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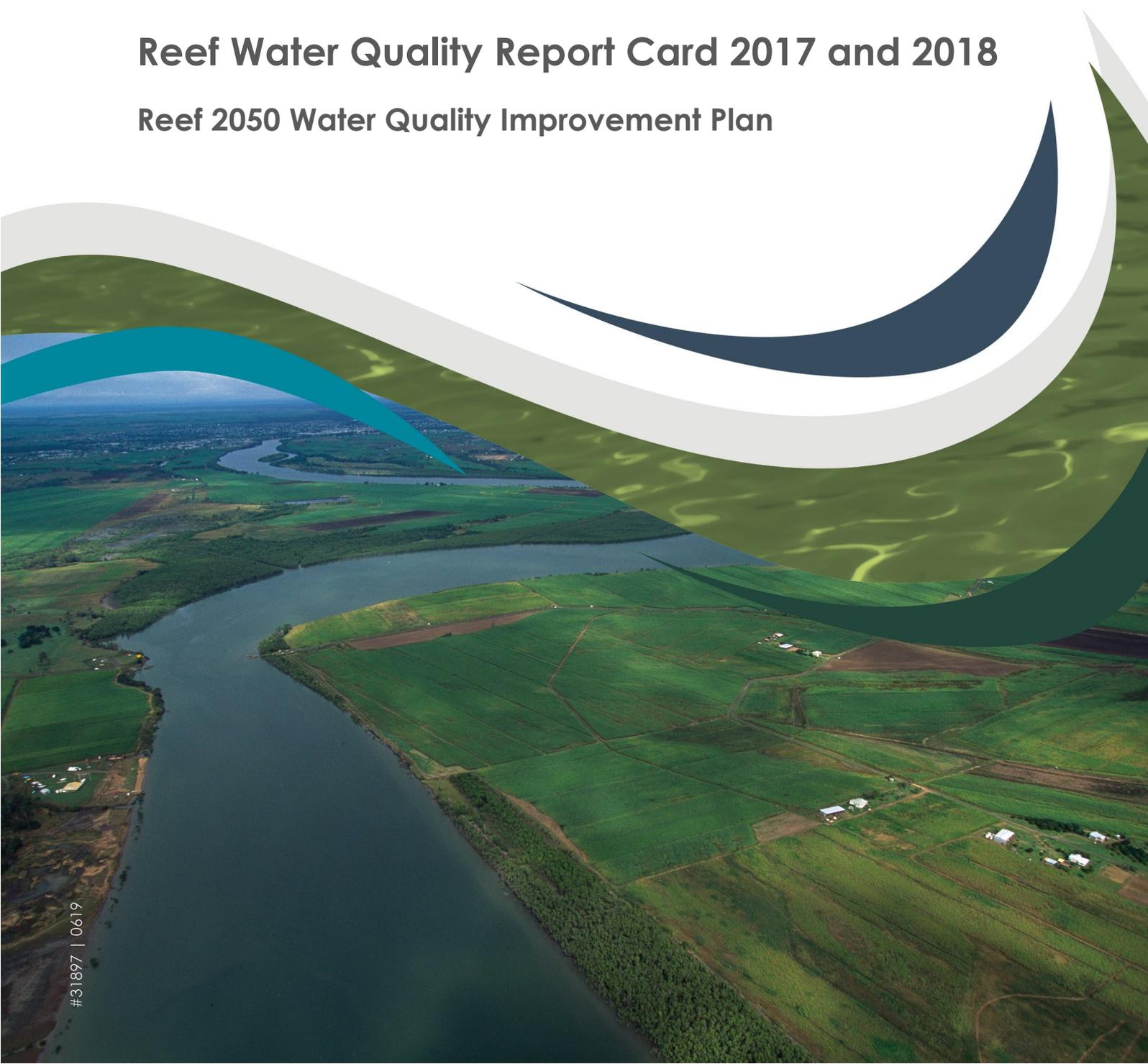
Queensland Government

# Catchment Loads Modelling

## Methods

Reef Water Quality Report Card 2017 and 2018

Reef 2050 Water Quality Improvement Plan



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# CATCHMENT POLLUTANT DELIVERY – CATCHMENT LOADS MODELLING METHODS

This report summarises the data and methods used for reporting progress toward the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) 2025 water quality targets. The catchment loads modelling program is one line of evidence used to report on progress in the Reef Water Quality Report Card 2017 and 2018.

The targets for water quality that will contribute to ecosystem health and social resilience and benefits are as follows (Australian and Queensland governments, 2018):

- 60% reduction in anthropogenic end-of-catchment dissolved inorganic nitrogen loads.
- 20% reduction in anthropogenic end-of-catchment particulate nutrient loads.
- 25% reduction in anthropogenic end-of-catchment fine sediment loads.
- Pesticide target: To protect at least 99% of aquatic species at the end-of-catchments.

## Catchment loads modelling

Quantifying the impact of land management practice change on long-term water quality through monitoring alone is not possible at the whole Great Barrier Reef (GBR) scale. Models are therefore used in conjunction with the monitoring program to predict long-term changes in water quality.

The purpose of the modelling is to report annually on the progress towards the Reef 2050 WQIP, 2025 load reduction targets for total suspended sediment (TSS), dissolved inorganic nitrogen (DIN), particulate phosphorus (PP) and particulate nitrogen (PN).

Modelling progress towards the new pesticide target will be reported from 2020 onwards and will account for the recorded progress made in 2017, 2018 and 2019. In its place, this report card will report the new [pesticide risk baseline](#) calculated from [monitoring data](#) by the catchment loads monitoring program (Australian and Queensland governments, 2019a). The new pesticide risk baseline, and future modelling, estimates the percent of aquatic species protected from 22 of the most common pesticides (photosystem II (PSII) herbicides, other herbicides and insecticides) detected in catchments and coastal ecosystems of the GBR. This is an expansion from previous modelling that reported only five PSII herbicides. The new approach estimates the cumulative risk of mixtures of the 22 pesticides based on wet season concentrations rather than an annual load, as was reported in previous years.

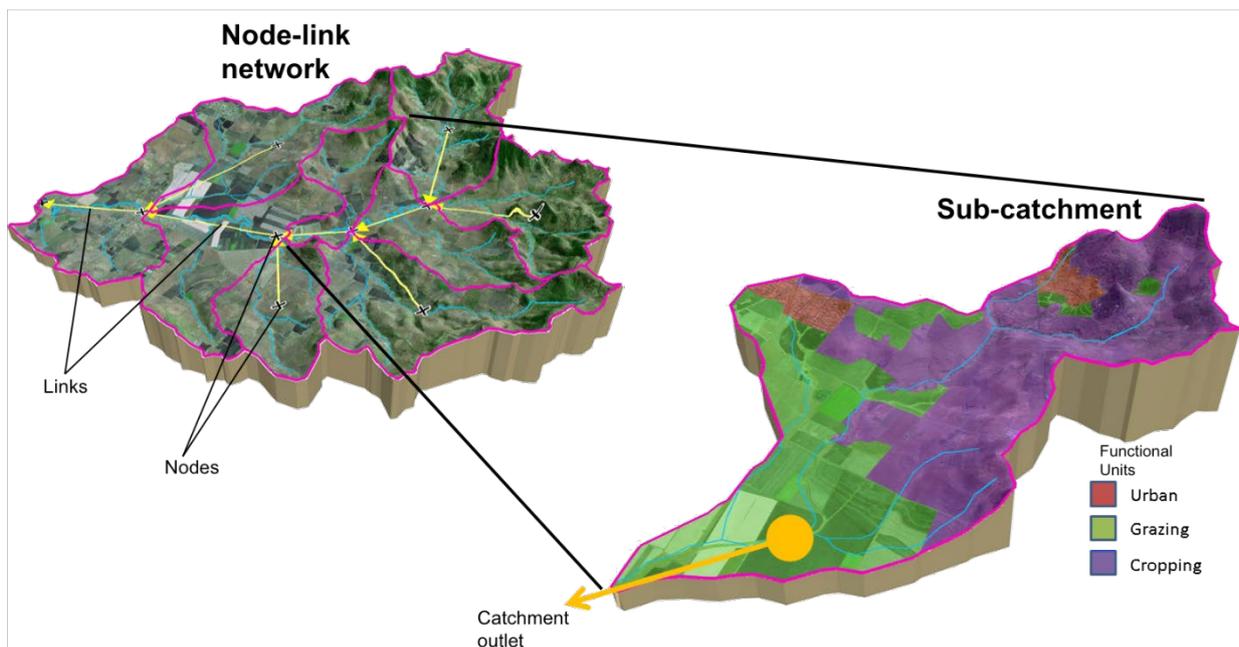
The Source Catchments modelling framework (eWater, 2010) synthesises management practice change, paddock monitoring and modelling, and catchment monitoring data to estimate end-of-catchment pollutant loads. The catchment models generate pollutant loads for current and improved practices for each individual land-use. Modelling is conducted over a fixed climate period, and enables the changes in water quality due to the implementation of improved management alone to be modelled.

Baseline loads are estimated for the current management practice benchmark (2016).

From the baseline, the reduction in loads resulting from improved management practice adoption are calculated by running the model with the new practice adoption layer for the

same 28-year modelling period as the baseline. The difference in load being the load reduction for the that investmtnet year.

Pollutant loads are summarised in the report card for the 35 basins draining to the GBR lagoon. This catchment-scale water quantity and quality model uses a node link network to represent processes of generation, transportation and transformation of water and constituents within major waterways in a catchment (Figure 1). The model generates estimates of run-off and pollutant loads for each functional unit (FUs - areas within a sub-catchment that have similar behaviour in terms of run-off generation and/or nutrient generation, e.g. land use) within a sub-catchment. Runoff and pollutants are transported from a sub-catchment through the stream network, represented by nodes and links, to the end of the catchment. These components represent the sub-catchment and waterway network.



**Figure 1. Example of a functional unit (FU) and node-link network generated in Source Catchments (source eWater)**

The Source Catchment model runs at a daily time-step which enables the interactions of climate and land management to be reflected in modelled outputs. Aggregated average annual catchment loads are required for the report card. The model runs for a fixed climate period (1986 to 2014), to remove the influence of climate on estimated load reductions. The most current land-use mapping is incorporated when models are periodically updated (details of the mapping data can be found here:

[www.qld.gov.au/environment/land/management/mapping/statewide-monitoring/qlump/qlump-datasets](http://www.qld.gov.au/environment/land/management/mapping/statewide-monitoring/qlump/qlump-datasets)).

The pollutants modelled were:

- fine sediment (TSS) and coarse sediment
- dissolved and particulate nutrients
- 22 pesticides<sup>1</sup>.

<sup>1</sup> Pesticides are normally modelled each year and the progress to target reported in each report card, however for this year, only the pesticide baselines will be reported (based on monitoring data), i.e. the modelled progress to the

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef program) agricultural management practice adoption program area has developed water quality risk frameworks for each agricultural industry. These frameworks articulate best management practice in relation to the Reef 2050 WQIP land and catchment management targets for agricultural management practice adoption. These practices are described in terms of their relative water quality risk, from low to high (A-D). See the Stewardship – Agricultural Management Practice Adoption program methods (Australian and Queensland governments, 2019b) report for more information about the water quality risk frameworks.

To reflect the modelled load reduction for each report card as a result of changes in adoption of improved agricultural management practices, three scenarios<sup>2</sup> are run:

- pre-development load (prior to agricultural development) for the 28-year modelling period. (Note hydrology is maintained as per baseline to enable load changes, due to management alone, to be quantified)
- the baseline load for the 28-year modelling period (i.e. representing the agricultural management practice benchmark 2016)
- change load for the 28-year modelling period with the proportion of land managed practice improvement adjusted to reflect the previous years adoption.

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 agricultural management practices to be reported. Approximately 10 land-uses are modelled in each region including grazing, sugarcane, cropping and bananas.

Modelled load estimates were calibrated and or validated against field data collected through the [Catchment Loads Monitoring program](#) at 43 monitoring sites across 20 catchments that discharge to the GBR lagoon. For further information on the model calibration and validation processes and results, refer to McCloskey et al. 2017A and Waters et al 2014.

The Catchment Loads Modelling program undergoes an external peer review every three to four years. The program was reviewed in 2012, 2015 and 2019. Prior to the release of each report card, modelled load estimates are reviewed both internally and externally.

## Management practice change

The Reef 2050 WQIP [management practice adoption frameworks](#) describe and categorise farming practices according to recognised water quality improvements at the paddock scale. Improvements in water quality as a result of adopting improved management practices were determined by linking paddock model timeseries outputs to catchment models.

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*pesticide target will not be reported for the Reef Water Quality Report Card 2017 and 2018. Progress made during these years will be modelled and reported in 2020.*

<sup>2</sup> A scenario describes the major processes in a river system or catchment that are modelled. This includes catchment and sub-catchment definition, rainfall runoff and constituent generation models, data sets and parameters. You can create multiple scenarios to break complex projects into distinct parts or duplicate existing scenarios to conduct what-if experiments without disrupting the original. Any change to the definition of sub-catchments, node-link network, FUs, or the models within FUs, forms a new scenario. Similarly, a different set of inputs or parameters can be used to set up a new scenario, such as a change in land use or a climate change (eWater Source User Guide 4.1).

Management practice change has been modelled for the sugarcane, grains, horticulture, banana and grazing areas of the GBR catchments. For details on how management practice changes are represented in the modelling, refer to McCloskey et al. 2017A and Waters et al 2014.

Improved management of gullies and streambanks are modelled to reflect activities such as gully restoration, excluding stock via fencing off gullies and streambanks, and installation of off-stream watering points. Spatial data on investments in improved practices are provided by industry and the six natural resource management (NRM) bodies within each region.

## Modelling assumptions

- Loads reported for each 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 are based on the latest available QLUMP data.
- Paddock model runs that are 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 GBR catchments.
- Paddock model simulations represent the reported management practice adoption water quality risk frameworks as a set suite of practices.
- Application rates of pesticides and fertilisers that are used to populate the paddock models are derived through consultation with relevant industry groups and regional NRM bodies.
- Management practice adoption areas represented in the model are applied at the spatial scale of the data supplied by the delivery organisations and collated in the Paddock to Reef Agricultural Management Practice Adoption program area.
- The water quality benefits from adopting a management practice change are assigned in the year that on-ground works were implemented, so time lags that may occur in the system are not accounted for.
- It is important to note that these modelled load reductions are based on improved land management adoption data supplied by organisations that receive funding from Reef 2050 WQIP programs. Results are therefore 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 publicly available version of the eWater Source Catchments model ([www.ewater.org.au](http://www.ewater.org.au)) was modified to incorporate hillslope constituent generation from the most appropriate paddock models for cropping, sugarcane and sugarcane areas, and the Revised Universal Soil Loss Equation (RUSLE) for grazing. Gully and streambank erosion and floodplain, channel and reservoir deposition processes added to the model were based on the SedNet/ANNEX approach (Wilkinson et al. 2014). A detailed description can be found in Ellis and Searle (2013) and Ellis (2017). The spatial and temporal representation of gully, streambank and in-stream

erosion processes were incorporated to better represent the erosion processes observed in the summer-dominant rainfall areas of northern Australia.

Two approaches were used to represent improved land management practices in the Source Catchments model depending on the land-use of interest. In the first approach, 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 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 the catchment models. For cropping (grain cereal crops) and bananas, the HowLeaky model was used (Ratray et al. 2004). For sugarcane modelling, the Agricultural Production Systems sIMulator (APSIM) (Holzworth et al. 2014) was used. For load reduction representation, the defined management practice for a particular land-use segment was altered between scenarios.

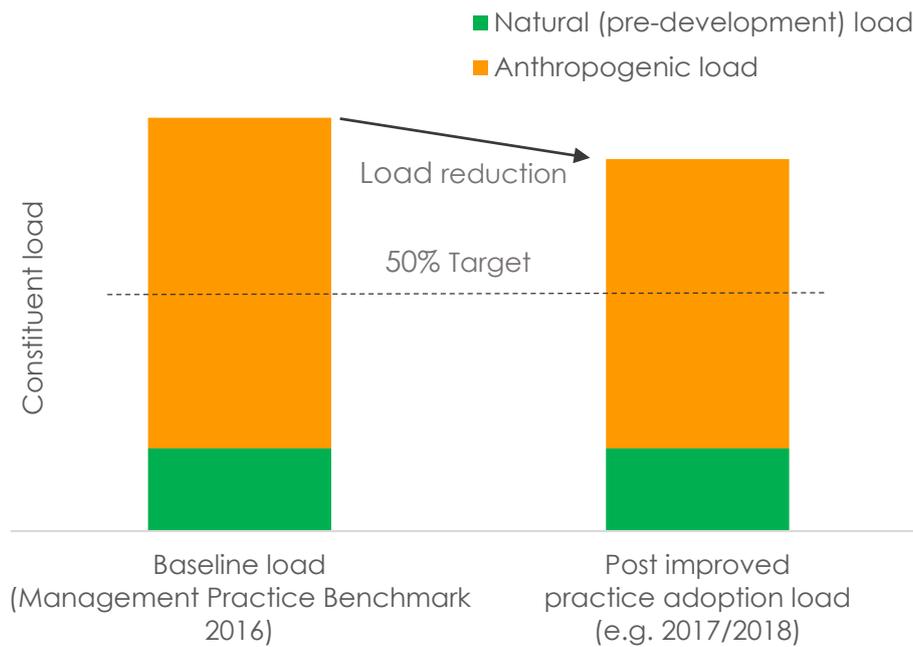
In the second approach, the RUSLE model was written into the Source Catchments model to model hillslope soil erosion in grazing lands. The cover term (C-factor) in the model is generated from remotely sensed ground cover satellite imagery seasonally (four scenes per year). The paddock-scale model GRASP (McKeon et al. 1990) was used to provide scaling algorithms for each scenario to account for changes in management in each identified land type; for example, 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 annually by regional NRM bodies. Calculations were performed pixel by pixel, with results accumulated to a single land-use representation in each sub-catchment. All loads generated for each land use represented within a sub-catchment were then aggregated at the sub-catchment scale and routed through the stream network.

## Total load

The **total baseline load** is the load modelled within each GBR catchment using the 2016 management practice benchmark. 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; **the pre-development load**. The **anthropogenic load** was calculated as the total baseline load less the pre-development load.

## Load reductions

To reflect investment in improved management practices since 2016, the model was then re-run in each year for the same climate period using the proportions of lowest risk to high risk management practice areas in that year. The relative change in pollutant loads from the anthropogenic baseline after investment reflects the load reduction due to changes in management practices (Figure 2).



**Figure 2. Example of modelled pre-development and anthropogenic pollutant loads, and the load reduction following investment in improved management practices.**

## Modelling improvements

In response to the independent external review of the program in 2015 by the Queensland Audit Office and the Great Barrier Reef Water Science Taskforce (GBRWST, 2016), improvements have been implemented in this program area in the last two years. These include:

- A desktop and field gully mapping program continues to improve the spatial representation of gully density and geometry in the models. Updated gully maps have been incorporated for selected areas within the Burdekin and Fitzroy regions and all of the Wet Tropics and Burnett Mary regions.
- Annual monitoring/modelling validation workshops are held to compare model performance against monitoring data.
- Updated land-use mapping incorporated for Wet Tropics, Fitzroy and Mackay Whitsunday regions.
- Modifications to the calculation of the cover factor in the hillslope erosion modelling to improve erosion estimates in steep, densely forested catchments.
- Updates to sewage treatment plant contributions.
- Improved alignment between modelled and actual stream location, and stream length and width.
- Updated datasets for riparian vegetation extent, streambank erodibility, floodplain area.
- Research into parameter sensitivity/uncertainty in modelled inputs and outputs is continuing to guide future data collection.

## How the information is reported

Progress towards the 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 as:**

$$\text{Reduction in load (\%)} = \frac{\text{anthropogenic baseline load} - \text{anthropogenic change}}{\text{Anthropogenic baseline load}} \times 100$$

where, anthropogenic baseline load = total load less pre-development load

Modelled TSS, DIN, PN and PP at the end of the catchment are reported for the total GBR and for the six regions that make up the GBR catchment.

## Qualitative confidence ranking

Confidence



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 expert opinion and direct measures of error for program components where available. Catchment loads modelling received a three-bar confidence ranking.

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## Glossary

**ANNEX:** Annual Network Nutrient Export model is a static model that predicts the average annual loads of phosphorus and nitrogen in each link in a river network.

**APSIM:** Agricultural Production Systems Simulator

**Agricultural Management Practice Adoption program area:** A program area of the Paddock to Reef Integrated Monitoring, Modelling and Reporting program which develops rigorous estimates of management practice adoption and annual management practice change for the major agricultural industries of the Great Barrier Reef catchments— sugarcane, grazing, horticulture, grains and bananas.

**Sediment:** Sediments in water include clay, silt, sand and coarser particulate material, and are referred to 'total suspended solids' (this is how they are measured in the water column) or 'total suspended sediment'. Sediments are characterised by different particle sizes. Not all sediment or particle size fractions present the same risk to the Great Barrier Reef, with **fine** (<20µm) **sediment** moving furthest into the marine environment, leading to increased turbidity and reduced light, and therefore posing the greatest risk.

**GRASP:** Soil water pasture growth model

**HowLeaky:** Agricultural system water balance and crop growth model based on PERFECT

**USLE:** Universal Soil Loss Equation

**C-factor:** cover management factor (**C**) in the USLE that represents effects of vegetation and other land covers

**SedNet:** Sediment River Network Model used to determine catchment sediment yields and sediment sources