Kilkee Flood Relief Scheme – Scheme Climate Change Adaptation Plan (SCCAP)

Final Report

July 2024

COMHAIRLE CONTAE AN CHLÁIR
CLARE COUNTY COUNCIL

OPW Oifig na nOibreacha Poiblí Office of Public Works

JBA Project Manager

Michael O'Donoghue
Unit 24, Grove Island
Corbally, Limerick
V94 312N

Revision History

Revision Ref/Date	Amendments	Issued to
S3-P01/ 17-11-2023	Draft Report	Steering Group
S3-P02/ 05-01-2024	Draft Report	Steering Group
S3-P03/ 13-03-2024	Draft Report	Steering Group
S3-P04/ 20-06-2024	Draft Report	Steering Group
A3-C01/ 12-07-2024	Final Report	Steering Group

Contract

This report relates to the Kilkee Flood Relief Scheme commissioned by Clare County Council, on behalf of the Office of Public Works. Anastasiya Ilyasova and Tom Sampson of JBA Consulting carried out this work.

Prepared by .... Anastasiya Ilyasova BSc MSc

Project Hydrologist

.... Tom Sampson BSc MSc FRGS CEnv MCIWEM C.WEM
Technical Director

Reviewed by .... Michael O'Donoghue BEng (Hons) CEng MIEI

Associate Director

Purpose

This document has been prepared as a Final Report for the Steering Group. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

JBA Consulting has no liability regarding the use of this report except to Clare County Council and the Office of Public Works.

Copyright

Carbon Footprint

A printed copy of the main text in this document will result in a carbon footprint of 58g if 100% post-consumer recycled paper is used and 73g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

JBA are aiming to reduce their per capita carbon emissions.

Contents

Glossary of key terms

Adaptation Measure	A potential amendment or addition to a flood relief scheme to mitigate potential future increases in flood risk, typically assessed for either the Mid-Range Future Scenario or the High-End Future Scenario.
Adaptation Pathway	A combination of one or more Adaptation Measures required over a period of time to mitigate potential future increases in flood risk.
Adaptation Pathway Process	The process of assessing Potential Options and the Preferred Option, through the identification and evaluation of Adaptation Measures including cost benefit analysis and a Preliminary Viability Review, and subsequent mapping out of Adaptation Pathways.
Current Scenario	The present-day flood risk that exists, with no inclusion for climate change.
Current Scheme	The flood relief scheme being developed to manage present-day flood risk, or the flood risk that exists in the Current Scenario.
High-End Future Scenario	The more extreme of two indicative potential futures adopted by the OPW for use in flood risk assessment. Based on information available on climate projections, these indicative futures are used to assess the vulnerability of a community to potential future increase in flood risk.
Mid-Range Future Scenario	The less extreme of two indicative potential futures adopted by the OPW for use in flood risk assessment. Based on information available on climate projections, these indicative futures are used to assess the vulnerability of a community to potential future increase in flood risk.
Preliminary Viability Review	A preliminary review of the potential future viability of identified Adaptation Measures, used as a tool to support and document the evaluation of the climate change adaptability of the Preferred Option only.
Scheme Climate Change Adaptation Plan	The final plan setting out the findings of the Adaptation Pathway Process, produced for the Preferred Option only.

1 Introduction

Clare County Council intends to apply for planning permission for a Flood Relief Scheme along the Atlantic and Victoria Streams in Kilkee, Co. Clare. The proposed development consists of development of a flood relief scheme to minimise the risks currently posed to people, the community, social amenity, environment, and landscape. The proposed planning permission relates only to the construction of fluvial flood defence assets as part of Phase 1. A separate coastal scheme for Kilkee will form part of Phase 2, but the works do not form part of the proposed planning submission or this adaptation plan for Phase 1.

Kilkee is located adjacent to Moore Bay along the west coast of County Clare. The study area for the scheme comprises the town centre with rural lands stretching outwards to the east. The Victoria Stream and the Atlantic Stream are the two main watercourses that flow through the town of Kilkee. Historically, the town has been subject to fluvial flooding and as such, Kilkee was part of the Office of Public Works (OPW) Catchment Flood Risk Management (CFRAM) study programme. This study's Preliminary Options Report concluded that a flood relief program for the local community would be feasible and effective. According to the CFRAM Options Report, the viable scheme option for Kilkee consisted of a series of flood embankments and flood walls.

The town of Kilkee and the contiguous areas were severely flooded during April of 2015 due to heavy rain, when a nearby stream burst its banks. Significant flooding events also took place in the surrounding areas in 2014 and 2019.

1.1 Purpose of this Plan

A climate change adaptation plan is required for all flood relief schemes. The overall process of assessing climate adaptation in the different stages of flood relief scheme development is set out in Table 1-1. Climate change has been considered in the initial screening of measures and the formation of potential options. The purpose of this report is to review and present how the preferred option is flexible and robust under a range of different future climate change conditions (bold rows in Table 1-1).

The scheme climate change adaptation plan (SCCAP) is a live document and should be reviewed on a regular basis as the proposed project description evolves during the design and construction stages, and also in response to new information in relation to climate change effects and the performance, maintenance and management of the infrastructure.

Table 1-1. Adaptation assessment at various stages of scheme development

Stage	Assessment of climate change adaptability	Output
Initial Screening of Measures	High-level consideration of climate change adaptability. Potential measures are not screened out based solely on adaptability.	Potential Measures
Formation of Potential Options	Use professional judgement to assess climate change adaptability.	Potential Options
Assessment of Potential Options	**Undertake Steps 1 and 2 of the Adaptation Pathway Process for Potential Options.**	**Preferred Option**
Assessment of Preferred Option	**Undertake Steps 3 to 8 of the Adaptation Pathway Process for the Preferred Option.**	**Scheme**
Identification of Preferred Option	**Draft Scheme Climate Change Adaptation Plan (SCCAP) for Preferred Option only.**	**SCCAP**

The development of the scheme climate change adaptation plan takes eight steps as set out in Table 1-2. The first two steps have already been considered in the development and selection of the preferred scheme option. The outputs for the SSCAP are included in this report, with the detailed considerations documented elsewhere in the Options Report. The remaining focus is on steps 3 to 8 of the process. The climate change adaptation plan starts with step 3.

Table 1-2. Stepped approach to the scheme climate change adaptation plan

Step	Details	Output
All Potential Options:		
1 – Baseline Economic Assessment	Determine the Standard of Protection for the Potential Options for 'Current Scheme' in the Current Scenario, MRFS and HEFS using the existing hydraulic model and hydrological / hydraulic assessments. Use existing damage assessment information (flood event damages, Annual Average Damages (AAD)) to estimate the PVd for the 'No Scheme' baseline for the Current Scenario, MRFS and HEFS. Use the Standard of Protection (SoP) of the 'With Current Scheme', and the benefit area to estimate 'With Current Scheme' PVd and NPVb for each Potential Option for the Current Scenario, MRFS, and HEFS using the 'damages avoided' approach.	SoP and PVd for "No Scheme" and SoP for "With Current Scheme" (Current, MRFS and HEFS)
2 – Initial Screening Assessment	Undertake a high-level screening assessment of the viability of potential physical and non-physical adaptation measures for each Potential Option to maintain / restore the Target Standard of Protection (physical), or manage the residual risk (non-physical) where the Target Standard of Protection cannot be maintained, for the MRFS and HEFS. Non-viable adaptation measures should be screened out.	Potential Adaptation Measures (MRFS and HEFS)
Preferred Option only:		
3 – Adaptation measure cost benefit analysis	This considers the economic viability of available adaption options for the MRFS and HEFS conditions. Potential adaptation measures are developed, to determine key design parameters e.g. length, volume, height etc., to enable the estimation of costs for each adaptation measure in isolation. This stage uses the existing damage assessment information (flood event damages, AAD, the SoP of the Preferred Option as the 'Current Scheme', and the benefitting area to estimate indicative economic indicators for 'MRFS Scheme' and 'HEFS Scheme' options. The appraisal is of each adaptation and not of an overall pathway. The economic indicators used is a Benefit Cost Ratio (BCR) based on the Present Value Damages (PVd) and Net Present Value Benefits (NPVb) for the MRFS and HEFS respectively using the 'damages avoided' approach. This is based on a Standard of Protection (SoP) to be provided by the adaptation. Detailed economic assessment (e.g. modelling the adaptation measure for 8 flood events) is not required. The MRFS adaptation measures are identified first and then HEFS adaptation measures. HEFS adaptation measures include those on top of MRFS adaptations and also HEFS adaptations that are on directly on top of the 'Current Scheme'.	SoP, PVd PVb for 'MRFS Schemes' and 'HEFS Schemes'. Adaptation measure costs (PVc).
4 – Adaptation measure preliminary viability review	This stage is a preliminary viability review for each potentially viable adaptation measure developed in isolation using existing information gathered during scheme development to assist. A simple Multi Criteria Analysis (MCA) process is used with six broad categories: Economic Social	Preliminary viability review for each adaptation measure.

Step	Details	Output
	Environmental Technical – Operational Robustness Technical – Health and Safety Technical – Climate change adaptability	
5 – Adaptation pathway assessment	In this stage the adaptive pathways are mapped to visually show how the scheme can adapt to a range of different possible future conditions. This includes commentary on the residual risks and how interdependencies could influence adaptive capacity. The adaptive pathway map shows the adaptability and flexibility of the Preferred Option.	Adaptation Pathways
6 – Timing of future adaptation	This is where a timescale is assigned for each Trigger Point and Tipping Point under each climate change timeline.	Trigger Point / Tipping Point timings
7 – Climate change provision in the preferred option	In this stage, additional provisions to be built into the preferred option are identified and clearly described. The timescale for future adaptation and flexibility of the preferred option can be confirmed. The findings of the Adaptation Pathway Process can be used to confirm and/or refine the Preferred Option. The appraisal step sets out the potential future investment that may be required, or whether to take a precautionary or hybrid approach that builds in resilience and adaptive capacity into the design.	Assumptive / Adaptive Provision Finalised Preferred Option
8 – Finalisation of the assessment	The final stage is to summarise the findings of the Adaptation Pathway Process for the preferred option only as a draft Scheme Climate Change Adaptation Plan (SCCAP). This should reflect the adaptive pathways which the preferred option can take in response to a range of different possible future conditions. This includes commentary on the residual risks and how interdependencies could influence adaptive capacity. This clarifies decisions made in relation to climate change allowance (Step 7) and, where necessary, re-map the adaptation pathways for the preferred option (developed in Step 5) where an assumptive or adaptive allowance has been included. A monitoring programme is also to be developed and included in the SCCAP. The monitoring plan identifies what aspects of climate change and scheme performance need to be monitored, who should be responsible for this, and the timing and trigger for mobilising future adaptation.	Draft Scheme Climate Change Adaptation Plan and Monitoring Programme

1.2 Climate Change and Uncertainty

1.2.1 Impacts of Climate Change

Impacts of climate change have been well documented in literature, and new research and data continues to evolve our understanding of these impacts. The potential impacts on flood risk are summarised below;

- Annual average rainfall was 7% higher in the period 1990-2019, compared with the 30-year period 1961-1990[1].

1 Cámaro Garcia, Walther C.A., Dwyer, N., and Gault, J. (2021) The Status of Ireland's Climate, 2020, EPA Research Report 386, Johnstown Castle, Co. Wexford

- An analysis of monthly rainfall shows the decade from 2006 to 2015 was the wettest on record and there is evidence of a trend towards an increase in winter rainfall[2].
- Met Éireann has predicted that in Ireland the autumns and winters may become wetter, with a possible increase in heavy precipitation events of approximately 20%[3], which could increase both fluvial and groundwater flooding.
- Climate change is not only reflected in terms of the average temperature, precipitation, etc., but also in the frequency and intensity of extreme weather conditions. The consensus among different modelling approaches is that extreme rainfall events are likely to increase in frequency in autumn and winter, although uncertainty remains in these projections and further research is required[4].
- Satellite observations indicate that the sea level around Ireland has risen by approximately 2-3mm per year since the early 1990s[1].
- The IPCC[5] has reported that it is virtually certain that global mean sea level will continue to rise over the 21st century. The likely global mean sea level rise by 2100 is 0.28-0.55m under a very low emissions scenario, and 0.63-1.01m under a very high emissions scenario.
- The number of very intense storms is projected to increase over the North Atlantic Region[6], and the winter track of these storms may extend further south and over Ireland more often.
- An increase in the number of intense storms over the North Atlantic could have a direct impact on storm surges, although there is uncertainty around the impact on storm surges[7].
- In the southwest of Ireland, significant wave heights have increased by 0.8 m per decade although there is still uncertainty around the impacts of climate change on wave heights in the longer term.

While uncertainty exists with regards to the rate and degree of change, as discussed below, there is a clear risk that flooding, arising from the projected change in climatic parameters, is likely to become more frequent and severe in the future.

---

2 Murphy, C., Broderick, C., Burt, T.P. et al. (2018) A 305-year continuous monthly rainfall series for the island of Ireland (1711-2016). Climate of the Past 14: 413-440.

3 Nolan, P. (2015), Ensemble of regional climate model projections for Ireland, EPA Research Report No. 159, Environmental Protection Agency, Johnstown Castle, Co. Wexford.

4 Dunne, S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Ratnam, J.V., Semmler, T., Sweeney, C. and Wang, S. (2009) Ireland in a Warmer World, Scientific Predictions of the Irish Climate in the Twenty-First Century. (R. McGrath and P. Lynch, eds.), Community Climate Change Consortium for Ireland.

5 IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

6 IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea,T.E. Bilir, M. Chaterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

7 Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts, C. and Wolf, J. (2018). United Kingdom Climate Projections 2018 Marine Report.

It is prudent therefore to plan for the potential for climate change and with flexible strategies, potential future requirements can, and need, to be considered today to promote resilience and embed adaptation in flood risk management.

On this basis, the OPW has made it a requirement that a SCCAP shall be prepared as part of the design process for all new OPW-funded flood relief schemes, and that separately SCCAPs will be developed retrospectively for all existing schemes previously built.

1.2.2 Uncertainty of Climate Change Impacts

Climate projections are based on computer models attempting to simulate complex natural systems, with different models leading to different projections in terms of the impacts on climatic parameters. Further, a key factor in making climate projections are the future global emissions of Green-House Gases (GHGs), and there is great uncertainty as to how emissions of GHGs will increase or decrease in the future.

Projecting the potential impacts of climate change is therefore subject to a range of uncertainties:

- The rate of future global emissions is uncertain, and will be determined by action at all levels, and in particular the development of and adherence to national and international agreements, policies and measures to control and reduce emissions, which will be subject to political and economic factors and pressures.
- There remains inherent uncertainty in all climate models that seek to simulate extremely complex and dynamic natural systems, and with an evolving understanding of some critical aspects, such as the melt-rates and potential behaviour of the Greenland and Antarctic ice sheets.
- There is a range of global and regional climate and circulation models in use internationally that create ensembles of varying impacts for a given emissions scenario.
- Different hydrological models can generate different projections in hydrological response for a given change in rainfall pattern over a particular catchment, providing a further dimension of uncertainty with regards to projections for climate change impacts on river and ground water flooding.

The uncertainties are greater for some climatic parameters, such as projections of changes in rainfall patterns, and in particular short time-step (e.g., daily) rainfall. For other parameters, the uncertainty is less, such as the short-medium term rise in mean sea level, noting that a rise is already being observed and evidence exists that this is accelerating.

While the uncertainty in impacts must not be a barrier to action and the potential for change cannot be ignored, care is also required to avoid ‘maladaptation’ whereby, based on assumed possible future impacts, actions are taken now and resources spent that may ultimately not be required. Such actions may act to restrict future adaptation measures and/or have unforeseen detrimental impacts on other objectives.

1.2.3 Scenario-based approach

A scenario-based approach to the assessment of the impacts of climate change has been embedded within flood risk management in Ireland since the commencement of the Catchment-based Flood Risk Assessment and Management (CFRAM) Programme in 2005. This approach centres around assessing the potential range of impacts of climate change across multiple emissions scenarios and models on the hydrological parameters that are of most direct relevance to flooding and flood risk, and the use of indicative potential future scenarios that are representative of this full range. This differs from a commonly used approach where projections are linked to specific emission scenarios and models.

Two potential future scenarios (see Figure 1-1) have typically been used to date, and will be adopted for use within this SCCAP guidance note; namely the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS). More extreme scenarios, the H+FS and H++FS, that include allowances for mean sea level rise of 1.5m and 2.0m respectively, have also been used with regards to coastal flooding. These more extreme scenarios (1.5m and 2.0m sea level rise) are currently considered to be very low likelihood scenarios for this century based on IPCC projections, and are not directly used within this SCCAP guidance note.

Parameter	MRFS	HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Peak Flood Flows	+ 20%	+ 30%
Mean Sea Level Rise	+ 500 mm	+ 1000 mm
Land Movement	- 0.5 mm / year[1]	- 0.5 mm / year[1]
Urbanisation	*No General Allowance – Review on Case-by-Case Basis*	*No General Allowance – Review on Case-by-Case Basis*
Forestation	- 1/6 Tp[2]	- 1/3 Tp[2] + 10% SPR[3]

Figure 1-1. Allowances in flood parameters for the Mid-Range and High-End Future Scenarios

The scenarios are not time-bound projections, i.e., they are not projections of what is likely to happen at a point in time, but rather reflect potential 'flood futures' that could arise at some point in time in the future. The scenarios can be used to assess the vulnerability of communities and to inform what future interventions (adaptation measures) may be required should the scenarios be realised. Notwithstanding the temporal independence of the scenarios, timelines for their occurrence are useful to guide when reviews of the adaptation plans and potential points of action may be required.

The advantages of adopting a scenario-based approach are:

- It is independent of specific climate models and emissions scenarios, but rather reflects the overall range of potential outcomes in terms of the parameters that are most relevant to flood risk management, and so they are less sensitive to debate around the merits of different models or the likelihood of different emissions scenarios.
- By fixing the climate change variables, rather than fixing the rate at which climate change occurs, it is possible to test the vulnerability of communities and potential adaptive measures required for different climate change timelines efficiently without undertaking additional hydraulic modelling.
- It provides different scenarios to inform vulnerability and assess appropriate responses within the community-specific context, rather than designing to fixed projections, reducing the risk of maladaptation.

It should be noted that it is quite possible that the impacts of climate change on fluvial flood risk and coastal flood risk are realised at different rates. As a purely hypothetical example, a 0.5m rise in sea levels, as per the MRFS, may be realised by 2070, whereas the corresponding MRFS increase in fluvial flows, i.e., 20%, could occur in 2050 or may not be realised until into the next century.

1.2.4 Climate Change Timelines

Timelines for the occurrence of the MRFS and HEFS are adopted for use within this SCCAP guidance note to assist on identifying when adaptation may be required (Table 1-3). Each timeline is scenario-based e.g. estimated year in which each defined scenario (MRFS and HEFS) occurs, rather than estimating the change in a key indicator in a given year.

Table 1-3. Trajectories for scenario-based climate change timelines for Ireland

Trajectory	Indicative IPCC Scenario	Current	MRFS	HEFS
Most Optimistic Case	SSP1-1.9	2020	2130	2270
Slower Onset	**SSP2-4.5**	**2020**	**2100**	**2160**
Medium Onset	SSP5-8.5	2020	2085	2120
Faster Onset	SSP5-8.5, including ice-sheet instability	2020	2060	2080

The Slower, Medium, and Faster Onset trajectories outlined above broadly reflect the midrange projection of the SSP2-4.5, SSP5-8.5, and SSP5-8.5 (including ice-sheet instability allowances) illustrative emissions scenarios as described within the IPCC Sixth Assessment Report.

The Most Optimistic Case is provided for comparative purposes only, and broadly reflects the SSP1-1.9 emissions scenario. It should not be directly used within the SCCAP. The published timelines may be subject to periodic review in light of new research and climate change observations.

1.2.5 The '4A's Approach

There are a range of design philosophies or approaches that can be taken in assessing how potential changes in flood hazard and risk can or should be managed that are captured within the '4A's framework:

- The ***Assumptive*** approach, where an allowance is designed and built into what is constructed now to provide for a degree of future change. Examples of this would include incorporating additional height on a flood defence wall or embankment, provision of additional capacity in by-pass channels or culverts or additional storage capacity in flood attenuation reservoirs. There is a risk of maladaptation with this approach, given that a fixed allowance is included, but it may be appropriate to provide for a foreseen minimum degree of change or apply this approach in circumstances where an Adaptive approach (see below) would be difficult to apply or would be disproportionately expensive, such as the construction of a culvert.
- The ***Adaptive*** approach, where provision to facilitate cost-efficient adaptation of a structure is designed for and built into what is constructed now. Examples of this would include designing and building the foundations of a flood defence wall now to provide for an increased height of defence, above that which is built now, or over-widening the footprint and/or crest-width of an embankment to allow for an increase in the height of the embankment in the future. This approach offers greater flexibility with regards to future interventions and reduces the risk of potential abortive costs associated with maladaptation, but may still limit the extent of future change depending on the adaptive allowance designed for.
- The ***Alternative*** approach, where it is not intended to provide for the impacts of climate change through making changes to what is built now, or to adapt or modify those structures in the future, but rather to implement different measures, potentially in other locations, to manage a potential increase in

risk. Examples of this would include introducing storage or nature-based solutions (NbS) upstream to offset potential future increases in flood flow to a given community downstream, or by providing increased conveyance to complement existing defences. This approach provides a significant degree of flexibility and limited risk of maladaptation as it does not involve any fixed change / provision in what is built today, but may require the protection of certain areas to ensure that the foreseen alternatives are not impeded by future development.

- The ***Acceptance*** approach, where a reduced standard of protection is accepted and it is not intended to provide protection against any increase in flood risk, but rather to address the increasing risk through non-structural risk reduction and property and community resilience measures, such as enhanced forecasting and response, property flood resistance or resilience, etc. It has been found to date there is typically a strong preference within at-risk communities for protection measures to be constructed, rather than accepting that floods will happen and relying on resilience, and so the adoption of this approach would require thorough engagement with the community and may only be locally acceptable where the other approaches are not technically viable or would entail significant impacts on other sectoral values or objectives.

Which of the above approaches is suitable for a given flood relief scheme will be very much scheme-specific and dependent on local constraints, objectives and considerations, taking into account costs both now and in the future, including the differential costs of adopting an assumptive or adaptive approach into what is built now. It should be noted that a mix of approaches may well be required or applied to different elements or flood cells within a single scheme.

1.2.6 Uncertainty

In addition to the uncertainty associated with the future impacts of climate change, it is uncertain how society, societal values and the political and economic situation will change in the future; both nationally and internationally. Such changes will set the future context for decision-making on what actions may or may not be taken at that time, which objectives are prioritised relative to others and could significantly impact on key factors such as materials and construction costs or the value of assets at risk.

While analysis now could indicate that a particular future route would appear to be clearly the most advantageous based on the decision-making criteria that exist today, the decision on what does actually happen in the decades to come will be made by future communities and professionals, under the conditions, context and decision-making rules that are in place then, which could be very different from those that apply now.

As such, it is not appropriate to identify a preferred adaptation measure or pathway that will be needed in the future but rather to set out a range of adaptation measures / pathways that future generations can decide upon, and to make provision now as necessary to maximise the flexibility, and minimise the costs, for future interventions. Similarly, it is not necessary at this point in time to economically justify potential future investment, nor to exclude potential adaptation measures / pathways on the basis of a benefit-cost ratio deficit below unity under today’s conditions, as those decisions will only need to be made, and justified, in the future when, as above, the decision-making criteria may be very different.

1.2.7 Freeboard

A key consideration in relation to determining the future standard of protection offered by a flood relief scheme or an adaptation measure is how freeboard is treated. Most flood relief schemes will incorporate a freeboard allowance to address sensitivity and uncertainty with regard to the design flood parameters, including flow and level as appropriate.

This freeboard does not form part of the Standard of Protection, but instead mitigates the risk associated with the residual uncertainty e.g. if the peak flow of the design flood event is actually higher than that estimated. In many cases, this freeboard allowance will also include a settlement allowance whereby the constructed defence or the ground beneath the constructed defence is anticipated to settle or compress over time.

For the purpose of the Adaptation Pathway Process, and in particular determining the standard of protection provided in the future, an 'operational freeboard allowance' shall be assumed and excluded from the as-built defence level.

For new flood relief schemes, this can be assumed to be the design freeboard allowance minus any settlement allowance included within that. So, if there is a 350mm design freeboard allowance, and 150mm of that is related to an allowance for settlement, the 'operational freeboard allowance' would be 200mm. Therefore, a defence which is constructed to a level of 38.0mOD would be assessed as being at 37.8mOD for the purpose of the Adaptation Pathway Process.

Similarly, if an adaptation measure needs to be constructed to 38.2mOD to reinstate the target standard of protection, it shall be costed to include the 'operational freeboard allowance' i.e. 38.4mOD.

This approach is more appropriate than ignoring freeboard allowances altogether. Future, more detailed appraisal of adaptation measures to be undertaken once the need to adapt is established should include detailed assessment of future freeboard requirements.

1.2.8 Tipping and trigger points

An understanding of when adaptation is required is essential to enable timely assessment and intervention to proactively manage the potential impacts of climate change on flood risk.

Tipping point(s) and trigger point(s) are identified to facilitate this. The tipping point relates to the level of flood risk to the community, and specifically the target standard of protection of the flood relief scheme. The identification of the tipping point is largely subjective and will vary on a scheme by scheme basis. However, advice is provided within this guidance note to support the identification of the tipping point.

Two Tipping Points, Point 1 and Point 2, should be established in line with the definitions below:

- Tipping Point 1 - The time at which the design flood level exceeds the surveyed Crest Level minus the operational freeboard allowance at any location (i.e., operational freeboard retained).
- Tipping Point 2 - The time at which the design flood level exceeds the surveyed Crest Level (i.e., no operational freeboard).

The design flood level will typically be the 1% AEP flood event for fluvial flooding, or the 0.5% AEP flood event for coastal flooding. Both of the above tipping points can be determined using the onset of flooding, and do not necessarily require exceedance events to be modelled.

Tipping points can be amended on a scheme by scheme basis where appropriate to do so.

Maintaining design flood levels below Tipping Point 1 at all times will assist in promoting sustainable communities and supporting our environment through the effective management of the potential impacts of climate change on flooding and flood risk. However, it is noted that it may not always be viable to achieve this goal at all times, and so Tipping Point 2 is included.

Trigger points relate to when the planning to implement an adaptation measure needs to commence in order to avoid the tipping point being reached.

The trigger point will always precede the tipping point as it must account for the lead-in time, or the time taken to verify the need for, appraise, design, and construct an adaptation measure. This should be estimated using professional judgement and experience of delivering flood relief schemes in Ireland and with consideration for the complexity of the adaptation measures proposed for the scheme. As such, it will be identified following the development of potentially viable adaptation measures.

An adaptation measure which, for example, requires raising an existing wall by 100mm over a 50m length will be much quicker to implement than an adaptation measure that requires the construction of a new tidal barrier. Similarly, in the case of NbS-CM, the time for these measures to mature (e.g. tree planting) may need to be factored in to the trigger point.

The adaptation measure with the longest lead-in time should always be used to determine the trigger point to ensure a conservative approach to future adaptation.

The trigger point will typically be determined as a defined period of time (in years) prior to the tipping point.

Figure 1-2 illustrates the relationship between tipping points and trigger points, with specific reference to Trigger Point 1 and Tipping Point 1 (the "desirable" threshold) and Trigger Point 2 and Tipping Point 2 (the "minimum required" threshold).

The green line illustrates how the standard of protection will change over time if an adaptation is implemented to avoid Tipping Point 1 being exceeded. The yellow line illustrates how the standard of protection will change over time if an adaptation is implemented to avoid Tipping Point 2 being exceeded.

In Figure 1-2, an assumptive allowance for climate change has been provided in both cases to ensure that Tipping Point 1 and 2 are pushed out to ensure the next adaptation is not required for some time. The date that each Trigger Point and Tipping Point occurs will vary for each climate change timeline.

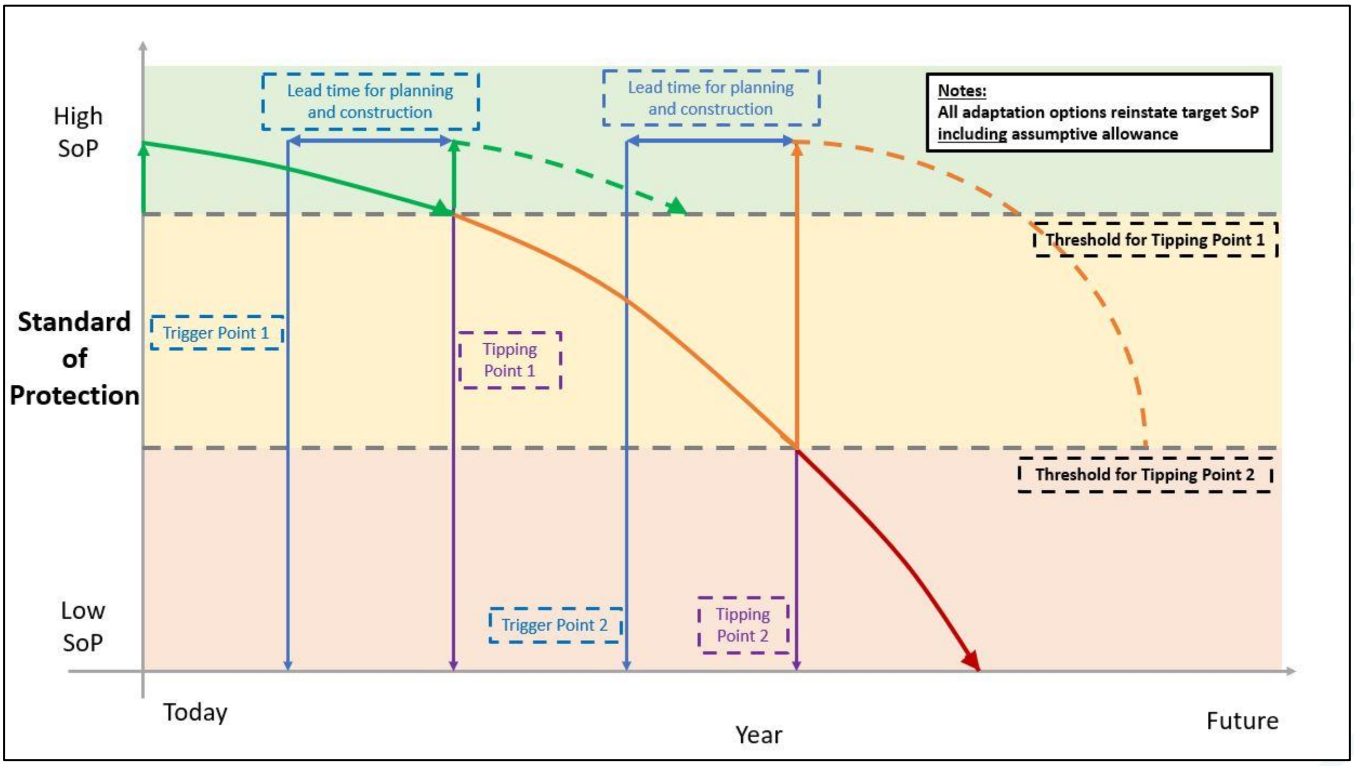

Figure 1-2. Schematic drawing to illustrate the Trigger Point and Tipping Point approach adopted in this SCCAP.

2 Description of Preferred Option

2.1 Site Location

The study area is outlined in red in Figure 2-1.

Kilkee is adjacent to Moore Bay on the West coast of County Clare. The AFA boundary defined by the CFRAM has an approximate area of 3.6km². The Victoria Stream and the Atlantic Stream are the two main watercourses that flow through the town of Kilkee and are the two main watercourses considered in the Flood Relief Scheme. Both streams flow from southeast to northwest, with the Victoria Stream located to the south of the town and the Atlantic Stream located to the north of the town. The two streams have a number of tributaries and drainage channels which contribute to the flow through the area. Both watercourses are tidal. Kilkee is susceptible to both coastal and fluvial flood risk.

There have been a few instances of flooding in Kilkee. The Victoria Stream is noted to overflow its banks over a length of 200-300m on an annual basis, causing flooding of Carrigaholt Road, Well Road and putting a number of residential and commercial properties at risk.

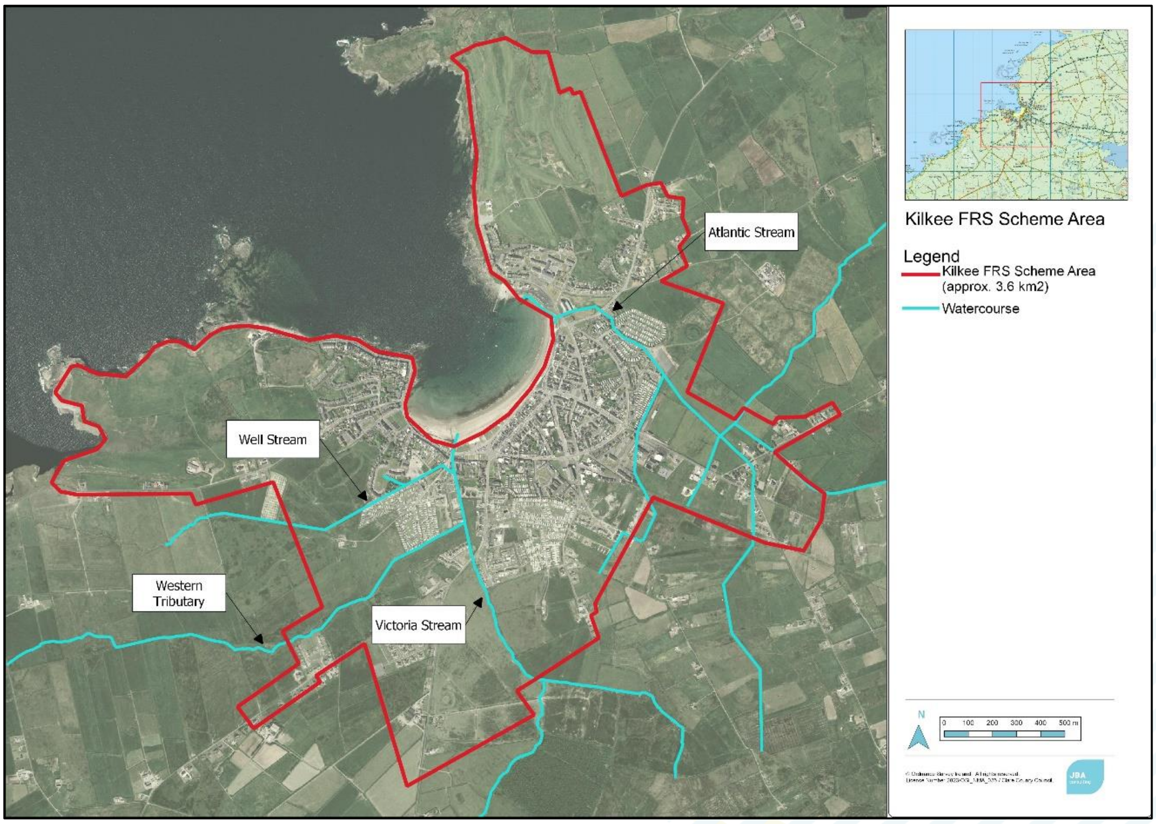

Figure 2-1. Kilkee FRS study area

2.2 Preferred Option

The preferred option is described hereunder for both the Atlantic Stream and Victoria Stream.

2.2.1 Atlantic Stream

The Atlantic Stream proposals include:

Kilkee Bay Hotel:

- Construction of c. 200m long embankment c. 1.3-1.6m high. This embankment will be constructed to HEFS defence levels.
- Diversion of c. 110m of open channel into centre of floodplain.
- Installation of new headwall and 600mmØ inlet culvert under embankment to link with existing culvert.

Dún an Óir estate:

- Increase the height of the existing boundary wall by c. 300mm over c. 103m length. This will be raised to HEFS defence levels.

Sandpark mobile park:

- Construction of c. 110m long embankment c. 700mm high. This embankment will be constructed to HEFS defence levels.

Waterworld:

- Installation of new debris screen at upstream culvert headwall.

Meadow View Court:

- Construction of 2 no. 2100mm dia. inlet manholes with grated covers on existing 1200mm dia. culvert.

2.2.2 Atlantic Stream Outfall

- Upgrade existing overflow chamber with raised cover (c. 2.7m long x 2m wide x 400mm high) with flap valves.
- Reconstruction of outfall manhole and installation of non-return valve on upstream 750mmØ culvert.
- Install non-return valve to existing 750mmØ overflow outfall culvert.
- Seal existing cover of manhole downstream of overflow chamber on main outfall culvert at existing ground level. (c. 2m long x 0.8m wide x 400mm high RC slab and new sealed lid).

These proposals consist of a reconstruction of the overflow manhole with a new pressure-releasing chamber cover to allow surcharged flows to be dissipated in a controlled fashion and allow flood waters to run down the promenade terracing and onto the beach. Non-return valves are proposed to the existing main outfall and overflow outfall culverts. The manhole on the main outfall culvert alignment downstream of the upgraded overflow manhole is to be sealed at its existing ground level.

2.2.3 Victoria Stream

The Victoria Stream proposals include:

Well Stream:

- Construction of c. 146m long embankment c. 1.1m high upstream of Cunningham's Holiday Park with inclusion of new headwall and 1050mmØ inlet culvert to existing culvert downstream.

- Installation of precast reinforced concrete u-channel along the existing Well Stream alignment c. 240m long and c. 1.6m above the adjacent road level. This will be constructed to MRFS defence levels.
- Installation of overflow on the Well Stream Tributary and non-return valve on the Well Stream u-channel left bank wall to maintain connectivity during normal flows and enable overflow to the carrier drain system during flood events.
- Decommissioning of existing Well Stream box culvert and circular overflow culverts at Crescent Place. Installation of new RC box culvert (c. 1.6m wide x 900mm high) c. 55m long under Crescent Place.
- Resurfacing and regrading of Well Road (c. 300m long x 5.5m wide x 300mm high).

Victoria Court:

- Reconstruction of Victoria Court boundary wall. The boundary wall is required to function as a flood defence in the HEFS.

Victoria Stream:

- Local repointing and thickening of existing left bank wall behind Crescent Place properties. Replacement of c. 3m section of wall to facilitate Well Stream RC box culvert installation at Crescent Place.
- Construction of c. 280m long embankment behind Carrigaholt Road c. 1.2-1.4m high above ground level.
- Construction of new flood defence wall c. 230m long along filled-in left hand bank from Victoria Park to Crescent Place c. 1.2-1.8m high above ground level. This will be constructed to MRFS defence levels.
- Diversion of c. 170m of open channel to centre of floodplain. Existing open channel to be filled in.
- Reconstruction of Victoria Crescent boundary wall c. 130m long.
- Construction of c. 37m long embankment c. 800mm high north of Victoria Crescent.

Western Tributary:

- Construction of embankment c. 980m long and c. 1.3-1.8m high around Western Tributary floodplain.
- Diversion of c.400m of open channel to centre of floodplain and filling in of existing channel.
- Regrading of floodplain in field north of Cluain na Mara estate by c. 700mm max.
- Regrading of floodplain in field west of Cunningham's Holiday Park (north of existing alignment of filled-in Western Tributary) by raising to 6.70mOD for the northern two-thirds section and lowering to 6.40mOD for the southern third section.
- Installation of 900mmØ culvert under Western Tributary embankment to link to diverted Victoria Stream alignment. Inclusion of headwalls on inlet and outlet of culvert.

3 Climate Change Adaptation Plan for Victoria Stream

3.1 Potentially viable adaptation measures, adaptive pathways and timelines

The screening of measures and development of options has been carried out with full consideration of climate change adaptability. Figure 3-1 shows the increase in water levels across the scheme area, with the proposed scheme in place for both the MRFS and HEFS.

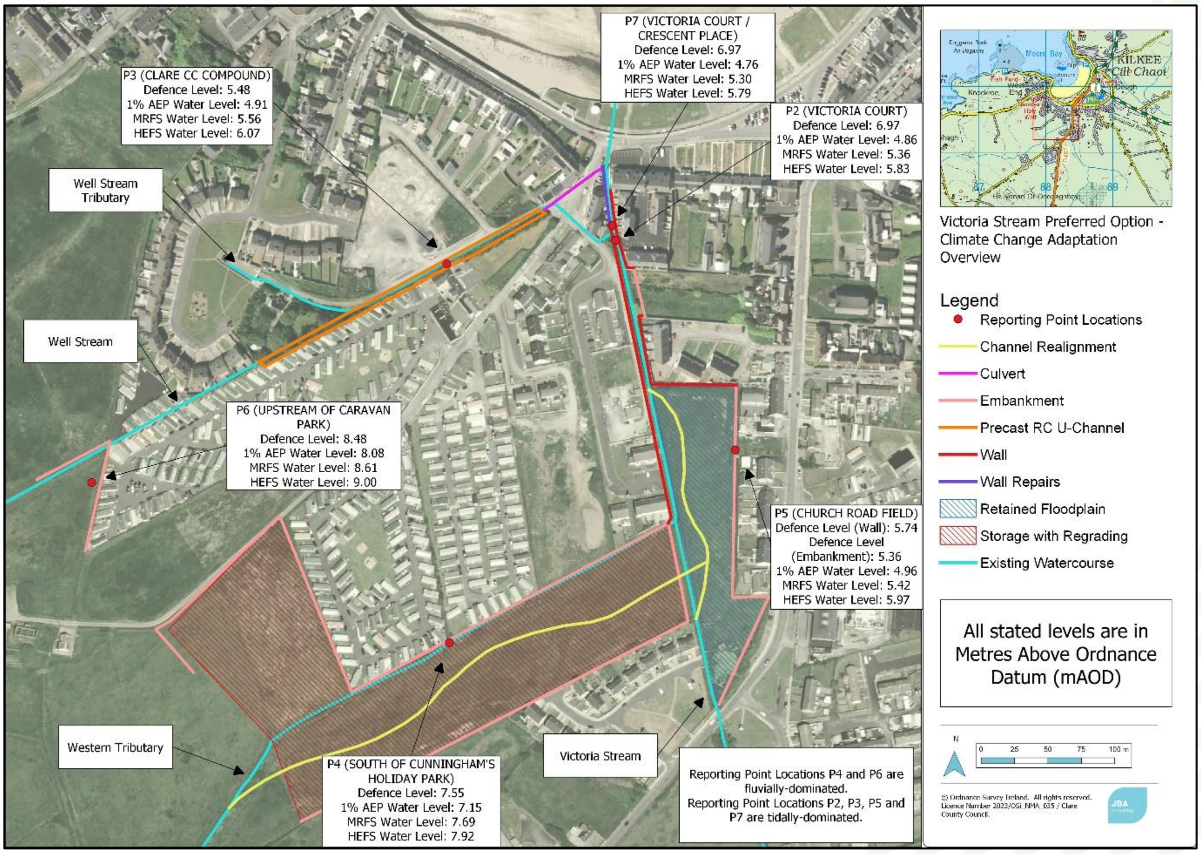

Figure 3-1. Victoria Stream level increases across scheme area

As is seen, there is significant increases in water levels at the Well Stream and downstream of the Carrigaholt Road field in both the MRFS and HEFS. This is dominated by the increased tidal boundary, with the dominant event being the T200/Q10. The critical locations and adaptations to focus the climate change adaptation plan for the Victoria Stream are outlined in Table 3-1.

These levels require more significant interventions at both the MRFS and HEFS.

Table 3-1. Victoria Stream - Climate Change Stages

Climate Change Stage	Adaptation Measure
Present Day	Increase Well Stream u-channel wall height to MRFS height now to accommodate increasing sea level. Increase Victoria Stream left hand bank wall height to MRFS height now.
MRFS	Introduction of Well Stream diversion into Western Tributary storage.
HEFS	Further increase in embankment heights. Throttle of flows to retain MRFS flows from Western Tributary storage into Carrigaholt Road Field. Introduction of storage upstream of R487 Bridge.

The introduction of the Well Stream diversion is clearly the most onerous intervention here. The impact on levels of this is shown in Figure 3-2.

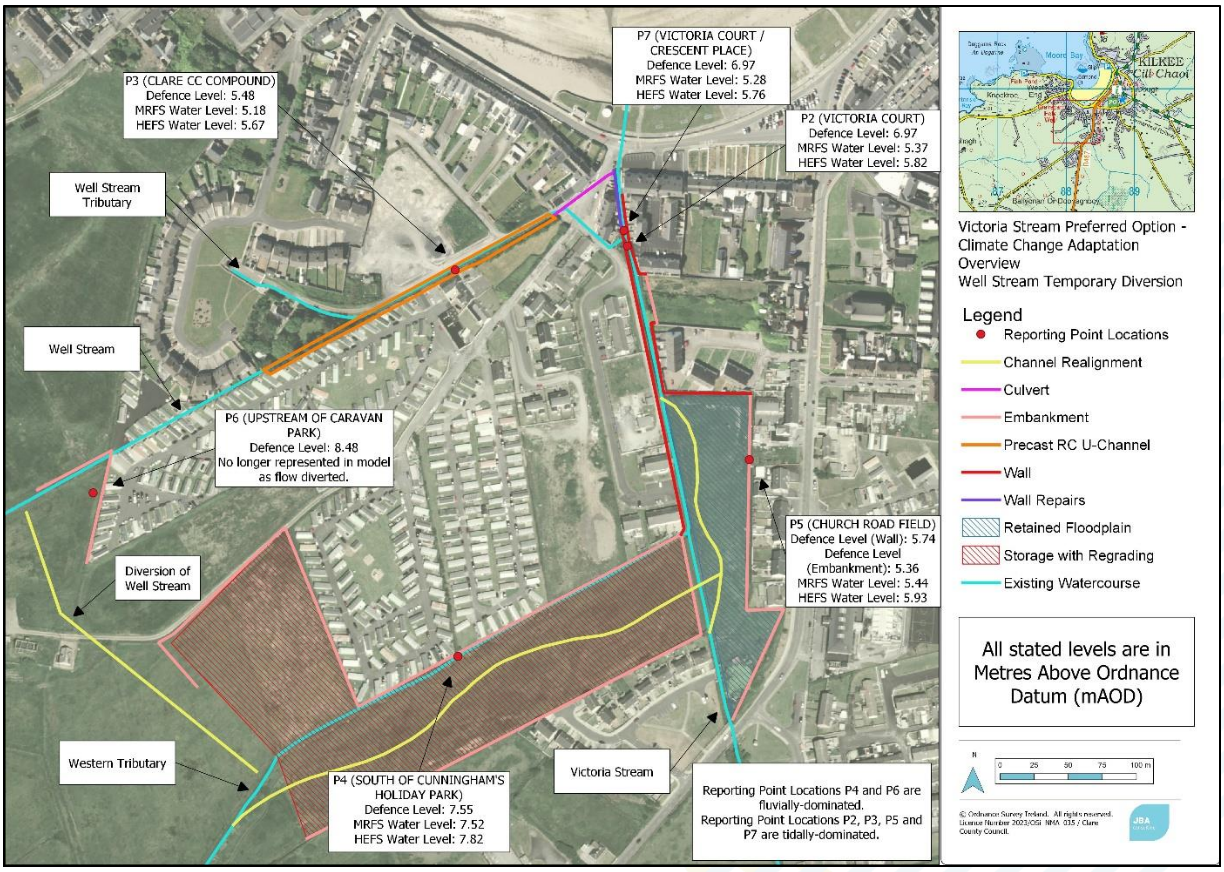

Figure 3-2. Victoria Stream with Well Stream diversion in place.

Through refinement of the preferred option using the hydraulic model to simulate different future scenarios we have identified a number of pathways and critical decision points. The future pathways are presented in Figure 3-3 and are discussed below in section 3.4. A summary of the proposed measures is provided in Table 3-2.

The pathways assume there are no changes in the management of storm runoff for water quality and sediment regime (deposition, erosion and transport) does not change.

It should be noted that significant uncertainty exists with the downstream boundary level considered in the climate change scenario. The downstream boundary considered in the current modelling set up does not allow for any reduction in wave set-up that may occur with the inclusion of any coastal scheme. This, therefore, is the worst-case scenario. However, it should be noted that without a coastal scheme in place preventing overtopping flood waters, the Well Stream culvert will become inundated with flood waters. This occurs at the MFRS. Therefore, the fluvial scheme will cease to operate as designed unless a measure is in place to prevent the overtopping volumes identified in the MFRS scenario. It is important, therefore, to include this in the Climate Change Pathway.

The management of stormwater runoff and discharge of river flow into Kilkee Bay is critical and with climate change the volume of design event storm runoff is likely to increase. This is an interdependency that must be considered and monitored. This adaptation plan is focused on the flood relief scheme only. Uisce Éireann are responsible for the management of stormwater runoff which enters the combined drainage networks, and will need to ensure that discharge of combined runoff does not adversely impact on the functionality of the flood relief scheme. Clare County Council and Uisce Éireann will need to collaborate to facilitate the separation of combined drainage networks into separate foul and stormwater networks, which will offer significant water quality and flood management benefits.

This pathway identifies a hold point approximately halfway towards the MRFS. This is to review any completed/pending coastal scheme and appraise the fluvial scheme with these new parameters.

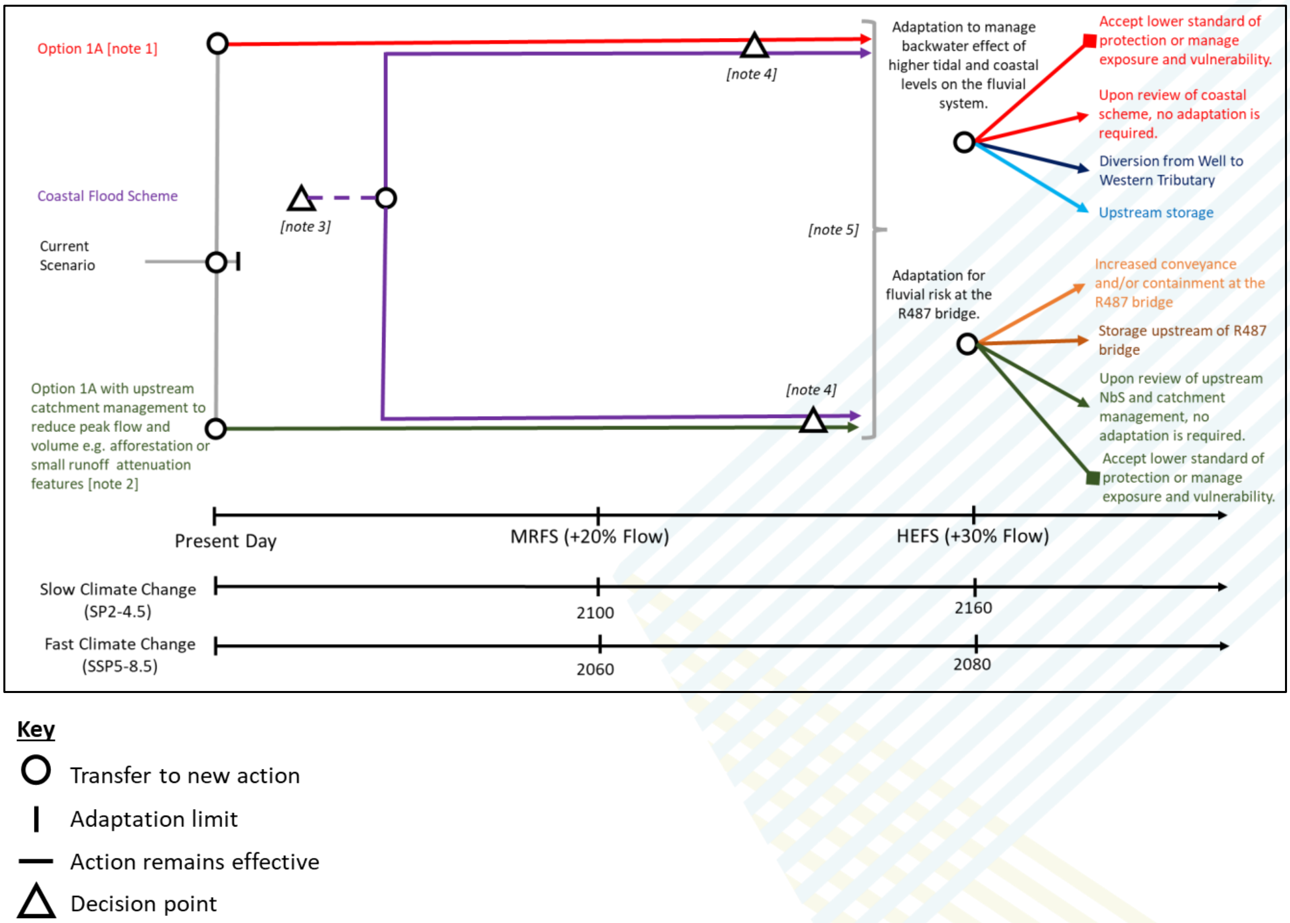

Figure 3-3. Adaptive Pathway for Victoria Stream Catchment.

Reference Notes to the adaptive pathway for the Victoria Stream Catchment

- [Note 1] Assumptive option up to the limit of acceptable and technical feasibility.
- [Note 2] Low regret adaptation with multiple benefits irrespective of adaptive pathway, such as water quality improvements, biodiversity habitat creation and possibly also recreation and tourism. They would complement any scheme option or adaptation. Unlikely to provide full future standard of protection alone but could continue to provide an acceptable level of protection. Nature-based Solutions will mature and increase in effectiveness over time. Could potentially buy time to delay need to implement structural adaptation measure.
- [Note 3] Review point at time when coastal flood scheme design is approved. Up to this point it is not possible to determine the effect of the coastal scheme on future coastal and tidal boundary. At this point the possible future adaptations for the fluvial scheme can be revisited.
- [Note 4] Review point for commencement of future adaptation. Possible that with upstream catchment management this point can be delayed.
- [Note 5] Both pathways have the same future adaptation options available. There are two independent locations which require adaptation decisions. With upstream catchment management and NbS future adaptation to HEFS could be delayed or may not be necessary.

Table 3-2. Summary of viable adaptation measures

Option	Description
MRFS Adaptation	The preferred option requires adaptation for the MFRS conditions. In all cases, this requires the installation of a diversion/overflow into the Western Tributary storage area. This is being driven by the downstream boundary created during the MRFS T200/Q10 event, the dominant event within the Well Stream. Given the significant uncertainty, it is appropriate to consider implementing this adaptation closer to the MRFS conditions than the HEFS.
Catchment management measures	Implement upstream catchment management measures on the Victoria Stream early to improve overall resilience, catchment conditions and potentially reduce peak water level loading on the proposed and existing river structures and flood defence infrastructure. It takes time for these measures to mature. The measures may not fully achieve the target standard of protection in the HEFS but could delay the need for any more structural adaptation. The catchment management measures will have significant other benefits in terms of water quality and biodiversity benefits but will require landowner participation, engagement and agreement. Implementing catchment management measures may extend the duration before a decision to adopt a structural adaptation is required.
HEFS Adaptation (H1)	The embankments in the Victoria Stream storage areas and the Western Tributary storage areas will also require an increase in height to cope with future conditions. On completion of the coastal scheme design the requirement and scale of future embankment adaptations should be revisited based on modelling undertaken during the coastal scheme development.
HEFS Adaptation (H2)	In order to remove the need to increase the embankments and walls in the Victoria Stream storage area, the outlet from the Western Tributary storage area will be reduced to ensure that flows from this storage area will be maintained at the MRFS flows. This will ensure no further increases in defences will be required.

Option	Description
HEFS Adaptation (H3)	Introduce storage upstream of R487 Bridge to prevent out of bank flows towards the school. This is a fluvially dominated adaptation required in the HEFS.
Monitoring for all adaptations	Monitoring of rainfall, runoff generation, river levels and coastal levels will be important to understand change in each of these variables with climate change and to assess with confidence the potential effectiveness of the Well Stream diversion, upstream catchment and storage measures. As a minimum, a water level gauge on each of the Well and Victoria streams, a coastal level monitoring station and a raingauge that is representative of the upstream catchment should be maintained.

3.2 Step 3: Adaptation Measure Cost Benefit Analysis

The outcome of the cost benefit analysis for the proposed option and adaptations to the MRFS is summarised in Table 3-3. Table 3-4 presents the same for the HEFS. The residual damages are those that remain with the various options in place under the MRFS or HEFS scenario. The benefits being the avoided damages in the MRFS or HEFS scenario. Details of how the costs have been estimated are provided in the following tables.

The BCR, Benefit and Costs are all discounted over a 50-year appraisal period and based on the adaptation only (i.e. excluding the costs and benefits of the preferred option) and always starting in year zero. The cost benefit analysis is to confirm whether the adaptation in its own right is economically viable. The slow onset trajectory is used for both, so the MRFS adaptation analysis has the present day annual average damages (with or without the preferred option) in year zero and a linear increase to the MRFS annual average damages in year 80. The net present values are discounted only over the first 50-year appraisal period. For the HEFS adaptation analysis the MRFS annual average damages are in year zero (again with or without the scheme or MRFS adaptation) increasing to the HEFS annual average damages in year 60. Also discounted over the first 50-year appraisal period. Cost estimate breakdown for the MRFS and HEFS adaptations are presented in Table 3-5 and Table 3-6. Figure 3-4 presents the extent of flooding with the current scheme elements in place when tested against both the MRFS and the HEFS.

Table 3-3. MRFS Adaptation Measure Cost Benefit Analysis.

Option	SoP	Capital Cost[8]	O&M Cost[9]	Total Cost	Residual Damage[10]	Benefit
No Scheme	-	-	-	-	€ 25,456,565	€ 0
With preferred option	2%AEP	-	-	-	-	€ 23,865,913
MRFS Adaptation	1%AEP	€606,795	€6,343	€613k	-	€ 25,456,565

8 Capital costs assumed to occur in year zero. Costs associated with adaptation are for the adaptation only and exclude costs associated with the initial scheme.

9 Ongoing costs are discounted over 50 year appraisal period.

10 AAD damages and benefits only include damages up to and including the 1% AEP event. Assumption is for zero damages in flood events with a lower probability than the provided Standard of Protection unless stated.

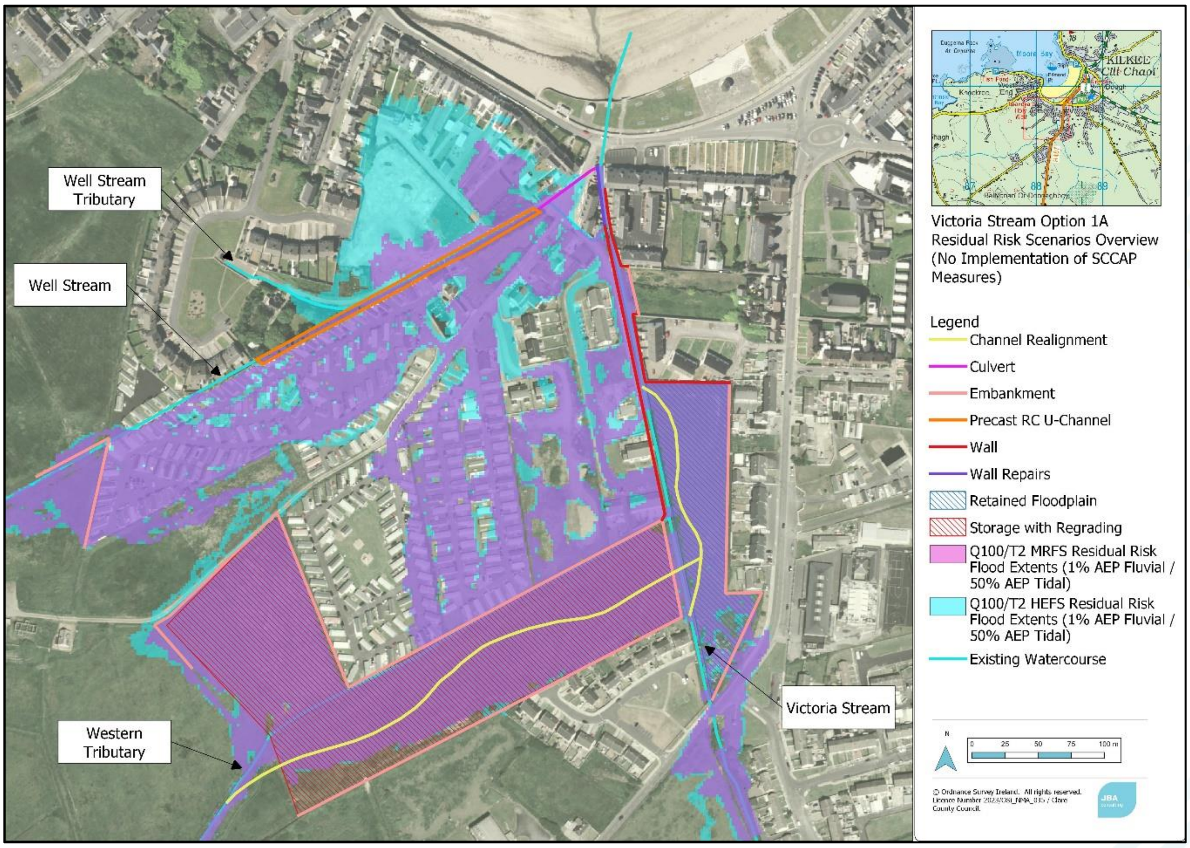

Figure 3-4. Residual Risk from MRFS and HEFS with present day scheme in place

Table 3-4. HEFS Adaptation Measure Cost Benefit Analysis.

Option	SoP	Capital Cost	O&M Cost	Total Cost	Residual Damage	Benefit
No Scheme		-	-	-	€ 26,515,266	€ 0
With preferred option, no adaptation	5%AEP	-	-	-	€ 5,956,158	€ 21,324,029
HEFS Adaptation	1% AEP	€150,054	€1,560	€151k	€ 26,515,266	€ 0

Table 3-5. Cost estimates for MRFS Adaptations

Component	Capital Cost	Annual O&M Cost
Increase embankments upstream of Well Stream	€10,870	€150
Increase embankments at Church Road Field	€25,286	€250
Increase embankments in Trib Storage	€93,705	€950
Diversion of Well Stream to Trib Storage area	€474,250	€4,742.50
Increase embankments at Victoria Court	€2,684	€250

Table 3-6. Cost estimates for HEFS Adaptations

Component	Capital Cost	Annual O&M Cost
Further increase in embankments in Trib Storage	€93,705	€950
Upstream storage of R487	€35,350	€400
Introduce throttle to increase storage in Trib Storage	€21,000	€210

3.3 Step 4: Appraisal of adaptation options

Multi Criteria Analysis is traditionally undertaken to compare future pathways. Given that there is only one pathway presented in this CCAP for the Victoria Stream, a comparative MCA can't be undertaken. In addition, any potential alternative pathways beyond the outcome of the coastal scheme retains a large level of uncertainty and thus these can't be defined with any detail or extent at this point. Therefore, only the known pathways are appraised here.

In lieu of this, commentary on the pathways using the MCA Objectives is provided below.

The MCA used are:

- Non-monetarised economic impacts
- Social
- Environmental
- Health and Safety (Construction and O&M risks)
- Operational robustness

Table 3-7 outlines the MCA appraisal of the MRFS and HEFS adaptations.

Table 3-7. MCA Appraisal of MRFS and HEFS Adaptations

CCA Stage	MFRS Adaptation	HEFS Adaptation
Non-monetarised economic & Social impacts	Proposed Option will provide full 1% AEP protection in the MFRS	Proposed Option will provide full 1% AEP protection in the HEFS. Future land take for storage on Victoria Stream reduces potential alternative land usage.
Environmental	Diversion of watercourse will ensure retention of passability when the Well Stream is gated.	Diversion of watercourse will ensure retention of passability when the Well Stream is gated. Introduction of upstream storage on Victoria Stream may provide increased habitat and water quality improvements.
Health & Safety	Introduction of gate introduces in-stream operations to ensure systems operates during a tidal event.	Introduction of gate introduces in-stream operations to ensure systems operates during a tidal event.
Operational Robustness	Introduction of the diversion requires mechanical elements to be maintained and operated.	Introduction of the diversion requires mechanical elements to be maintained and operated.

3.4 Step 5. Adaptive Pathways and Step 6. Timing of Future Adaptation

The adaptive pathway is presented in Figure 3-3. The proposed project is Option 1A in red and modelling of the MRFS and HEFS climate change scenarios has confirmed that this doesn't provide 1% AEP standard of protection to properties and infrastructure in the MRFS or the HEFS. The adaptive measures are heavily influenced by the incremental sea level rises and are concentrated around the Well Stream's performance. The adaptation limit of the preferred scheme therefore also needs to take consideration of the coastal scheme as this has a direct influence on the future performance of the fluvial scheme. Depending on the rate of climate change this could occur soon before 2080 in a fast climate change (comparable to SSP 5-8.5) and 2160 in a slower climate change (comparable to SSP 2-4.5).

A number of possible adaptive pathways have been identified to map out how the preferred option may evolve into the future.

PATHWAY 1A. The first (red) is to continue with the preferred option and accept a lower standard of protection in the future under both the MRFS and HEFS. The preferred option is therefore robust up to a point. There are few raised defences proposed and so excessive water level loading is not a key concern. This means that residual risk is not excessive should a flood defence structure fail or breach. The highly vulnerable nature of the exposed mobile home parks and camp sites does need to be considered.

The red pathway has two future adaptations, both dependant on the coastal scheme. These are explained below:

- **Post-coastal scheme, Well Stream**. Depending on the outcome of both monitoring and the coastal scheme there are additional routes that the scheme could proceed down in relation to the Well Stream.
    - Acceptance of a lower level of protection across the scheme.
    - Diversion of Well Stream to ensure 1% Annual Exceedance Probability (AEP) SoP.
    - On review of coastal scheme, there may be a scenario where the level of intervention is reduced, requiring only embankment increases and potentially introduction of increased upstream storage.

- **Post-coastal scheme, Victoria Stream**. The adaptations on the Victoria Stream are more straightforward and are fluvially dominated.
    - Acceptance of lower standard of protection**.**
    - Introduction of storage upstream of R487 (only required in the HEFS)**.**
    - Upon review of upstream management intervention, no adaptation is required.

All of the above pathways assume there are no changes in the management of storm runoff for water quality (through changes in land use, runoff regime or urban foul and stormwater systems) and sediment regime (deposition, erosion and transport) does not change. The pathways also assume that all structures are maintained and where necessary refurbished.

The management of stormwater runoff and discharge of river flow into Kilkee Bay is critical and with climate change the volume of design event storm runoff is likely to increase. This is an interdependency that must be considered and monitored. This adaptation plan is focused on the fluvial scheme only. Uisce Éireann are responsible for the management of stormwater runoff which enters the combined drainage networks, and will need to ensure that discharge of combined runoff does not adversely impact on the functionality of the flood relief scheme. Clare County Council and Uisce Éireann will need to collaborate to facilitate the separation of combined drainage networks into separate foul and stormwater networks, which will offer significant water quality and flood management benefits.

3.5 Step 7. Climate Change Provision in the Preferred Option

The extent of climate change provisions built into the preferred option are modest. This is partly due to the uncertainty around the downstream boundary in the MRFS/HEFS scenarios, unknown until the coastal scheme appraisal has concluded.

There are certain hard defences, however, that are including provisions for climate change. The left-hand bank of the Victoria Stream has included in it the MRFS requirements. This is evidenced in Figure 3-2, which presents the proposed defence levels in the preferred scheme against the MFRS & HEFS levels. The Well Stream u-channel wall has included in it the MRFS requirements.

Similarly, the Victoria Court boundary walls are being upgraded now even though they only become flood defences in the HEFS. This is borne out of the efficiencies of working in the area once and reducing any need to undertake further in-stream works in the future.

The pluvial systems that are included in the scheme are designed with the MRFS rainfall intensities.

In summary, the following elements have in-built climate change resilience:

- Well Stream u-channel wall height
- Victoria Stream left-hand bank flood defence wall
- Pluvial system

4 Climate Adaptation Plan for Atlantic Stream

4.1 Potentially viable adaptation measures, adaptive pathways and timelines

A significant amount of adaptations for the Atlantic Stream will be included in the baseline construction stage.

The increase in levels across the Atlantic Stream system due to climate change are presented in Figure 4-1.

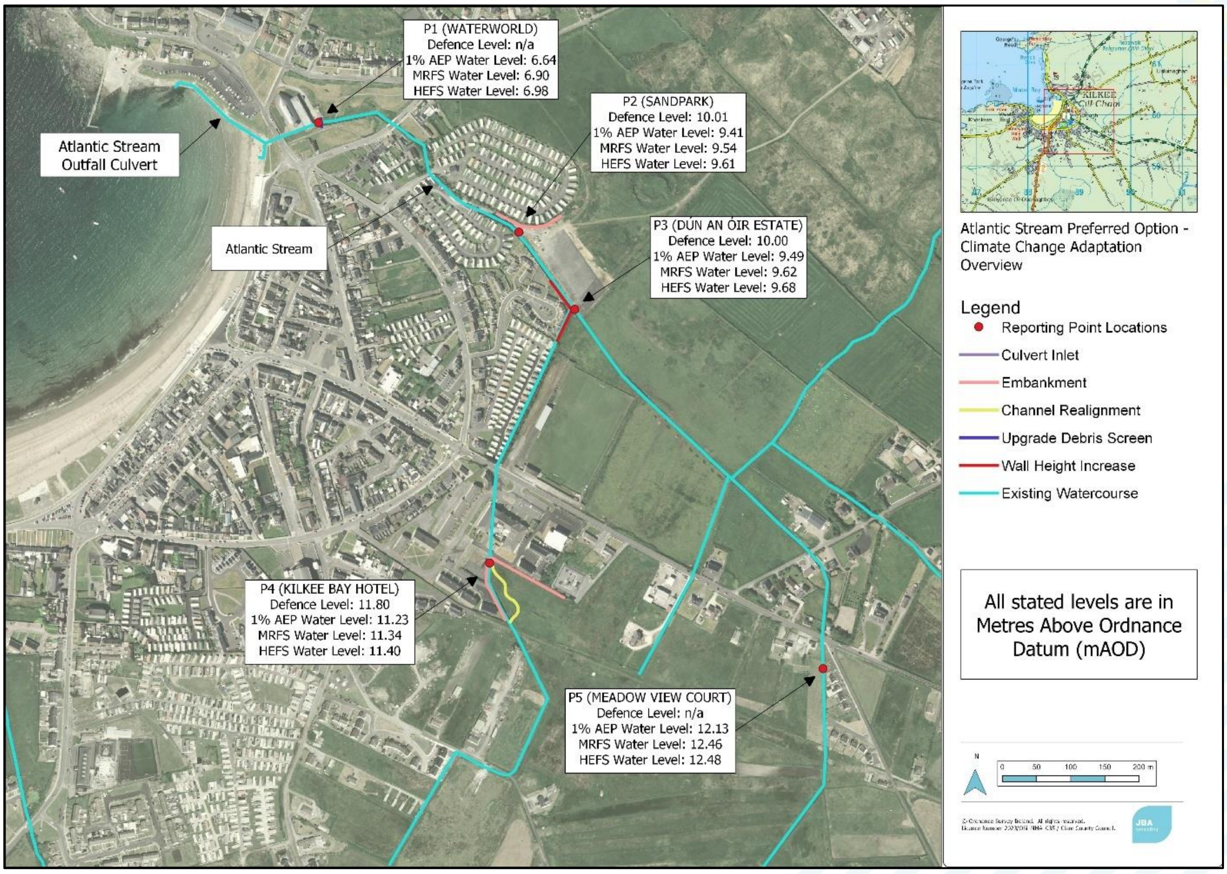

Figure 4-1. Atlantic Stream level increases across the scheme area

The screening of measures and development of options has been carried out with full consideration of climate change adaptability. The Atlantic system is far less onerous in its adaptability requirements and can incorporate a large number of climate change provisions into the present-day design. The levels presented here indicate a minor increase in water levels in both the MRFS and HEFS scenarios. The most significant changes are located at Meadow View Court, Moonin Estate and at Waterworld. The intended adaptability approach is summarised in Table 4-1.

Table 4-1. Atlantic Stream Climate Change Adaptation stages

Climate Change Stage	Adaptation Measure
Present Day	Increase heights of all embankments to HEFS requirement. Increase height of Dún an Óir boundary wall to HEFS required height
MRFS	Replacement of downstream outfall network at the promenade. To avoid inundation of the Moonin Estate, some flood storage is required. The intended land bank to accommodate this is immediately to the south of the estate itself. The storage capability of the flooded land to the west of Meadow View Court will need to be increased for the MFRS. This is to ensure flood levels do not encroach on the properties to the east of the existing culvert.
HEFS	The interventions in the MFRS stage will be undertaken so as to account for HEFS requirements.

A fuller description is provided in Table 4-2. An adaptive pathway is presented in Figure 4-2.

The pathways assume there are no changes in the management of storm runoff for water quality and sediment regime (deposition, erosion and transport) does not change.

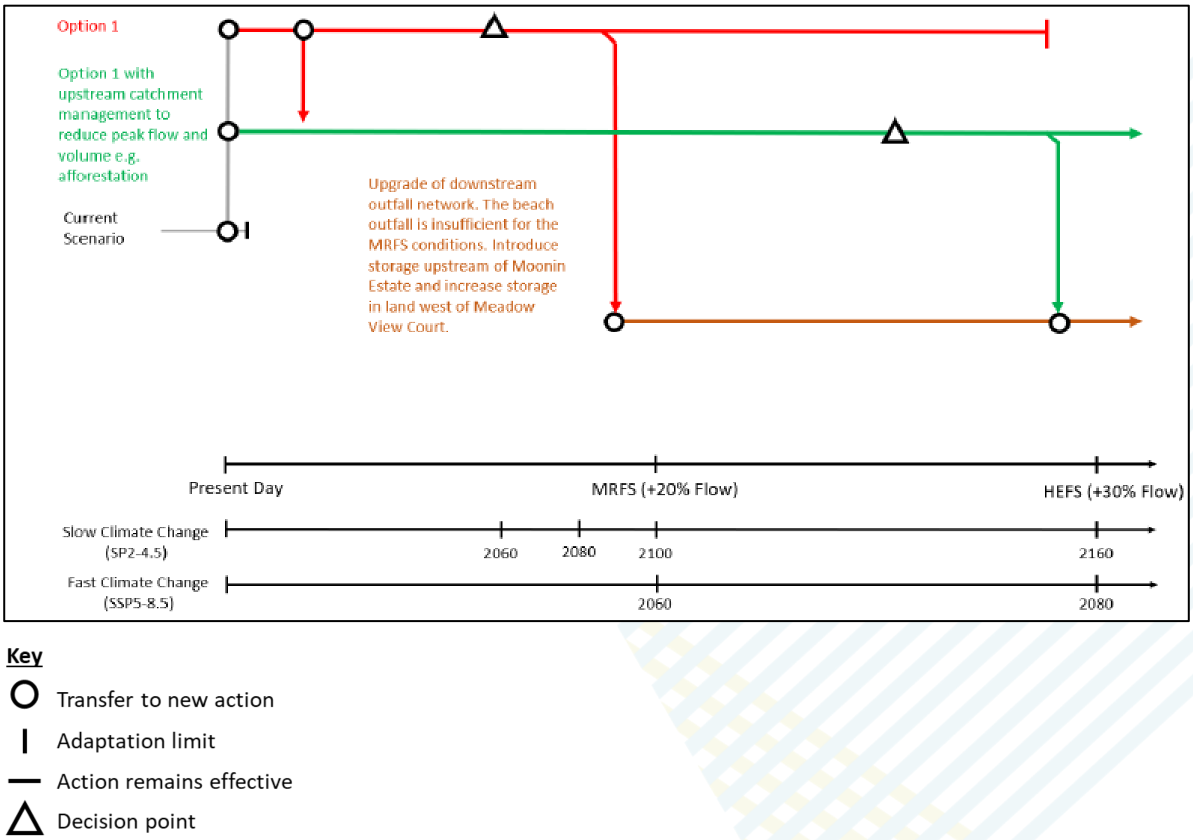

Figure 4-2. Adaptive Pathway for Atlantic Stream Catchment.

Table 4-2. Description of potentially viable adaptation measures

Option	Description
MRFS Adaptation	Replacement of downstream outfall network at the promenade. To avoid inundation of the Moonin Estate, some flood storage is required. The intended land bank to accommodate this is immediately to the south of the estate itself. The storage capability of the flooded land to the west of Meadow View Court will need to be increased for the MFRS. This is to ensure flood levels do not encroach on the properties to the east of the existing culvert. The nature of these interventions will depend on the HEFS approach and whether upstream catchment management measures were considered at an earlier stage. Whilst not necessarily replacing the need for these interventions, they may have an impact on their scale.
HEFS Adaptation	Implement upstream catchment management measures early to improve overall resilience, catchment conditions and potentially reduce peak water level loading on the proposed and existing river structures and flood defence infrastructure. It takes time for these measures to mature. The measures may not fully achieve the target standard of protection in the HEFS but could delay the need for any more structural adaptation. The catchment management measures will have significant other benefits in terms of water quality and biodiversity benefits but will require landowner participation, engagement and agreement. Implementing catchment management measures may extend the duration before a decision to adopt a structural adaptation is required.

4.2 Step 3: Adaptation Measure Cost Benefit Analysis

The outcome of the cost benefit analysis for the proposed option and adaptations is presented in Table 4-3. The residual damages are those that remain with the various options in place under the MRFS or HEFS scenario. The benefits being the avoided damages in the MRFS or HEFS scenario. Details of how the costs have been estimated are provided in the following tables.

The BCR, Benefit and Costs are all discounted over a 50-year appraisal period and based on the adaptation only (i.e. excluding the costs and benefits of the preferred option) and always starting in year zero. The cost benefit analysis is to confirm whether the adaptation in its own right is economically viable. The cost is presented in Table 4-4. Figure 4-3 presents the extent of flooding with the current scheme elements in place when tested against both the MRFS and the HEFS.

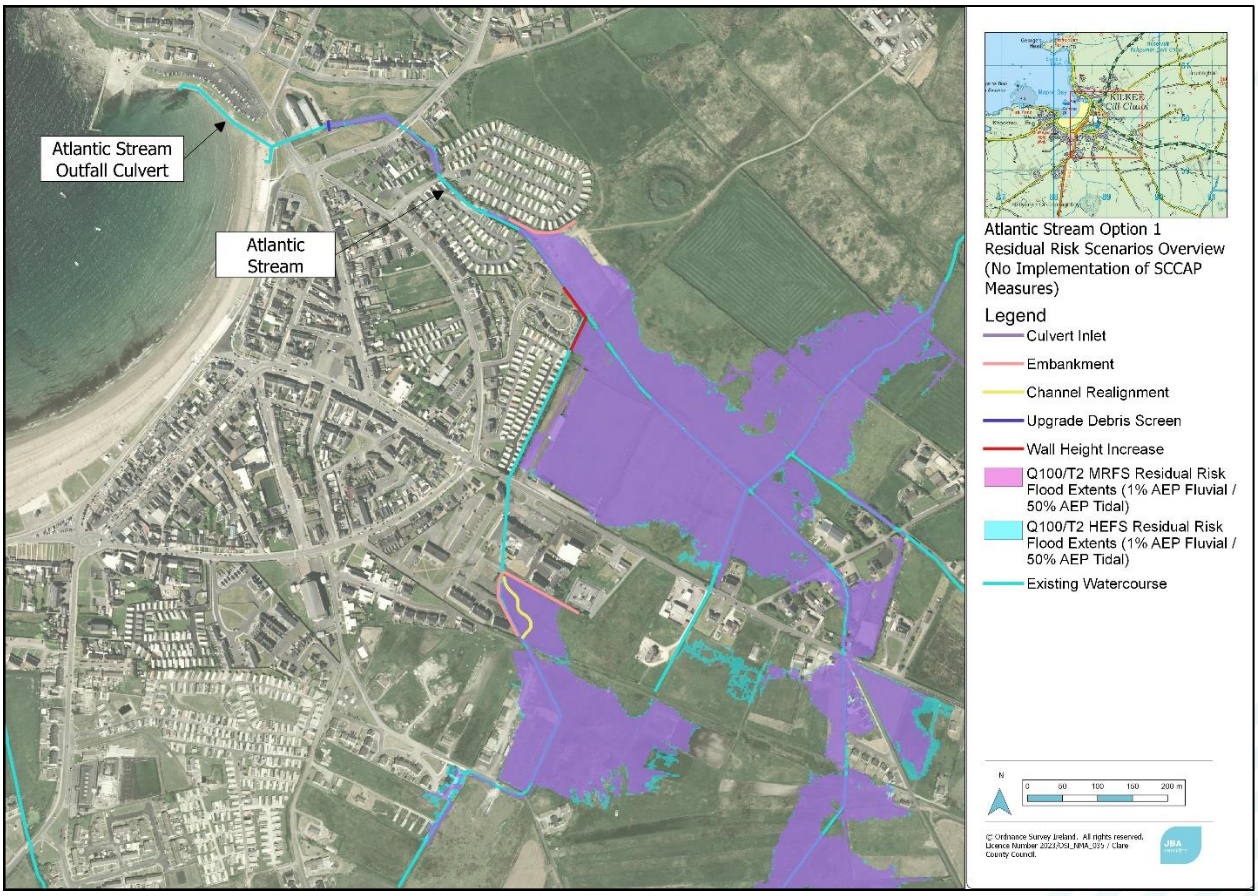

Figure 4-3. Residual Risk from MRFS and HEFS with present day scheme in place

The residual risk extents for both the MRFS and HEFS are largely the same. Therefore the cost comparison is undertaken against the HEFS costs.

Table 4-3. Adaptation Measure Cost Benefit Analysis.

Option	SoP	Capital Cost[11]	O&M Cost[12]	Total Cost	Residual Damage[13]	Benefit
No Scheme					€ 2,865,706	€ 0
With preferred option (against HEFS)	<20% AEP	n/a	n/a	n/a	€ 351,438	€2,514,268

11 Capital costs assumed to occur in year zero. Costs associated with adaptation are for the adaptation only and exclude costs associated with the initial scheme.

12 Ongoing costs are discounted over 50 year appraisal period.

13 AAD damages and benefits only include damages up to and including the 1% AEP event. Assumption is for zero damages in flood events with a lower probability than the provided Standard of Protection unless stated.

Option	SoP	Capital Cost[11]	O&M Cost[12]	Total Cost	Residual Damage[13]	Benefit
MRFS Adaptation	1% AEP	€791,285			€0	

Table 4-4. Cost estimates for MRFS Adaptation on Atlantic Stream

Component	Capital Cost	Annual O&M Cost	Notes
Upgrade of Outfall pipework	€660,008.00	€6,600	1% Annual Capital Cost
Acquiring land for flood storage at Moonin Estate and Meadow View Court (1Ha)	€20,000	€200	
Moonin Estate floodwall – 105m	€115,028	€1,150	
Re-grading of Meadow View Court lands (2,500m2)	€6,250		

4.3 Step 4: Appraisal of adaptation options

Multi Criteria Analysis is traditionally undertaken to compare future pathways. Given that there is only one pathway presented in this CCAP for the Atlantic Stream, a comparative MCA can't be undertaken. In addition, any potential alternative pathways beyond the outcome of the coastal scheme retains a large level of uncertainty and thus these can't be defined with any detail or extent at this point. Therefore, only the known pathways are appraised here.

In lieu of this, commentary on the pathways using the MCA Objectives is provided below.

The MCA used are:

- Non-monetarised economic impacts
- Social
- Environmental
- Health and Safety (Construction and O&M risks)
- Operational robustness

Table 4-5 outlines the MCA appraisal of the MRFS adaptations.

Table 4-5. MCA Appraisal of MRFS Adaptation

CCA Stage	HEFS Adaptation
Non-monetarised economic and	The at-risk area due to failure of the downstream network includes Kilkee Waterworld therefore there are substantial social benefits to introducing the

social impacts	MRFS.
Environmental	The works would require intrusive works adjacent to the SAC and thus would be environmentally sensitive. It would provide opportunity to improve water quality and passability of the system.
Health & Safety	Works would be undertaken in the foreshore, therefore would be significantly onerous and need careful control measures.
Operational Robustness	The installation of an upgraded outfall system would help reduce maintenance costs by increasing flows and reducing sediment drop off within the network

4.4 Step 5. Adaptive Pathways and Step 6. Timing of Future Adaptation

An adaptive pathway has been developed for the Atlantic Stream catchment of the study area. This is presented in Figure 4-2. The proposed project is Option 1 in red and modelling of the MRFS and HEFS climate change scenarios has confirmed that this is expected to provide 1% AEP standard of protection to properties and infrastructure in the present-day only, but not in the MRFS in all locations. It is to be noted that some areas will have climate change adaptations incorporated into the present-day design.

The adaptive measures are concentrated in three areas:

- around the downstream boundary where the system discharges into Moore Bay;
- Adjacent to Moonin Estate
- West of Meadow View Court

The adaptation limit of the preferred scheme option 1 is therefore at a point between the present day and MRFS. Depending on the rate of climate change this could occur soon before 2080 in a fast climate change (comparable to SSP 5-8.5) and 2160 in a slower climate change (comparable to SSP 2-4.5).

A number of possible adaptive pathways have been identified to map out how the preferred option may evolve into the future.

PATHWAY 1. The first (red) is to continue with the preferred option and accept a lower standard of protection in the future under the MRFS and HEFS. The preferred option is therefore robust up to a point. There are few raised defences proposed and so excessive water level loading is not a key concern. This means that residual risk is not excessive should a flood defence structure fail or breach. The highly vulnerable nature of the exposed mobile home parks and camp sites does need to be considered.

The red pathway has two future adaptations as it can shift onto the green and/or brown pathway. This confirms there is flexibility as there are a number of different options available in the future. These are explained below:

- GREEN PATHWAY. The green pathway is to implement upstream catchment management measures early to improve overall resilience, catchment conditions and potentially reduce peak water level loading on the proposed and existing river structures and flood defence infrastructure. It takes time for these measures to mature. The measures may not fully achieve the target standard of protection in the HEFS but could delay the need for any more structural adaptation. The catchment management measures will have significant other benefits in terms of water quality and biodiversity benefits but will require landowner participation, engagement and agreement.

Implementing catchment management measures may extend the duration before a decision to adopt a structural adaptation is required.

- BROWN PATHWAY. This reflects the pathway that implements both catchment management and engineered adaptation.

All of the above pathways assume there are no changes in the management of storm runoff for water quality and sediment regime (deposition, erosion and transport) does not change. Coastal risk is also assumed to be managed through coastal protection measures. The pathways also assume that all structures are maintained and where necessary refurbished.

The management of stormwater runoff and discharge of river flow into Moore Bay is critical and with climate change the volume of design event storm runoff is likely to increase. This is an interdependency that must be considered and monitored. This adaptation plan is focused on the fluvial scheme only. Uisce Éireann are responsible for the management of stormwater runoff which enters the combined drainage networks, and will need to ensure that discharge of combined runoff does not adversely impact on the functionality of the flood relief scheme. Clare County Council and Uisce Éireann will need to collaborate to facilitate the separation of combined drainage networks into separate foul and stormwater networks, which will offer significant water quality and flood management benefits.

4.5 Step 7. Climate Change Provision in the Preferred Option

A number of climate change provisions have been made in the preferred option. The embankments at Sandpark and the Kilkee Bay Hotel will be set to heights that match the requirements of the HEFS. The wall height increases at Dún an Óir will also incorporate climate change level requirements. This is evidenced in Figure 4-1 which presents the preferred option defence levels against the MFRS and HEFS water levels.

5 Part 3: Climate Adaptation and Monitoring Plan

As is evidenced in Figure 4-2, the implementation of the adaptive measures sits within a wide time spectrum given the uncertainties around climate change projections. Consideration of the existing outfall assets and their deterioration over that time may also result in implementation of the HEFS adaptive measures at an earlier stage.

Irrespective of the selected pathway, project monitoring of climate impacts and scheme performance is essential.

All adaptation measures are within the existing remit of the relevant authorities. Monitoring of defined climate and scheme performance indicators will inform when adaptation actions need to be considered.

Clare County Council will be responsible for monitoring of the flood scheme performance, maintenance of the flood scheme and implementation of future adaptations.

Clare County Council is responsible for ensuring land use and building regulations are complied with, and that land for potential future adaptations is secured.

The OPW and EPA, through the hydrometric gauge networks and climate change monitoring are responsible for monitoring the change in hydrological conditions. Potential locations for future flow gauges are identified in Figure 5-1 for the Western Tributary, Victoria Stream, Well Stream and Atlantic Stream, and correspond with the Hydrological Estimation Points (HEP) where practical. Flow gauges on the downstream reaches of the Victoria and Atlantic Streams are identified to monitor post-scheme flow conditions.

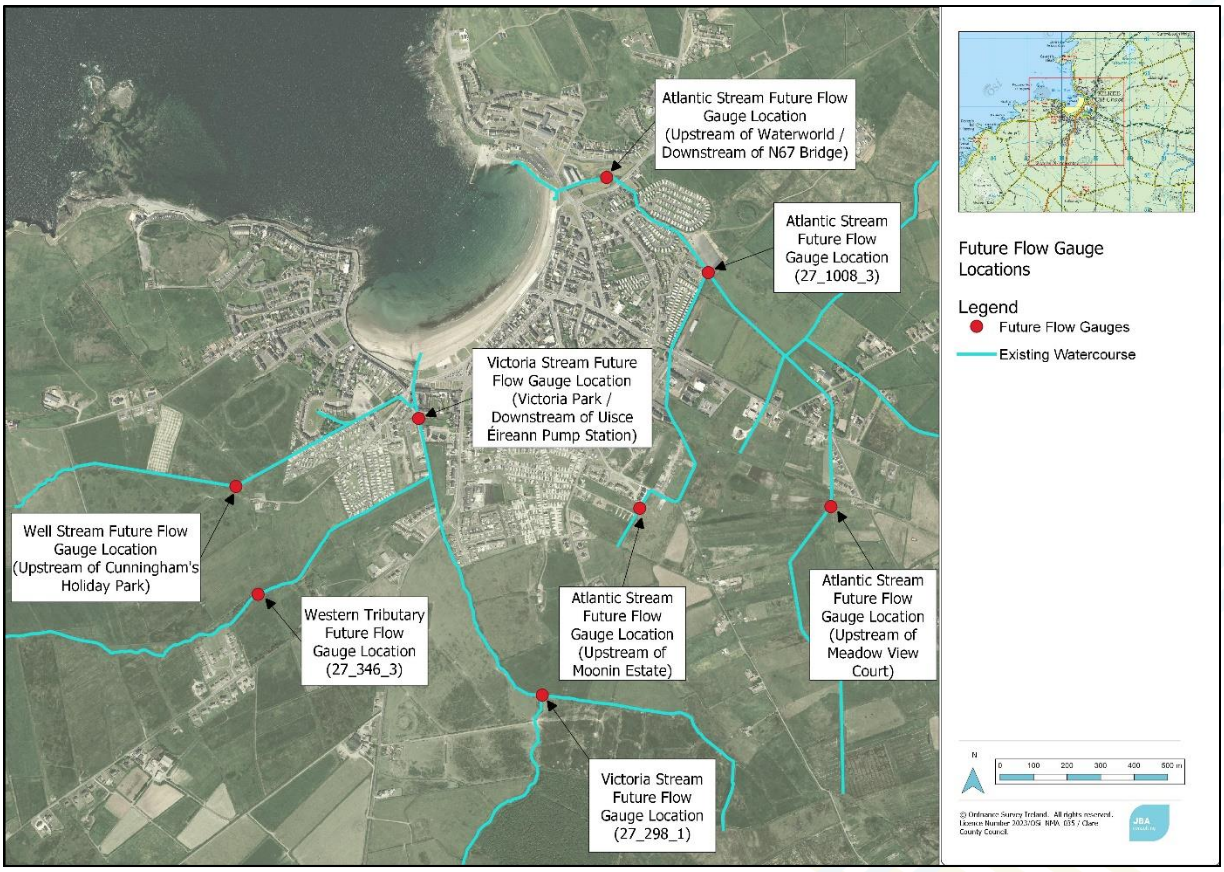

Figure 5-1. Future Flow Gauge Locations

Offices at

Dublin
Limerick

Registered Office
24 Grove Island
Corbally
Limerick
Ireland

+353(0)61 579400
info@jbaconsulting.ie
www.jbaconsulting.ie
Follow us:

JBA Consulting Engineers and Scientists Limited

Registration number 444752

JBA Group Ltd is certified to:
ISO 9001:2015
ISO 14001:2015
OHSAS 18001:2007