Eflow Projector: Assessing the performance of environmental watering

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Key Points

- Existing approaches to reporting environmental flow performance do not adequately account for partially successful watering events.
- We have developed a new method reporting environmental watering performance that quantifies the partial success of flow components (magnitude, duration, count and event independence).
- The approach allows for customized flow reporting at the individual flow requirement level.
- Reporting the partial success of flow components allows for a more sophisticated analysis of the underlying flow deficiencies.
- Reporting the performance of watering actions enables managers to demonstrate watering program outputs and undertake rigorous trend analysis which helps to communicate the effectiveness of environmental flows in achieving overall environmental objectives.

Abstract

The environmental water needs of most of our river systems have been quantified, and in many cases, significant water assets have been reassigned to help achieve those watering needs. Reporting the performance of watering actions enables managers to demonstrate watering program outputs and undertake rigorous trend analysis which helps to communicate the effectiveness of environmental flows in achieving overall environmental objectives. Traditional approaches to assessing environmental watering performance are binary pass or fail reporting. This binary approach to reporting misses the subtlety of most environmental requirements. We have developed an approach to allow the scoring of partial success of delivering environmental watering requirements and to report the proportional contribution to performance from environmental water holdings.

We applied the method to report performance of environmental watering actions in the Victorian Environmental Water Holder’s (VEWH) Seasonal Watering Plan 2019-20. We used 171 environmental watering actions across Victoria in order to test and refine the method. We have compared the reported results using the partial series reporting method (proposed here) against three alternative reporting approaches. The partial success approach consistently provides a higher overall reported score. To allow determination of the deficient component of the flow regime, the partial success analysis also reports success against the flow characteristics (magnitude, duration, timing and independence). The magnitude characteristic of the tested flow rules was most commonly the flow characteristic responsible for low success scores.

The method is delivered as a web-based system ‘eflow Projector’ to provide a more efficient, consistent and validated approach to assessing environmental watering performance than those used previously.

Keywords

Up to 8 words
Environmental flow, reporting partial success, ewater, eflow

Introduction

The development of water plans in Australia usually results in the explicit description of environmental watering requirements for each reach of the river. The development of environmental flow requirements follows a process of identifying objectives for important species or ecological processes and determining environmental flow requirements to achieve the objectives. The water requirements are then presented as a quantitative definition that may cover multiple objectives, for example a single water requirement definition may allow fish passage and maintain water quality. These quantitative environmental watering requirements (flow rules) can usually be described in terms of up to five characteristics:

1. Timing (the time of the year that the flow is required)
2. Magnitude (the desired flow magnitude)
3. Duration (the length that the flow magnitude is required)
4. Count or frequency (how many events of the desired magnitude and duration are required)
5. Independence (what is the minimum time between the flow events).

This definition of the flow rules (timing, magnitude, duration, count and independence) is simplified for low flow conditions to only consider timing, magnitude, and duration.

Partial Success

Whilst environmental water requirement parameters may be defined as absolute values, the environmental response is more subtle. For example, if the desired magnitude is 100 ML/day but 90 ML/day is achieved it is expected that the environmental objective is at least partially achieved. The concept of partial success is introduced to record some level of environmental value for flows that do not fully meet all the environmental flow requirement parameters. Past reporting tools such as eflow Predictor (Marsh 2009) accounted for partial success in duration and count by simply scaling the performance result by the proportion of success in these parameters. However, this approach assumes a linear response in environmental value, and it does not consider partial success for flow magnitude or independence between events.

The challenge addressed here is conduct partial success performance reporting across magnitude, duration, count and independence. A further challenge is to allow the partial success reporting to be tailored for each individual flow requirement. Note that partial success in timing is not considered here, although it could be in future iterations.

Prevailing climatic conditions

To account for the effect that variability in stream flow within and between years has on environmental objectives (for example, during wet years major processes of reproduction occur, however during periods of drought, biological processes may be limited to focusing on survival), flow rules in modern eflow studies describe the watering requirements under different prevailing climatic conditions. In VEWH’s seasonal watering plan, normally four but up to five prevailing climatic conditions are considered (drought, very dry, dry, average, and wet).

Contribution of environmental water holdings

In regulated systems (where there is significant water held in reservoirs and is licenced for use) considerable public investment has been made to secure water for environmental use. For example, in the Commonwealth Environmental Water Holder manages entitlements for 2,875,956 ML across the Murray Darling Basin (CEWH, 2021). An important aspect of reporting environmental flow performance is to therefore be able to report how these held entitlements contributed to meeting environmental flow requirements.

Method

Setting up the reporting system

To report annual performance of the environmental watering actions identified in the seasonal watering plan we have developed a web application called eflow Projector that includes the following.

Prevailing climatic conditions

The method developed requires the definition of the prevailing climatic conditions for each reporting catchment for the reporting year. If the prevailing climatic conditions change throughout the water year, the flow rule parameters are adjusted pro-rata based on the proportion of the flow rule season that the prevailing climate applies to.

Flow requirements including partial success

A flow rule is defined as having a watering season (typically related to calendar seasons). The water requirements (magnitude, duration, count, independence) are defined for each of five potential prevailing climatic conditions.

For each of the flow rule parameters (magnitude, duration, count, independence) a partial scoring table is recorded. The partial success provides a relationship between the proportion of the 'target' success and the reported score (Table 1). A linear interpolation is applied between the scoring levels in the partial success table.

Table 1. Example partial success table for flow magnitude.

Target (%)	Success (%)	Description
0	0	Success score =0 if flow magnitude is zero
25	0	Success score =0 if flow magnitude is less than 25% of the flow rule target magnitude
50	10	Success score =10% if flow magnitude is 50% of the flow rule target magnitude
75	40	Success score =40% if flow magnitude is 75% of the flow rule target magnitude
100	100	Success score =100% if flow magnitude is 100% or more of the flow rule target magnitude

Flow data

Each reporting reach requires an input daily time series of stream flow against which to analyse the flow rules. Additionally, for those reaches with contributed water holdings, this is also entered as a daily time series to allow reporting of the proportion of success due to released environmental water.

Running the analysis

Defining flow events

The basic premise of the analysis is based on defining flow events against which to score performance. In order to determine the flow events, eflow Projector firstly identifies 'event opportunities'. Event opportunities commence when the discharge meets the minimum partial success magnitude requirement. For the example in Table 1, this would be when the flow reaches 25% of the target flow. The event opportunity ends under the following conditions;

1) If the flow never reaches the target flow, then the event opportunity ends when the flow falls below the minimum partial success flow magnitude.

2) If the flow reaches the target flow magnitude, then the event opportunity ends when the flow falls below the target flow magnitude and there is an inflection in the flow. That is, there is local minima in the flow. If there is no inflection in the flow, the event opportunity ends when the flow passes below the minimum partial success flow.

For each day of the event opportunity, a flow magnitude score is recorded (based on the magnitude partial success table). Once an event opportunity is identified, then a list of potential events up to the target event duration are extracted from the event opportunity. The potential event with the highest average magnitude score is selected as the preferred event.

This procedure is repeated across the watering year to produce a list of preferred events. The preferred events list is sorted, and the target event count number of events is extracted from the event list. This forms the identified events that are used for scoring.

Scoring

The average of the magnitude score across the selected events is the season magnitude score. For each selected event, a duration score is determined using the duration partial success tables. The average of these duration scores is the season duration score. The period between each selected event is determined and a partial success score is determined for each between-event period based on the independence partial success table. The average of these independence scores is the season independence score. The number of selected events is used to determine the count partial score based on the count partial success table.

The overall score for the flow rule is determined by multiplying the underlying partial success scores. This approach provides a conservative result and ensure a zero overall score if any one of the flow components is zero.

Low flow rules are a simplified case where only the magnitude and cumulative duration are considered.

Contributing environmental water

For each day in the selected events, the time series of contributed environmental water is analysed and the proportion of the water derived from the contributed environmental water (up to the target magnitude) is reported. The average of these flow contribution percent scores is determined for each selected flow event and the average of the event based flow contribution scores represents the ewater contribution score.

Results

In order to test the partial success method we have applied it to all quantitative flow rules for the VEWH Seasonal Watering Plan 2019-20. There are 171 flow rules relevant for the prevailing climatic conditions across 4 regions, and 39 reporting reaches. These flow rules are composed of 97 freshes type rules and 74 low flow rules.

In order to demonstrate the method we have run comparative analyses across the four regions covering four alternative reporting approaches:

1) Classic: No prevailing climatic conditions (apply wet prevailing rules) with binary (pass/fail) on all flow characteristics
2) Classic with prevailing climate: Binary (pass/fail) on all flow characteristics, with prevailing climatic conditions considered
3) eFlow Predictor: Linear success on duration and count and binary pass fail on magnitude and independence criteria as used in eflow Predictor with prevailing climatic conditions
4) Partial success: Used the same default partial success tables across all flow rules with prevailing climatic conditions considered.

We have used the eflow Projector tool to run all four analyses by altering the default partial success tables for the flow components in reporting approach (Table 2).

Table2. Partial success table values used in the comparative analysis

Target (%)	Classic Success (%)	Classic With climate Success (%)	Eflow Predictor Success (%)	Partial Success Success (%)
		Magnitude		
	Must hit target	Must hit target	Must hit target	Variable
25	0	0	0	0
50	0	0	0	10
75	0	0	0	40
100	0	0	0	100
100	100	100	100	100
		Duration		
	Must hit target	Must hit target	Scaled linearly from zero to 100	Variable
0	0	0	0	0
25	0	0		40
50	0	0		40
75	0	0		60
100	0	0	100	100
100	100	100	100	100
		Count		
	Must hit target	Must hit target	Scaled linearly from zero to 100	Scaled linearly from 0 to 100
0	0	0	0	0
100	0	0	100	100
100	100	100	100	100
		Independence		
	Must hit target	Must hit target	Must hit target	Scaled linearly from 75 to 100
75				0
100	0	0	0	100
100	100	100	100	100

Note that for this analysis we have used the same partial success table for each flow component for all flow rules within each method, however the approach allows these partial success tables to be tailored for every flow rule to provide site specific scoring which is more closely related to the needs of the targeted environmental assets.

We have used the eflow Projector tool to conduct all the analysis. The three alternative methods to the partial success approach were treated as special cases of partial success and were controlled by setting the partial success tables to reflect the reporting approach.

The overall comparison across all four regions (top four rows of table 3 and first set in Figures 1-3) shows that the partial success method has a consistently higher overall score result than other methods. In the basic case of considering all flow rules, the classic method provided an overall performance of 36% (36% of flow rules were fully met). This is compared to an overall score of 73% using the partial success method when partially successful flow events are also considered.

The eflow contribution score shows that there were similar proportions of successful flows provided by contributed environmental water for both high flow (33%) and low flow events (37%).

There is clearly a spatial difference (Figures 1-3), with the western region being severely penalized with the classic reporting system. Figure 3 shows there were no fully successful low flows in the western system, however, if partial success is considered then the low flows provided, presented 60% of the environmental requirement as defined by the partial success criteria.

Table3. Comparative results (average of scores across flow rules).

	Flow rules (count)	Classic (avg % success)	Classic with climate (avg % success)	Linear success with climate (avg % success)	Partial success (avg % success)	Avg of % contribution by eflow
All regions						
All flow rules	171	35.7	41.9	64.7	73.3	34.8
freshes	97	41.4	48.6	63.3	72.1	32.9
low flow	74	26.2	33.0	66.5	74.9	37.0
Northern region						
All flow rules	58	33.0	38.9	65.3	73.7	46.2
freshes	31	36.9	45.6	60.6	67.4	45.6
low flow	27	28.0	31.3	70.7	81.0	46.7
Central region						
All flow rules	46	57.2	58.2	69.8	77.3	21.2
freshes	27	63.7	65.7	71.0	80.7	18.5
low flow	19	42.9	47.4	68.1	72.5	25.0
Gippsland region						
All flow rules	25	45.8	61.0	80.8	88.3	34.1
freshes	15	41.2	55.0	78.2	87.8	41.4
low flow	10	57.1	70.0	84.8	89.0	23.2
Western region						
All flow rules	42	14.3	16.7	48.5	59.5	35.7
freshes	24	23.3	29.2	48.7	58.8	30.5
low flow	18	0.0	0.0	48.2	60.5	42.5

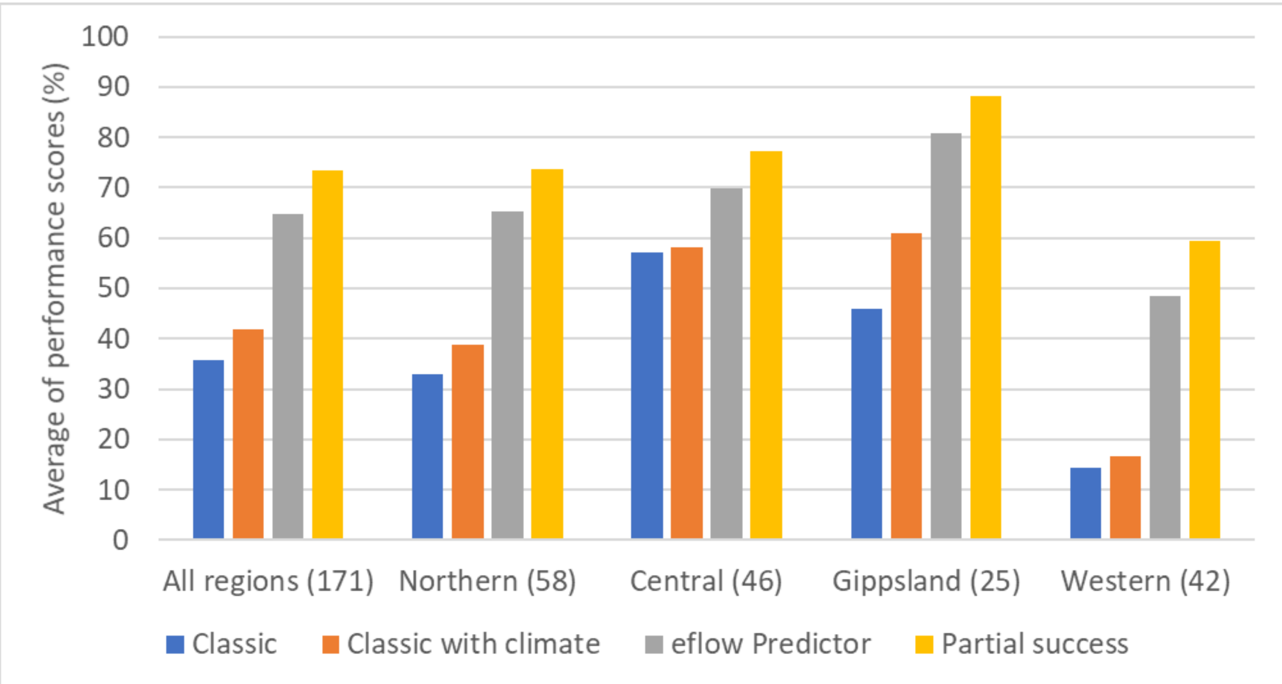

Figure 1. Average of flow rule performance for all flow rules (flow rule number)

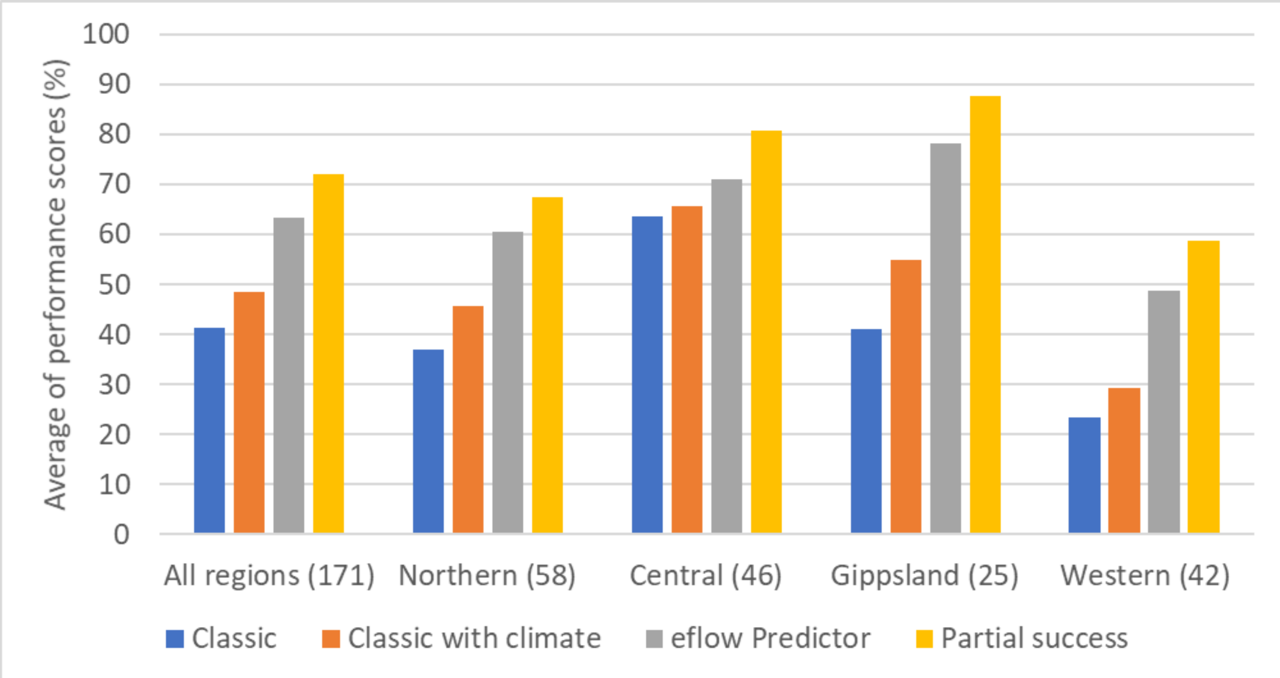

Figure 2. Average of flow rule performance for freshes flow rules (flow rule number)

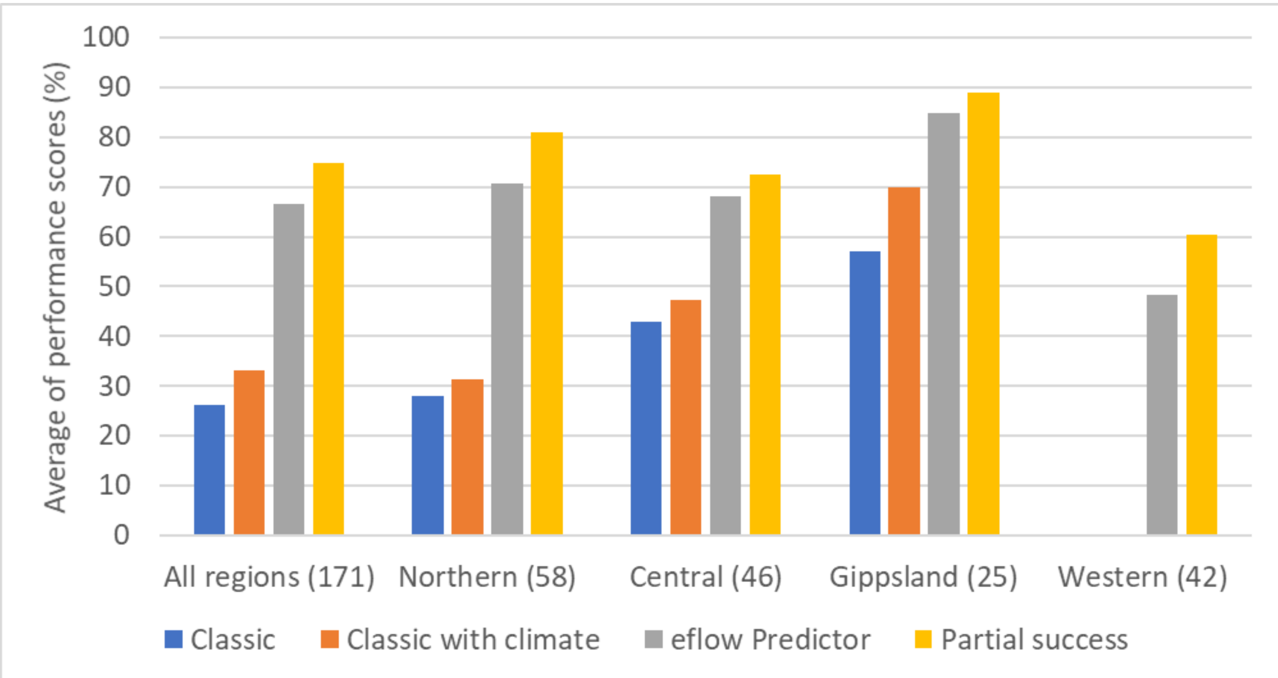

Figure3. Average of flow rule performance for low flow flow rules (flow rule number)

The eflow Projector allows reporting of success at the flow component level. This allows interrogation into the reason for flow rule partial success. Consider the performance across the flow characteristics for all the 2019-20 freshes flow rules (97) and low flow rules (74) (Figure 4). Most of the flow characteristics were met most of the time. The magnitude component of the flow rules was only partially met 47% of the time for freshes and 55% for low flow rules. For freshes, the 47% of flow magnitude partial success, 16% of flow rules had a magnitude score of 25% or less, and 13% had a flow magnitude score of 75% to 99%. For low flow, the 55% of flow magnitude partial success 11% was 50-75% success and 32% was 75%-99% success. This breakdown by flow component demonstrates that to achieve higher overall performance, focus should be on providing a higher discharge magnitude (not extending the duration of events or increasing the count of events).

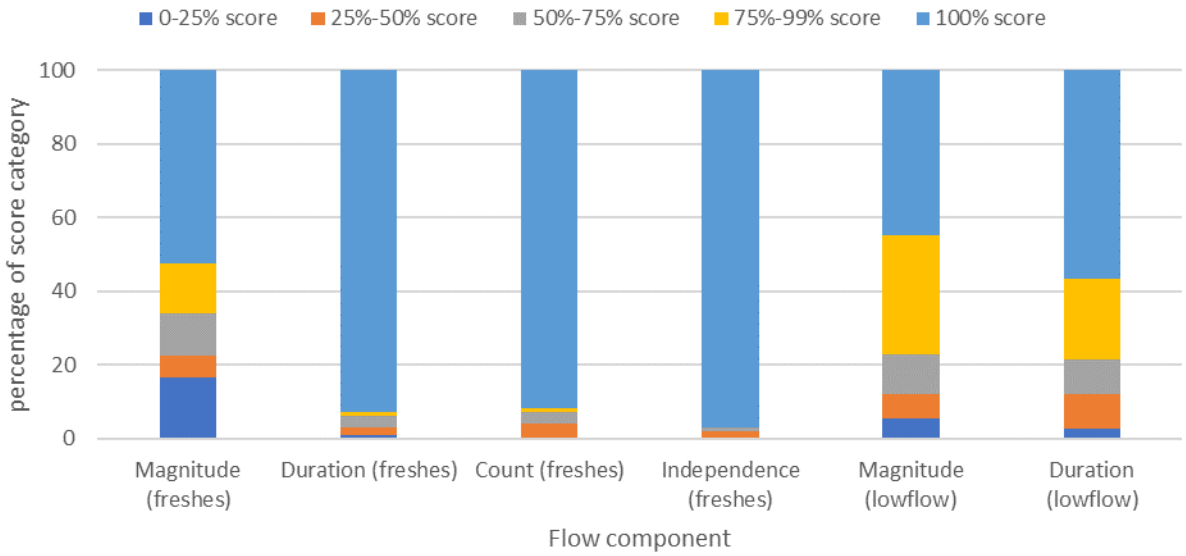

Figure 4. Percentage of flow rule component scores.

Conclusions

We present and test a method of environmental flow reporting that accounts for partial success in meeting environmental water requirements across the flow component parameters. The approach allows for site specific setting of assessment criteria through the creation of partial success tables. The method can be used to recreate previous reporting methods, and as such can force binary (pass/fail) reporting for flow components where that matches the environmental asset water needs.

Future extensions of the eflow Projector tool will focus on interactive data exploration through data visualisation and live 'within season' progress reporting through connection to hydrological monitoring services.

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