Indicators and trends

Monitoring climate change adaptation

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Indicator name				Version
BT6 Trunk road 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	FL8a Roads at significant risk of flooding TR1 Risk of traffic disruption

At a glance

- Scotland's road network is at risk of flooding from fluvial sources
- Flood prevention schemes are vital for climate risk management as they help to manage flooding impacts. Schemes with a higher standard of protection (SOP) may be more resilient to climate change flood challenges but represent only 21% of schemes
- Flood prevention schemes are located across Scotland, and are focused on main urban centres
- Only a small portion of the trunk road network in Scotland benefits from fluvial flood protection

Latest Figure	Trend
Proportion of the entire trunk road network benefitting from fluvial flood protection measures: **0.13%.** Proportion of the trunk road network at risk of a 1 in 200 year flood event benefitting from fluvial flood protection measures[1]: **6%**	Trend data not available

Why is this indicator important?

Flooding of roads can result in physical damage to road infrastructure and increase the risk of accidents. Flooding can also disrupt the operation of the road network with knock-on consequences for many social and economic functions – e.g. delaying deliveries, preventing or delaying people from accessing employment, disrupting vital healthcare services. Communities located in remote areas are

[1] Only 2.13% of the trunk road network is at risk of a 1 in 200 year flood event from fluvial sources (see BT2 *Road network at risk of flooding)*. This means that about 6% or 1/16th of the trunk road network which would otherwise be exposed to fluvial flooding is currently protected. The assessment has been undertaken for 0.5% probability (1:200 year) flood events only (see Limitations section for further information)

particularly vulnerable to road network disruption as they rely more heavily on road transport than those living and working in other parts of Scotland and alternative routes (where these exist) often require long diversions.

Climate change predictions suggest that flooding of road infrastructure will become more extensive and more frequent. This indicator will provide insight into whether such predictions are realised.

Related Indicators:
BT2 Road network at risk of flooding
BT4 Flood events affecting the trunk road network
BT17 Risk of traffic disruption as a result of flooding

What is happening now?

Figure 1 shows the location of all flood defence schemes. It also shows the location of schemes that have been designed to a standard of protection (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 the trunk road network benefitting from flood protection measures. Figure 2 also shows a close up of these issues for a small section of the trunk road network benefitting from flood defence at Junction 2 of the M77 in south-west Glasgow (Silverburn Shopping Centre).

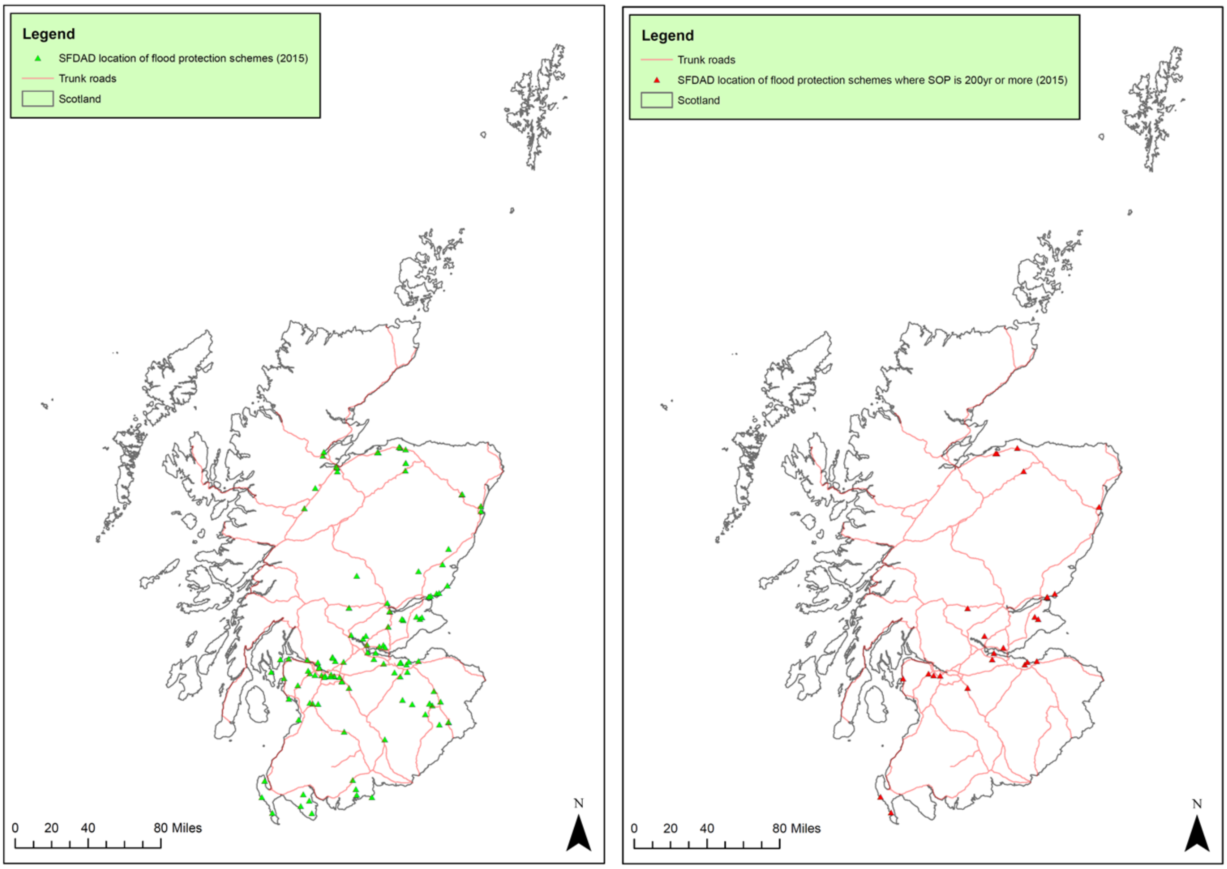

Figure 1 Location of flood defence schemes in Scotland: all schemes (left-hand map); schemes designed to an SOP of 200 years or more (right-hand map) Data source: SFDAD, 2015.

The length of the trunk road network benefitting from flood prevention measures for a 0.5% probability (1:200 year) fluvial flood event (i.e. the length of the network located within the areas defended from fluvial flooding where SOP is 200 years or) is 6,207m. The proportion of the trunk road network benefiting from fluvial flood prevention measures is therefore 0.13%[2].

To put this figure in context, for a 0.5% probability (1:200 year) fluvial flood event, 2.13% of the trunk road network is at risk of flooding (see related indicator BT2, Metric No.6). For a flood event of this magnitude therefore, approximately 6% or 1/16 of the trunk road network at risk of flooding is afforded protection by flood prevention schemes with an adequate SOP[3].

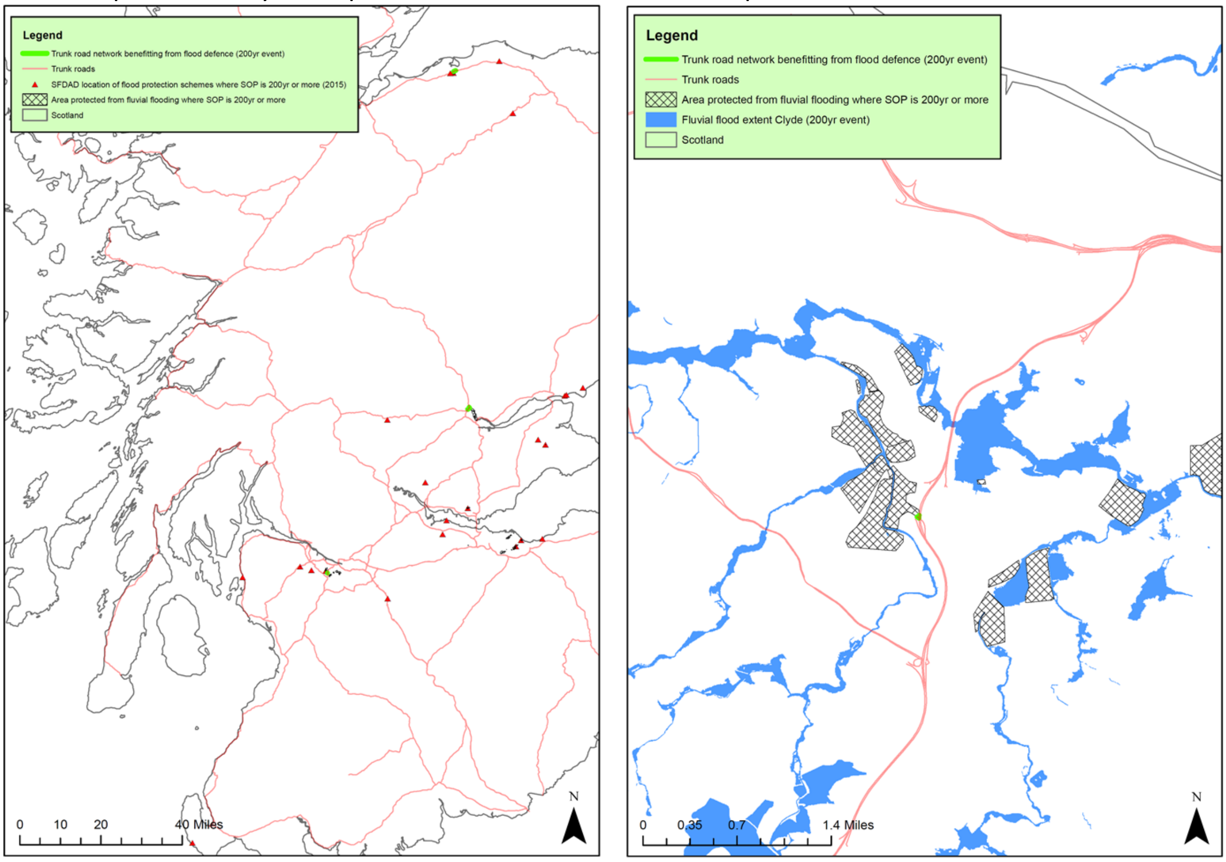

Figure 2 Location of fluvial flood defence scheme defended areas where SOP is 200 years or more (LH map) and detail of the section of the M77 benefitting from flood defence scheme in south-west Glasgow at Silverburn Shopping Centre (RH map). Data source: SFDAD, 2015

The left-hand map shows the location of fluvial flood defence schemes in Scotland where the SOP is 200 years or more. These are focussed on key population centres (Edinburgh and Glasgow) as well as strategic transport links (e.g. A9 at Perth, A96 at Forres) reflecting the consequence element of risk (i.e. where risk is a function of event likelihood and consequence). The right-hand map shows the area defended by the Brock Burn and Levenwater Flood Prevention Scheme, SW Glasgow (black hatched area). This scheme affords some protection to the M77 at Silverburn (bright green line).

[2] The total length of the trunk road network in Scotland is 4,634.72km (2015)

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

What has happened in the past?

Due to resource constraints historic flood prevention scheme and trunk road network data has not been assessed. This section reviews other key drivers of flood prevention activity including legislation and guidance.

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 have been 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 and residential properties in Scotland (Bassett *et al*, 2007). As such, any protection of road 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 (e.g. where there are large numbers of properties in the floodplain).

The Design Manual for Roads and Bridges (DMRB) was first introduced in 1992 to provide standards, advice notes, guidance and other published documents relating to the design, assessment and operation of trunk roads (DfT, 2015). The current iteration of the DMRB requires that trunk roads are designed to accommodate surface water (pluvial) flooding for 20% probability (1:5 year) flood events with limited surcharging onto the hard shoulder only (Highways Agency *et al*, 2004). For rarer, more severe flood events (i.e. longer return periods), the DMRB anticipates that there would be some flooding of the carriageway but that flooding would only last for short time periods before draining away, thereby causing minimal disruption to traffic (ibid). In principle therefore the DMRB has been providing for the management of pluvial source flooding on the trunk road network since the early 1990s (this is in addition to design standards and various technical memoranda that were in existence prior to DMRB and that DMRB superseded).

What is projected to happen in the future?

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 / 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 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).

Given the above, it is anticipated that the type, scale, location and strategic targeting of flood prevention measures will change in the future, arguably for the better given that a more risk based, catchment scale approach will be adopted. Without knowing the detail of what will be included in the forthcoming Flood Risk Management Strategies (FRMS) and Local Flood Risk Management Plans (LFRMP) it is impossible to say exactly how, where and to what degree the trunk road network will benefit. However given the nature of the PVA approach (see above), one might expect the proportion of the network benefitting from flood prevention measures to increase and therefore that the overall flood risk to the trunk road network might be reduced as a result.

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 and more resilient to climate change, by accounting for possible future flows and flood events within the design process.

Patterns of change

The following key themes are evidenced in the data for a 0.5% probability (1:200 year) flood event:

1. Based on the data assessed (fluvial source flooding / 200 year SOP only), only a small portion of the trunk road network (**0.13%**) is benefitting from flood prevention measures.
2. Flood prevention schemes are located throughout Scotland but are focussed on areas where the consequences of flooding are most pronounced (i.e. Scotland's main urban centres).
3. Flood prevention schemes that are designed to a high SOP (200 years or more) are also located throughout Scotland (particularly in and around the main urban centres) but are fewer in number. Schemes with an SOP of 200 years or more make up 21% of all schemes.

Interpretation of indicator trends

No trends identified 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 was 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 the BT6 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 / 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 / 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 / floods for a given return period at the time of construction. Bassett *et al* (2007) highlight how in the majority of cases, updated flow / 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 on 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 risk alleviation measures. There is no consideration of road network design for pluvial flood risk mitigation or the benefit afforded to the road 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. It is therefore likely that the proportion of the road network benefitting from flood prevention measures is underestimated, particularly when multiple sources of flooding are considered.
5. Due to resource constraints assessment was only undertaken for 0.5% probability (1:200 year return period) modelled flood events. These are medium 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

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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

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

Appendix One: Indicator metadata and methodology

Table 1: Indicator metadata

	Metadata
Title of the indicator	BT6 Trunk road network benefitting from fluvial flood protection
Indicator contact: Organisation or individual/s responsible for the indicator	ClimateXChange
Indicator data source	• **Ordnance Survey** – Master Map Integrated Transport Network (ITN) Layer • **SEPA** – Scottish Flood Defence Asset Database (SFDAD) data
Data link: URL for retrieving the indicator primary indicator data.	Ordnance Survey: http://www.ordnancesurvey.co.uk/business-and-government/products/itn-layer.html 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.	SFDAD data: 1961 – present day, but with data gaps
Frequency of updates: Planned or potential updates	OS ITN Layer data is updated six weekly. SFDAD data is updated as and when new schemes are constructed and Local Authorities make data available
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	See 'Limitations' section
Spatial resolution: Scale/unit for which data is collected	Individual defence schemes
Categorical resolution: Potential for disaggregation of data into categories	
Data accessibility: Restrictions on usage, relevant terms & conditions	Ordnance Survey ITN Layer data is available for purchase under licence. SFDAD data is available under license 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.
Ordnance Survey Master Map Integrated Transport Network (ITN) Layer: http://www.ordnancesurvey.co.uk/business-and-government/products/itn-layer.html 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 single metric used is 'Proportion of trunk road network benefitting from flood prevention measures'. The assessment is based primarily on flood defence asset data held in the Scottish Flood Defence Asset Database – the SFDAD (Bassett *et al*, 2007). The assessment 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[4] will protect against a 0.5% probability (200 year) flood event (at the time of construction[5]). 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 trunk road 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). Crucially, 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 BT6 outcome metric is simply to clip the OS MasterMap ITN Trunk Roads only layer to SFDAD defended area polygons for schemes where the SOP is 200 years or more. This identifies the portion of the trunk road network located within the defended area. This then facilitates calculations of the total length and proportion of the trunk road network benefitting from

[4] Noting that schemes with an SOP of **more than 200 years** will provide protection against a 0.5% probability (1:200 year) flood event

[5] 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

flood prevention measures[6]. 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.

Calculations of length and proportion of trunk road network benefitting from flood prevention measures are based on the ITN Trunk Road layer 'link lengths' field, as opposed to just the trunk road sections located within the defended area. In effect, the metric considers the wider road link benefitting instead of just the clipped trunk road section within the SFDAD defended area polygon (see Assessment Step No.2 in the table below). We suggest that this approach provides a better proxy for the networked nature of trunk road infrastructure by considering the whole road link (i.e. the section of road between two nodes) that is afforded protection by the flood defence scheme.

The SFDAD was developed to provide a register of fluvial and coastal flood defences (ibid). However fluvial flood defences only are considered. In future is may be possible to consider different flood return periods (e.g. the scale of protection afforded to more frequent events) and coastal defence assets too.

Methodology adopted in this assessment

This section provides details of the methodology adopted to assess the 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 the outcome metric – proportion of the trunk road network benefitting from flood prevention measures	
Assessment Step	**Method**
1	Sum the SHAPE_Length field from the OS MasterMap Integrated Transport Network (ITN) Trunk Roads only 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 OS MasterMap Integrated Transport Network (ITN) Trunk Roads only Layer to Assessment Output **No.2**
4	Sum the LINKLENGTH 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 outcome metric: *Proportion of trunk road network benefitting from flood prevention measures*

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