eFlow Predictor:

Testing of Computational Procedures.

Fiona Dyer

eWater Report

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The University of Canberra and eWater CRC

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eWater CRC is a cooperative joint venture whose work supports the ecologically and economically sustainable use of Australia’s water and river systems. eWater CRC was established in 2005 as a successor to the CRCs for Freshwater Ecology and Catchment Hydrology, under the Australian Government’s Cooperative Research Centres Program.

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1 Introduction

The eWater CRC has developed a software utility called 'eFlow Predictor' which aims to provide ecological experts and other non-modelling personnel with a simple-to-use tool to volumetrically quantify environmental water associated with different management scenarios. Within the water planning process eFlow Predictor helps to 1) understand the possibilities and consequences of different environmental flow release schedules 2) explore trade-offs between reduced human water use and increasing risks to environmental assets, 3) communicate the volumetric cost and priority of restoring environmentally significant components of the flow regime and 4) inform dam release and other operational rules by examining different release strategies such as augmenting existing high flows (often called piggy-backing) or relating the release rules to historical seasonal cycles.

eFlow Predictor constructs flow time series incorporating environmental flow 'rules' via augmentation of a current (consumptive) flow regime, and quantifies the water volume associated with implementing those rules. The user, who does not need to be a hydrological modelling expert, can rapidly evaluate a range of flow augmentation (eco-hydrological) strategies such as mimicking the natural frequency of events, augmenting existing flows, or waiting until the last possible day in the season of interest before allowing augmentation to commence. Augmentation strategies can also vary through time to reflect the observation that as the time since successfully achieving a specific flow component increases, so to does the importance of delivering the next event.

The output from the *eFlow Predictor* allows users to quantify the additional water requirements of meeting specific environmental flow components and to then investigate the sensitivity of the water cost to different trigger flow thresholds or event durations.

Descriptions of the computational methods are contained within the softwares help documentation, and an overview of the principles of operation and example applications are documented in Marsh, Bond and Jones (2011) Testing and application of eFlow Predictor, eWater CRC technical report. The purpose of this document is to report on the range of computational testing procedures conducted on the beta version (V1.3.4b) of the eFlow Predictor.

There are a large number of alternative settings within the software tool, and as these features have been designed and implemented they have been tested. However for successful use of the tool, the features need to be tested in combination using real world examples to ensure that no unexpected results occur and that the computational processes are accurate. As there are many settings it is impractical to test every conceivable combination and permutation of these, so necessarily a subset of settings has been tested, and this subset has been selected to be representative of the likely ways in which the tool would be used. The range of testing configurations is presented in this report to provide users with confidence over the range of applications that the tool has been used in, but also to allow them to identify when they are 'in new territory' and are using the tool beyond the bounds for which it has been tested.

The procedure for this testing procedure has been to conduct parallel computational procedures using a spreadsheet application to verify that identical results are obtained. This list of known applications and verified results can then be used to form the basis of automated 'unit testing' procedures whereby these tests are run automatically whenever the code base is altered to ensure that any future functionality changes does not adversely affect any previously implemented functionality.

Specifically the terms of reference for the testing procedure was to:

1. Verify the assessment of the time series produced by eFlow Predictor; and
2. Corroborate the resulting time series that is produced by eFlow Predictor based on implementing different augmentation strategies.

In performing the testing, the underlying logic and assumptions as well as the implementation of the logic was reviewed. This report provides the results of testing a range of flow rules and data sets.

The list of test scenarios documented here forms the basis of testing eFlow Predictor between subsequent version releases. It is anticipated that as eFlow Predictor starts being used in real world applications and as more functionality is added, more example scenarios will be developed for subsequent testing.

2 Testing

2.1 Software Version

Multiple versions of the software were tested, with computational issues identified through the testing process being resolved incrementally. The final version of software tested was: eFlow v1.3.4b pre-release 09/03/2010 and the remainder of this report is concerned with this version.

2.2 Data

Two data sets were tested. The first was 10 years of data from the lower reaches of the Werribee Catchment (Victoria) which was tested against the flow recommendations this reach. Relevant files were:

- Natural Flows: R8Natflow 1990-2000 Ml_d.csv
- Current Flows: R8Current flow 1990-2000 Ml_d.csv

The second was data from the Cotter River catchment supplied by Sue Nichols (University of Canberra) and Heath Chester (ACT Department of Environment, Climate Change and Water). These data were slightly modified to allow testing of eFlow predictor. The data files subsequently used were:

- Natural Flows: CotterNatTest.csv (Heath Chester – data from 1963 onwards based on 1910 -1963 data)
- Current Flows: Cotter CurFlow.csv (Sue Nichols – flows from Cotter @ Kiosk 1910 onwards)

2.3 Flow Rules

2.3.1 Werribee data

A basic suite of flow rules (low and freshes) was tested and then additional complexity was added in terms of the timing and combinations of rules. The rules tested are listed in Tables 1, 2 and 3.

Different options for augmenting flows were also tested using the rules listed in Table 3.

2.3.2 Cotter Data

The flow rules presently used in the Cotter catchment were used for testing (refer Table 4).

This raised an issue because environmental flow rules for the Cotter River system are set on a monthly basis and incorporate elements of variability. This required *“work-arounds”* to be applied to developing the flow rules that are used in eFlow Predictor because eFlow Predictor does not explicitly represent a variability measure as a flow outcome.

Table 1. Baseflow Rules for testing eFlow Predictor

Rule	Start	End	Time required	Success Criteria (days)	Min duration (days)	Flow threshold (ML/day)	File	Verified
1	1/1	31/5	100%	150	75	10	Test 1-1.xml	Yes
2	1/6	31/12	100%	213	106.5	36	Test 1-2.xml	Yes
3	1/1	31/5	100%	150	75	5	Test 1-3.xml	Yes
4	1/6	31/12	100%	213	106.5	25	Test 1-4.xml	Yes
5	1/1	31/5	100%	150	75	2	Test 1-5.xml	Yes
6	1/6	31/12	100%	213	106.5	20	Test 1-6.xml	Yes
7	1/1	31/5	50%	75	37.5	10	Test 1-7.xml	Yes
8	1/6	31/12	75%	160	40	36	Test 1-8.xml	Yes
9	1/1	31/5	20%	30	30	5	Test 1-9.xml	Yes
10	1/6	31/12	80%	170	85	25	Test 1-10.xml	Yes
11	1/1	31/5	30%	45	45	2	Test 1-11.xml	Yes
12	1/6	31/12	20%	43	43	20	Test 1-12.xml	Yes
13	1/12	30/4	35 %	75	37.5	10	Test 1-13.xml	Yes
14	1/5	30/11	21%	45	22.5	36	Test 1-14.xml	Yes
15	1/12	30/4	100%	214	107	5	Test 1-15.xml	Yes
16	1/5	30/11	100%	214	107	25	Test 1-16.xml	Yes
17	1/10	31/3	100%	182	91	5	Test 1-17.xml	Yes
18	1/4	30/9	100%	183	91	25	Test 1-18.xml	Yes
19	1/10	31/3	100%	182	91	2	Test 1-19.xml	Yes
20	1/4	30/9	100%	183	91	20	Test 1-20.xml	Yes

Table 2. Flood/Fresh Rules for testing eFlow Predictor

Rule	Start	End	Return Period	Success criteria	Min duration (days)	Flow threshold (ML/day)	Spell Independence	File	Verified
1	1/1	31/5	1 year	Total number of spells: 3	1	167	1	Test 2-1.xml	Yes
2	1/6	31/12	1 year	Total number of spells: 7	1	350	1	Test 2-2.xml	Yes
3	1/1	31/5	1 year	Total number of spells: 10	1	167	1	Test 2-3.xml	Yes
4	1/6	31/12	1 year	Total number of spells:20	1	350	1	Test 2-4.xml	Yes
5	1/1	31/5	1 year	Total duration: 8 days	1	167	1	Test 2-5.xml	Yes
6	1/6	31/12	1 year	Total Duration 15 days	1	350	1	Test 2-6.xml	Yes
7	1/1	31/5	1 year	Single Longest 5 days		167	1	Test 2-7.xml	Yes
8	1/6	31/12	1 year	Single Longest 10 days		350	1	Test 2-8.xml	Yes
9	1/1	31/5	1 year	Total number of spells: 3	1	167	5	Test 2-9.xml	Yes
10	1/6	31/12	1 year	Total number of spells: 7	1	350	5	Test 2-10.xml	Yes
11	1/1	31/5	1 year	Total number of spells: 10	1	167	5	Test 2-11.xml	Yes
12	1/6	31/12	1 year	Total number of spells:20	1	350	5	Test 2-12.xml	Yes
13	1/1	31/5	1 year	Total duration: 8 days	1	167	5	Test 2-13.xml	Yes
14	1/6	31/12	1 year	Total Duration 15 days	1	350	5	Test 2-14.xml	Yes
15	1/1	31/5	1 year	Single Longest 5 days		167	5	Test 2-15.xml	Yes
16	1/6	31/12	1 year	Single Longest 10 days		350	5	Test 2-16.xml	Yes
17	1/1	31/5	1 year	Total number of spells: 3	1	167	14	Test 2-17.xml	Yes
18	1/6	31/12	1 year	Total number of spells: 7	1	350	14	Test 2-18.xml	Yes
19	1/1	31/5	1 year	Total Duration of Spell: 8 days	1	167	14	Test 2-19.xml	Yes
20	1/6	31/12	1 year	Total Duration of Spells: 15 days	1	350	14	Test 2-20.xml	Yes
21	1/1	31/5	1 year	Total Duration of Spell: 5 days	1	167	14	Test 2-21.xml	Yes

Rule	Start	End	Return Period	Success criteria	Min duration (days)	Flow threshold (ML/day)	Spell Independence	File	Verified
22	1/6	31/12	1 year	Total Duration of Spells: 10 days	1	350	14	Test 2-22.xml	Yes
23	1/1	31/5	1 year	Total Duration of Spell: 30 days	1	167	14	Test 2-23.xml	Yes
24	1/6	31/12	1 year	Total Duration of Spells: 90 days	1	350	14	Test 2-24.xml	Yes
25	1/1	31/5	1 year	Single longest spell: 5 days		167	14	Test 2-25.xml	Yes
26	1/6	31/12	1 year	Single longest spell: 10 days		350	14	Test 2-26.xml	Yes
27	1/1	31/5	1 year	Total number of spells: 3	3	167	14	Test 2-27.xml	Yes
28	1/6	31/12	1 year	Total number of spells: 3	5	350	14	Test 2-28.xml	Yes
29	1/1	31/5	1 year	Total Duration of Spell: 6 days	3	167	14	Test 2-29.xml	Yes
30	1/6	31/12	1 year	Total Duration of Spells: 15 days	5	350	14	Test 2-30.xml	Yes
31	1/1	31/5	1 year	Total number of spells: 1	5	167	14	Test 2-31.xml	Yes
32	1/6	31/12	1 year	Total number of spells: 1	8	350	14	Test 2-32.xml	Yes

Table 3. Variations of Rules from Table 1 and 2 used for testing variations in rule set up and augmentation options

Set	No	Start	End	Time required/Return period	Success Criteria	Min duration (days)	Flow threshold (ML/day)	Filename	Verified
1	A	1/1	31/5	100%	151 days	75	2	Test 3-1.xml	Yes
	B	1/6	31/12	100 %	214	107	25		Yes
	C	1/1	31/5	1 in 1 yr	Number = 3	1	167		Yes
	D	1/6	31/12	1 in 1 yr	Number = 7	1	350		Yes
2	A	1/12	30/4	50%	75	37	5	Test 3-2.xml	Yes
	B	1/5	1/11	60%	128	64	25		Yes
	C	1/12	30/4	1 in 1 yr	Total duration = 6 days	3	120		Yes
	D	1/5	1/11	1 in 1yr	Total duration = 15 days	5	340		Yes

Set	No	Start	End	Time required/Return period	Success Criteria	Min duration (days)	Flow threshold (ML/day)	Filename	Verified
3	A	1/11	31/3	50%	75	37	7	Test 3-3.xml	Yes
	B	¼	31/10	60%	128	64	28		Yes
	C	1/8	15/11	1 in 1 yr	Number = 3	2	200		Yes
	D	¼	31/10	1 in 2 yr	Number = 3	5	500		Yes
4	A	1/1	31/5	50%	75	37	7	Test 3-4.xml	Yes
	B	1/6	31/12	60 %	128	64	28		Yes
	C	1/1	31/5	1 in 1 yr	Total Duration = 8	2	120		Yes
	D	1/6	31/12	1 in 1 yr	Total duration = 21	7	500		Yes
	E	1/1	31/12	Limiting flow	Total Duration = 360		1000		Yes

Table 4. Flow Rules for the Cotter Catchment

Set	No	Start	End	Time required/Return period	Success Criteria	Min duration (days)	Flow threshold (ML/day)	Filename
Drought Flows	Baseflow	1/1	31/12	100%	365 days	365	2	Cotter Drought Rules Testing.xml
	*Monthly Flushing Flow	1/1	31/12	3 days in each month	Tot duration = 3	3	20	
“Normal” Flows	Baseflow	1/1	31/12	100%	365	365	15	Cotter Normal Rules Testing.xml
	*Monthly Flushing Flow	1/1	31/12	3 days in each month	Total duration = 3	3	20	
	**Bi-Monthly flushing flow	1/1	31/12	1 day every 2 months	1	1	100	

* Note that this rule required a rule for each month to be entered. Testing involved testing first a single month, then 2, 4, 8 and 12 months. ** This flow rule required a rule for each pair of months to be entered. Testing involved a single pair, then 2, then all pairs.

3 Results

3.1 Test 1: Base Flow and Freshes

All the assessments of the base flow rules (Table 1) and fresh/high flow rules (Table 2) appear to be working effectively.

3.2 Test 2: Testing additional complexity of rules

Rules	Match with Manual Calculation	Comments
1 & 2 from Table 3	Yes	Changing the timing of flow rules is handled effectively
3 from Table 3	Depends on the definition of 1 in 2.	A difficulty arises where environmental flow performance is specified as a number of successful years say 5 years in 10, where a successful year is specified as having a multiple events (say 3). Eflow Predictor allows the user to specify multiple events, but these are considered over the entire reporting period, so in this case it would be three events over 10 years, which is not what is intended in specifying the rule. Future versions should consider separating the definition for a successful year and then recording the return interval of successful years, from the current operation of specifying a successful event and recording that over the entire reporting period. With the current version 1.3.4b, users would have to conduct a series of trial and error runs by setting the reporting period to 1 year and adjusting the ‘force’ return interval.
4 from Table 3	Yes	Note that the limiting flow rule is a valuable rule for inclusion but can be a point of confusion. Clear documentation will be required to ensure this is applied effectively.

3.3 Test 3: Augmentation of Flows

Flow augmentation seems to be augmenting flows in seasons where the current flow already successfully meets the specified criteria. For example sometime late in the season, the flow rule may be met without any need to augment the flow, however if one uses an option such as mimic natural flow, the base flow series may be augmented early in the season to match the modelled natural conditions. This outcome is as intended, in so much as a river operator does not have perfect knowledge of the future flow and may therefore pre-emptively augment the flow even though a high flow may occur at some later time. Forecast functionality is a feature of the tool, this allows users to define a reasonable forward looking period about which they are likely to have knowledge, this is only ever likely to be of the order of days and not for an entire reporting season.

If using the "*force after a certain number of failures"* and the "*if natural>current*" rule, then the *natural>current* rule seems to take precedence and augmentation of flow occurs earlier than expected. The internal precedence in the rule sets needs to be clearly defined in the help documentation.

3.4 Test 4: Cotter Rules

Aside from the issues noted in Table 4 and section 3.5.4, these were able to be assessed quite effectively.

3.5 Notable exclusions from testing

Throughout the testing phase reported here the eFlow Predictor was under beta development which resulted in the addition of several enhancements (listed below) which have not been tested here. This is the nature of ongoing software development and future testing should include these features;

1. Rates of rise and fall: the maximum rates of rise and fall can be set to produce a more realistic representation of the total water requirement, which is particularly relevant for short duration events which may require several days of lead up and ramp down water.
2. Match Natural Rate of Rise: In order to restrict the rate of rise to that which may occur naturally.
3. Forecast: the user can set a future period to look ahead and base the augmentation decision on near future flows as well as the current flow
4. 'or natural' threshold: this applies particularly to low flow rules whereby natural low flow periods (below the specified threshold) are permitted by having a temporally vary threshold which looks to the modelled natural.

3.6 Other Observed issues

Two additional issues were noted during testing. These are not considered key to the computational functionality of eFlow Predictor, but should be considered when reviewing functionality for future versions.

3.6.1 Augmentation of flows.

I have concerns with the conceptual approach adopted within eFlow Predictor that propagates the view that an environmental flow regime must always involve an augmentation of flow. While this is the case in extractive systems, in many regulated systems, it is as much the drying/reduction of flows that is required for environmental purposes as an increase.

I refer to a situation where the recommended environmental flow rule is that at least two short freshes occur during early summer to refresh a significant floodplain wetland. Under current conditions there is one single long fresh because of the transfer of irrigation water. At present, the "augmentation" rules can not 'hold back' water to allow such an environmental flow rule to be met. Rather the method of implementing this type of constraint is by defining both the need for the freshes as one rule and the need for a 'limit flow' rule to hold flow below an upper limit. I would recommend that the concept of a 'flow pattern' be included in future versions whereby the flow rule can represent variable flow through time and define that variable flow level as an upper or lower bound of acceptable flow.

3.6.2 Real world examples

Running the environmental flow rules for the Cotter River system revealed a number of issues with the practical implementation of eFlow Predictor in an ACT context.

- Environmental flow rules for the Cotter River system are defined on a monthly rather than annual basis. Entering these rules was possible (but time consuming) when the rules related to events occurring each month but where rules are defined as occurring with a return period of 1 in 2 months it was more challenging and a work around was implemented.
- eFlow requires that the natural and current flow data contain concurrent time periods. It is not possible to use the flow record of pre-development conditions to compare with a flow record subsequent to development as the basis for flow augmentation. While it is recognised that doing so introduces issues of differing climate signals, it is often the only data available. Hence an option to less tightly couple the prediction of flow requirements to an absolute daily value taken from a modelled natural case such as a statistical representation of flow for that day of year taken from a pre-development period would improve the usefulness of the tool where a modelled natural scenario is not available.
- It would be useful to be able to assess just a single flow sequence – at present this is not possible and the software will not run unless a second dummy time series is loaded .
- eFlow Predictor does not consider flow rules based on a total volumetric and average flow requirement. A real world example is an environmental flow release within the Wimmera system for the McKenzie River defined as an 'average' flow of 16 Ml/day for a certain time period (using a specified total volume of water). The inclusion of volume based flow rules should be considered as a functionality requirement for future versions.

4 Conclusion

Testing of the eFlow Predictor's computational processes was conducted prior to release of the software. Testing verified the computational processes used in the assessment of the time series produced by eFlow Predictor; and corroborated the resulting time series that are produced by eFlow Predictor based on implementing different augmentation strategies.

It was noted that there were some points at which the user could become confused in the application of the software. These points are predominantly differences in application of certain terms and will require clear articulation and definition within the supporting documentation and help material.

Some future improvements in the software were also suggested.