Report: May 2026

Draft Galway Wastewater Strategy

Appendix 2 – Our Approach to Modelling and Climate Change

Safeguarding our water for our future

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Our Approach to Modelling and Climate Change	
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V1.0	May 26	Andrew Harte	Uisce Éireann	For Public Consultation

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1. Introduction to this Appendix

1.1 Scope of this Report

The purpose of this appendix is to document our approach to the sewer network hydraulic, hydrological and water-quality modelling undertaken in support of the Galway Wastewater Strategy (GWS). It summarises how each model was developed and applied to:

- Establish baseline performance of the existing sewerage networks and wastewater treatment works across the study area.
- Determine the key influences impacting current agglomeration performance as well as under future demand and growth scenarios to design horizons 2040, 2055 and 2080, including sensitivity to climate-driven rainfall and sea-level changes.
- Assess the frequency, volume and pollutant load of stormwater overflow (SWO) discharge events and treated effluent discharges to understand any impact on receiving waters.
- Identify system vulnerabilities, flood risk hotspots, headroom constraints at WWTPs and water quality compliance risks
- Provide evidence for the optioneering process and performance indicators, informing both the long list / short-list screening of interventions (See *Appendix 3: Status and Performance of the Wastewater System* and *Appendix 5: Our Approach to Optioneering*)

By clearly describing the modelling framework, assumptions, limitations and key findings, this report ensures transparency and consistency in how technical evidence underpins strategic decisions within the GWS.

This document also assembles current insights on potential climate change impacts in Ireland and, specifically, in Galway. This information is essential for the development of models that predict sewer network flows and river water quality, where model variables like rainfall, temperature, and evapotranspiration influence sewer system flows, and sea level impacts coastal discharge operations. Any simulated data from these models will focus on changes to the sewer network and impacts on receiving waters, while other climate-related risks, such as fluvial and tidal flood risks, remain outside the scope of the GWS.

1.2 Model Overview

There are two main aspects to the modelling framework in support of the GWS. These are:

1. Network Modelling (covering sewerage system networks) – to replicate the piped drainage systems collecting flow and pollutant load generated within the agglomerations of interest and assess the treated effluent, storm overflow performance as well as sewer flooding.
2. Water Quality Modelling (covering waterbody impacts) – to evaluate impacts and benefits of strategic options to both freshwater and marine waters with the inputs from observed monitoring data and network model outputs.

Where relevant, network modelling is required to understand sewer flooding, available capacity and storm overflow performance. These network models are tools that are calibrated and/or verified to observed data, gathered via surveys, and so require significant investment to ensure they represent system performance against observations and historical records. The outputs from these models can be used as inputs to water quality models to understand impacts to receiving waterbodies.

These network models are required for large and complex drainage systems like Galway City. However, in smaller agglomerations like Moycullen and Claregalway, available monitoring information at the WWTP can be sufficient to assess water quality performance of receiving waterbodies as the drainage systems are far simpler and a less complex model may be sufficient for GWS requirements.

Table 1-1 presents an overview of the modelling undertaken for each agglomeration in the study area and are discussed further in this report.

Table 1-1: Overview of modelling for each agglomeration in the GWS

Agglomeration	Network Modelling	WWTP Representation	Freshwater Water Quality Modelling	Marine Initial Dilution Modelling
Galway City	🟢	🟢	🔴	🟢
Athenry	🟢	🟢	🟢	N/A
Claregalway	🟢	🟢	🟢	N/A
Moycullen	🟢	🟢	🟢	N/A

2. Network Modelling

2.1 Introduction

The resilience of Galway's wastewater infrastructure is challenged by population growth, urban expansion, and climate change impacts. Climate change impacts consider:

- **Rising sea levels** affecting coastal infrastructure, leading to increased flood risk at key WWTPs.
- **Fewer storms / longer dry periods with more intense rainfall events**, which can overload combined sewer networks, resulting in greater flood risk[1] and a change in storm overflow performance.
- **Increased storm surges**, impacting effluent treatment and outfall surcharging requiring advanced flood mitigation measures.

Network modelling allows for an understanding of the current and future performance of wastewater infrastructure. Through modelling scenarios, the following can be assessed:

- Change in flood risk that impact communities, public health and operation of assets,
- environmental needs to determine if water quality standards are achieved,
- social needs to determine the risk to public health by understanding SWO discharges to waterbodies.

The modelling software used to undertake the network model build and modelling assessment was InfoWorks ICM Version 2021. InfoWorks ICM is an advanced integrated catchment modelling software and is suitable for all types of hydraulic sewer models and is used widely within the UK and Ireland. Uisce Éireann's (UÉ) models are built to technical standards defined in the Drainage Area Plan (DAP) which goes from Stages 1&2 Model Build and Verification to Stage 3 Risk Assessment and Stage 4 Option Development. The DAP hydraulic model has been considered fit for purpose as a basis for future horizon models and has undergone model build and audit processes in accordance with UÉ asset standards.

2.2 Network Model Summary

The following sections relate to the sewerage network models which were built in accordance with the relevant UÉ modelling standards and the CIWEM UDG Code of Practice for the Hydraulic Modelling[2] of Urban Drainage Systems at the time of development.

A summary of the models for each agglomeration is tabulated for context of scale across the study area:

[1] MetOffice UKCP18 Science Overview Report March 2019.

[2] CIWEM UDG Code of Practice 2017.

Table 2-1: Summary of the network model objects

Model Object	Athenry	Claregalway	Galway City	Moycullen
Nodes	602	115	13,552	253
Conduit Length (km)	22.5	6	554.8	9.6
Pumping Stations	9	6	48	4
SWOs	2	0	26	1

Including the baseline, three future design horizon models were developed as part of the GWS for the following years to incorporate study area growth:

- 2040
- 2055
- 2080

These models included uplifts to rainfall to account for varying climate change at the 2055 and 2080 design horizons. See climate change section for more details.

Populations have been uplifted using the population projection and growth assessments in the Appendix 1 of the GWS.

2.2.1. Model Build Summary

Existing hydraulic models for Galway City (verified in 2022), Athenry (verified in 2015) and Moycullen (verified in 2000s) were combined in InfoWorks ICM version 2021. The recent Galway City model was built in accordance with the UÉ modelling specifications set out in Stages 1 and 2 of the DAP process. In addition to this, the UÉ Asset Planning – Agglomeration Loading Technical Guidance Note has been followed for the Claregalway model build stage.

The Galway City model used in this study is the recently constructed Galway DAP Stage 3 model where no additional updates were required representing the year 2022.

The Galway City and Athenry networks represent the most recent InfoAsset and GIS asset data and was verified to flow-survey data. An update to the existing Moycullen network model was undertaken to incorporate recent developments using the available InfoAsset and GIS data. A new model was constructed for Claregalway utilising available data sets as well as WWTP flow data to calibrate and verify system response.

All four models are Type II – Planning level of detail in accordance with the CIWEM UDG Code of Practice[3]. These four models have been combined into a single network model.

2.2.2. Data Collection Summary

Data collection to build the network model in Galway City was comprehensive throughout the Stage 1 and Stage 2 DAP processes and can be tracked in the DAP Data Manual. A summary of the

[3] This type of model detail is considered as "general multi-purpose". They provide an overview of a specific drainage area, which might be a discrete catchment in its own right or may be part of a larger catchment.

surveys completed during Stage 2 of the Galway City DAP are detailed in Table 2-2. The survey detail for Athenry and Moycullen network models was not available for this study.

Table 2-2: Surveys Completed as part of Galway City Stage 1 and 2 DAP

Survey Type	Description
Manhole (No.)	1,883
CCTV (Length)	36.9km
PS (No.)	35
SWO (No.)	25
Flow Monitors (No.)	188
Depth Monitors (No.)	30
Rain Gauges (No.)	26
Flow Survey (Duration)	18 weeks (April – August 2019)

2.2.3. Modelled Dry Weather Flow

Population:

The application of population data in the models has followed the UÉ DAP Stage 2 Specification (IW-TEC-800-06). Galway City DAP model had been updated to 2022 as part of the Stage 3 DAP process so populations in the network were deemed fit for purpose.

In Athenry, Moycullen and Claregalway a detailed desktop review of the GeoDirectory with 2022 Census data was undertaken to derive occupancy rates in electoral divisions of the agglomerations. Applying these occupancy rates with the domestic houses connected into the sewer collection network is the basis for the calculations.

Infiltration:

Baseflow, which is the term used for constant Infiltration in the hydraulic models, has been verified based on the widespread monitoring data in Galway City between April-August in 2019 and the historical monitoring in Athenry (2015) and Moycullen. The lack of available network monitoring data in Claregalway lead to the approach to use 50 litres / head / day using the population as an initial start which was then calibrated to the available WWTP inlet monitoring.

In Galway City, the modelled baseflow has been calibrated to dry days during late spring and summer periods in 2019 which may underrepresent baseflow for an annual average considering seasonal variations.

There was tidal ingress observed in specific locations of the network in Galway City based on the monitoring data in 2019 and is discussed in Section 2.2.8.

Consented Trade Effluent and Commercial Discharge:

The existing modelled trade flows in Galway City, Athenry and Moycullen were deemed appropriate based on the respective verification to network monitoring data. The lack of available data in Claregalway lead to an alternative approach where the trade flow accounts for 16% of the total domestic load in the agglomeration and distributed proportionately across the model at identified nondomestic locations.

2.2.4. Wet Weather

The existing modelled rainfall runoff to generate wet weather flows in Galway City, Athenry and Moycullen were deemed appropriate based on the respective verification to network monitoring data. The lack of available data in Claregalway lead to an alternative approach where a high-level verification was undertaken using the available daily inlet volumes at the WWTP in 2022 with the nearby Met Éireann rainfall data.

2.2.5. Rainfall

Design rainfall storms were generated in the Galway City DAP in accordance with the UÉ Technical Standards Guidance Note on the Application of Rainfall Data in Wastewater Network Modelling (IW-TEC-800-13). This comprises of series of summer design rainfall events with return periods of 1m (1 hour duration only), 1y, 2y, 5y, 10y, 20y, 30yr and standard durations of 30, 60, 90, 120, 240, 480 minutes. In addition to this a 10 Year Time Series Rainfall series has been used for SWO Spill Assessments.

2.2.6. Recent Agglomeration Changes

Recently constructed schemes have been identified in Athenry and were completed in 2024/2025. Therefore, the proposed network modifications were included in the baseline models.

- A new sewer in the west of the agglomeration will serve a small number of existing buildings and will provide a means for future developments to connect to the Athenry treatment plant.
- A new sewer on the eastern side of the agglomeration will receive a significant portion of the existing catchment in addition to future developments in the vicinity, and will serve the catchment in such a way that several key assets will be decommissioned, notably the pumping station and overflow at Sli An Chlairin, the overflow at Court Lane, and the package plant at Pairc Na hAbhainn. This sewer will discharge to a new terminal pumping station which will transfer flows to the Athenry treatment plant.
- There were no other known changes that were significant to the GWS in the other agglomerations.

2.2.7. Model Confidence and Fitness for Purpose

The Galway City, Athenry and Moycullen hydraulic models have undergone flow monitoring in the network and verification to observed data to represent both dry and wet weather flows. More detailed information is available in the Galway City Stage 2 DAP as well as Athenry and Moycullen reports. There is sufficient model confidence in these network models that they are fit for the purposes of the GWS.

The Claregalway model has been built and verified at the WWTP to ensure that there is sufficient confidence in the model outputs to assess the performance of the system for the purposes of the GWS.

The hydraulic network models are considered fit for purpose as a basis for future horizon models, particularly with the inclusion of ongoing construction work in the baseline model which has ensured that analysis will not be undertaken on assets that will be made redundant.

2.2.8. Tidal Ingress and Joint Probability Assessment

Tidal ingress can occur into sewer networks due to high water levels in surrounding waterbodies and flow paths into the sewer network. This may be a result of a defective valve / penstock to protect the sewer network. The monitoring data showed signs of tidal ingress into the Galway City sewer network at locations shown in Figure 2-1.

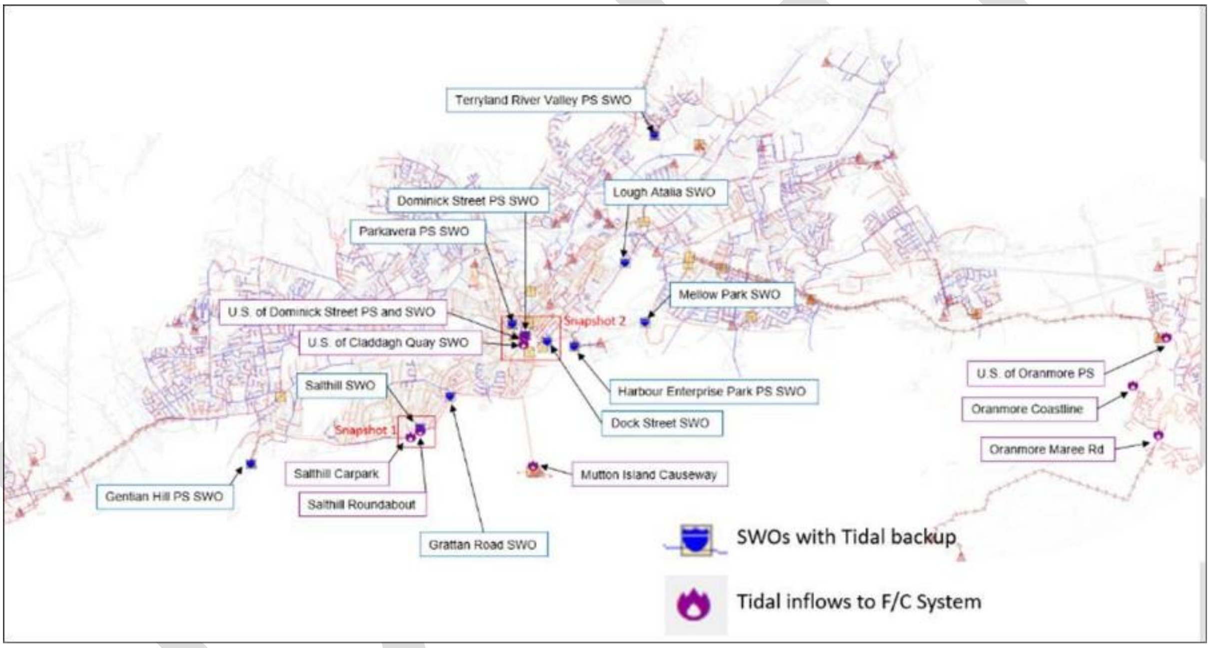

Figure 2-1: Tidal Ingress Points within the Galway Wastewater Strategy Study Area.

This tidal ingress was represented for model verification purposes in the Galway DAP. As part of the Galway DAP Hydraulic Model Audit, it was recommended that appropriate tidal data and potentially river data is used for using the model to assess catchment performance.

This study has used the representation of a high tide during the wet weather events in line with the analysis undertaken during the Galway City DAP. This is deemed to be a conservative approach based on the likelihood of a high tide occurring at the same time as extreme rainfall events. The joint probability of a 1 in 5yr event and a high tide occurring is approximately the 0.033% annual exceedance probability that sewer networks can provide for level of service. Further information on Selection of Tide Levels for Joint Probability Assessments can be found in WaPUG User Note No. 22.

Tidal inflows and levels in the Galway City area are currently being investigated, and sewerage network improvements are ongoing. The improvements will require some model maintenance to be undertaken to reflect the benefits and have been commissioned in parallel with the Strategy.

2.2.9. Network Model Limitations

This study identified some specific model limitations such as the representation of tide in the Galway City DAP model – investigations are currently ongoing to understand and improve the representation of tidal interaction. The representation of Dock Street SWO in the Galway City model is also under further investigation to improve the representation which is currently a cross connection as opposed to an SWO. Future interventions could benefit from a further review of rainfall runoff response in the specific hydraulic area.

Further surveys and monitoring would be recommended in Athenry and Moycullen where performance indicates intervention and would be required to increase confidence in the investment strategy and magnitude. The available historic flow monitoring was used to verify the inlet flows in Claregalway. There remains some uncertainty on upstream uncharted private pumping stations which could be investigated for future studies focussing on the sewer network in Claregalway.

3. Water Quality Modelling

3.1 Introduction

To evaluate the relative benefits of strategic options and inform the performance indicators of each agglomeration, water quality modelling was undertaken for both freshwater and marine environments. Several scenarios were assessed and are described in further detail within *Appendix 4: Impact on Water Quality.*

The following sections outline the modelling methods, tools, determinands of interest and standards used to assess the wastewater discharges on the relevant receiving waterbodies.

3.1.1. Continuous Discharge Impacts to Freshwater Waterbodies

The impact of final effluent from the wastewater treatment plants (WWTP) was assessed using UÉ's Monte Carlo Wastewater Assimilative Capacity (WAC) tool. Discharges from Athenry, Moycullen and Claregalway agglomerations were all assessed using the Monte Carlo assessment.

The Monte Carlo assessment checked waterbody compliance to both WFD percentile and mean standards for BOD, ammonia and ortho-phosphate. It was also used to estimate the proposed Emission Limit Values (pELVs)[4] required to ensure discharges are compatible with a waterbody's assimilative capacity to achieve compliance with WFD targets.

The inputs were river and wastewater flows, WWTP effluent quality sampling and river quality sampling upstream and downstream of the respective WWTPs. The river quality data was obtained from the most recent four years of samples from the EPA water quality database and effluent quality was obtained from UÉ asset records.

The calibrated Monte Carlo model was used to assess the various future scenarios, by replacing the river and final effluent flows, but retaining the water quality parameters and the flow calibration factor. For further details on this calibration exercise, please refer to *Appendix 4: Impact on Water Quality.*

For the assessment for a new WWTP, there was limited assimilative capacity in inland freshwaters to accommodate future increase in loads envisaged for a new WWTP. The River Corrib was the only technically viable option for a freshwater discharge for the WWTP and the assessment results are included in Appendix 4.

3.1.2. Intermittent Discharge Impacts (SWOs) to Freshwater Waterbodies

Intermittent discharges from Athenry and Moycullen agglomerations were assessed. Claregalway has no SWOs, so no assessment was required.

[4] Setting of ELVs is a statutory function of the Environmental Protection Agency, the tool is used for strategic planning purposes to give an indication on the level of treatment that may be required to aid performance assessment and optioneering.

Ten-year simulations of the InfoWorks model for Athenry and Moycullen were undertaken using a 10-year observed rainfall timeseries to generate a 10-year timeseries of SWO discharges and flows into the inlet of each WWTP to represent the final effluent (where applicable).

The intermittent discharge impact assessment takes the 10 years of simulated SWO discharges and final effluent from the InfoWorks ICM model and mixes that with statistically representative samples of river flow and quality. This creates a large series of in-river samples of dissolved oxygen (DO), BOD, ammonia, plus pH and temperature.

These are then routed into a river water quality model which simulates reaeration and biological decay in the river to develop a series of dissolved oxygen and unionised ammonia concentrations which can be assessed against UPM Fundamental Intermittent Standards and High Percentile Standards[5]. These are non-regulatory standards in Ireland.

Individual surface water network inputs were excluded to focus the source apportionment solely on SWO discharge impact.

The modelling aimed to determine whether rivers and canals met and could continue to meet Water Framework Directive standards under current conditions, projected growth, and future climate scenarios.

All models were calibrated using observed upstream and downstream data, ensuring a reliable assessment of future capacity and informing where reduction in load discharged may be needed. Assessments were also undertaken using "Notionally Clean Boundaries" where applicable and further information is detailed within *Appendix 4: Impact on Water Quality.*

3.1.3. Discharges to Marine Waters

Marine modelling was undertaken to assess the feasibility of a marine discharge for a new WWTP recommended as part of the Galway Wastewater Strategy. The objective was to identify potential outfall locations in Galway Bay / Corrib Estuary and evaluate whether treated effluent could be dispersed in compliance with dilution guidance thresholds, and demonstrably compatible with achievement of WFD objectives.

An initial screening was undertaken using an indicative target of 50:1 dilution at the 95th percentile (in line with UÉ Marine Modelling Standard) which proposes this as a minimum dilution target for secondary treated effluent *for new discharges only*. This target in the technical standard is based on guidance from the Scottish Environmental Protection Agency (SEPA) to avoid oils slicks and odour nuisance[6]. This was used to screen the potential discharge locations for further analysis against relevant EQS targets. Further details are included in *Appendix 4: Impact on Water Quality.*

The initial dilution (ID) assessment provides a preliminary estimate of appropriate locations and sizing / configuration of potential marine outfalls for the proposed new WWTPs. It used tidal depth and current data to assess the dilution occurring as the discharged effluent disperses as it rises towards the surface from the outfall.

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[5] Urban Pollution Manual (UPM) – The Foundation for Water Research

[6] WAT-SG-11

A set of one-year hourly time series of hydrodynamic data, including hourly current velocities and depths, were provided by the Marine Institute having been extracted from their 3D ROMS model, based on a high-resolution (66 m) grid. This was processed to provide velocities and depths under both spring and neap tidal conditions at each of the sites for the dispersion calculations.

Discharge scenarios were assessed using the WRc dispersion equations, which estimate initial dilution based on tidal conditions, effluent flow and outfall configuration. A range of configurations was assessed, from single-port low-flow discharges to multi-port, higher-flow systems. These permutations enabled a comparative analysis of design options under operational and environmental constraints.

The assessment focused on sites within two general areas as shown in Figure 3-1: a western marine outfall within an area of rapidly sloping seabed and stronger tidal currents, and a shallower eastern marine outfall characterised by gradual slopes. These differing conditions influenced the dilution potential and feasibility of marine outfalls at each site.

The eastern area lies within the Galway Bay Complex special area of conservation (SAC) and the Inner Galway Bay special protection area (SPA), adding environmental sensitivity to any proposed discharge which must be considered further during optioneering.

The level of treatment proposed from the new WWTP (quaternary treatment) is such that there is a low risk of impacts on sensitive receptors and any nearby bathing and shellfish waters. While Initial dilution assessment did not demonstrate that bathing water and shellfish targets would be met at outfall locations, these targets only apply at Designated Bathing Waters and Designated Shellfish Waters. Based on engineering and modelling judgment there is likely to be sufficient far-field dilution and dispersion available to ensure discharges are compatible with water quality objectives for Protected Areas, however it is recommended that dispersion modelling is undertaken at project stage to ensure any proposed new WWTP discharges are compatible with marine receptors.

The existing outfall at Mutton Island was not assessed as it was not proposed to increase pollutant loads from this discharge location, and the waterbodies are achieving compliance with WFD objectives.

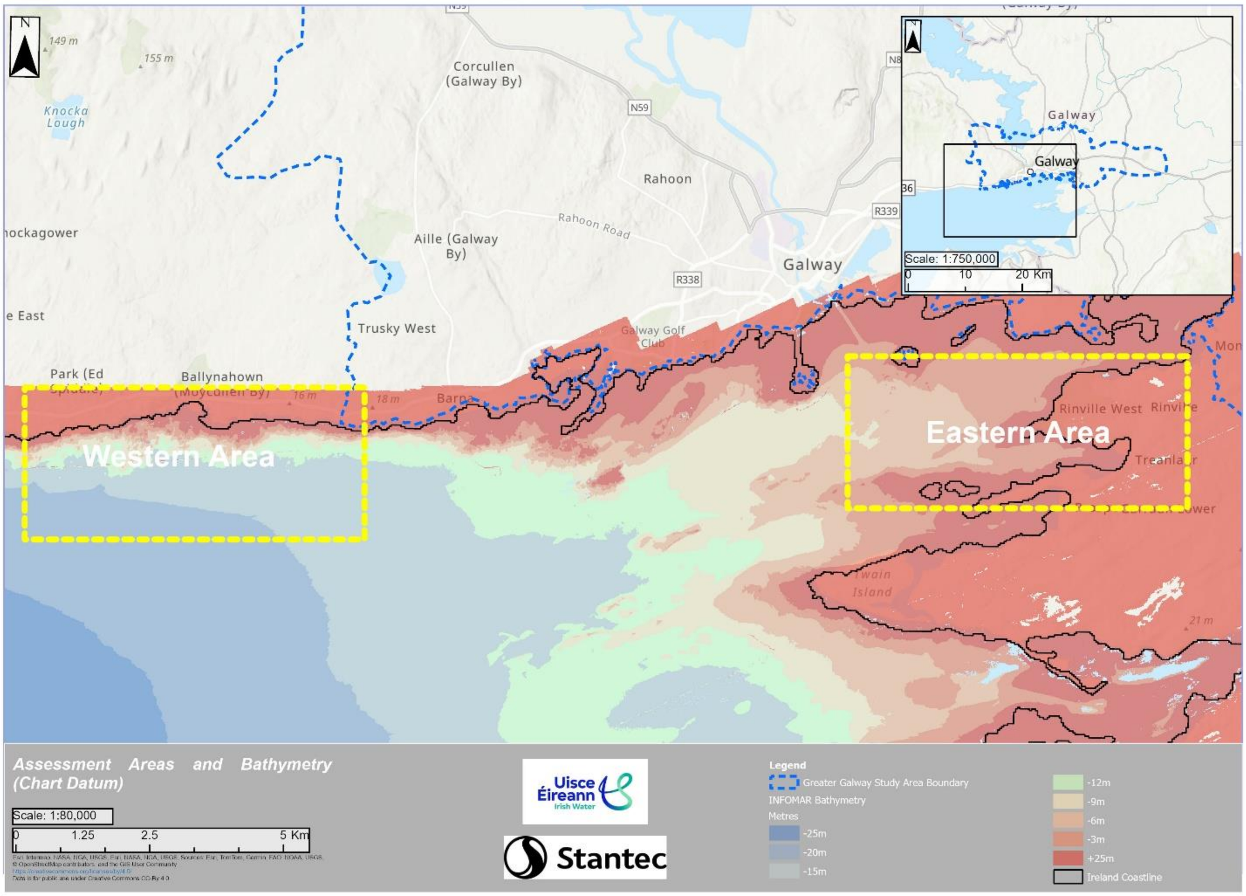


Figure 3-1: Assessment Areas and Bathymetry (Chart Datum)

4. Climate Change

This section outlines the data sources consulted to estimate the effects of climate change over the 21st century. Sections 4.2 to 4.5 analyse each relevant climate variable in detail. Together, these sections provide a comprehensive basis for understanding and managing future wastewater infrastructure challenges related to climate change pressures that have been assessed as part of the Strategy.

4.1 Data Sources

4.1.1. Climate Projections

The Environmental Protection Agency's (EPA) National Climate Change Risk Assessment (NCCRA)[7] is a critical resource for identifying reliable data sources on projected climate conditions in Ireland. For many meteorological variables, the NCCRA endorses data from the TRANSLATE project[8] developed by Met Éireann. This project offers a standardized suite of bias-corrected climate projections and services tailored to the Irish context, which are accessible through Met Éireann's TRANSLATE portal (TRANSLATE Project). The TRANSLATE dataset enables accurate projections for temperature, precipitation, and other key variables, helping to inform climate resilience strategies across multiple sectors, including water resource management and urban planning.

However, certain critical meteorological variables fall outside the TRANSLATE project's scope. For example, with respect to sea level rise, the NCCRA references publications by the Office of Public Works (OPW) and utilizes data from the UK Climate Projections 2018 (UKCP18) for extended insights. These resources are instrumental in assessing coastal flood risks and inform strategies to address potential impacts on coastal infrastructure and habitats in Ireland.

Additionally, the Climate Ireland platform (Climate Ireland[9]) provides supplementary climate projections from the Coupled Model Intercomparison Project Phase 5 (CMIP5), released in 2012. For more recent climate data, the World Bank Climate Change Knowledge Portal (World Bank Portal[10]) includes CMIP6 data from 2016, which enhances the available data pool with updated projections on temperature, precipitation, and other variables. Together, these additional sources support the NCCRA's comprehensive approach to climate risk assessment in cases where TRANSLATE data is either unavailable or requires supplementary information.

By combining these data sources, the NCCRA provides a robust foundation for climate adaptation planning in Ireland, enabling stakeholders to account for a range of possible future climate scenarios in policy and infrastructure development, including projects like the Galway Wastewater Strategy.

[7] https://www.climateireland.ie/media/epa-2020/monitoring-amp-assessment/climate-change/climate-ireland/EPA_NCCRA_Methodology_September_Final_2024_10_07.pdf

[8] https://www.met.ie/science/translate

[9] https://www.climateireland.ie/climate-change/projections-of-climate-change/

[10] https://climateknowledgeportal.worldbank.org/country/ireland/climate-data-projections

4.1.2. Global Warming Levels and Representative Concentration Pathways

The NCCRA specifies that climate change risk assessments should consider three time slices throughout the 21st century (2040, 2050 and 2100) and two scenarios of changing concentrations of greenhouse gases, known as Representative Concentration Pathways (RCP). RCPs specify a timeline of evolving atmospheric radiative forcing through to the year 2100, and the NCCRA specifies that RCP4.5 and RCP8.5 should be considered, representing a medium level of emissions and a high level of emissions, respectively.

For the Galway Wastewater Strategy, projections for 2100 were used for the 2080 design horizon and projections for 2050 for the 2055 design horizon for both RCP4.5 and RCP8.5 emission levels were applied at both epochs. Climate change projections have not been applied to the 2040 design horizon.

RCP4.5 and RCP8.5 are "standard" scenarios used in the production of many sets of climate projections. TRANSLATE uses a slightly different approach, in which climate projections are assessed against different Global Warming Levels (GWLs), each representing a specified change (increase) in global mean temperature, such as 2ºC, 3ºC or 4ºC, relative to the pre-industrial era.

When using the TRANSLATE climate projections, it's essential to align the Representative Concentration Pathways (RCPs) RCP4.5 and RCP8.5 with corresponding Global Warming Levels (GWLs). GWLs represent specific increases in global mean temperature (e.g., +1.5°C, +2°C) and serve as key benchmarks for comparing and interpreting climate impacts across scenarios. To establish this relationship, Figure 2.1 in the UKCP18 climate projection documentation (Figure 4-1), provides a visual overview of projected global mean temperature changes under various RCPs from 2000 to 2100. This figure facilitates an approximate alignment of RCP4.5 and RCP8.5 with relevant GWLs for key time points, namely 2040, 2050, and 2100. The approximate equivalent GWLs for these RCP scenarios are summarized in Figure 4-1, which helps translate the projected outcomes under RCP4.5 and RCP8.5 into GWLs appropriate for specific planning needs. An important observation in the projections is that the difference between RCP4.5 and RCP8.5 scenarios remains minor through 2030, indicating that the degree of warming from present day to 2030 is relatively small and may be considered negligible. However, by 2100, RCP8.5 projects a GWL of around 5°C, which exceeds the 4°C GWL – the highest level for which the TRANSLATE project provides projections.

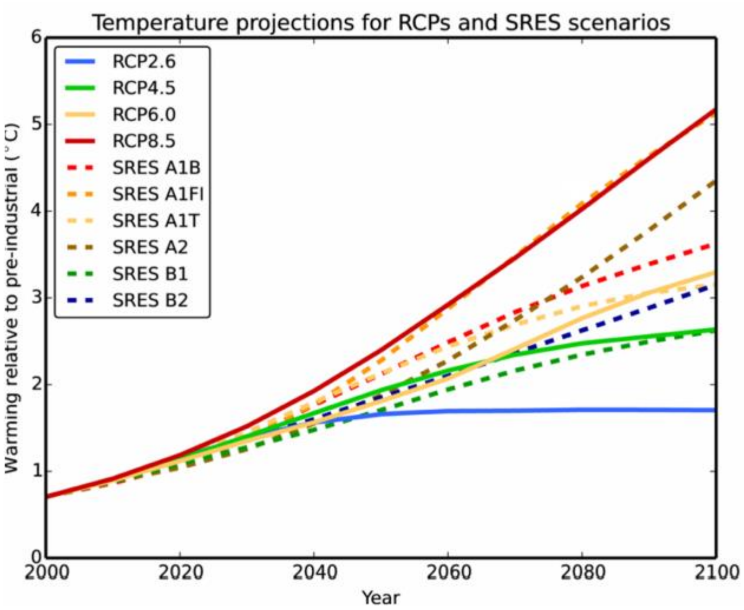


Figure 4-1: UKCP18 projections of warming for RCP

Table 4-1: Approximate relationship between RCP4.5 and RCP8.5 and GWLs

RCP	2030	2050	2100
RCP4.5	-	2ºC	2.5ºC
RCP8.5	-	2.5ºC	5ºC

4.2 Air Temperature

4.2.1. Projected changes in air temperature

TRANSLATE provides projections of increases in air temperature in Galway for various Global Warming Levels as shown in Table 4-2. The values shown are changes relative to a baseline period of 1976-2005.

Table 4-2: TRANSLATE projected increases in air temperature for Galway

GWL	Change in annual mean air temperature
2ºC	+1ºC
3ºC	+2ºC
4ºC	+2.1ºC

Using the relationships between GWLs and RCPs shown in Table 4-2, these correspond to changes in mean air temperature as shown in Table 4-3.

Table 4-3: TRANSLATE projected increases in air temperature for Galway for RCP4.5 and RCP8.5

RCP	2030	2050	2100
GWS Design Horizon		2055	2080
RCP4.5	-	+1ºC	+2ºC
RCP8.5	-	+2ºC	+2.1ºC

In terms of seasonal variation to air temperature, TRANSLATE does provide information on projected increases in summer and winter temperature but there is generally little difference between them for any given GWL, and so it is considered sufficient to apply a single uplift figure for all seasons.

Figure 4-2 from Climate Ireland shows maps of projected changes in mean air temperature for RCP4.5 and RCP8.5, for the 2050s and 2080s. These projections are broadly consistent with those from TRANSLATE, although the projected changes are slightly smaller than those TRANSLATE suggests. The CMIP5 projections from Climate Ireland are older than those from TRANSLATE, and it is suggested that the latter are used.

4.2.2. Applicability to the GWS Modelling Framework

The projected changes in air temperature have been applied to water quality modelling. We have applied the changes in air temperature to the assumed surface water temperature applied in the river models, i.e. we assumed that changes in river water temperature match those in air temperature. River water temperature governs ammonia decay rates, proportions of ionised and unionised ammonia factions and dissolved oxygen dynamics and hence changes in river temperature will affect predicted water quality.

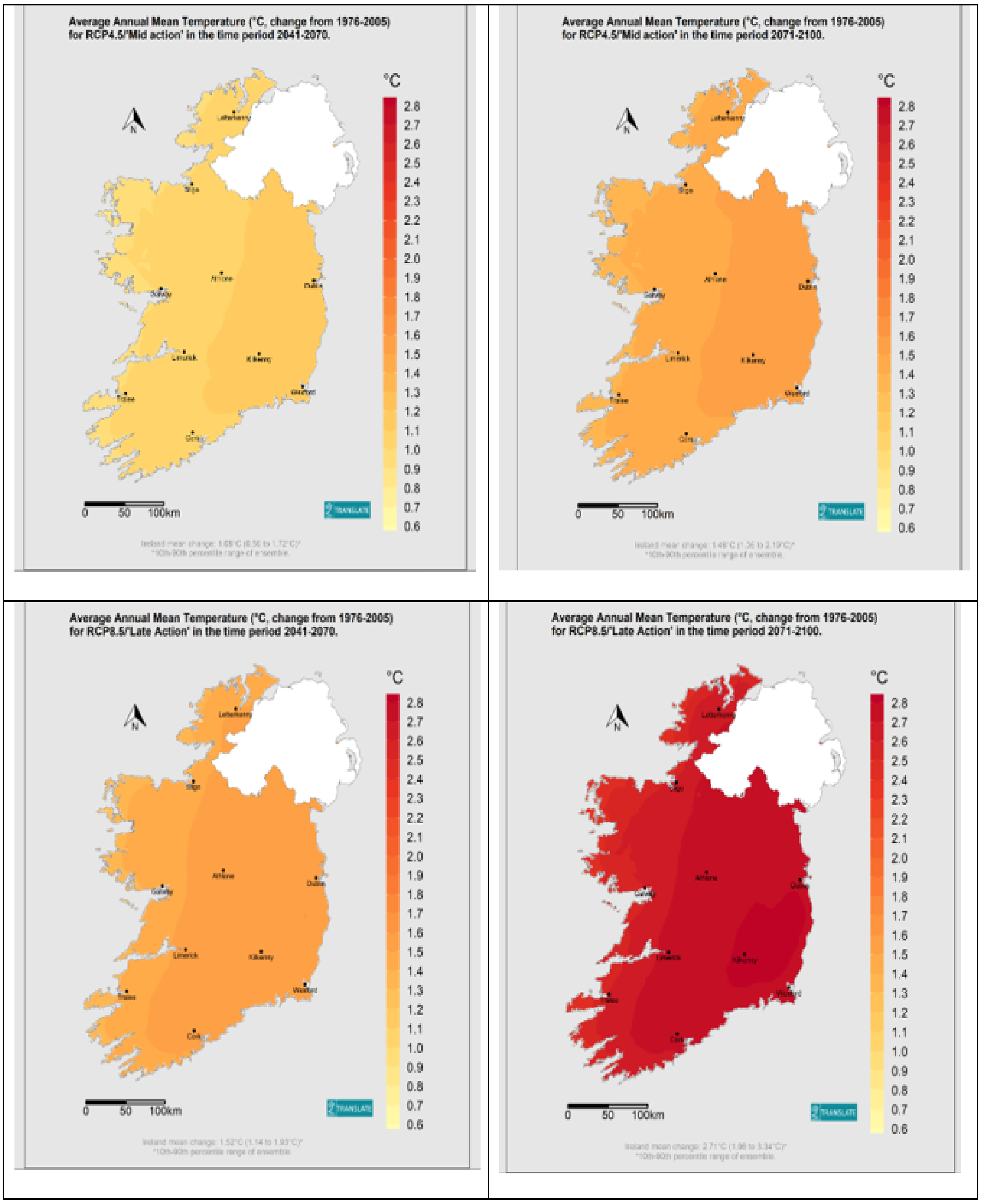


Figure 4-2: Projected change in air temperature under RCP4.5 and RCP8.5[11]

[11] https://www.climateireland.ie/data-explorer (accessed October 2024)

4.3 Evapotranspiration

4.3.1. Projected changes in evapotranspiration

As air temperature increases it would be expected that potential evapotranspiration (ET), which is a function of temperature, wind speed and humidity (and other variables) will also increase. However, projections of changes in evapotranspiration are sparse compared with projections of changes in other meteorological variables.

Climate Ireland provides results from the CMIP5 project, including projected changes in ET for the 2050s, as shown in Figure 4-3.

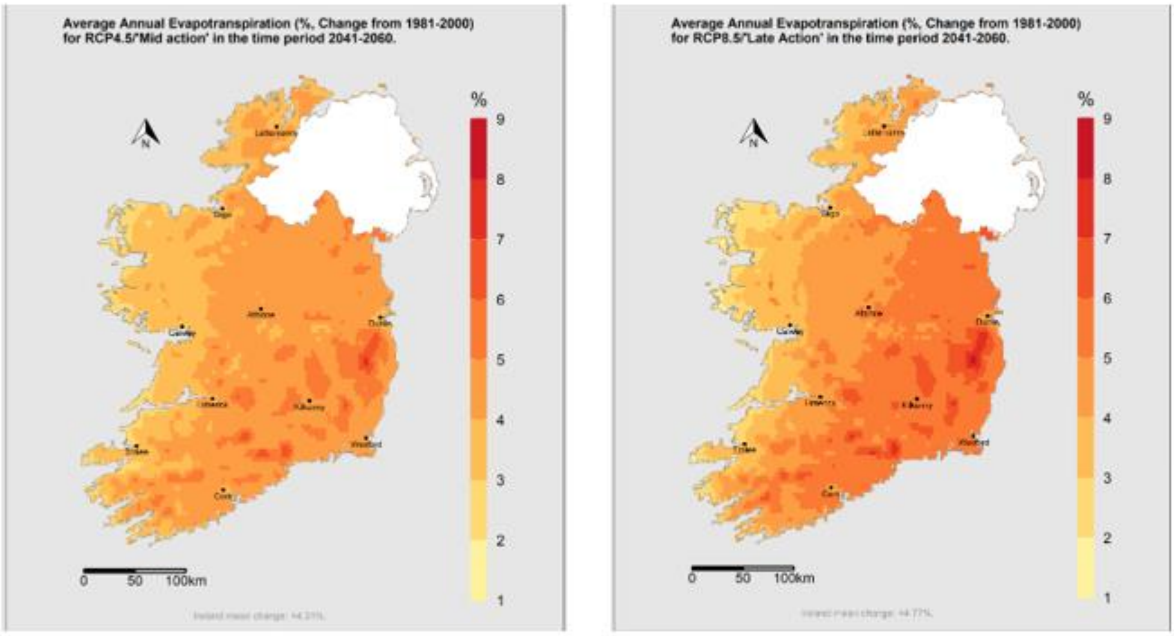


Figure 4-3: Projected change in evapotranspiration under RCP4.5 and RCP8.5 for the 2050s.[12]

The projected changes are relatively modest for Galway, at around 2-3% under RCP4.5 and 3-4% under RCP8.5. No information is available for the 2100 time period, but if it is assumed that changes in ET correlate linearly with changes in air temperature it might be expected that ET will increase by about 4-6% by 2100 under both RCP4.5 and RCP8.5.

4.3.2. Applicability to GWS Modelling Framework

It is recommended not to incorporate changes to evapotranspiration within the parameters of the sewer network model. Evapotranspiration is expected to be a relatively insignificant factor in determining environmental and flooding performance outcomes. Sewer networks are primarily impacted by variations in rainfall intensity, frequency, and duration, which directly influence runoff, peak flow rates, and sewer capacity under different climate scenarios. Changes in rainfall are therefore expected to drive the primary impacts on both flood risk and water quality within sewer systems. Given this, it is more practical to focus modelling efforts on accurately representing

[12] https://www.climateireland.ie/data-explorer (accessed October 2024)

rainfall variability and intensity rather than incorporating uncertain changes in evapotranspiration, which would add complexity without providing meaningful improvements to model accuracy.

4.4 Rainfall

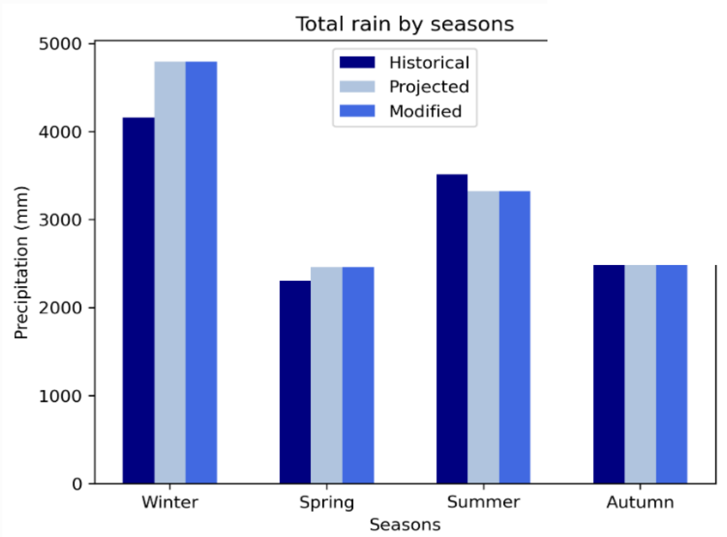
4.4.1. Projected changes in Rainfall

In the context of sustainable urban drainage planning, rainfall will be one of the most critical variables influencing project outcomes and planning decisions related to climate change impacts. As urban areas face increasing challenges from climate variability, understanding and accurately predicting rainfall patterns becomes essential for effective infrastructure design and resilience planning.

The TRANSLATE project offers valuable projections of changes in annual mean rainfall depths across various Global Warming Levels. However, it is important to note that even modest shifts in annual mean precipitation can obscure more significant seasonal variations. These seasonal effects can lead to pronounced impacts on drainage systems, necessitating a nuanced understanding of rainfall dynamics throughout the year. For effective drainage modelling, daily or sub-daily time series of rainfall amounts are essential, as typical sewer network models simulate drainage processes using sub-hourly timesteps. This level of temporal resolution is critical for capturing peak flow events and ensuring that drainage systems are adequately designed to handle potential flooding and limit storm overflow operation.

To support this need, the TRANSLATE2RED tool, developed by Amphos 21 on behalf of UÉ provides perturbed daily and sub-daily rainfall time series based on the TRANSLATE climate projections for Ireland. The perturbation process employed in TRANSLATE2RED is built upon the methodology established by the REDUP tool, which utilizes uplift factors to adjust historical rainfall time series, thereby accommodating for the anticipated impacts of climate change. Although the REDUP tool is recognized as an industry-standard solution for rainfall adjustments, it is primarily limited to applications within the UK. The TRANSLATE2RED tool enhances the availability of rainfall time series for all Representative Concentration Pathways (RCPs) and across various time periods for which the TRANSLATE project provides projections. These outputs are generated at the county level, ensuring that local variations in rainfall patterns can be accounted for in urban drainage planning.

For instance, Figure 4-4 illustrates the rainfall projections for Galway under RCP8.5 for the period of 2041-2070, highlighting the tool's capability to provide detailed and relevant data for informed decision-making.



Historical, projected and modified (obtained after perturbation) total rain (mm)

Figure 4-4: Projected seasonal rainfall totals for Galway under RCP8.5 for the 2050s

4.4.2. Applicability to the GWS Modelling Framework

The climate change risks facing the drainage networks which are the subject of the Galway Wastewater Strategy are primarily twofold: impacts on environmental performance and increased flooding potential. For assessing environmental performance, it is recommended to use the TRANSLATE2RED rainfall time series projections for Galway, developed by Amphos 21 for UÉ. These projections allow for climate-adjusted assessments of environmental risks to assets by providing future rainfall patterns aligned with climate change scenarios. According to the National Climate Change Risk Assessment (NCCRA) requirements, projections targeting 2050 should utilize data from the 2041-2070 period, while projections for 2100 should use data from 2071-2100. Both RCP4.5 and RCP8.5 scenarios will be assessed to provide a range of emission pathways, reflecting varying levels of climate impact.

The TRANSLATE2RED tool's uplifted rainfall time series was incorporated into both sewer network models and water quality models. This approach simulates the effect of climate-driven changes in hydraulic loading which is used to calculate the increased pollutant loading on river water quality across seasonal shifts. It enables an assessment of how increased rainfall in wetter winters and reduced rainfall in drier summers might impact pollutant dynamics, affecting water quality and associated risks within freshwater ecosystems. The calibrated rainfall-runoff models for Athenry and Claregalway will be simulated using the TRANSLATE2RED climate-adjusted rainfall time series.

Flooding performance presents an additional challenge, as future storm events are expected to become more intense and potentially more frequent. To address this, uplift factors for design storms, as recommended by UÉ modelling specifications, for 2055 (20%) and 2080 (25%) are applied. These uplift factors will help account for increased peak storm intensities and ensure that sewer and drainage systems are resilient to projected flooding risks.

This dual approach, using climate-adjusted time series for environmental performance assessments and design storm uplifts for flooding risks, provides a robust framework to address the multifaceted impacts of climate change on the Galway Wastewater Strategy's sewer networks.

4.5 Sea Level Rise

4.5.1. Scope of Sea Level Rise Modelling

Sea levels are projected to rise significantly in the coming decades due to a combination of two primary factors: the melting of land-based ice sheets, particularly in Greenland and Antarctica, and the thermal expansion of ocean water as it warms. Together, these processes are expected to drive a persistent increase in global mean sea levels, with regional variations based on factors like ocean currents, gravitational changes from ice mass loss, and local land subsidence or uplift.

In addition to rising mean sea levels, the severity and frequency of storm surges are also anticipated to increase in many regions due to climate change. Warmer sea surface temperatures and changes in atmospheric circulation patterns can intensify storms, leading to larger storm surges. These surges, combined with elevated baseline sea levels, are likely to contribute to more frequent and severe coastal flooding, particularly during extreme weather events, and could amplify impacts on vulnerable coastal infrastructure.

However, for the purposes of the Galway Wastewater Strategy, the focus is solely on projected changes in mean sea level. By concentrating on mean sea level rise, we account for baseline shifts that inherently influence storm surge impacts without layering storm surge estimates on top of future sea levels, which may result in excessively conservative design criteria. While mean sea level projections incorporate the baseline changes that intensify storm surge effects, a compounded addition of storm surge to projected mean sea levels could lead to overly conservative planning assumptions, potentially inflating costs without a proportionate gain in resilience.

In combination, the scope of the GWS is not to consider the effects of tidal inundation, across land for example, as it is out with the scope of the strategy, which considers the effect that rising sea levels may have on the interface between the sewer network and the coast and/or tidally affected river reaches.

6.2 Projected Changes in Mean Sea Level

There are relatively few projections of sea level rise for Ireland. The NCCRA refers to reports published by the OPW and the UKCP18 climate projections. The latter obviously does not include projections for Ireland.

The Climate Ireland site[13] states that "*Satellite observations indicate that sea level around Ireland has risen by approximately 2-3mm per year since the early 1990s" and that "Global mean sea level increases will occur under all scenarios and continue for thousands of years after the global temperature is stabilised. By 2100 projected additional rises range from 0.32–0.6m under Early action to 0.63– 1.01m under Late action scenarios.*"

[13]https://www.climateireland.ie/impact-on-ireland/future-climate-of-ireland/sea-level-rise/#:~:text=Global%20sea%20level%20increased%20by,year%20since%20the%20early%201990s

The Irish Government's Climate Adaptation Policy[14] quotes the OPW (2018): "*the OPW uses the evidence from the IPCC and other authoritative sources, so that we project two possible scenarios that might arise in the future:*

- *Mid-Range Future Scenario - increase in rainfall of 20% and sea level rise of 500mm (20 inches), and*
- *High-End Future Scenario - increase in rainfall of 30% and sea level rise of 1,000mm (40 inches).*"

These figures refer to potential increases by the year 2100.

The UKCP18 climate projections include detailed projections of sea level rise around the UK coast from the present day to the year 2300. Table 4-4 shows projected sea level rise under RCP4.5 and RCP8.5 for a site on the east coast of the island of Ireland, close to the border between Northern Ireland and the Republic of Ireland. At the 50th percentile level, these projections equate to values as shown in Table 4-4 relative to a baseline period 1981-2000.

Table 4-4: UKCP18 projections of sea level on the Irish east coast for RCP4.5 and RCP8.5

RCP	2030	2050	2100
GWS Design Horizon		**2055**	**2080**
RCP4.5	9 cm	17 cm	39 cm
RCP8.5	11 cm	21 cm	59 cm

It is worth noting that The UKCP projections are on the other side of the island of Ireland and suggest smaller rises in sea level than the EPA and OPW figures, but the use of EPA or OPW figures is recommended over UK data sources.

The EPA and OPW figures for sea level rise by 2100 are broadly consistent, with figures of 0.63-1.01m (Late action scenarios) and 1.0m (High end Future Scenario), respectively. A figure of 1.0m is therefore recommended as a conservative estimate.

4.5.2. Applicability to Galway Wastewater Strategy Modelling Framework

An uplift factor of 1.0m has been applied to the tidal level file within the Galway City Sewer Network model as this network will only be affected by changes in mean sea level. It was not applied for initial dilution modelling as it was deemed conservative to use the existing Marine Institute model for purposes of strategic planning.

[14] https://www.gov.ie/en/policy-information/dfb37-climate-adaptation/

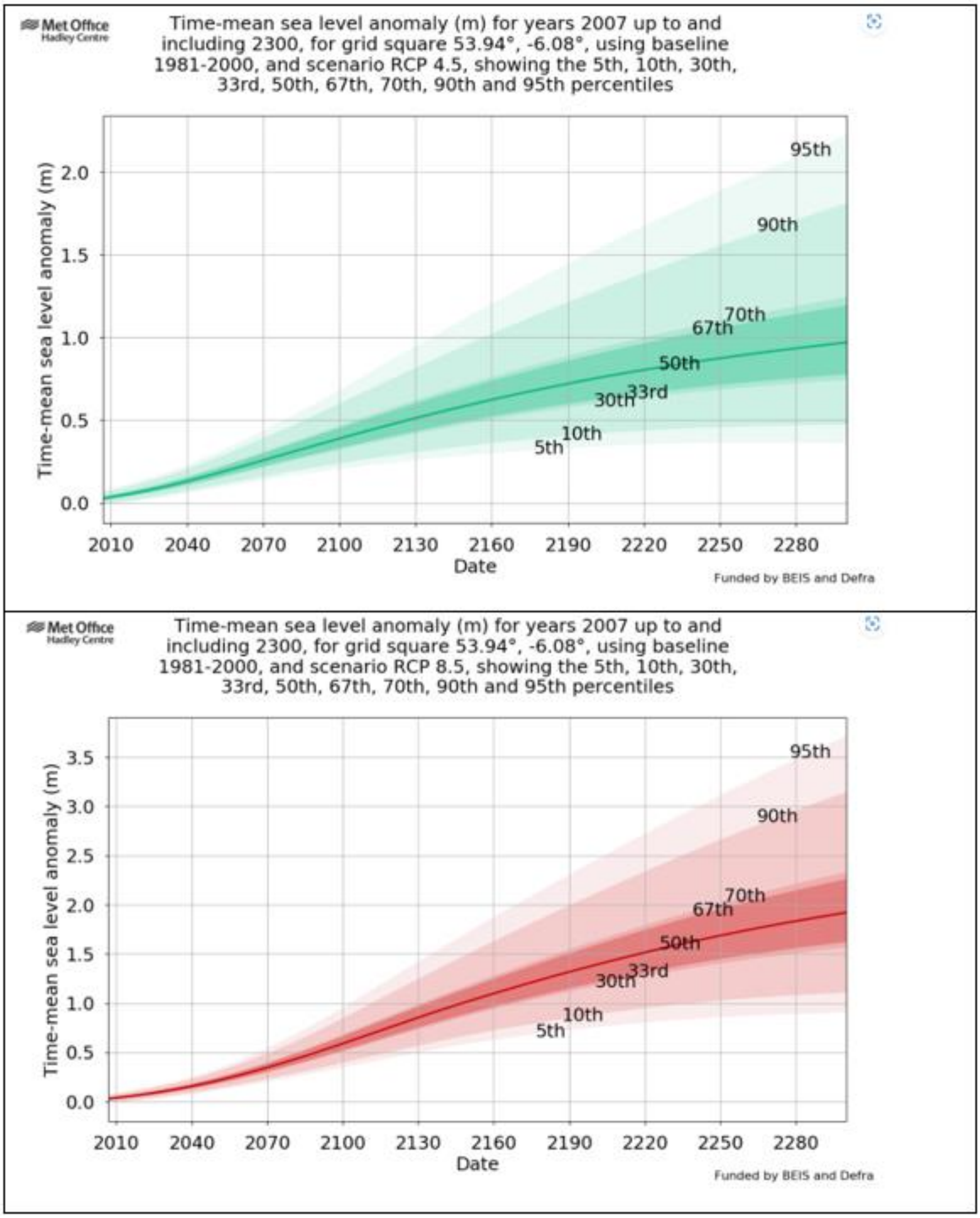


Figure 4-5: Projected change in mean sea level under RCP4.5 and RCP8.5 (UKCP18).

5. Summary

This appendix presents the approach for modelling and climate change analysis within the GWS, detailing the network models available and their integration as inputs to water quality assessment frameworks for evaluating performance and impacts on receiving water bodies. It describes the suite of network and receiving water quality models developed for the four agglomerations - Galway City, Athenry, Claregalway, and Moycullen - and includes a strategic initial dilution study focused on to marine outfalls to Galway Bay for a new WWTP.

Site-specific assessments were completed for Athenry, Claregalway and Moycullen to determine compliance with Water Framework Directive standards under current, growth and climate scenarios. In parallel, marine modelling using Marine Institute tidal and current data applied WRc initial dilution methods to evaluate potential marine outfall locations in Galway Bay. These modelling approaches identify assimilative capacity constraints, determining likely compliance outcomes.

Hydraulic models were created or refined using InfoWorks ICM to simulate foul and stormwater conveyance for both current and projected growth scenarios. Impacts were evaluated using a combination of Monte Carlo analyses and UPM river impact modelling, supported by EPA monitoring data, UÉ records, and hydrometric datasets. Where applicable, both continuous and intermittent discharges, including SWOs and storm tank discharges, were incorporated into the analysis to assess the impacts of existing and future wastewater discharges on both freshwater and coastal environments.

The appendix outlines the available network models and monitoring data used for the GWS. It demonstrates that these models and recent updates ensure that they are fit for the purposes for the GWS by summarising the level of detail included in these models. Model limitations are outlined within Appendix 4 for the future use and next steps as the GWS progresses for more detailed assessment.

For this study, the climate change emission scenarios utilized were RCP4.5 and RCP8.5 at the 2055 and 2080 design horizons. Sensitivity analyses focused on variables including rainfall, growth, air temperature, and sea level rise. to assess the impact that climate change may have on optioneering decisions and long-term planning.