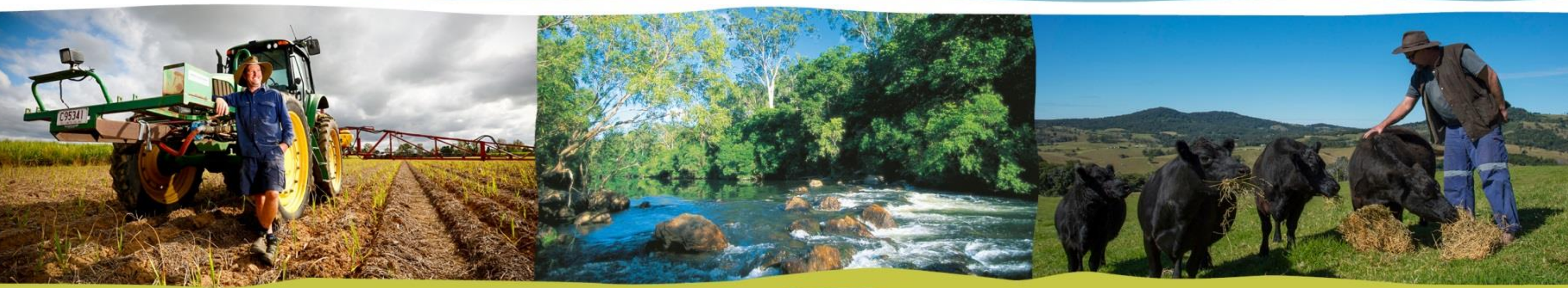
Catchment pollutant loads modelling methods



Great Barrier Reef

Report Card 2015

Australian Government

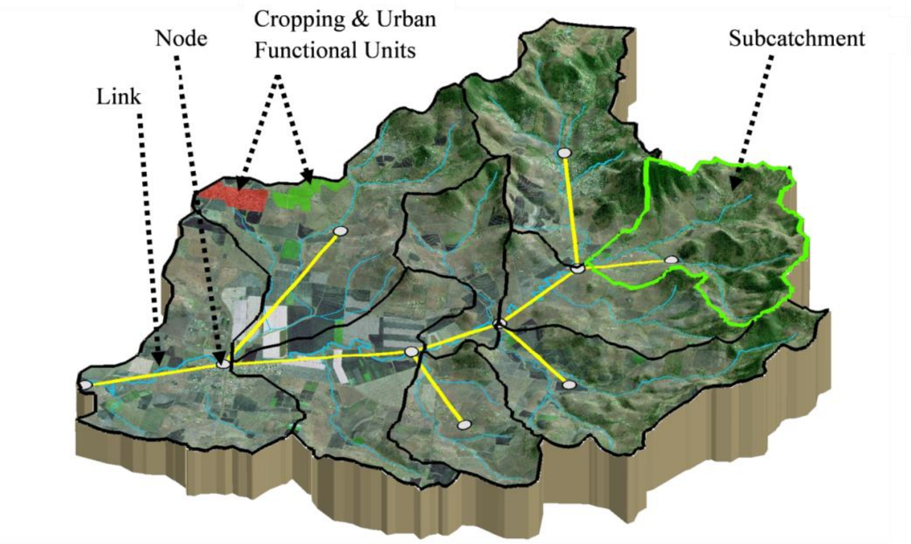
Queensland Government

Catchment pollutant loads methods

Catchment modelling

Why use modelling to measure pollutant load reductions?
Monitored pollutant loads leaving catchments vary significantly year-to-year, mainly due to differences in annual rainfall and runoff. Therefore, catchment modelling is used to estimate the long-term annual pollutant load reductions due to the adoption of improved land management practices. This removes the impact of factors such as climate variability. Research suggests time lags to monitor the improvements from land management practice change could range from years for pesticides up to decades for nutrients and sediments, due to the high level of climate variability. The models use measured changes in on-ground management and well-documented and accepted methods and assumptions. Long-term water quality monitoring data is used to validate and improve the models, continuously improving confidence in the estimates of water quality over time.

Catchment modelling framework
The Source Catchments modelling framework (eWater 2010) is used to model pollutant loads for the 35 catchments in the Great Barrier Reef region. It is a catchment scale water quantity and quality model which uses a node link network to represent the stream. The model generates runoff and pollutant loads for each functional unit (landuse) within a sub-catchment, and runoff and pollutants are transported from a sub-catchment through the stream network via nodes and links to the end of the catchment.



Example of a functional unit (FU) and node-link network generated in Source Catchments. These components represent the sub-catchment and stream network.

Source Catchments runs at a daily time step which allows for the exploration of the interactions of climate and management at a range of time-steps. However, for the Great Barrier Reef Report Card, average annual catchment loads are reported.

The model was run for each scenario using a fixed climate period from 1986 to 2014 to remove the influence of climate on estimated load reductions. The latest land use mapping (Department of Science, Information Technology, Innovation and the Arts, 2012) was used to describe the spatial extent of each agricultural land use for the baseline year.

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program has developed water quality risk frameworks for each agricultural industry. These frameworks articulate best practice in relation to the Reef Water Quality Protection Plan adoption targets.

These practices are described in terms of their relative water quality risk, from low to high. This is a departure from the ABCD management practice frameworks which were the basis for prioritising and reporting investments under the Reef Water Quality Protection Plan 2009.

See Management Practice methods for more information about the frameworks.

Three scenarios are run each year: predevelopment, the baseline (2013) then each subsequent year with the proportion of land managed using defined practices adjusted each year, to reflect the reported increase in adoption of improved management practices.

The proportion of land managed using defined management practices is the only variable that changes between modelled scenarios. This allows for the relative load reductions attributed to the areas of improved land management to be reported.

Fine and coarse sediment, dissolved and particulate nutrients and five photosystem II pesticides were modelled. Key land uses were modelled for the baseline scenario including grazing, cane, cropping, horticulture and forestry.

Modelled load estimates are validated against monitored data at 25 sites across the Great Barrier Reef catchments. For further information on the model validation processes, see Waters *et al*. (2014).

The catchment loads modelling program undergoes an external peer review every three years. The program was reviewed in 2012 and again in 2015. Prior to the release of each Great Barrier Reef Report Card, modelled load estimates are reviewed both internally and externally.

Management practice change

The management practice adoption frameworks describe and categorise farming practices according to recognised water quality improvements at a paddock scale. Improvements in water quality as a result of adopting improved management practices were determined by linking paddock model time series outputs to catchment models.

Management practice change has been modelled for the sugarcane, grains, horticulture, bananas and grazing areas of the Great Barrier Reef catchments. For details on how management practice changes are represented in the modelling, see the modelling technical reports volume 1-7 (references are listed in further reading below).

Investments in improved grazing management (in particular vegetation cover management) through riparian and streambank fencing was also modelled. Spatial data on the length of stream and gully fencing was provided by regional bodies.

Modelling assumptions

Loads reported for each Great Barrier Reef Report Card reflect the relative change in modelled average annual loads for the specified model run period (1986 to 2014).

- Land use areas in the model are static over the model run period and were based on the latest available Queensland Land use Mapping Program (QLUMP) data (Department of Science, Information Technology, Innovation and the Arts, 2012).
- Paddock model runs used to populate the catchment models represent 'typical' management practices for a given management class and do not reflect the actual array of management practices that occur year-to-year across the Great Barrier Reef catchments.
- Application rates of pesticides and fertilisers used to populate the paddock models were derived through consultation with relevant industry groups and regional bodies.
- Practice adoption areas represented in the model are applied at the spatial scale of the data supplied by regional Natural Resource Management bodies.
- The water quality benefits from adopting a management practice change are assigned in the year that investment occurs.
- It is important to note that these are modelled load reductions based on improved land management adoption data supplied by industry and regional Natural Resource Management groups. Therefore, results are indicative of the likely long-term water quality response due to adoption of improved land management practices for a given scenario rather than a measured reduction in load.

Linking paddock and catchment models

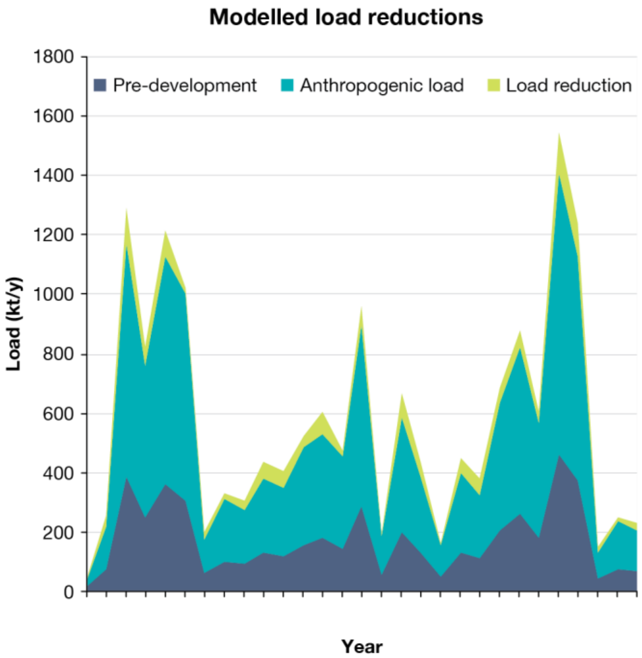
The public version of the eWater Source Catchments model was modified to incorporate hillslope constituent generation from the most appropriate paddock models for cropping and sugarcane areas, and the Revised Universal Soil Loss Equation (RUSLE) for grazing. In addition, gully and streambank erosion and floodplain deposition processes were added based on the SedNet/ANNEX approach (Wilkinson *et al*. 2014). A more detailed description can be found in Ellis and Searle (2013). These features were incorporated to better represent the erosion processes observed in the summer dominant rainfall areas of Northern Australian reef catchments.

Two approaches were used to represent improved land management practices in Source Catchments depending on the land use of interest. For sugarcane, bananas and cropping the constituent time-series (e.g. load per day per unit area) for the given land use was supplied from an output time-series from a paddock model. Unique combinations of climate, soil type and defined management practices within each land use were identified and represented spatially in the paddock model simulations used to inform catchment models. For cropping (grain cereal crops) and bananas, the HowLeaky model was used (Rattray *et al*. 2004). For sugarcane modelling, the Agricultural Production Systems sIMulator (APSIM) (Keating *et al* .2003) was used.

In the second approach, the RUSLE model has been written into Source Catchments to model hillslope soil erosion in grazing lands, where the cover term (C-factor) in the model is generated from remotely sensed ground cover satellite imagery seasonally (four scenes per year). The paddock scale model GRASP (McKeon *et al*. 1990) was used to provide scaling algorithms for each scenario to account for changes in management in each identified land type, e.g. shifting areas from moderate risk to moderate-low risk. These scaling algorithms were applied at the pixel scale to each ground cover satellite image for the modelling period. This is applied according to a spatial representation of areas of defined management practices as provided by regional Natural Resource Management groups annually. Calculations were performed pixel by pixel, with results accumulated to a single landuse representation in each sub-catchment. All loads generated for each landuse represented within a subcatchment were then aggregated at the sub-catchment scale and routed through the stream network.

Total load
The total baseline load was the load modelled within each Great Barrier Reef catchment as at 2012-13 land management. A pre-development land use map was also developed and modelled. The model was then run for a 28-year period to establish an average annual load for this period. Thus, the anthropogenic load was the total baseline load less the pre-development load.

Load reductions
The model was then re-run for the same climate period using updated proportions of lowest risk to high risk management practice areas to reflect investment in improved management practices since 2012-13. The relative change in pollutant loads from the anthropogenic baseline after investment reflects the load reduction due to changes in management practices.



Example of modelled loads for natural (pre-development), human-caused (anthropogenic) and the load reduction following investment in improved practices.

Modelling improvements
As part of the continuous program improvement, updated model input layers are incorporated when they become available. Paddock to Reef program phase 2 improvements already implemented include: seasonal ground cover, improved soils layer, extended modelling climate period and hydrology parameter updates, finer resolution topographic data and expanded water quality monitoring data sets. Improvements to the paddock modelling include more detailed modelling of bananas and grains, as well as representation of water recycling pits in the lower Burdekin region.

Gullies and stream bank erosion are modelled based on scientifically peer reviewed process understanding. Where updated gully maps are available these have been incorporated (areas included to date are the Normanby, Burdekin and Fitzroy catchments). A significant gully mapping program is continuing and further updates will be incorporated.

Pollutants losses via groundwater, such as nitrogen leaching through soils, are monitored at the Paddock to Reef farm trial sites and modelled through the paddock models. From Phase 2, the catchment modelling now represents this pollutant loss pathway as well.

How the information is reported

Progress towards Reef Water Quality Protection Plan targets is estimated by determining how much the modelled pollutant load has reduced from the average annual modelled anthropogenic baseline (total load less the pre-development load). This is calculated as a percentage reduction in average annual modelled load.

> **The average annual percentage reduction in load is calculated from:**
>
> $$\text{Reduction in load (\%)} = \frac{\text{(Anthropogenic baseline load less anthropogenic change) x 100}}{\text{Anthropogenic baseline load}}$$
>
> Where, anthropogenic baseline load = total load less pre-development load.

Modelled total suspended sediment, nitrogen, phosphorus and pesticide loads at the end of the catchment are reported for the total Great Barrier Reef and for the six regions that make up the Great Barrier Reef catchment.

The program now reports on overall toxic loads for pesticides. A pesticide toxic equivalent load is the calculated load of a pesticide multiplied by the relative toxicity of the pesticide compared to diuron.

Qualitative confidence ranking

Dissolved inorganic nitrogen

Sediment

Pesticides

A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the report card from low to high. The approach combined the use of expert opinion and direct measures of error for program components where available.

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