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EPA Research

The Irish Hydrometric Reference Network Version 2.0

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Lead organisation: The Irish Climate Analysis and Research Units (ICARUS), Department of Geography, Maynooth University

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Rialtas na hÉireann
Government of Ireland

Environmental Protection Agency

The EPA is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

Regulation: Implementing regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.

Knowledge: Providing high quality, targeted and timely environmental data, information and assessment to inform decision making.

Advocacy: Working with others to advocate for a clean, productive and well protected environment and for sustainable environmental practices.

Our Responsibilities Include:

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- Large-scale industrial, waste and petrol storage activities;
- Urban waste water discharges;
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- Sources of ionising radiation;
- Greenhouse gas emissions from industry and aviation through the EU Emissions Trading Scheme.

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- Engage with national and regional governance and operational structures to implement the Water Framework Directive;
- Monitor, assess and report on the quality of rivers, lakes, transitional and coastal waters, bathing waters and groundwaters, and measurement of water levels and river flows.

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- Provide the Secretariat to the Climate Change Advisory Council and support to the National Dialogue on Climate Action;
- Support National, EU and UN Climate Science and Policy development activities.

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- Design and implement national environmental monitoring systems: technology, data management, analysis and forecasting;
- Produce the State of Ireland's Environment and Indicator Reports;
- Monitor air quality and implement the EU Clean Air for Europe Directive, the Convention on Long Range Transboundary Air Pollution, and the National Emissions Ceiling Directive;
- Oversee the implementation of the Environmental Noise Directive;
- Assess the impact of proposed plans and programmes on the Irish environment.

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- Coordinate and fund national environmental research activity to identify pressures, inform policy and provide solutions;
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Radiological Protection

- Monitoring radiation levels and assess public exposure to ionising radiation and electromagnetic fields;
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- Monitor developments abroad relating to nuclear installations and radiological safety;
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- Provide independent evidence-based reporting, advice and guidance to Government, industry and the public on environmental and radiological protection topics;
- Promote the link between health and wellbeing, the economy and a clean environment;
- Promote environmental awareness including supporting behaviours for resource efficiency and climate transition;
- Promote radon testing in homes and workplaces and encourage remediation where necessary.

Partnership and Networking

- Work with international and national agencies, regional and local authorities, non-governmental organisations, representative bodies and government departments to deliver environmental and radiological protection, research coordination and science-based decision making.

Management and Structure of the EPA

The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:

1. Office of Environmental Sustainability
2. Office of Environmental Enforcement
3. Office of Evidence and Assessment
4. Office of Radiation Protection and Environmental Monitoring
5. Office of Communications and Corporate Services

The EPA is assisted by advisory committees who meet regularly to discuss issues of concern and provide advice to the Board.

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What did this research aim to address?

The research aimed to update and expand the Irish Hydrometric Reference Network (IHRN) for monitoring and detecting climate-driven changes in river flows across the island of Ireland. Addressing a critical knowledge gap, the study also undertook detailed analysis of trends in river flows (floods, average conditions and low flows) that will support adaptation planning in the water sector and beyond. This new dataset will provide a foundation for climate impact assessments, hydrological modelling and water resource management in a changing climate. The approach was innovative in integrating novel approaches to infill missing data and extend flow records, thereby improving the robustness of trend detection and climate change attribution in river flows. The research has significant policy implications, offering evidence for adaptive water resource planning and climate resilience strategies.

What did this research find?

The research found clear increasing trends in high and mean flows, particularly in winter and in north-western catchments, indicating a heightened risk of extreme hydrological events. Wetter catchments with a high proportion of peat cover exhibit stronger increasing trends in high and mean flows, whereas catchments with extensive alluvial deposits demonstrate weaker trends. Observed records show decreasing trends towards more extreme low flows in spring and summer months. Longer flow reconstructions extending back to 1941 show even greater decreasing trends in spring, summer and autumn. These findings demonstrate the importance of maintaining high-quality long-term records of river flows and underscore the increasing risk of drought conditions during summer and autumn. The influence of large-scale climate drivers, particularly the North Atlantic Oscillation (NAO), was evident in the analysis. A strong positive correlation was found between the NAO and winter flows in north-western catchments, while summer flows exhibited a negative correlation. Additional outputs from the project include long-term daily flow reconstructions (1941–2022) and the identification of fledgling stations that may be included in future updates to fill spatial gaps in the network, especially in the east of the country and in smaller upland catchments. These should be a priority for monitoring.

How can the research findings be used?

The IHRN Version 2 dataset provides a critical resource for policymakers, researchers and water managers, facilitating evidence-based decision-making to enhance climate resilience and water resource management in Ireland. The updated IHRN can be used to track and monitor climate variability and the emergence of climate change signals in Irish river flows. Reconstructed flows for each catchment can be used to assess changing extremes and contextualise recent changes in the context of long-term records. This dataset will improve hydrological modelling, flood risk management, and water resource and climate adaptation planning. Immediate next steps include incorporating the updated dataset and findings from the analysis of trends into national water and flood management strategies. Tagging of each station in the network as being included in the IHRN or as a fledgling IHRN station can support ongoing high-quality monitoring of river flows and be used to prioritise investment in observational records. Future research should focus on expanding the network to include groundwater and lake monitoring, ensuring a holistic approach to Ireland's hydrological resilience in a changing climate. The findings underscore the need for continued investment in hydrometric monitoring infrastructure to support a climate-resilient Ireland, and oversight and planning by hydrometric teams at the EPA, Office of Public Works, Geological Survey Ireland and local authorities will be crucial to realising this.

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EPA Research Report

Prepared for the Environmental Protection Agency

by

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This report is based on research carried out/data from 1 January 2023 to 31 December 2024. More recent data may have become available since the research was completed.

The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

The Irish Hydrometric Reference Network Version 2.0 (IHRN V2) provides an updated network of high-quality river flow stations for monitoring and detecting climate-driven changes in Irish river flows. Hydrometric reference networks play a crucial role in tracking climate variability and change, as well as in hydrological modelling and extreme event analysis. The first iteration of Ireland's reference network (IHRN V1) was established in 2013, comprising 43 stations. A decade later, the IHRN V2 expands this network to 51 stations, with enhanced spatial coverage, improved station performance assessments and extended flow records. The selection process for IHRN V2 was guided by internationally recognised criteria, ensuring the inclusion of stations with high-quality, long-term and near-natural flow data. Each station's performance was assessed across high-, mean- and low-flow regimes, with classifications enabling targeted hydrological assessments. The average record length within the network has increased to 49.2 years, supporting more robust trend detection and climate impact assessments. Data gaps have been addressed using a combination of conceptual modelling and artificial neural networks, providing an extended and infilled dataset that enhances the reliability of long-term hydrological analyses.

Trend analysis of IHRN V2 data, from observations over the past 30 years and reconstructions dating back to the 1940s, reveals clear signals of changing hydrological patterns. Maximum and mean flows show significant increasing trends, particularly in winter and in north-western catchments. Seasonal trends indicate increasing high flows in winter, spring and autumn, with low flows ("Q95") exhibiting decreasing trends, especially in longer, reconstructed records. Wetter catchments tend to show stronger increasing trends, especially for high and mean flow indices, than low-lying well-drained catchments. The North Atlantic Oscillation shows strong positive correlation with winter maximum and mean flows in the north-west and negative correlations in the south-east. Results suggest that the island of Ireland is experiencing more frequent and intense hydrological extremes, likely influenced by climate variability and change and shifting precipitation patterns. The persistence and significance of these trends highlight the importance of maintaining long, high-quality hydrometric records.

The findings underscore the need for continued investment in hydrometric monitoring infrastructure, particularly in areas where data gaps remain. The identification of fledgling stations – those that will meet reference network criteria in the next decade – points to future opportunities for expanding the network. Extension of such reference networks to lakes and groundwater would also add considerable value to evidence-based decision-making in managing our water resources in a changing climate. The IHRN V2 dataset provides a critical resource for policymakers, researchers and water managers, facilitating evidence-based decision-making to enhance climate resilience and water resource management in Ireland.

1 The Irish Hydrometric Reference Network Version 2.0

1.1 Introduction

Long-term, quality-assured observational flow records are required to understand hydrological processes, river flow variability and the impacts of extreme events (Machiwal and Jha, 2006; Hannaford *et al.*, 2013; Garner *et al.*, 2015). Hydrologists often rely on reference networks for such purposes (Whitfield *et al.*, 2012), which consist of quality-assured, long-term river flow observations with limited anthropogenic influences (e.g. Cobb and Biesecker, 1971; Stahl *et al.*, 2010; Turner *et al.*, 2025). Standard criteria are applied when selecting stations for inclusion in hydrometric reference networks. These include limited land use change, water regulations, abstractions and/or diversions, a minimum record length of 30 years and high-quality gauge data with adequate supporting metadata. Catchments are usually selected to represent a broad range of catchment characteristics representative of the hydrology of the network area (Whitfield *et al.*, 2012). Reference networks play a crucial role in determining climate variability and change influences in river flows (Burn *et al.*, 2012) and have been widely employed for this purpose (e.g. Hannaford, 2015; Caillouet *et al.*, 2017; Burn and Whitfield, 2023). Murphy *et al.* (2013a,b) developed Ireland's first hydrometric reference network, consisting of 43 quality-assured river flow stations, henceforth the Irish Hydrometric Reference Network Version 1.0 (IHRN V1). This network has not been updated in over 10 years. Given the passage of time and the availability of additional data and metadata, together with scientific advances during this period, this study seeks to update the IHRN V1 to identify stations that might now be considered for inclusion and to ensure previous stations remain suitable for inclusion. This chapter outlines the steps taken to develop an updated hydrometric reference network for Ireland, henceforth the IHRN V2.

1.2 Selection of Network Stations

A total of 366 river flow stations were assessed for inclusion in the IHRN V2. Data were downloaded from the Environmental Protection Agency (EPA) (www.epa.ie/hydronet/) and the Office of Public Works (OPW) (http://waterlevel.ie/) websites, and the seven criteria outlined in Table 1.1 applied to ascertain suitability for inclusion in the network. Metadata were sourced from hydrometric organisations, which provided details on station performance at high, mean and low flows, together with details on abstractions, arterial drainage and other anthropogenic influences on catchment flows. Once a station met initial criteria, data were further assessed using exploratory data analysis via station hydrographs, histograms and missing data plots. A final list of stations was selected and a questionnaire developed for hydrometric experts that further queried hydrometric performance at each gauge and sought feedback on inclusion in the final network. Upon receipt of this feedback, a second assessment of candidate stations was carried out to produce a final list of stations for inclusion in the IHRN V2.

The final list of stations included in the IHRN V2 can be found in Table 1.2. Each station has been assigned a performance ranking at high, mean and low flows, with 1 representing a well-performing station, 2 a moderately performing station and 3 a poorly performing station. Where a station has a poor ranking for part of the flow regime (e.g. high flows), it is not recommended that it be used for trend analysis for that part of the flow regime. This partitioning of performances across the flow regime was necessary to ensure adequate spatial distribution of the network, and follows the approach taken in the development of the UK Benchmark Network (Harrigan *et al.*, 2018). Of the 51 stations identified for inclusion in the IHRN V2, 20 are ranked as good at high flows, 29 at mean flows and 21 at low flows. There are 25 moderately performing stations at high flows, 21 at mean flows and 21 at low flows. The locations of the final 51 stations and their performances across the flow regime are displayed in Figure 1.1. Only 12 stations achieved a good performance ranking across the full flow regime. Of note is the high number of moderately

Table 1.1. Selection criteria used to identify stations suitable for inclusion in the IHRN V2

Key selection criterion	Comment
Active	Stations must be active and collecting data and be expected to continue to do so into the future. Note: temporarily suspended stations were considered for inclusion.
Hydrometric data quality	High-quality, consistent hydrometric data with adequate supporting metadata are required. A well-defined stage–discharge relationship, particularly at high and low flows (identified with a rating curve), is desirable, with details on the gauge, channel and station performance provided in supporting metadata (e.g. detail on weed growth, high flow bypassing and other channel disturbances).
Record length	Long and continuous records are essential (covering at least 30 years), with continuity of ongoing measurements (less than a 10% gap in the record).
Near-natural flow regime	Catchments should be subject to limited flow regulation, extractions or discharges. When unavoidable, a threshold of 10% influence on flow values at or below Q95 (the flow exceeded 95% of the time) is applicable to low-flow stations.
Limited land use change and drainage	Flow regimes must be relatively free from development and other anthropogenic influences (here we classify relatively free from development as the catchment having <2.5% urban extent). Catchments subject to arterial drainage are flagged, with only post-drainage records employed.
Geographical location	Geographical spread that encompasses the entirety of the island, representing differing rainfall regimes, geology, catchment orientation and vegetation cover. The spatial distribution of candidate stations, record length, data quality at high, mean and low flows and overall hydrological representativeness were considered when choosing stations, with importance adjusted depending on circumstances.
Confirmation	Station nomination for inclusion in the IHRN V2 was flagged with the relevant hydrometric authority (i.e. EPA, OPW). Feedback on station selection was also obtained using a query sheet with a questionnaire addressing all issues identified through previous examination.

performing stations, in particular in the midlands and the south-east.

1.3 Representativeness of the IHRN V2

The representativeness of the IHRN V2 was assessed using available physical catchment descriptors (PCDs; Mills *et al.*, 2014). This assessment was applied for high, mean and low flows. Box plots for selected PCDs can be seen in Figure 1.2. The IHRN V2 captures a large range of catchment types for high, mean and low flows. There are some overall gaps in the network, however, including underrepresentation of upland catchments, something that has previously been identified as an issue in Ireland (Broderick *et al.*, 2019), along with the lack of a station on the eastern seaboard and in the Greater Dublin Area. Low-flow stations tend to be smaller in area than mean- and high-flow stations and have a higher proportion of peat landcover.

1.4 Record Length and Missing Data

Record length of IHRN V2 stations varies from 31 to 71 years, with an average length of 49.2 years (see Table 1.2 for a breakdown by station). The locations of stations with shorter records do not cluster in any particular region. Missing data in the IHRN V2 averaged 4.5%, ranging from 0.9% to 9.3%. Again, there is no spatial pattern to missing data. Figure 1.3 plots record lengths and corresponding accumulated missing days for each IHRN V2 station. Missing data can have considerable impacts when assessing historical change, particularly for extremes (Wilby *et al.,* 2017; Gao *et al.*, 2018). Therefore, we infilled all missing observational flow values using hydrological models.

1.5 Infilling Missing Data and Extending Records

Daily river flow simulations were generated using the GR4J (génie rural à 4 paramètres journalier) model (Perrin *et al.*, 2003), a four-parameter conceptual rainfall runoff model that has been shown to perform well in Irish hydrological conditions (e.g. Meresa *et al.*, 2022). For each catchment, spatially averaged daily precipitation and temperature were extracted from Met Éireann's gridded 1 km × 1 km datasets (Walsh, 2012), with temperature data extended to 1941 using the European Centre for Medium-Range Weather Forecasts Reanalysis version 5 (ERA5) (Hersbach *et al.*, 2020). Potential evapotranspiration was generated using the Oudin technique (Oudin *et al.*, 2005). One day-lagged GR4J flows, temperature, precipitation and precipitation lagged by 1 to 4 days were subsequently applied as inputs

Table 1.2. Details of the 51 stations selected for inclusion in the IHRN V2

Station no.	Station name	River name	Latitude	Longitude	Start year	Missing flows (%)	High flow rating	Mean flow rating	Low flow rating
6012	Clarebane	Fane	54.093	–6.665	1972	4.89	1	1	1
6013	Charleville	Dee	53.856	–6.413	1975	1.8	1	1	1
6014	Tallanstown	Glyde	53.921	–6.549	1975	2.83	1	1	2
6030	Ballygoly	Big (Louth)	54.026	–6.243	1975	9.28	3	1	1
7002	Killyon	Deel (Raharney)	53.488	–6.970	1979	4.95	2	1	3
7005	Trim	Boyne	53.556	–6.791	1975	3.61	2	2	3
7006	Fyanstown	Moynalty	53.726	–6.802	1986	4.4	2	2	2
7033	Virginia Hatchery	Blackwater (Kells)	53.834	–7.078	1980	5.7	2	1	2
11001	Boleany	Owenavorragh	52.643	–6.270	1972	3.34	3	2	2
12001	Scarawalsh	Slaney	52.548	–6.549	1955	3.71	2	2	3
14007	Derrybrock	Stradbally	53.039	–7.084	1980	1.86	1	1	1
14019	Levitstown	Barrow	52.935	–6.949	1954	6.98	2	1	3
15011	Mount Juliet	Nore	52.531	–7.188	1990	0.93	2	1	1
16009	Caher Park	Suir	52.357	–7.922	1954	3.21	2	1	2
16011	Clonmel	Suir	52.351	–7.694	1972	3.02	1	1	3
18002	Ballyduff	Blackwater (Munster)	52.144	–8.051	1972	1.55	1	1	1
18003	Killavullen	Blackwater (Munster)	52.149	–8.515	1972	3.8	2	2	1
18005	Downing Br.	Funshion	52.168	–8.258	1972	1.32	2	3	2
19001	Ballea	Owenboy	51.822	–8.421	1972	6.99	1	1	1
20002	Curranure	Bandon	51.765	–8.682	1975	4.88	1	1	1
22035	Laune Br.	Laune	52.061	–9.617	1991	6.57	3	1	1
23001	Inch Br.	Galey	52.468	–9.534	1972	3.84	1	2	2
24030	Danganbeg	Deel	52.409	–9.002	1980	8.12	2	2	2
25002	Barrington S Br.	Newport	52.645	–8.474	1953	4.37	2	2	2
25006	Ferbane	Brosna	53.270	–7.827	1952	7.38	1	1	3
25022	Syngefield	Camcor	53.093	–7.881	1953	4.13	2	2	1
25030	Scarriff	Graney	52.908	–8.532	1972	4.66	2	2	2
25038	Tyone	Nenagh	52.851	–8.185	1990	3.12	1	1	1
26005	Derrycahill	Suck	53.432	–8.262	1954	2.6	2	2	2
26008	Johnston S Br.	Rinn	53.828	–7.862	1979	7.43	2	2	2
26019	Mullagh	Camlin	53.733	–7.823	1953	3.64	3	2	2
26021	Ballymahon	Inny	53.563	–7.757	1972	5.03	2	2	3
26029	Dowra	Shannon	54.191	–8.014	1975	2.3	3	1	1
26058	Ballinrink Br.	Inny Upper	53.776	–7.250	1981	3.63	2	2	2
26108	Boyle Abbey Br.	Boyle	53.973	–8.296	1990	4.92	1	2	2
27002	Ballycorey	Fergus	52.870	–8.974	1954	2.7	1	1	1
30002	Ower Br.	Black (Shrule)	53.481	–9.159	1974	6.64	2	2	2
30007	Ballygaddy	Clare	53.531	–8.874	1974	4.1	2	2	1
30020	Ballyhaunis	Dalgan	53.762	–8.764	1988	3.39	2	1	2
30021	Christina S Br.	Robe	53.685	–8.992	1985	5.65	2	2	2
31002	Cashla	Cashla	53.288	–9.530	1979	6.57	1	1	1
32012	Newport Weir	Newport	53.889	–9.524	1981	6.33	1	1	1
33001	Glenamoy	Glenamoy	54.240	–9.696	1977	4.62	2	1	2
34001	Rahans	Moy	54.104	–9.157	1972	1.27	1	1	2
34007	Ballycarroon	Deel (Crossmolina)	54.086	–9.344	1972	6.94	1	1	3
34010	Cloonacannana	Moy	53.967	–8.930	1972	3.93	2	1	1

Table 1.2. Continued

Station no.	Station name	River name	Latitude	Longitude	Start year	Missing flows (%)	High flow rating	Mean flow rating	Low flow rating
34024	Kiltimagh	Pollagh	53.848	–9.013	1977	7.47	3	2	2
35005	Ballysadare	Ballysadare	54.209	–8.509	1989	2.12	1	2	3
35011	Dromahair	Bonet	54.227	–8.299	1986	4.24	1	1	1
36019	Belturbet	Erne	54.098	–7.450	1957	6.43	1	1	1
39006	Claragh	Leannan	55.028	–7.684	1977	4.34	2	1	1

Note: High, mean and low flow ratings are categorised for each station as good (1), moderate (2) or poor (3).

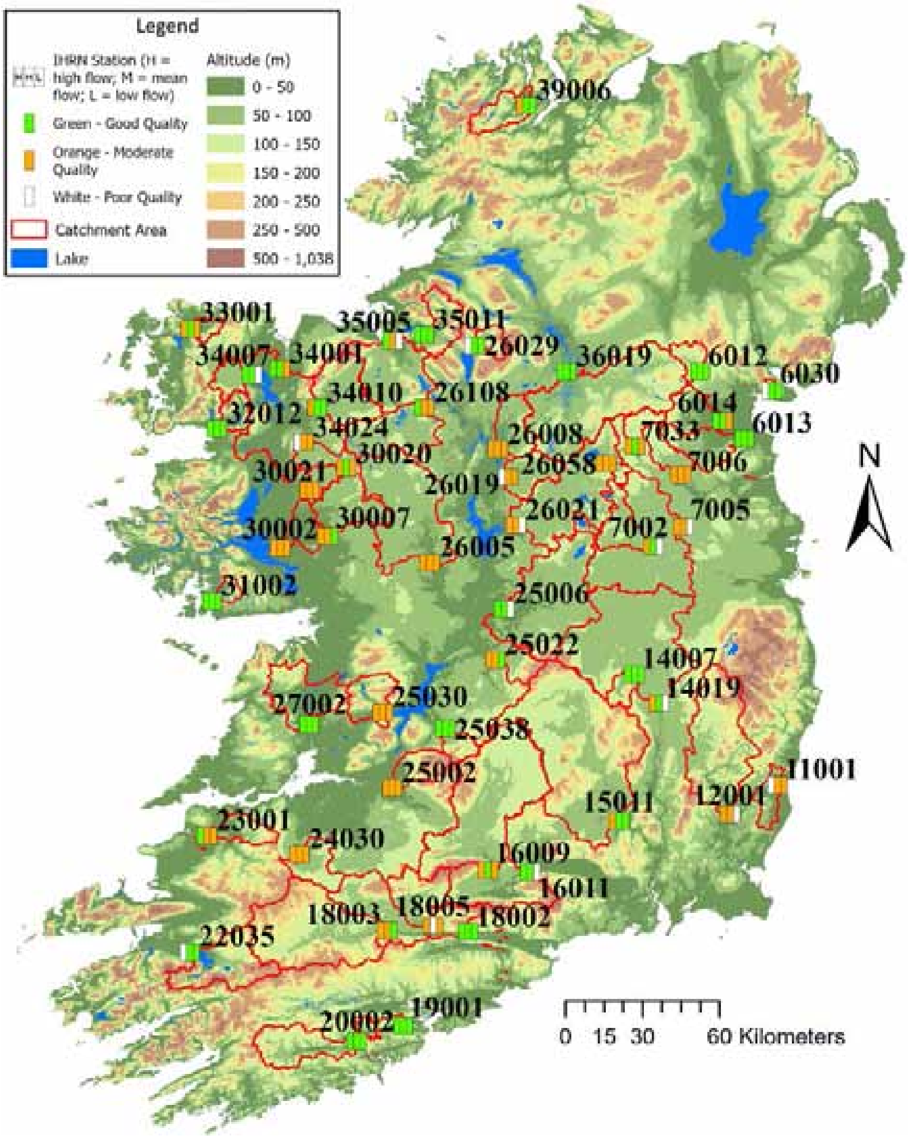

Figure 1.1. Map of stations selected for inclusion in the IHRN V2 together with their performances at high (left box), mean (middle box) and low (right box) flows. Station performance is indicated by colour, with green representative of well-performing stations, orange of moderately performing stations and white of poorly performing stations for the given flow regime.

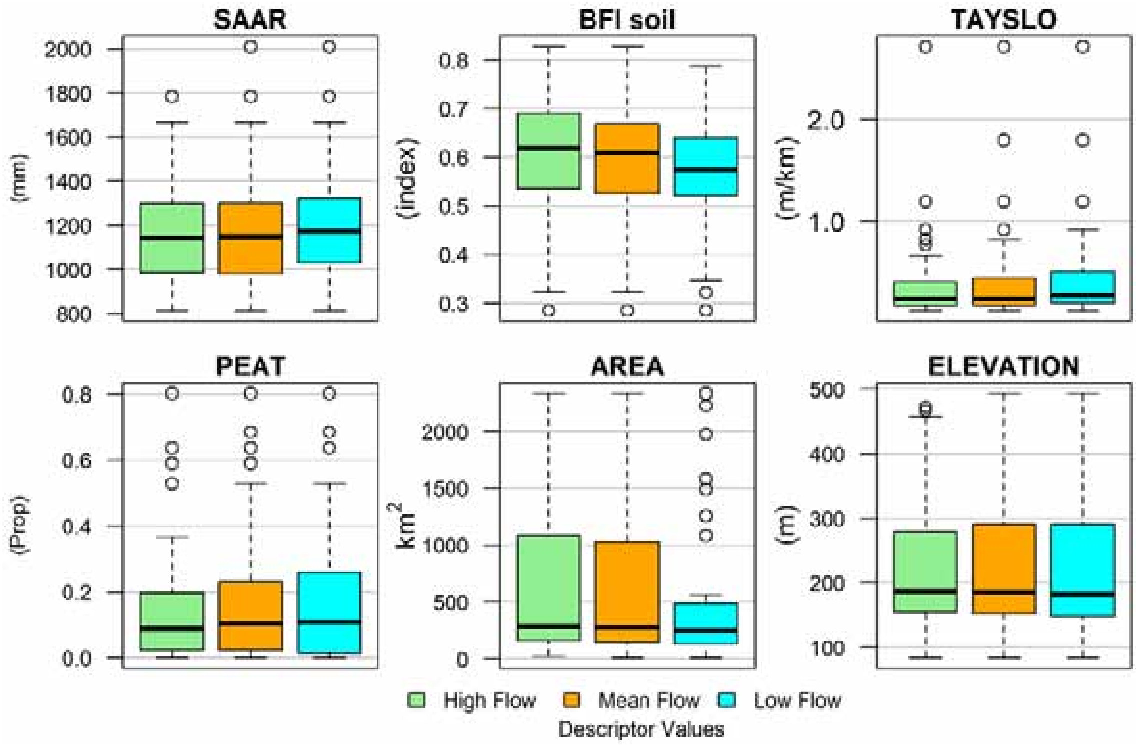

Figure 1.2. Box plots of six catchment PCDs for IHRN V2 stations. Included are SAAR (standard annual average rainfall in mm, derived from the 1961–1990 period), BFI soil (base flow index, based on catchment permeability), TAYSLO (slope of main channel of the river in metres, derived using the Taylor–Schwartz method), PEAT (proportion of peatland), AREA (catchment area) and ELEVATION (average elevation of the catchment). Values are identified for high-, mean- and low-flow catchments.

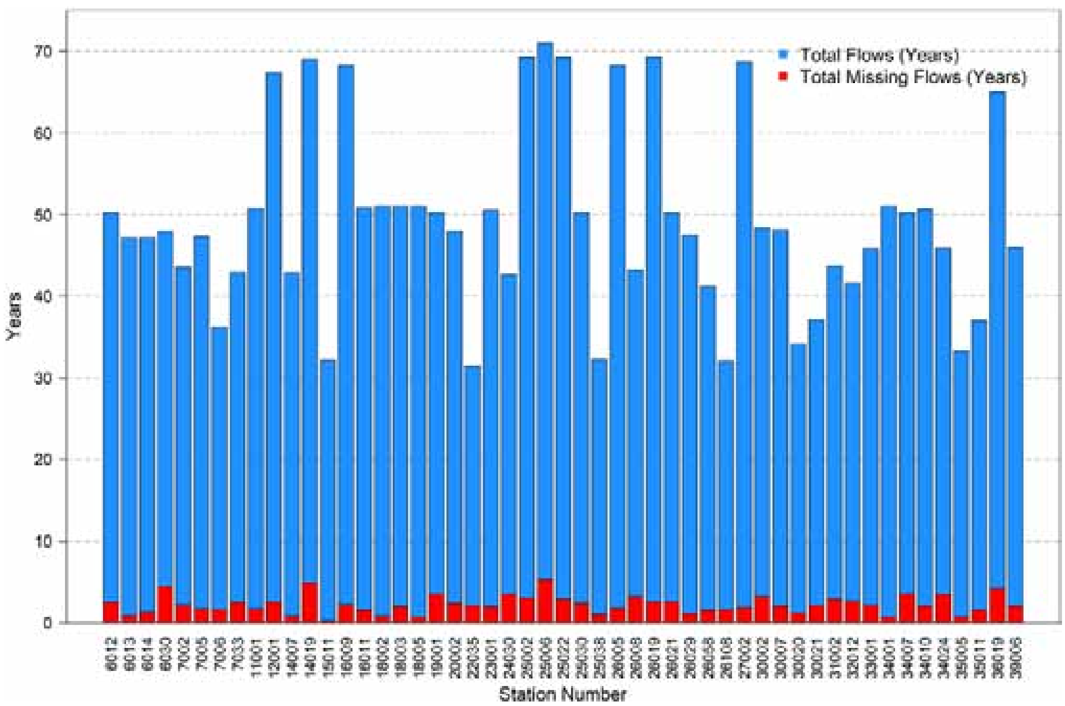

Figure 1.3. Record length of each of the 51 IHRN V2 stations in years (blue) and missing data contained within each series (red).

to an artificial neural network (ANN). The numbers of hidden layers and nodes within the ANN were varied to generate a large number of plausible flow outputs. Nash–Sutcliffe and Kling–Gupta objective functions were calculated for each output, with the top 20 performing model structures returned by each retained. The median simulated daily flow series from these 40 best-performing models was also derived for each station. Nash–Sutcliffe efficiency, Kling–Gupta efficiency and *R*-squared performance scores for the validation period for flows simulated by the original GR4J model and subsequent ANN models are shown in Figure 1.4.

Given the availability of input data dating back to 1941, daily flow series were simulated for all IHRN V2 stations for the period 1941–2022 (see Figure 1.5 for an example of output) and were used for two purposes. First, they were used to infill missing flow values in the observational record for each station. Infilled flow series together with supporting metadata are available to download for each station from https://doi.org/10.5281/zenodo.13943987. Second, simulations were used as reconstructions of daily flows for each catchment for the period 1941–2022. These reconstructions allow variability and change in shorter observed records to be analysed in the context of the past 80 years. Flow reconstructions for the 1941–2022 period for all 51 IHRN stations can be downloaded from https://doi.org/10.5281/zenodo.14523764.

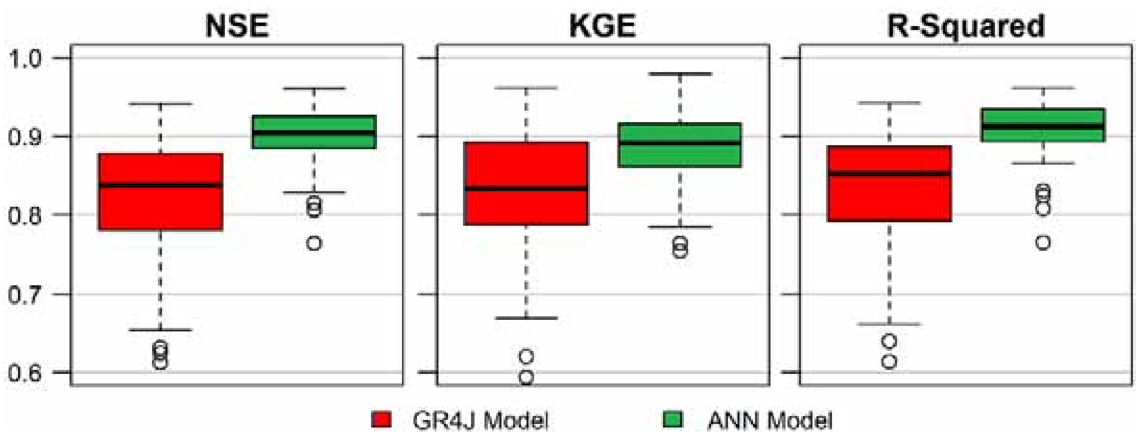

Figure 1.4. Model performance indicators for the GR4J (red) and ANN (green) models across all 51 IHRN V2 stations. Scores are derived from the validation period (2000–2022). KGE, Kling–Gupta efficiency; NSE, Nash–Sutcliffe efficiency.

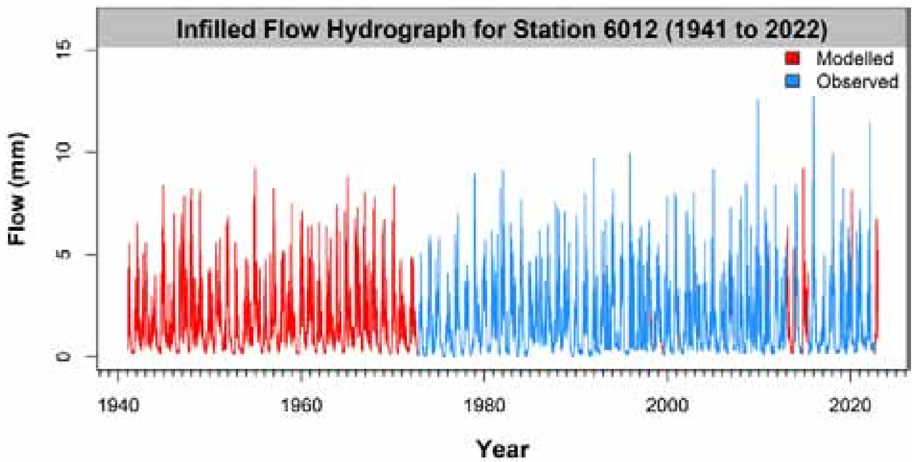

Figure 1.5. Example model output (red) used to both infill gaps in observed flow data (blue) and extend the flow record for Clarebane station (ID: 6012).

1.6 Conclusion

This chapter presents an overview of the IHRN V2, a newly updated hydrometric reference network of river flow stations for Ireland. Stations were selected for inclusion based on criteria including sufficient record length and quality, spatial distribution and representativeness of hydrological characteristics.

The IHRN V2 is organised around sub-networks of stations with a performance rated as good or moderate at high, mean and low flows, allowing targeted applications. For all 51 catchments, hydrological modelling was used to infill gaps in observational records and to reconstruct 80 years of daily flows for the period 1941–2022, which can be used to add context to findings from shorter observed records.

2 Analysis of Trends in River Flows from IHRN V2

2.1 Introduction

Ireland's Climate Change Assessment report (Murphy *et al.*, 2023; Thorne *et al.*, 2023) presents the most up-to-date assessment of knowledge on climate change and its projected impacts for Ireland. For river flows, increases in extremes of flood and drought are expected; however, the exact timing of change remains relatively uncertain. Even for observations, relatively short records of gauged flows, large temporal variability in river flows, human influences on river catchments and other confounding factors all mask climate change impacts on flow regimes (Hannaford, 2015). Hydrometric reference networks go some way to addressing many of these issues due to their long record lengths and high-quality data from near-natural catchments, and therefore play a central role in accurately detecting change and links to climate drivers. Based on assessment of the IHRN V1, Murphy *et al.* (2013a) found climate-driven increasing trends in annual maximum, maximum 10-day and maximum 30-day flows over the 1976–2009 period, particularly in western parts of the island. Summer mean flows were found to be increasing and winter mean flows decreasing (on average). Murphy *et al.* (2013a) also noted the importance of the North Atlantic Oscillation (NAO) in influencing change in river flows, particularly in winter and spring. Variability and change in river flows are sensitive to the period assessed (Hannaford and Buys, 2012), so the longer record length provided by the updated IHRN V2 together with the newly available daily flow reconstructions offer the ability to update the assessment of Murphy *et al*. (2013a) and to place findings within the context of the last 80 years.

This chapter presents the results of our assessment of trends in the IHRN V2. In section 2.2, we outline the methodology used. In section 2.3, we investigate the influence of infilling on derived trends, while section 2.4 reports on trends in annual and seasonal maximum, mean and Q95 observed and reconstructed flows. The sensitivity of trends to the period of record analysed is assessed, while trends from observed records are contextualised using flow reconstructions. Finally, in section 2.5, we investigate the relationship between the NAO and observed trends.

2.2 Trend Assessment Methods

Annual and seasonal trends in indicators representative of high, mean and low flows (maximum, mean and Q95 flows) were assessed following O'Connor *et al.* (2022). Trends were identified using (i) a modified version of the Mann–Kendall test (Yue and Wang, 2004), a non-parametric statistical method that accounts for serial correlation in flow data; and (ii) the Theil–Sen approach to identify the magnitude of change in non-parametric flow data (Theil, 1950; Sen, 1968). Trends for fixed periods in observed (infilled) (1992–2022) and reconstructed (1942–2022) flows were identified and mapped to assess spatial patterns. The significance of trends was evaluated at the 0.05 level using the Mann–Kendall Z statistic. As trends can be sensitive to the period of record tested (Hannaford, 2015), the persistence of trends for different start years was also assessed. Trend persistence is evaluated by applying the Mann–Kendall test to the full period of record (e.g. 1980–2022), then the start year of the test is incremented annually (i.e. 1981–2022, 1982–2022 etc.) up to 2000–2022 and the Mann–Kendall Z-score recorded. The resultant series of Z-scores allows the persistence of trends and their sensitivity to the period of record to be assessed. Correlation of flows with the NAO was undertaken for fixed periods as above using the non-parametric Spearman's rank test, with significance also evaluated at the 0.05 level.

2.3 Sensitivity of Trends to Missing Data and Infilling

The impact of infilling on trends was evaluated by comparing trends from observed (including missing data) and infilled data for all IHRN V2 stations. This analysis was carried out for annual and seasonal maximum, mean and Q95 flows. Results for mean flows can be seen in Figure 2.1. Here,

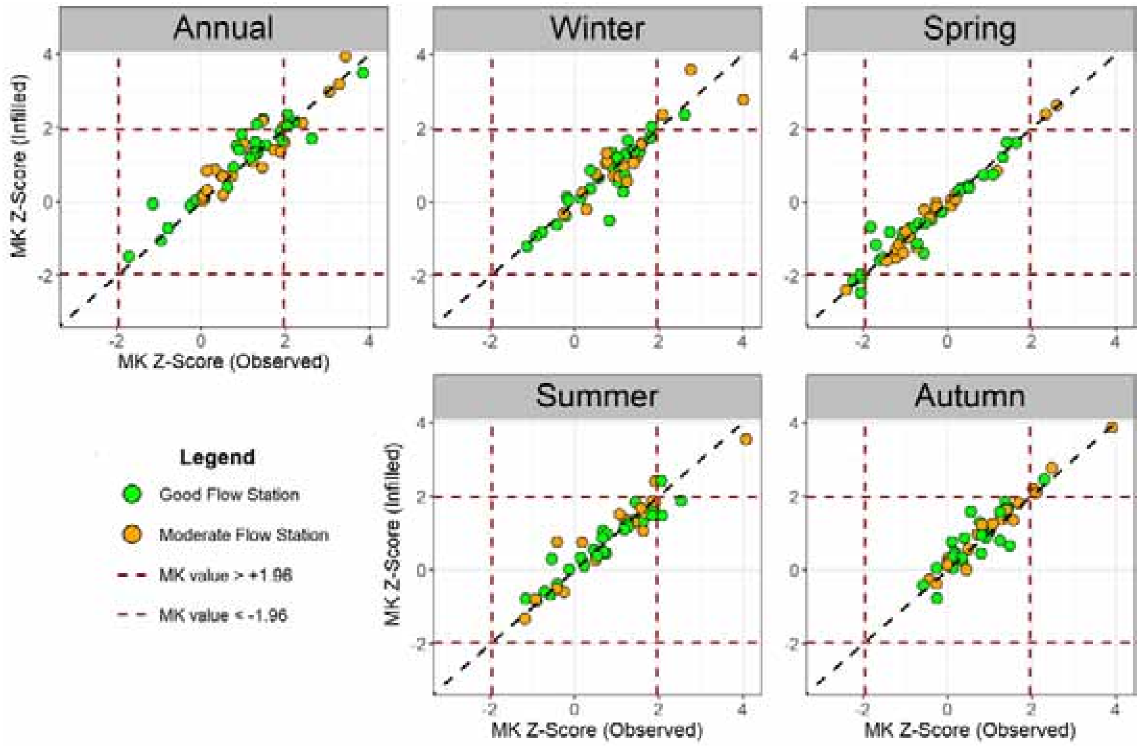

Figure 2.1. Plot of Mann–Kendall (MK) Z-scores for observed (not infilled) and infilled mean annual flow series across IHRN V2 catchments.

Mann–Kendall Z-scores greater than 1.96 and less than –1.96 represent statistically significant increasing and decreasing trends, respectively. Ideally, trends derived from observed and infilled data should be similar in magnitude and direction and should cluster around the 1:1 line. This is the case for most stations and adds confidence in the use of infilled data for trend detection.

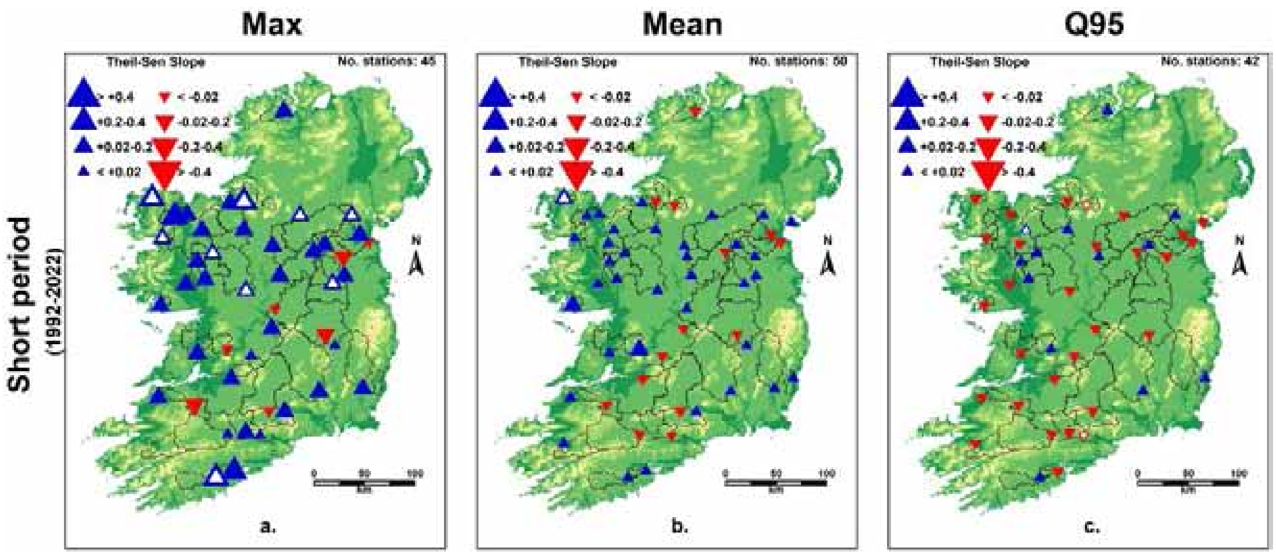

Figure 2.2. Trend magnitude and significance for annual maximum, mean and Q95 infilled flow series for the period 1992–2022. Blue triangles represent increasing trends and red triangles represent decreasing trends, with size representative of the magnitude of change. Statistically significant trends (0.05 level) are represented by white triangles.

2.4 Trend Results

2.4.1 Annual trends from observed (infilled) series

Figure 2.2 maps trends in annual maximum, mean and Q95 flows for the 1992–2022 period. Maximum annual flows show strong increasing trends, particularly in the north-west, with many stations showing statistically significant increasing trends (nine stations). Annual mean flows show a mixed pattern of change, with increasing trends marginally more dominant (36 of 50 stations). Increasing trends are found mainly in the north-west, but only one station shows statistically significant increases. Annual Q95 flows show predominantly weak, non-significant decreasing trends (29 of 42 stations), with only two stations having statistically significant trends (one increasing, one decreasing).

The persistence of trends in observed records for varying start years is presented in Figure 2.3. For annual maximum flows, increasing trends are persistent for various start years. While some stations show decreasing trends, particularly for tests commencing post 1988, there are no statistically significant negative trends in annual maximum flows for any testing period in the available record. Annual mean flows show similar trend patterns to annual maximum flows, with increasing trends dominating across catchments for all tests. Increasing trends are strongest for tests commencing pre-1965, when there

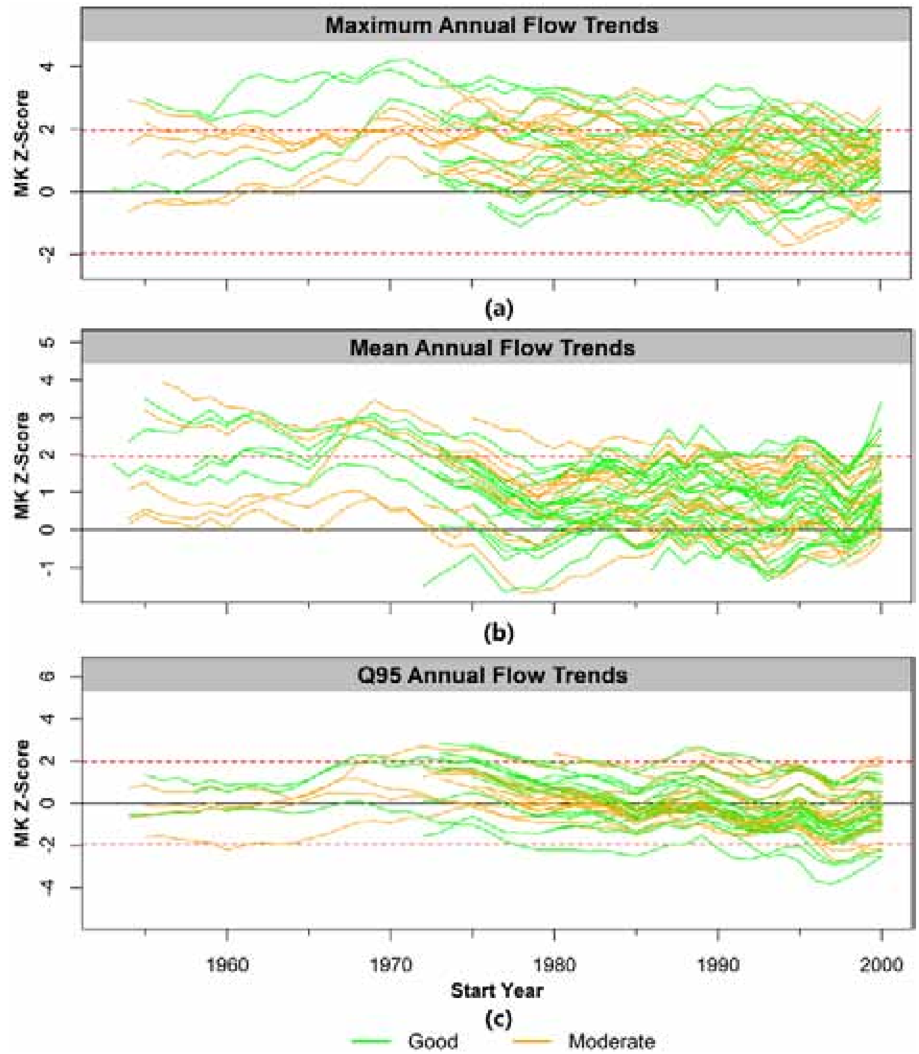

Figure 2.3. Persistence of trends in annual (a) maximum, (b) mean and (c) Q95 flows for 45, 50 and 42 IHRN V2 stations, respectively. Mann–Kendall (MK) Z-scores are derived from infilled observed flows for the given start year to the end of 2022. Stations classified as good are in green and those classified as moderate are in orange.

are no negative trends identifiable across the network. Annual Q95 flows show the least persistent trends, with the magnitude and sometimes the direction of the trend depending on the period of record tested.

2.4.2 Annual trends from reconstructed series

To contextualise observed trends from short records, assessment of the same indices was undertaken using reconstructed flows for the period 1942–2022 (Figure 2.4). Overall trend patterns are more consistent than for the shorter observed period (1992–2022). All stations show increasing trends for annual maximum flows, with 30 stations returning statistically significant increasing trends. Annual mean flows are also dominated by increasing trends, with significant increases at 29 stations. In contrast to the shorter observed records, trends in reconstructed annual Q95 flows are dominated by decreases, with the number and significance of decreasing trends being greater in the longer 1942–2022 period (40 stations), highlighting the importance of long records and the value of reconstructions for contextualising trends from shorter observational records.

The persistence of trends in reconstructed flows is assessed in Figure 2.5. Increasing trends dominate annual maximum flows, particularly for earlier start years (long records), with most stations showing strong and significant increasing trends. The greatest number of statistically significant increasing trends is found for tests commencing in 1942 (36 stations), with a minimum for tests commencing in 1998 (2 stations). Annual mean flows show the strongest increasing trends for tests commencing before 1970, with weaker and sometimes decreasing trends for tests commencing after 1970, indicating the high variability of annual mean flows. The greatest number of statistically significant increasing trends in annual mean flows is for tests commencing in 1951 (31 stations). Trend persistence in annual Q95 flow reconstructions shows a clear tendency for decreasing trends for tests commencing prior to the 1970s. Tests commencing after the 1970s tend to show weak increases and decreases, likely due to extreme drought conditions in the 1970s. For tests commencing in 1942, all but one station show decreasing trends (21 being statistically significant), emphasising the importance of long records in identifying change in low flows.

2.4.3 Seasonal trends from observed series

Seasonal trends in maximum, mean and Q95 observed flows for the period 1992–2022 are shown in Figure 2.6. For maximum flows, winter shows increasing trends (36 of 45 stations; statistically significant at 4 stations). A mixture of decreasing and

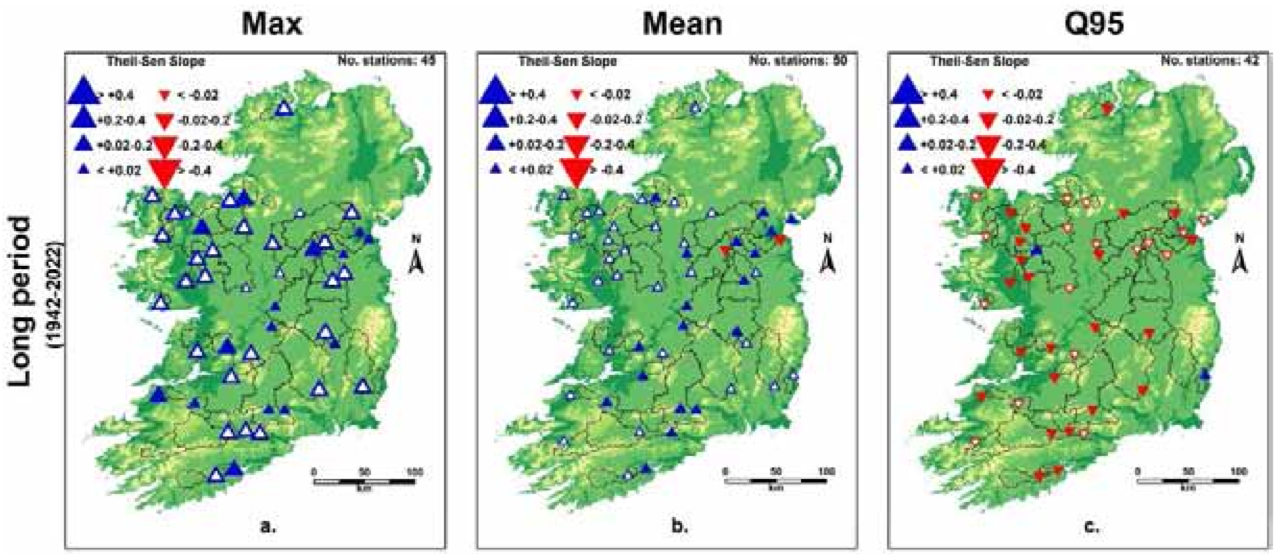

Figure 2.4. Trend magnitude and significance for annual maximum, mean and Q95 flow series for the period 1942–2022, derived from reconstructed flow values. Blue triangles represent increasing trends and red triangles represent decreasing trends, with size representative of the magnitude of change. Statistically significant trends (0.05 level) are represented by white triangles.

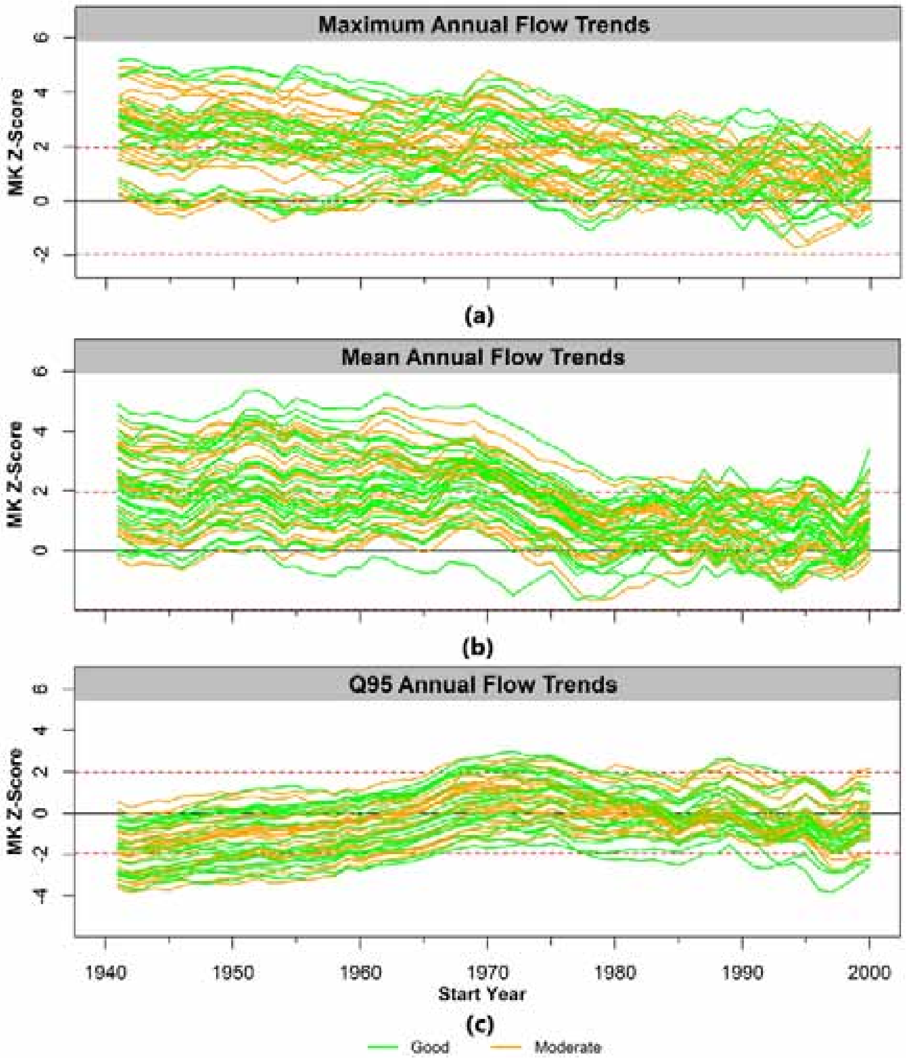

Figure 2.5. Persistence of trends in annual (a) maximum, (b) mean and (c) Q95 flows for 45, 50 and 42 IHRN V2 stations, respectively. Mann–Kendall (MK) Z-scores are derived from reconstructed flows. Stations classified as good are in green and those classified as moderate are in orange.

increasing trends are found in spring, with evidence of a north/south divide. Summer shows marginally more increasing than decreasing trends, with no stations showing statistically significant trends. Autumn displays marginally more increasing trends, with no clear spatial patterns evident and only one statistically significant increasing trend. Mean flow trends show similar patterns. Winter shows increasing trends overall (46 stations); however, none are significant at the 0.05 level. Decreasing trends dominate in spring (41 stations), with the most significant decreases found in the north-west (3 stations). Summer mean flows show a mixture of increasing and decreasing trends, with marginally more of the former (30 vs 20 stations). No statistically significant trends are evident in this season. Autumn mean flows return strong increasing trends (41 stations), with 4 stations showing statistically significant increases. Decreasing trends are limited to southern catchments.

Seasonal Q95 flows in winter show increasing trends at the majority of stations (35 stations). Decreasing trends (more extreme low flows) also dominate in spring (31 stations; 3 statistically significant). Summer Q95 flows are also dominated by decreasing trends, with three catchments showing significant decreases. Autumn Q95 flows show mixed trends, with nine catchments in southern Ireland showing decreases, and increasing trends predominant elsewhere, particularly in the northern half of the country.

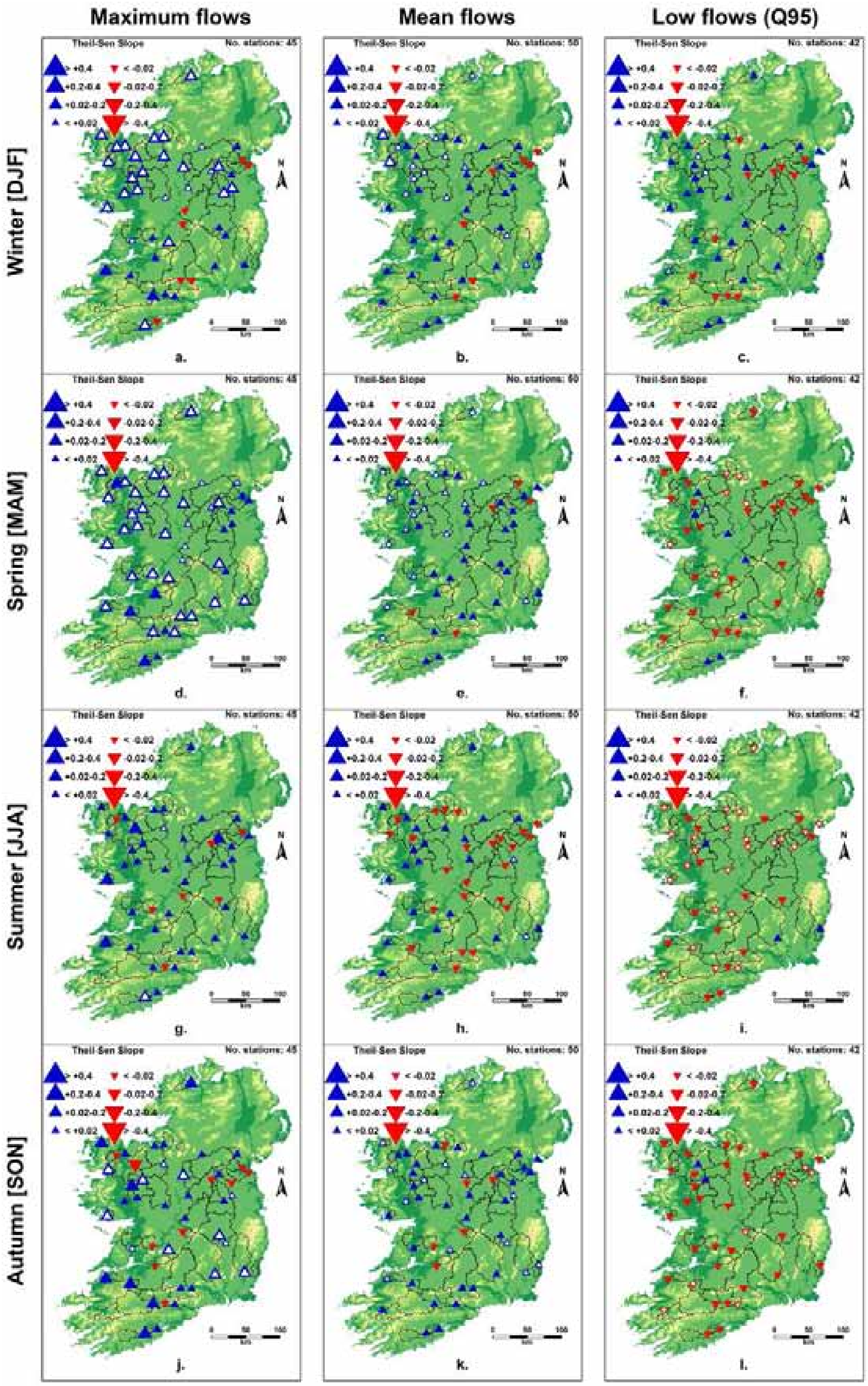

Figure 2.6. Trend magnitude and significance for seasonal maximum, mean and Q95 infilled flow series for the period 1992–2022. Blue triangles represent increasing trends and red triangles represent decreasing trends, with size representative of the magnitude of change. Statistically significant trends (0.05 level) are represented by white triangles. DJF, December, January, February; JJA, June, July, August; MAM, March, April, May; SON, September, October, November.

The persistence of trends in seasonal maximum, mean and Q95 observed flows is shown in Figure 2.7. For maximum flows, winter shows persistent increasing trends for different start years at many stations, but persistent decreasing trends are evident for a small number of catchments. In spring, strong and significant increasing trends are evident across many stations for tests commencing before the 1970s. Persistent but weak and non-significant increasing trends are found for various start years in summer maximum flows. Autumn displays a mixed picture, with an overall tendency towards increases, but the magnitude and direction of trends can be dependent on the start year. Tests commencing after the mid-1990s tend to show a prevalence of decreasing trends in autumn maximum flows. Seasonal mean flows show overall increasing trends in winter, strongest for earlier start dates. For tests commencing after 1970, trends in winter mean flows are notably weaker. Spring mean flows show strong increasing trends for tests commencing before the 1970s, but the magnitude and direction of trends is dependent on the start year, with tests commencing after the 1970s showing weak and often decreasing trends. Summer mean flows show a mix of increasing and decreasing trends, with significance depending on the period tested. Autumn shows a similar pattern to summer but with a tendency towards a larger number of increasing trends. Across all indices and seasons, Q95 flows show the most variable trends and sensitivity to period tested due to variability in low flows, groundwater and surface water interactions and the influence of drought in the 1970s on longer records. Trend direction is highly dependent on the chosen start year for all seasons, especially in summer and autumn (Table 2.1).

2.4.4 Seasonal trends from reconstructed series

Seasonal trends in maximum, mean and Q95 flows for the period 1942–2022 are shown in Figure 2.8. Trends in these longer series are more consistent and statistically significant relative to changes in shorter observed records. In winter, strong increasing trends are evident for maximum flows. Overall, 38 stations have increasing trends, 25 of which are statistically significant, particularly in the northern half of the country. Increasing trends dominate spring maximum flows, with all stations having increasing trends (32 statistically significant). Trends in summer maximum flows are weaker and largely non-significant. Autumn maximum flows show a mixed pattern of

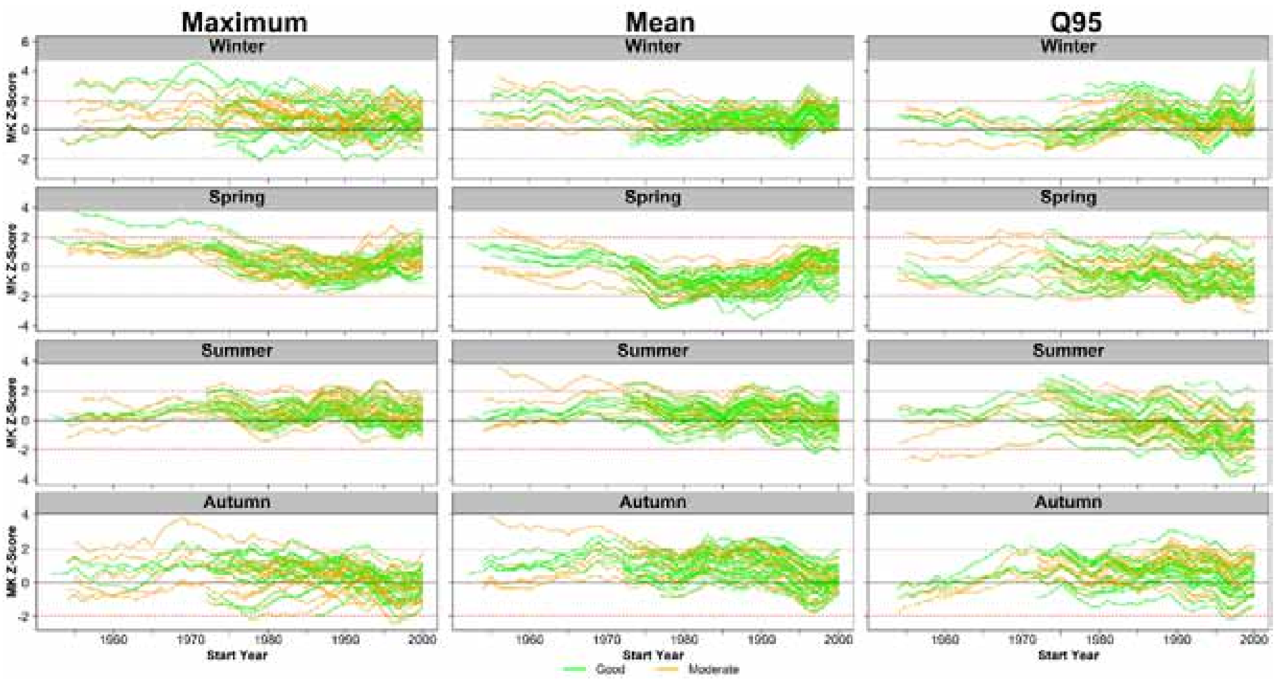

Figure 2.7. Mann–Kendall (MK) Z-scores derived from seasonal maximum, mean and Q95 flows for 45, 50 and 42 IHRN V2 stations, respectively. MK Z-scores are derived from infilled flows for the given start year through to the end of 2022. Stations classified as good are in green and those classified as moderate are in orange.

Table 2.1. Annual and seasonal trends in maximum, mean and Q95 observed (1992–2022) and reconstructed (1942–2022) flows for IHRN V2 stations

Indicator (flow regime)	Time period	% increasing (sig.) 1942–2022	% increasing (sig.) 1992–2022	% decreasing (sig.) 1942–2022	% decreasing (sig.) 1992–2022
Maximum (high flows)	Annual	100 (66.6)	84.4 (20)	0 (0)	15.6 (0)
	Winter	84.4 (55.6)	80 (8.9)	15.6 (0)	20.0 (0)
	Spring	100 (73.3)	44.4 (0)	0 (0)	55.6 (0)
	Summer	84.4 (4.4)	66.7 (0)	15.6 (0)	33.3 (0)
	Autumn	77.8 (26.7)	73.3 (2.2)	22.2 (0)	26.7 (0)
Mean (mean flows)	Annual	98 (60)	70 (2)	4 (0)	30 (0)
	Winter	86 (28)	90 (0)	14 (0)	10 (0)
	Spring	90 (36)	14 (0)	10 (0)	86 (8)
	Summer	52 (4)	58 (0)	48 (0)	42 (0)
	Autumn	88 (28.8)	82 (8)	12 (0)	18 (0)
Q95 (low flows)	Annual	4.8 (0)	31 (2.4)	95.2 (39.5)	69 (4.8)
	Winter	73.8 (7.1)	71.4 (2.4)	26.2 (0)	28.6 (0)
	Spring	19 (2.4)	16.7 (0)	81 (14.3)	83.3 (14.3)
	Summer	7.1 (0)	23.8 (2.4)	92.9 (57)	76.2 (7.1)
	Autumn	4.8 (0)	78.6 (2.1)	95.2 (21.4)	21.4 (0)

Note: For each time period, the percentage of increasing and decreasing trends (based on Mann–Kendall trend scores) are given along with the percentage of these trends that are significant (sig.) in brackets.

increasing and decreasing trends, with 12 catchments showing significant increases and none displaying significant decreasing trends.

Winter mean flows are dominated by increasing trends (43 stations), with the most statistically significant trends occurring in the north-west of the island. Increasing trends also dominate spring mean flows (45 stations), with significant trends in the north-west. Summer mean flows show the greatest number of decreasing trends of any season (24 stations), but decreases are not statistically significant. Autumn mean flows show a strong tendency towards increasing trends (44 stations), with 13 stations showing statistically significant increases. Seasonal Q95 flows show the most decreasing trends of any indicator, especially in spring, summer and autumn. Thirty-four catchments show decreasing trends in spring Q95 flows (6 statistically significant). For summer Q95, all but three catchments have decreasing trends (24 statistically significant). Autumn Q95 has the most decreasing trends of all seasons (40 stations), but they tend to be weaker, with fewer significant trends than summer.

Seasonal trend persistence was also assessed, with the results shown in Figure 2.9. Maximum flows are dominated by increasing trends for earlier start years in all seasons, particularly winter. For mean flows, winter shows the most increasing trends with the greatest number of statistically significant increasing trends for tests commencing in 1950 (48 stations). Spring shows the greatest sensitivity of trends to start year, with tests commencing prior to 1970 dominated by increasing trends and those commencing post 1970 often returning decreasing trends. Summer mean flows display a tendency towards decreasing trends for longer records, but no catchment returns significant decreasing trends. Autumn mean flows show strong increasing trends for earlier start years; however, a small number of stations do have negative trends, albeit non-significant.

For Q95 flows, both summer and autumn show a high proportion of strong and significant decreasing trends for earlier start years across almost all catchments. This is in contrast to the increasing trends found in shorter records, again highlighting the importance of record length for trend detection, especially for summer and autumn low flows. To further illustrate

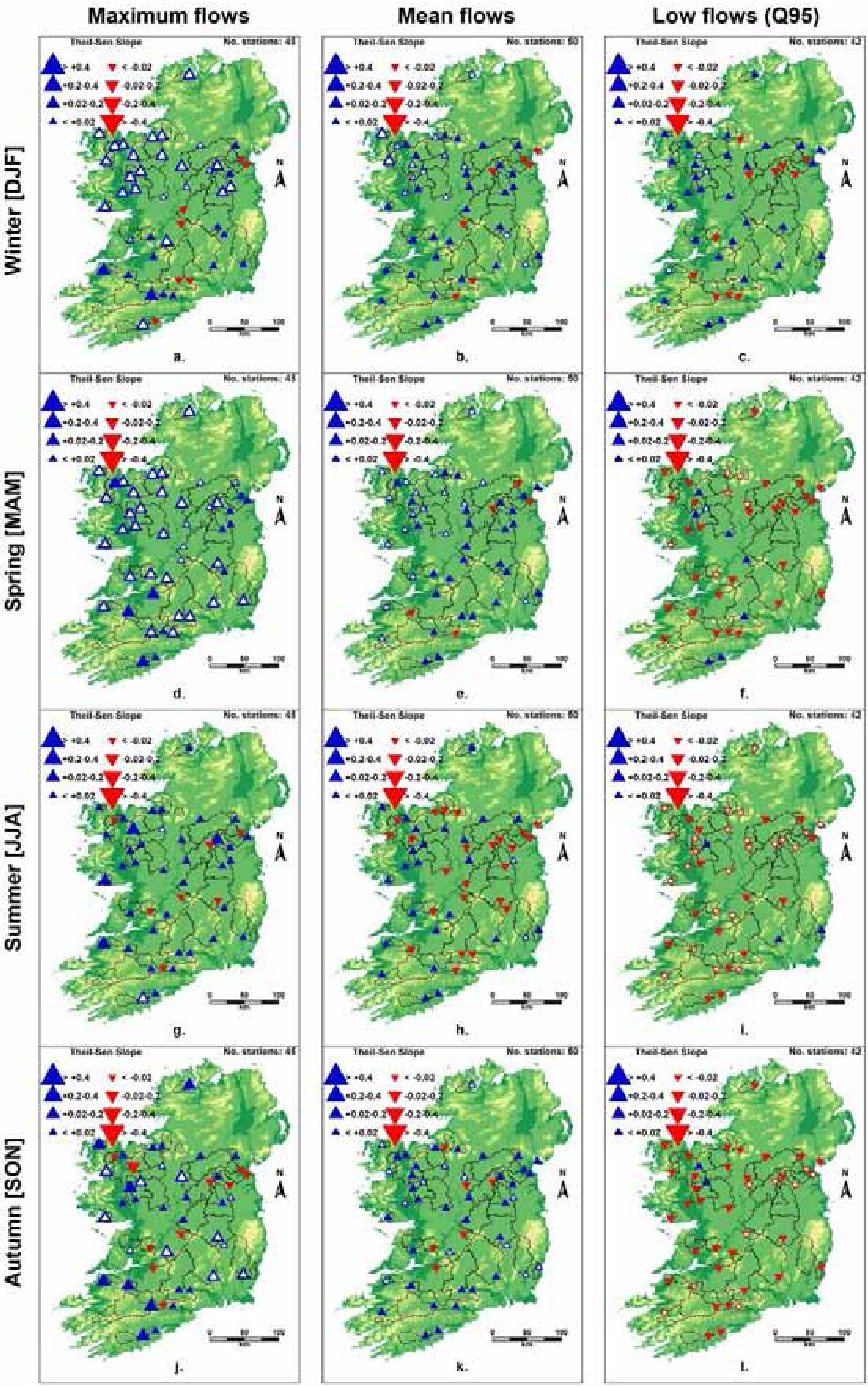

Figure 2.8. Trend magnitude and significance for seasonal maximum, mean and Q95 reconstructed flows for the period 1942–2022. Blue triangles represent increasing trends and red triangles represent decreasing trends, with size representative of the magnitude of change. Statistically significant trends (0.05 level) are represented by white triangles. DJF, December, January, February; JJA, June, July, August; MAM, March, April, May; SON, September, October, November.

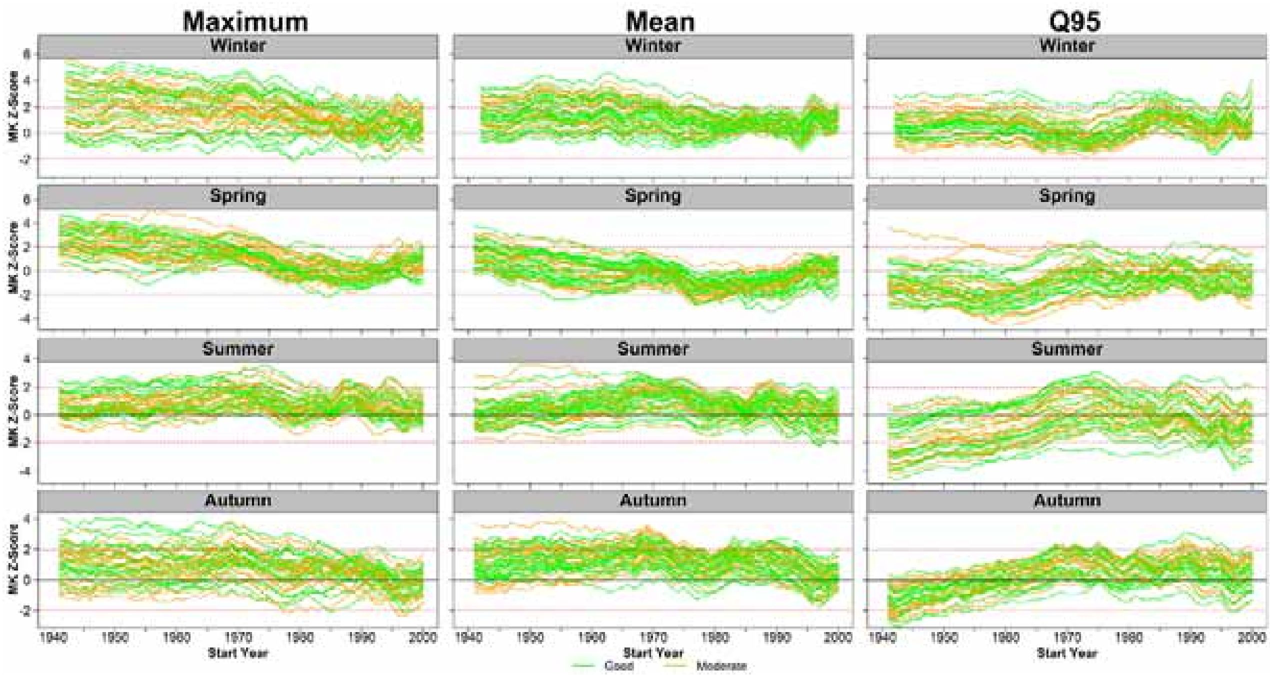

Figure 2.9. Mann–Kendall (MK) Z-scores derived from seasonal maximum, mean and Q95 flows for 45, 50 and 42 IHRN V2 stations, respectively. MK Z-scores are derived from reconstructed flows for the 1942–2022 period. Stations classified as good are in green and those classified as moderate are in orange.

this point, the sensitivity of trends in summer Q95 to the period tested was examined by varying the start and end years of analysis throughout the period of available reconstructions (1942–2022). Trend tests were conducted for all combinations of start and end years, with a minimum record length of 5 years to a maximum of 80 years (full period). Sample results for Clarebane station (ID: 6012) can be seen in Figure 2.10. The heat maps shows that trend direction and significance are dependent on the start and end years of the analysis. For example, increasing trends (many statistically significant) are identifiable for tests commencing in the early 1970s and ending in the mid-2010s, while tests commencing in the early 1940s and ending in the mid-1990s produce many statistically significant negative trends. Such patterns are a prominent feature of summer and autumn Q95 flows across the majority of stations, and highlight the importance of assessing trends over longer periods to attain a full understanding of change. By chance, most longer-term flow observations for Irish catchments commenced in the 1970s, a period dominated by increasing trends. Furthermore, the period of common record for all stations in the IHRN V2 is 1990 to present, which also coincides with a period marked by increasing trends in low flows and is unrepresentative of the decreasing trends evident in longer records.

2.5 Correlation with the North Atlantic Oscillation

Correlations between river flow indicators and the NAO index were evaluated on an annual and seasonal basis to understand the co-variation of trends with natural climate variability. The NAO is an important mode of climate variability in the region, and understanding correlation can be important for understanding drivers of change and possibilities for seasonal and decadal forecasting. Correlations were derived using Spearman's non-parametric correlation coefficient, using observed flow data for the period 1992–2022 and flow reconstructions for the period 1942–2022. We employed the National Center for Atmospheric Research (NCAR) version of the NAO index, which is derived from principal component analysis of empirical orthogonal functions of pressure differences over the North Atlantic (Hurrell *et al.*, 2003).

2.5.1 Annual correlation with the NAO

Figure 2.11 shows correlation scores between annual NAO index values and annual maximum, mean and Q95 flows. Across the three indicators, positive correlations, particularly for mean flows, were found in

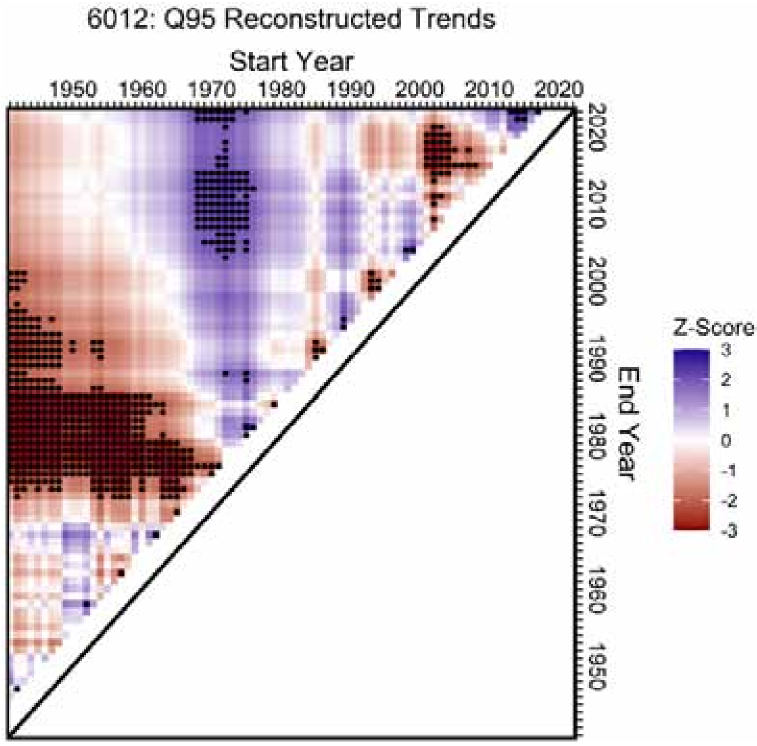

Figure 2.10. Mann–Kendall (MK) Z-scores derived from annual Q95 reconstructed flows for Clarebane station (ID: 6012). MK Z-scores are derived for differing start and end years across the 1942–2022 period, with a minimum length of 5 years. Positive trends are shown in purple and negative trends are shown in red. Statistically significant trends for a given period are identified by black dots.

the north-west, where most stations show statistically significant (0.05 level) positive correlations. For maximum flows, there is a tendency towards stronger positive correlations in the midlands and north of the island, with negative correlations predominant in the south and south-east. For annual Q95 flows, positive correlations are strongest in western catchments but not significant. Assessment of the longer 1942–2022 period revealed a greater number of statistically significant correlations. Annual maximum flows displayed positive correlations (10 statistically significant) in western and north-western catchments and negative correlations in some eastern and southern stations, matching similar patterns found in the shorter 1992–2022 period. Annual mean flows also show positive correlations with the NAO index in the west and north-west of the island and negative (non-significant) correlations in the east and south. A large portion of stations in the west reveal statistically significant positive correlations (22 stations). Q95 flows reveal the largest differences in correlation with the NAO index between the two periods, with the longer period returning predominantly negative correlations across the country, with local exceptions. A total of 10 stations show statistically significant (0.05 level) negative correlations between annual Q95 flows and the NAO index.

2.5.2 Seasonal correlations with the NAO

Seasonal correlations between the NAO index and seasonal maximum, mean and Q95 flows for the reconstructed period 1942–2022 are shown in Figure 2.12. Strong and significant correlations are evident for each flow indicator and the winter NAO index, especially in the western half of the island. Negative correlations of winter flow indices with the winter NAO index are seen in the east and south. Spring correlations display a similar pattern to winter for annual maximum and mean flows, but correlations are not as strong. For spring Q95 flows, only western catchments show a positive correlation with the spring NAO index, with the remainder of the country showing negative correlations. For summer, all three flow indices (maximum, mean and Q95) show strong and significant (0.05 level) negative correlations with the summer NAO index. Similarly to winter and spring, autumn displays strong positive correlations between

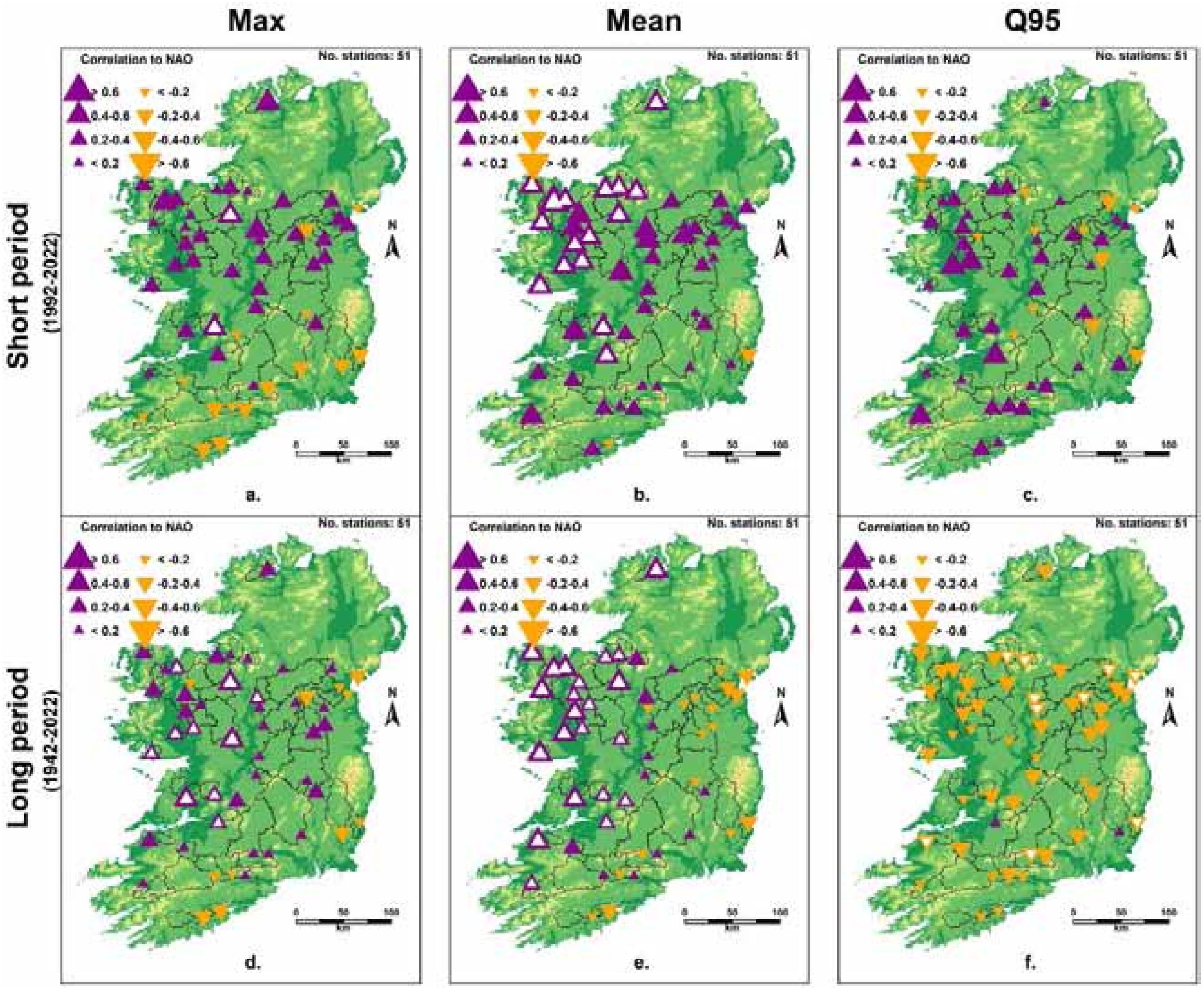

Figure 2.11. Correlation between annual maximum, mean and Q95 flows and the NAO index for the 1992–2022 period (top row) and the 1942–2022 period (bottom row). Purple triangles represent positive correlations and orange triangles represent negative correlations, with size representative of the strength of correlation. White triangles represent statistically significant correlations (0.05 level).

the NAO index and all three flow indicators in western catchments. Notably, catchments in the north-east tend to show a negative correlation between autumn maximum flows and the autumn NAO index. The greatest number of significant correlations is returned for autumn mean flows, especially in western margins. For Q95 flows, the strength of positive correlations tends to decrease moving east.

2.6 Conclusion

This chapter presented the results of our assessment of trends in annual and seasonal maximum, mean and Q95 river flows for IHRN V2 stations for the observed and reconstructed periods. Analysis of observed flows found that overall increasing trends are evident in winter maximum and mean flows, particularly in north-western catchments, and that changes in low flows are inconsistent. Longer flow reconstruction series provide a clearer picture of change, with many more statistically significant increasing trends evident in maximum and mean flows (in winter but also in spring and autumn). Q95 flows show strong decreasing trends in observed records, particularly in spring and summer months. Longer flow reconstructions show more significant decreasing trends in spring, summer and autumn. Our analysis shows that trends are temporally dependent, with chosen start and end years greatly influencing trend magnitude, direction and significance. These findings demonstrate the importance of long records. For a complete breakdown of trends from the observed period (1992–2022) and

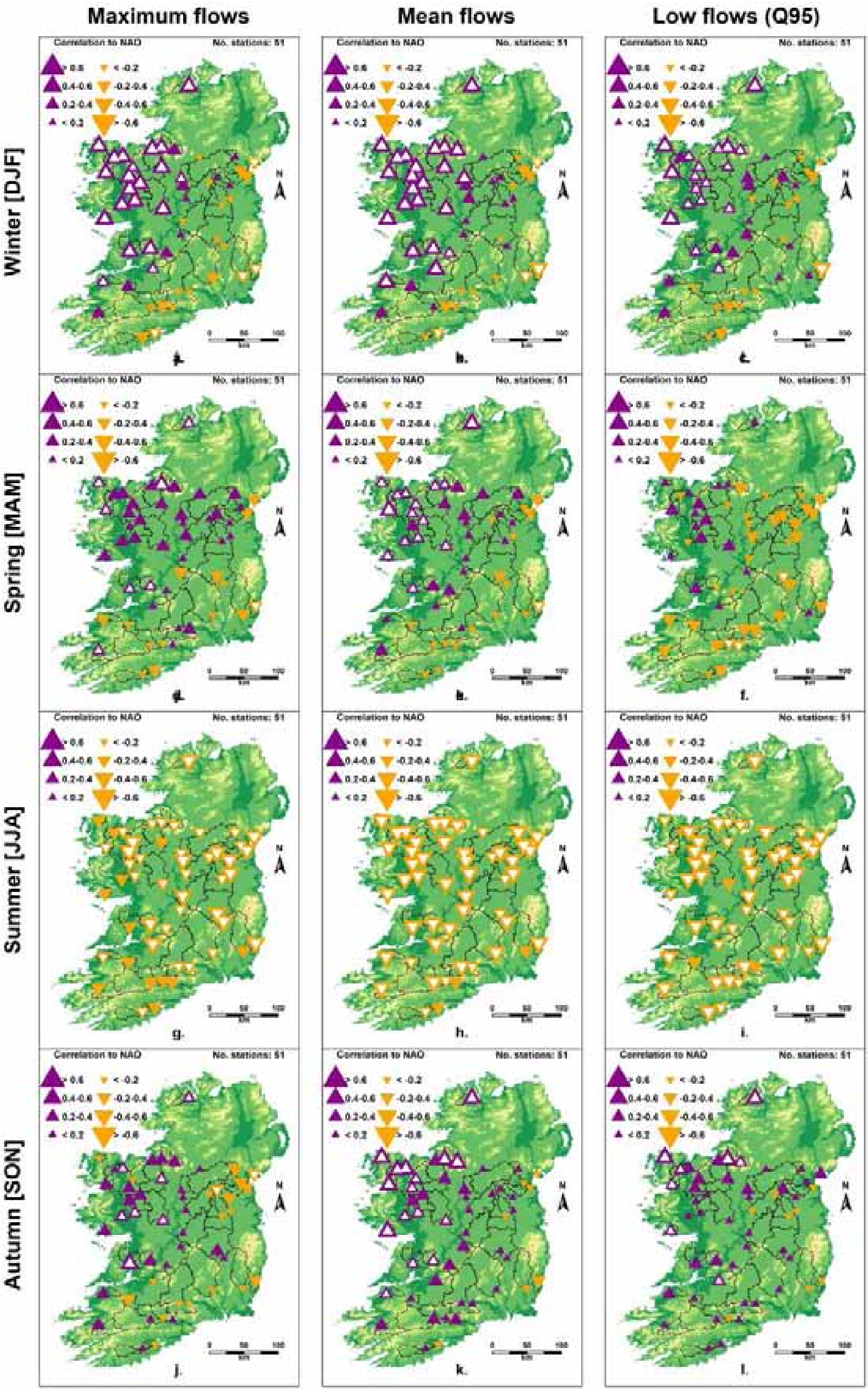

Figure 2.12. Correlation between annual maximum, mean and Q95 flows and the NAO index for seasonal values derived from the 1942–2022 period. Purple triangles represent positive correlations and orange triangles represent negative correlations, with size representative of the strength of correlation. White triangles represent statistically significant correlations (0.05 level). DJF, December, January, February; JJA, June, July, August; MAM, March, April, May; SON, September, October, November.

the reconstructed period (1942–2022), see Table 2.1. We found the NAO to be an important driver of trends across the island, particularly for winter flows. We identify a clear spatial divide in correlation patterns, with positive correlations in the north-west and negative correlations in the south-east, particularly for winter maximum and mean flows. Summer flows show a strongly negative correlation with the NAO, consistent with Folland *et al.* (2009).

3 Sentinel Indicators and Stations

3.1 Introduction

This chapter identifies sentinel stations and indicators that have been identified within IHRN V2 as those most likely to show the earliest emergence of an anthropogenic climate change signal, making them especially valuable for continued monitoring to track evolving climate impacts on river flows. The chapter explores relationships between trends and PCDs to examine what types of catchments tend to show the strongest trends across flow indicators. Wilby (2006) showed that detecting statistically significant changes due to climate can take decades to centuries in the case of some rivers. For sentinel stations, however, the signal could be detected much sooner. Candidate sentinel stations tend to have the highest signal (climate change) to noise (natural variability) ratio. Given the predominance of natural variability in the observed records, sentinel stations are assumed to have low variance in observed flows. Murphy *et al.* (2013b) were able to show that the percentage change in river flows over a given baseline (1976–1990 in this instance) needed to produce statistically significant trends by the year 2025 was directly proportional to the coefficient of variance (CV) of river flows (Figure 3.1).

Using this relationship, we identify sentinel stations and indices from the IHRN V2. In section 3.2, we identify which indicators perform best at identifying change and which stations can be classified as sentinel. In section 3.3, we investigate the relationship between PCDs and trends in maximum, mean and Q95 indicators, and identify which PCDs are most important in determining the magnitude and direction of changes in flows.

3.2 Identifying Sentinel Indicators and Stations

The CV is a relative measure of dispersion calculated as the ratio of the standard deviation to the mean. Here, we derived CV values from observed data for each indicator for the period 1992–2022. Figure 3.2 presents bar plots of CV for observed indices, with mean values across all IHRN V2 stations shown. Certain indicators are seen to have very high CV values, such as maximum summer flows. However, others, such as annual mean, annual maximum, mean spring and mean winter flows, all return relatively low CV values, allowing them to be classified as sentinel indicators.

Figure 3.3 shows the distribution of CV values across catchments for the four indicators that returned the lowest CVs from Figure 3.2 (i.e. annual mean, annual maximum, winter maximum and spring mean flows).

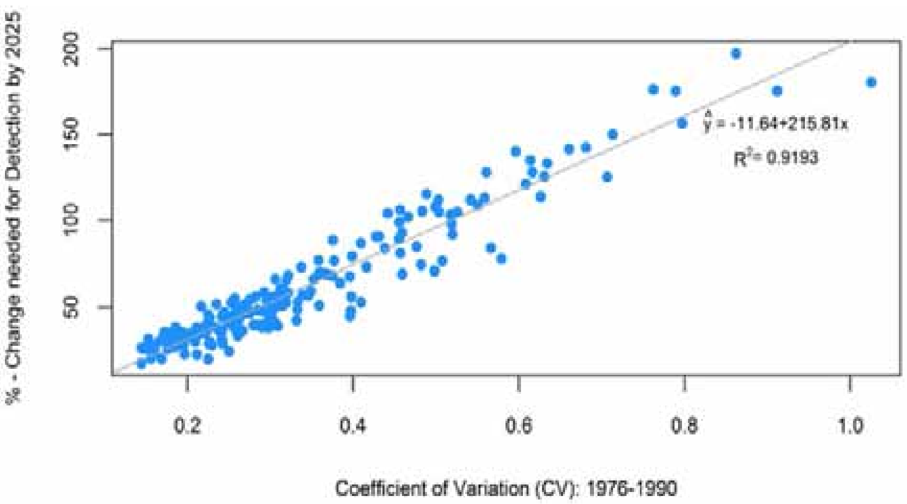

Figure 3.1. Plot of CV values (for the baseline period 1976–1990) vs percentage change in flows required to detect a statistically significant change by the year 2025. Source: Murphy *et al.* (2013b).

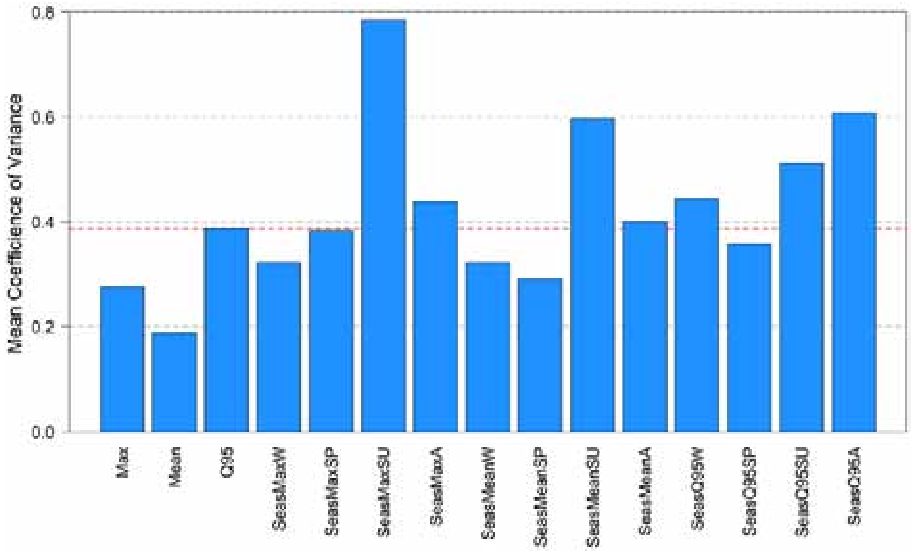

Figure 3.2. Mean CV (average across all IHRN V2 stations) derived from annual and seasonal maximum, mean and Q95 flow indices for the period 1992–2022. The dashed red line represents the average CV across indicators assessed. A, autumn; Seas, seasonal; SP, spring; SU, summer; W, winter.

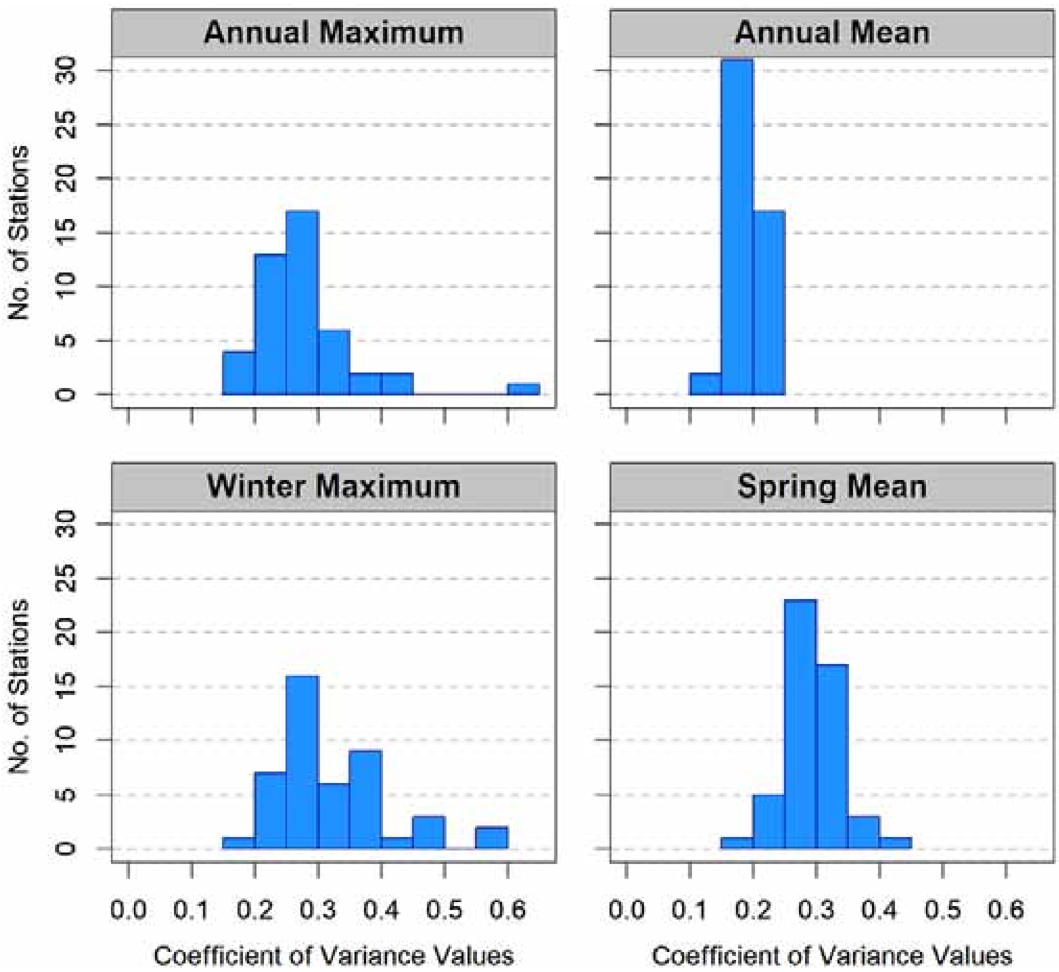

Figure 3.3. Histogram of stations showing spread of CV values across IHRN stations for annual maximum, annual mean, winter maximum and spring mean flows. Stations with the lowest values can be classified as sentinel for these particular indicators.

Across the four indicators, there are considerable differences in station performances, with 5 stations returning a CV value between 0.1 and 0.2 for annual maximum flows, 33 stations for annual mean flows, 1 for spring mean flows and 1 for winter maximum flows. The high number of stations with low CV values in annual mean flows suggests that this indicator is best for identifying sentinel stations. Annual maximum flows also perform well. The limited number of stations with low (below 0.2) CV values for seasonal indicators suggests that, overall, these indicators are not as suitable for early detection of change due to the high degree of variability across catchments. Table 3.1 lists CV scores for all stations and indicators that generate CV values of less than 0.2 on at least one occasion. This includes annual maximum, mean and Q95 flows (4, 33 and 1 station(s), respectively) and spring mean, winter maximum, spring Q95 and summer Q95 (one

Table 3.1. CV scores for 33 stations that generate at least one CV value of < 0.2 across high-, mean- and low-flow indicators

Station no.	Station name	Annual max	Annual mean	Annual Q95	Seas meanSP	Seas maxW	Seas Q95SP	Seas Q95SU
6012	Clarebane	0.285	0.167	0.369	0.287	0.295	0.444	0.503
6013	Charleville	0.248	0.198	0.425	0.327	0.317	0.347	0.502
6030	Ballygoly	NA	0.170	0.330	0.414	NA	0.407	0.560
7002	Killyon	0.257	0.196	NA	0.268	0.333	NA	NA
14019	Levitstown	0.236	0.198	NA	0.267	0.259	NA	NA
16009	Caher Park	0.222	0.170	0.305	0.263	0.273	0.265	0.425
16011	Clonmel	0.268	0.171	NA	0.279	0.333	NA	NA
18002	Ballyduff	0.154	0.152	0.353	0.264	0.244	0.329	0.431
18003	Killavullen	0.204	0.159	0.416	0.251	0.263	0.301	0.467
20002	Curranure	0.320	0.178	0.389	0.300	0.344	0.393	0.565
22035	Laune Br.	NA	0.144	0.284	0.205	NA	0.314	0.384
23001	Inch Br.	0.305	0.198	0.476	0.310	0.365	0.366	0.674
25006	Ferbane	0.174	0.183	NA	0.255	0.252	NA	NA
25022	Syngefield	0.283	0.179	0.288	0.264	0.369	0.279	0.460
26008	Johnston S Br.	0.198	0.182	0.675	0.291	0.189	0.603	0.849
26019	Mullagh	NA	0.173	0.428	0.310	NA	0.418	0.591
26021	Ballymahon	0.230	0.178	NA	0.261	0.236	NA	NA
26029	Dowra	NA	0.137	0.304	0.280	NA	0.277	0.397
26108	Boyle Abbey Br.	0.272	0.178	0.452	0.245	0.253	0.409	0.523
30007	Ballygaddy	0.260	0.191	0.358	0.251	0.292	0.271	0.338
30020	Ballyhaunis	0.401	0.161	0.192	0.189	0.454	0.196	0.196
30021	Christina S Br.	0.253	0.186	0.374	0.279	0.293	0.295	0.413
31002	Cashla	0.228	0.171	0.429	0.305	0.240	0.427	0.623
32012	Newport Weir	0.182	0.158	0.323	0.263	0.225	0.358	0.484
33001	Glenamoy	0.267	0.157	0.291	0.246	0.357	0.352	0.362
34001	Rahans	0.219	0.174	0.327	0.249	0.241	0.333	0.377
34007	Ballycarroon	0.347	0.153	NA	0.262	0.443	NA	NA
34010	Cloonacannana	0.376	0.176	0.361	0.307	0.462	0.308	0.408
34024	Kiltimagh	NA	0.182	0.291	0.275	NA	0.280	0.347
35005	Ballysadare	0.362	0.172	NA	0.255	0.390	NA	NA
35011	Dromahair	0.295	0.161	0.251	0.307	0.363	0.326	0.345
36019	Belturbet	0.248	0.173	0.557	0.251	0.246	0.489	0.655
39006	Claragh	0.288	0.178	0.466	0.316	0.376	0.435	0.531

Note: Indicators generating no CV values < 0.2 were not included. Cells containing CV values < 0.2 are highlighted in blue and classified as sentinel for the given indicator. NA, not available; Seas, seasonal; SP, spring; SU, summer; W, winter.

station each). Of note is Ballyhaunis (ID: 30020), which reaches sentinel status across annual and seasonal mean and low flow indictors. Johnstons Br. (ID: 26008) reaches sentinel status across annual and seasonal maximum flow indicators. The large geographical spread of stations reaching sentinel status for annual mean flows highlights the importance of this commonly measured indicator in detecting climate signals.

3.3 Relationship of Trends to Physical Catchment Descriptors

Hotspot catchments were assessed using correlation analysis between PCDs (Mills *et al.*, 2014) and trend patterns to identify which catchment characteristics most strongly relate to specific patterns of change and identify catchment types that are most susceptible to climate-driven changes. The correlation analysis was carried out using Mann–Kendall Z-scores for annual and seasonal high-, mean and low-flow indicators derived for the observed (1992–2022) and reconstructed (1942–2022) periods. PCDs were available for 48 of the 51 IHRN V2 stations and included catchment area (AREA km^2), standard-period average annual rainfall (SAAR mm), flood attenuation by reservoirs and lakes (FARL index), urban extent (URBEXT Prop), forest cover (FOREST Prop), peat cover (PEAT Prop), extent of floodplain alluvial deposits (ALLUV Prop), proportion of time that soils are expected to be typically quite wet (FLATWET) index, standard-period average annual potential evapotranspiration (SAAPE mm), flood attenuation index (FAI Prop), base flow index linked to catchment soil properties (BFI soil index), length of the stream network (NETLEN km), number of stream segments in the catchment (STMFRQ), main-stream's length (MSL km), Taylor–Schwarz channel slope (TAYSLO m/km), slope of the main-stream channel excluding the bottom 10% and top 15% of length (S1085 m/km), network length divided by the area of polygon catchment (DRAIND km/km^2), catchment area benefiting from arterial drainage (ARTDRAIN Prop) and proportion of the river network included in OPW arterial drainage schemes (ARTDRAIN2 Prop).

Figure 3.4 displays the correlation scores for four PCDs that showed the strongest correlations with flow trends. FLATWET (an indicator of catchment wetness) and PEAT Prop were found to have almost universal positive correlations with flow trends. These indices suggest that wetter catchments tend to show stronger increasing trends, especially for high and mean flow indices. The opposite is found to be the case for PCDs describing ALLUV Prop and SAAPE mm values, which tended to have negative correlations with flow trends. This suggests that low-lying catchments with wide floodplains in drier parts of the country are associated with weaker or negative trends. For seasonal indices, there is greater variability in correlations depending on the period analysed. For example, for spring maximum flows for the period 1992–2022, a significant negative correlation is found for FLATWET, while a significant positive correlation is found for the 1942–2022 period. Similarly, for the longer period, significant negative correlations are found between trends in summer low flows (Q95) and FLATWET and PEAT Prop, with no notable correlation evident for the shorter period.

Figure 3.5 plots the Mann–Kendall trend scores across all stations for the six highest correlating annual and seasonal flow indicators (as identified in Figure 3.4) against ALLUV Prop and FLATWET values for the 1942–2022 period. It is clearly evident that as ALLUV Prop values increase, the magnitude of trends in annual, winter and spring maximum and mean flows decreases. The opposite is the case for the FLATWET index, indicating that as catchment wetness increases, the magnitude of trends also increases, especially for annual and winter maximum flows. Correlations are less clear for low flows on an annual and seasonal basis. The presence of lakes and reservoirs within a catchment was found to have a moderating effect on trends. In particular, the FARL index was found to be negatively correlated with trends in winter and spring maximum flows, indicating the role of reservoirs and lakes in moderating increasing trends. Similarly to Q95 low flows in spring and summer, the FARL index tended towards moderate trends.

3.4 Conclusion

This chapter explored the identification of sentinel indicators and stations in addition to the identification of PCDs that moderate trends in flows. Employing the CV derived from the 1992–2022 period, we have shown that mean annual river flows are most likely to display the earliest emergence of climate change signals due to the relatively low noise in this indicator. We identified Ballyhaunis (ID: 30020) as an important station in terms of identifying change

MK Trends	ALLUV Prop.	FLATWET index	PEAT Prop	SAAPE mm
Max	**-0.47**	**0.53**	0.26	**-0.42**
Mean	**-0.56**	**0.51**	**0.47**	**-0.42**
Q95	-0.21	0.08	0.08	-0.21
SeasMaxW	-0.11	0.14	0.13	-0.08
SeasMaxSP	0.20	**-0.32**	**-0.23**	0.23
SeasMaxSU	**-0.38**	**0.56**	**0.56**	**-0.55**
SeasMaxA	-0.28	0.26	0.20	-0.09
SeasMeanW	**-0.45**	0.29	**0.54**	-0.21
SeasMeanSP	-0.06	0.01	0.18	0.06
SeasMeanSU	**-0.48**	**0.49**	**0.49**	**-0.53**
SeasMeanA	**-0.55**	**0.50**	**0.44**	**-0.51**
SeasQ95W	-0.17	0.05	**0.34**	0.03
SeasQ95SP	-0.29	0.27	0.21	-0.27
SeasQ95SU	-0.02	0.00	-0.05	-0.11
SeasQ95A	**-0.50**	**0.42**	**0.46**	**-0.54**

(a)

MK Trends	ALLUV Prop.	FLATWET index	PEAT Prop.	SAAPE mm
Max	**-0.47**	**0.37**	**0.35**	**-0.32**
Mean	**-0.41**	**0.47**	**0.55**	**-0.33**
Q95	0.15	-0.22	-0.22	0.16
SeasMaxW	**-0.67**	**0.71**	**0.60**	**-0.57**
SeasMaxSP	**-0.44**	**0.38**	**0.44**	**-0.39**
SeasMaxSU	-0.12	0.25	0.29	-0.09
SeasMaxA	-0.14	-0.08	0.01	0.13
SeasMeanW	**-0.57**	**0.62**	**0.66**	**-0.50**
SeasMeanSP	**-0.37**	**0.48**	**0.68**	**-0.39**
SeasMeanSU	-0.15	0.12	0.25	-0.01
SeasMeanA	-0.26	0.17	0.24	-0.12
SeasQ95W	-0.04	0.24	**0.38**	-0.20
SeasQ95SP	0.26	-0.18	-0.11	0.10
SeasQ95SU	0.22	**-0.35**	**-0.31**	0.24
SeasQ95A	-0.22	**0.30**	**0.32**	-0.22

(b)

Figure 3.4. Correlation scores between PCDs and trends (Mann–Kendall (MK) Z-scores) in different flow indices for (a) 1992–2022 and (b) 1942–2022. Here, ALLUV Prop represents the proportional extent of floodplain alluvial deposits, FLATWET index represents the proportion of time that soils are expected to be typically quite wet, PEAT Prop represents the proportion of peat in the catchment area and SAAPE mm represents the standard-period average annual potential evapotranspiration. Positive correlations are shown in blue and negative correlations are shown in red. A, autumn; Seas, seasonal; SP, spring; SU, summer; W, winter.

in annual and seasonal mean and low flows, while Johnstons Br. (ID: 26008) is well suited to detecting changes in annual and seasonal maximum flows. Of the 19 catchment descriptors we investigated, we found that FLATWET index and PEAT Prop returned almost universally positive correlations with trends in annual and seasonal maximum and mean flows, indicating that trends in mean and high flows tend to be greater in already wet catchments. Conversely, ALLUV Prop and SAAPE mm values returned almost universally negative correlations with these indicators, indicating that already dry catchments and those with large, low-lying, well-drained flood plains are less likely to reveal early trends in mean and high flows. This is physically consistent, given that wetter catchments tend to have a more linear and rapid rainfall runoff response, while the signal between rainfall input and river flows becomes more muted and less linear when storage is available. No clear pattern emerged for low flows. Future work could expand the range of PCDs assessed, with an emphasis on understanding how catchment characteristics modify sensitivity to trends in low flows. Finally, the presence of lakes and reservoirs within a catchment was found to have a moderating effect on trends. In particular, the FARL index was found to be negatively correlated with trends in winter and spring maximum flows, indicating the role of reservoirs and lakes in moderating increasing trends. Similarly to Q95 low flows in spring and summer, the FARL index tended towards moderate trends.

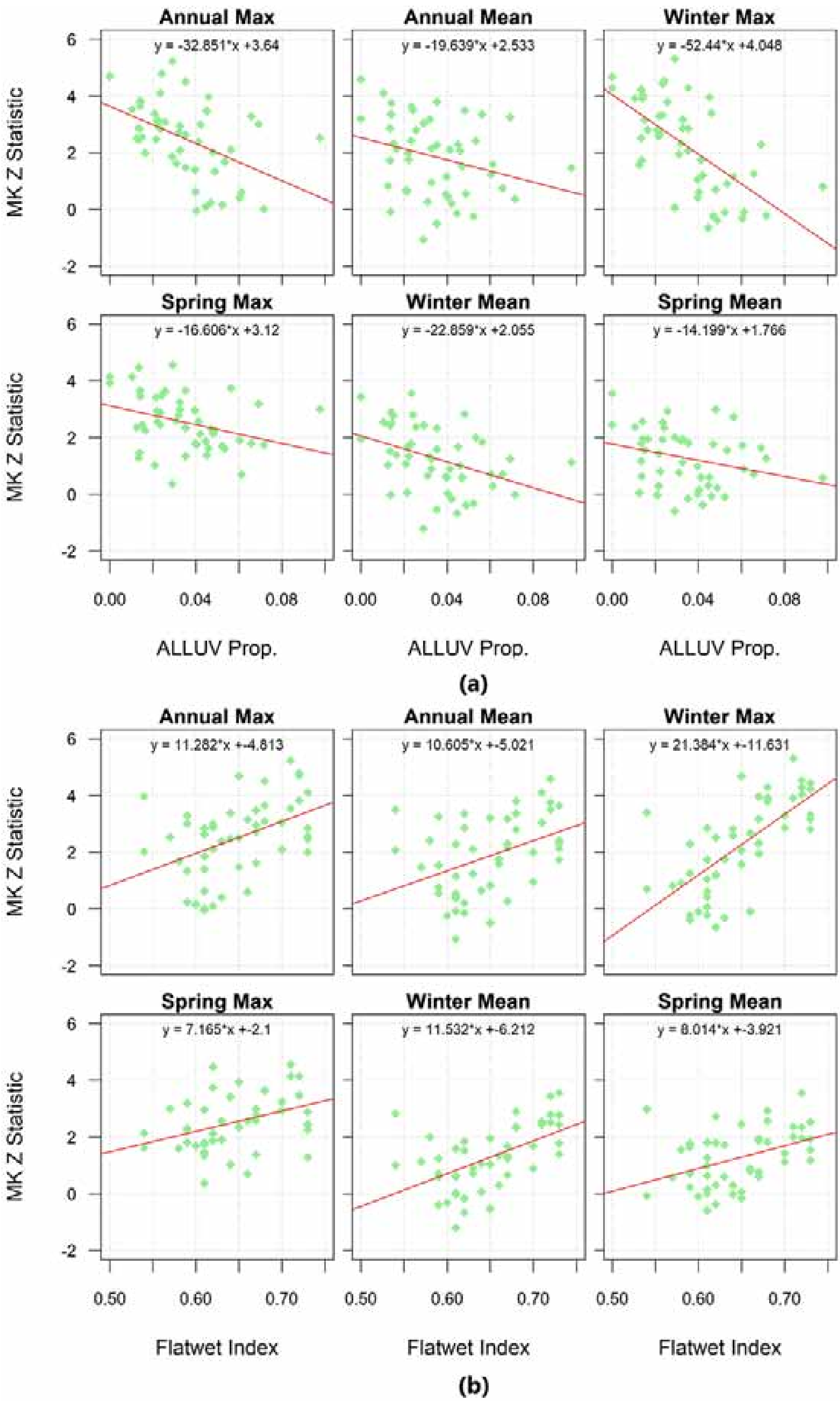

Figure 3.5. Mann–Kendall (MK) Z-score trends derived from annual, winter and spring maximum flows and annual, winter and spring mean flows versus (a) ALLUV Prop and (b) FLATWET index PCD values for the period 1942–2022.

4 Conclusions

4.1 Key Findings

The IHRN V2 provides an updated network of high-quality river flow stations for monitoring and detecting climate-driven changes in Irish hydrology. This update has resulted in the expansion of the IHRN from 43 to 51 stations. This increased spatial coverage enhances the representativeness of hydrological conditions within the IHRN and ensures better data availability for long-term hydrological and climate studies, and will be of benefit to climate risk monitoring, adaptation planning, flood risk management and water resource management, among other activities. Within the IHRN V2, stations were assessed for their performance across high-, mean- and low-flow regimes. This targeted evaluation allows for more precise hydrological studies, supporting both research and policy applications. The quality-control measures implemented ensure consistency and reliability in long-term data records, making IHRN V2 a robust tool for understanding climate-driven hydrological trends. The average record length of stations in the IHRN V2 is 49.2 years, with the additional years of observation providing stronger statistical confidence in identifying patterns of hydrological change, particularly in response to climate variability.

A key contribution of this work has been the production of daily flow reconstructions for all IHRN V2 stations for the period 1942–2022, developed using a combination of conceptual models and ANNs. This methodological improvement has enhanced the reliability of trend assessments, providing a more comprehensive picture of long-term hydrological changes. These reconstructions play a critical role in infilling missing data in observations and understanding historical variability and long-term trends in river flows. By extending flow records beyond the observational period, reconstructions provide a more comprehensive picture of how river systems respond to climate variability and external influences. This methodological advancement ensures that long-term hydrological trends are more accurately captured, supporting informed decision-making in water management and climate adaptation.

Trend analysis of IHRN V2 stations indicates that maximum and mean flows are increasing across many stations, particularly in winter and in north-western catchments. These trends suggest that Ireland is experiencing more frequent and intense hydrological extremes, likely influenced by climate change and shifting precipitation patterns. Conversely, long-term reconstructions reveal a decline in low flows (Q95), highlighting the risk of future drought conditions. Such findings have significant implications for flood management and water resource planning. A strong positive correlation was found between the NAO and winter flows in north-western catchments, while summer flows exhibited a negative correlation. Understanding these relationships helps in predicting hydrological responses to changing climate conditions and can inform long-term water resource planning. The persistence and significance of these trends highlight the importance of maintaining long, high-quality hydrometric records.

Sentinel stations and indicators have been identified within IHRN V2 as those most likely to show the earliest emergence of an anthropogenic climate change signal, making them especially valuable for continued monitoring to track evolving climate impacts on river flows. Employing the CV derived from the 1992–2022 period, we show that mean annual river flows, together with the annual maximum flow, are among the indicators most likely to display the earliest emergence of climate change signals due to their relatively low noise. Catchment characteristics play a significant role in moderating observed flow trends. Wetter catchments with high proportions of peat cover exhibit stronger increasing trends in high and mean flows, whereas catchments with extensive alluvial deposits demonstrate weaker trends. These findings emphasise the importance of local landscape features and catchment characteristics in shaping hydrological responses to climate variability.

4.2 Fledgling Stations

While the IHRN V2 network covers the vast majority of Ireland, there are some spatial gaps in the network, particularly in high- and low-flow regimes. These gaps can be found in the north-western, eastern and mid-western regions. They exist because we could not identify catchments that met the criteria applied presently. However, we have identified 13 stations from these regions that will meet the selection criteria for inclusion in a future version of the IHRN (see Figure 4.1). Currently, these fledgling stations meet all reference network selection criteria with the exception of record length, and should therefore be prioritised for ongoing monitoring.

4.3 Extending Reference Networks to Groundwater and Lake Systems

Expanding the development of reference hydrometric networks beyond river flows to include groundwater and lakes in Ireland presents a significant opportunity for enhancing long-term hydrological monitoring and understanding climate-driven changes throughout the water cycle. Such networks would complement the IHRN for river flows, offering a more comprehensive picture of water resource dynamics and interactions, and increase the potential for truly integrated catchment management. Groundwater and lake systems act as important reservoirs of water storage. Monitoring these systems within a reference network would provide critical insights into the resilience and sensitivity of Ireland's water resources to climate variability and long-term changes. Extension of reference networks in this way would also enable better integration of hydrological data for decision-making in flood risk management, water supply planning, and ecosystem conservation. Moreover, high-quality, long-term datasets on groundwater and lake levels would improve hydrological models,

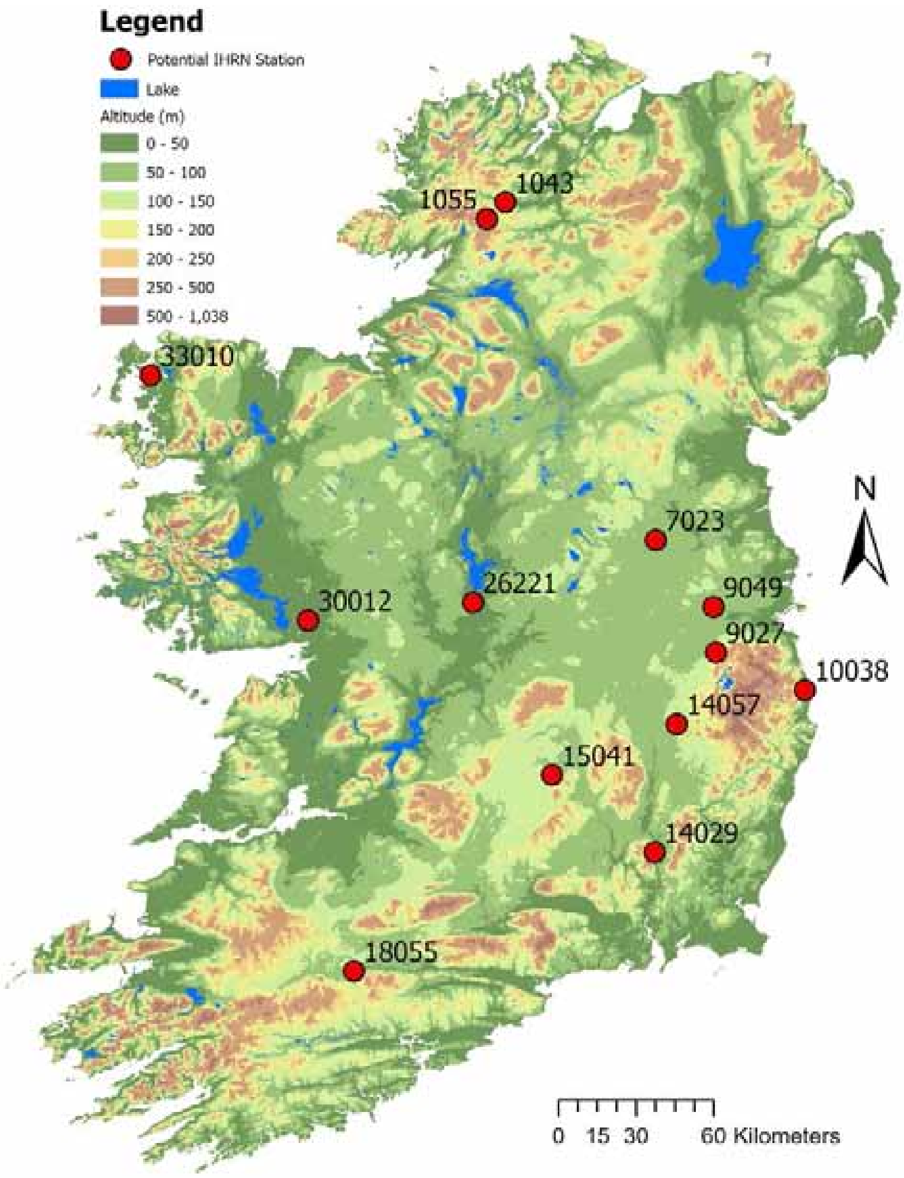

Figure 4.1. Fledgling stations that will meet reference network standards within the next 10 years.

particularly in assessing base flow contributions to rivers, groundwater recharge patterns and lake hydrodynamics. Groundwater and surface water interactions could also be better characterised, improving predictions of low-flow conditions and drought susceptibility. Ireland already has a network of groundwater monitoring sites operated by Geological Survey Ireland and the EPA, and lake monitoring is carried out by the OPW and EPA. Expanding and integrating these datasets with the hydrometric reference network would create a robust, multi-domain hydrological reference system.

Unlike river flow datasets, groundwater and lake datasets tend to have shorter record lengths, and sometimes intermittent observations that fall short of current requirements for reference networks. Additional complexities regarding groundwater systems include the spatial heterogeneity in aquifer characteristics, and the slow, damped response of groundwater to climatic and anthropogenic pressures may necessitate a different approach to reference network design. Geological Survey Ireland's GWClimate project provides a valuable foundation, identifying long-term monitoring sites in different hydrogeological settings to assess climate-related trends while minimising the influence of abstraction or land use change. However, expanding this into a broader groundwater reference network will require clear criteria for site selection, including representativeness across aquifer types and data continuity.

For lakes, limited record length is a constraint, but it is by no means the only issue when considering the development of lake reference networks. As Dalton (2018) highlights, Ireland's lake population is large, with the vast majority of individual lakes being small (< 0.1 km²). For water level, the EPA monitors approximately 40 lakes and the OPW approximately 20 lakes.

Lakes and lake level are increasingly recognised for their important role in biodiversity and carbon cycling (Downing, 2010). The National Water Quality Monitoring Programme assessed 224 lakes during the 2016–2021 period. These represent the majority of large lakes in the country, including lakes used for drinking water abstraction and those that are of regional, local or scientific interest in relation to protected habitats and species. Given the multifunctional nature of lakes as biogeochemical and ecological systems, any reference network might integrate water quality elements alongside lake level and thermal data. Therefore, the development of successful lake reference networks requires interdisciplinary and long-term, high-resolution and multi-variable data. A future network should prioritise representativeness, that is, the inclusion of the diversity of lake types on the island, guided by concepts from landscape limnology and ecosystem service valuation.

Expanding the development of reference networks to include groundwater and lakes presents an opportunity for Irish science and policy. Such an initiative would provide a more complete and integrated understanding of Ireland's water cycle, helping to detect and understand climate-driven changes across surface and sub-surface domains. It would also support more resilient and adaptive catchment management, complementing the IHRN by capturing water storage dynamics, base flows and slow-response systems often missed in river-only datasets.

An important step forward might be the designation of long-term *reference catchments*, where integrated monitoring of rainfall, river flows, lakes, groundwater levels, water quality and ecological indicators can be conducted in tandem. These catchments would serve as sentinel systems for detecting and understanding interactions within the hydrological cycle under changing climate conditions. By capturing the full suite of inputs, storages and outputs, such sites would provide a powerful foundation for studying surface–groundwater–ecology linkages, shifts in runoff generation, and the timing and magnitude of hydrological responses. Internationally, similar approaches have proven invaluable for identifying early warning signals of change and for calibrating modes used in policy and planning. In the Irish context, such integrated reference catchments could provide a unifying framework for long-term observation, inter-agency coordination and climate adaptation planning.

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Abbreviations

ALLUV Prop	Extent of floodplain alluvial deposits
ANN	Artificial neural network
CV	Coefficient of variance
FARL	Flood attenuation by reservoirs and lakes
FLATWET	Proportion of time that soils are expected to be typically quite wet
GR4J	Génie rural à 4 paramètres journalier
IHRN	Irish Hydrometric Reference Network
NAO	North Atlantic Oscillation
OPW	Office of Public Works
PCD	Physical catchment descriptor
PEAT Prop	Peat cover
SAAPE mm	Standard-period average annual potential evapotranspiration

An Ghníomhaireacht Um Chaomhnú Comhshaoil

Tá an GCC freagrach as an gcomhshaol a chosaint agus a fheabhsú, mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ar thionchar díobhálach na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialáil: Rialáil agus córais chomhlíonta comhshaoil éifeachtacha a chur i bhfeidhm, chun dea-thorthaí comhshaoil a bhaint amach agus díriú orthu siúd nach mbíonn ag cloí leo.

Eolas: Sonraí, eolas agus measúnú ardchaighdeáin, spriocdhírithe agus tráthúil a chur ar fáil i leith an chomhshaoil chun bonn eolais a chur faoin gcinnteoireacht.

Abhcóideacht: Ag obair le daoine eile ar son timpeallachta glaine, táirgiúla agus dea-chosanta agus ar son cleachtas inbhuanaithe i dtaobh an chomhshaoil.

I measc ár gcuid freagrachtaí tá:

Ceadúnú

- Gníomhaíochtaí tionscail, dramhaíola agus stórála peitril ar scála mór;
- Sceitheadh fuíolluisce uirbigh;
- Úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe;
- Foinsí radaíochta ianúcháin;
- Astaíochtaí gás ceaptha teasa ó thionscal agus ón eitlíocht trí Scéim an AE um Thrádáil Astaíochtaí.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Iniúchadh agus cigireacht ar shaoráidí a bhfuil ceadúnas acu ón GCC;
- Cur i bhfeidhm an dea-chleachtais a stiúradh i ngníomhaíochtaí agus i saoráidí rialáilte;
- Maoirseacht a dhéanamh ar fhreagrachtaí an údaráis áitiúil as cosaint an chomhshaoil;
- Caighdeán an uisce óil phoiblí a rialáil agus údaruithe um sceitheadh fuíolluisce uirbigh a fhorfheidhmiú
- Caighdeán an uisce óil phoiblí agus phríobháidigh a mheasúnú agus tuairisciú air;
- Comhordú a dhéanamh ar líonra d'eagraíochtaí seirbhíse poiblí chun tacú le gníomhú i gcoinne coireachta comhshaoil;
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Dramhaíola agus Ceimiceáin sa Chomhshaol

- Rialacháin dramhaíola a chur i bhfeidhm agus a fhorfheidhmiú lena n-áirítear saincheisteanna forfheidhmithe náisiúnta;
- Staitisticí dramhaíola náisiúnta a ullmhú agus a fhoilsiú chomh maith leis an bPlean Náisiúnta um Bainistíocht Dramhaíola Guaisí;
- An Clár Náisiúnta um Chosc Dramhaíola a fhorbairt agus a chur i bhfeidhm;
- Reachtaíocht ar rialú ceimiceán sa timpeallacht a chur i bhfeidhm agus tuairisciú ar an reachtaíocht sin.

Bainistíocht Uisce

- Plé le struchtúir náisiúnta agus réigiúnacha rialachais agus oibriúcháin chun an Chreat-treoir Uisce a chur i bhfeidhm;
- Monatóireacht, measúnú agus tuairisciú a dhéanamh ar chaighdeán aibhneacha, lochanna, uiscí idirchreasa agus cósta, uiscí snámha agus screamhuisce chomh maith le tomhas ar leibhéil uisce agus sreabhadh abhann.

Eolaíocht Aeráide & Athrú Aeráide

- Fardail agus réamh-mheastacháin a fhoilsiú um astaíochtaí gás ceaptha teasa na hÉireann;
- Rúnaíocht a chur ar fáil don Chomhairle Chomhairleach ar Athrú Aeráide agus tacaíocht a thabhairt don Idirphlé Náisiúnta ar Ghníomhú ar son na hAeráide;
- Tacú le gníomhaíochtaí forbartha Náisiúnta, AE agus NA um Eolaíocht agus Beartas Aeráide.

Monatóireacht & Measúnú ar an gComhshaol

- Córais náisiúnta um monatóireacht an chomhshaoil a cheapadh agus a chur i bhfeidhm: teicneolaíocht, bainistíocht sonraí, anailís agus réamhaisnéisiú;
- Tuairiscí ar Staid Thimpeallacht na hÉireann agus ar Tháscairí a chur ar fáil;
- Monatóireacht a dhéanamh ar chaighdeán an aeir agus Treoir an AE i leith Aeir Ghlain don Eoraip a chur i bhfeidhm chomh maith leis an gCoinbhinsiún ar Aerthruailliú Fadraoin Trasteorann, agus an Treoir i leith na Teorann Náisiúnta Astaíochtaí;
- Maoirseacht a dhéanamh ar chur i bhfeidhm na Treorach i leith Torainn Timpeallachta;
- Measúnú a dhéanamh ar thionchar pleananna agus clár beartaithe ar chomhshaol na hÉireann.

Taighde agus Forbairt Comhshaoil

- Comhordú a dhéanamh ar ghníomhaíochtaí taighde comhshaoil agus iad a mhaoiniú chun brú a aithint, bonn eolais a chur faoin mbeartas agus réitigh a chur ar fáil;
- Comhoibriú le gníomhaíocht náisiúnta agus AE um thaighde comhshaoil.

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta agus nochtadh an phobail do radaíocht ianúcháin agus do réimsí leictreamaighnéadacha a mheas;
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha;
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta;
- Sainseirbhísí um chosaint ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Ardú Feasachta agus Faisnéis Inrochtana

- Tuairisciú, comhairle agus treoir neamhspleách, fianaise-bhunaithe a chur ar fáil don Rialtas, don tionscal agus don phobal ar ábhair maidir le cosaint comhshaoil agus raideolaíoch;
- An nasc idir sláinte agus folláine, an geilleagar agus timpeallacht ghlan a chur chun cinn;
- Feasacht comhshaoil a chur chun cinn lena n-áirítear tacú le hiompraíocht um éifeachtúlacht acmhainní agus aistriú aeráide;
- Tástáil radóin a chur chun cinn i dtithe agus in ionaid oibre agus feabhsúchán a mholadh áit is gá.

Comhpháirtíocht agus Líonrú

- Oibriú le gníomhaireachtaí idirnáisiúnta agus náisiúnta, údaráis réigiúnacha agus áitiúla, eagraíochtaí neamhrialtais, comhlachtaí ionadaíocha agus ranna rialtais chun cosaint chomhshaoil agus raideolaíoch a chur ar fáil, chomh maith le taighde, comhordú agus cinnteoireacht bunaithe ar an eolaíocht.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an GCC á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóir. Déantar an obair ar fud cúig cinn d'Oifigí:

1. An Oifig um Inbhunaitheacht i leith Cúrsaí Comhshaoil
2. An Oifig Forfheidhmithe i leith Cúrsaí Comhshaoil
3. An Oifig um Fhianaise agus Measúnú
4. An Oifig um Chosaint ar Radaíocht agus Monatóireacht Comhshaoil
5. An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tugann coistí comhairleacha cabhair don Ghníomhaireacht agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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