HydroBOT: an integrated toolkit for assessment of hydrology-dependent outcomes

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## 1 Tables

Loading required package: sf

Linking to GEOS 3.12.1, GDAL 3.8.4, PROJ 9.3.1; sf\_use\_s2() is TRUE

Attaching package: 'dplyr'

The following objects are masked from 'package:stats':  
  
 filter, lag

The following objects are masked from 'package:base':  
  
 intersect, setdiff, setequal, union

test glossary

| Word/Phrase | Definition |
| --- | --- |
| Bankfull flow | River flows at maximum channel capacity with little overflow to adjacent floodplains. Engages the riparian zone, anabranches and flood runners and wetlands located within the meander train. Inundates all in channel habitats including all benches, snags and backwaters. |
| Baseflow | Reliable background flow levels within a river channel that are generally maintained by seepage from groundwater storage, but also by surface inflows. Typically inundates pools and riffle areas. |
| Basin Plan | The Basin Plan as developed by the Murray-Darling Basin Authority under the Water Act 2007. |
| Cease-to-flow | The absence of flowing water in a river channel. Partial or total drying of the river channel. Streams contract to a series of isolated pools. |
| Ecological function | The resources and services that sustain human, plant and animal communities and are provided by the processes and interactions occurring within and between ecosystems. |
| Ecological objective | The defined goal for a state, condition or characteristic of an ecological asset or function. |
| Ecological target | Level of measured performance that must be met to achieve the defined objective. |
| Ecological value | An object, plant, animal or process which has value based on ecological significance. |
| Environmental asset | An object, area, species or ecological community that has ecological value, e.g. wetlands, species, riverine forests. |
| Ecological theme | Ecological groupings that reflect high-level values and management priorities in the MDB (Native fish, Native vegetation, Waterbirds, Other species, and Priority ecosystem functions). Depend on |
| Environmental water requirement (EWR) | The water required to support the completion of all elements of a lifecycle of an organism or group of organisms (taxonomic or spatial), consistent with the objective/target, measured at the most appropriate gauge. Includes all water in the system including natural inflows, held environmental water and planned environmental water. |
| Flow category | The type of flow in a waterway defined by its magnitude, season, shape and role (e.g. bankfull). |
| Flow-dependent asset | In the context of the LTWPs, this an ecosystem, community or species that depends on periodic or sustained inundation, waterlogging or significant inputs of surface water for part or all of its lifecycle. See also water-dependent. |
| Flow regime | The pattern of flows in a waterway or wetland over time that will influence the response and persistence of plants, animals and their ecosystems. |
| Freshes | Temporary in-channel flow pulse that typically happens in response to rainfall or release from water storages. Very important for a range of ecological values. |
| Hydrograph | Graphical illustration of the occurrence of water (flows) through time. |
| Indicator | A measurable quantity thought to indicate the achievement of a value or contributing to value achievement. Often (but not always) hydrological, e.g. bankfull thresholds. |
| Key environmental asset | An asset that is identified for its special conservation significance based on selected temporal and spatial criteria. |
| Key ecological value | A species or community that is identified for its special conservation significance based on selected temporal and spatial criteria. Examples include Murray cod or river red gum woodlands. |
| Large fresh | A high-magnitude flow pulse that remains in-channel. May engage flood runners with the main channel and inundate low-lying wetlands. Connects most in channel habitats and provides partial longitudinal connectivity, as some low-level weirs and other in channel barriers may be drowned out. Highly important for aquatic ecosystems. |
| Long Term Water Plan (LTWP) | Plans required of Basin States by the Murray-Darling Basin Plan. Long term water plans give effect to the Basin-wide Environmental Watering Strategy relevant for each river system and will guide the management of water over the longer term. These plans will identify the environmental assets that are dependent on water for their persistence, and match that need to the water available to be managed for or delivered to them. The plan will set objectives, targets and watering requirements for key plants, waterbirds, fish and ecosystem functions. DPIE is responsible for the development of nine plans for river catchments across NSW, with objectives for five, 10 and 20-year timeframes. |
| Longitudinal connectivity | The flow link along the length of a river. |
| Long-term target | 5, 10 and 20 year ecological targets described in The Basin-wide Environmental Watering Strategy and LTWPs |
| Overbank flow | Flows that spill over the riverbank or extend to floodplain surface flows. |
| Planning Unit (PU) | A geographical division of a water resource plan area based on water requirements (in catchment areas in which water is actively managed), or a sub-catchment boundary (all other areas). |
| Priority ecosystem function | In the context of the LTWPs, this is a water-dependent ecological function that can be influenced by environmental water. |
| Priority environmental asset | In the context of the LTWPs, is a place of particular ecological significance that contains values and functions that are water-dependent and can be influenced by environmental water. |
| Sustainable diversion limit (SDL) | The total amount of water that can be extracted from Murray-Darling Basin rivers for human uses. Water in the system above the SDL is protected to achieve environmental outcomes. |
| Value | General term for any management target, typically assumed to be water-dependent here. Encompasses economic, social, cultural, and ecological assets, e.g. economic performance, recreation opportunities, biodiversity |
| Very low flow | Minimum flow in a channel that prevents a cease-to-flow. Provides limited connectivity between pools and maintains water level in refuge pools. |
| Value dimension | Alike to the spatial dimension defining the scale or aggregation in space, the value dimension defines the scales of aggregation in values that are defined in the causal network. |
| Water resource plan area (WRPA) | Catchment-based divisions of the Murray-Darling Basin defined by a water resource plan. |

Comp

| General HydroBOT components | Type | General component definitions | Specific components used in our example |
| --- | --- | --- | --- |
| Input data | Not part of HydroBOT | Hydrologic data (timeseries). Typically representing multiple scenarios, e.g. climate and climate adaptations. May include other inputs as needed by response models. | Modified historical hydrographs to represent hypothetical climate change and adaptations (45 gauges, 15 scenarios) |
| Controller | Workflow | Interface between input data, response model, and other toolkit components. Sets up run(s). | Sets up links to data and parameters for EWR tool and aggregations. |
| Response models | External, integrated | A model of the response of values, e.g. social, cultural, environmental, or economic values in response to hydrologic drivers. | EWR tool |
| Aggregator | Workflow | Aggregates response model results to scales across the dimensions of time, space, and theme. | Response model sets the base scale for aggregation. EWR tool assesses hydrologic indicators (value) at gauges (space) and year (time). |
| Comparer | Workflow | Compares scenarios (typically) or other groupings. Provides standard outputs including comparison methods, plots, and tables. | Comparison of environmental values at various theme scales for the example climate and adaptation scenarios |
| Causal networks | External, integrated | Describe causal relationships between values. | Long Term Water Plan (LTWP) |
| Spatial data | External, integrated | Describe spatial relationships | Gauge locations, Sustainable Diversion Limits (SDL) units, Murray-Darling Basin |

COMP in div- FOR TESTING

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Table S1: Components of HydroBOT architecture. Input data is included here to discuss its properties, but is not part of the architecture proper, which consists of three workflow components and three integrated external components.   | General HydroBOT components | Type | General component definitions | Specific components used in our example | | --- | --- | --- | --- | | Input data | Not part of HydroBOT | Hydrologic data (timeseries). Typically representing multiple scenarios, e.g. climate and climate adaptations. May include other inputs as needed by response models. | Modified historical hydrographs to represent hypothetical climate change and adaptations (45 gauges, 15 scenarios) | | Controller | Workflow | Interface between input data, response model, and other toolkit components. Sets up run(s). | Sets up links to data and parameters for EWR tool and aggregations. | | Response models | External, integrated | A model of the response of values, e.g. social, cultural, environmental, or economic values in response to hydrologic drivers. | EWR tool | | Aggregator | Workflow | Aggregates response model results to scales across the dimensions of time, space, and theme. | Response model sets the base scale for aggregation. EWR tool assesses hydrologic indicators (value) at gauges (space) and year (time). | | Comparer | Workflow | Compares scenarios (typically) or other groupings. Provides standard outputs including comparison methods, plots, and tables. | Comparison of environmental values at various theme scales for the example climate and adaptation scenarios | | Causal networks | External, integrated | Describe causal relationships between values. | Long Term Water Plan (LTWP) | | Spatial data | External, integrated | Describe spatial relationships | Gauge locations, Sustainable Diversion Limits (SDL) units, Murray-Darling Basin | |

EWRs

| Code | Start month | End month | Target freq. (%) | Max freq. (%) | Events per year | Days per year | Consecutive days | Min flow (ML/d) | Max flow (ML/d) | Max inter-event |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CF1\_a | 7 | 6 |  |  | 1 | 6 | 6 | 0 | 0 | 0.00 |
| CF1\_c | 7 | 6 | 35 |  | 1 | 1 | 1 | 0 | 0 | 0.00 |
| CF1\_b | 7 | 6 | 5 |  | 1 | 29 | 29 | 0 | 0 | 0.00 |
| VF1\_a | 7 | 6 | 50 |  | 1 | 365 | 1 | 1 | 1000000 | 0.08 |
| VF1\_b | 7 | 6 | 100 |  | 1 | 280 | 1 | 1 | 1000000 | 0.08 |
| BF1\_a | 7 | 6 | 50 |  | 1 | 240 | 1 | 200 | 1000000 | 0.30 |
| BF1\_b | 7 | 6 | 100 |  | 1 | 70 | 1 | 200 | 1000000 | 0.30 |
| BF2\_a | 9 | 3 | 50 | 100 | 1 | 140 | 1 | 200 | 1000000 | 2.00 |
| BF2\_b | 9 | 3 | 100 | 100 | 1 | 25 | 1 | 200 | 1000000 | 2.00 |
| SF1\_P | 10 | 4 | 100 |  | 1 | 10 | 10 | 600 | 1000000 | 1.00 |
| SF1\_S | 7 | 6 | 100 |  | 1 | 10 | 10 | 600 | 1000000 | 1.00 |
| SF2 | 9 | 4 | 75 | 100 | 1 | 14 | 14 | 600 | 5400 | 2.00 |
| LF1\_P | 7 | 9 | 75 | 100 | 1 | 5 | 5 | 5400 | 1000000 | 2.00 |
| LF1\_S | 7 | 6 | 75 | 100 | 1 | 5 | 5 | 5400 | 1000000 | 2.00 |
| LF2 | 10 | 4 | 40 | 50 | 1 | 5 | 5 | 5400 | 1000000 | 4.00 |
| AC1\_P | 8 | 2 | 65 | 100 | 1 | 5 | 5 | 4600 | 1000000 | 3.00 |
| AC1\_S | 7 | 6 | 65 | 100 | 1 | 5 | 5 | 4600 | 1000000 | 3.00 |
| AC2 | 10 | 4 | 50 |  | 1 | 5 | 5 | 4600 | 1000000 | 4.00 |
| BK1 | 9 | 4 | 30 | 50 | 1 | 2 | 2 | 32700 | 1000000 | 5.00 |
| BK2\_P | 9 | 2 | 30 | 50 | 1 | 3 | 3 | 32700 | 1000000 | 5.00 |
| BK2\_S | 7 | 6 | 30 | 50 | 1 | 3 | 3 | 32700 | 1000000 | 5.00 |
| OB2\_P | 9 | 2 | 40 | 50 | 1 | 2 | 2 | 40000 | 1000000 | 5.00 |
| OB2\_S | 7 | 6 | 40 | 50 | 1 | 2 | 2 | 40000 | 1000000 | 5.00 |
| OB3\_P | 8 | 2 | 33 | 50 | 1 | 2 | 2 | 45000 | 1000000 | 5.00 |
| OB3\_S | 7 | 6 | 33 | 50 | 1 | 2 | 2 | 45000 | 1000000 | 5.00 |

Scenarios

| Climate code | Flow multiplier | Adaptation code | Flow addition (ML/d) |
| --- | --- | --- | --- |
| A | 0.50 | 1 | 0 |
| B | 0.67 | 2 | 250 |
| C | 0.80 | 3 | 6,500 |
| D | 0.91 | 4 | 12,000 |
| E | 1.00 |  |  |
| F | 1.10 |  |  |
| G | 1.20 |  |  |
| H | 1.50 |  |  |
| I | 2.00 |  |  |