05 – Characterising environmental flows in Ireland and what this means for water resource management in Ireland

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Abstract

Environmental flows or e-flows are the river flows required to support and maintain healthy river ecology and the rivers function, including its ability to provide amenity and assimilate point source and diffuse pressures. The critical metrics required to evaluate e-flows are river flow, either directly measured or modelled; the artificial influences, such as abstractions, diversions or discharges; and the ecological condition of the river, primarily considering the biological quality elements sensitive to reduced, and sometimes increased, river flows and levels. Additional consideration must be given to the natural typology of river catchments e.g. are they flashy upland catchments or heavily groundwater influenced lowland catchments, and also the impact of climate change on the naturalised or uninfluenced flow.

The EPA completed an initial e-flow screening assessment to support implementation of the Water Framework Directive (WFD). However, it is recognised that considerable uncertainty remains on the location and magnitude of abstractions and also in relation to the ecological response to changing river flows and levels. Notwithstanding these uncertainties, as expected, the screening assessment highlighted that less than four percent of rivers in Ireland have e-flow related pressures. Legislative drivers and measures have been put in place to further assess and formally identify any significant abstraction pressures by 2021, in order to support the effective management of water resources in the context of the Water Framework Directive's environmental objectives.

Such legislative drivers include the introduction of a statute to capture information on water abstractions and targeted local catchment assessments, planned under the auspices of the Water Framework Directive's River Basin Plan, to identify significant pressures and further evaluate water quality. The formalisation of a National Hydrometric Monitoring Programme, to support the capture of hydrometric data required under the Water Framework Directive and the Floods Directive; the enhanced water resource management capability of the Wallingford Hydrosolutions Qube low flow system, a successor to the EPAs HydroTool system, enables assessment of the natural and influenced flow; and the wider discussion about the influence of climate change that is being factored into flood flow, low flow and planning decision making are all necessary steps to improve our ability to manage water in the future. Given the recent drought and flooding events, it is incumbent on us all to work collaboratively to effectively manage our waters and the response of the various public agencies and hydrological practitioners in Ireland over the past decade is testimony to the fact that this joint up management approach is happening.

Key words: *Environmental flows, e-flows, low flows, drought, hydrometric monitoring, hydrometric modelling*

1. INTRODUCTION

Ecological flows or e-flows are defined within the context of the WFD as "an hydrological regime consistent with the achievement of the environmental objectives of the WFD in natural surface water bodies as mentioned in Article 4(1)".

Considering Article 4(1) of the WFD, the environmental objectives refer to:

- Non-deterioration of the existing status;
- Achievement of good ecological status in natural surface water body; and
- Compliance with standards and objectives for protected areas, including the ones designated for the protection of habitats and species where the maintenance or improvement of the status of water is an important factor for their protection, including relevant Natura 2000 sites designated under the Birds and Habitats Directives (BHD) (EC, 2015).

Bunn and Arthington (2002) have described the fundamental elements of e-flows. The overarching logic proposes that the biota in a river or lake are adapted to all elements of the naturally present hydrological regime in the water body in which they live. The biota in a river will have adapted to thrive under a specific regime of low flow, high flow and flow dynamics of a given magnitude and frequency. Changing this flow regime is likely to be detrimental to the biology of an aquatic environment, as it will not provide suitable flows to support the various organisms present during different parts of their life cycles, and channel-forming flows in terms of depositional or erosive periods will be altered. The silting-up of salmon redds in a drained catchment being an example of such an impact. The four principles of e-flows are presented in Figure 1.

Setting e-flows requires several components and is constrained by a range of factors (Webster *et al*, 2017). There are four main components required for e-flow characterisation including: flow regime, catchment pressures, ecology and flow paths / connectivity. These components must be considered in light of constraints that are, or may be present in catchments including; climate driven changes, national policies and legislation, data quality and availability, multiple stakeholders, and socio-economic factors.

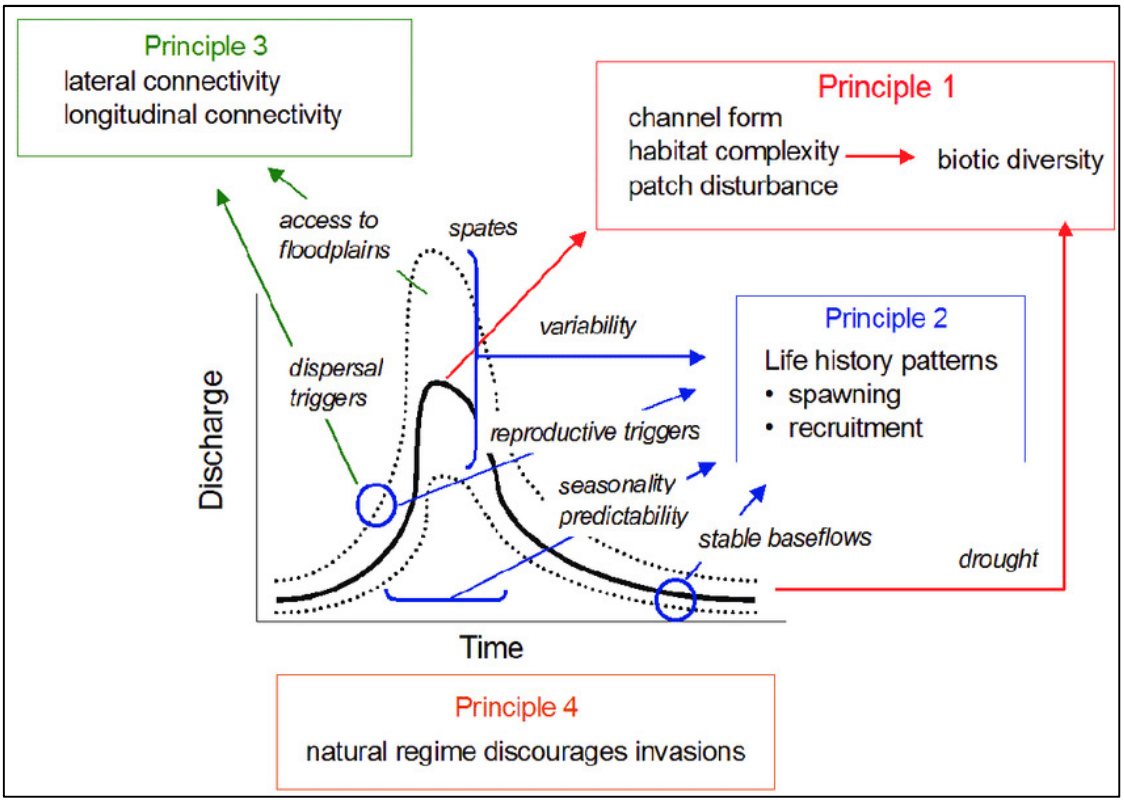

Figure 1: *Key principles to highlight the importance of the natural flow regime (Bunn and Arthington, 2002)*

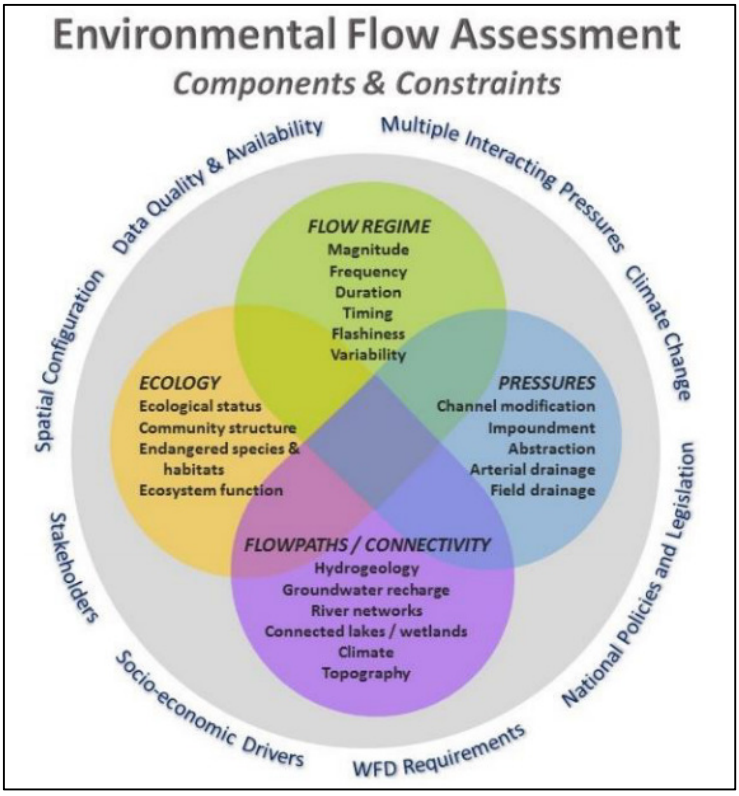

Figure 2: *Components and constraints in e-flow assessment (Webster et al, 2017)*

Setting and maintaining e-flows is an integral element in the effective implementation of the Water Framework Directive. While the European Communities Common Implementation Strategy (EC CIS) guidance document (EC, 2015) sets out a shared understanding of e-flows at a European level, it does not propose a uniform implementation of or provide a standard protocol for the implementation of e-flows in Member States. The purpose of this paper is to set out the approach to e-flow implementation being proposed in Ireland.

2. SETTING E-FLOWS IN AN IRISH CONTEXT

There has been limited research on characterising e-flows in Ireland. A comprehensive literature review of relevant research was completed by Webster *et al.* (2015) which concluded that there is presently an insufficient evidence base on which to propose bespoke e-flow standards in an Irish context at the current time. This work highlighted an important research gap that remains unfilled. Specifically, an analysis of flow augmentation driven ecological impacts in Irish river and lake habitats is required.

In the absence of bespoke Irish e-flow standards, previous screening assessments were completed using the current e-flow standards employed in Northern Ireland. This approach classifies catchments into six types based on rainfall, base flow index and catchment size (Table 1). These six river types are then grouped into three bands of sensitivity to abstraction pressure (Figure 4). When this classification method is applied to Ireland, the catchments classified as highly sensitive to abstraction pressure comprise of the upland areas and the catchments along the western seaboard. The medium sensitivity catchments are in the low-lying central and eastern parts of the country, while a small number of low sensitivity catchments are in the east of the country (CDM, 2017).

These classes, together with modelled 'naturalised flows' and augmented flow data, based on cumulative assessment of abstraction and discharge data and WFD waterbody objectives, are then used as the basis of a hydrological assessment of abstraction impact. Initially, naturalised flow duration curves (FDCs) are calculated for every river in the country. These naturalised FDCs represent the natural flow that would be in each river where all abstractions and discharges are absent. This represents naturalised background conditions. The cumulative impact from headwater to catchment outflow is then modelled by adding in discharges and subtracting abstractions. Using the Northern Ireland standards, when these calculations result in a reduction of the remaining water in a river below the thresholds shown in Table 2, for High Status objective water bodies and in Table 3 for Good Status objective water bodies, e.g. more than 5% of the Q95 of a river with a High Status Objective, this is classified as an exceedance of the e-flow. The overall proportion of an individual waterbody classified as an exceedance is then factored in to produce a final e-flow impact assessment result. There are drawbacks with this approach, in that it is not ground-truthed to Irish conditions, and is purely hydrological, without encompassing hydromorphological or ecological elements. However, it is conservative and therefore provides a high level of protection in terms of abstraction risk assessment and provides an appropriate initial step as a screening tool to identify waterbodies that require more detailed assessment.

The most recent screening exercise using the Northern Ireland standards, completed in 2017, concluded that up to 3% of river water bodies, 9% of lake water bodies and 4% of groundwater bodies are potentially at risk from abstraction pressures. Almost all the identified abstractions potentially causing risk belong to Irish Water. The actual number of water bodies impacted by abstraction is almost certainly significantly lower than the totals identified through this screening process. A fieldwork during the 2018 drought has focused on establishing actual abstraction impact in many of these waterbodies. Analysis of the data collected during the drought is ongoing. Several hydrometric stations in the east

and south of the country recorded their lowest flow on record, including a small number of stations where flows recorded during 2018 were lower than those measured during the 1976 drought. A preliminary analysis of river and lake level and flow data recorded during the 2018 drought indicates that while unabstracted waterbodies did not reach lows equalling those recorded during the 1970s, some waterbodies from which there are relatively large abstractions, did, in fact reach record lows, such as Lough Owel in County Westmeath.

Criteria for identifying types of river to which the river flow standards apply

Column 1	Column 2	Column 3	Column 4	
Type	*Standard Average Annual Rainfall mm (period 1961-1990)*	*Base Flow Index (BFI)*	*Catchment area (km^2)*	
A1	< 810.5	< 0.715	Any	
		≥ 0.715	≥ 251.8	
A2	< 810.5	≥ 0.715	< 251.8	≤ 100 (A2 headwaters) > 100 (A2 downstream)
	≥ 810.5 and < 1413	≥ 0.7495	Any	≤ 100 (A2 headwaters) > 100 (A2 downstream)
B1	≥ 810.5 and < 1155	≥ 0.3615 and < 0.7495	< 267.4	
B2	≥ 810.5 and < 1413	≥ 0.3615 and < 0.7495	< 267.4	
C2	≥ 1155 and < 1413	≥ 0.3615 and < 0.7495	< 267.4	
	≥ 1413	≥ 0.3615	≥ 32.33	
D2	≥ 1413	≥ 0.3615	< 32.33	
	≥ 810.5	< 0.3615	Any	

Table 1: *Northern Ireland e-flow river type classification standards (DoE(NI), 2015)*

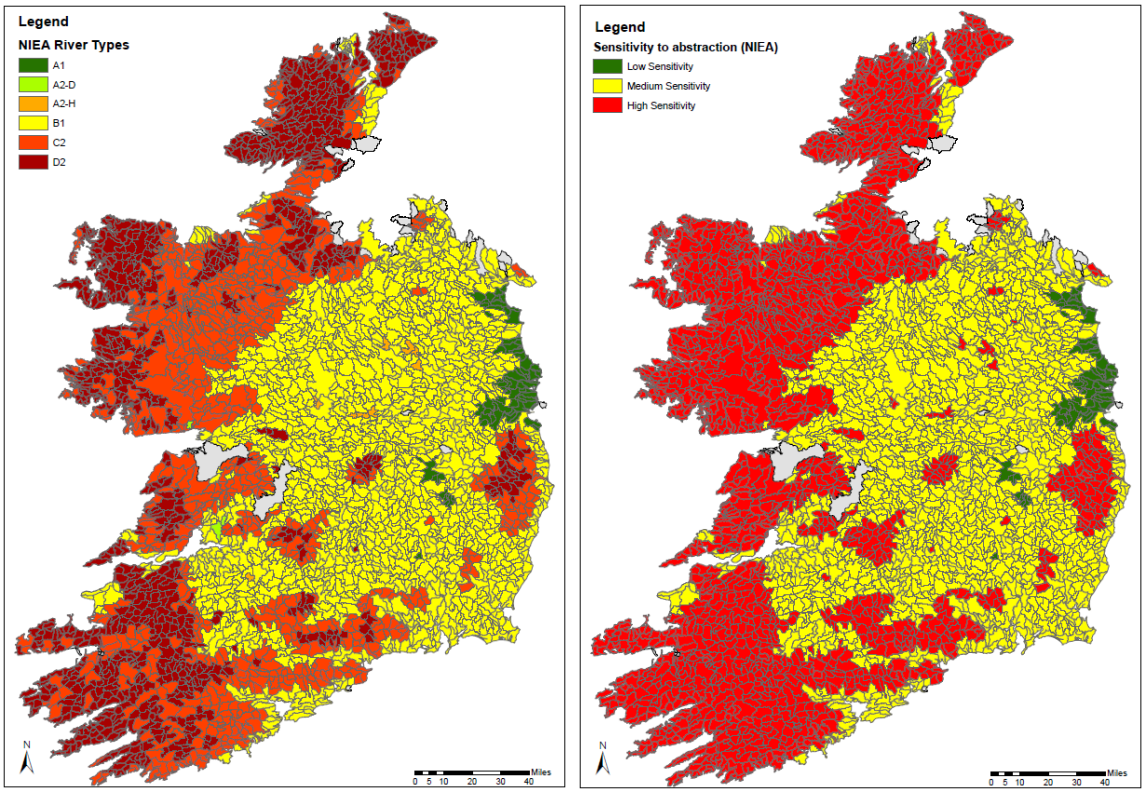

Figure 4: *River typology classification based on the Northern Ireland standards (CDM, 2017)*

High environmental standards for river flows

Permitted abstraction per day as a percentage of the natural mean daily flow(Q)[1]		
High		
Column 1	Column 2	Column 3
	Maximum permitted % abstraction at Q exceeding Q_{95}[2]	Maximum permitted % abstraction at Q **not** exceeding Q_{95}
A1, A2 (downstream), A2 (headwaters), B1, B2, C2, D2	10	5

[1] 'Q' is the mean daily flow for a specified period of time

[2] 'Qx' is the Q that is expected to be exceeded by 'x' percent for a specified period of time

Table 2: *Northern Ireland e-flow standards for High Status objective rivers based on flow percentile abstraction proportion by river abstraction sensitivity class (DoE(NI), 2015).*

Good environmental standards for river flows

Permitted abstraction per day as a percentage of the natural mean daily flow(Q)				
Good				
Column 1	Column 2	Column 3	Column 4	Column 5
River type	Maximum % abstraction at Q exceeding Q_{60}	Maximum % abstraction at Q exceeding Q_{70}	Maximum % abstraction at Q exceeding Q_{95}	Maximum % abstraction at Q **not** exceeding Q_{95}
A1	35	30	25	20
A2 (downstream), B1, B2	30	25	20	15
A2 (headwaters), C2, D2	25	20	15	10

Table 3: *Northern Ireland e-flow standards for Good Status objective rivers based on flow percentile abstraction proportion by river abstraction sensitivity class (DoE(NI), 2015).*

Data required to set and manage e-flows include ecological monitoring and classification, hydromorphological classification, water quality, hydrological time series, long-term flow statistics in gauged catchments and modelled data in ungauged catchments, and national abstraction and discharge data sets.

Ecological, water quality and hydromorphological data is collected under the EPA WFD monitoring programme. Additional hydromorphological information such as the location and potential impact of barriers for specific species is being collected by Inland Fisheries Ireland. Abstraction data will be available from the National Abstraction Register, currently being collated by the EPA. This register will include all abstractions >25m^3/d. Discharge information will be collated from Section 4 discharges, wastewater treatment plant certifications and licences and from the AERs (Annual Environmental Reports) of EPA licenced facilities.

The e-flow assessment will be underpinned by a robust national hydrological model. To calibrate the model, hydrometric data collected by the EPA, OPW and ESB have been used. The model is deployed in the Qube water resources management application, developed by Wallingford Hydro Solutions (Figure 7). This model is a refinement of the EPA HydroTool model using improved descriptor parameters and hydrometric data up to 2015. This application provides generalised modelled flows for ungauged catchments and uses local data in gauged catchments. To refine the model in areas such as controlled, impounded or karsitifed catchments, local spot flow data from the EPA, OPW, and Irish Water will be included where appropriate.

To ensure the continued collection of accurate, regionally representative flow data to calibrate the model and to identify ongoing hydrological changes due to pressures such as land use change, anthropogenic flow augmentation and climate change, the EPA published the National Hydrometric Monitoring Programme 2018-2021 in June of 2018. This programme aims to integrate the hydrometric monitoring data obtained by these organisations to ensure there is sufficient national and regionally representative data available to complete eflow and WFD work requiring hydrometric information. The EPA will periodically update their national flow statistics, at least every 6 years to coincide with each WFD characterisation cycle. The appropriateness of the national hydrometric network will also be assessed in each cycle. For each cycle, an updated National Hydrometric Programme will be published. In

subsequent programmes, stations that have become obsolete or have otherwise fulfilled their purpose will be deactivated, and new stations may be proposed where significant data gaps in the network are identified.

3. LEGISLATION, REGULATION AND ASSESSMENT

To underpin a risk based approach for the implementation of e-flows as set out in the River Basin Management Plan for Ireland 2018-2021, regulations establishing a national register of abstractions were enacted in August 2018. Heads of bill for a proposed abstraction control regime legislation were open to public consultation from August 29th to October 12th 2018, and it is envisaged that this legislation will be published in near future.

This draft legislation contains proposals to introduce a risk-based control regime governing all abstractions from surface and groundwater in Ireland. Under the Head of Bill being consulted on general binding rules will apply to all abstractions irrespective of volume or duration, with specific general binding rules governing construction dewatering and geothermal abstractions. General binding rules include maintaining infrastructure to minimise leakage, enabling the rate of abstraction to be measured, preventing the ingress of contaminants into an aquifer and decommissioning abstractions in a safe manner, amongst other regulations. All abstractions >25m^3/d must be registered with the EPA. All abstractions >2,000 m^3/d and all abstractions >250 m^3/d deemed to be a significant pressure to an "at risk" waterbody will be required to obtain a licence. The EPA will be responsible for maintaining the register of abstractions, completing the abstraction impact assessment, and is proposed as the authority for licencing abstractions where necessary. The proposed legislation does not account for impoundments and it is not proposed to regulate such features at this time. The impact of impoundments on water body ecology will be assessed under WFD hydromorphology characterisation.

Under the proposed abstraction impact assessment procedure, existing abstractions will be treated differently to new abstractions. Where existing abstractions are deemed to be potentially causing risk, the intention will be to licence them with a longer term aim of sourcing a more sustainable permanent alternative. New abstractions will be assessed using the Qube application. All new registrations will be added to the model, which will also incorporate new discharges, as they become known to the EPA.

One potential assessment procedure being considered could consist of an analysis of the predicted new augmented flow in a catchment that will be present once a proposed abstraction becomes active. All abstractions could initially be analysed based on a maximum and permanent abstraction volume as per their registration. The predicted augmented flow could then be compared to the calculated e-flow for the catchment in question, and in all downstream waterbodies to identify any potential e-flow exceedances using the Qube application (Figure 7). If the proposed abstraction brings the predicted augmented flow below or to within a certain proximity to the calculated e-flow, then a more detailed assessment may be required. The precise conditions that will trigger the requirement for a licence will be determined under the finalised legislation.

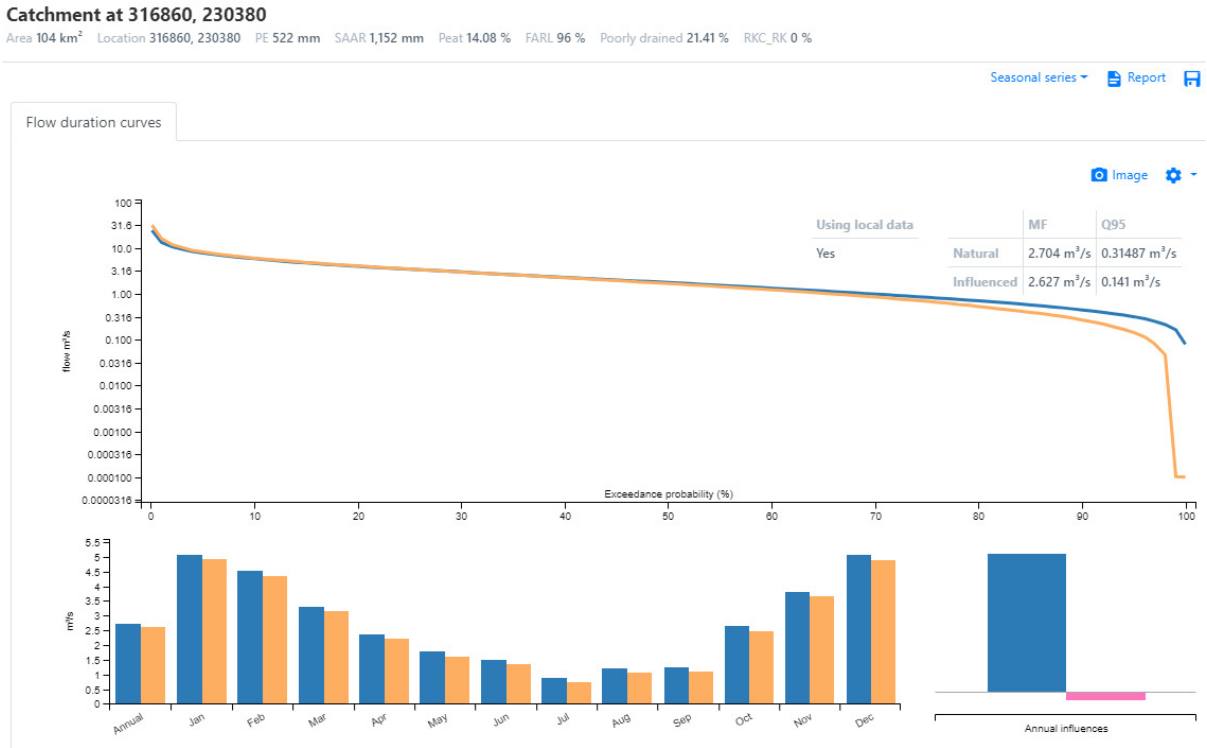

Figure 7: *Modelled flow duration curve for an ungauged catchment from the Qube application*

4. CLIMATE CHANGE ADAPTATION

The EPA as a central stakeholder in the national effort to mitigate, plan for, and adapt to climate change impacts is tasked with demonstrating leadership in incorporating climate change adaptation into its programmes. Current predictions of future climate driven changes on river flows in Ireland are based on a relatively small body of research. Research efforts need to be expanded to provide robust predictions of future changes and likely regional variations in such changes. It is envisaged that incorporating the outcomes of this research will be achieved by: a) maintaining a nationally and regionally representative long-term hydrometric network to provide baseline data for ongoing modelling, and to identify where predicted changes are or are not emerging, and to measure the magnitude of such changes, b) incorporating up to date hydrometric data in subsequent WFD characterisation cycles to identify water bodies at risk from abstraction pressures due to climate driven changes in river flows and c) operating a sufficiently dynamic, risk-based abstraction licencing system that facilitates pro-active regulation of the aquatic environment in the face of climate driven changes to river flows in accordance with WFD characterisation in future.

Recent research (Noone, *et al*, 2017) has indicated that most of our existing long-term flow statistics are likely to have been recorded during an atypically wet period when compared to the entire historical climatological record. If this is the case, it is likely that our current low flow statistics over-estimate long-term historic low flows. As predicted climate driven changes to low flows indicate that these longer term low flows are likely to reduce by >20% in future, this indicates a requirement for a dynamic and pre-emptory water resources management regime to sustainably adapt to such changes, protecting our aquatic environment and providing for the need of our population.

5. CONCLUSIONS

When fully operational, the assessment and licencing system will result in an applied e-flow methodology that will be as simple as possible, transparent, consistent, and capable of integrating future advances in our regulatory systems and the scientific understanding of the links between hydrology and ecology in our rivers. Fundamental gaps remain in our knowledge of the links between ecology and hydrology in various Irish landscape settings and river types. Also, the system has the long-term potential to become integrated with licencing and enforcement databases, with abstraction and discharge data automatically updated from annual environmental reports for example. In any case, this evidence-based, risk-based, forward-looking approach will enable the EPA to provide a high level of environmental protection and regulatory efficiency in the task of estimating the available surface and groundwater resources nationally into an uncertain future.

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