Indicators and trends

Monitoring climate change adaptation

Indicator name				Version
BT16 Rail network benefitting from fluvial flood protection				**14/03/16**

Indicator type:	Risk/opportunity	Impact	Action
			X

SCCAP Theme	SCCAP Objective	CCRA risk/opportunity
Buildings and infrastructure networks	B1; B2; B3	FL8b Railways at significant risk of flooding

At a glance

- Scotland's rail network is at risk of flooding from fluvial sources
- Climate change predictions suggest that flooding of rail infrastructure in Scotland will become more extensive and more frequent
- Flood prevention schemes are important for climate risk management as they help to manage flooding impacts
- Flood prevention schemes are located across Scotland, and are focused on main urban centres. 21% of schemes provide a high standard of protection (SOP)
- Only a small proportion of the rail network benefits from fluvial flood protection measures

Latest Figure	Trend
The proportion of the entire rail network benefitting from fluvial flood protection (regardless of whether it is at flood risk or not) is **0.24%.**[1] The proportion of the rail network which is at fluvial flood risk and that also benefits from fluvial flood protection is around **9%** (1/11th)[2].	

Why is this indicator important?

Transport supports many different social and economic functions. In 2013/14, 86.3 million passenger journeys were made by rail in Scotland - 16% of all public transport journeys. Rail patronage has increased by 35% since 2004/05 and constitutes a growing share of public transport journeys. In contrast, there has been a decline of 8.2% in the amount of freight (tonnes) lifted by rail between

[1] The assessment of this indicator has been undertaken for 0.5% probability (1:200 year) flood events only

[2] Just 2.62% of the rail network is at risk of fluvial flooding (see indicator BT8).

2002/03 and 2012/13. The modal share of freight (in tonne-km) carried by rail in Scotland in 2010 was 7% (Transport Scotland, 2014).

Flooding of rail infrastructure can cause disruption to rail transport with knock-on consequences for these functions – e.g. preventing or delaying people from reaching work, delaying rail freight. Climate change predictions suggest that flooding of rail infrastructure will become more extensive and more frequent. This indicator will provide insight into action taken to protect the rail network.

Related indicators:
BT8 Railway network at risk of flooding
BT9 Disruption risk to railway services as a result of flooding
BT12 Flood events affecting the railway network

What is happening now?

Figure 1 shows the location of all fluvial flood defence schemes, and the location of schemes that have been designed to an SOP of 200 years or more. Figure 2 shows the areas defended from fluvial flooding (where SOP is 200 years or more) as well as the sections of rail network that benefit. Figure 2 also shows a close up for a small section of the urban rail network in southern Glasgow in proximity to Pollokshaws West, Thornliebank and Cathcart train stations.

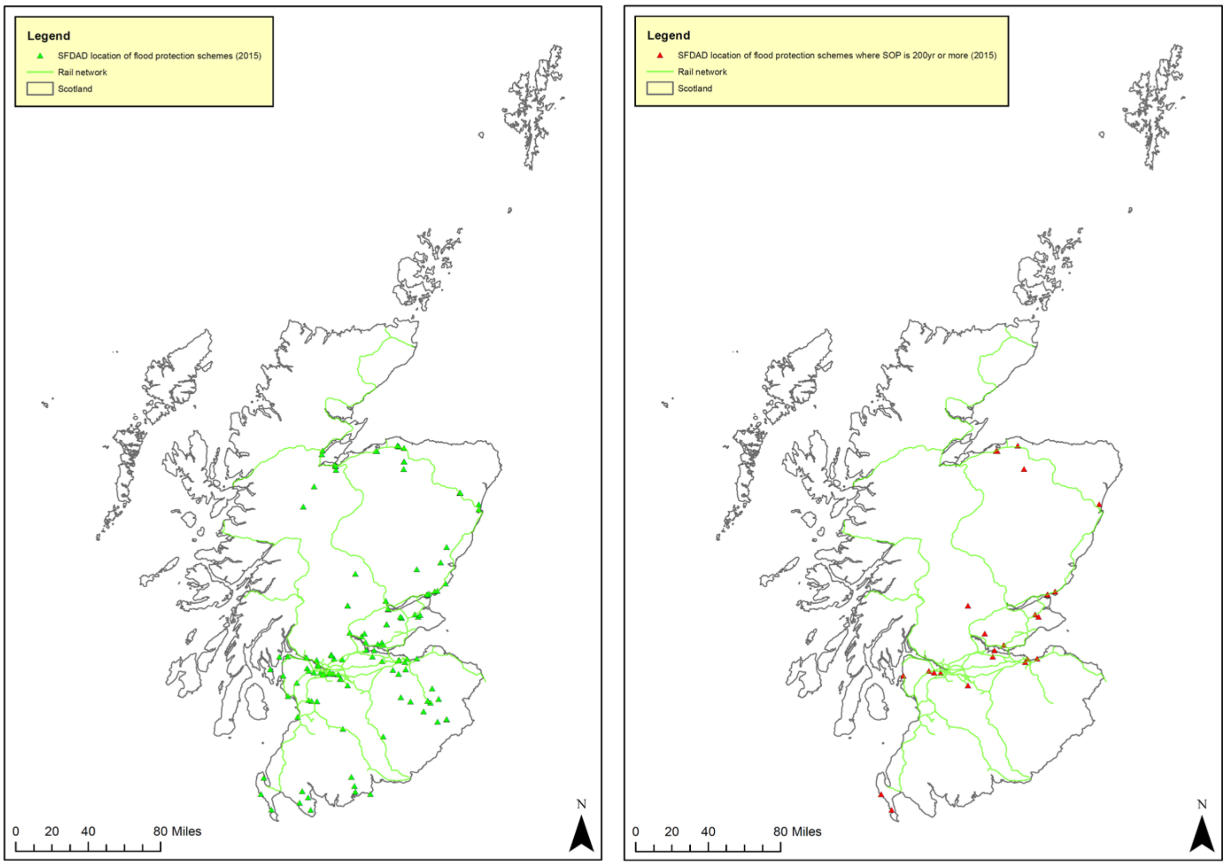

Figure 1 Location of flood defence schemes in Scotland: all schemes (LH map); Schemes designed to an SOP of 200 years or more (RH map)

Note: The Figure is based on data from SFDAD[3] for 2015.

The length of the rail network benefitting from flood protection measures for a 0.5% probability (1:200 year) fluvial flood event is 11.24km which represents 0.24% of the rail network[4].

To put this figure in context it is sensible to compare this to the proportion of the rail network that is actually at fluvial flood risk – which is 2.62% (see Indicator BT8). The proportion of the rail network which is actually at fluvial flood risk and also benefits from fluvial flood protection is around **9%** (1/11th).

This indicator is based on data from the SFDAD only (2015 data) and relates to protection from fluvial source flooding only. See Limitations section for further discussion.

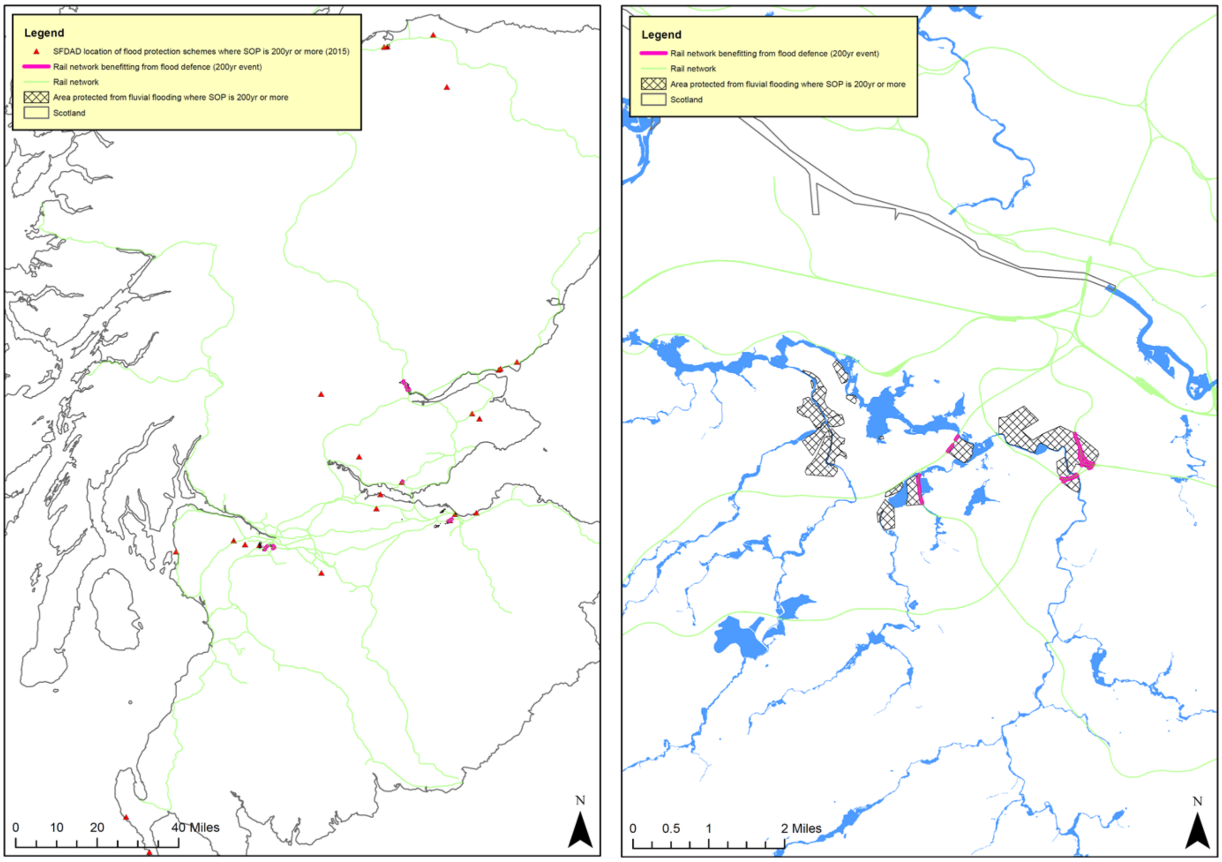

Figure 2 Fluvial flood scheme defended areas where SOP is 200 years or more (LH map) and detail of the urban rail network in southern Glasgow benefitting from flood defence schemes (RH map)

Note: The LH map shows the fluvial flood defence schemes with a SOP of 200 years or more. These focus on key population centres (Edinburgh and Glasgow) as well as strategic transport links (e.g. the Highland Main Line at Perth, A96 at Forres), reflecting the consequence element of risk. The RH map shows the defended area of the White Cart Flood Prevention Scheme (black hatch). This scheme protects the urban rail network in southern Glasgow close to Pollokshaws West, Thornliebank and Cathcart train stations (pink lines).

What has happened in the past?

[3] SFDAD is the Scottish Flood Defence Asset Database

[4] The total length of the Scottish rail network used in this analysis was 4,696.51km (2015 data)

Legislation has been a key driver of historic flood prevention activity. The Flood Prevention (Scotland) Act 1961 provides powers to enable Councils in Scotland to take measures for the prevention or mitigation of flooding of non-agricultural land in their areas (HMSO, 1961). Some 72 flood prevention schemes were funded and delivered in Scotland under this legislation (JBA Consulting, 2012). The objectives of these flood prevention schemes focus on the protection of commercial, industrial or residential properties in Scotland (Bassett *et al*, 2007). As such, any protection of rail infrastructure appears to be a secondary consideration. The nature of flooding is such that most flood prevention schemes provide for the management rather than prevention of flooding (JBA Consulting, 2012). In effect, most schemes built under the 1961 Act are 'hard engineered' interventions (e.g. embankments) located in flood risk areas designed to help prevent localised flooding where the consequences of a flood would be severe.

What is projected to happen in the future?

Network Rail's Scotland Route Weather Resilience and Climate Change Adaptation Plans include a range of ongoing and proposed actions to help address flooding impacts to the rail network, including impacts that are expected to worsen or become more frequent as a result of climate change (Network Rail, 2014). This includes actions at specific sites to address known flooding issues as well as more general measures to reduce the vulnerability of the rail network to current and possible future flood risks including an asset strategy to upgrade small diameter culverts (e.g. on the West Highland Line) and various measures to make track assets more resilient to flooding (ibid).

The 2009 Flood Risk Management (Scotland) Act introduced a more sustainable approach to flood risk management (FRM) suited to the impacts of a changing climate (Scottish Government, 2015). In particular, the 2009 Act establishes a framework for coordination and cooperation between FRM stakeholders, helping to pave the way for catchment scale approaches including the use of natural flood management (e.g. restoring watercourses to a more natural form by reducing morphological pressures, planting vegetation and managing slopes to reduce runoff at source) to help restore more favourable runoff patterns and reduce flood risk (Scottish Government, 2011). Although there will always be a requirement for more traditional 'hard engineered' flood prevention schemes (e.g. embankments) in high risk areas, the 2009 Act establishes a statutory basis for considering wider catchment or land based approaches that may be more resilient in the face of climate change (ibid). In consequence, it may be the case that the location, scale and type of flood risk alleviation measures adopted in the future changes to reflect the 2009 Act's more integrated, catchment scale approach. For example the use of land management measures in rural upper catchments could reduce the need for flood embankments in urban areas lower down the catchment.

The National Flood Risk Assessment (NFRA) carried out under the 2009 Act identifies a number of Potentially Vulnerable Areas (PVAs) across Scotland (SEPA, 2011). The PVAs highlight areas that are particularly vulnerable to flooding based on a range of different receptors as well as proxies for receptor value and vulnerability (SEPA, undated). In effect, the more receptors exposed to flooding (and the more valuable and vulnerable they are) the greater the overall risk, whereby risk is a function of event likelihood and consequence (Scottish Government, 2011). Transport (roads, railways and airports) are included as receptors in the NFRA (SEPA, undated). The PVAs are used to focus FRM effort to the locations where actions will deliver the greatest benefit by reducing overall flood risk. As a result, FRM action under the 2009 Act is likely to take a more strategic, targeted approach. Also, the criteria used in the NFRA (e.g. rurality provides a proxy for vulnerability) means that PVAs are spread variously around the country and not just concentrated on densely populated urban areas (though most PVAs do cluster around the central belt).

Thus it is anticipated that the type, scale, location and strategic targeting of flood prevention measures will change in the future, given the focus on risk based, catchment scale approaches. As the contents of the forthcoming Flood Risk Management Strategies (FRMS) and Local Flood Risk Management Plans (LFRMP) are not yet known it is not yet possible to determine how the rail network might benefit. However, given the nature of the PVA approach, it seems plausible that the proportion of the network benefitting from flood prevention measures will increase.

The design of flood prevention schemes is constantly being improved through the use of design flows or floods that account for climate change and through more detailed hydraulic models (Bassett *et al*, 2007). As a result, future schemes are likely to be better designed to cope with the demands of climate change.

Patterns of change

No patterns of change have been identified.

Interpretation of indicator trends

No trends identified for BT16 due to lack of historical data.

Limitations

There are several key limitations to the assessment as summarised below:

1. The SFDAD aims to be fully comprehensive although there are some gaps – e.g. in terms of historic (1961 onwards) flood prevention scheme data that has been destroyed, lost data as a result of restructuring of Local Authority boundaries (e.g. as a result of the 1994 Local Government Act) and the scope of the SFDAD which is focussed on schemes constructed under the Flood Prevention (Scotland) Act 1961 (Angus Pettit – JBA Consulting Principal Analyst, personal communication, June 4, 2015). Furthermore, Bassett *et al* (2007) highlight inconsistencies between flood prevention scheme data held centrally (by the then Scottish Executive) and locally by Local Authorities – e.g. some Local Authorities were unaware of schemes within their jurisdictional area and others held information on schemes that were not held centrally. It is not clear if (or to what degree) these data management issues have been resolved through the SFDAD. Any under representation of flood defence schemes within the SFDAD would affect the comprehensiveness of this assessment.
2. The intention is for the SFDAD to be kept up to date and for new schemes to be added when data is made available by Local Authorities (Angus Pettit – JBA Consulting Principal Analyst, personal communication, June 4, 2015). However it is not clear if or how the SFDAD is kept current in terms of scheme maintenance, condition and upgrade, all of which could influence the SOP afforded by the scheme. For example, Bassett *el al* (2007) highlights a number of projects and activities that were undertaken even during the course of the SFDAD project (e.g. repairs, maintenance, updates to surveys or modelling). It may be the case that interventions such as these are commonplace and associated alterations to schemes would affect the accuracy of the assessment.
3. The SOP afforded by schemes covered within the SFDAD is based on design flows or floods for a given return period at the time of construction. Bassett *et al* (2007) highlight how in the majority of cases, updated flow or flood estimates (e.g. those undertaken as part of the SFDAD project) are higher than those used in the original scheme design. This could be caused by a number of factors

including climate change (e.g. higher rainfall and associated flows means that higher magnitude flood events are becoming more frequent), land use change and hydraulic changes to channel, banks and floodplain upstream of the scheme. Bassett *et al (*2007 p.64) conclude that *"the results of this study indicate that few schemes currently protect to the designed standard"*. This could affect the accuracy of the assessment – e.g. if schemes are selected for assessment the basis of the SOP field in the SFDAD data (see Assessment Step No.2 in Table 4) yet they are not providing 200 year SOP for current climatic and hydrological conditions.

4. This indicator only considers the benefits of fluvial flood protection measures. There is no consideration of rail network design for mitigation of pluvial or drainage flooding[5] or the benefit afforded to the rail network by coastal flood prevention schemes. Furthermore, it is anticipated that a number of schemes designed to manage coastal erosion or provide coastal protection under the Coastal Protection Act 1949 will also provide an element of flood protection (JBA Consulting, 2012). The flood risk alleviation benefit of these schemes is currently not considered. As such, it is likely that the extent of the rail network benefitting from flood prevention measures is greater than stated here.
5. Major railways located in the floodplain are often raised above the ground surface on embankments. The difference in elevation afforded by these embankments is not always identified in flood modelling and mapping (Thornes et al, 2012). As such it may be the case that the flood protection (from SFDAD schemes) to rail infrastructure is over-estimated – i.e. where the embankment itself would raise the railway above the protected area.
6. Network Rail's Network Links Layer which was used in this analysis includes double sections of track at many locations as well as railway siding etc. It should be noted that the total length of track used in this analysis does not correspond with the length of track published by Transport Scotland (2014) which counts one kilometre of single or double-track as one kilometre of route length.
7. Due to resource constraints assessment was only undertaken for 0.5% probability (1:200 year return period) modelled flood events. These are low probability events and are located at the more severe end of the flood event spectrum. It should also be noted that the magnitude of a 1:200 year event is based on historic data and may be greater in the future as a result of climate change than represented in this analysis.

References

Bassett, D., Pettit, A., Anderton, C., and Grace, P (2007). *Scottish Flood Defence Asset Database Final Report* [online]. Available at: http://www.gov.scot/resource/doc/195446/0052419.pdf [accessed 02/06/15]

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JBA Consulting (2012). *Scottish Flood Defence Asset Database Website User Guide* [online]. Available at: http://www.scottishflooddefences.gov.uk/Site/Documents/SFDAD_User_Guide.pdf [accessed 05/06/15]

Network Rail (2014). *Route Weather Resilience and Climate Change Adaptation Plans – Scotland* [online]. Available at: http://www.networkrail.co.uk/publications/weather-and-climate-change-resilience/ [accessed 08/06/15]

Scottish Government (2011). *Flood Risk Management (Scotland) Act 2009: Delivering Sustainable Flood Risk Management* [online]. Available at: http://www.gov.scot/Resource/Doc/351427/0117868.pdf [accessed 05/06/15]

[5] Both of which are important sources of flooding to the rail network (Network Rail, 2014)

Scottish Government (2015). *Scottish Government flooding pages* [online]. Available at: http://www.gov.scot/Topics/Environment/Water/Flooding [accessed 05/06/15]
SEPA (2011). *National Flood Risk Assessment* [online]. Available at: http://www.sepa.org.uk/environment/water/flooding/flood-risk-management/national-flood-risk-assessment/ [accessed 05/06/15]
SEPA (undated). *Flood Risk Management (Scotland) Act 2009 – National Flood Risk Assessment Methodology* [online]. Available at: http://www.sepa.org.uk/media/99914/nfra_method_v2.pdf [accessed 21/05/15]

Further information

ClimateXChange (2016) Adaptation to Climate Change: Context and Overview for Transport Infrastructure Indicators. Available online at: http://www.climatexchange.org.uk/adapting-to-climate-change/indicators-and-trends/

Acknowledgements

Analysis and development was undertaken by Dr Neil Ferguson (University of Strathclyde) and Dr Peter Phillips (Collingwood Environmental Planning Limited).

Katherine Beckmann, Heriot-Watt University / CXC contributed to this indicator.

SEPA and Network Rail provided the bulk of the data underpinning this assessment (SFDAD polygons and rail network polyline respectively).

Appendix One: Indicator metadata and methodology

Table 1: Indicator metadata

	Metadata
Title of the indicator	BT16 Rail network benefitting from fluvial flood protection
Indicator contact: Organisation or individual/s responsible for the indicator	ClimateXChange
Indicator data source	• Network Rail – Network Links (geographic representation of the rail network model) • SEPA, Scottish Flood Defence Asset Database (SFDAD)
Data link: URL for retrieving the indicator primary indicator data.	SEPA (data available by request only): http://www.scottishflooddefences.gov.uk/Site/SE_Splash.asp

Table 2: Indicator data

	Indicator data
Temporal coverage: Start and end dates, identifying any significant data gaps.	Network Rail data was updated 01/04/15 SFDAD data is probably 1961 – present day
Frequency of updates: Planned or potential updates	Network Rail– frequency of updates unknown. SFDAD is updated as and when new schemes are constructed and Local Authorities make data available to SEPA.
Spatial coverage: Maximum area for which data is available	Scotland-wide
Uncertainties: Uncertainty issues arising from e.g. data collection, aggregation of data, data gaps	
Spatial resolution: Scale/unit for which data is collected	Network Rail data: 0.5m
Categorical resolution: Potential for disaggregation of data into categories	
Data accessibility: Restrictions on usage, relevant terms & conditions	Network Rail data is available on request. SFDAD data is available under licence from SEPA.

Table 3 Contributing data sources

Contributing data sources Data sets used to create the indicator data, the organisation responsible for them and any URLs which provide access to the data.
Network Rail network links Scottish Flood Defence Asset Database (SFDAD) data: http://www.scottishflooddefences.gov.uk/Site/SE_Splash.asp

Table 4 Indicator methodology

Indicator methodology The methodology used to create the indicator data
Introduction to the approach The BT16 metric is based primarily on flood defence asset data held in the Scottish Flood Defence Asset Database – the SFDAD (Bassett *et al*, 2007). The assessment of BT16 has been undertaken for 0.5% probability (1:200 year) flood events only. For each flood defence asset included, the SFDAD includes modelled defended and undefended areas for 1:100 year, 1:200 year and 1:1000 year flood events, based on the outputs of a hydraulic model for each scheme (ibid). The schemes included within the SFDAD are varied in nature and have been designed to protect against flood events of different magnitudes – referred to as the standard of protection (SOP) afforded by a given scheme (ibid). For example, a scheme designed to an SOP of 200 years or more will protect against a 0.5% probability (200 year) flood event (at the time of construction[6]). In effect therefore, the defended area polygon included in the SFDAD is the area that would have been inundated under the SOP flood event – i.e. it is assumed that rail infrastructure located within the defended area would have otherwise been at risk of flooding (for a flood event equivalent to the SOP of the scheme). The SFDAD includes schemes where the SOP is less than 200 years. These schemes would not protect against 0.5% probability (1:200 year) flood events and are therefore discounted from this analysis (which only considers 1:200 year events); to ensure that there is no overestimation of benefit. The overall approach to the metric is to clip the rail network layer to SFDAD defended area polygons for schemes where the SOP is 200 years or more. This identifies the portion of the rail network located within the defended area. This then facilitates calculations of the total length and proportion of the rail network benefitting from flood prevention measures[7]. Inherent to this approach is a focus on 0.5% probability (1:200 year) flood events only, reflecting the approach adopted in all other transport infrastructure indicators. The SOP field in the SFDAD defended areas dataset facilitates this assessment.

[6] Noting that for the same return period the characteristics (e.g. flood extent) of current flood events may be different to the historic design flood used in hydraulic models, due to climate change and other factors

[7] That is flood prevention measures that are held in the SFDAD

The SFDAD was developed to provide a register of fluvial flood defences (though information on coastal schemes could be gathered and included in future as well (ibid)). This indicator has therefore considered fluvial flood defences only. In the future it may be possible to consider different flood return periods (e.g. the scale of protection afforded to more frequent events) and coastal defence assets if and when this data becomes available in SFDAD.

Methodology adopted in the assessment of BT16 outcome metric
This section provides details of the methodology adopted to assess the BT16 outcome metric. The methodology include steps that are undertaken in a GIS indicated in pale green and steps that are undertaken in Microsoft Excel indicated in dark green.

Assessment methodology for BT16 outcome metric – proportion of the rail network benefitting from flood prevention measures	
Assessment Step	**Method**
1	Sum the SHAPE_LEN field from the Network Rail NetworkLinks layer
2	Select flood defence schemes from the SFDAD FLUVIAL_Defended_Areas output where SOP is 200 years or more using the following query: “sop” = ‘200Yr’ OR “sop” = ‘250Yr’ OR “sop” = ‘1000Yr’
3	Clip the Network Rail NetworkLinks layer to Assessment Output **No.2**
4	Sum the SHAPE_LEN field from Assessment Output **No.3**
5	Divide the output of Assessment Step **No.4** by the output of Assessment Step **No.1** and multiply by 100. This produces a figure for the BT16 outcome metric: *Proportion of rail network benefitting from fluvial flood prevention measures*