08 - PLANNING FOR CLIMATE CHANGE ADAPTATION WITHIN FLOOD RELIEF SCHEMES

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Abstract

RPS are supporting the delivery of 12 Flood Relief Schemes (FRS) across Ireland on behalf of the Office of Public Works and local authorities as part of the National Development Plan 2021-2030. Each scheme requires the development of a Climate Change Adaptation Plan (CCAP). The CCAP ensures the need for adaptation is fully embedded in the analysis, design, and construction of the schemes. As part of FRS Stage I (Scheme Analysis and Development), CCAP development has provided key lessons on the importance of hydrometric data, extreme value analysis and modelling, and the impact the CCAP can have on scheme design.

Building on lessons from the Catchment Flood Risk Assessment Management (CFRAM) Studies, 1D/2D hydraulic models have been used to synthesise upper limbs of gauging station ratings beyond their gauged limits. The review of data using in-house tools has looked at trends in the index flood (Q_{med}) and subsequent effect on the flood frequency behaviour.

The economic appraisal of schemes has traditionally been undertaken on the assumption that stationary flood frequency conditions persist over the scheme design life. To calculate the true economic benefit of a scheme that is adapted for future scenarios, the economic appraisal must consider a transition from Present Day flood frequency conditions towards a Future Scenario. A sliding economic damage assessment method has been developed to offset the cost of adaptation and determine a benefit cost ratio for the adapted scheme.

Future Scenarios are predicted using uplifts on a number of key factors, including design flow estimates to capture climate change combined with uplifts on urban extent as population grows over the scheme horizon. Modelling these changes allows the rate at which the scheme Standard of Protection (SoP) will deteriorate over its design life to be estimated.

Key insights from the work to date include the upward shift in Annual Maxima flow events across the island of Ireland and subsequent uplift in flood frequency curves. These findings are largely in line with the recommended uplifts factors applied for Future Scenarios as part of the CCAPs. Hydrometric data within the scheme area is therefore crucial to monitor the pace of deterioration of the design SoP to determine trigger points at which adaptation actions will be required.

The CCAP impact on Year 1 preferred option and design was also a key lesson learned. Maladaptive elements are often only highlighted once comprehensively assessed through CCAP adaptation pathways and alterations made to the Year 1 scheme. A feedback loop is created due to the CCAP that should be anticipated within FRS programming to ensure resilient and sustainable solutions.

1. Introduction

1.1. Recent Events and Climate Change

Climate change adaptation planning within Flood Relief Schemes (FRS) is becoming vital due to global warming and the increase in frequency of extreme rainfall events (Kendon, et al., 2023; O'Neill, et al., 2022). Ireland has recorded an increase in extreme rainfall events which have coincided with severe flooding (Murphy, et al., 2023; M. Boudou, 2021). Recent events such as June 17th, 2023, saw the town of Tralee, Co. Kerry, experience damaging pluvial flooding. 30mm of rain fell over a 45-to-50-minute period, overwhelming the urban drainage capacity leading to the flooding of business, homes, and disruption to infrastructure throughout the town (McGlynn & Heaney, 2023). A similar event impacted the towns of Raphoe and Castlefinn, Co. Donegal, on the 22nd July 2023, resulting in reported flooding of 10 commercial and eight residential properties (Doe, 2023). 66mm of rainfall was recorded over five hours at Raphoe. Both rainfall events when compared against the FSU Depth Duration Frequency rainfall model are considered to be in excess of 1 in 200 year rainfall return periods.

Climate models predict more frequent extreme rainfall events to impact Ireland as we move through the 21st century, with severity dependent on the IPCC Shared Socioeconomic Pathway (SSP) scenario. It is anticipated that flood events become more damaging relative to the severity of the events when few adaptation measures are taken, however this is not certain due to the complex nature of fluvial flooding (Nolan & Flanagan, 2022).

1.2. Irish Flood Relief Schemes

As part of the National Development Plan 2021-2030 (Department of Public Expenditure, 2021), the Office of Public Works (OPW) and Local Authorities are delivering FRS through a five-stage process:

- Stage I: Scheme Analysis and Development
- Stage II: Planning Process or Public Exhibition/Confirmation
- Stage III: Detailed Design
- Stage IV: Implementation/Construction
- Stage V: Handover of Works

Stage I requires the Preferred Option to be developed as the best solution economically, technically, socially, and environmentally, in eliminating flood risk to the agreed SoP. A Climate Change Adaptation Plan (CCAP) is to be developed in tandem with the Preferred Option to ensure the adaptability of the scheme is fully embedded in the analysis, design, and construction of the scheme.

Climate change and its impact on peak flows and peak rainfall is not the only contributing factor to the Future Scenarios which inform the CCAP. Other factors, such as catchment changes through urbanisation and forest cover, are also considered for two future scenarios: the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS), which cover the time period from the present day to 2100. Thus, future scenarios and analysis contained within the Stage I of FRSs which informs CCAPs are much more complex and nuanced than attributing future change in peak flood flows to global warming. **Table 1** is a summary of the factors applied for the MRFS and HEFS in Irish FRSs.

***Table 1**: Indicative factors to be applied as part of the Future Scenario analysis in Republic of Ireland Flood Relief Schemes (OPW, 2019).*

Parameter	MRFS	HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Peak Flood Flows	+ 20%	+ 30%
Mean Sea Level Rise	+ 500mm	+ 1000mm
Land Movement	-0.5mm / year for southern part of the country (applicable to Dublin – Galway and south of this)	
Urbanisation	Individual Assessment	Individual Assessment
Forestation	Reduce hydrograph time to peak by 1/6	Reduce hydrograph time to peak by 1/3 + 10% on Standard Percentage Runoff

1.3. Aim of Paper

RPS are supporting the OPW and Local Authorities in the delivery of 12 Flood Relief Schemes across Ireland. As part of Stage I, hydrological analysis using the most up to date, in-situ hydrometric data has been carried out. Hydrometric gauging station rating reviews at a number of stations across the study areas have been completed. These rating reviews employ high resolution hydraulic models to calibrate the ratings used to convert the recorded water level data to flow data. They are particularly useful for informing the ratings at flood flows. The Annual Maxima flow data available, following rating review and interrogation through detailed scheme level hydrological and hydraulic analysis, is considered by the project team to be amongst the most robust available in Ireland.

This paper looks at a number of gauging stations in different study areas across Ireland which have robust, long-term hydrometric data. Extreme value analysis (EVA) is carried out and climatic periods are analysed to determine any climate change fingerprint to support the development of CCAPs.

A sliding scale methodology is used to capture a more representative cost of Future Scenario schemes and to account for the reduction in SoP of the scheme over its lifetime, typically 50 years in an Irish context. This paper examines the impact of this reduction in SoP and the resulting consequence for Scheme CCAP.

Developing the Scheme 'Preferred Option' through the CCAP process has resulted in a number of lessons learned in relation to FRS development.

2. DATA ANALYSIS

The number of hydrometric gauging stations with a robust, long-term flood flow record suitable for statistical analysis is limited. As part of the hydrological analysis for the flood relief schemes in Lifford and Glenties (Co. Donegal), Ballina (Co. Mayo), Drogheda (Co. Louth), Limerick (Co. Limerick), Tralee (Co. Kerry) high quality, robust flood flow records are available at eight stations shown in **Figure 1**.

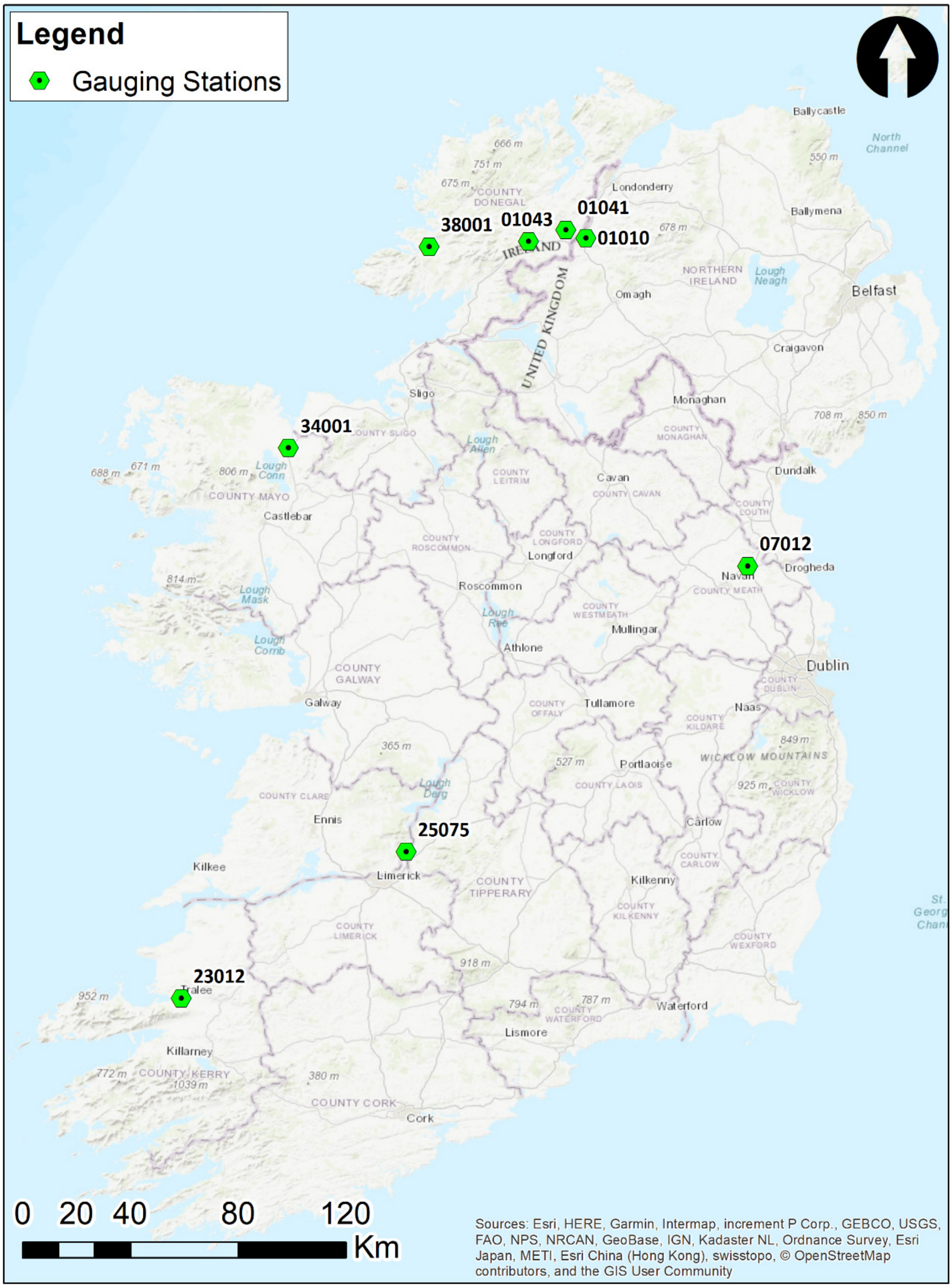

***Figure 1**: Geographical location of hydrometric gauging stations used in the flow and extreme value analysis carried out in this paper.*

2.1. Trend Analysis of Annual Maxima Record

Annual maxima (AMAX) records have been extracted from each of the eight station flow records. An AMAX event is the peak flood flow recorded at a station during the hydrological year, defined as October 1st to September 30th.

Where rating reviews were carried out and new ratings adopted as part of Stage I, these new rating curves were used to process the water level records at the respective station. The AMAX record for each station is summarised in **Table 2**, alongside the estimated median flow (Q_{med}) and the catchment size.

***Table 2**: Catchment characteristics and Annual Maxima record with Q_{med} summarised for the eight stations included in the analysis.*

Station No.	Waterbody and Station Name	Catchment Size (km²)	Record Period (years)	Missing Data (years)	Q_{med} (m³/s)
1010	Mourne at Drumnabuoy House	1,845	40	-	603
1041	Deele at Sandy Mills	116	49	1	64
1043	Finn at Ballybofey	313	32	-	227
07012	Boyne at Slane	2,408	33	-	274
23012	Lee at Ballymullen	62	25	-	31
25075	Shannon at Parteen Weir	10,782	81	-	547
38001	Oweneagh at Clonconwal Ford	111	51	-	65
34001	Moy at Rahans	1,975	51	1	188

Trend analysis at each station was carried out by fitting the AMAX data with a first order polynomial regression fit using the least-squares method (**Figure 2**). The slope of the fit was indicative of the rate of change of flow over the record period, and thus allowed an estimation of percentage change year-on-year in AMAX values at each station. Estimated percentage increase in AMAX values are included in **Figure 2**, alongside a rolling 12-year index flood flow, Q_{med}.

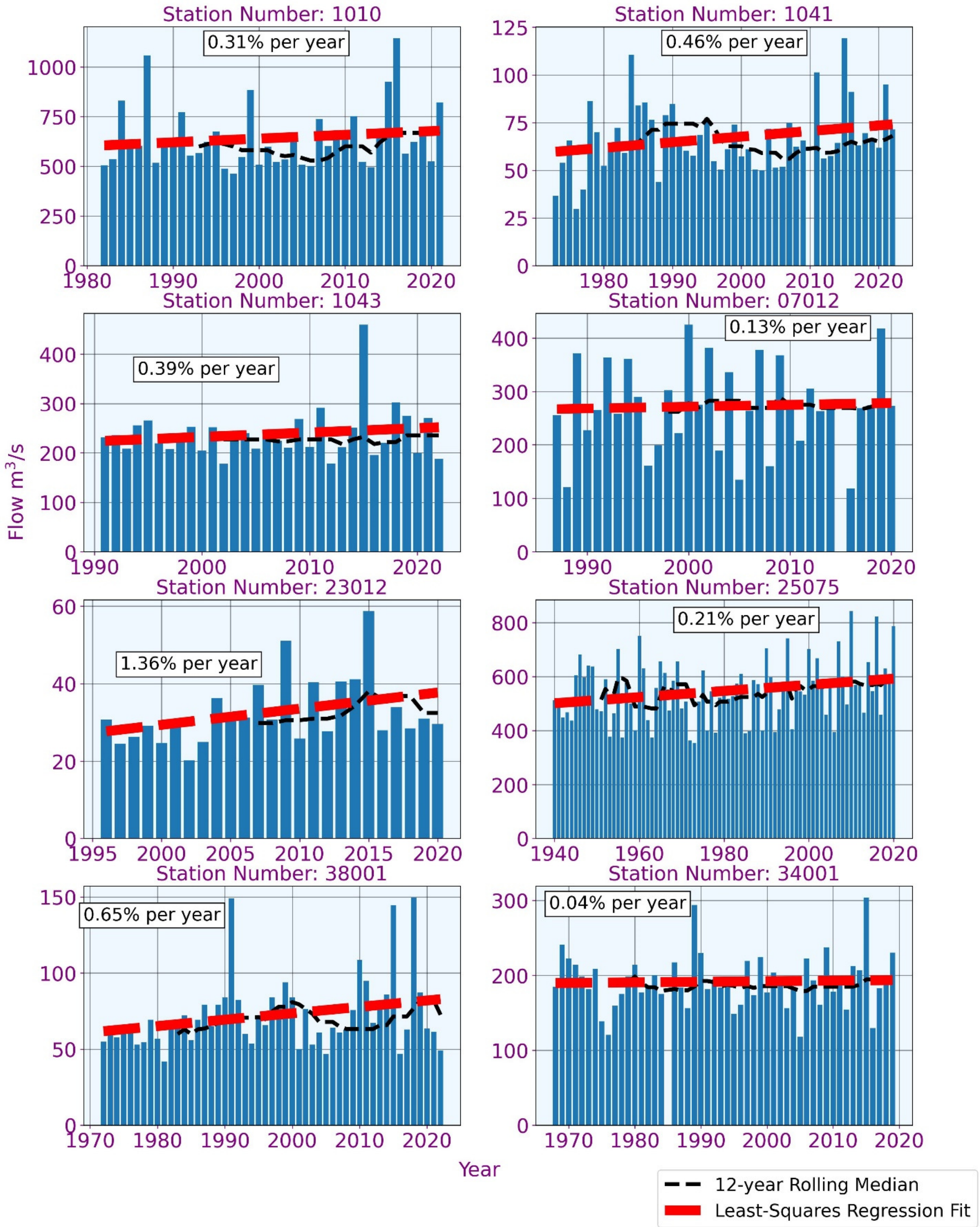

***Figure 2**: Annual Maxima (AMAX) records for each of the eight stations included for analysis (blue bars). Shown is the least-squares 1st order polynomial fit to the AMAX records (red) with a 12-year rolling median (Q_{med}) estimation (black).*

A 0.04% to 1.36% range year-on-year percentage increase in AMAX values is found at the stations. The only station in the eastern half of Ireland on the River Boyne has the lowest (negligible) trend in AMAX series. More data would be required to identify if this represents any kind of regional trend. What is discernible is that all stations experienced an upward trend in AMAX values recorded over their record period, and thus an upward trend in Q_{med}, albeit negligible at one location.

While it is not possible to attribute this upward trend in AMAX and Q_{med} solely to global warming without carrying out a detailed attribution study, it is expected any change observed is likely driven by climate change rather than change in catchment behaviour. Where major catchment change has occurred, e.g. arterial drainage works, the flow record has been edited accordingly to only consider present-day catchment conditions.

The upward trend in AMAX values across the island of Ireland is coincident with the largest AMAX events occurring in recent times (**Figure 3**). All stations analysed have recorded the largest flow event on record since 2010 (inclusive), with the only exception being 07012, the River Boyne at Slane, in the east of the country.

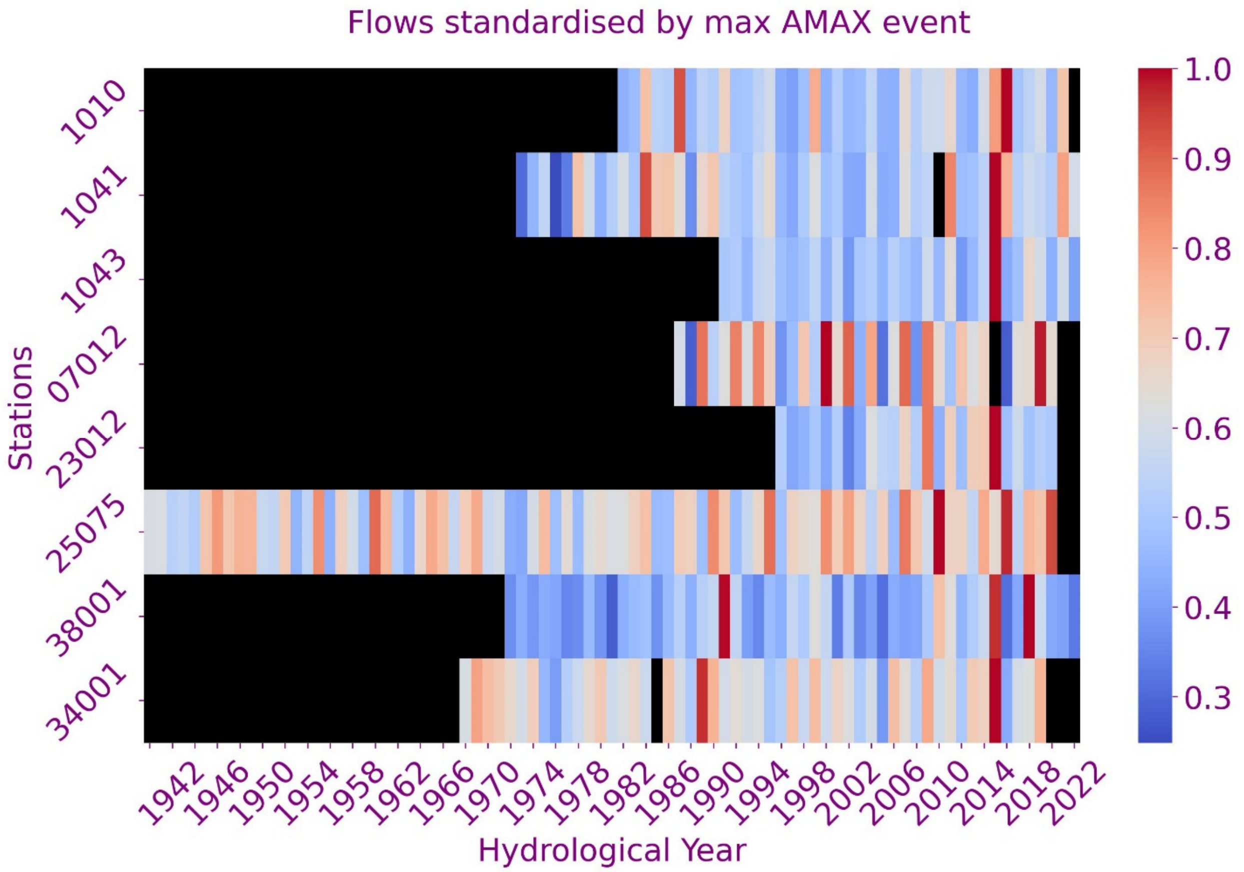

***Figure 3**: Heatmap of Annual Maxima (AMAX) events standardised by the largest AMAX event on record at each station.*

2.2. Flood Frequency Analysis

Extreme Value Analysis (EVA), in line with procedures set out in the Flood Studies Update (FSU) Work Package 2.2 (Office of Public Works, 2009), was undertaken for each station. By considering temporal slices of the station records, analysis was carried out to detect any shift in flood frequency curves between time periods for each individual station.

When considering climate change 15 to 30 years is an appropriate window to represent climatic conditions (Met Office, 2023; National Geographic, 2023). The hydrological year 2005 was chosen as a date before which the station records were considered representative of a past climate period, while inclusive and post 2005 was considered representative of present-day climatic conditions. This threshold was chosen primarily to split the records fairly equally but at a consistent date. It is in line with climatic periods often selected in climate science while also allowing for the full use of the records (Copernicus - ECMWF, 2023).

The station records were split, and extreme value distributions fitted to the data from both periods. A number of distributions were tested, and the best fit distribution was selected. The Generalised Logistic (GLO) and Generalised Extreme Value (GEV) distributions were noted as the best fitting for the data[1] for both pre- and post-2005 data. The data used in the EVA is summarised in **Table 3**.

***Table 3**: Record period and number of years available at each station to carry out flood frequerncy analysis. The respective best fit extreme distribution for both pre- and post-2005 is included.*

Station	Record Period Pre-2005 (years)	Record Period Post-2005 (years)	Distribution (pre- and post-2005)
1010	24	17	GEV
1041	33	17	GLO
1043	15	18	GEV
07012	19	15	GEV
23012	10	16	GEV
25075	66	16	GEV
38001	34	18	GEV
34001	37	15	GEV

When carrying out at an-site flood frequency analysis, estimation for return periods greater than two times the length of the AMAX record is considered highly uncertain (Robson & Reed, 2009).

Reutrn periods up to and including the 1% Annual Exceedance Probability (AEP) event were considered, that is the event with a return period of 100 years. Considering the length of the records after splitting the data into pre- and post-2005 (**Table 3**), pre-2005 records allow for a reasonable estimation in return periods ranging from 20 to 130 years, while post-2005 records allow for a reasonable estimation from 30 to 40 years. Therefore, a signifincat level of uncertainty exists in the analysis pertaining to return periods greater than 30 to 40 years for all stations.

Figure 4 shows the percentage increase in predicted flood flow between pre 2005 and post 2005, for a range of return periods at each of the eight gauging stations. The analysis indicates that the greater the return period the greater the increase in the flood flow between the two periods. This indicates that between the two periods (pre and post 2005) the impact on more extreme events is greatest. It should be noted however that the higher the return period the higher the uncertainty in the analysis.

[1] The analysis presented in this paper is separate and individual to any and all analysis produced by RPS as part of the Stage I Flood Relief Scheme analysis.

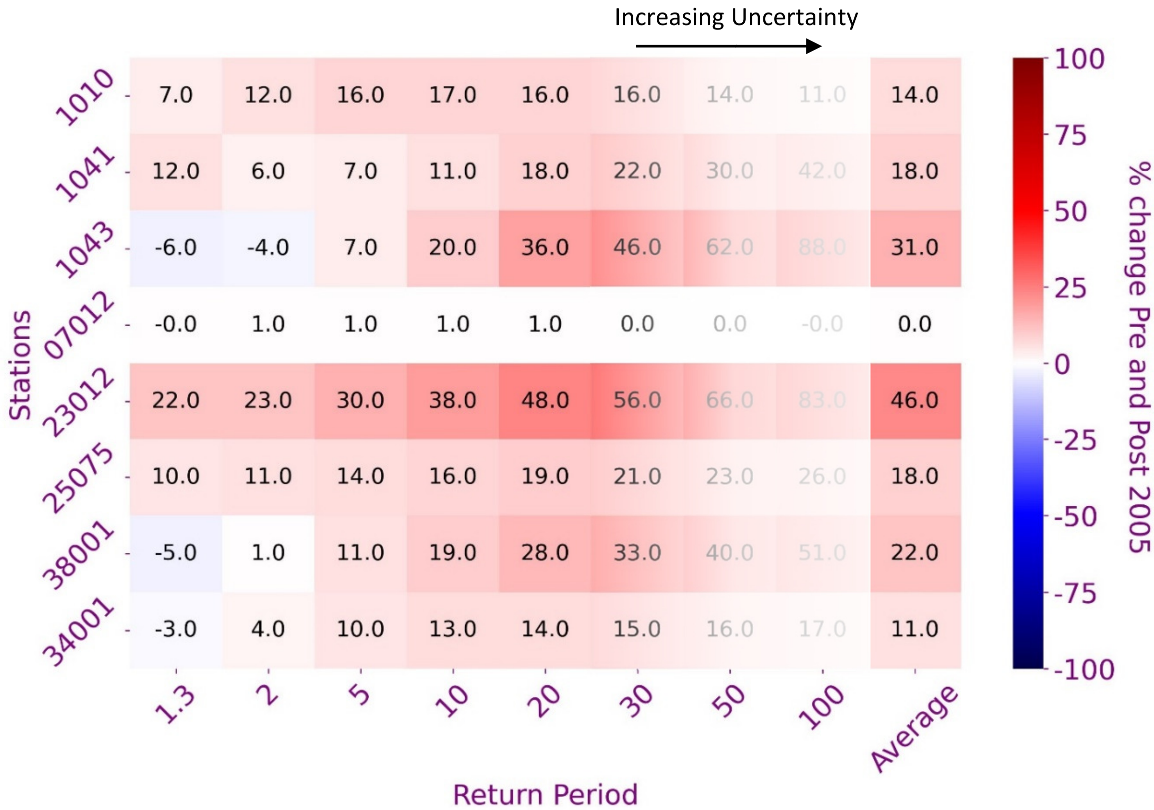

Figure 4*: Heatmap of percentage increase from pre- to post-2005 in flood flows for discrete return periods.*

This finding indicates an increase in the frequency of extreme fluvial flood events occurring at the stations included in this analysis. This is consistent with the trend analysis of the AMAX events with the largest events occurring in the present climate period (see **Figure 3**).

The one station considered an outlier in the AMAX trend and flood frequency analysis is 07012. Located in the east of the country. 07012 is a long-term, robust record on the Boyne River at Slane. Insignificant percentage change in return values is observed between pre- and post-2005 data. 07012 may reflect a regional variation in flood frequency curves pre- and post-2005, or it may be reflective of nuanced catchment behaviour. Further analysis would be required to determine whether a regional variation in observed trends is present.

2.3. Discussion

The analysis highlights the non-stationarity of the available data upon which scheme design flow estimation is based. This must be considered in the selection of data periods for use in the analysis of flood schemes.

Although the increases are very large there are a number of reasons other than climate change that may be driving the changes:

- Catchment changes such as increased drainage works between the two periods.
- Data quality / rating issues in the pre-2005 period; hydraulic and hydrological analysis are less equipped to interrogate this period due to data limitations.
- Natural variation; the post 2005 period may simply be a flood rich period.
- There may be a bias in the datasets chosen as they are from current flood relief schemes; recent flooding is likely to be a driver for the prioritisation of these areas for FRS.

Similar exercises carried out at a national scale are required to inform the guidance in relation to dealing with both non-stationarity in hydrometric data and recommendations for climate change uplifts.

3. DEVELOPMENT OF SCHEME CLIMATE CHANGE ADAPTATION PLANS

3.1. Standard of Protection

In developing future Mid-Range and High End Future Scenarios (MRFS and HEFS) for design of scheme adaptation measures in Ireland the uplifts identified in **Table 1** are applied.

The application of +20% and +30% uplifts to peak flood flows for climate change in the MRFS and HEFS, respectively, is broadly in line with the increase in peak flood flows observed between pre- and post-2005 in-situ data. This could be considered alarming given the type of uplifts expected between now and the year 2100 are already in evidence over 15-20 years in the recent past. However the qualifications noted in 2.3 are important. Furthermore the guidance in **Table 1** notes the need to consider other factors, namely changes within the catchment in addition to climate change.

Across FRS catchments the potential for urbanisation to increase flows is widely dependent on the type of catchment. In large rural catchments such as the Shannon or Boyne it is considered low. In smaller tributary catchments that flow in through built up areas, there is large potential for increased peak flow rates due to urbanisation, where the settlement expands through the small tributary catchment area. These smaller urban catchments tend to have critical storm durations (the storm duration which causes flooding) which are very short (<10 hours). It is these shorter duration, high intensity storms which are predicted to become more frequent due to climate change. Thus urbanisation is likely to have a compounding impact on climate change.

The level of urbanisation which is likely to be experienced over the MRFS and HEFS time horizon (assumed to be 2100) is highly contingent on unpredictable social, economic and environmental events. The level at which future urbanisation transfers into increases in peak flow rates is highly dependent on future drainage design and construction practice. For example the effective implementation of Sustainable Drainage practice for new development could mitigate the impact of urbanisation.

Within the FRS the compounding effect of climate change and urbanisation was considered to have a large potential impact in the MRFS and HEFS leading to peak flow uplifts well in excess of +20% and +30% respectively. The urbanisation component of the uplift in peak flow was calculated by increasing the urban extent (URBEXT) FSU physical catchment descriptor by an estimated growth rate. The growth rate was chosen following analysis of:

- the historical trend in urban fabric growth within the FRS Study catchment (using current and historic CORINE landuse datasets), and;
- the historic trends and future projections of population growth from the CSO.

The average MRFS and HEFS uplift factors for peak flows for various FRS are shown in **Table 4**.

Table 4: *Average composite uplifts for peak flows in MRFS and HEFS*

FRS	Average MRFS Peak Flow Uplift (%)	Average HEFS Peak Flow Uplift (%)
Burnfoot	43	86
Castlefinn	27	50
Downings	78	110
Glenties	25	50
Lifford	21	37
Limerick	35	83
Tralee	25	36
Drogheda	35	49

With uplifts applied to design flows as part of the Future Scenarios, the SoP deteriorates over the scheme lifetime (typically 50 years in an Irish context). **Figure 5** shows the projected deterioration in SoP for a number of schemes which are complete or nearing completion of Stage I in Ireland. The graphs show the SoP projected out to the year 2100 for both the MRFS and HEFS scenario. Across all schemes, the SoP drops significantly throughout the century if either scenario is realised.

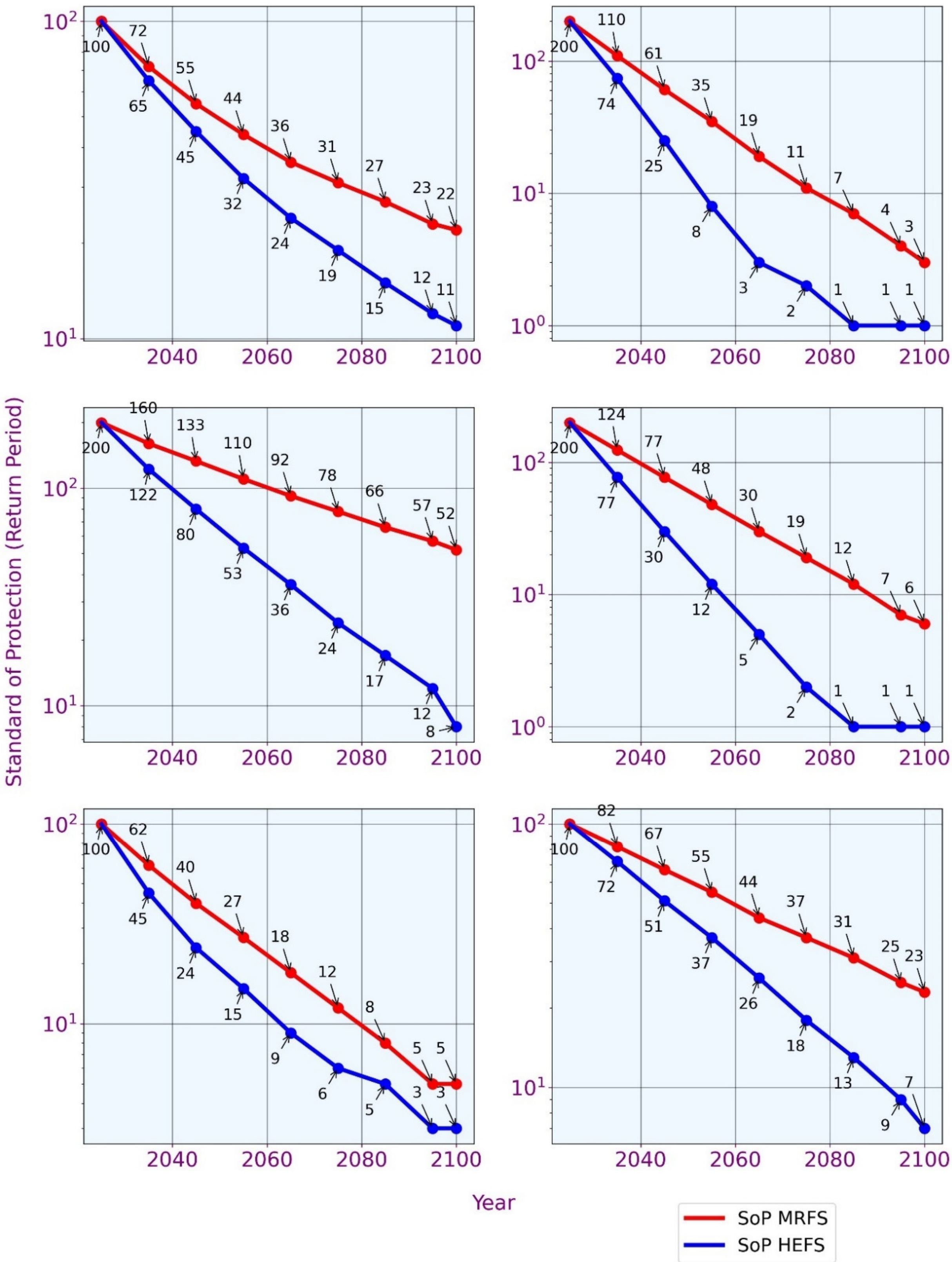

Figure 5*: Standard of Protection deterioration for schemes following both the Mid-Range Future Scenario (MRFS – red) and the High-End Future Scenario (HEFS – blue) if the Preferred Option is implemented and no adaptation measures are implemented throughout the scheme lifetime (typically 50 years).*

3.2. Uncertainty, Monitoring and Freeboard

Based on a 50 year design life **Figure 5** demonstrates that scheme Standard of Protection (SoP) will typically be reduced to approximately a 1 in 10-20 year SoP at the end of the design life (estimated 2075) assuming the MRFS.

Within each scheme a freeboard is allowed for to account for uncertainty in the analysis. Within the schemes analysed so far this has ranged from a minimum 300mm up to 580mm. This does not include 200mm additional allowance for embankments where there is potential for settlement.

The driver for the scheme freeboard allowance is almost always the uncertainty within the hydrological analysis. The freeboard allowance is generated by simulating peak flood levels from an uncertainty scenario where uplifts are applied to the design flows at the SoP.

If we consider the scheme SoP over time with the freeboard included it can be shown that the scheme may maintain the SoP over much of the design life as shown in **Figure 6**.

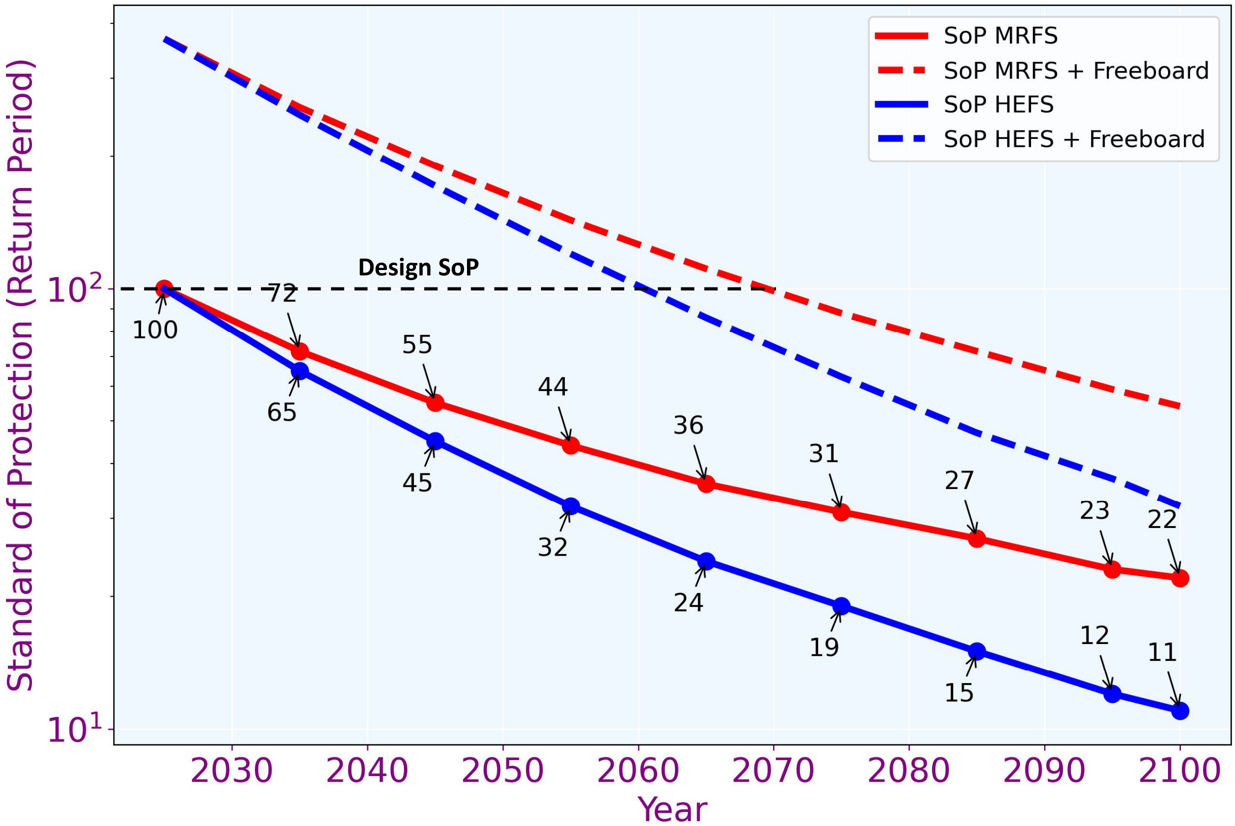

Figure 6*: Example of Reduction in Scheme SoP with and without Freeboard*

Scheme freeboard, of course, cannot be assumed to provide this additional protection. It is included to cover uncertainty and should be left out of any assessment of SoP unless the level of uncertainty can be reduced.

The most effective way to reduce uncertainty over the life of the scheme is to implement hydrometric gauging of water levels at the scheme area. The collection of data over the scheme life would significantly reduce the uncertainty and may allow a proportion of the freeboard allowance to be counted towards the SoP.

Hydrometric monitoring at the scheme area is also necessary in order to accurately identify trigger points for scheme adaptation measures.

3.3. Adaptation Pathways

Adaptation Pathways are developed to identify all of the potential routes to ensuring the SoP is sustained throughout the design life of the scheme. The starting point is the Preferred Option / Scheme.

A large number of Adaptation Pathways may exist for each individual flood scheme dependent on:

- the number of flood cells the scheme is broken down into for analysis purposes;
- the number of flood mechanisms;
- the number of viable measures available to maintain the SoP; and
- the number of additional properties / flood cells in the future scenarios.

Each of the elements above can act in a compounding way leading to an excessive number of potential adaptation pathways. Effective screening and a flood cell by flood cell approach can be used to manage this process.

Figure 7 outlines the preferred Adaptation Pathway for the Burnfoot Flood Relief Scheme. This was arrived at following assessment of three separate Adaptation Pathways. Burnfoot is a relatively straightforward scheme for assessment given it is dominated by one flood mechanism and one flood cell.

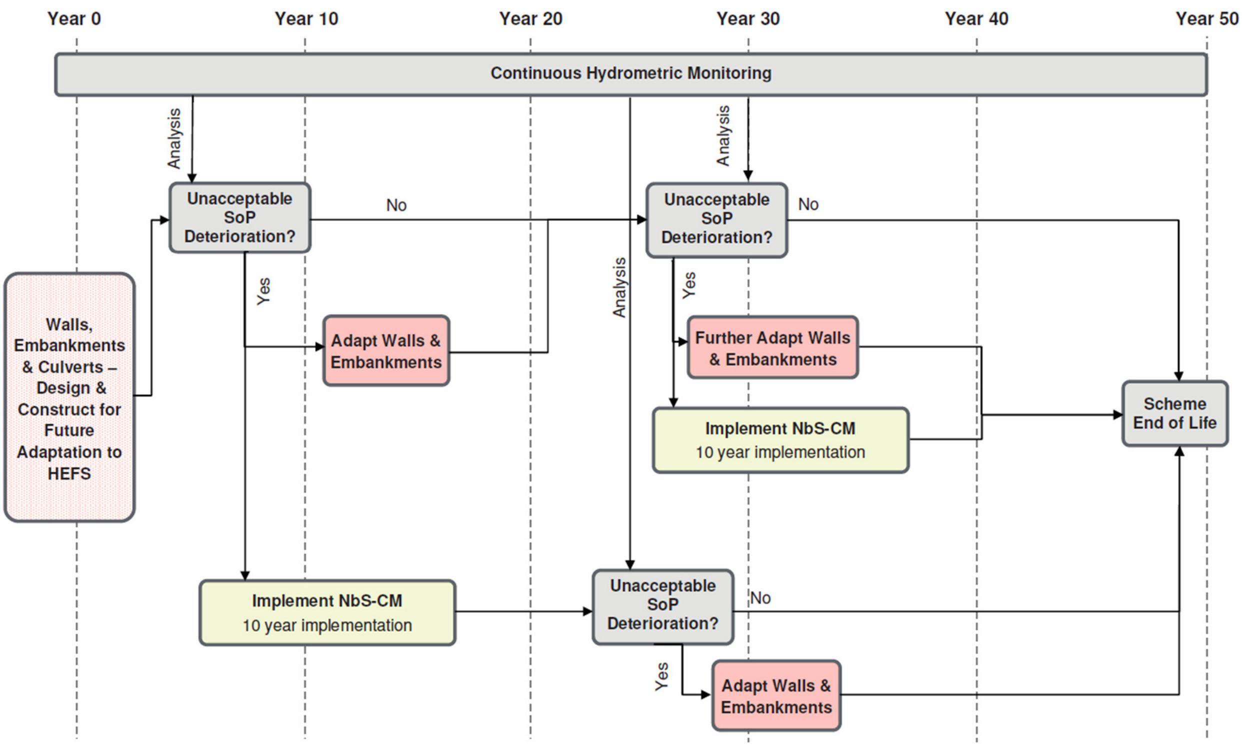

Figure 7: Preferred Adaptation Pathway for the Burnfoot FRS

3.4. Adaptation Measures

Adaptation measures are heavily influenced by the measures included in the initial scheme. Hard defences (walls and embankments) and culvert upgrades (increased conveyance) are measures included across all of the schemes (5 no.) for which a Scheme CCAP has been developed.

Table 5 sets out the proportion of the schemes for which each group of measure has screened in. 'Do nothing' involves observing the SoP throughout the design life based on hydrometric monitoring. As discussed there is a significant chance that this measure may be effective.

***Table 5**: Proportion of Schemes for which Adaptation Measures are viable*

Measure	Proportion of Schemes for which measure is viable
Do nothing (subject to monitoring)	100%
Walls and embankments	100%
Increased conveyance	100%
Upstream flood storage	80%
Nature-based Solutions to Catchment Management	60%
Relocation of properties/Managed retreat	40%
River diversion/Flood bypass channel	20%

Increasing the heights and lengths of walls and embankments is almost always a technically viable adaptation measure. The social acceptability of increased wall heights is difficult to assess within the context of the CCAP given it is based on a future context.

Nature-based Solutions to Catchment Management (NbS-CM) are better suited as adaptation measure as opposed to FRS measures delivered in year 1 of a scheme. There are long lead-in times before they reach full effectiveness and there is high uncertainty in the level of protection they will provide. However the current framework for assessing their effectiveness within the context of a Flood Relief Scheme area does not capture the geographical extent or the wide range of benefits, in addition to flood risk management, they may deliver. Delivery costs are dependent on the delivery mechanism (e.g. by a private contractor or a community based group) which at this stage have not been defined. Where there is the technical potential for NbS-CM to deliver adaptation then it is prudent that it is facilitated within the CCAP pathways. Developments in the science, assessment framework and delivery mechanisms may demonstrate these measures as being the appropriate Adaptation Pathway at a later date.

The most important feature of the CCAP is the hydrometric monitoring on the waterbodies driving flood risk at the scheme area. Without hydrometric monitoring it is very difficult to identify adaptation trigger points. Without monitoring or advances in climate change science the only alternative may be to deliver scheme adaptation measures at the outset of the scheme .

3.5. Year 1 Adaptation Measures

To ensure schemes are adaptable often requires significant adjustments to the scheme at the outset (Year 1). To ensure existing walls and embankments are adaptable adequate foundations must be designed and installed in Year 1. Culverts which are installed as part of the scheme should be sized to convey MRFS or HEFS flows. The additional costs of the larger conveyance structures is typically a small fraction of the cost required to replace/upsize the culvert in the future.

The CCAP must also consider the land required to facilitate future adaptation of the scheme. This includes the land required to expand future earthen embankments and where additional future defences are required to ensure the existing scheme is not bypassed.

The effect of these Year 1 measures is to increase the cost of the scheme and reduce the benefit-cost ratio (BCR). However the fully adapted scheme may be considered against the 'sliding' damage assessment benefit, i.e. assuming damages are increasing year on year towards the appropriate future scenario. It may be the case that an adapted scheme has a higher BCR than the initial Flood Relief Scheme.

The integration of the Year 1 adaptation changes within the Preferred Scheme can be difficult to manage in terms of the FRS programme. The identification of the Preferred Option for the present day is often the trigger for many other tasks within environmental assessment and design development. Revision of the Preferred Option following the CCAP can lead to abortive work and programme delay.

4. CONCLUSIONS

It is difficult to accurately quantify the progression of climate change as it pertains to fluvial flood risk. Hydrometric flow data is affected by quality issues associated with the indirect measurement method (using a stage-discharge relationship). Uncertainty in the data can be significantly reduced through the high resolution hydraulic and hydrological analysis supporting a Flood Relief Scheme. Following this analysis hydrometric data from a number of scheme areas across the country was assessed for evidence of climate change. Within most of the gauging station datasets there is evidence of growth in both the index flood flow (Q_{med}) and more extreme events when considering recent versus older data. The nature of extreme value analysis however means there is low statistical confidence in such conclusions relating to the more extreme events (>30 year return period).

Within the trends observed in the hydrometric flow data it is very difficult to differentiate between climate and catchment changes. The OPW guidance on Climate Change Adaptation recommends that these are both considered within 'Future Scenarios'. For Flood Relief Schemes there is potential for rapid catchment urbanisation within smaller tributary catchments draining through settlements. Predicting the rates of urbanisation is highly uncertain but it is expected to compound the effect of climate change within the Mid-Range and High End Future Scenarios.

In the Future Scenarios the Standard of Protection of the schemes is expected to reduce progressively over the scheme design life. Assessment of potential adaptation pathways is complex for large schemes. Hydrometric monitoring is a key measure to assess the requirement for adaptation and identify trigger points in the future. A result of the Climate Change Adaptation Plan is the inclusion of measures to be delivered in Year 1 to ensure future adaptation of the scheme is possible. Nature-based Solutions for Catchment Management are often well suited to provide adaptation of flood relief schemes but a different assessment framework is needed to proof the economic, environmental and social case for such measures.

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