Project Plan SP 2022-033

Ellen Brook catchment nutrient export: sources and pathways

BCS Rivers and Estuaries Science

Project Core Team

X X **Supervising Scientist** Kerry Trayler
Data Custodian Sri Adiyanti

Project status as of June 9, 2023, 10:09 a.m.

X X Pending project plan approval

Document endorsements and approvals as of June 9, 2023, 10:09 a.m.

X X
Project Team granted
Program Leader required
Directorate required
Biometrician required
Herbarium Curator not required
Animal Ethics Committee not required

Ellen Brook catchment nutrient export: sources and pathways

Program

BCS Rivers and Estuaries Science

Departmental Service

Service 6: Conserving Habitats, Species and Communities

Project Staff

X X X **Role Person Time allocation (FTE)**

Research Scientist Sri Adiyanti 0.5

Supervising Scientist Kerry Trayler 0.0

Technical Officer Amy Basnett 0.06

Related Science Projects

None

Proposed period of the project

Sept. 1, 2022 – Sept. 1, 2024

Relevance and Outcomes

Background

Ellen Brook catchment (716 km^2) is a major tributary to the Swan Canning Estuary which is identified as the major contributor nutrient loads to the system (Kelsey, *et al*. 2010 & Paraska, *et al*. 2022). A nutrient stripping wetland was established at the bottom end of the catchment in 2014 with the view to reducing nutrient load from the Ellen Brook catchment before it reaches the downstream estuary. While effective in reducing loads during winter and spring flows, the wetland is bypassed during low flow periods when baseflow continue to flow. This is important given the nature of soils in the catchment and shallow groundwater. Key performance indicators for nutrient (TN and TP) management of Ellen Brook have not been met in the past years (Swan River Trust, 2022).

Since residential development commenced in 1990s (following the EPA approval), Ellen Brook catchment has undergone significant changes in land use land cover (LULC) from a landscape dominated by trees, crop and farm, animal keeping and horticulture (>85%) to partially converted into urban development. Given its location adjacent to the Gnangara Groundwater Mound, the Swan Valley and shallow groundwater, the rezoning from rural to urban raises concerns for downstream waterways and nutrient management. To satisfy the environmental approval condition in drainage and nutrient management, as well as provision of water and sewer services for urban activities, Better Urban Water Management framework (WAPC, 2008) have been adopted, which include key principles in drainage nutrient and irrigation management and water sensitive urban design.

To better inform land management policy and support decision making with respect to management interventions to reduce nutrient export from Ellen Brook catchment, a refined hydrological and nutrient model is required. In order to be effective, the hydrological model must take into account the contribution from surface runoff, subsurface flow (including baseflow and groundwater discharge) and needs to quantify nutrient export from specific land use types, to differentiate active and legacy source, to identify the sources and sinks of nutrient, and how they vary in space and time.

Due to the spatiotemporal dynamics of water fluxes (as transport) and biogeochemistry of dissolved solutes occurring within the catchment, estimating the contribution of subsurface transport to the overall catchment nutrient loading is particularly elusive and uncertain. Modelling water fluxes at a mesoscale catchment (basins whose area are within the range of 10^2-$10^4 km^2$) such as Ellen Brook needs to address nonlinearity, scale, uniqueness, equifinality and uncertainty issues in the model parameters, as their effective quantities cannot be measured but need to be inferred by an indirect procedure called calibration (Kumar, *et al*., 2013).

This project utilizes state-of-the-art hydrologic simulations driven by observed hydroclimatic forcing using the distributed (2D) and processed-based mesoscale Hydrologic Model (mHM) developed by Helmholtz Centre for Environmental Research (Kumar, *et al.*, 2013) to perform the catchment-scale hydrological simulations over 14 years, from 21 October 2009 (the first record at upstream gauge) to 31 December 2023. The model features the multiscale parameter regionalization (MPR) technique (Samaniego, *et al.*, 2010) to integrate the spatial heterogeneity of physiographic characteristics of Ellen Brook catchment with distinct differences in topography between the west and east of the Gingin Scarp and corresponding landscape properties such as soil, vegetation and depth to groundwater.

Using MPR, parameters at a coarser scale, where dominant hydrological processes are represented, are linked with their corresponding ones at a finer resolution where input data sets are available. This is an advanced technique to: (1) reduce model overparameterization, (2) confine the parameterization search to realistic values, and (3) allow the transfer of model parameters from gauged to ungauged basin.

Aims

The project aims to generate a hydrological and nutrient export model for the Ellen Brook Catchment to estimate the catchment nutrient export based on sources (surface runoff, baseflow and groundwater-derived), land use categories[*)] (forest, crops, urban, rural, livestock, wetlands, and nutrient stripping) and pathways from the catchment to the estuary. The model will be a predictive tool enabling managers to understand the potential impact of climate and management scenarios on nutrient export.

*) forest land use includes trees, plantation, conservation.

*) crops land use includes viticulture, turf farm, nursery, horticulture, lifestyle block/hobby farm.

*) urban land use includes residential, transport, sewage, utility, recreation, landfill, drainage, manufacturing.

*) rural land use includes rural residential, unused-cleared-base soil, unused-cleared-grass, quarry farm.

*) livestock land use includes farm animals, animal keeping.

Specifically, the project will address the following items:

1. Estimate the surface water flux (discharge), baseflow, and regional groundwater contribution to the Ellen Brook catchment nutrient export.
2. Identification of active and legacy source contributing to stream nutrient load.
3. Estimate the relationship between nutrient export and change in land use and land cover (LULC).
4. Estimate the land use-specific nutrient export rate (with uncertainty estimates).
5. Predict climate change impact and catchment management scenarios on the Ellen Brook nutrient export.

Expected outcome

i. Understanding of a relationship between a change in land use and land cover (LULC) (2009 to 2023) and nutrient export within the catchment, and relative contribution of baseflow and shallow groundwater to total nutrient export.
ii. Understanding the effect of Water Management Strategies and Plans and Water Sensitive Urban Design measures in relation to nutrient export, including the impact that different nutrient management approaches might have on nutrient export.
iii. Understanding contribution of active and legacy source contributions to nutrient export.
iv. Understand how climate and catchment management scenarios will influence nutrient export and loads to the estuary.

Knowledge transfer

During the life of the project, reference group meetings are scheduled every 6 weeks. At the meeting, the project leader presents the project progress and discusses any issues that arise with reference/experts, project team members and stakeholders. This forms an on-going knowledge transfer process. Additional meetings will be organized as required.

The project leader will work with managers (State, local and NRM) during development of the model to ensure relevant datasets are incorporated. In addition, managers will be able to input advice into scenario development. Approaches taken in this project will form part of educational material to support managers/junior scientists in understanding model frameworks.

At the mid-point and end of the project, progress knowledge gained will be conveyed to the Swan Canning Water Quality Improvement Plan (SCWQIP) team within Rivers and Estuaries Branch (REB), the Ellen Brockman

Integrated Catchment Group (EBICG), local government, DWER and other relevant teams within Rivers and Estuaries Science (RES) through presentations and publication.

Tasks and Milestones

Deliverables and time frames:
Year 1 (2022/23):

1. Investigation a fit for purpose distributed hydrological model for Ellen Brook catchment with possibility of coupling with groundwater model: December 2022.
2. Preparation of all raster files and netcdf4 files for the selected hydrological model (mHM) input files and first run of Ellen Brook mHM: May 2023.

Year 2 (2023/24):

1. Flow and soil moistures calibration and validation, investigation of a fit for purpose optimisation scheme (out of 4 options) and objective function (out of 34 options): August 2023.
2. Investigation of flow (Q) and Load (L) relationships at 34 monitoring sites (32 EBICG sites + 2 DWER sites) to distinguish active and legacy source contributions to stream nutrient load: September 2023.
3. Investigation of multiyear land use and nutrient export relationships: November 2023.
4. Simulations completed February 2024.
5. Application of some climate change (multiple cases of meteorological and rainfall) and management scenarios: May 2024. Note, WA future climate model by DWER Climate Science Initiative is anticipated to be accessible from DWER platform in 2024.

Year 3 (2023/24)

1. Draft Report: September 2024
2. Final Report: November 2024

References

Adiyanti, S., Maruya, Y., Eyre, B.D., Mangion, P., Turner, J.V., Hipsey, M.R., 2022. Using inverse modeling and dual Isotopes (^{15}N and ^{18}O of NO_3) to determine sources of nitrogen export from a complex land use catchment. Water Resour. Res., 58, https://doi.org/10.1029/2022WR031944

Destouni, G., Cantoni, J., Kalantari Z., 2021. Distinguishing active and legacy source contributions to stream water quality: Comparative quantification for chloride and metals. Hydrol. Proc. 35(7), https://doi.org/10.1002/hyp.14280.

Kelsey, P., Hall, J., Kitsios, A., Quinton B. and Shakya, D., 2010. Hydrological and nutrient modelling of the Swan-Canning coastal catchments. *Water Science Technical Series report* prepared by the Department of Water, Western Australia.

Kumar, R., Samaniego, L. and Attinger S., 2013, Implications of distributed hydrologic model parameterization on water fluxes at multiple scales and locations, *Water Resour. Res.*, 49, https://doi.org/10.1029/2012WR012195.

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Thober, S., Cuntz, M., Kelbling, M., Kumar, R., Mai, J., Samaniego, L. (2019). The multiscale routing model mRM v1.0: simple river routing at resolutions from 1 to 50km. Geosci. Model Dev. 12(6), 2501-2521, https://doi.org/10.5194/gmd-12-2501-2019.

mHM: Luis Samaniego et al., mesoscale Hydrologic Model. Zenodo. https://doi.org/10.5281/zenodo.1069202.

Study design

Methodology

The methodology is developed to be consistent with output required to inform the Swan Canning Water Quality Improvement Plan (SCWQIP).

Detailed steps required to achieve the 5 specific aims are described below.

Aim 1: Estimate the surface water flux (discharge), baseflow and shallow groundwater contribution to the Ellen Brook catchment nutrient export.

Detailed steps required to achieve Aim 1 include the model setup, calibration and validation described below.

1. Ellen Brook mHM model setup

mHM is based on numerical approximation of dominant hydrological processes which include canopy interception, soil moisture dynamics, infiltration and surface runoff, evapotranspiration, subsurface storage and discharge generation, deep percolation and baseflow, and discharge attenuation and flood routing.

In each layer of soil horizons within the model, the incoming water in the form of rainfall, after accounting for the canopy interception, is partitioned into soil-water storage and exfiltration based on a power function depending on the degree of saturation of the corresponding soil horizon, which then infiltrate to the horizons underneath. Evapotranspiration losses from each horizon are modelled as a fraction of evapotranspiration which are dependent upon water storage capacity and the fraction of the vegetation roots in each horizon.

In the Ellen Brook mHM setup, three mHM levels will be prepared for the following scale with data sources presented in Table 1.

i. Level-0: 100m grids of spatial morphological data: filled DEM (digital elevation model), slope, aspect, flow direction, flow accumulation, gauges, soil characteristics at 3 horizons (0-5cm, >5-30cm, >30-100cm), monthly LAI (leaf area index) of each land use type, land use types (1974, 1984, 2005, 2018), land cover (forest, pervious, impervious), and geology. All level-0 data files are in form of raster files. For each soil horizon, soil characteristics inputted into the model are upper and lower limit of soil particle diameter (mm), bulk density (g/cm^3), clay (%) and sand (%).
ii. Level-1: 1km grids, hydrological processes (model domain) which is also model output in a netcdf4 file.
iii. Level-2: daily resolution of 1km grids spatial meteorological forcing (precipitation, air temperature, potential evapotranspiration) in netcdf4 files.

Table 1:
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Data	Source/Product	Digital Elevation M
5m grid DEM, LiDAR (Geoscience Australia, Geocat #89644, March 2019	Soil characteristics	Soil and Landscape for Western Australi https://data.csiro.au
1:50,000 scale geological map (Geological Survey of WA and Geoscience Australia)	Leaf Area Index (LAI)	OzWALD accessible Infrastructure: https://dapds00.nci. OzWALD/8day/LAI/
Land Use classification 1974, 1984, 2005, 2018 (DWER) Urban Monitor (CSIRO, DPLH, WAPC)	Land Cover	Sentinel-2 10m grid world.
1km grid daily soil moisture https://www.tern.org.au/news-smips-soil-moisture/	Meteorological forcing: Potential evapotranspiration, precipitation, average temperature.	1km daily: SILO - A to yesterday
DWER Water Information Reporting, LWMS pre-development monitoring data, UWMP post-development monitoring data, Ellen Brook nutrient stripping wetland monitoring data (DBCA)	Groundwater level and quality	DWER Water Inform

Daily simulation October to December 2023 will be run in a WSL2 Linux environment.

Outputs from the model (1km km spatial dataset) include:

i. Water content at each soil horizon (mm);

ii. Volumetric soil moisture at each soil horizon (mm/mm);
iii. Reservoir of sealed area and unsaturated zone (mm);
iv. Water level in groundwater storage (mm);
v. Potential and actual evapotranspiration (mm/day);
vi. Total runoff, direct runoff, fast and slow interflow, and baseflow generated at every grid (mm/day);
vii. Groundwater recharge (mm/day).

2. Ellen Brook mHM calibration and validation

The mHM will be first calibrated using observed flow at the upstream gauging (617165) and downstream (616189), with contributing catchments 56.5km^2 and 554.4 km^2, respectively. The second stage of the calibration is using time-series gridded soil moistures.

The options for optimisation scheme (4 option) and objective function (34) in the mHM will be assessed to produce the best fit for purpose optimisation scheme for Ellen Brook catchment.

3. Groundwater level validation

Simulated water level in groundwater storage within mHM setup will be analysed against measured groundwater level.

Aim 2: Identification likelihood of active and legacy source contribution to stream nutrient load.

Total runoff (Q) output of the model and nutrient concentration measured at 34 monitoring sites will be used to calculate nutrient load (L) at each site. Investigation of the L-Q at each site will be done using the regressions lines approach described in Destouni, *et al.* (2021).

Aim 3: Estimate the relationship between nutrient export and change in land use and land cover (LULC).

mHM results (flow, soil moistures) and nutrient loading will be dissected spatially using land use land cover observed in 1974, 1984, 2005, 2018, and 2022.

Aim 4: Estimate the land use-specific nutrient export rate (with uncertainty estimates).

The land use-specific nutrient export rate (mg/ha/day) will be estimated using an inverse method described in Adiyanti, et al. (2022). Output from this approach is nutrient export rate (mg/ha/day) of dissolved nitrogen and phosphate during dry and wet periods, exported from each land uses, i.e., forest, crops, urban, rural, livestock, wetlands, and nutrient stripping.

Aim 5: Predict climate change impact and catchment management on the Ellen Brook nutrient export.

Daily potential evapotranspiration, precipitation and temperature derived from future climate 2030 and 2100 product of CMIP6 (Coupled Model Intercomparison Project 6) regional climate model (4km grids) will be applied into calibrated Ellen Brook mHM model to illustrate the impact of the climate change on the nutrient export. Selected shared socioeconomic pathways (SSPs) are SSP1-2.6 and SSP3-7.0.

List of softwares utilised:

Technique Programming Software:

Programming and numeric computing MATLAB® and programming languages Python and R are used for the project for data acquisition, processing and extraction throughout the project.

Mapping Software:

Commercial licence and open-source geographic information system ArcMap ArcGIS and QGIS (respectively) are used to process all spatial dataset and perform spatial analysis.

Biometrician's Endorsement

required

Data management

No. specimens

None

Herbarium Curator's Endorsement

not required

Animal Ethics Committee's Endorsement

not required

Data management

Data utilised, model setup and resulted from this project are stored in DBCA OneDrive. Following DBCA Record Keeping Policy, every month data will be transferred to the RES project SharePoint: Ellen Brook Subcatchment modelling.

Model setup and input files will be shared via DBCA Science GitHub: https://github.com/orgs/dbca-wa/teams/science

Biometrician's Endorsement:

Advice from Rohini Kumar of Department Computational Hydrosystems (CHS) of Helmholtz Centre for Environmental Research, on mHM setup and calibrations has been sought and to continue.

Advice from Matt Hipsey (UWA) and Gavan McGrath (DBCA) on the appropriate methodology has been sought and to continue via the 6-weekly reference group meetings.

Advice from the Department's biometrician Matthew Williams will be sought when reporting on the data, especially in future phases where scientific publications may occur.

Budget

Consolidated Funds

to | X | X | X | X |

Source: BCS	Year 1	Year 2	Year 3
Software:			
-eWater software maintenance fee	2,500	–	–
- ArcGIS Spatial Analyst annual fee	300	300	300
- MATLAB software maintenance fee	1,000	1000	1,000
Travel			
Other			
Total	3,800	1,300	1,300

External Funds

to | X | X | X | X |

Source: 06 BCS /REB	Year 1	Year 2	Year 3
FTE Scientist	64,041	65,962	67,941
Overheads			
Equipment			
Vehicle			
Travel			
Other			
Total	64,041	65,962	67,941