eFlows Explorer webtool

Webinar to SWIM SIG, 10th June 2021

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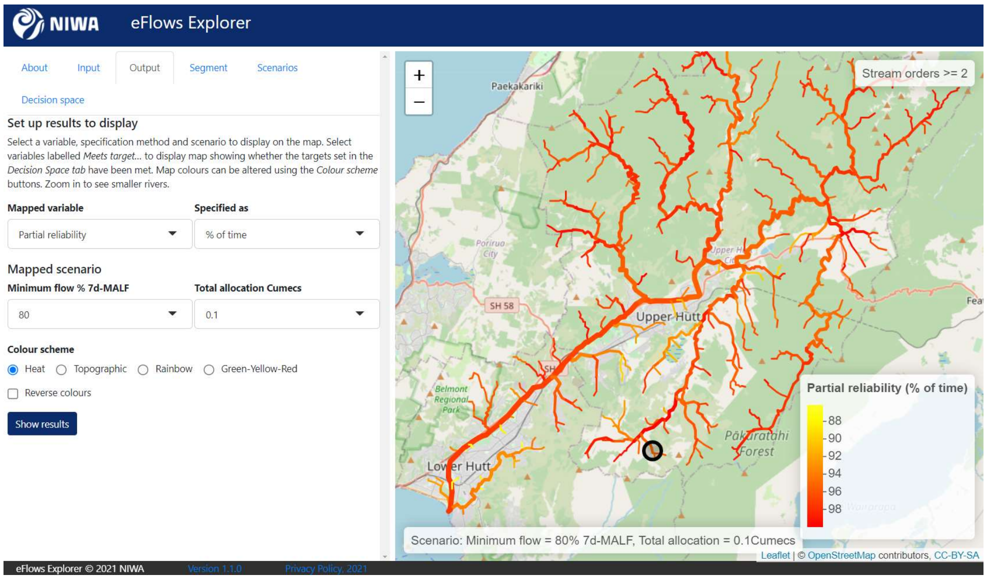
eFlows Explorer is an interactive web-app
https://shiny.niwa.co.nz/eflowsexplorer/



2

We are going to give a talk and then a demonstration.
We will get to something that looks like this, which is the really interesting part.
But first we will explain some background and theory.

Agenda

1. Background
   - NPS-FM requires rules that set environmental flows
   - Quick theory on water resource use limits
2. eFlowsExplorer
   - Intended purpose
   - How it works
   - Limitations
3. Demonstration
   - 2008 proposed NES on ecological flows and water levels default
   - using reliability of supply to set water resource use limits
4. Answers to Frequently Asked Questions

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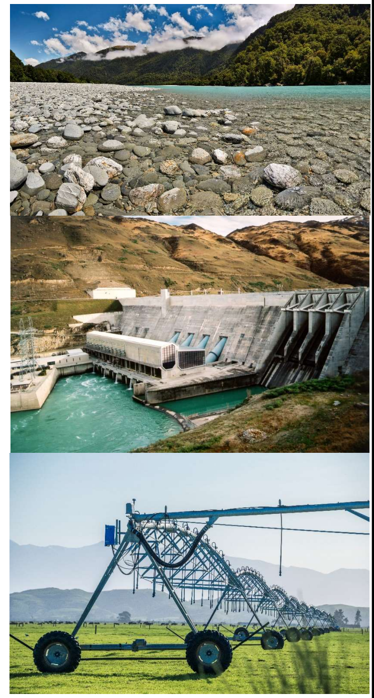


15 minute presentation followed by 15 minute demonstration.

NPS-FM 2020

3.16 Setting environmental flows and levels

(1) Every regional council must include rules in its regional plan(s) that set environmental flows and levels for each FMU, and may set different flows and levels for different parts of an FMU.

(2) Environmental flows and levels:

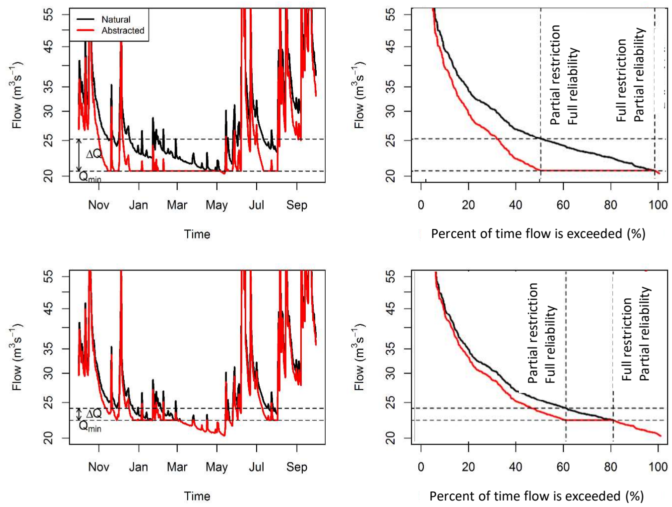
(a) must be set at a level that achieves the environmental outcomes for the values relating to the FMU or relevant part of the FMU and all relevant long-term visions; but

(b) may be set and adapted over time to take a phased approach to achieving those environmental outcomes and long-term visions.

NPS-FM says this.
Of course, the situation is complicated by:
Variety of environmental outcomes/values.
Variety in available data.
These rules need to be transferred into individual consents to take effect.
Historic reasons such as consistency between plans, existing consents.

Rules in regional plans that seek to achieve environmental flows

- Often comprise:
  - minimum flow (Qmin) = flow below which no further water is to be taken
  - maximum allocation rate (ΔQ) = maximum rate of abstraction
- NPS-FM (2017) required water resource use limits that must comprise at Qmin & ΔQ
- NPS-FM (2020) leaves scope for different forms (e.g. seasonal variations, flushing flows) and adaptation where appropriate



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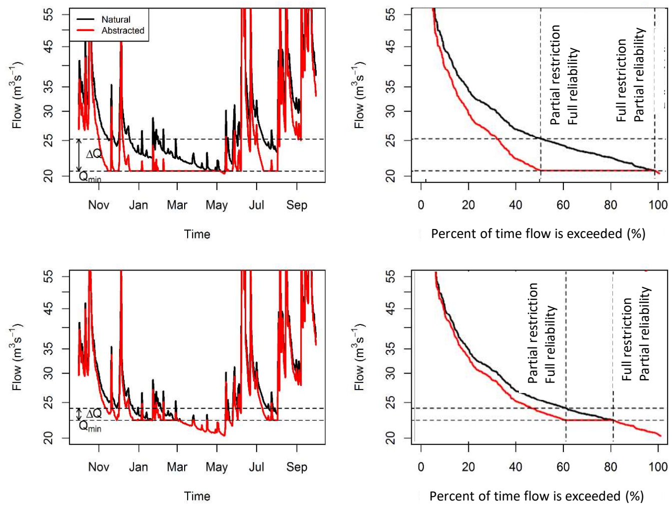
5

In many existing regional plans the rules that the NPS-FM 2020 requires take the form of Qmin and ΔQ.
Graphs on right show how an environmentally conservative scenario and a more resource enabling scenario result in different changes to a hydrograph and a flow duration curve.
This is consistent with NPS-FM 2014-amended 2017 which required that rules comprise at least Qmin and ΔQ.
For me, NPS-FM 2020 doesn't remove the need for Qmin and ΔQ, it just leaves scope for different forms of rules and adaptation where appropriate.

Rules in regional plans that seek to achieve environmental flows

- Qmin trades off acceptable magnitude of low flow & full restriction of water supply
- Qmin + ΔQ trades off acceptable duration of low flow & partial restriction of water supply
- Note: management flow (ΔQ + Qmin) = flow above which total allocation can be taken
- Qmin & ΔQ jointly influence flow regimes
- 2008 NES "default rules" e.g. for large rivers
  - Qmin = 80% MALF
  - ΔQ = 50% MALF



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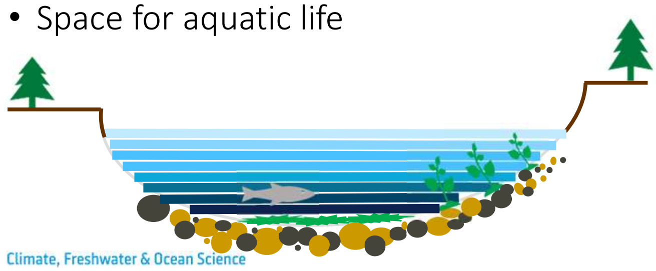
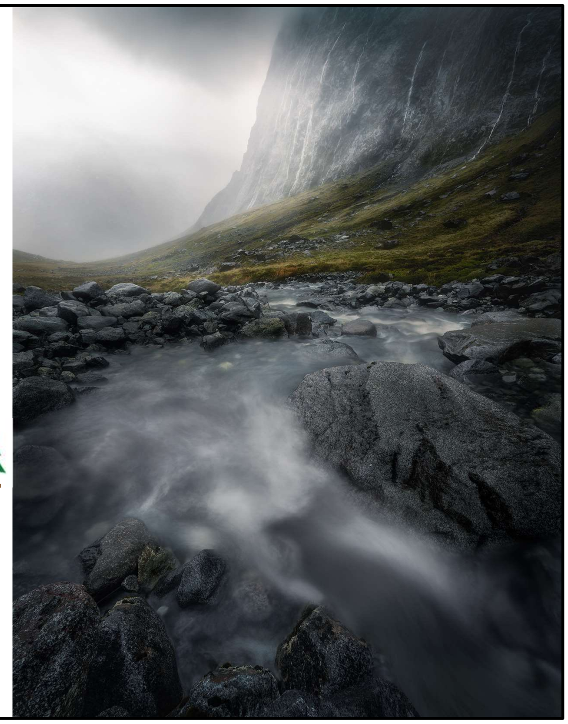
6

Just to clarify for anyone who is not familiar with these terms:
Qmin trades off … lower Qmin results in less flow left in river and more time when uses can access water.
ΔQ trades off … higher ΔQ results in lower flows in the river for longer and a greater maximum rate at which users can abstract water.
Alternatively, bottom plot shows a more environmentally conservative scenario.
Note; we can derive a third term (management flow) by addition of Qmin and ΔQ. This is the flow below which some form of restriction must be applied.

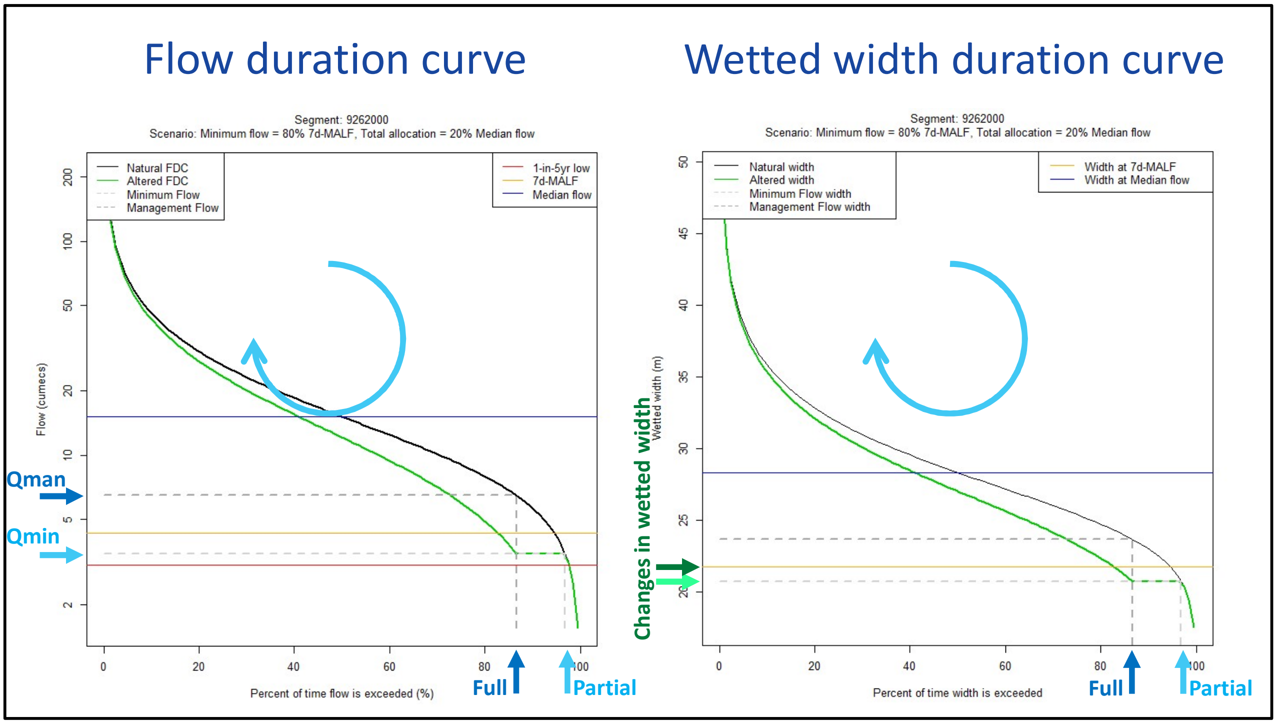
How could rules in regional plans link to environmental outcomes?

- Let's use wetted width as an example environmental outcome
- Wetted width determines area of aquatic habitat
- Space for aquatic life

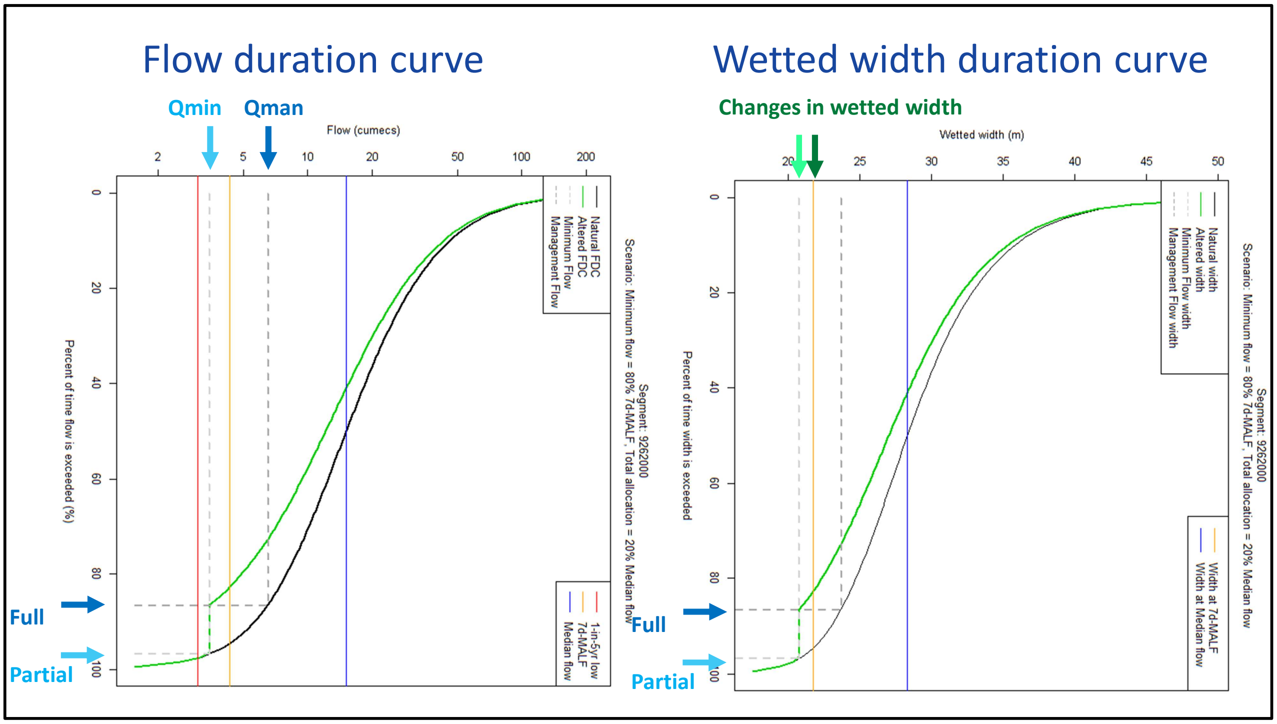




So the NPS-FM mentioned environmental outcomes that relate to the FMU.
These could be many and varied, but let's imagine that area of aquatic habitat has been identified as a metric relevant to values in an FMU.
This might make sense because area of aquatic habitat might equate to space for aquatic life, space for fish, invertebrate production etc.
If another flow-outcome relationship were available, then this could also be used.



On the left is a flow duration curve similar to the one we previously looked at.
Again we can draw on Qmin and ΔQ, and then read-off reliability of supply.
Now, if we have a width-flow relationship we can draw a width duration curve as seen on the right.
We can position reliability onto the width duration curve, and obtain a change in width (over all time, or at the minimum flow relative to a reference low flow such as MALF).
This is easier to visualise if we flip the plots 90 degrees clockwise as shown in the next slide.



Here you can see that the time of no alteration is the same for both plots

Physical habitat

Hydraulic survey & model + Suitability criteria for depth, velocity, substrate = Weighted Useable Area (WUA)

- WUA quantifies combined quantity and quality availability of suitable physical habitat for species (e.g. large longfin)
- e.g. RHYHABSIM, PHABSIM, CASiMIR, EVHA, RSS, …
- Jowett IG, Hayes JW, Duncan MJ (2008) A guide to instream habitat survey methods and anlasysis. NIWA Sci and tech series No. 54, 121pp.

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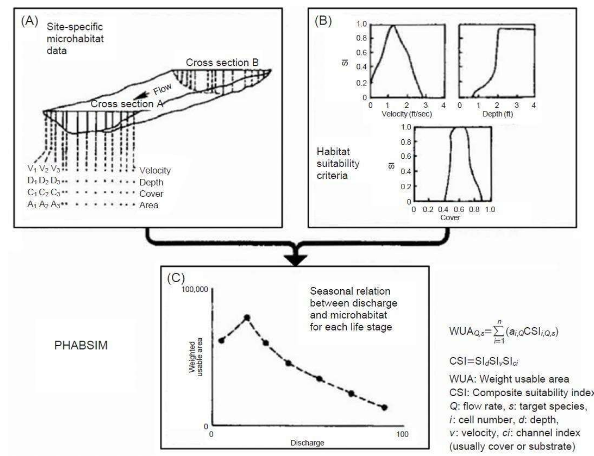

As I mentioned earlier, width is not the only metric that could be used to represent an environmental outcome.
Availability of suitable physical habitat is another metric that has been used to inform environmental flow setting.

Physical habitat

- Often used in environmental flow setting
- Application is highly debated
  - Lancaster, J., Downes, B.J. 2010. Linking the hydraulic world of individual organisms to ecological processes: putting ecology Into ecohydraulics. *River Research and Applications* 26: 385–403.
  - Lamouroux, N., S. Merigoux, H. Capra, S. Doledec, I.G. Jowett, Statzner, B. 2010. The generality of abundance-environment relationships in microhabitats: a comment on Lancaster and Downes (2010). *River Research and Applications* 26: 915–920.
- Pros: replicable, transparent, understandable
- Cons: available habitat for a species not its abundance, site specific, expensive, doesn't consider flow variability or water quality
- Other metrics could/should be considered (e.g. wetted width, removal of nuisance periphyton, cultural flow assessments, …)

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Application of physical habitat models has pros and cons. See these two publications for further information on this topic.

Data on National Digital River Network

- Flow duration curves, median flow, mean annual low flow, 1 in 5year low flow
  - Booker DJ, Woods RA (2014) Comparing and combining physically-based and empirically-based approaches for estimating the hydrology of ungauged catchments. Journal of Hydrology 508: 227–239.
- Wetted width
  - Booker DJ (2010) Predicting width in any river at any discharge. Earth Surface Processes and Landforms 35: 828–841.
- Generalised availability of suitable physical habitat
  - Booker DJ (2016) Generalized models of riverine fish hydraulic habitat. The Journal of Ecohydraulics 1: 31–49.

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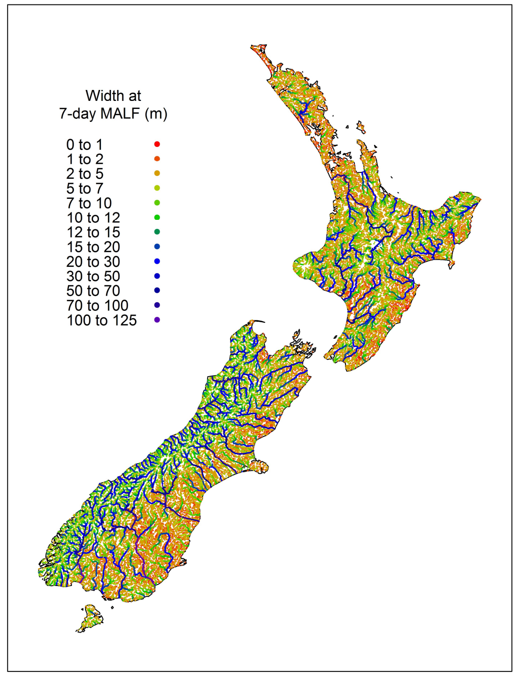

We do have estimates of the various datasets that have mentioned so far mapped onto the whole country.
To the best of our knowledge the models applied in eFlowsExplorer represent the best available set of predictions for hydrology, wetted width, and generalised habitat for ungauged sites across NZ.
Each of these papers applies some testing of predictions against independent observations, and quantifies uncertainties in the predictions.
This is important because these are not shown in the app.

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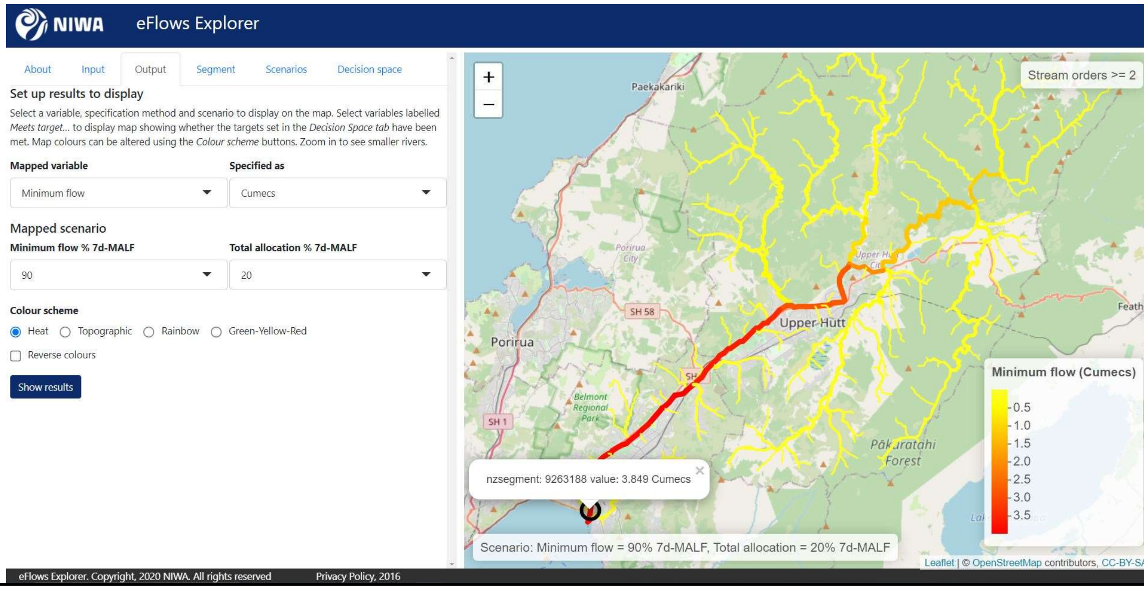

eFlows Explorer is an interactive web-app https://shiny.niwa.co.nz/eflowsexplorer/

- A tool to help evaluate consequences of water resource-use rules across all parts of a catchment or region
- It integrates scientific tools to enable evaluation of consequences for in-stream habitat and reliability of supply for out-of-channel water uses
- Runs on a server; you don't have to download software
- Publicly available

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14

What is the eFlowsExpoler web app?

How might it be used in the flow setting process?

1. Demonstrates principles associated with setting rules to achieve environmental flows to planners or local groups
   - trade-off between environmental state and resource use
   - Qmin & ΔQ can be defined in a variety of different ways (e.g., %MALF, %Q5, …)
   - Same rules can have different outcomes across a catchment/region
2. Catchment/region specific investigations of rules in data sparse situations
   - Compare consequences for reliability of supply and habitat from different scenarios for Qmin & ΔQ (e.g., NRC %MALF, %Q5)
   - Qmin & ΔQ calculated from a target level of reliability of supply or habitat protection

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15

This question came from Juliet. She asked "how do you expect people to use it". We can think of two situations what we envisage a regional council using this tool.
The first one is just to demonstrate principles. You could use a catchment that wasn't in your region.
The second one is to explore rules and their potential implications is situations with no gauging stations or environmental impact studies.

Apply several scenarios to many river reaches

Scenario	Minimum flow	Total allocation	Management flow	Partial reliability (full restriction)	Full reliability (partial restriction)	Width loss
A	Set % MALF	Set % MALF	Calculate	Calculate	Calculate	Calculate
B	Set % Q5	Set % Q5	Calculate	Calculate	Calculate	Calculate
C	Set % median	Set % median	Calculate	Calculate	Calculate	Calculate
D	Set in cumecs	Set in cumecs	Calculate	Calculate	Calculate	Calculate
E	Calculate	Calculate	Calculate	Set %	Set %	Calculate
F	Calculate	Calculate	Calculate	Calculate	Set %	Set %
Etc.	…	…		…	…	…

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16

When I said "Qmin & ΔQ can be defined in a variety of different ways" this is what I meant. Minimum flow and total allocation can be defined in a variety of units.
When various combinations two of these variables are defined, then the other four can be calculated.

More details and general principles discussed in:

- Snelder TH, Booker DJ, Lamouroux N (2011) A method to assess and define environmental flow rules for large jurisdictional regions. Journal of the American Water Resources Association 47: 828-840.
- Booker DJ, Franklin PA, Dietrich JC, Rouse HL (2014) Implementing water resource use limits: same rules different outcomes. Journal of Hydrology (NZ), 53, 129-151.

eFlows Explorer summary

Advantages

- Demonstrates trade-off between instream and out-of-stream values
- Summarises consequences for all locations on river network
- Provides transparent comparison various scenarios
- When linked to clear objectives, leads to more justifiable limits
- Simplifies communication to stakeholders
- Free

Disadvantages

- Doesn't account for temporal variability & sequencing of events
- Reaches considered independently
- Uncertainty in input data (e.g. MALF, FDC, width) not explicitly quantified
- Uses National River Network v2.4
- Uses wetted width, generalised physical habitat and reliability only (not fish population or crop production estimates, etc.)

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Demonstration

https://shiny.niwa.co.nz/eflowsexplorer/

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Let’s move onto the demonstration.

Many thanks for all the interest following our demo. Here are some frequently asked questions & some answers

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“Generalised habitat”

- Q) This provides a very useful independent third party tool to illustrate the effects of different flow scenarios. Is there any intention to add in some ecological data such as the generalised WUA relationships for a handful of fish species?
- A) EflowsExplorer currently includes 12 generalised habitat species/life-stages to choose from (e.g. large longfin) taken from the 2016 TJoE paper mentioned. There is a balance between adding more options (like generalised habitat) weighted against making a more complicated tool and prompting more questions about appropriate settings and uncertainties in the predictions. We like use of wetted width as a metric representing an environmental outcome because it has a monotonic relationship with flow (width goes up as flow goes up). We do have some generalised habitat predictions for periphyton and some invert taxa but haven’t included them in the tool as they are not published.

“Seasonal hydrology”

- Q) Is reliability of water supply shown as a percentage of total year or an irrigation season
- A) Reliability of water supply is calculated from the flow duration curve. Within eFlowsExplorer you can select the “all-time” flow duration curve or the flow duration curve from any calendar month (e.g. February).

“Naturalised flows”

- Q) Good presentation, thank you. I would say that the majority of our rivers are over allocated and the impact on broader groundwater levels is considerable. I wonder to what extent this has influenced the predictions of ‘reasonably natural flow’ (like that term).
- A) We agree with you about the naturalised/reasonably natural. In heavily abstracted locations it is possible that the Booker and Woods hydrology predictions are underestimates of “naturalised flows”, but without good quality data on actual water use from many locations it would be hard to quantify the spatial extent and magnitude of this possible underestimate compared to broader uncertainties in the predictions as a whole as would be associated with all locations regardless of abstraction.
- When Ross and Doug were working on ungauged site hydrology we went for “more data is better for training and testing because we wanted to capture as much of NZ spatial variability as possible” rather than “lets only use gauges that we think are 100% natural which will leave us with only a few mountain-fed catchments”. For training and testing we therefore used all available records (485 records from NIWA and regional councils with +5 years of data) except those from gauges that were known to be influenced by dams, large diversions or heavy abstraction. One thing to remember is that the training data contain some longer records including times that were less influenced by abstraction and some records where we did not use the most recent period because we knew it was heavily influenced by abstractions. Interdecadal climate cycles and climate changes also cause complications when characterising long-term hydrological conditions. Ideally all records would be long enough to capture these, but that is rarely the case in NZ due to the relatively short hydrological records.

“Further work and certainty/uncertainty”

- Q1) This looks like a handy tool but I’m keen to know how much testing with actual recorded flow has been undertaken.
- Q2) Thanks for your presentation this morning. We see the value in this model if it provides greater certainty in the future as you train the model further - but it appears to have limited value at present in terms of the outputs being challenged due to uncertainty? Are you planning on training/calibrating the model further?
- A) To the best of our knowledge the models applied in eFlowsExplorer represent the best available set of predictions for hydrology, wetted width, and generalised habitat for ungauged sites across NZ. Methods and testing of these models against recorded data are published in the international scientific literature. Details of blind tests applied to quantify predictive performance at unvisited sites across NZ are provided in these publications. In the case of hydrological estimates, several models were compared, and the best performing set of results are applied within eFlowsExplorer. It may be possible to improve predictive power further if more data becomes available. For example, NIWA has recently created a region-specific set of predictions for Otago. However, it is our view that all predictive models will contain some level of predictive uncertainty.

“Groundwater, drying rivers and springs”

- Q) Any ability to include groundwater i.e. gaining or losing reaches? Is that included in the training data?
- A) Yes. It is the case that predicted river flows (e.g. MALF) usually increase in the downstream direction but can decrease in the downstream direction. This type of result is produced by the statistical models used as they mimic patterns seen in the observed data.
- Q) Do the hydrological predictions account for springs?
- A) Hydrological behaviour associated with springs is not explicitly incorporated since a empirical machine learning approach was taken. More importantly hydrological predictions are strongly dependent on catchment area. This causes difficulties when predicting outflows from springs since the real-world catchment (water contributing) area is unknown or not well represented in the current national river network.

“Smaller systems”

- Q) Presumably there is less data available for smaller systems, if so would it be correct to assume that there is greater uncertainty in estimates for those systems
- A) It is not necessarily true that there is less (hydrological) data available for smaller systems. River flow time-series used for training and testing hydrological models were available from several “small catchments”.

“Inclusion of monitoring data”

- Q) it might be useful to include the monitoring stations analysis as spot points – if using this tool for public discussion there will always be questions about how well the results relate to actual recorded data
- A1) Recorded data from monitoring stations are not currently included. This might be possible in the future, but would require a full set of available monitored data to be held within the app or be linked to from within the app.
- A2) Clicking the “Download output.csv” after having run a set of scenarios downloads a full csv file of results. These results could be compared to data from monitoring stations independently.

"Tidal reaches"

- Q) Is it appropriate to use in tidally influenced reaches?
- A) Although some tidally influenced reaches are represented within the digital river network, data used for training and testing of the hydrological, wetted width and physical habitat models applied within eFlowsExplorer were from non-tidal locations. It would therefore not be appropriate to use eFlowsExplorer to assist environmental flow setting in tidal reaches. See this paper for some further information on environmental flow setting in estuaries and tidal situations:
- Stein, E.D., Gee, E.M., Adams, J.B., Irving, K., Van Niekerk, L., 2021. Advancing the science of environmental flow management for protection of temporarily closed estuaries and coastal lagoons. Water 13, 595. https://doi.org/10.3390/w13050595

“Multiple bands and separate sub-catchments”

- Q) Can this tool cope with multiple bands (different minimum flows and allocation blocks)?
- A) There is currently no ability to include multiple bands simultaneously within the same analysis as this would require a more detailed set of inputs (i.e. more than one minimum flow and more than one allocation block). It is possible to conduct this type of analysis outside of the app but using the same data and functionality as shown in eFlowsExplorer.
- Q) Can sub-catchment allocation scenarios be set separately?
- No, this is not currently possible. Different scenarios can be run separately for all selected reaches. It is possible to download results files and then join results from different scenarios in different locations together.

Thanks for your interest

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