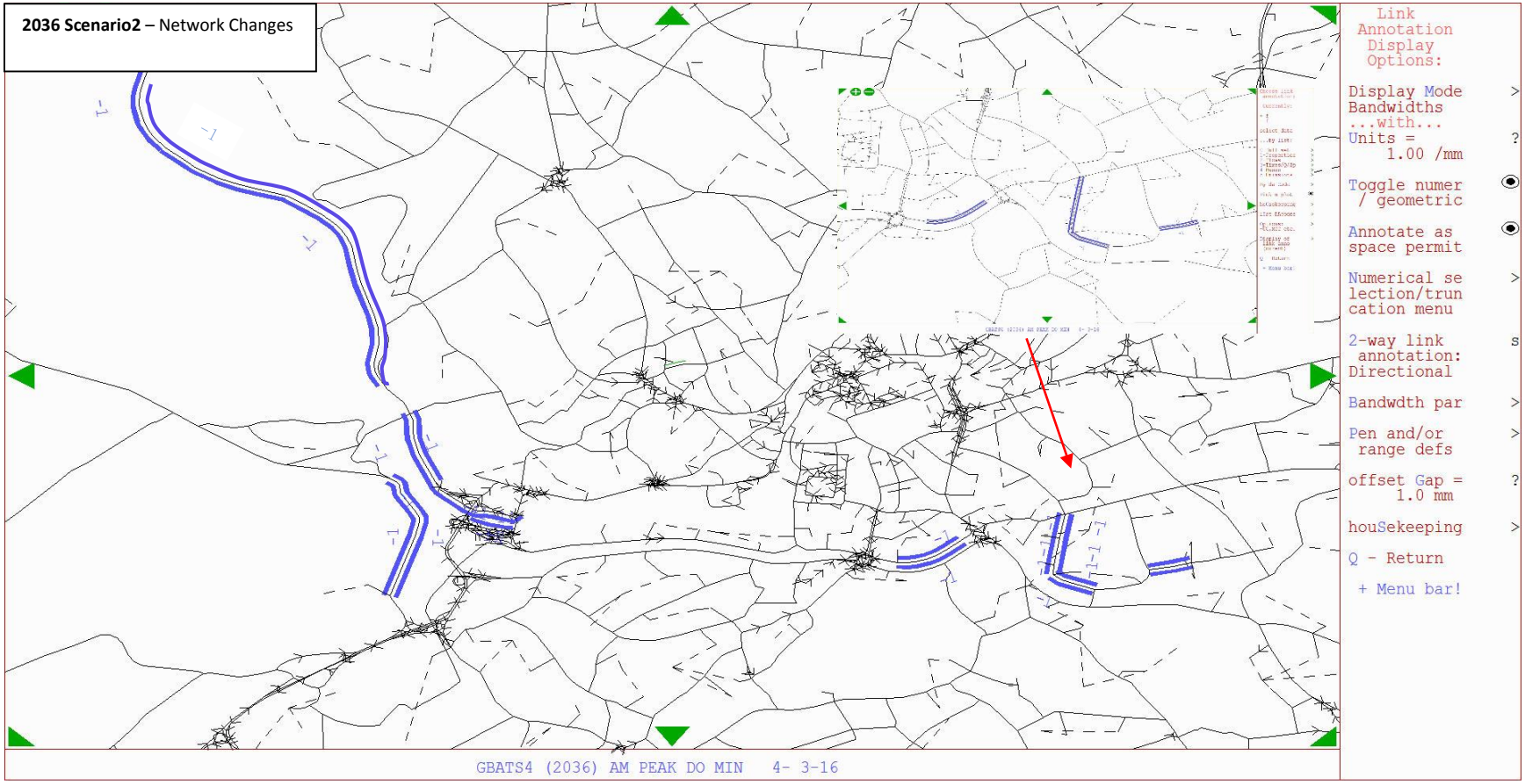
$$\frac{1}{2}(T_0 + T_1)(C_0 - C_1)$$

Calculated for each OD, user class, time slice and mode separately and then summed this is known as the 'rule of a half'. The assumption that the demand curve is linear will normally only be appropriate for relatively small changes in costs. Modifications to deal with large changes in cost are discussed in Section 11. Problems also arise during the appraisal of a new mode (see Section 12).

The above diagrams are a simplification of the actual situation. In most transport models there are a number of different OD pairs, different modes and different time periods, all of which interact in the demand and supply functions. However, the rule of a half is equally valid in these cases.




Note, all edits correctly shown except for Portway southbound, which has been coded correctly.

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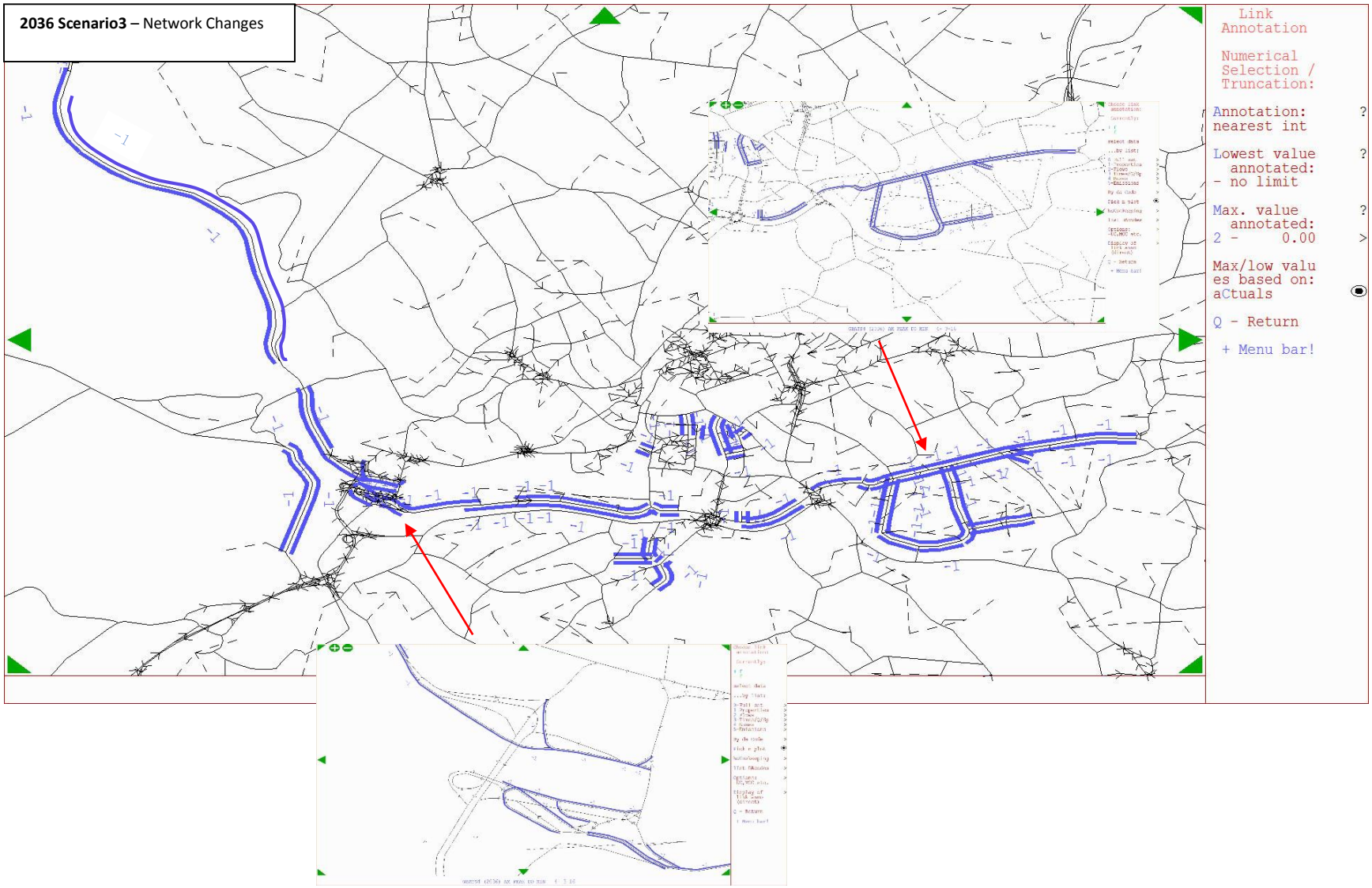


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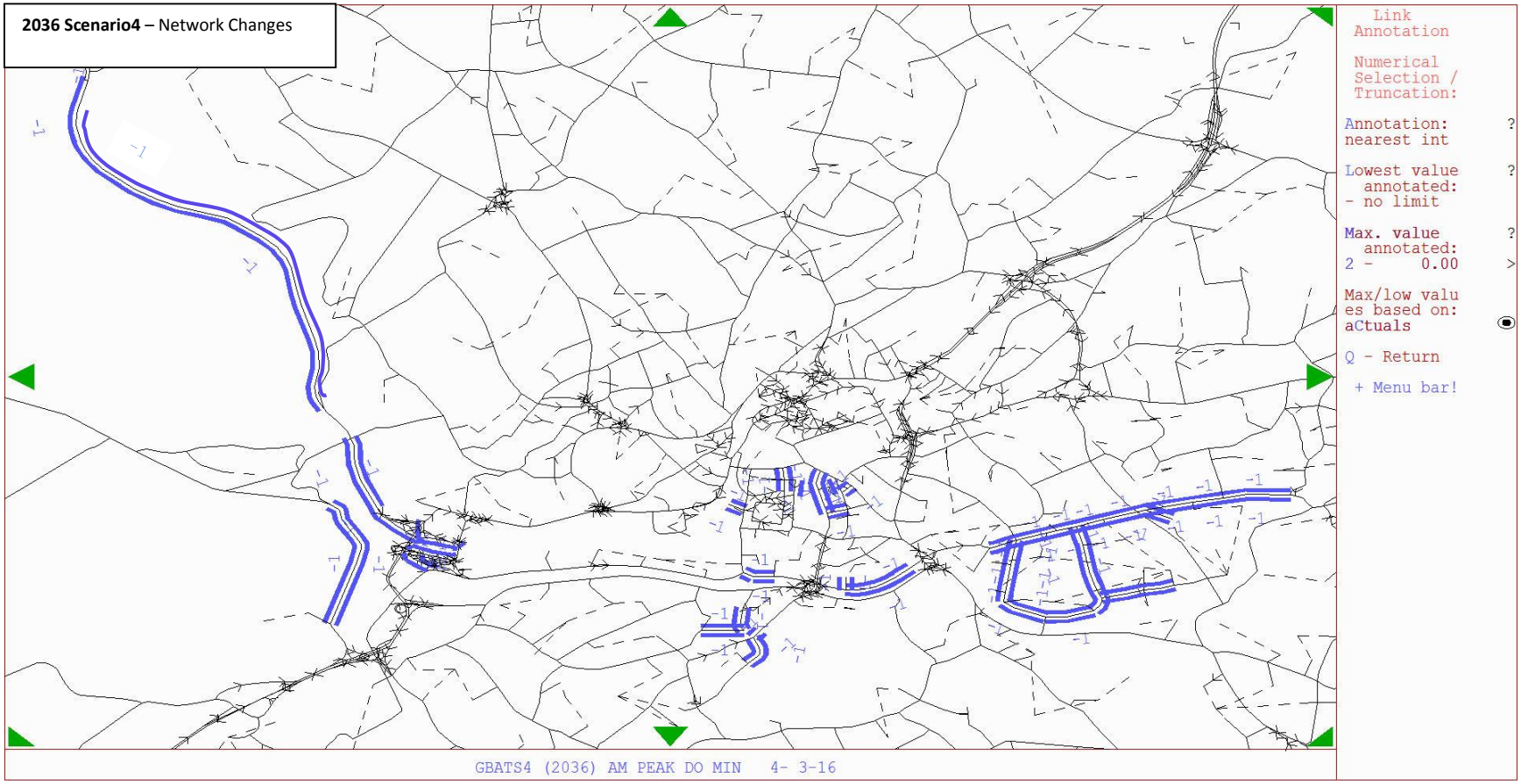


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