Reef Water Quality Protection Plan 2013

Modelling pollutant load changes due to improved management practices in the Great Barrier Reef catchments: updated methodology and results

Technical Report for Reef Report Card 2014

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Prepared by
Gillian McCloskey
David Waters

Contact
07 42225447
07 45291395

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Executive Summary

Declining water quality from agricultural land uses, is one of the major pressures affecting the health and resilience of the Great Barrier Reef (GBR). In response to this, Reef Plan was established as a joint commitment by the Australian and Queensland governments, which sets targets for water quality improvement. The long term goal of Reef Plan is to ensure the quality of the water entering the GBR has no detrimental impact on the health and resilience of the Reef. To achieve the targets, improvements in land management are being driven by a combination of the Australian Government's reef investments, along with Queensland Government and industry led initiatives in partnership with regional Natural Resource Management (NRM) groups. Annual progress made towards the targets is monitored through the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (P2R).

Catchment modelling is one of multiple lines of evidence used to report on the progress being made towards the water quality targets. Other components of the program include: paddock scale monitoring and modelling of the effectiveness of land management practices, monitoring of the prevalence of improved practices over time, catchment loads monitoring, catchment indicators, and finally, marine monitoring. This report provides the most recent baseline load estimates and reports on progress towards Reef Plan targets for Report Card 2014 (RC2014) for all six GBR NRM regions, including modelled load reductions for sediment, nutrients, and pesticides resulting from the adoption of improved management practices. The report also provides an update on the methodology described in the 2013 catchment modelling technical reports.

The eWater Ltd Source Catchments water quantity and quality modelling framework is used to simulate how catchment and climate variables affect runoff and constituent transport by integrating a range of component models, data and knowledge. Major updates to the six GBR Source Catchment models occur on a five year cycle to align with the Reef Plan funding cycle. Major updates have occurred to the models as part of the RC2014 Source Catchments modelling. The next major update will occur in 2018. The RC2014 updates include eWater upgrades to the Source platform, upgrades to the GBR component models developed and maintained by the Queensland Government, and updates to input data sets.

These updates include recalibration of the hydrology using an alternative rainfall runoff model, an extended model run period, changes to the algorithm used on the remote sensing ground cover imagery, updates to paddock model simulations, significant changes to the management practice adoption framework, and numerous minor changes that are discussed in the body of this report.

The model run period was extended by five years and now runs from 1986–2014. The extended run period allows the models to be validated against an additional five years of monitoring data. An improved hydrological calibration performance was achieved using the Sacramento Rainfall-Runoff model in comparison to the previously used SimHyd Rainfall-Runoff model. This is especially the case for calibrating high flows, which was identified as the component of the previous calibration needing to be improved. Furthermore, the Sacramento model is used by the Queensland Government in water planning models, thus allowing calibration tools to be developed in partnership.

There were three significant changes to the ground cover inputs used in the calculation of hillslope erosion. Firstly, estimates of ground cover levels under trees have been developed, which were previously unavailable. Secondly, the temporal resolution of ground cover data has increased from one to four scenes per year. Finally, an improvement was made to how the cover term in the soil erosion models (C-factor) was derived from the remotely sensed data. Combined, these changes reduced the average cover estimates in all NRM regions by approximately 20%. This results in a higher hillslope load being generated.

Improvements were made to the sugarcane paddock model which had an impact on dissolved inorganic nitrogen (DIN) loads across the GBR. Firstly, a modification was made to the DIN generation algorithm which improved the correlation between fertiliser inputs and DIN runoff concentration. This was derived from the GBR wide pool of experimental data to improve the prediction of DIN in runoff across a season. Secondly, functionality was added to enable a proportion of the DIN reported as deep drainage from the sugarcane paddock modelling to be returned to streamflow. This approach enabled improvements to water quality as a result of reduced fertiliser application to be expressed in streamflow which was not possible previously. DIN deep drainage is known to be a major loss pathway, and the inclusion of the new approach is a major improvement to the modelling of DIN.

In the previous Report Cards, management practices were described using an ABCD management practice framework. Management practices are now described in terms of their relative water quality risk from low to high. Not all management practices are equal, and the updated frameworks allows a percentage weighting to each practice depending on its relative potential influence on off-farm water quality. Soil, nutrient, and pesticide management practices are decoupled in the new management data, meaning that a parcel of land can move from a C to B practice for nutrients, for example, without improving the soil and pesticide practices. This means there are many combinations of management practices in the paddock modelling (e.g. 15 for cropping, 39 for sugarcane in most regions). Practices such as recycling pits were also added in the Burdekin and Burnett Mary sugarcane industry.

A number of minor and regionally specific model updates were also undertaken to improve model performance. These include: an improved gully density map in Cape York, Burdekin and Fitzroy regions; instream deposition and remobilisation enabled in Cape York model; updating of constituent generation values (EMC/DWC) where additional monitored data was available within a region; and updated land use data for expanding industries such as bananas. Collectively these changes result in a better representation of catchment processes, and thus improved model performance.

The average annual baseline load for all constituents for Report Card 2014 (RC2014) are presented in Table 1.

Table 1 Baseline GBR constituent loads

TSS (kt/y)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII TE) (kg/yr)
9,398	48,275	11,868	17,972	18,435	12,045	2,294	851	8,871	7,493

Cumulative load reductions are presented in Figure 1. Reef Plan rate performance in terms of load reductions from very good to poor (refer www.reefplan.qld.gov.au). According to the Reef Plan ratings, 'very good' progress has been made towards the fine sediment load reduction target of 20%. The estimated cumulative reduction across the GBR is 12%, with the BU region reporting a cumulative reduction of 17%. 'Very good' progress is also reported for PP reduction, which is well over half way towards the target at 14.5%. The WT is the only region to have reached the PP reduction target having achieved a 20.5% reduction. For PN the estimated cumulative reduction is 11.5%, which is classified as 'good' progress, with the BU region showing the greatest progress with a reported 15% reduction thus far. Progress towards the DIN target of 50% is classified as 'poor' as it stands at 17% for RC2014. Only the Burnett Mary region is making 'very good' progress at 31.5%. Finally, reduction in PSII TE load is rated as 'good' with a reduction of 30.5% across the GBR. Progress was greatest in the MW region with a 41% reduction in PSII TE thus far. In summary, progress is being made towards the Reef Plan water quality targets. There is room for improvement for further reductions in DIN loads in the WT where progress was rated as 'very poor' at 14.5%; similarly for the Fitzroy and BM regions for fine sediment, both recorded 'very poor' progress at 4.5% and 3% respectively.

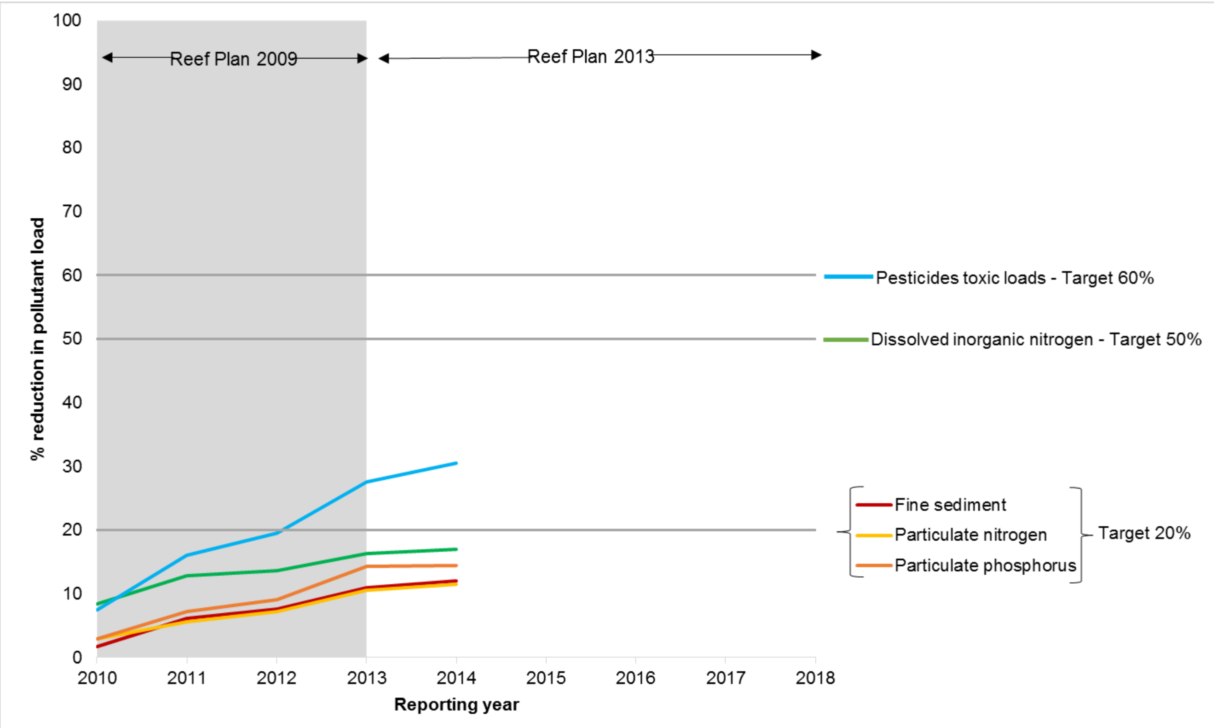


Figure 1 Progress towards Reef Plan targets to 2014 for the whole of GBR

The current modelling framework is flexible, innovative and fit for purpose. The RC2014 catchment modelling is considered to be a substantial improvement on previous modelled GBR load estimates with a consistent methodology adopted across all NRM regions. The model is appropriate for assessing load reductions due to on-ground land management change. Areas for further improvement include re-calibration of hydrology to better represent the baseflow portion and ongoing incorporation of new science and mapped data.

Table of Contents

List of Tables

List of Figures

Acronyms

Acronym	Description
BM	Burnett Mary
BU	Burdekin
CY	Cape York
DIN	Dissolved inorganic nitrogen
DIP	Dissolved inorganic phosphorus
DNRM	Department of Natural Resources and Mines
DON	Dissolved organic nitrogen
DOP	Dissolved organic phosphorus
DR	Delivery ratio e.g. HSDR hillslope delivery ratio
DS	Dynamic SedNet—a Source Catchments 'plug-in' developed by DNRM/DSITI, which provides a suite of constituent generation and in-stream processing models that simulate the processes represented in the SedNet and ANNEX catchment scale water quality model at a finer temporal resolution than the original average annual SedNet model
DSITI	Department of Science, Information Technology, and Innovation
DWC	Dry weather concentration—a fixed constituent concentration to base or slowflow generated from a functional unit to calculate total constituent load
EMC	Event mean concentration—a fixed constituent concentration to quickflow generated from a functional unit to calculate total constituent load
EOS	End-of-system
FRCE	Flow Range Concentration Estimator—a modified Beale ratio method used to calculate average annual loads from monitored data
FU	Functional Unit
FZ	Fitzroy
GBR	Great Barrier Reef
GBRCLMP	Great Barrier Reef Catchment Event Monitoring Program (supersedes GBRI5)
HowLeaky	Water balance and crop growth model based on PERFECT
LH	Lyne-Hollick baseflow
MW	Mackay Whitsunday
NRM	Natural Resource Management
NSE	Nash Sutcliffe Coefficient of Efficiency
P2R	Paddock to Reef Integrated Monitoring, Modelling and Reporting Program
PN	Particulate nitrogen
PP	Particulate phosphorus
PSII herbicides	Photosystem II herbicides—ametryn, atrazine, diuron, hexazinone and tebuthiuron
PSII TE	PSII herbicide Toxic Equivalents—the total load of PSII herbicides weighted for their toxicity
RC2–RC5	Report Card 2 (Report Card 2010) through to Report Card 5 (Report Card 2013) - published outputs of Reef Plan/Paddock to Reef
Reef Rescue	An ongoing and key component of Caring for our Country. Reef Rescue represents a coordinated approach to environmental management in Australia and is the single largest commitment ever made to address the threats of declining water quality and climate change to the Great Barrier Reef World Heritage Area

Acronym	Description
RUSLE	Revised Universal Soil Loss Equation
SedNet	Catchment model that constructs sediment and nutrient (phosphorus and nitrogen) budgets for regional scale river networks (3,000–1,000,000 km^2) to identify patterns in the material fluxes
TSS	Total suspended sediment
TN	Total nitrogen
TP	Total phosphorus
WT	Wet Tropics

Definitions of sources and sinks

Supply Definitions

Particulate

Hillslope: Source of TSS, PP and PN supplied to the stream network by surface erosion processes (surface and rill erosion).

Gully: TSS, PP and PN supplied to the stream network by gully erosion processes).

Streambank: TSS, PP and PN supplied to the stream network by streambank erosion processes.

Channel remobilisation: TSS, PP and PN supplied by channel remobilisation processes.

Dissolved

Diffuse dissolved: Source of dissolved constituents supplied to the stream network from all land uses.

Seepage: Dissolved constituents supplied to the stream network from sugarcane via subsurface loss pathways.

Point source: Dissolved constituents supplied to the stream network from point sources; in this case Sewerage Treatment Plants (STP).

Loss Definitions

Storage deposition: TSS, PP and PN losses via the process of particle settling and resultant deposition in storages.

Floodplain deposition: TSS, PP and PN losses via the process of particle settling and resultant deposition in on floodplains.

Storage decay: Dissolved constituents lost via the process of decay processes.

Extraction: Dissolved and particulate constituents lost via extraction, (e.g. pumped losses for irrigation, stock or domestic water supplies) from the stream network.

Stream deposition: Particulate constituents lost to the stream network via instream and resultant deposition.

Modelling assumptions

The key modelling assumptions to note are:

- Loads reported for each scenario are the modelled, or estimated, average annual load for the specified model run period (July 1986 – June 2014).
- Land use areas in the model are static over the model run period and were based on the latest available QLUMP data in each NRM region.
- The predevelopment land use scenario includes all water storages, weirs and water extractions are represented as in the baseline model. There is no change from the baseline scenario hydrology. This approach was undertaken upon the advice of the Independent Reef Science Panel (ISP), to isolate changes to water quality which are due solely to a change in land management practices.
- Paddock model runs used in the catchment models represent 'typical' management practices in each management class and do not reflect the actual array of management practices being applied on a particular area of land. This applies to application rates of herbicides and fertilisers used to in the paddock models which were derived through consultation with relevant local industry groups and technical experts in each region.
- Distribution of baseline land management practices is not able to be captured (in its entirety) in a spatial format. Regional and sub-regional estimates of this distribution have been made, and these estimates are used as required in the preparation of the data inputs for the baseline scenarios used for each report card. The distribution will vary between reporting years, to accommodate the reported land management improvements that get supplied in spatial format.
- All land management improvements to be represented in the relevant scenarios are supplied in a spatial format. This data is used to inform the data preparation for the necessary scenarios. In situations where the spatial data does not coincide with a representative modelling unit, the land management improvement is reallocated to the nearest suitable location for grazing and riparian investment. For cropping and cane management improvements, the area of improvement that is not coincident with a relevant modelling unit is applied evenly throughout the relevant region or sub-region for that industry.
- Water quality improvements for the horticulture, dairy, and cotton industries are currently not modelled due to a lack of management practice adoption data and limited experimental data on which to base load reductions, and also the small area these industries occupy.
- Modelling of the banana industry and the associated water quality improvements have been included in the Wet Tropics and Cape York models in Report Card 2014.
- Dissolved inorganic nitrogen (DIN) load reductions are modelled for sugarcane systems with APSIM. DIN load reductions are not modelled in grain systems as no DIN export are provided from these simulations and few if any investments are made.
- The number of paddock model simulations available to represent the vast array of possible management practices within each region has increased markedly from the simple 'ABCD' approach used prior to RC2014. The increase in available simulations allows many more

management improvements to be represented, however these are often representing changes to processes that yield a small benefit in terms of reducing pollutant generation. As a result the estimated loads reductions associated with this more detailed paddock modelling regime are significantly smaller than experienced previously. The smaller load reduction estimates are considered to be more accurate and reliable than estimates made using the old, limited suite of simulations.

- For land uses that require spatially variable data inputs for pollutant generation models (USLE based estimates of hillslope erosion and SedNet-style gully erosion), data pre-processing captures the relevant spatially variable characteristics using the specific 'footprint' of each land use within each sub-catchment. These characteristics are then used to provide a single representation of aggregated pollutant generation per land use in each subcatchment.
- Groundwater movement to streams is not explicitly modelled. Groundwater to streams is represented as the product of a calibrated baseflow and 'dry weather concentrations' (DWC) of constituents. However, these loads are not subject to management effects.
- For RC2014, a proportion of the sugarcane DIN load lost to deep drainage through leaching beyond the root zone can now be delivered to the stream to represent lateral or seepage flow. The proportion of seepage load delivered to the stream is calibrated for the baseline to improve the alignment of modelled and measured DIN loads at the closest load monitoring gauging station. The loads will vary with the given management practice simulated.
- It is important to note that this report summarises simulated, not actual, average annual load reductions of key constituents to the GBR lagoon. The modelled changes in water quality are a function of the area of improved land management adoption. Estimates of adoption areas are supplied by regional NRM groups. Results from this modelling project are therefore a useful indicator of the likely (theoretical) effects of investment in changed land management practices rather than a measured (empirical) reduction in loads.

Introduction

The Great Barrier Reef (GBR) is the world's largest living organism, and one of the seven natural wonders of the world. However, the health and resilience of the GBR is under threat from many pressures including declining water quality and climate change. Over the past 150 years, the GBR basins have been extensively modified for agricultural production and urban settlement, leading to a decline in water quality entering the GBR lagoon (Brodie et al. 2013). The largest contribution of poor water quality comes from agricultural land use activities within the GBR basins (QDPC, 2013). Poor water quality, by way of high sediment, nutrient and pesticide loads, can affect the GBR ecosystem by reducing light availability, smothering corals, promoting algal growth and propagating crown of thorns (COTS) starfish outbreaks by increasing plankton blooms on which the COTS larvae feed (GBRMPA 2016).

The Reef Water Quality Protection Plan (Reef Plan) was established in 2003, updated in 2009 (Reef Plan 2009 (QDPC, 2009)) and again in 2013 (Reef Plan 2013 (QDPC, 2013)) in response to the decline in water quality entering the GBR lagoon. Reef Plan is a collaborative program that includes a set of water quality and land management practice targets for catchments discharging to the GBR. The long-term goal is to ensure the quality of water entering the GBR has no detrimental impact on the health and resilience of the Reef. The plan is a joint commitment of the Australian and Queensland Governments.

The Paddock to Reef Integrated Monitoring, Modelling and Reporting (P2R) Program provides the monitoring and evaluation framework to measure and report on progress towards the Reef Plan water quality targets. Monitoring and evaluation is undertaken for a range of targets including water quality targets in the annual Reef Report Card. These targets will be reviewed in 2017 and basin scale water quality targets will be set. The Report Cards show cumulative progress towards the Reef Plan 2013 water quality targets resulting from regional investments in improved land management practices each year. Five previous report cards (Report Cards 2009–2013) have been released (www.reefplan.qld.gov.au) tracking the progress being made towards the Reef Plan targets. The Reef Plan 2013 water quality targets were set for the whole of GBR. Progress was reported for the whole of GBR plus the six contributing NRM regions: Cape York (CY), Wet Tropics (WT), Burdekin (BU), Mackay Whitsunday (MW), Fitzroy (FZ) and Burnett Mary (BM).

The Reef Plan 2013 water quality targets state that by 2018 there will be:

- a minimum 20% reduction in anthropogenic sediment and particulate nutrient loads at the end of catchment in priority areas
- a minimum 50% reduction in anthropogenic dissolved inorganic nitrogen (DIN) loads at the end of catchment in priority areas
- a minimum 60% reduction in pesticide loads at the end of catchment in priority areas

The Reef Plan 2009 targets were updated to be more specific about which nutrient species load reductions are aimed at, for example identifying DIN as a key target for water quality improvement.

Catchment modelling is used as one of multiple lines of evidence to report on progress towards the Reef Plan water quality targets. In this technical report the Report Card 2014 (RC2014) modelled load reductions resulting from the adoption of improved land management practices for the 2014 year are summarised for the GBR and for the six NRM regions, and model updates are outlined.

This report outlines:

- Changes to Source Catchments water quantity and quality modelling methodology
- Updated predevelopment, baseline and anthropogenic loads for the 1986–2014 climate period
- Progress towards meeting Reef Plan 2013 water quality targets following the adoption of improved management practices.

Model improvement cycle

The Paddock to Reef (P2R) Program strives for continual improvement in all areas. Therefore, the catchment and paddock modelling teams aim for continual improvement in the modelling approach to improve predictions of pollutant loads and the associated improvements in water quality resulting from improved practice adoption.

In Table 2 the catchment modelling cycle is presented, with the green highlighted cell indicating the current Report Card (RC2014). Phase 1 relates to the Reef Plan 2 period, which covers the models produced from 2010–2013. Report Card 2009 provided the first GBR-wide load estimates of predevelopment, total baseline and total anthropogenic loads using the best available monitoring and modelling data at the time (Kroon et al. 2010). Subsequent Report Cards used the Source Catchment modelling framework to report on load reductions due to adoption improved practices. Major updates to the Source Catchment models occur on a five year cycle to align with the Reef Plan funding cycle. Minor changes occur between the individual Report Cards, where required. RC2014 is the first major rebuild. All model updates will be discussed at length in this Report. A major improvement which will impact on the modelling is the new management practice adoption framework. This is important to note, because a new management practice baseline year was also set at 2013 to align with the development of the new framework. The baseline year was previously 2009 in Phase 1. Other updates include improved hydrology recalibration, paddock and catchment model data sets, and rebuilding of models in a new Source Catchment modelling platform. Each successive Report Card is considered the best representation of load estimates generated from each GBR NRM region, and the most recent Report Card should always be used when reporting or referencing Source Catchments GBR load estimates. A full summary of model changes for RC2014 are listed in Table 3.

Table 2 Summary of catchment modelling cycle

Phase 1 Modelling 2009 - 2013		**Management Practice data baseline year and climate period**
Report Card 2009	Kroon et al. (2012) model results	2009 1986 to 2009
Report Card 2010	Model build; hydrology calibration;	
Report Card 2011	Minor model changes	
Report Card 2012	Minor model changes	
Report Card 2013	Minor model changes	
Phase 2 Modelling 2014 - 2018		
Report Card 2014	Major model changes; update Source platform; hydrology recalibration; incorporate new management practice framework, climate period for reporting extended	2013 1986 to 2014
Report Card 2015	Minor model changes; hydrology calibration modified for better alignment of baseflow in some regions	
Report Card 2016	Minor model changes (if required)	
Report Card 2017	Minor model changes; research major changes for post RC 2018 rebuild	
Report Card 2018	Minor model changes; research major changes for post RC 2018 rebuild	

Integrating modelling and monitoring

Modelling is a way to extrapolate monitoring data through space and time, and provides an opportunity to explore the climate and land management interactions and their associated impacts on water quality. Monitoring data, where it has been well collected and analysed to be representative of the sampling location, is the most important point of truth for model validation and parameterisation (refer to www.reefplan.qld.gov.au/measuring-success/paddock-to-reef/catchment-loads/ for information on both the P2R catchment modelling and monitoring programs). With the continuation of the Reef Plan projects, increased monitoring data becomes available, and as such, the models become more refined and a better representation of reality as they aim to integrate the sum of all information (measured and modelled data). Given the scale of the P2R program and its objectives, it would be impossible to measure the impact of land management practice change on water quality, hence models are applied that can predict changes in water quality when set against a baseline or benchmark (in this case the model run period of 1986–2014). The baseline model for each region contains the 2009 land use data (except for CY where it has been updated to 2013), and management practice data as at June 2013.

Combining the two programs (catchment modelling and monitoring) ensures continual improvement in the models while at the same time identifying data gaps and priorities for future monitoring. A key example of this is the recent endorsement by the Independent Science Panel of 16 new monitoring sites as part of the GBR Catchment Loads Monitoring Program. The selection of these sites involved consultation with other Reef Plan programs, catchment modellers, and each regional NRM body. The addition of the 16 sites means that 20 of the 35 GBR basins are now monitored, and measure approximately 95% and 89% of the TSS and DIN loads (respectively) discharged to the GBR lagoon.

Application of modelling outputs

While the sole objective of the Catchment Modelling Program is to report on changes to water quality discharging to the GBR lagoon as a result of improved land management practices, the modelled load estimates have been used by a number of other Reef funded Programs. A key process that has utilised the results of the catchment modelling is the development, or updating, of Water Quality Improvement Plans (WQIP) for a number of NRM regions. For example, the CY data has been used in developing targets for maintaining water quality in the first WQIP developed for that region (CYNRM). In regions such as the BU and WT, WQIPs have long been established but the latest modelling data has been incorporated to updated plans to provide an indication of current condition, as well as to set targets or limits for water quality.

Other applications for the modelled data include the use of the model outputs to provide cost estimates to achieve the Reef Plan water quality targets (Alluvium 2016). Catchment modelling outputs have also be used as an input to the eReefs receiving water models (www.ereefs.org.au), which aims to build comprehensive coastal information systems for Australia. The eReefs program will use the latest technologies to collate data, provide visualisation tools using new and integrated modelling, as well as providing communication and reporting tools.

Bartley et al. (2015) utilised the catchment modelling outputs in a streambank erosion handbook, used to prioritise investments areas in GBR catchments. In the Burnett Mary region, a bio-economic model was developed to assess the impacts of alternative land management practices on both profit and constituent loads, to assess the feasibility and cost of achieving water quality targets (Beverly et al. 2016). Catchment model outputs have also been used to inform discussion on priority investment areas in the GBR with regard to delivering Reef Plan water quality targets (Barson et al. 2014) and also for a relative risk assessment to GBR ecosystems (Waterhouse et al. 2012). The uses of the modelled data are wide-ranging, however the models were developed for the specific purpose of reporting load reductions due to improved management practice at the average annual scale; therefore caution should be exercised when using the models for alternative purposes.

Quality assurance and peer review

At the inception of the program, the eWater CRC best practice modelling guidelines (Black et al. 2011) were used to develop the modelling approach and quality assurance process as described in Waters and Carroll (2012). A systematic model build process has been developed by the catchment modelling team, which is presented in Figure 2. Modelled loads generated for annual reef report cards are reviewed in the first instance internally by scientists from DNRM and DSITI. Once approved, loads and the associated reductions are reviewed externally, before final approval by the Queensland Government. A Coordination and Advisory Group (CAG) and an Independent Science Panel (ISP) oversee model development and proposed updates or changes (see Waters and Carroll (2012) for description of project governance arrangements). An external review of the catchment and paddock modelling is required every three to five years. The first was in 2012 (Jakeman et al. 2012) the second in 2015 (Jakeman et al. 2015). In addition the Queensland Audit Office undertook a review of the P2R Program in 2015 (Queensland Audit Office, 2015). Recommendations from the peer review process and the Audit form the basis for model development and improvements.

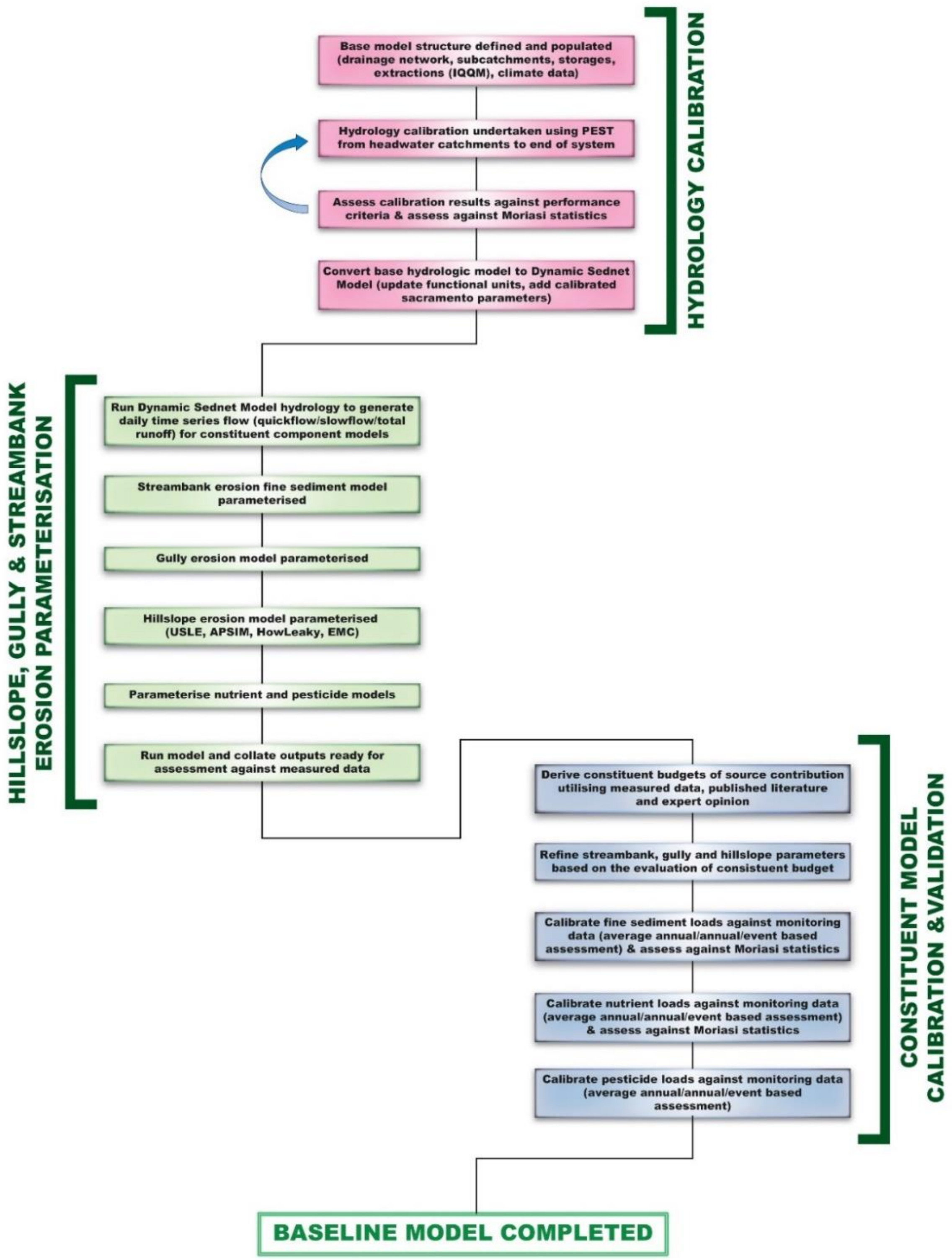


Figure 2 Model build process

Methods

The Source Catchments water quantity and quality modelling framework is used to simulate how catchment and climate variables affect runoff and constituent transport, by integrating a range of component models, data and knowledge. Between Report Card releases there have been several upgrades to the Source Catchments platform, developed and maintained by eWater Ltd. In conjunction with the eWater upgrades, there have been several upgrades to the GBR component models maintained by DNRM. The timing of upgrades are summarised in Table 2 and updates specific to RC2014 are described in detail below. Those methods that have not changed since the previous Report Card are not discussed, but rather can be found in the series of previously released Technical Reports completed following post-2013 Report Card (refer Waters et al. (2014) and the six supplementary regional reports).

Table 3 Model updates undertaken for RC2014

Modification	Rationale	Impact	Report page number
Migration to latest Source modelling framework	• GBR models previously built and run in an older version of software • New functionality available in updated version	No change to model results.	N.A.
Higher resolution DEM to derive subcatchment network	• Improved delineation of catchment boundaries, particularly in flat, coastal areas	• Better representation of the flow paths and spatial distribution of runoff	33
Extended model run period	• Extended model run period for reporting from 1986–2009 to 2014. Incorporated wet years 2010–2012 and extension provided an additional 5 years of monitored data to validate model	• Extended validation period improved confidence in modelled load estimates by including the extremes for wet and dry years	35
Hydrology recalibration using Sacramento	• Published literature suggests improved calibration performance using Sacramento • Sacramento used by Qld Government for water planning models • Opportunity to extend calibration period from 1970–2009, to 1970–2014	• Significantly better high flow calibration across all basins • Difference between measured and modelled flow reduced from ± 30% to ± 10%	35
Single gauge hydrology calibration	• Improvement in process coupled with other hydrological recalibration factors • In-line with water quantity modelling within DNRM for water planning purposes	• Single gauge calibration allows for parameters to be fixed before moving downstream and recalibrating next region • Error is not accumulated downstream	35
Utilised remotely sensed ground cover estimates under trees	• For previous report cards, remotely sensed ground cover estimates were not available under heavy canopy areas (35%	• Now have remotely sensed ground cover estimates for 95% of the GBR, which was previously 35%.	38

Modification	Rationale	Impact	Report page number
	of the GBR), now available in 95% of the GBR. • Improved analysis techniques have enabled estimates under treed areas	• This has enabled models to adopt the USLE model in excess of 90% of the GBR	
Modified calculation of C-factor from remotely sensed ground cover index estimates	• Algorithm used to convert the GCI estimate to ground cover was modified to adjust for differences between objective and visual estimates	• Average annual cover across basins was reduced by up to 20% • Resulted in increased hillslope erosion rates	38
Move from annual to seasonal cover	• Improved temporal resolution of remotely sensed cover layers. Now using four scenes as opposed to one scene per year	• Improved inter-annual erosion patterns	38
Updated gully density layers in CY, BU and FZ models	• NLWRA layers used previously recognised to be a poor representation of gully density. • Gullies a major contributor to fine sediment loads from GRB catchments	• Improved spatial representation of gully locations and density	41
Refined APSIM DIN generation algorithm for sugarcane	• Aimed to improve the correlation between fertiliser inputs and DIN runoff concentration. Pool of GBR wide experimental sugarcane DIN runoff data available to improve predictions of DIN concentrations in runoff	• Better prediction of DIN paddock loads across a season	43
Added functionality to enable a proportion of sugarcane DIN deep drainage load to be returned to the stream to represent lateral or seepage flow	• Deep drainage is a major loss pathway for DIN in sugarcane which was not previously represented in the model	• DIN loads better align with monitored data • Improved management now reflected in lateral/seepage loads	43
Capture of irrigation tail water into recycle pits in sugarcane in BU and BM	• Not previously modelled • Tail water recycle pits are a practice that can attract funding	• Reduction in DIN loads exported to streams	43
Banana module developed in HowLeaky to account for water quality improvement investments	• Previous Report Cards did not explicitly model bananas • Representing banana management practices and investment significant in WT and CY	• Better representation of constituent generation for bananas regionally and temporally	43
HowLeaky modelled loads corrected for slope	• Previous paddock model simulations generated loads for constant 1% slope, and outputs adjusted to local slope during loading into Source • HowLeaky outputs now corrected to account for slope	• Increase in paddock modelled loads for cropping areas • In most basins cropping not a major contributor to overall constituent budgets hence small impact on loads exported	43
EMC/DWC concentration values refined where applicable in the model	• Additional three years of monitoring data provided opportunity to recalculated values and update model with a larger pool of data	• Improved estimates of constituent generation for those land uses/constituents that use an EMC model	43
Changes to the management practice data collation and representation	• Management practice was previously given an ABCD rating, now it is ranked as a risk to water quality from low to high • Each management practice now weighted	• Baseline management data redistributed • Reductions in loads likely to be smaller than for previous report cards since	45

Modification	Rationale	Impact	Report page number
	• Management practices for soils, nutrients and pesticides distinguished from one another	practices for soil, nutrients and pesticides can move management class, without moving the whole farm management class	
Land use layer updated in CY to 2013	• Includes rapidly expanding banana areas; plus increased areas of nature conservation	• Improved representation of land use	48
Instream deposition and remobilisation enabled for CY	• Instream deposition and remobilisation have not been enabled in the models previously. • Both processes are known to be important and the pool of data to evaluate against this component is increasing	• Increased sediment and particulate nutrients lost as instream deposition • Some sediment and nutrients now also remobilised	51

The methodology updates described below are split into two sections: updates applied across all of GBR models, and regionally specific updates, listed under each NRM region headings.

GBR methodology updates

Subcatchment delineation

In RC2014 data inputs derived from Digital Elevation Models (DEM) were re-produced from a new data source, the Geoscience Australia provided '1 second SRTM Derived Digital Elevation Model', re-projected and re-sampled to 30 metre pixels (Gallant et al. 2011). For identification of major stream networks (and resulting subcatchment identification for Source Catchments network creation) the SRTM DEM-H (hydrologically enforced) product was used. With some minor modifications to this data set, the resulting stream (and subcatchment) network was able to better represent the known stream patterns in some modelling regions, particularly in very flat areas. In this process, some flat coastal areas were not captured as the contributing area to any identifiable stream fell beneath the automated threshold. In order to include these coastal areas, they were added manually to the DEM derived subcatchment layer in a GIS environment, based on drainage data and imagery, as per previous Report Card modelling. This improves regional estimates of aggregated GBR export loads due to the more accurate representation of the subcatchment and basin boundaries (i.e. coastal areas are not excluded from the NRM boundary), and also helps to improve confidence in estimated in-stream processing of water and pollutants due to the inclusion of the otherwise absent coastal streams. Minor changes to total model area have occurred due to the use of an improved DEM, and subsequent subcatchment network generation, as described above, as well as the change in projection to standard Australian Albers coordinate system (GDA94). A summary of changes between RC2013 and RC2014 to the number of subcatchments and average subcatchment area, due to the higher resolution DEM, is presented in

Table 4.

Table 4 Summary of number of subcatchments and average subcatchment area for each GBR NRM region

Region	Number of subcatchments RC2013	Average area (km^2)	Number of subcatchments RC2014	Average area (km^2)	Total area (km^2) RC2013	Total area (km^2) RC2014
CY	546	78	551	78	42,988	43,009
WT	450	48	517	42	21,722	21,707
BU	1,568	86	1,718	82	142,317	140,602
MW	191	47	203	44	9,130	9,029
FZ	1,798	87	1,917	81	156,286	156,102
BM	597	88	682	78	52,818	53,031

To improve data inputs for pollutant generation models, the SRTM-S (smoothed) product was used. Key topographic inputs for the Revised Universal Soil Loss Equation (slope and slope-derived parameters) were re-created for the entire GBR modelling region. Raster data sets representing soil properties were also recreated using a raster environment (extent and pixel size) matching that of the re-projected SRTM-S product. The hydrologically enforced DEM ensures that catchment delineation will extend from river mouth to head waters in an un-interrupted manner, however this assurance does increase the probability of artefacts being introduced that might impact other DEM derivatives, such as slope. For this reason, the non-hydrologically corrected but 'smoothed' DEM was used for all other landscape derivatives.

Incorporation of gauging stations and additional nodes in the network

Apart from the DEM, a point shapefile of gauging station locations and other miscellaneous locations of relevance was incorporated into the subcatchment generation process. The number and location of the additional nodes is determined by the number and location of gauging stations used for validation, loss, extraction and environmental demands required to be represented in the models for each region.

Flow data used for recalibration was extracted from DNRMs Hydstra Surface Water Database to provide the 'observed' flow values for recalibration. The following criteria were used to select appropriate gauging stations for recalibration:

- Located on the modelled stream network
- Minimum of 10 years of flow record (post 1970) with suitable corresponding quality codes

The number of gauges used in the previous report card and RC2014 recalibration are presented in Table 5. The number of gauges used in calibration decreased in CY, FZ and BM, while the number of gauges increased in the remaining regions. In the CY, BM and FZ regions, the reduction in calibration gauging stations was based on the realisation that some of the gauges in the RC2013 calibration were redundant as they represented very small areas that could be calibrated by a downstream gauge. In the FZ region, the large number of gauges was reduced to rationalise calibration time due to the increased processing time of the Sacramento model. In the SimHyd calibration the FZ region had 62 gauges calibrated, 25 more gauges than the BU. The reduction of gauges for calibration in the FZ region and increase in gauges for the BU was possible due to the availability of the HPC, which could handle the increased processing time for the Sacramento Rainfall-Runoff model (due to the increased number of parameters). It was not possible to calibrate all 62 gauges for the FZ region using Sacramento, even with the increased computing power of the high performance computer (HPC). In the WT, MW and BU regions the number of gauges was increased to improve spatial resolution of gauges. A HPC was used for calibration. The latest calibration statistics indicate that the calibration was not compromised where fewer gauges were used.

Table 5 Number of gauges used in recalibration for RC2014 (Sacramento) and the previous Report Cards (SimHyd)

Region	Sacramento	SimHyd
CY	15	18
WT	30	21
BU	46	37
MW	10	9
FZ	44	62
BM	29	32

Climate simulation period

The model run period has been extended from 1986-2009 to 1986-2014 (28 years). This extension has enabled an additional five years of loads monitoring data to be included for model validation. Importantly the extended period includes the extreme flood events of 2010-2011. The extreme wet years provide additional calibration points at the high flow end, important for improving load predictions.

Hydrology calibration

Hydrology calibration is a major focus of ensuring accurate constituent load modelling, given that constituent generation is largely driven by rainfall and runoff. In the previous Report Cards (2010–2013) the SimHyd rainfall-runoff model was applied for runoff prediction. SimHyd was chosen due to its extensive application and proven performance to satisfactorily estimate streamflow across Australia (Chiew et al. 2002) including a large catchment in the GBR (Ellis et al. 2009). However the calibration resulted in some large difference between observed and predicted runoff predictions (up to 30% bias) and misalignment in simulated peak flow and recession curves for large flow events for numerous gauging stations. Zhang et al. (2013) found that Sacramento rainfall-runoff model achieved lower bias of total flow volume compared to SimHyd. Importantly, the revised method achieved better results in the simulation of the recessions of the flow hydrograph, peak flows and the timing of big events compared to SimHyd. Large events are the major contributors to sediment load generation and export for GBR catchments, thus improving the simulation of large events was the main objective of recalibration.

Sacramento rainfall-runoff model calibration

A Source project file which configures the 2-dimensional catchment network including link, node and gauge locations was used to simulate the hydrology in the catchment. The rainfall-runoff model used for simulating the hydrology was the "Sacramento with Lag Unit Hydrograph" model. Flow routing was simulated for each sub-catchment by using the "Storage Routing with Reach Length Modifier" model option developed as part of the GBR specific suit of tools. Two parameters are used in the routing model to simulate the flow routing processes, the Routing Power (m) and the Routing Constant (k). The Routing Constant (k) for a particular reach in the catchment is calculated as the product of the 'regional constant' and the 'reach length', thus providing each link with a unique routing constant parameter value (k) whilst presenting fewer, regionally varying, parameters to the calibration process. The reach lengths were calculated from the raster data set representing streams that were produced during the sub-catchment identification process. To simplify calibration, 11 land use types were grouped into two land use groupings, forest and non-forest, with two sets of Sacramento parameters derived upstream of each calibration gauge for the two land use groupings . The Lower Zone Tension Water Storage parameter (LZTWM) was the only parameter which differed between these land use types and was forced to always be larger for forested areas than non-forested with the assumption that deep rooted vegetation would have a larger water store than the shallow rooted grassed areas. All other parameters were identical for the two land use types. There are a total of 21 parameters calibrated for the Sacramento model (Table 67).

For calibration of parameters, the command-line Source model was coupled with a model-independent parameter calibration software tool called PEST (Parameter Estimation Tool) (Doherty 2005). PEST was set up to use one of its parameter global optimisers, the CMAES (Covariance Matrix Adaptation Evolutionary Strategy) to estimate the optimised value of the 21 hydrological parameters. PEST's CMAES optimises model parameters using automated search algorithms that minimise the difference between modelled and measured flows, i.e. the objective function. In this calibration, we used an objective function introduced by Coron et al. (2012). Lerat et al. (2013) further modified this objective function to reduce the volume difference between the simulated and observed total flow volumes and the misalignment of observed and simulated peak flow timing through its three function terms. The modified objective function comprised three terms which aimed to ensure that the total flow difference was within ± 10%, that the high flow peaks were well represented and that the timing and duration of events was also well represented. During the optimisation, the PEST's CMAES optimiser repeats a process of selecting a set of new parameter to obtain lower objective function values, until a minimum value is found. The objective function has been used by the Queensland Hydrology Centre (QHC) in DSITI to conduct hydrologic calibrations of other Queensland catchments and achieved good calibration statistics (however QHC typically impose stricter parameter boundary conditions than was used for our purpose). Before the calibration, the initial values of the parameters were set up as the middle values of their allowable ranges based on requirement's in PEST's user manual.

The observed flows were used to assess the performance of calibrated models for total and high flow volume. The model performance was assessed against observed flow data using the following criteria (Moriasi et al. 2015):

- The coefficient of determination of linear regression (R^2) for daily flow >0.5
- Daily Nash Sutcliffe Coefficient of Efficiency (NSE) >0.5
- Percent Bias (Percentage Volume Difference) for total flow volume and for high-range (0-10% percentile) flow volume within ± 20%.

The performance criteria above have been applied elsewhere in water quantity modelling by the QHC, and are recommended as appropriate performance criteria for water quality and quantity modelling by Black et al. (2011), and Moriasi et al. (2015).

In this calibration process, the upstream independent gauges were calibrated first and then the calibrated hydrological parameters for the upstream sub-catchments were transferred into the model and 'fixed' (i.e., they are no longer considered as adjustable for subsequent parameterisation steps). The downstream gauges were then calibrated. This process is consistent with that used by the Queensland Hydrology Centre (QHC) in their water quantity modelling for water planning purposes. A benefit of this single gauge calibration approach is that errors are not accumulating downstream, in that rainfall-runoff parameters are calibrated, then fixed for a region, before moving downstream to the next region.

Several changes to the management and operation of storages were made for this report card. Extractions and instream losses were updated to align with the latest IQQM models. Storage dimensions and valve details were also altered where updated data was provided by the QHC from their IQQM models.

Rules around environmental flow releases were added to storage models in the Nogoa, Mackenzie, Dawson, and Fitzroy catchments. In these same catchments additional rules were implemented, to maintain operating levels in downstream weirs and for fish ladders releases. Storage releases for recharging ground water aquifers were included for both the Kroombit Dam and Callide Dam all located in the Fitzroy basin.

Constituent modelling

Nine constituents were modelled in the RC2014 modelling and the previous iteration. These are: fine sediment (TSS), total nitrogen (TN), dissolved inorganic nitrogen (DIN), dissolved organic nitrogen (DON), particulate nitrogen (PN), total phosphorus (TP), dissolved inorganic phosphorus (DIP), dissolved organic phosphorus (DOP) and particulate phosphorus (PP) and the five PSII herbicides previously reported. A number of additional frequently detected herbicides are being investigated for future modelling if required. Pesticide loads are now reported as toxic equivalence loads (Smith et al. 2012). This is calculated by multiplying the individual pesticide mass by a toxic equivalency factor for diuron in this case. This accounts for the toxicity of any given pesticide relative to a single high risk pesticide (diuron).

Land use

All regions, except for CY, continued to use the QLUMP land use map from RC2013. The land use data for CY was updated in 2013, which is a significant improvement in the model from RC2013, as the previous land use data was from 1999. In Table 6, a summary of land use data in the model is presented, including proposed future updates.

Table 6 QLUMP land use data used in the models and proposed updates

NRM region	Land use in the model	Proposed land use update/availability of data
CY	2013	N.A.
WT	2009	2015
BU	2009	2016/2017
MW	2009	2016/2017
FZ	2009	2017/2018
BM	2009	2016/2018

Hillslope generation model (RUSLE)

The modification of the cover input dataset and the algorithm used to covert remotely sensed cover to c-factor in the RUSLE modelling is comprehensively outlined in Trevithick and Scarth (2013). Briefly, the models for Report Card 2013 and prior, used the Bare Ground Index (BGI) (Scarth et al. 2006) as the cover input for the RUSLE c-factor parameter, and a coverage was created for each year towards the end the dry season.

Several shortcomings were identified with the input datasets (Waters et al. 2014). In RC2014 a number of adjustments were made to improve the ability of the RUSLE model to represent hillslope erosion. There were three significant changes to the RUSLE parameterisation for RC2014, relating to both the calculation of the C-factor input data and the availability of this data. Firstly, estimates of ground cover levels under trees have been developed. Secondly, the temporal resolution of ground cover data has increased from annual to four times per year. Finally, an improvement was made to how the C-factor was derived from the remotely sensed ground cover data.

Fractional ground cover index (fGCI) (Cover under trees)

A major limitation of the BGI product was its inability to resolve cover in treed areas (FPC >15%). resulting in a 95% product coverage of GBR catchments. Recent updates to the methodology used to derive ground cover have resulted in a new fractional ground cover product (fGCI) which adjusts for trees and hence is representative of actual cover on the ground both in open areas and under trees (Trevithick et al. 2014). This new ground cover data is masked at 60% woody vegetation (seasonal persistent green), at which point estimates become unreliable. This has resulted in an increase from approximately 35% reef reporting area with ground cover data to 95% of the area with ground cover estimates.

Seasonal ground cover

In addition to the modification of the algorithm used to convert cover to c-factor, seasonal c-factor rasters were used to provide better temporal resolution of cover. In the previous Report Cards one c-factor raster per year was used to estimate cover (23 cover time steps). In RC2014 four rasters were used per year, 118 cover time steps in total, with each raster representing a season and thus providing a better temporal representation of groundcover.

The reason being that in recent years the USGS Landsat imagery archive has been made publicly available increasing the temporal availability of data from which to derive ground cover from once per year to, on average, 16 times per year. This increased availability has made it possible to derive high quality seasonal ground cover images using a medoid (clustering) approach (Flood 2013). This approach requires three valid, cloud free observations for each pixel and produces a 'representative' ground cover image for each season. The seasonal cover is produced for each calendar season per year. In previous Report Cards only one date was available per year, usually captured during the late dry season, so this is a significant improvement.

Because the seasonal product requires three valid observations for each pixel, there are many areas, particularly in the wetter coastal regions, where data is still not available to produce a ground cover estimate. 'Patched' seasonal ground cover data was utilised to fill in these gaps in the seasonal fractional ground cover. These patches are created by using an observation in areas where there was only one or two valid observations each season. It should be noted that patched data is not publicly available.

Satellite to visual cover conversion

To convert the remotely sensed ground cover estimates into C-factor values, the bare ground component of seasonal fGCI layer was extracted and converted to a percentage and then subtracted from 100 to provide an estimate of ground cover (equivalent of green and other cover), also as a percentage.

Original relationships of cover to c-factor from RUSLE research pre-date modern remote sensing technologies and were formulated on visual estimates of ground cover, which have been shown to differ by 15–25% when compared to objectively recorded cover, to which the satellite based estimates are calibrated (Trevithick and Scarth 2013) as the fGCI has been calibrated to objective ground cover measurements which often differ to visual cover estimates made at the same site. This particularly occurs in the middle ranges of ground cover, with agreement at low levels and high levels of ground cover being greater, regardless of the measurement method (Trevithick et al, 2012).

Cover estimates from the fGCI are typically higher than visual quadrat estimates, particularly in the mid ranges of cover (Trevithick and Scarth 2013), as the fGCI has been calibrated to objective ground cover measurements which often differ to visual cover estimates made at the same site. To account for this difference, the remotely sensed estimates of cover were converted to a visual cover estimate and then this adjusted cover was converted to a cover factor (C-factor) used in the calculation of hillslope erosion in grazing applying the RUSLE equation.

The satellite ('objective') cover was converted to a 'visual' estimate of cover.

$$GC\ (Visual)\ \% = 0.00925*(Satellite\ \%\ ^2)$$

C-factor rasters were created from 'visual' cover estimate using the following equation (Rosewell 1993):

$$C = e^{(-0.799 - (4.74\times10^{-2}\times GC) + (4.49\times10^{-4}\times GC^{2}) - (5.2\times10^{-6}\times GC^{3}))}$$

Where GC is total ground cover (visual) as a percentage (%)

During the conversion phase the objective cover measured by satellite imagery was converted to visual cover. This process on average decreased the cover value used to supply C-factor data to the RUSLE by approximately 20%, with the largest decrease occurring in the range of 30% to 80% cover. This change on its own increased generation rates of fine sediment from hillslope erosion across the GBR Source Catchments models.

Maximum annual load cap

During parameterisation, mountainous areas in all regions were found to be generating particularly high loads of sediment from hillslope erosion. Many of these areas have very steep slopes and high rainfall and also contain large areas of rock outcrops and stony soils. McIsaac et al. (1987) and McCool et al. (1987) found that the RUSLE over predicts soil loss for steep slopes. Risse et al. (1993) found that the RUSLE tended to over predict soil loss on plots with lower erosion rates and that the RUSLE has a poorer predictive capability on rangeland settings compared to agricultural conditions. Lu et al. (2003) added to this by stating that erosion rates can be overestimated in steep arid tropical mountain ranges when using the RUSLE to estimate hillslope erosion. This is the main reason that the EMC/DWC has been applied to nature conservation and forestry areas in the WT and MW models, and why annual erosion rates have been 'capped' in these steep, often coastal subcatchments in the CY, BU, FZ and BM models.

Therefore, a 'maximum annual load' parameter was introduced as part of RUSLE parametrisation. This functionality replaced the 'maximum quickflow concentration' that was previously in place. The maximum annual load parameter is used to scale transported daily loads, and effectively cap hillslope erosion. It was apparent from analysis of the USLE spatial data inputs that there were naturally occurring areas of extremely high slope that coincided with K factor (soil erodibility) values that were not appropriate. That is, these extremely steep areas were more likely to be represented by bare rock than by any significant erodible soil. In an attempt to limit the (potentially erroneous) USLE derived sediment from these combinations of data inputs, a ‘Maximum Annual Load’ parameter (interpreted daily) was introduced. The parameter was intended to be used cautiously and in a spatially specific manner, however during RC2014 it was applied uniformly and in some cases too ‘severely’. This resulted in some instances where, despite rainfall and runoff varying significantly over the period of a model run, the daily sediment load generated and delivered to the stream was identical.

A more robust approach to addressing the issue of unexpected combinations arising from USLE spatial data inputs is to ‘fix’ the data inputs at their point of generation. This needs to happen in a repeatable and transparent manner, and as such can only be approached as a long term solution.

Gully sediment and nutrient generation models

In three regions an updated gully density layer was used to calculate gully sediment and particulate nutrient loads. Previously, the NLWRA gully density maps (Hughes et al. 2001) were used as the best available data sets. This data was shown to provide a poor representation of gullies in Queensland coastal areas (Hughes et al. 2001). Since 2013, DNRM (S. Darr pers. comms. Dec 2016) have been mapping gully locations across priority areas of the GBR to improve on the NLWRA estimates of gully density. Improved gully maps were used where available (CY, BU and FZ NRM regions). In conjunction with this work, CY gully change data from a two year study undertaken by Brooks et al. (2013) in the Normanby Basin was used to derive a gully density layer for the Normanby Basin and incorporated into the CY model for RC2014 (refer to regional headings for specific details).

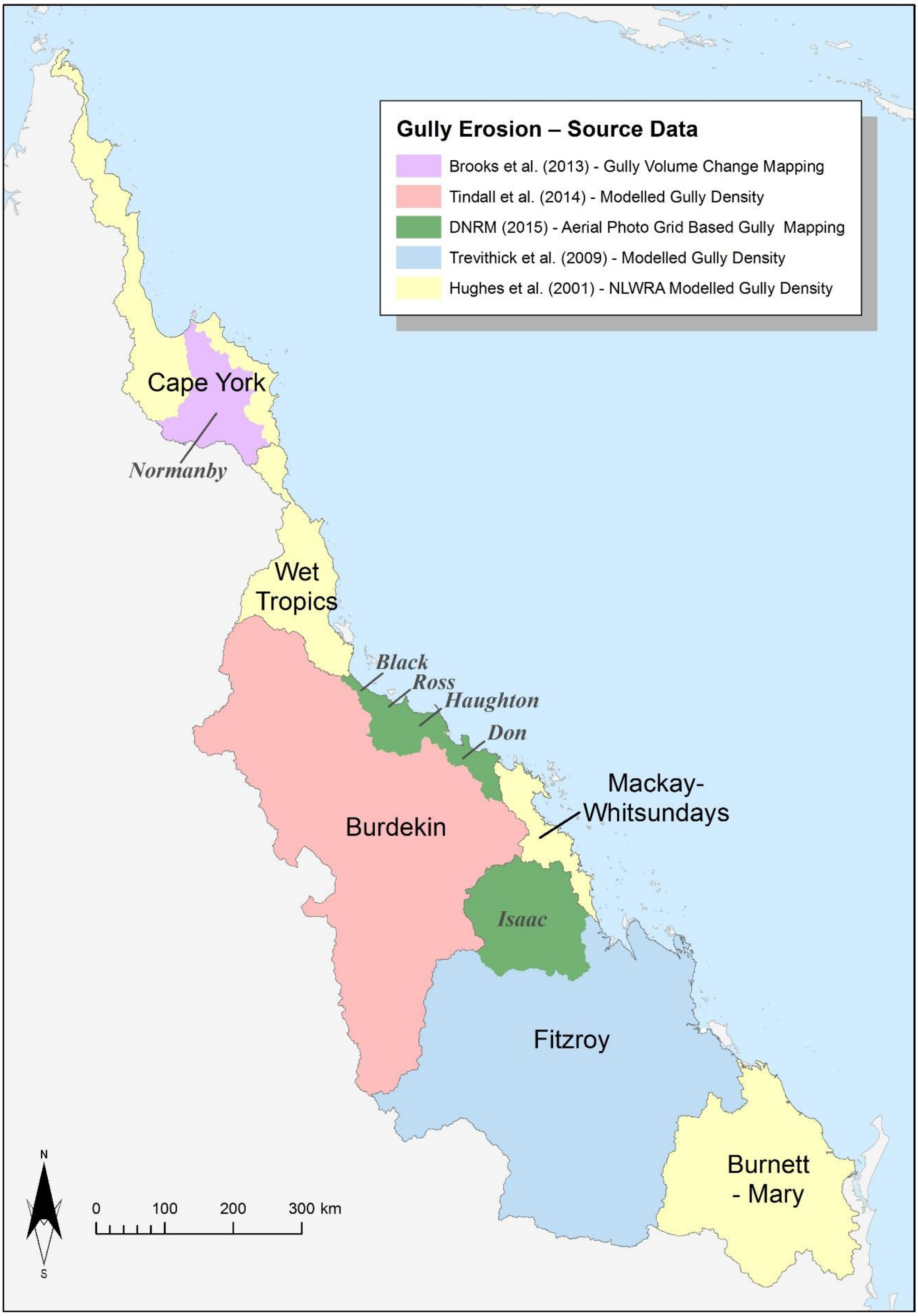


Figure 3 Gully density products used in the regional models

Sugarcane and cropping constituent generation models

A number of changes were implemented between RC2013 and RC2014 for sugarcane and cropping constituent generation models. The changes were applied within the paddock model and are summarised in Table 80. These include revision of the soil profile parameters, additional management scenarios (the greatest change occurred in the BU where the initial four management scenarios used in RC2013 were expanded to 112 for RC2014. The expanded runs are a combination of the 28 management combinations possible by four irrigation management practices, and changes to the DIN runoff model which was updated to incorporate a new algorithm which correlates fertiliser input to nitrogen in runoff derived from P2R field monitoring data (Fraser et al. 2016). This daily model of DIN concentration in runoff was based on >200 cane field monitored DIN runoff events. Modelled DIN runoff concentrations relate to nitrogen fertiliser application rates and then decrease after application as a result of time and rainfall (Fraser et al. 2016, Shaw and Silburn 2016).

Timeseries of DIN lost to drainage were supplied by the paddock modelling (Fraser et al. 2016, Shaw and Silburn 2016). A proportion of this DIN may be delivered to the stream via the slowflow pathway (proportion adjusted by the modeller) and is labelled as ‘seepage’ supply. The remaining DIN lost to deep drainage is reported as ‘leached’, and is not included as a supply source (it is only reported for the modellers benefit). This means that the catchment models report two ‘sources’ of sugarcane DIN: hillslope (the surface runoff component) and seepage. Paddock scale monitoring has repeatedly shown that deep drainage is a major loss path for DIN in sugarcane in Wet Tropics catchments (Armour, Davis, et al. 2013).

Seepage DIN is a combination of any non-zero DWC and the proportion of the deep drainage timeseries DIN (supplied via APSIM model runs) that is returned to the stream (via a user-supplied seepage delivery ratio). The leached and seepage components can be combined to represent total deep drainage occurring in the model.

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

All regions reviewed EMC/DWC values based on any new monitoring data that became available within a region and updated values within the models as appropriate, given the larger pool of monitoring data with which to generate appropriate values. EMC/DWC values applied for each region are provided in Appendix 2.

In-stream models

Streambank erosion, in-stream and floodplain deposition, and remobilisation

In-stream deposition and remobilisation was only enabled in the CY model in RC2014. Further details are provided below on page 51. In future Report Cards this functionality will be enabled in all regional models as our understanding of these processes in each region improves, and as data becomes available to validate this component.

Riparian vegetation

In most regions, a new riparian vegetation layer was used (QLD 2013 Foliage Projective Cover (FPC)) which typically increased vegetation cover in riparian zones. Inspection of aerial photography indicated the 2009 FPC layer, used in the previous Report Card, under represented riparian vegetation in most regions. Only the WT and BU region continued to use the 2009 FPC as used in RC2013, because a desktop analysis comparing aerial photography of riparian vegetation and the various FPC layers showed that the 2009 layer was more representative, and also lined up with the QLUMP land use data layer.

Constituent load validation

Two main approaches were used to evaluate the GBR Source Catchments modelling of constituent loads. Firstly, a comparison was made using short-term load estimates from monitoring results that commenced in 2006 in ten high priority catchments (Turner et al. 2012, Joo et al. 2012). Secondly, a comparison was made with long-term catchment load estimates derived from all available measured data for the 23 year modelling period (Joo et al. 2014); the Flow Regression Concentration Estimator (FRCE) model. Both of these sources are discussed in detail in the previous Report Card modelling technical reports (Waters et al. 2014). In the Normanby and Burnett basins, the long-term FRCE data was not used as a validation source as the FRCE model uses the Source Catchments derived hydrology, not observed flow.

In addition to the datasets of the GBR Catchment Loads Monitoring Program and the long-term FRCE loads (Joo et al. 2014), in some NRM regions a range of other measured datasets at smaller time scales were also included.

Performance ratings

Moriasi et al. (2007) developed statistical model evaluation techniques for streamflow, sediment and nutrients, which were updated more recently (Moriasi et al. 2015). Four quantitative statistics were recommended: Nash-Sutcliffe coefficient of efficiency (NSE), percent bias (PBIAS), the ratio of the root mean square error to the standard deviation of validation data (RSR), and the coefficient of determination (R^2). Model evaluation performance criteria are presented in Table 7. In this report modelled and measured loads are assessed against these ratings where applicable.

The PBIAS performance measure can be applied for all constituents at an annual scale, as can flow for R^2 and NSE. However, sediment and nutrient ratings for the R^2, NSE, and RSR measures are recommended to be used at a monthly scale (Moriasi et al. 2015). It was not possible to calculate daily or monthly loads from some of the GBRCLMP data due to the method used to calculate loads. If a Beale approach was used to calculate a load then no daily load was available because the method requires a minimum of three samples per timestep. At many of the GBRCLMP monitoring sites a mix of Beale and Linear load calculations were used, thus model performance was only assessed at an annual scale using the load calculated by the GBRCLMP. In the absence of another method for rating model performance against measured data at an annual scale, the monthly performance criteria has been applied.

Table 7 Performance ratings for recommended statistics for a monthly time-step (from (Moriasi et al. 2007), Moriasi et al. (2015))

Performance measure	Constituent	Performance evaluation criteria			
		Very good	Good	Satisfactory	Indicative
R^2 (Moriasi, 2015)	Flow	$R^2 > 0.85$	$0.75 < R^2 \le 0.85$	$0.60 < R^2 \le 0.75$	$R^2 \le 0.60$
	TSS/P	$R^2 > 0.80$	$0.65 < R^2 \le 0.80$	$0.40 < R^2 \le 0.65$	$R^2 \le 0.40$
	N	$R^2 > 0.7$	$0.60 < R^2 \le 0.70$	$0.30 < R^2 \le 0.60$	$R^2 \le 0.30$
NSE (Moriasi, 2015)	Flow	NSE > 0.80	0.70 < NSE ≤ 0.80	0.50 < NSE ≤ 0.7	NSE ≤ 0.5
	TSS	NSE > 0.80	0.70 < NSE ≤ 0.80	0.45 < NSE ≤ 0.70	NSE ≤ 0.45
	N/P	NSE > 0.65	0.50 < NSE ≤ 0.65	0.35 < NSE ≤ 0.50	NSE ≤ 0.35
PBIAS (%) (Moriasi, 2015)	Flow	PBIAS < ±5	±5 ≤ PBIAS < ±10	±10 ≤ PBIAS < ±15	PBIAS ≥ ±15
	TSS	PBIAS < ±10	±10 ≤ PBIAS < ±15	±15 ≤ PBIAS < ±20	PBIAS ≥ ±20
	N/P	PBIAS < ±15	±15 ≤ PBIAS < ±20	±20 ≤ PBIAS < ±30	PBIAS ≥ ±30
RSR (Moriasi, 2007)	Flow	RSR ≤ 0.5	0.50 < RSR ≤ 0.60	0.60 < RSR ≤ 0.70	RSR > 0.7
	TSS				
	N/P				

Progress towards Reef Plan 2013 targets

The major aim of the modelling is to assess progress towards achieving the Reef Plan water quality targets. Water quality targets were set under Reef Plan 2013 in relation to the anthropogenic baseline loads. That is, the estimated increase in human induced constituent loads from predevelopment conditions. State and Federal government funds were made available under Reef Plan to the six regional NRM groups and industry bodies to co-fund land holder implementation of improved land management practices. Organisations receiving funding through Reef Plan 2013 are required to report the impacts of their work as per the relevant industry water quality risk framework, described in further detail below.

Modelling baseline management practices and practice change

The following information on management practice data was provided by DAFF staff (pers. comms. Mr. K. McCosker (25 July 2016)). Since RC2013, a significant change occurred in how the management practice baselines for Reef Plan 2013 were developed. In the previous Report Cards, management practices were described using an ABCD management practice framework. Management practices are now described in terms of their relative water quality risk from low to high. Not all management practices are equal, and the updated frameworks allows a percentage weighting to each practice depending upon its relative potential influence on off-farm water quality. The process of management practice data collation is presented in Figure 4.

Management practice baselines were developed for each of these critical farm management practices, for each agricultural industry (see Table 8 for grazing, and Table 9, in each region (and river basin). At the farm scale these management practices combine to form a management system. Progress in terms of adoption over time of improved and/or best management practices and management systems is monitored through the reporting processes of Queensland and Australian Government programs. Where management change has occurred, the 2013 management system baseline was amended (area moving from one modelled management state to another) to reflect that change.

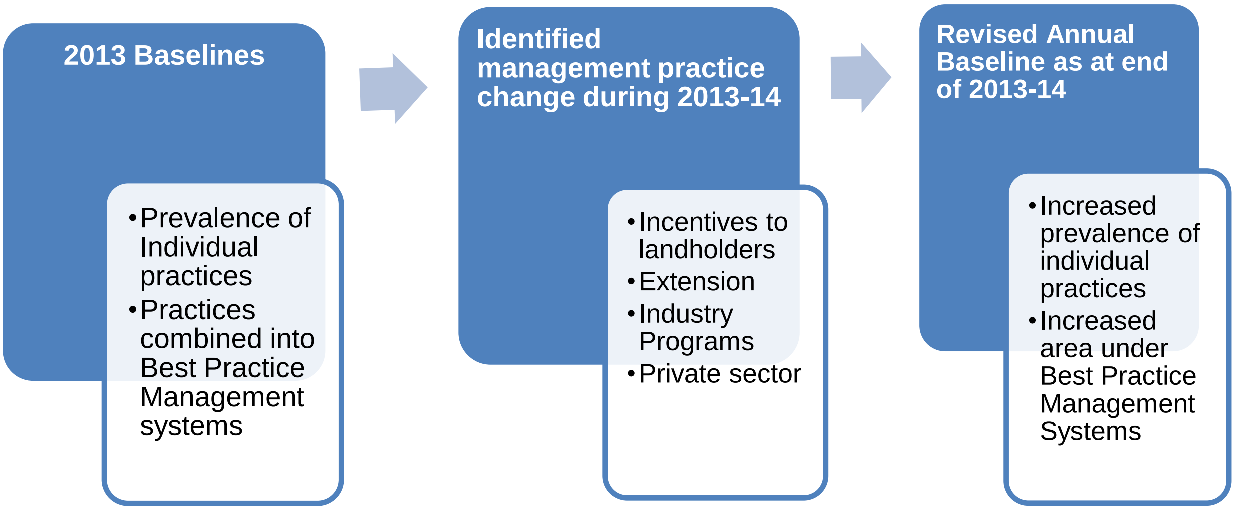


Figure 4 Process of developing new water quality risk management practice framework, and the continuous process of data collection and baseline revision

For grazing systems, the framework describes management practices related to dominant sources of soil erosion; surface (hillslope), streambank, and gully erosion. For cropping systems, the water quality risk frameworks describe management practices related to managing nutrients, pesticides, sediments, and water.

Table 8 P2R classification of management practices in the grazing industry based on relative risk to water quality

2013 Water Quality Risk	Low	Moderate-Low	Moderate-High	High
Resource condition objective	Practices highly likely to maintain land in good (A) condition and/or improve land in lesser condition	Practices are likely to maintain land in good or fair condition (A/B) and/or improve land in lesser condition	Practices are likely to degrade some land to poor (C) condition or very poor (D) condition	Practices are highly likely to degrade land to poor (C) or very poor (D) condition
Previous Reef Plan 2009 "ABCD" nomenclature	A	B	C	D

Table 9 P2R classification of management practices in the cropping industries (sugarcane, bananas, and grains)

2013 Water Quality Risk	Low	Moderate-Low	Moderate-High	High
Description	Lowest water quality risk, commercial feasibility not well understood	Best Management Practice	Minimum Standard	Superseded
Previous Reef Plan 2009 "ABCD" nomenclature				
Sugarcane	A	B	C	D
Grains	A	B	C/D	
Bananas	Not applicable – Bananas previously were not described (included in Horticulture).			

A critical element of this process put in place for RC2014 and beyond is the provision of spatial data describing the exact location of reported investments. The process of management data collection through to inclusion in regional models is abbreviated as:

1. Delivery organisations provide annual evidence of impact to P2R, in the form of GIS data (geographic information system data, or electronic mapping of locations) and detailed management practice data.
2. This data is reviewed by P2R on a site by site basis to provide assurance that reporting towards adoption targets and modelled pollutant load reductions is sensible. This review includes:
    - Identification of data handling errors;
    - Checking that the nature of the intervention aligns with the reported impact;
    - Checking that the degree of impact (farm management change) is sensible and realistic;
    - Checking that individual sites and impacts on those sites have not previously been reported to P2R and included in estimates of progress towards Reef Plan targets;
    - Checking that the reported impacts are congruent with other independent lines of evidence available to P2R.
3. For every site (usually a paddock or farm), the degree of management change is aligned to modelling simulations which best represent the management in place on that site (for example, the tillage regime, the nutrient rates, the weed and irrigation management on a cane farm).
4. The GIS data and aligned modelling simulations are provided to the P2R catchment modelling team for the purposes of modelling estimated average annual pollutant load reductions expected as outcomes of the reported farm management change.
5. The estimated spatial baseline distribution of management practice (2013 baseline) is adjusted as necessary to accommodate the practice improvements detailed in the GIS data. This baseline adjustment does not carry through to subsequent report card simulations, as export load reductions are not made cumulatively and are relevant to the original baseline estimates (2013 baseline).

Details on the specific weightings of management practices for each of the major industries is presented in Appendix 3, Table 89 to Table 95.

The ratings of performance for load reductions based on the catchment modelling are available at www.reefplan.qld.gov.au, where each region is rated as 'very good', 'good' etc for cumulative load reductions due to management practice change.

Cape York

The following section describes methodology changes that are only applicable to the CY region.

Hydrology

Hydrology was recalibrated with the Sacramento rainfall runoff model to improve the representation of high flows, as described above on page 35.

Land Use

In CY the 2013 QLUMP land use data was used (DSITI 2015), whereas all other regions continued to use the 2009 QLUMP mapping as this was the most up to date data available. Due to the expansion of the banana industry in the CY region, bananas were included as a new functional unit (FU) (Figure 5). A large shift into nature conservation has occurred in CY from the land use map applied in previous Report Cards. This is due to the expansion of a number of national parks, including the Cape Melville and Jack River national parks, and also areas of ‘traditional land uses’ including various Land Trusts in the area. Indigenous managed land is classified as nature conservation. The main shift to nature conservation occurred from closed grazing; 42% in RC2013 to 32% in RC2014 (Table 10).

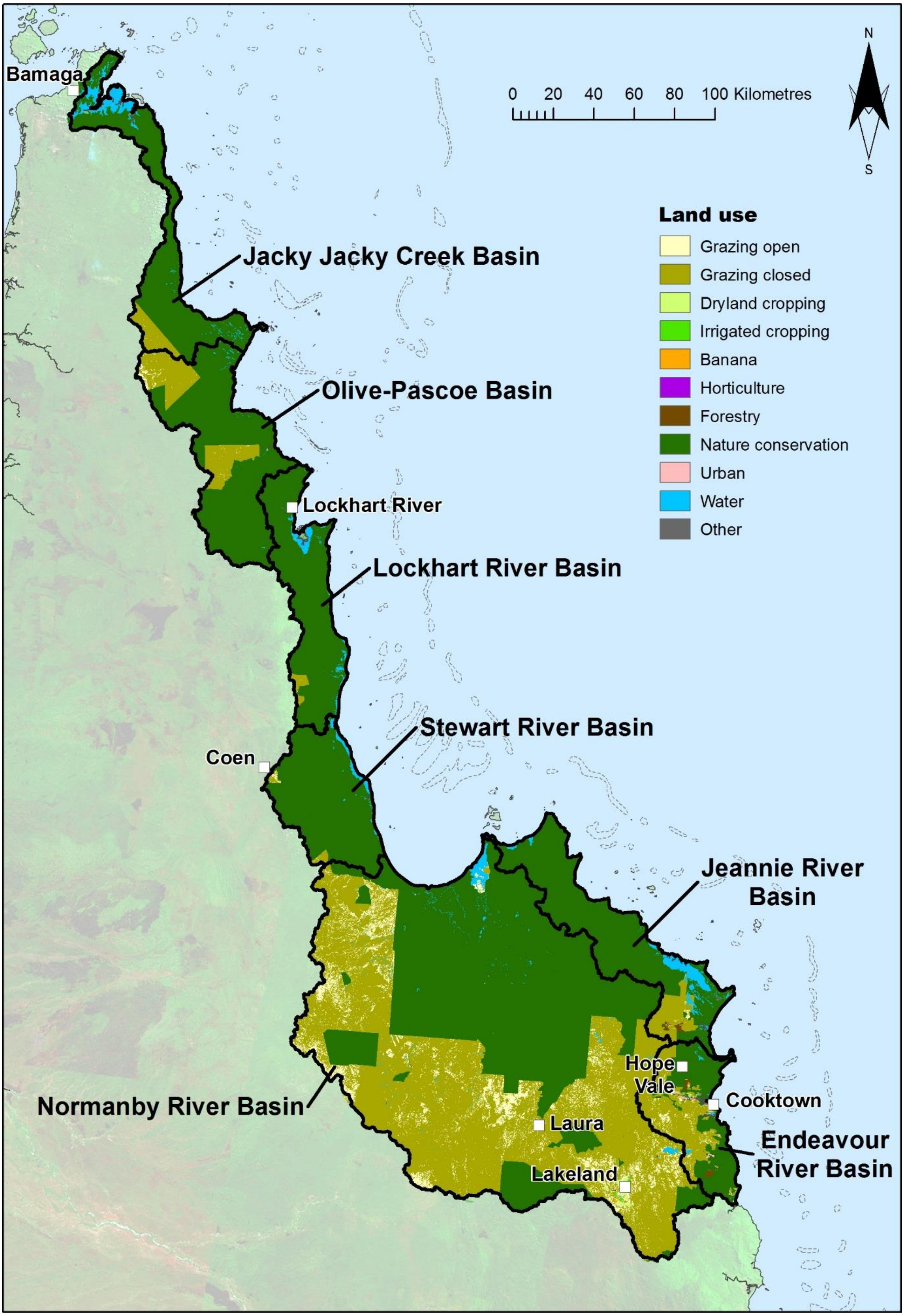


Figure 5 CY NRM region land use classification

Table 10 CY land use (percent of area); largest land use area is highlighted green

Land use	RC2013	RC2014
Grazing - open	8	5
Grazing - closed	42	32
Nature Conservation	45	61
Horticulture	<1	<1
Irrigated cropping	<1	<1
Dryland cropping	<1	<1
Forestry	3	<1
Other	<1	<1
Urban	<1	<1
Bananas	NA	<1
Water	2	3

Model groups

In CY the RUSLE model has now been applied to nature conservation and forestry whereas an EMC/DWC model was applied in the previous model iteration. A RUSLE approach has been applied in CY for consistency across the regions. Much of the nature conservation area in CY is in the Normanby Basin, which is more like the drier FZ and BU catchments, than it is the steep, rainforest areas of the WT (where the RUSLE is known to over-estimate erosion). Bananas are modelled using HowLeaky.

Hillslope sediment, nutrient and herbicide generation

Changes to cover products as described above on page 38.

Gully sediment and nutrient generation

In CY, a study looking at the change in gully volume over a two year period, undertaken by Brooks et al. (2013) in the Normanby Basin, was incorporated into the Normanby model for RC2014. The two year gully volume change (or t/yr) data for the Normanby was firstly converted to a gully density. Alluvial and colluvial loads from the Brooks et al. (2013) were added together, as the Source model does not distinguish between gully types.

To determine an average annual and annual gully load exported for modelling period, the annual runoff for each relevant Source modelling subcatchment was analysed to determine the proportion of total long term runoff attributable to the years represented by the Brooks et al. (2013) data. A suitable long term average annual gully load and annual gully load was then calculated, and loads apportioned as a function of annual runoff, ensuring that modelled gully loads in the two years of the study were as close as possible to the loads predicted by the Brooks et al. (2013) data. The long term average annual gully loads were then converted to an appropriate gully density layer (using assumed bulk density, age of gullies, and cross sectional area), allowing seamless use with complimentary data for the rest of the CY area outside of the Normanby. The density map created for the Normanby Basin was then combined with the NLWRA map (Hughes et al. 2001) for the remainder of CY. This improved gully density map for the Normanby has resulted in a better spatial representation of gully load in this region.

Average gully cross sectional area was increased to 7.5 m^2 from 5 m^2 in RC2013 to better align with monitored data (Brooks et al. 2013).

Sugarcane constituent generation

Not applicable in CY.

HowLeaky cropping constituent generation

A HowLeaky module was developed to account for water quality improvement investments in bananas and was applied spatially to the soil and climate combinations in the banana FUs (Rattray et al. 2016).

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

EMC/DWC values (for urban, other, and horticulture FUs) were updated in line with monitored data, see Appendix 2, Table 81.

In-stream models

Streambank erosion, in-stream and floodplain deposition, and remobilisation

Due to recent research in CY (Brooks et al. 2013), against which model results can be compared, in-stream deposition and remobilisation models were enabled in the CY model. A range of parameter values were tested and the final parameter values are in Appendix 2, Table 88.

Predevelopment model

In line with the baseline model, nature conservation and forestry areas were modelled using the RUSLE, as opposed to an EMC/DWC approach in the previous models.

Wet Tropics

The following section describes methodology changes that are only applicable to the WT region.

Hydrology

Hydrology was recalibrated with the Sacramento rainfall runoff model to improve the representation of high flows, as described above on page 35.

Rainfall Scaling

During the initial calibration for the WT, the modelled versus measured flow at seven gauging stations was under-predicted by greater than 10%. It has been identified that the spatially interpolated daily SILO rainfall dataset (Queensland 2011) in some places was less reliable in generating mean annual rainfall totals when compared against an 'independently' generated QLD mean annual 50-year isohyets map (DSITIA 2013f). For the period 1920–1969, monthly rainfall sequences were compiled for all long-term rainfall stations to give a uniform 50 years of data (DSITIA 2013f). All available rainfall data from the time was incorporated, which included records from BOM, local government, statutory authorities, and the Water Resources Commission (DSITIA 2013f). Meteorologists developed isohyets using plotted mean annual rainfall values and considered topography and prevailing wind conditions (DSITIA 2013f). The 50-year isohyets map was found generally to be more reliable in reflecting mean annual rainfall variation in some parts of the WT compared to the SILO dataset (DSITIA 2013b, e, a, c, d). The SILO derived daily rainfall datasets were therefore scaled by a factor dependant on the subcatchment isohyets weighted average (DSITIA 2013d) to improve the total flow bias for those gauges that were under-predicted by greater than 10% in the initial calibration.

Fourteen subcatchments had scaled rainfall applied (Table 11). During an early iteration of the hydrology calibration for this study, it was identified that the Koombooloomba Dam was not operating as expected. Scaled rainfall was also applied to the subcatchment draining into Koombooloomba Dam and the rainfall file attached to the storage. It is hypothesised that there was a lack of inflow into the storage during the hydrology calibration period. It is also possible that the actual daily extractions from the dam were generally much larger than the short observed record dataset used to extrapolate to long term daily extractions for the calibration period and/or that seepage is occurring. In a previous calibration of Sacramento for the Wet Tropics Draft Water Resource Plan (DSITIA 2013f), the scaling factor for the subcatchment draining to 111101D was 1.11 (subcatchment 437). It was reported that both the SILO dataset and isohyet rainfall were both likely under predicting from this area (DSITIA 2013d) and a scaling factor of 1.11 was increased to 1.25. The scaling factor for RC2014 was increased to 1.14, which is simply the difference of the two scaling factors generated in the previous study. This subcatchment contains Queensland's tallest peak Bartle Frere and is characterised by very high rainfall gradients due to steep costal ranges (DSITIA 2013f). The other issue is the short rainfall records for the two rainfall stations contributing to the first-stage of the two-stage interpolation process to generate the SILO grids were excluded (DSITIA 2013d). For gauge 109002C, the scaling factors were halved as the initial scaling factors produced a bias of total flow >20%. The scaling technique will be investigated for other basins where isohyet maps are available.

Table 11 Gauges and storages and the associated rainfall scaling factors in the Wet Tropics

Gauge or storage	Scaling factor	Subcatchment number
108003A	1.29	9
	1.18	8
	1.47	6
	1.14	7
109001A	1.45	42
109002C	1.20	425
	1.27	486
111102B	1.27	454
	1.04	438
111101D	1.14	437
113004A	1.22	443
116008B	1.18	446
	1.26	365
	1.22	364
Koombooloomba Dam and associated storage rainfall	1.25	459
Subcatchment draining to Koombooloomba Dam	1.25	457

Extraction, Inflows and loss node models

Prior to model development for RC2014, Water Resource Plan (WRP) analyses were undertaken for all of the Wet Tropics basins, excluding the Daintree and Barron (Barron model had already been developed) using the Integrated Quantity and Quality Model (IQQM). The water demand data were taken from each basin and aggregated at appropriate nodes in Source. In addition to the five Barron extractions that were already implemented, an additional 25 aggregated extractions were incorporated across the WT.

Model groups

In the WT the only change was for Bananas which are now modelled using HowLeaky, compared to an EMC/DWC approach for the previous Report Cards.

Hillslope sediment, nutrient and herbicide generation

The RUSLE maximum annual load (t/ha/yr) was set at 50 t/ha/yr in all subcatchments, based on monitored loads from a grazing subcatchment in the Herbert Basin (O'Brien 2015).

Gully sediment and nutrient generation

Gullies were disabled in sugarcane, irrigated and dryland cropping FUs (gully density manually set to 0). It was considered that gullies were generally not a major source of sediment in these FUs and were therefore disabled in the model.

Sugarcane constituent generation models

Changes were made to APSIM paddock scale modelling, inducing improved DIN runoff and representation of deep drainage, as described on page 43.

HowLeaky cropping constituent generation

A HowLeaky module was developed to account for water quality improvement investments in bananas and was applied spatially to the soil and climate combinations in the banana FUs (Rattray et al. 2016). Additional management scenarios were modelled, in line with the updated management practice framework outlined on page 45 of this document.

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

Updated EMC/DWC values in line with monitored data, see Appendix 2, Table 82.

In-stream models

No changes were made between RC2013 and RC2014.

Predevelopment model

No changes were made between RC2013 and RC2014.

Burdekin

The following section describes methodology changes that are only applicable to the BU region.

Hydrology

Recalibration with the Sacramento rainfall runoff model to improve the representation of high flows, as described on page 35.

Constituent models

No changes were made to the constituent models between RC2013 and RC014.

Hillslope sediment, nutrient and herbicide generation

Changes to cover products as described above on page 38.

Gully sediment and nutrient generation

In the BU region, a new gully density map was used in place of the modified National Land and Water Audit gully density layer (Kuhnert et al. 2010). The new layer provided improved resolution, spatial accuracy and a better range of density values. The gully density layer was produced by combining the two gully density datasets.

The coastal basins (Ross, Black, Haughton and Don) were mapped using a grid based gully erosion presence or absence map that was captured at a 100 m pixel scale (Darr et al., unpublished data; see above). The remainder of the Burdekin Basin was covered by a probabilistic gully presence dataset that was created at a 30 m^2 resolution (Tindall et al. 2014). The dataset does not however supply a density value that is directly applicable to the Source gully erosion model. However, it was noted that areas with a gully probability greater than zero, contained first order linear drainage mapping that could be defined as gullies. This was confirmed and cross-referenced against published fine scale gully density mapping (Bartley et al. 2010). All subregions were also subjectively sampled by the author for further general agreement. The drainage dataset was clipped against the gully presence dataset. In simple terms, if the drainage line intersected any defined probability of gully, the drainage line was classed as a gully, thereby providing a measurement of density for the model.

Sugarcane constituent generation models

Changes were made to APSIM paddock scale modelling, inducing improved DIN runoff and representation of deep drainage, as described on page 43.

HowLeaky cropping constituent generation

Additional management scenarios were modelled in the BU region, changing from four in RC2013 (ABCD) to 15 in this Report Card.

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

Updated EMC/DWC values in line with monitored data, see Appendix 2, Table 83.

In-stream models
No changes were made between RC2013 and RC2014.

Predevelopment model
No changes were made between RC2013 and RC2014.

Mackay Whitsunday

The following section describes methodology changes that are only applicable to the MW region.

Hydrology

Recalibration with the Sacramento rainfall runoff model to improve the representation of high flows, as described on page 35.

Constituent models

No changes were made to the constituent models between RC2013 and RC014.

Hillslope sediment, nutrient and herbicide generation

Changes to cover products as described above on page 38.

Gully sediment and n*u*trient generation

Gullies were disabled in sugarcane, irrigated and dryland cropping FUs (gully density manually set to 0). It was considered that gullies were generally not a major source of sediment in these FUs and were therefore disabled in the model.

Sugarcane constituent generation models

Changes made to APSIM paddock scale modelling, leading to improved DIN runoff and representation of deep drainage, as described on page 43.

HowLeaky cropping constituent generation

No changes were made between RC2013 and RC2014.

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

Updated EMC/DWC values in line with monitored data, see Appendix 2, Table 84.

In-stream models

No changes were made between RC2013 and RC2014.

Predevelopment model

No changes were made between RC2013 and RC2014.

Fitzroy

The following section describes methodology changes that are only applicable to the FZ region.

Hydrology

Recalibration with the Sacramento rainfall runoff model to improve the representation of high flows, as described on page 35.

Extraction, Inflows and loss nodes

Several changes to the management and operation of storages were made for this report card. Extractions and instream losses were updated to align with the latest QHC IQQM models of the Fitzroy. Storage dimensions and valve details were also altered where updated data was provided from IQQM models.

Simulated time series extractions provided from IQQM models were scaled according to water allocations made by SunWater in their annual reports. Both supplemented and un-supplemented extractions were altered using the same scaling factor. The assumption was made that if conditions prevented full allocation of supplemented extractions being available to water users then water available for un-supplemented extractions would have decreased by at least a similar proportion.

Environmental flows were implemented for seasonal base flow and first post-winter flows in the Nogoa, Mackenzie, Dawson and Fitzroy catchments. Additional rules were implemented for pass flow management strategies and for fish ladders releases in these same catchments where required. Storage releases for recharging ground water aquifers were included for both the Kroombit Dam and Callide Dam.

Storages

In RC2014, 20 storages were included in the Fitzroy model while only 15 were in the previous calibration. Additional storages were included in this model to improve calibration where releases are made from upper scheme storages to supply downstream irrigation orders, maintain storage levels in lower scheme storages or to meet environmental flow requirements. These additional storages were:

- Bingegang Weir
- Moura Weir
- Theodore Weir
- Orange Creek Weir
- Theresa Creek Dam

This is a new feature adopted for RC2014 for storages. For those storages that were constructed during the hydrology calibration period, the storages turned on at their commission date. This approach to commissioning of storages was designed to improve the calibration results by allowing the model to better estimate the flow regime of the streams pre and post dam construction. Storages that were commissioned during the hydrology calibration are shown in Table 12.

Table 12 Storages commissioned during hydrology calibration

Storage	Commission Date
Burton Gorge Dam	1 July 1992
Callide Dam	1 July 1992
Edan Bann Weir	1 Jan 1995
Kroombit Dam	1 July 1992
Gyranda Weir	1 July 1987
Tartrus Weir	1 July 1986
Teviot Creek Dam	1 July 1995

After the hydrology calibration was completed the storages were permanently turned on for all scenario runs.

Constituent models

No changes were made to the constituent models between RC2013 and RC014.

Hillslope sediment, nutrient and herbicide generation

In the previous models a uniform delivery ratio of 10% was used. For RC2014 a variable hillslope delivery ratio was employed. Due to the generally flat terrain and long hillslope lengths of dry-tropical catchments of the GBR a lower delivery ratio of 5% was applied for most areas and is considered appropriate (Lu et al. 2003a; Rustomji et al. 2010). In smaller steep wet coastal catchments a 10% delivery ratio was applied.

Steep conservation and forestry areas were found to be generating high fine sediment concentrations and loads that were of similar magnitude to those being produced by areas of dryland cropping. For example, the Connors range has significant areas of conservation and forestry areas that were producing some of the highest concentrations of fine sediment in the region. Water quality sampling indicates that the Connors Range produces relatively low concentrations compared to other catchments within the FZ region (Packett et al. 2009) indicating that these areas may be approaching sediment exhaustion. To improve the models prediction of concentrations and loads within conservation and forestry areas, a lower delivery ratio of 2.5% was applied to these areas.

Gully sediment and nutrient generation

In the FZ region, a new gully erosion density map was used in place of the National Land and Water Audit gully density map (Hughes et al. 2001). This new mapping provided improved resolution, spatial accuracy and a better range of density values based on observed data (Trevithick et al. 2009). The new gully density layer was produced by combining two different gully density datasets. The Isaac catchment was mapped using a grid based gully erosion presence or absence map that was captured at a 100 m pixel scale (Darr et al., unpublished data). The remainder of the FZ Basin was covered by modelled data that was created at a 1 km^2 resolution (Trevithick et al. 2009). The grid based gully presence data was converted from original mapping units to km/km^2 based on estimated gully dimensions and then combined with the modelled data to form a single dataset.

Two additional changes were made to gully model parameters in the FZ model. The cross sectional area of gullies was reduced from 10 m^2 to 5 m^2. Hughes and Croke (2011) found that by Australian standards gullies tend to be quite small throughout Theresa Creek and suggested a cross-sectional area of 5 m^2 is more appropriate. Assessment of aerial imagery confirmed that 5 m^2 is a better estimate of the cross-sectional area for gullies for the entire Fitzroy region. The gully activity parameter was lowered from 1 to 0.5 (this activity parameter reduces the annual gully erosion by the parameter value provided starting from a user specified date) based on the assessment of Hughes and Croke (2011) who suggested that an activity factor of 0.5 may be appropriate for Theresa Creek due to recent reductions of floodplain accretion rates from areas where sediment loads are dominated by gully erosion. A brief assessment of aerial photography throughout the Fitzroy Basin confirmed this value may be more appropriate.

Sugarcane constituent generation models

Not applicable in the FZ region.

HowLeaky cropping constituent generation

As described above on page 43.

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

Updated EMC/DWC values were scaled to improve model estimation of observed loads, see Appendix 2, Table 85.

In-stream models

Storage trapping

In RC2013 sediment and nutrient trapping in storages was only applied to a small number of storages. To reflect the storage trapping that occurs in all storages within the FZ region the trapping model was implemented for all dams and large weirs. An important parameter in the trapping model, reservoir length was calculated for all storages by measuring the centreline of storage impoundments from aerial photos when at full capacity (Lewis et al. 2013).

Predevelopment model

No changes were made between RC2013 and RC2014.

Burnett Mary

The following section describes methodology changes that are only applicable to the BM region.

Hydrology

Recalibration with the Sacramento rainfall runoff model to improve the representation of high flows, as described on page 35.

Storages

The number of storages included in the model in RC2014 remained the same as that in RC2013. Prior to RC2014, calibration was undertaken with the assumption that all storages existed for the full calibration period. This was not the case in reality and to improve calibration, storages were turned on after their commissioning date (see Table 13 for details of these storages). Once the hydrology calibration was completed the storages were permanently turned on for all scenario runs.

Table 13 Storages commissioned during hydrology calibration

Storage	Catchment area (km2)	Capacity (ML)	Year of completion
Baroon Pocket Dam	67	61,000	1988
Bjelke-Petersen Dam	1670	125,000	1988
Bucca Weir	2385	9,780	1987
Burnett River Dam	30,785	300,000	2005
Claude Wharton Weir	23,490	12,600	1987
Ned Churchward Weir (Walla Weir)	32,760	29,500	1998

Model groups

In BM the RUSLE model has now been applied to nature conservation and forestry whereas an EMC/DWC model was applied in the previous model iteration.

Hillslope sediment, nutrient and herbicide generation

Changes to cover products as described above on page 38.

Gully sediment and nutrient generation

No changes were made between RC2013 and RC2014.

Sugarcane constituent generation

Changes were made to APSIM paddock scale modelling, inducing improved DIN runoff and representation of deep drainage, as described on page 43.

HowLeaky cropping constituent generation

Additional management scenarios were modelled in the BU region, from four in RC2013 (ABCD) to 15 in this Report Card. Additional pesticide products have also been modelled, with locally derived degradation parameters applied.

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

Updated EMC/DWC values in line with monitored data, see Appendix 2, Table 86.

In-stream models

No changes were made between RC2013 and RC2014.

Predevelopment model

No changes were made between RC2013 and RC2014.

Results

The overall GBR results, and the results section for each of the six NRM regions are separated into hydrology and modelled loads. In the hydrology section, the updated calibration results are presented. The modelled loads section includes the updated baseline load estimates and the overall progress towards the Reef Plan 2013 targets. For each NRM region, the predevelopment loads, constituent load validation, loads by land use, identification of sources and sinks, and management change loads are also presented.

Hydrology calibration performance

Recalibration of the hydrology using the Sacramento model resulted in significant improvement in the representation of flow in the model. For all regions there was a marked improvement in the flow bias/total volume percent difference (Table 14), but this was particularly pronounced in the BU and FZ regions. All regions, except CY, improved the percentage of gauges meeting all three performance criteria although many of the CY gauges were close to meeting the criteria. The results for each region are discussed in more detail below, in the relevant report sections.

Table 14 Summary of hydrology recalibration results between RC2013 and RC2014

NRM Region	Flow Bias range (%)		Percentage of gauges meeting all performance criteria	
	RC2013	RC2014	RC2013	RC2014
CY	-18% – 25%	-5% – 4%	89	53
WT	-31% – 7%	-8% – 5%	81	100
BU	-60% – 40%	-7% – 5%	38	94
MW	-27% – 9%	-23% – 1%	89	90
FZ	-71% – 22%	-6% – 13%	38	96
BM	-35% – 52%	-6% – 4%	25	100

Regional flow comparison

The whole of GBR modelled average annual flow (1986–2014) for RC2014 was 72,753,502 ML/yr. The Wet Tropics contributed 32% (23,232,507 ML/yr) of the total flow (Figure 6), while the Burnett Mary contributed the least 7% (4,830,502 ML/yr).

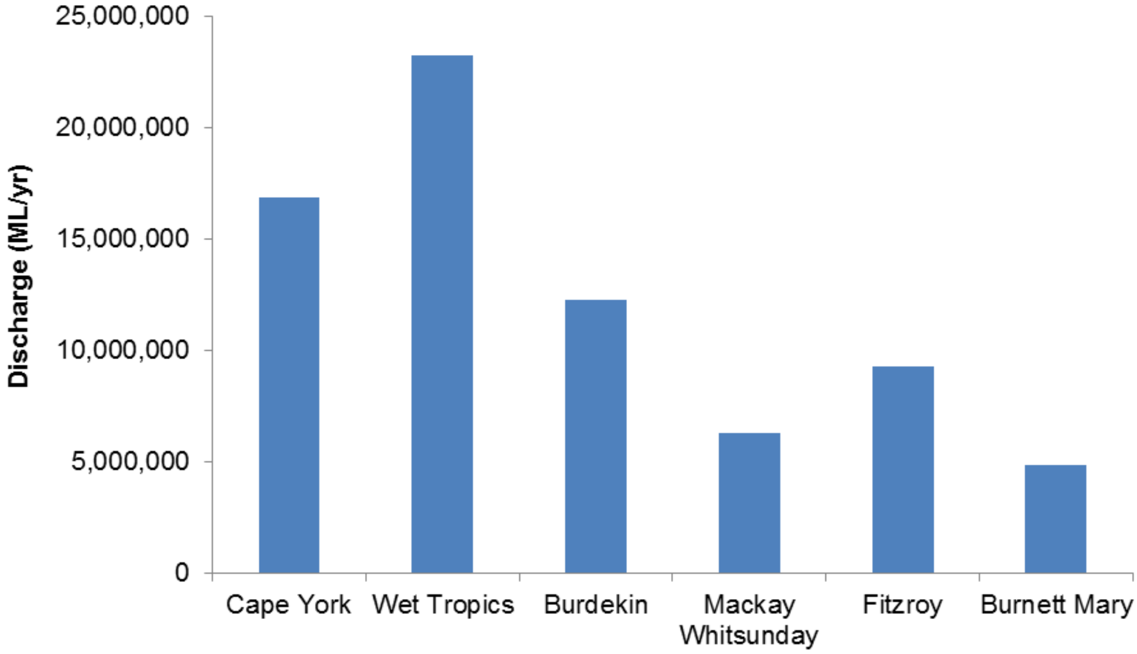


Figure 6 Average annual modelled flow for the GBR (1986-2014)

Modelled loads

It is estimated that 9,398 kt/yr of fine sediment is exported from the six GBR NRM regions, of this 2,480 kt/yr is the predevelopment load, and 6,917 kt/yr the anthropogenic baseline load across the GBR. This is the portion of the load that can be affected (reduced) through improved by management practice. Total constituent baseline loads for all regions are presented in Table 15, while in Table 17 this data is presented as a per cent contribution.

The BU region is the greatest contributor of fine sediment (39% of the total load). This is due to a combination of the catchment area, large runoff volumes, erodible soils, and prevalence of gullies in the region. Grazing is the primary land use in the BU. The WT is the greatest contributor of TN, DIN, PN, and PP. The large DIN (42% of total GBR load) in the WT is a function of land use, especially the large areas of sugarcane, bananas, and other irrigated crops within the region, as well as the close proximity of these land uses to the coast, and high runoff volumes. The FZ NRM region contributes the greatest TP and PP load and is attributed to the large catchment area, large runoff volumes, and the high proportion of fertile cropping soils.

The MW region is the greatest contributor of PSII pesticides, contributing 33% of the total load, with the WT contributing 28% of the load (Table 16). This is due to the large percentage of sugarcane in these regions, and the proximity of sugarcane crops to the coast. The PSII TE load and PSII load and the ratio of the two are presented in Table 16. The closer the PSII TE load is to the PSII load, the higher the proportion of diuron. Therefore if only diuron was used, the ratio of PSII/PSII TE would equal 1.

Table 15 Total baseline loads for the GBR region

Basin	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)
Cape York	371	6,907	427	4,422	2,057	680	76	153	451
Wet Tropics	1,665	15,049	5,041	4,202	5,807	3,016	240	199	2,566
Burdekin	3,695	8,463	2,446	2,488	3,530	2,735	424	138	2,173
Mackay Whitsunday	611	4,031	1,237	1,375	1,419	959	267	69	623
Fitzroy	1,793	9,568	1,842	3,646	4,080	3,856	1,171	226	2,454
Burnett Mary	1,264	4,257	874	1,839	1,543	800	116	66	617
Total	**9,398**	**48,275**	**11,868**	**17,972**	**18,435**	**12,045**	**2,294**	**851**	**8,871**

Table 16 PSII pesticide load and PSII toxic equivalent (TE) load for the GBR region

Basin	PSII (kg/yr)	PSII TE (kg/yr)	Proportion of PSII TE load to PSII load
Cape York	18	1	0.06
Wet Tropics	3,694	2,807	0.76
Burdekin	2,295	1,273	0.55
Mackay Whitsunday	4,365	3,152	0.72
Fitzroy	2,368	51	0.02
Burnett Mary	563	210	0.37
Total	**13,303**	**7,493**	**0.56**

CY is the lowest contributor to total export for seven of the 11 constituents (Table 15). This is a function of land use given that nature conservation comprises 61% of the total CY area which typically has low generation rates of most constituents, and the limited cropping in the region. CY is the greatest contributor of DON to the total GBR load. The high load is a reflection of the naturally occurring DON in the Normanby Basin (Turner et al. 2012).

Table 17 Regional contribution of each constituent as a percentage of the GBR total baseline load

Basin	TSS	TN	DIN	DON	PN	TP	DIP	DOP	PP	PSII	PSII TE
Cape York	4	14	4	25	11	6	3	18	5	0	<1
Wet Tropics	18	31	42	23	31	25	10	23	29	28	37
Burdekin	39	18	21	14	19	23	18	16	24	17	17
Mackay Whitsunday	7	8	10	8	8	8	12	8	7	33	42
Fitzroy	19	20	16	20	22	32	51	27	28	18	<1
Burnett Mary	13	9	7	10	8	7	5	8	7	4	3
Total	100	100	100	100	100	100	100	100	100	100	100

For the whole GBR, fine sediment is approximately four times the predevelopment load. This varies for each region from two times the predevelopment load in CY, to seven times the load in the FZ NRM region and six times the load in the BU region. Total phosphorus is approximately three times the natural load across the GBR, ranging from 1.5 times in CY to 4.5 in the FZ. Total nitrogen is more consistent across the regions with an approximate doubling of the natural load.

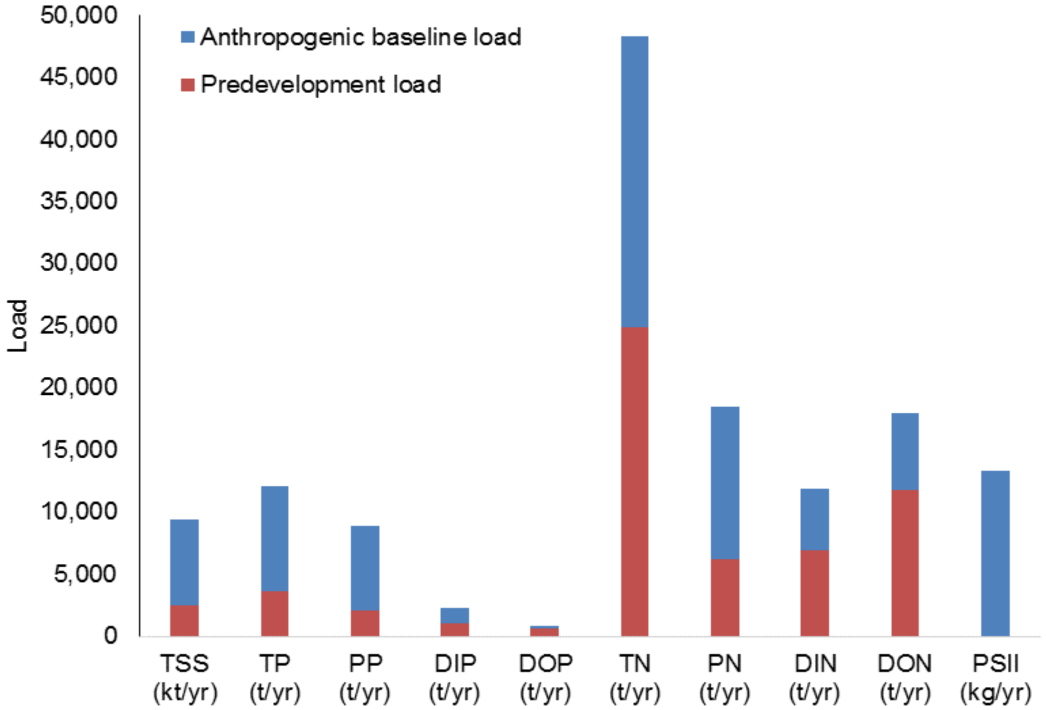


Figure 7 Predevelopment and anthropogenic baseline contributions for all constituents across the GBR

Progress towards Reef Plan 2013 targets

Progress towards targets for RC2014 is presented in Figure 8. Across the GBR, we estimate that the anthropogenic TSS load has been reduced by a further 0.7% for RC2014, taking the cumulative reduction to 12%. Particulate nitrogen and phosphorus load reductions are estimate to be 0.4% and 0.5% respectively, taking cumulative reductions to 11.5% and 14.5% respectively. Both fine sediment and particulate nutrient reductions are over half way towards the 20% reduction target, and the reductions for TSS and PP are classified as 'very good', and 'good' for PN. The BU region made the greatest contribution to the fine sediment and particulate nutrient reductions, with a 1.3% TSS reduction, a 0.8% PP and 1% PN reduction.

The modelled anthropogenic DIN loads have been further reduced by 1% for RC2014, taking progress towards the 50% target to 17%. This is classified as 'poor' progress and further work is required to improve DIN load reductions. Again, the BU and WT made the most improvement in DIN reductions, with 1.8% and 1.3% load reductions respectively. The largest decrease in load has been the PSII TE load reduction of 1.5%, which takes the cumulative reduction is 30.5%, over half way towards the 60% reduction target. This is classified as 'good' progress. The BU load reduction was 6%, with 1.7% reduction from the WT.

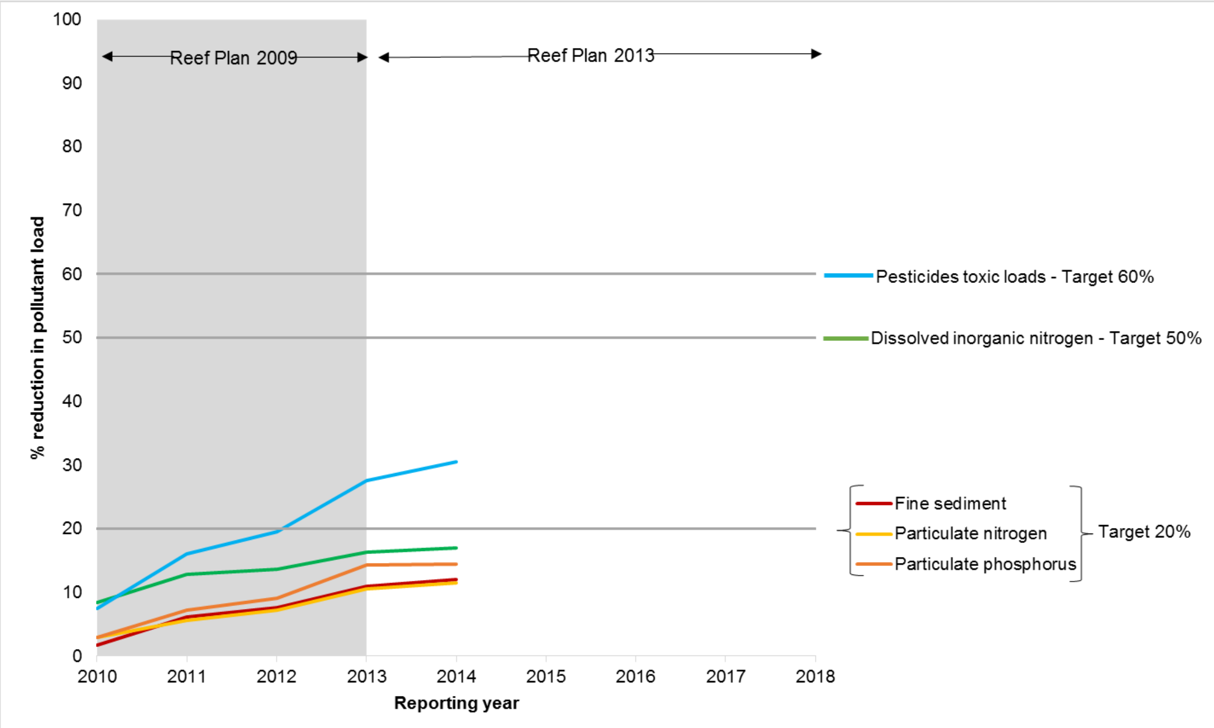


Figure 8 Progress towards Reef Plan targets to 2014 for the whole of GBR

Cape York

The results of the Cape York modelling are presented below, separated into hydrology and modelled loads. In the hydrology component, the results of the updated calibration process will be presented per gauge, as well as the impact on the total flow for the CY region. The modelled loads section includes the results of the total baseline, anthropogenic baseline and predevelopment loads. The validation of the CY Source Catchments modelled data is then presented using load estimates from measured data. No management changes were reported for CY in RC2014, hence no progress towards targets for the RC2014 period are presented. A summary of the total baseline load by land use, and land use by basin is also reported, as well as a mass balance summary of the sources and sinks by constituent. For a full list of the CY region loads for RC2014 refer Appendix 4, Table 96.

Hydrology calibration performance

Model performance was assessed for the 15 CY gauges used in the recalibration process. Performance was assessed for the calibration period 1970–2014. The results for the three performance criteria: daily $R^2 > 0.5$, daily NSE >0.5, percent bias (p-bias) for total flow volume and high flow volume ± 20% are listed in Appendix 1, Table 68 . All gauges met the R^2 and volume difference (p-bias) criteria, while eight of 15 gauges met the daily NSE criteria. Eleven of fifteen gauges were over-predicting flow, though it was typically less than 5%.

As a result of the recalibration, the total average annual flow for CY for the model run period (1986-2014) was reduced by approximately 700,000 ML/yr from the previous modelling period (1986-2009). Total average annual flow for the region is estimated to be ~16,900,000 ML/yr. The recalibrated flow for the Normanby Basin altered the most, with the average annual flow decreasing by 21% to ~3,900,000 ML/yr from ~4,700,000 ML/yr in the previous Report Card. However the decrease in flows improved the estimate, with the total flow bias (volume difference) for the Kalpowar gauge improving from being over-predicted by 25% to less than 4%. The total flow bias for the five most improved gauging stations in CY region are listed in Table 18. The full table of flow volume statistics can be found in Appendix 1, Table 69.

Table 18 Comparison of total volume differences for the five most improved calibration gauges between RC2013 and RC2014 (negative values indicate an under-prediction)

Gauge	Basin	RC2013 total volume diff. (%)	RC2014 total volume diff. (%)
102102A	Pascoe	-13	-5.4
105103A	Normanby	-7.8	-0.6
105106A	Normanby	8.3	0.8
105107A	Normanby	25.4	3.8
107002A	Endeavour	-17.6	0.8

Modelled loads

Cape York contributes 4% of the total baseline TSS load being exported to the GBR. CY was the lowest contributor of TSS load, and is one of the lowest contributors for all constituents other than DON. Within the CY region, the Normanby Basin was the greatest contributor for all constituents, because it is the largest basin, and also because it has the greatest anthropogenic impacts.

Unlike previous Report Cards, the updated land use map included dryland and irrigated cropping lands in the Normanby, Endeavour and Jeannie River basins. This has resulted in these basins now exporting some pesticides in the model simulations.

Table 19 Contribution from CY basins to the total CY baseline load

Basin	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
Jacky Jacky	16	955	73	785	97	54	12	24	18	0	0
Olive Pascoe	35	1,432	107	1,130	195	101	19	37	45	0	0
Lockhart	18	739	49	530	161	51	8	15	28	0	0
Stewart	25	398	30	331	36	27	5	10	12	0	0
Normanby	230	2,299	96	894	1,310	358	20	39	299	12	0.41
Jeannie	26	482	32	336	115	39	5	11	22	1	0.02
Endeavour	21	601	41	416	144	51	8	16	27	5	0.22
Total	**371**	**6,907**	**427**	**4,422**	**2,057**	**680**	**76**	**153**	**451**	**18**	**1**

Anthropogenic baseline and predevelopment loads

The predevelopment and anthropogenic baseline load for fine sediment for each of the major basins in CY are presented in Figure 9. The Normanby Basin is by far the largest contributor of TSS load from CY (85%). The Lockhart, Jacky Jacky, Olive-Pascoe, and Jeannie Basins, are largely undisturbed with very little anthropogenic load generated (any anthropogenic contribution is due to pockets of open grazing in each of these basins).

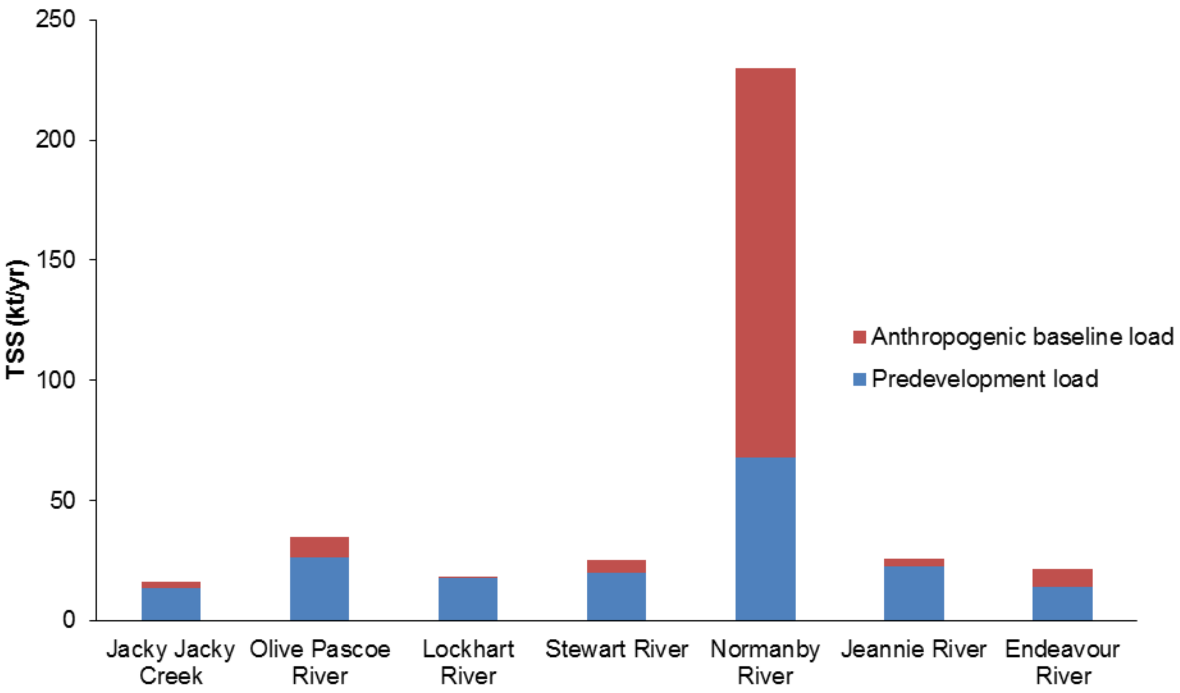


Figure 9 Predevelopment and anthropogenic baseline fine sediment (kt/yr) contribution for the CY basins

Constituent load validation

Due to the extension of the modelling period to 2014 there are now eight years of water quality monitoring data from the Kalpowar gauging station (Joo et al. 2012, Turner et al. 2012, Turner et al. 2013, Garzon-Garcia et al. 2015, Wallace et al. 2015), collected as part of the GBR Catchment Loads Monitoring Program (GBRCLMP). Given the increased water quality data collected by the GBRCLMP, the load estimates in Kroon et al. (2012) and Joo et al. (2014) used in previous validation has not been utilised for this Report Card. This is primarily due to the lower confidence in data in these reports for CY, as they are based limited event data and or no monitoring data in some years.

A comparison was made between the mean GBRCLMP measured loads (averaged over 6–8 years, depending on data availability) and the modelled load for the same time period (Figure 10). The modelled constituent loads at the Kalpowar Crossing gauging station were within ±50% of the observed loads. Modelled flow was within ±5% of the observed flow for the eight year monitoring period, and most constituents are within 30% of the monitored load. Across the monitoring period, the model is under-predicting all constituents apart from TSS, which is over predicted by 45%. DON is being under-predicted by 29% and this is an area for improvement in future model runs.

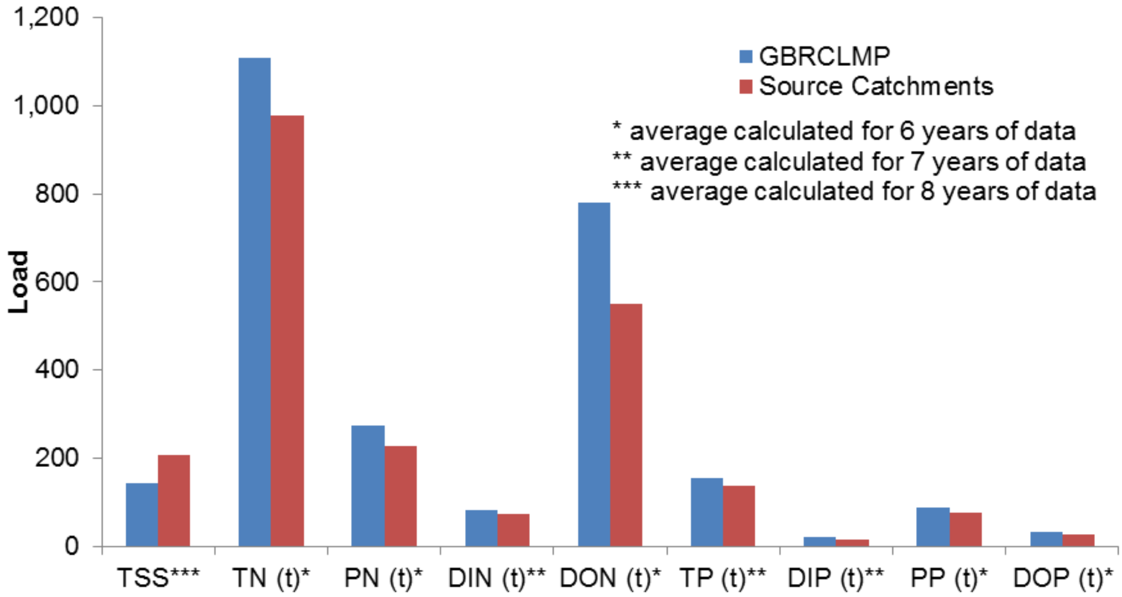


Figure 10 Comparison between average Source Catchments modelled and GBRCLMP monitored loads for the period 2006–2014 for the Normanby River at Kalpowar Crossing (105107A)

The performance of the RC2014 baseline model to predict the water quality processes across the CY region was also assessed using a number of quantitative statistics recommended in Moriasi et al. (2015). The estimated quantitative statistics and the corresponding model performance ratings are presented in Table 20 for the Normanby River. For ease of presentation, 'very good' and 'good' rated sites are coloured green, while 'satisfactory' and 'indicative' are coloured orange, signalling that further work is required to improve the representation of these constituents.

All measures yielded similar results for all constituents, with a mix of 'good' or better rankings and some 'indicative' rankings (Table 20). Flow was ranked as 'good' or 'very good' across three measures, as was TP. DIN was 'very good' on three measures and satisfactory for R^2. Most other constituents achieved mixed results suggesting improvements can be made. Statistics could not be calculated at the daily or monthly time-step due to the load calculation method used in the GRBCLMP data. It is also important to highlight that there is a degree of uncertainty around the GBRLCMP load estimates.

Table 20 Moriasi et al. (2007), Moriasi et al. (2015) annual statistical measures of performance for each constituent at the Kalpowar Gauge, Cape York

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.2	Very good	5.4	Good	1.0	Very good	1.0	Very good
TSS	1.4	Indicative	46.2	Indicative	-0.9	Indicative	0.4	Indicative
TN	0.8	Indicative	-40.9	Indicative	0.4	Satisfactory	0.9	Very good
PN	0.7	Satisfactory	-22.4	Satisfactory	0.6	Good	0.6	Satisfactory
DIN	0.5	Very good	-2.5	Very good	0.8	Very good	0.6	Satisfactory
DON	0.8	Indicative	-8.5	Very good	0.3	Indicative	0.3	Satisfactory
TP	0.4	Very good	-8.3	Very good	0.9	Very good	0.9	Very good
DIP	0.7	Satisfactory	-21.0	Satisfactory	0.5	Good	0.6	Good
PP	0.6	Satisfactory	-4.3	Very good	0.6	Good	0.5	Satisfactory
DOP	0.7	Indicative	-31.4	Indicative	0.5	Satisfactory	0.8	Very good

Contribution by land use

The modelling indicates that nature conservation and grazing (open and closed) account for 61% and 37% of the CY area respectively, and generate 89% of the TSS load (Figure 11). Streambank erosion accounts for 10% of the TSS supply, with minor contributions from the other land uses. Particulate nutrients have a significant contribution from 'stream' sources. The major process contributing to this is channel remobilisation.

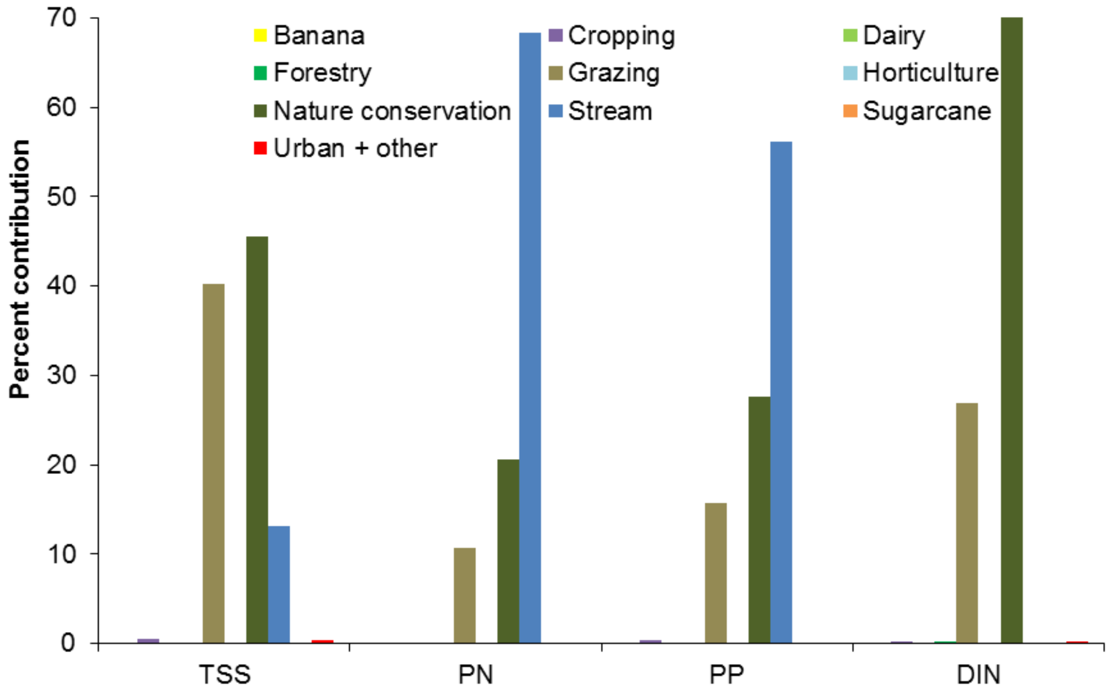


Figure 11 Contribution to fine sediment, particulate nutrient and DIN export by land use for the CY region

The disparity seen between the relative contributions of streams (streambank erosion plus remobilisation) versus other land uses for TSS compared to particulate nutrients in Figure 11, is a result of the daily nutrient remobilisation rate being calculated as a function of stream power and supplied sediment not as a function of supplied particulate nutrients. Therefore any significant deviation in the relative daily supply of particulate nutrients, when compared to sediment, can cause very large differences in the impact of the instream remobilisation rate when applied to each constituent.

The most common cause of differences in the supply of particulate nutrients and sediment in a given timestep are associated with the hillslope and gully sediment generation models. The sediment gully generation model can generate and deliver a sediment load on any day where 'quick flow' is greater than zero. The sediment hillslope generation model (specifically the USLE model) however will not deliver sediment loads on days where rainfall is below the threshold (default 12.5mm daily rain). In addition, depending on the magnitude of nutrient enrichment ratios used to calculate the daily hillslope derived particulate nutrient load, the relative rates of daily hillslope and gully generation (and delivery) of particulate nutrients may vary significantly from the daily supplied sediment. This in turn will alter the impact of the calculated instream particulate remobilisation rate across different constituents. The impact of this on re-mobilisation in streams further downstream is often amplified, as the perceived daily supply of particulates from 'upstream' begins to deviate.

Sources and sinks

Of the total modelled fine sediment generated in the CY region (625 kt/yr), 60% is exported to the GBR lagoon, with the remaining 40% deposited on the floodplain (35%) or in-stream (5%). Of the 625 kt/yr of fine sediment generated, 55% can be attributed to gully sources, 35% to hillslope sources, and the remaining 7% and 3% to streambank and remobilised in-stream sediment sources respectively (Table 21). The proportion of fine sediment generated from gullies is greater when only the Normanby basin is considered (Table 22).

System storage of fine sediment has been identified as a significant component of the sediment budget in the Normanby Basin, while gullies and 'secondary channels' have been identified as the major sediment sources (Brooks et al. 2013). The breakdown of sediment sources and sinks for the Normanby Basin, and for CY, are presented in Table 22.

Table 21 Sources and sinks for fine sediment in CY

	TSS (kt/yr)
SOURCE	**625**
Hillslope	218
Gully	344
Streambank	42
Channel remobilisation	21
SINK (loss)	**254**
Storage deposition	
Floodplain deposition	220
Stream deposition	34
Extraction and losses	
Stream decay	
EXPORT	**371**

Table 22 Sources and sinks of fine sediment in CY and the Normanby Basin (as percent of total supply)

	Cape York (%)	Normanby (%)
SUPPLY		
Channel remobilisation	3	4
Gully	55	70
Hillslope	35	22
Streambank	7	4
LOSS		
Floodplain deposition	35	45
In-stream deposition	5	7

Progress towards Reef Plan 2013 targets

No management practice data was provided for any component (streambank, gully, or grazing) in RC2014, and thus no reductions are reported for this region. The cumulative reduction from CY to date for fine sediment is 8%, with cumulative reductions for PP and PN at 12% and 8% respectively.

Wet Tropics

The results of the Wet Tropics modelling are presented below, separated into hydrology and modelled loads. In the hydrology component, the results of the updated calibration process will be presented per gauge, as well as the impact on the total flow for the WT region. The modelled loads section includes the estimates of the total baseline, anthropogenic baseline and predevelopment loads produced by the model. The validation of the WT Source Catchments modelled data is then presented using load estimates derived from measured estimates. Progress towards targets are also presented. A summary of the total DIN baseline load and areal rate by land use, as well as a mass balance summary of the sources and sinks by constituent. For a full list of the WT region loads for RC2014 refer Appendix 4, Table 97.

Hydrology calibration performance

As a result of the recalibration of hydrology using the Sacramento rainfall runoff model and extending the model period (1986 – 2014), the total average annual flow for WT increased by approximately 9%, with the total average annual flow for the region being ~23,200,000 ML/yr. Across the eight basins, the biggest differences in flow compared to RC2013 was an increase in the Barron, Murray and Herbert basins (~19% each). Most basins had an increase in flow, with the Tully and Mossman basins having a slight decrease in flow. The five gauging stations in WT region that had the largest flow bias in RC2013 along with the flow bias from the Sacramento calibration (RC2014) are listed in Table 23. The biggest improvement in the total volume difference was the gauge in the Daintree Basin, improving from -31% in RC2013 to 0% difference in RC2014. The full table of statistics can be found in Appendix 1, Table 70.

Table 23 Comparison of total volume differences for five gauges that had the biggest flow difference in RC2013 and the flow difference generated from the Sacramento calibration (RC2014) (negative values indicate an underprediction)

Gauge	Basin	RC2013 total volume diff. (%)	RC2014 total volume diff. (%)
108003A*	Daintree	-31	0
109001A*	Mossman	-24	-2
110003A	Barron	-20	-0.1
111101A-D*	Russell	-20	-2.5
116012A	Herbert	-19	-7.7

*rainfall scaled in subcatchments draining to gauge

The 30 gauges used in the hydrology calibration for the region all met the daily Nash-Sutcliffe criterion (>0.50), the R^2 criterion (>0.50) and the total volume error criterion (PBIAS ± 20%). The Percent Bias of total flow volume for all gauges were ≤7.7% and Percent Bias of high flow were ≤10.3%.

Modelled Loads

It is estimated that the WT contributes the third highest proportion of the total baseline TSS load being exported to the GBR at 18% and the highest particulate N and P proportions at 31% and 29% respectively (Table 24). The WT is the highest contributor of DIN at 42% of the GBR load, double that of the second highest contributor the BU. The WT contributes the second highest load of DON, DOP and PSIIs. For all constituents except PSIIs, there was an increase in the export at the WT regional scale, with the main cause due to an increase in average annual flow. The PSII TE load was 0.76 of the PSII load indicating a higher toxicity compared other regions (Table 16). The MW proportion was similar at 0.72. Within the WT region, the Herbert and/or Johnstone basins produced the largest loads for most constituents. The Mulgrave-Russell Basin is also an important contributor for most constituents. Compared to RC2013 for TSS, the ranking of basins for TSS export didn't change significantly, with the top three being Herbert, Johnstone and Mulgrave-Russell for both Report Cards. For DIN, the top three basins did change in ranking from highest to lowest, with the Herbert Basin ranked highest, followed by Johnstone in this report card and the reverse of RC2013; the reasoning for this is outlined in the discussion. For PSIIs the Johnstone has the largest export load followed by, Herbert and then Mulgrave-Russell. In the previous Report Card, the Herbert has the largest load followed by Johnstone. The shift in the ranking is also outlined in the discussion.

Table 24 Contribution from WT basins to the total WT baseline load

Basin	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
Daintree	108	1,688	481	809	398	135	24	24	87	104	86
Mossman	21	272	134	62	77	34	5	4	26	64	56
Barron	80	641	159	217	265	96	13	9	74	160	42
Mulgrave-Russell	265	2,487	918	600	969	453	50	38	365	678	569
Johnstone	409	3,616	989	730	1,896	1,268	43	39	1,186	928	752
Tully	177	1,815	678	472	665	329	32	26	271	502	422
Murray	89	1,027	388	306	332	189	19	13	156	389	328
Herbert	515	3,504	1,294	1,007	1,203	512	54	46	412	868	551
Total	**1,665**	**15,049**	**5,041**	**4,202**	**5,807**	**3,016**	**240**	**199**	**2,578**	**3,694**	**2,807**

Anthropogenic baseline and predevelopment loads

The estimated TSS anthropogenic baseline load was 989 kt/yr or 59% of the total baseline load with the remaining 41% attributed to the predevelopment load. The predevelopment increase factor to total baseline load for WT TSS is 2.5. For TSS, all basins except the Daintree and Mossman had a 2 or higher predevelopment increase factor to the total baseline load (Figure 12). Loads are also presented in tabular form, see Appendix 4, Table 97. The anthropogenic baseline DIN load was 2,207 t/yr or 44% of the total baseline load, with the remaining 2,834 t/yr or 56% attributed to the predevelopment load. The predevelopment increase factor to total baseline load for WT DIN was 1.9. The Mossman and Barron basins have the highest DIN increase factors of ~2.3 (Figure 13). Predevelopment DIN proportions to the total load were highest in the Daintree (76%), followed by the Tully and Mulgrave-Russell basins (58% each).

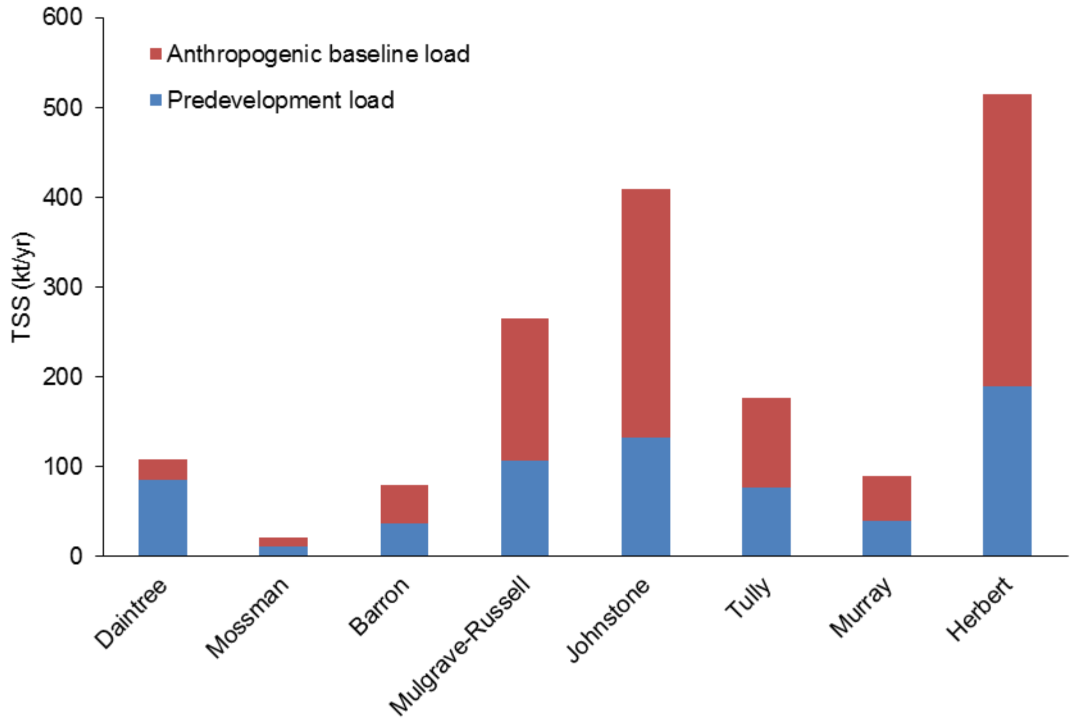


Figure 12 Fine sediment (kt/yr) load for the WT basins, indicating the predevelopment and anthropogenic baseline contributions

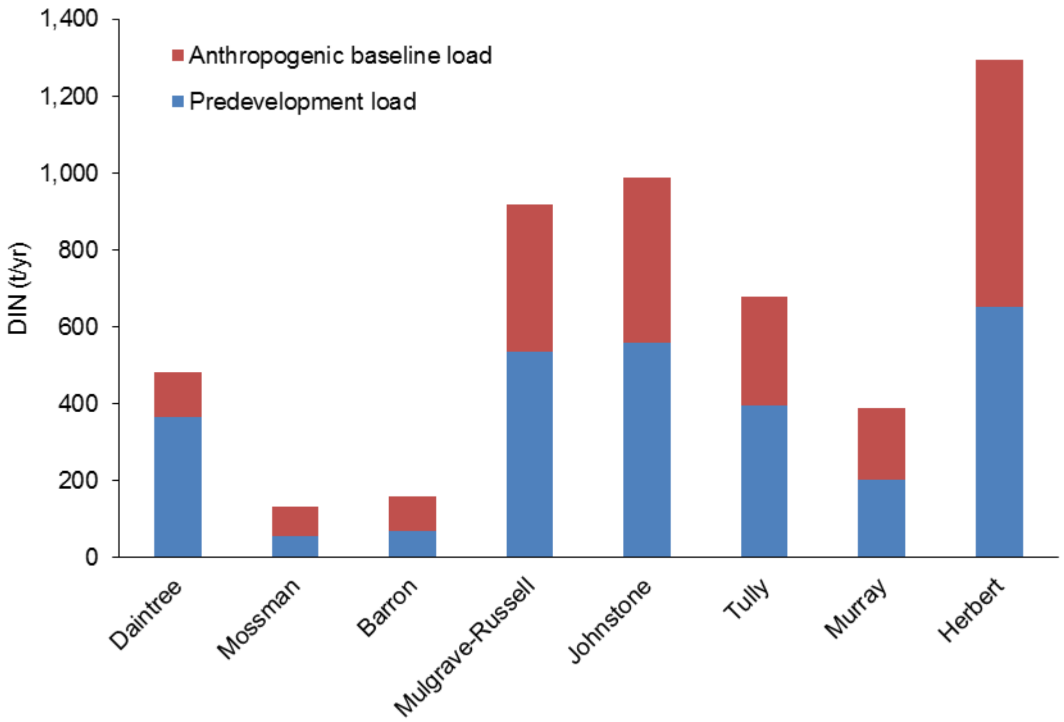


Figure 13 DIN (t/yr) load for the WT basins, indicating the predevelopment and anthropogenic baseline contributions

Constituent load validation

Due to the extension of the modelling period from 1986-2009 through to 2014, there are now eight years of water quality monitoring data for the six sites in the WT. The monitoring data was collected under the GBR Catchment Loads Monitoring Program (GBRCLMP) (Joo et al. 2012, Turner et al. 2012, Turner et al. 2013, Garzon-Garcia et al. 2015, Wallace et al. 2015). At a number of locations, loads are only available for a shorter time period (Table 25). Monitoring data for pesticides for example has been collected since 2010 in Johnstone, Tully, and Herbert rivers.

Table 25 Monitoring details for the six water quality sites in the WT

Site	Monitoring period	Observed load period for this report	Average samples collected per year	Notes
Barron River (EOS)	2006–2014	2006–2014	69	
North Johnstone River (EOS)	2006–2014	2009–2014	40	Measured loads for 2008 period indicative only. Excluded period 2006–2008
South Johnstone River (EOS)	2006–2014	2006–2014	57	
Tully River at Tully Gorge	2010–2014	2010–2014	64	Operational since 2010
Tully River at Euramo (EOS)	2006–2014	2006–2014	169	
Herbert River (EOS)	2006–2014	2009–2014	72	Measured loads for 2007–2008 period indicative only. Excluded period 2006–2008

The GBRLMP validation data is the most current data and of high sample frequency, targeted at event sampling specifically for model validation. Therefore the load estimates calculated by Kroon et al. (2012) and Joo et al. (2014) used in previous validation have not been used for this Report Card. The primary reason for this is the lower confidence in the loads calculated in these reports, as they are based on minimal or no monitoring data in some years.

The load estimates derived from the GBRCLMP measured data were compared to the modelled loads at six sites for the same time periods, see Appendix 5, Table 103 to Table 106. For the modelled baseline loads, there is a general under prediction in modelled TSS (Figure 14) and particulate loads compared to the GBRCLMP loads, except for Tully River at Euramo.

For TSS, the smallest percent difference (PBIAS) was for Tully River at Tully Gorge (-20%), followed by Herbert River at Ingham (-23%). Barron River at Myola had the largest PBIAS at -57%. For PN, North Johnstone at Tung Oil had the smallest PBIAS (-30%). The South Johnstone river at Upstream Central Mill had the smallest PBIAS for PP (-15%). There is a general under prediction for DIN (Figure 15), except for Barron River at Myola. The PBIAS was smallest at North Johnstone at Tung Oil (-11%)

DON, DIP and DOP are within ±70% and are a combination of over and under-prediction, but mostly under-predicted compared to the measured estimate. The PSII modelled load was under-predicted at two sites and over-predicted at Nth Johnstone (Figure 16). The PSII modelled loads were within ±72% of the measured estimate.

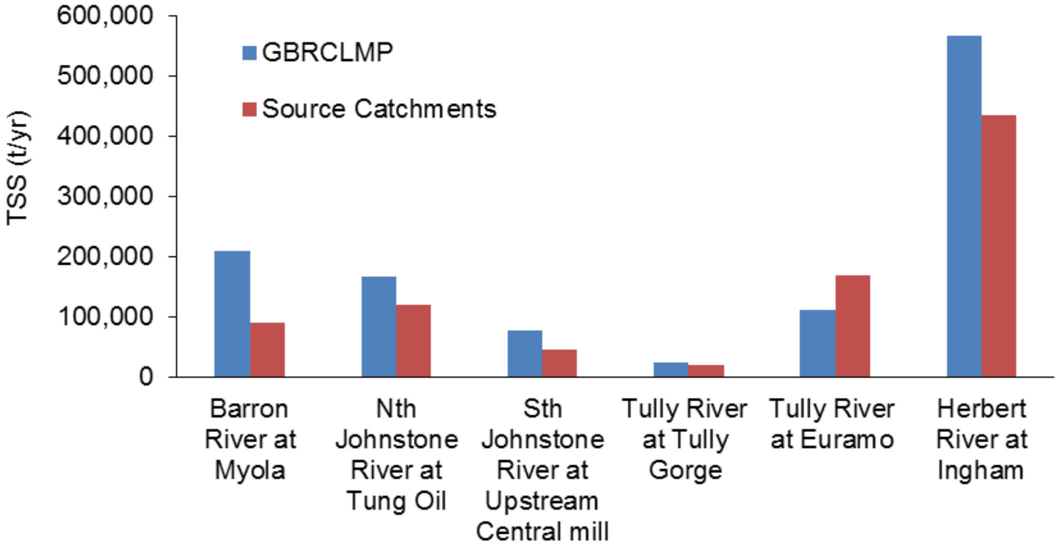


Figure 14 Comparison between average Source Catchments modelled and GBRCLMP monitored loads for the 2006–2014 period for TSS at the five WT sites

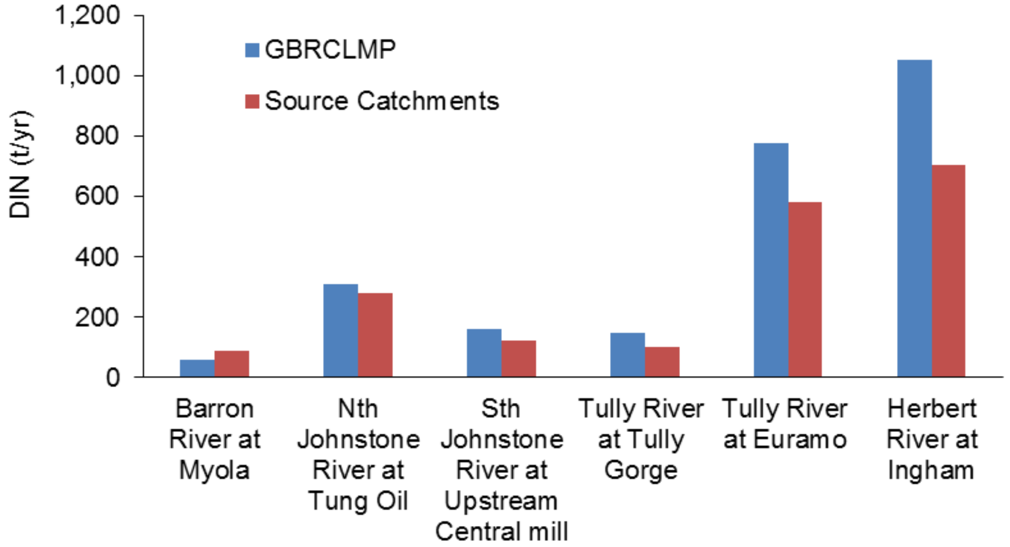


Figure 15 Comparison between average Source Catchments modelled and GBRCLMP monitored loads for the 2006–2014 period for DIN at the five WT sites

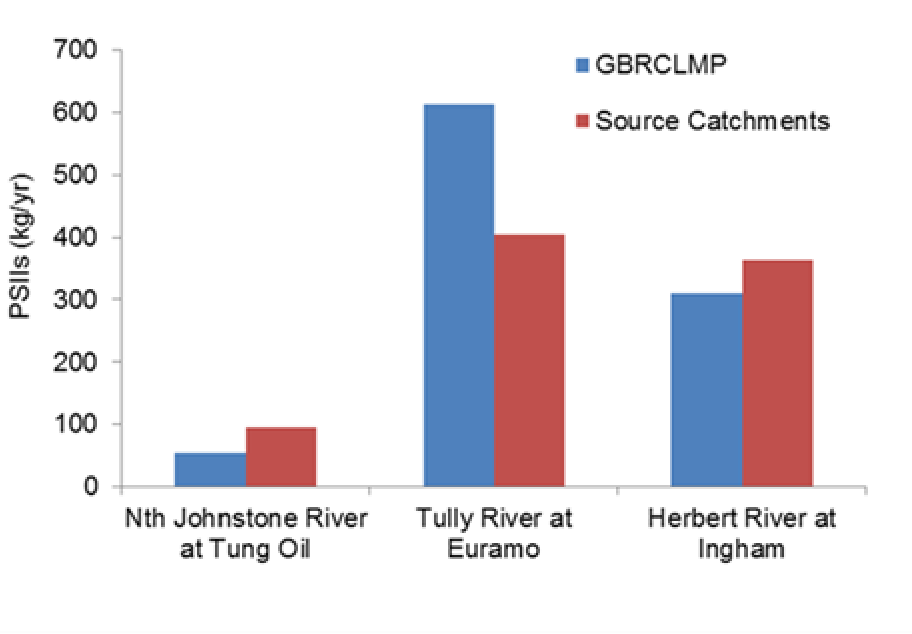


Figure 16 Comparison between average Source Catchments modelled and GBRCLMP monitored loads for the 2006–2014 period for PSII at the three WT sites

The performance of the RC2014 baseline model to predict the water quality processes across the WT region was also assessed using a number of quantitative statistics recommended in Moriasi et al. (2015). The estimated quantitative statistics and the corresponding model performance ratings are presented in Table 26 for the North Johnstone River and Table 27 for the Tully River. The statistics for the remaining sites can be found in Appendix 5, Table 107 and Table 108. For ease of presentation, 'very good' and 'good' rated sites are coloured green, while 'satisfactory' and 'indicative' are coloured orange, signalling that further work is required to improve the representation of these constituents.

All performance measures yielded similar results for all constituents at the North Johnstone site, with a mix of 'good' or better rankings and some 'indicative' rankings (Table 26). Flow was ranked as 'good' or better across three measures, as was DIN, DON and DIP. Most other constituents achieved mixed results suggesting improvements can be made. Statistics could not be calculated at the daily or monthly time-step due to the load calculation method used in the GRBCLMP data, and as such were only calculated at the annual scale. At the Tully River site, only TN rated 'good' or better across all measures (Table 27).

Table 26 RC2014 112004A North Johnstone River at Tung Oil, (n = 8 years for flow and n = 7 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.5	Good	-13.7	Satisfactory	0.7	Good	1.0	Very good
TSS	0.8	Indicative	-36.6	Indicative	0.3	Indicative	0.6	Satisfactory
TN	0.6	Satisfactory	-21.0	Satisfactory	0.6	Good	0.8	Very good
PN	0.8	Indicative	-31.5	Indicative	0.4	Indicative	0.7	Very good
DIN	0.3	Very good	-13.5	Very good	0.9	Very good	0.9	Very good
DON	0.5	Very good	11.0	Very good	0.8	Very good	0.8	Very good
TP	0.7	Indicative	-16.4	Good	0.5	Satisfactory	0.5	Satisfactory
DIP	0.3	Very good	-9.7	Very good	0.9	Very good	0.8	Very good
PP	0.7	Indicative	-24.7	Satisfactory	0.5	Satisfactory	0.5	Satisfactory
DOP	1.	Indicative	-59.7	Indicative	0.0	Indicative	0.9	Very good

Table 27 RC2014 113006A Tully River at Euramo, (n = 8 years for flow and n = 8 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.9	Indicative	-22.8	Indicative	0.2	Indicative	1.0	Very good
TSS	1.2	Indicative	53.0	Indicative	-0.3	Indicative	0.9	Very good
TN	0.6	Good	-2.8	Very good	0.7	Very good	0.7	Very good
PN	0.9	Indicative	34.8	Indicative	0.2	Indicative	0.8	Very good
DIN	1.0	Indicative	-25.0	Satisfactory	-0.1	Indicative	0.6	Satisfactory
DON	0.9	Indicative	-9.9	Very good	0.2	Indicative	0.4	Satisfactory
TP	2.2	Indicative	108.3	Indicative	-4.0	Indicative	0.7	Very good
DIP	1.1	Indicative	37.3	Indicative	-0.2	Indicative	0.1	Indicative
PP	2.7	Indicative	128.7	Indicative	-6.3	Indicative	0.7	Very good
DOP	1.3	Indicative	-61.8	Indicative	-0.7	Indicative	0.6	Satisfactory

Contribution by land use

The contribution to regional export by land use is presented in Figure 17 for each of TSS, PN, PP and DIN. Sugarcane is the largest contributor for all constituents, followed by nature conservation. Streambanks are also a large contributor to the TSS and particulate nutrient load.

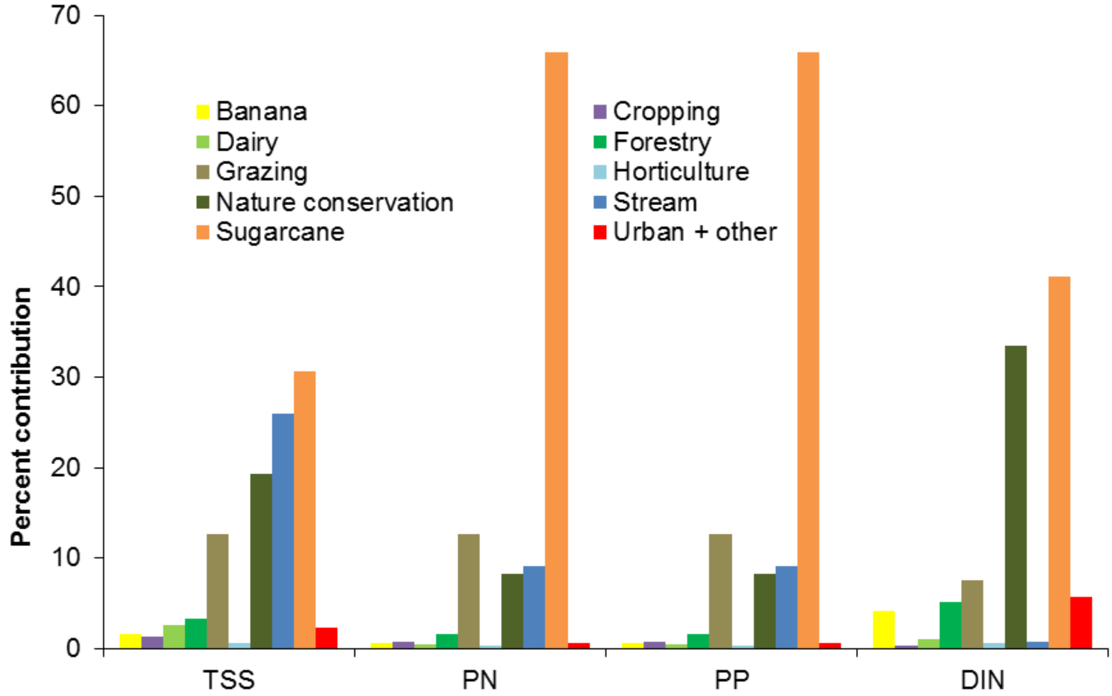


Figure 17 Contribution to fine sediment, particulate nutrient and DIN export by land use for the WT region

Sugarcane and nature conservation account for 8% and 45% of the WT area respectively, and between them generate 75% of the DIN export load (Figure 18). Sugarcane generated the largest load (2,071 t/yr). Per unit area, bananas generate the highest average annual load (14 kg/ha/yr), followed by sugarcane (12 kg/ha/yr) (Figure 18). The average DIN per unit area rate for all land uses in the WT is 2 kg/ha/yr.

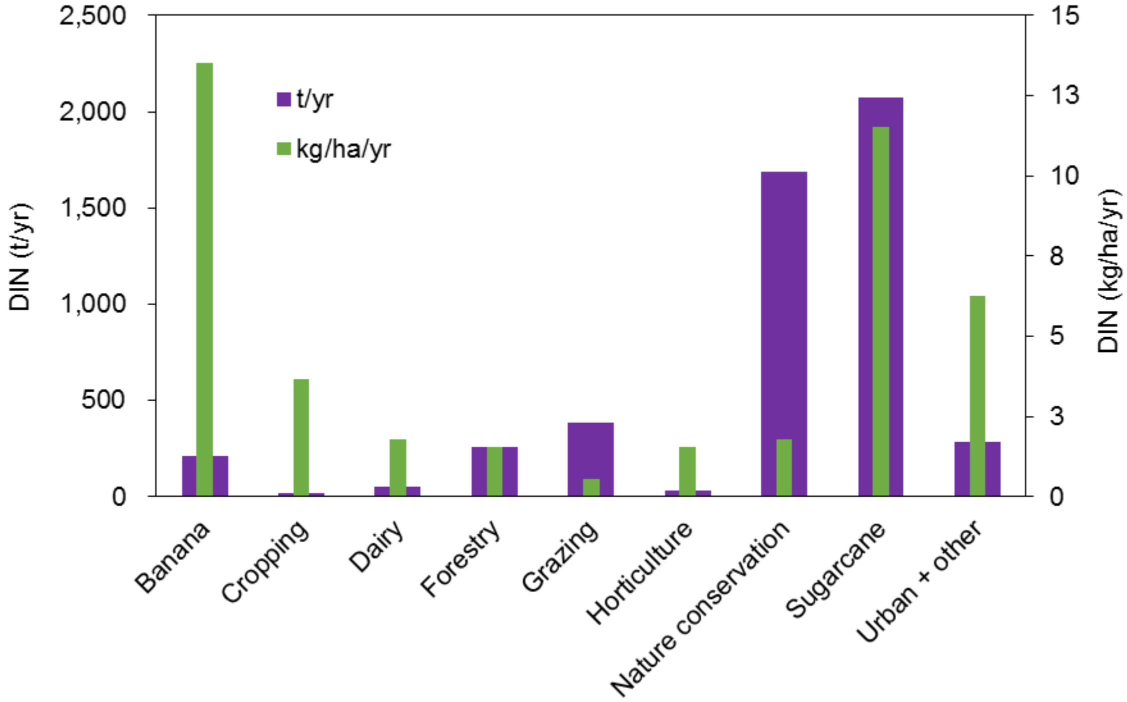


Figure 18 DIN export load and areal rate for each land use in the WT

Sources and sinks

The sources, sinks and resultant export of each constituent are presented in Table 28. It is estimated that the greatest sources of TSS in the WT were from hillslopes (71%) and streambanks (26%), with contribution from gullies at 3%. Only 2% of TSS is lost to in-stream deposition, with 98% of the TSS being exported to EOS.

Constituent losses occurred mainly through extractions for irrigation. For herbicides, the main loss pathway was from instream decay. The majority of the dissolved nutrient supply (99%) was from diffuse dissolved land uses, with the remaining 1% from point sources (sewage treatment plants). Most of the dissolved nutrients were exported (>99%). Total dissolved N load is greater than particulate N load. The DIN load for sugarcane is spilt between a surface runoff load and a seepage load. Of the total DIN export load from sugarcane (2,258 t/yr), 81% of the DIN load was exported to the stream as seepage and 19% as surface runoff. The modelled PSII herbicide supplied to the stream was 4,255 kg/yr, with 87% of supply exported to EOS (3,694 kg/yr). The total pesticide, exported from the WT was 10,284 kg/yr, which includes key non-PSII pesticides.

Table 28 Sources and sinks of each constituent in WT

	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSIIs (kg/yr)	PSII TE (kg/yr)
SOURCE	**1,701**	**13,285**	**5,090**	**4,267**	**5,967**	**3,074**	**243**	**202**	**2,629**	**4,255**	**3,139**
Hillslope	1,216	5,825			5,572	2,471			2,370	4,255	**3,139**
Gully	48	136			136	22			22		
Streambank	437	259			259	237			237		
Point source		48	38	10		9	7	2			
Diffuse dissolved		7,017	3,013	4,257		335	236	200			
Seepage		2,039	2,039								
SINK (loss)	**36**	**274**	**49**	**65**	**160**	**57**	**3**	**3**	**51**	**561**	**333**
Storage decay											
Extraction	27	237	47	61	129	45	3	3	39	50	7
Floodplain deposition	6	17			17	8			8		
Storage deposition	1										
Stream decay										505	325
Stream deposition	1	7			7	3			3		
Residual (instream)	1	13	2	4	7	1			1	6	
EXPORT	**1,665**	**13,011**	**5,041**	**4,202**	**5,807**	**3,017**	**240**	**199**	**2,578**	**3,694**	**2,807**

Progress towards Reef Plan 2013 targets

Overall, limited management changes were reported for the WT region for RC2014. Investments were made to improve soil and nutrient management in sugarcane and bananas, and pesticide management in sugarcane. The modelling results suggest there was a 0.35% reduction in average annual TSS load for the WT region, a 1.29% reduction for DIN and a 1.72% reduction for PSIIs. No management practice changes were reported for hillslope, streambank or gully management in grazing areas. The modelled cumulative reduction in loads (2010–2014) for TSS is 12.9%, 13.9% for DIN and 27.6% for PSIIs.

The management changes for sugarcane are presented in Table 29. For soil, nutrient and pesticides, a large proportion of the 2013 baseline management status for sugarcane is in C and D class (>=59%) (Table 29). Soil management for sugarcane saw a 4.2% change into mostly A class with the largest shift out of D class. Similarly for nutrients there was a 5.9% shift into mostly A class with the largest shift out of C class. For pesticide management there was a 7.5% shift mostly into B class, with most moving from C class. The management practice summary for bananas is presented in (Table 30). For banana soil and nutrient management, there was a more even spilt between B and C/D class compared to sugarcane. However no A class management for either soil or nutrients exists in the WT (Table 30). For bananas, there were shifts out of D and C class practices for soils, into B class (8.75%); with a similar trend occurring for nutrients (into B class 10.74%). Most of the shift for soils and nutrients was out of C class. For bananas in the WT pesticide management is not considered in the management framework and no PSII herbicides are used.

Table 29 WT sugarcane management practice change summary; values are percent of total area

Soil	Baseline 2013	RC2014	Change
A	9.2	13.4	4.2
B	31.4	31.9	0.4
C	43.4	42.4	-1.0
D	16.0	12.3	-3.7
Nutrients			
A	2.0	7.9	5.9
B	10.4	11.1	0.7
C	84.3	77.7	-6.6
D	3.2	3.2	0.0
Pesticides			
A	3.9	4.1	0.2
B	8.4	15.9	7.5
C	80.9	74.9	-6.0
D	6.9	5.2	-1.7

Table 30 WT banana management practice change summary; values are percent of total area

Soil	Baseline 2013	RC2014	Change
A	-	-	-
B	45	53.5	8.75
C	38	29.4	-8.46
D	17	17.2	-0.29
Nutrients			
A	-	-	-
B	42	52.3	10.74
C	50	40.0	-10.07
D	8	7.7	-0.67

Burdekin

The results of the BU modelling are presented below, separated into hydrology and modelled loads. In the hydrology component, the results of the updated calibration process will be presented per gauge, as well as the impact on the total flow for the BU region. The modelled loads section includes the results of the total baseline, anthropogenic baseline and predevelopment loads. The validation of the BU Source Catchments modelled data is then presented using load estimates from measured and modelled data. Progress towards targets are also presented. A summary of the total baseline load by land use, and land use by basin is also reported, as well as a mass balance summary of the sources and sinks by constituent. For a full list of the BU region loads for RC2014 refer Appendix 4, Table 98.

Hydrology calibration performance

The recalibration of the model using the Sacramento model produced significantly better runoff predictions. Differences in runoff volumes (PBIAS) for RC2014 for the key sites listed in Table 31 were on average within 0.5% of observed flow ranging from -3.6% to + 3.2%. In comparison, Report Card 2013 was on average 5% of observed flow ranging from -61% to +21.5%. Key sites are defined as the catchment scale sites in the BU, including the Burdekin Falls Dam and the EOV Burdekin River at Clare. For the coastal basins, gauges with the largest catchment area were selected. There was significant improvement in all three performance measures (PBIAS/volume, daily NSE and R^2), and, using the Moriasi et al. (2007) classification all gauges are now classed as “good” to “very good” for RC2014 at the daily scale.

Table 31 Model Performance PBIAS (volume); Key sites, BU region hydrology calibration, RC2013 and RC2014. (negative values indicate an underprediction)

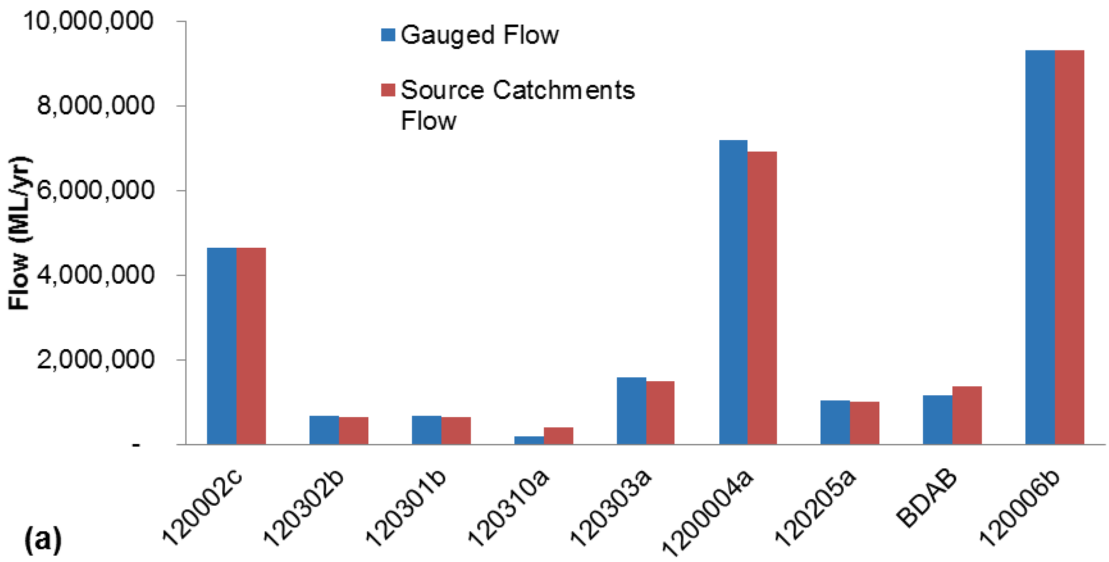
Basin	Gauge name and number	RC2013 % volume difference	RC2014 % volume difference
Black	Black River at Bruce Highway – 117002A	-8.6	1.3
Haughton	Haughton River at Powerline - 119003A	-5.6	0.0
Don	Don River at Reeves – 121003A	10.6	0.1
Burdekin	Burdekin River at Sellheim – 120002C	2.3	0.0
Burdekin	Cape River at Taemas – 120302B	6.0	0.0
Burdekin	Suttor River at St Anns – 120303A	-18.0	3.2
Burdekin	Belyando River at Gregory Development Rd – 120301B	-61.0	-3.6
Burdekin	Bowen River at Myuna – 120205A	21.5	0.0
Burdekin	Burdekin Falls Dam – 120004A	5.6	-2.8
Burdekin	Burdekin River at Clare – 120006B	2.3	-0.6

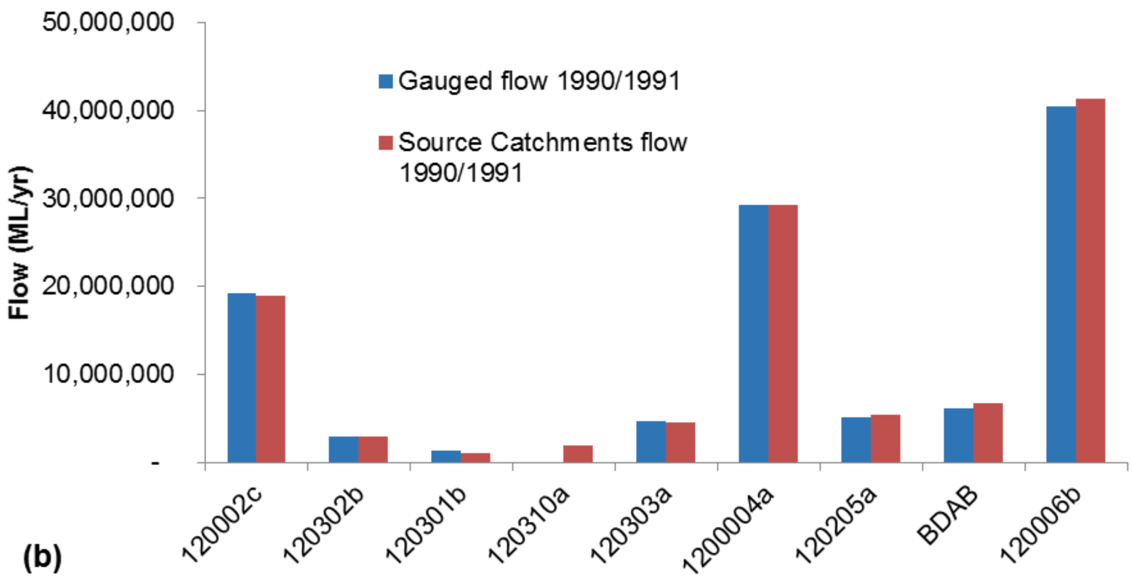
A full list of RC2014 calibration results and ratings are shown in Appendix 1, Table 71. In the Black Basin, NSE and percent volume difference averaged 0.69 and -1% respectively. The Ross Basin recorded very good calibration for gauges 118003a and 118104a. In contrast, performance statistics for 118001b were only satisfactory for total volume bias. The Haughton Basin had “very good” to “good” calibration for all gauges. Likewise in the Don Basin the recorded statistics showed a very good to good calibration.

In the larger Upper Burdekin catchment, the NSE gauge average was greater than 0.65 and generally improved with a greater catchment area. The Bowen catchment was the worst performed catchment, with average NSE of 0.66 which is still regarded as a satisfactory result. This could be due to a lack of rainfall gauging stations/data in this basin.

Water year performance

Annual comparisons for wet and dry periods were carried out to ensure the model is representing the extreme climate periods adequately. The model run period from 1986–2014 captured both wet and dry periods across the BU region. Figure 19 shows the gauged and modelled flow volumes for (a) the average annual flow during the period, (b) the water year with the most flow and (c) a low flow year. Modelled average annual flow volumes in general match the observed. In addition, wet years such as the 1990/1991 water year also closely match the observed. However in the dry years, the model did not simulate observed runoff as well (Figure 19 C).





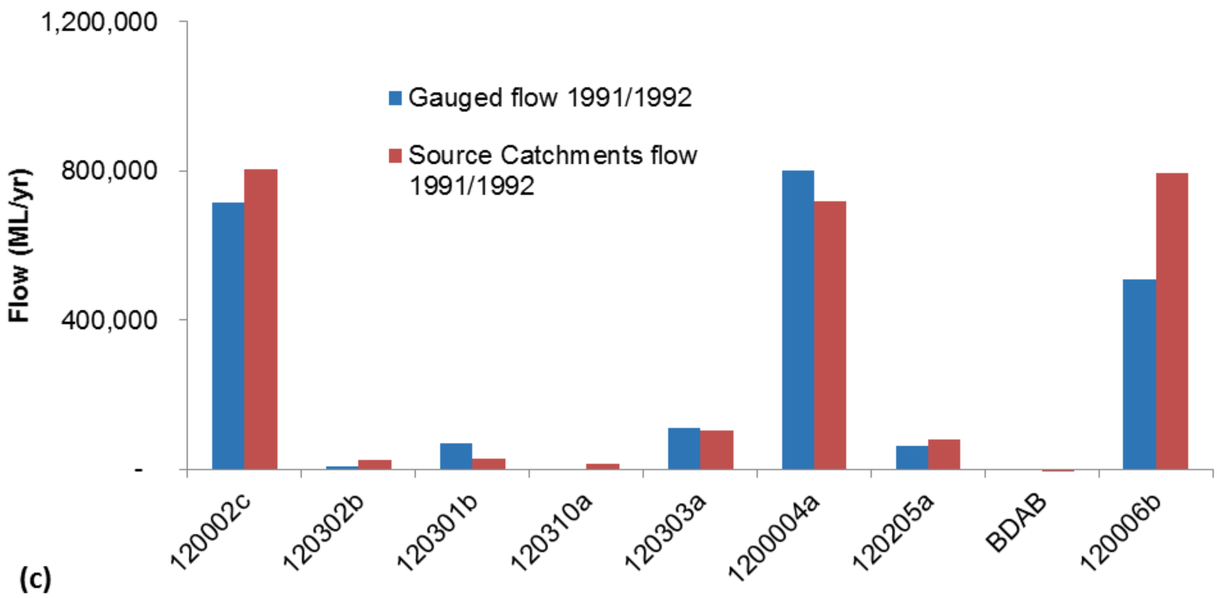


Figure 19 Gauged and modelled flow (ML) for key BU catchment sites. A) Average annual flow (1986–2014), B) 1990/1991 water year (wettest year in model period), C) 1991/1992 water year (driest year in model period).

Modelled Loads

It is estimated that the BU region contributes ~40% of the total baseline TSS load being exported to the GBR. The BU region was the highest contributor of TSS load, and is one of the highest contributors for most constituents. Within the region, the Burdekin River Basin was the greatest contributor for all constituents apart from PSIIs. As was the case for RC2013, the majority of the pesticide loads are generated from the Haughton and Burdekin basins. The contribution from each basin in the BU region to the total load for each constituent is presented in Table 32.

In terms of differences to the RC2013 modelling, for the coastal catchments there are large reductions in particulate loads (TSS and PN) and this is more in line with the limited monitoring data. However when considering the other constituents there is relatively little change given the assumed uncertainties.

Table 32 Contribution from BU basins to the total BU baseline load

Basin	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
Black	67	402	98	147	157	119	21	7	91	16	12
Ross	46	376	178	142	55	71	33	11	27	2	0
Haughton	160	1,310	855	212	243	244	63	18	163	1,591	894
Burdekin	3,222	5,737	1,144	1,802	2,791	2,104	279	92	1,733	533	288
Don	200	637	170	184	283	197	28	10	159	154	78
Total	**3,695**	**8,463**	**2,446**	**2,488**	**3,530**	**2,735**	**424**	**138**	**2,173**	**2,295**	**1,273**

Anthropogenic baseline and predevelopment loads

The estimated TSS anthropogenic baseline load was 3,069 kt/yr or 83% of the total baseline load with the remaining 17% attributed to the predevelopment load. The predevelopment increase factor to total baseline load was 6 for TSS and all basins except the Black were dominated (>50%) by the anthropogenic baseline load compared to the total baseline load (Figure 20). Loads are also presented in tabular form, see Table 99, Appendix 1. The anthropogenic baseline DIN load was 1,236 t/yr or 51% of the total baseline load, with the remaining 1,210 t/yr or 49% attributed to the predevelopment load. The Haughton Basin had the highest proportion of the DIN anthropogenic baseline load to the total load at 89% and along with the Ross (55%) were the only two basins to be dominated by the anthropogenic load (>50% of total load) (Figure 21).

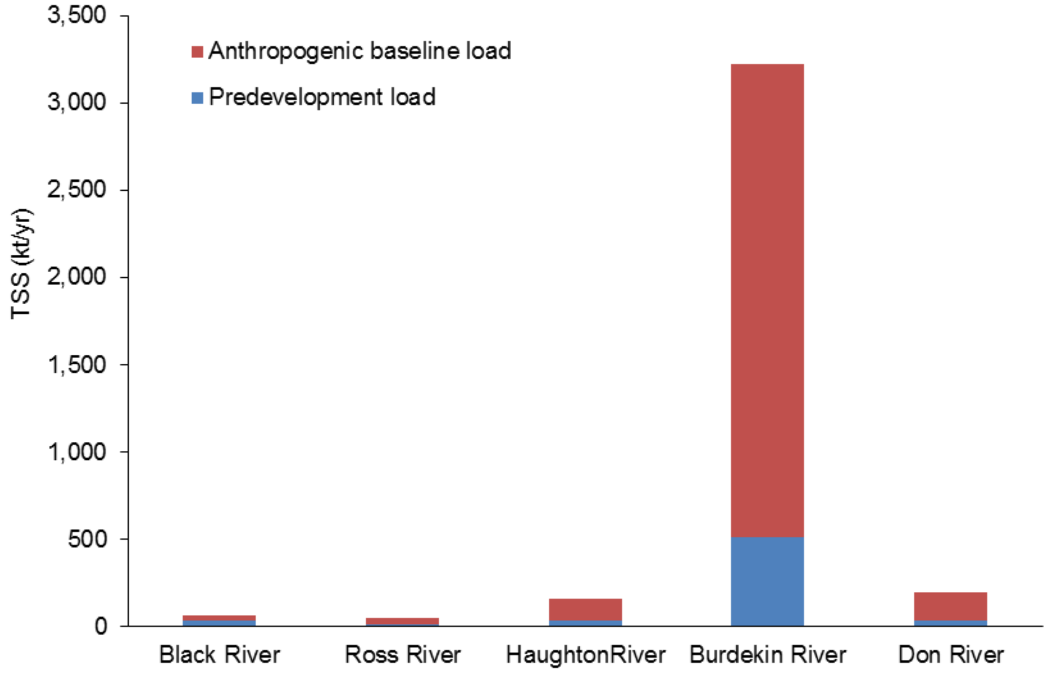


Figure 20 Fine sediment (kt/yr) load for the BU basins, indicating the predevelopment and anthropogenic baseline contributions

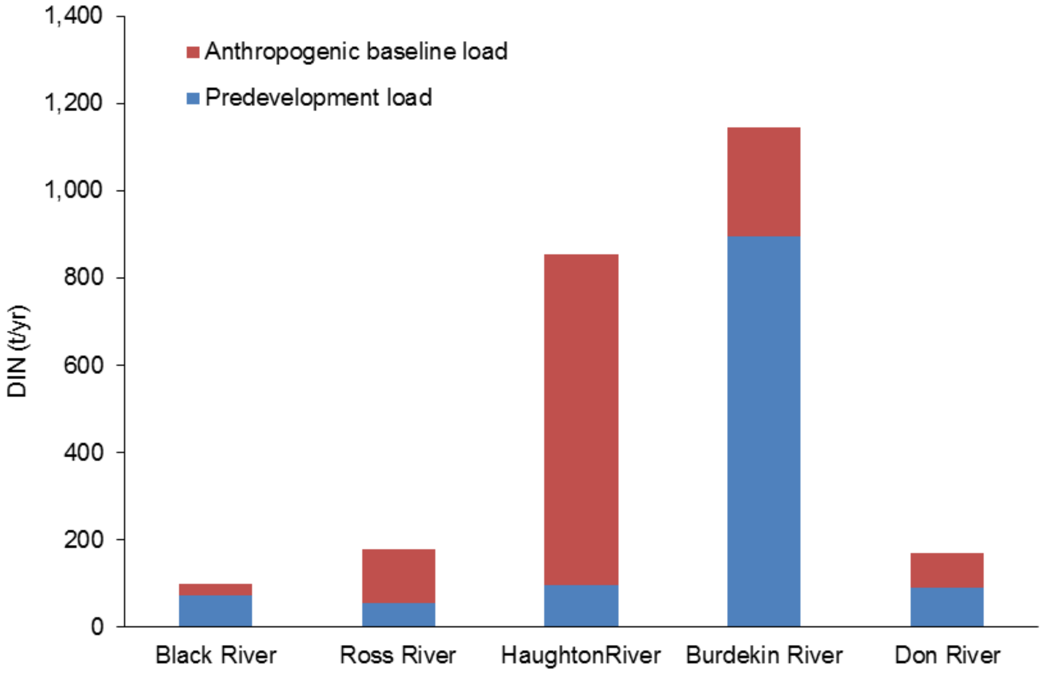


Figure 21 DIN (t/yr) load for the BU basins, indicating the predevelopment and anthropogenic baseline contributions

Constituent load validation

Three major sources were used to compare the performance of the model. A key validation dataset used to validate the model were the GBRCLMP 2006–2014 monitoring program established by the Qld State Government (Turner et al. 2012). Further validation was conducted against the long-term loads report (1986–2009) using the FRCE method (Joo et al. 2014) and other additional datasets.

Due to the extension of the modelling period from 1986–2009 through to 2014, there are now up to eight years of water quality monitoring data for the six GBRCLMP sites in the BU Region. The monitoring data was collected under the GBR Catchment Loads Monitoring Program (GBRCLMP) (Joo et al. 2012, Turner et al. 2012, Turner et al. 2013, Garzon-Garcia et al. 2015, Wallace et al. 2015). At a number of locations, loads are only available for a shorter time period (Table 33). GBRCLMP monitoring data for example has only been collected since 2012 in the Bowen Basin.

Table 33 Monitoring details for the six water quality sites in the BU

Site	Monitoring period	Observed load period for this report	Average samples collected per year	Notes
Burdekin River at Home Hill (EOV)	2006–2014	2006–2014	52	
Burdekin River at Sellheim	2006–2014	2006–2014	20	Measured loads for 2009 period indicative only
Bowen river at Myuna	2012–2014	2012–2014	39	Operational since 2012
Belyando River at Gregory Development Road	2006–2013	2006–2013	65	
Cape River at Taemas	2006–2013	2006–2013	52	
Suttor River at Bowen Development Road	2007–2013	2007–2013	29	Measured loads for 2007–2008 period indicative only

A comparison was made between the mean GBRCLMP flow and loads (averaged over eight years, 2006–2014) and the Source Catchments modelled loads for the same locations and the same time period (Figure 22). For the EOV site Burdekin River at Home Hill (120001a) modelled flow is within 6% of the gauged flow for the period (Table 36), and this site is not used for hydrology calibration. Fine sediment (TSS) shows a good match. Modelled constituent loads for TN (-35%), TP (-26%) are under predicted. The DIN load is ~9.5% higher than the GBRCLMP estimate.

For the sites above the Burdekin Falls Dam (BFD), the Burdekin River at Sellheim has the largest upstream loads and not surprisingly this site shows similar trends to the EOV site (Burdekin River at Home Hill 120001a). The Cape, Belyando and Suttor sites loads are relatively low and they show comparatively good prediction for flow and fine sediment. However, discrepancies are noted in the Cape for sediment and PN and in particular particulate phosphorus in the Belyando.

The only catchment site below the BFD, the Bowen River at Myuna has only two well sampled years (2012 and 2013). These are relatively low flow years, with difficulties reported in sampling (e.g. poor access) during previous years. Loads are relatively small, with flow under predicted, and this in turn is passed onto the other constituents.

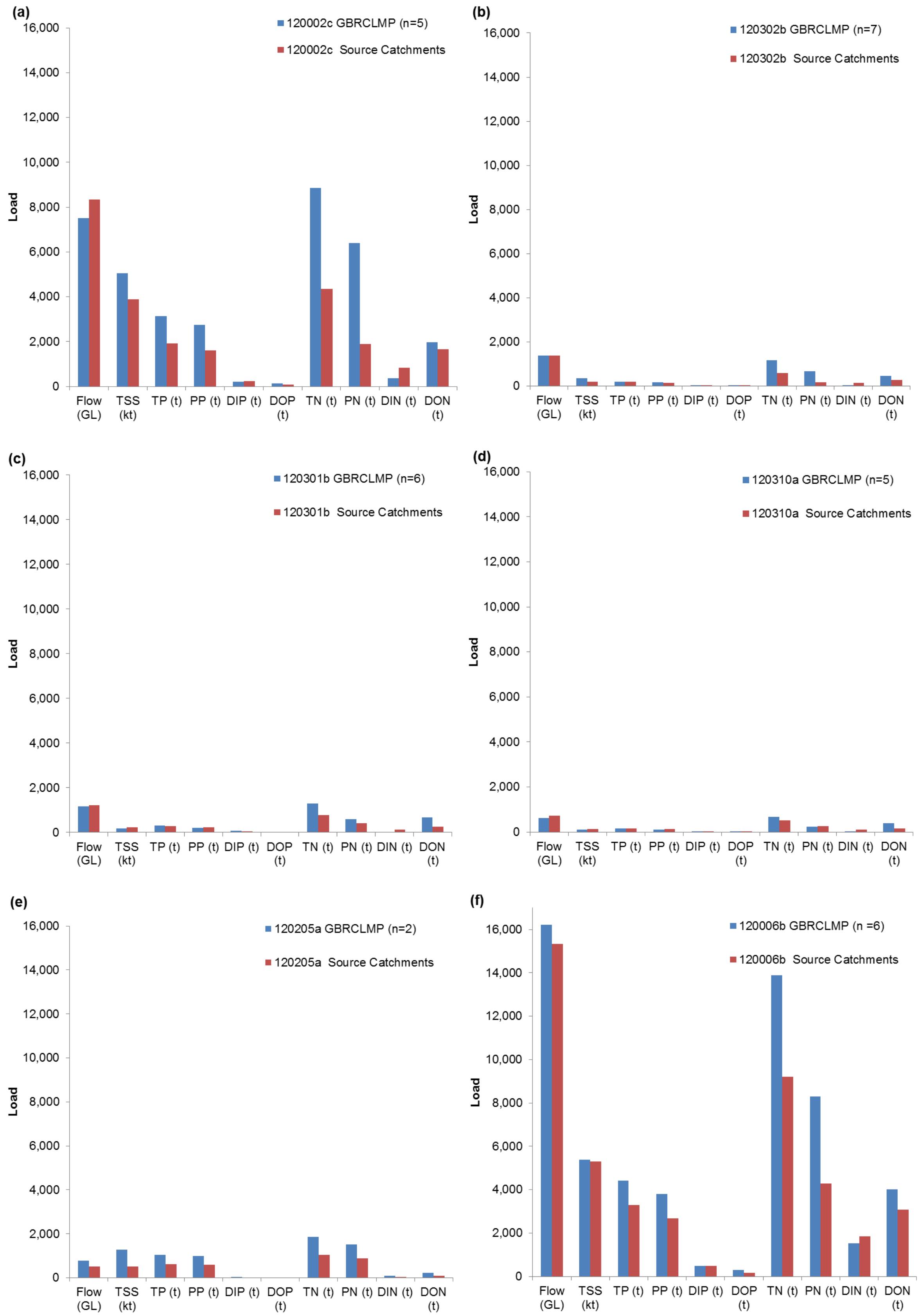


Figure 22 Comparison between modelled and GBRCLMP loads for the period 2006–2014. Note number of year sampled (n) during the period eight year period.

Barratta Creek at Northcote (119003a) is the only "coastal catchment" site with sufficient data for model comparison (Figure 23). Modelled flow is within 30% of the gauged flow for the period. Modelled constituent loads for TSS and TN are under predicted. The DIN load is ~8% higher than the GBRCLMP estimate.

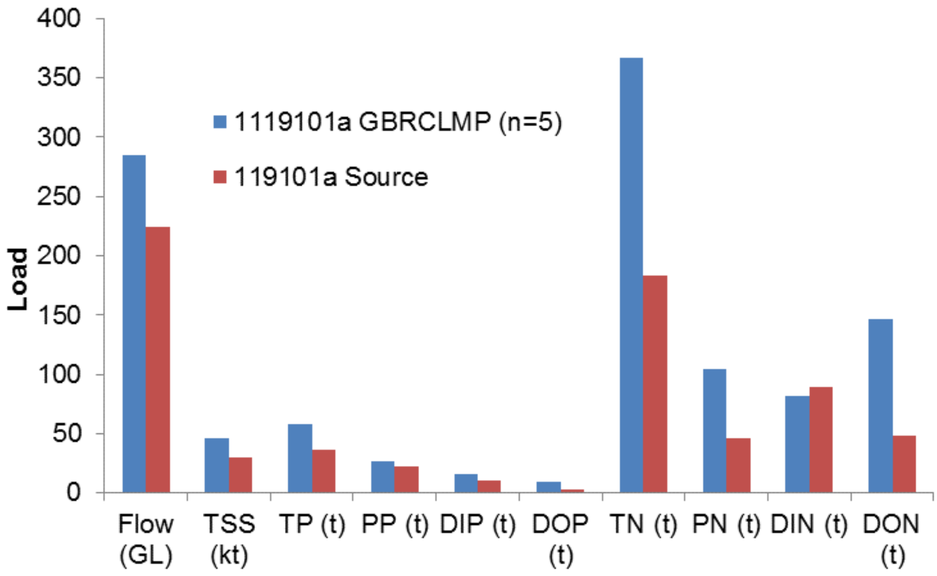


Figure 23 Comparison between modelled and GBRCLMP loads for the period 2009-2014 for Barratta Creek at Northcote (119003a).

The performance of the RC2014 baseline model to predict the water quality across the BU region was also assessed using a number of quantitative statistics recommended in Moriasi et al. (2015). The estimated quantitative statistics and the corresponding model performance ratings are presented in Table 34 for the Burdekin River at Selheim, Table 35 for the Suttor River at the Bowen Development Road, and Table 36 for the Burdekin River at Home Hill (the EOS site), in comparison to the GBRCLMP calculated annual loads. The summary table for each of the remaining validation sites in the BU is presented in Appendix 5. For ease of presentation, 'very good' and 'good' rated sites are coloured green, while 'satisfactory' and 'indicative' are coloured orange, signalling that further work is required to improve the representation of these constituents.

Of the 10 modelled constituents (flow, sediment and nutrients) across the six sites, the majority were ranked as 'indicative', with the remaining ranking as Satisfactory or better. The Burdekin River at Home Hill site ranked as the best overall, followed by the Belyando River and Burdekin River at Sellheim sites. Flow and TP were the best performing parameters. DOP was the worst performing parameters, being rated as 'indicative' at each of the six sites. The performance data at each of the five sites is presented in Appendix 5. Statistics could not be calculated at the daily or monthly time-step due to the load calculation method used in the GRBCLMP data.

Table 34 RC2014 120002C Burdekin River at Sellheim, (n = 8 years for flow and n = 7 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.2	Very good	3.5	Very good	1.0	Very good	1.0	Very good
TSS	0.4	Very good	-22.9	Indicative	0.8	Very good	0.9	Very good
TN	0.8	Indicative	-50.8	Indicative	0.4	Satisfactory	1.0	Very good
PN	1.0	Indicative	-70.5	Indicative	-0.0	Indicative	0.9	Very good
DIN	4.0	Indicative	131.8	Indicative	-15.4	Indicative	0.6	Good
DON	0.3	Very good	-16.8	Good	0.9	Very good	1.0	Very good
TP	0.6	Satisfactory	-38.4	Indicative	0.6	Good	0.9	Very good
DIP	0.3	Very good	15.3	Good	0.9	Very good	1.0	Very good
PP	0.7	Satisfactory	-41.9	Indicative	0.5	Good	0.9	Very good
DOP	0.8	Indicative	-44.0	Indicative	0.4	Satisfactory	0.7	Very good

Table 35 RC2014 120310A Suttor River at Bowen Development Road, (n = 8 years for flow and n = 8 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.5	Very good	1.4	Very good	0.8	Good	0.7	Satisfactory
TSS	0.4	Very good	34.8	Indicative	0.8	Very good	0.9	Very good
TN	0.4	Very good	-24.5	Satisfactory	0.8	Very good	0.7	Good
PN	0.5	Very good	-1.2	Very good	0.8	Very good	0.4	Satisfactory
DIN	5.3	Indicative	394.0	Indicative	-26.7	Indicative	0.9	Very good
DON	0.7	Indicative	-58.7	Indicative	0.5	Good	0.7	Very good
TP	0.6	Good	2.8	Very good	0.7	Very good	0.3	Satisfactory
DIP	0.6	Good	-35.8	Indicative	0.7	Very good	0.5	Satisfactory
PP	0.7	Satisfactory	36.7	Indicative	0.5	Good	0.4	Satisfactory
DOP	0.9	Indicative	-76.5	Indicative	0.1	Indicative	0.4	Satisfactory

Table 36 RC2014 120001A Burdekin River at Home Hill, (n = 8 years for flow and n = 8 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.2	Very good	-4.2	Very good	1.0	Very good	1.0	Very good
TSS	0.4	Very good	-3.2	Very good	0.9	Very good	0.9	Very good
TN	0.7	Satisfactory	-34.7	Indicative	0.5	Good	0.9	Very good
PN	0.9	Indicative	-48.7	Indicative	0.2	Indicative	0.9	Very good
DIN	0.6	Satisfactory	9.5	Very good	0.6	Good	0.9	Very good
DON	0.4	Very good	-21.9	Satisfactory	0.8	Very good	1.0	Very good
TP	0.6	Good	-25.5	Satisfactory	0.7	Very good	0.9	Very good
DIP	0.5	Very good	1.2	Very good	0.8	Very good	0.8	Very good
PP	0.6	Satisfactory	-30.3	Indicative	0.6	Good	0.9	Very good
DOP	0.9	Indicative	-46.1	Indicative	0.	Indicative	0.5	Satisfactory

The same quantitative statistics were also calculated on the long-term monitored monthly loads (Joo et al. 2014) versus the modelled load, with the overall ranking for each constituent at the Burdekin River at Home Hill station (see Table 37). Of the 10 modelled constituents (flow, sediments and nutrients) across the five sites, six were ranked as ‘indicative’, four as ‘good’/’very good’.

Table 37 Moriasi et al. (2015) overall monthly performance rating for each constituent for the Burdekin River at Home Hill sites

Overall rating RC2014 (2006-2014) Monthly	
Parameter	**Burdekin R. at Home Hill**
Flow	Very good
TSS	Indicative
TN	Indicative
PN	Indicative
DIN	Good
DON	Very good
TP	Very good
DIP	Indicative
PP	Indicative
DOP	Indicative

Burdekin Falls Dam (2005–2009) dataset

Comparisons between the modelled sediment trapping and the estimates of (Lewis et al. 2013) for the Burdekin Falls Dam are shown in Figure 24. The average annual (2005–2009) model estimate of the inflow and outflow of fine sediment compares well for the study period (Figure 24a). On an annualised basis, the model predicts 16% less fine sediment inflow and 30% more outflow than (Lewis et al. 2013) estimates. This equates to an annualised trapping percentage of 52% for the model and 66% for (Lewis et al. 2013). At the annual time step, the trapping efficiency fits within the Lewis error bars for the first three years, and then deviates for the last two (Figure 24b). The 2008 and 2009 values are lower than Lewis, while the 2004, 2005 and 2006 years show an exact match. For the total modelling period (1986–2014) the annualised trapping is 59%; varying from a low of 45% in the 1990 water year to a high of 100% in 1986 (Figure 24 c).

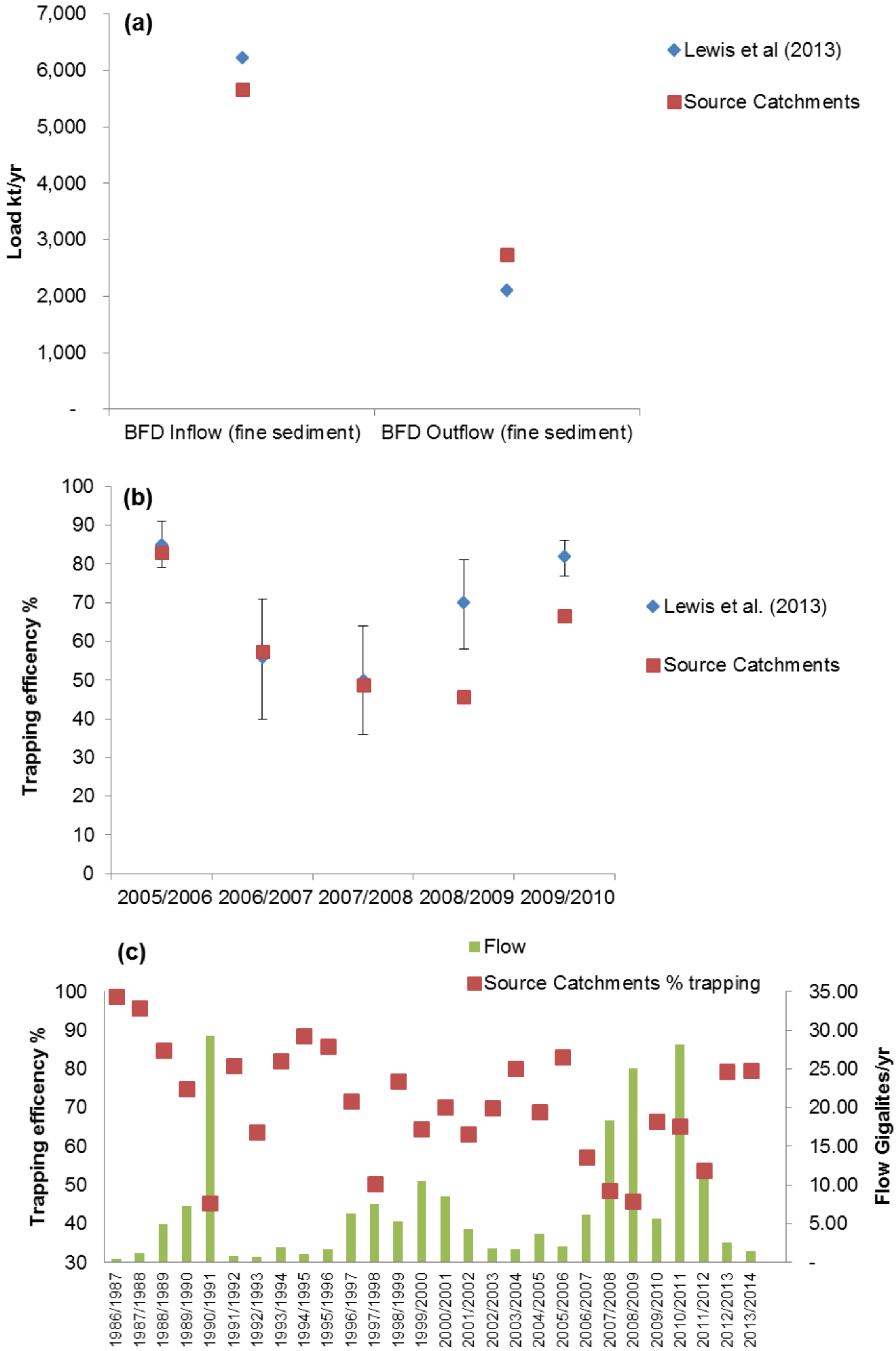


Figure 24 (a) Comparison of Source Catchments and Lewis et al. (2013) average annual fine sediment load (05-09 water years) estimated to enter and exit the Burdekin Falls Dam **(b)** Lewis et al. (2013) estimated Burdekin Falls Dam trapping by water year **(c)** Gauged BFD outflow and Source Catchments (%) sediment trapped

For a series of events at various locations the sediment tracing work of (Wilkinson et al. 2013) predicts that ~80% of fine sediment is sourced from sub-surface soil and the most likely source is gullies; however channel (bank) and hillslope rilling and scalds may also contribute (Table 38). In contrast, the RC2013 model predicts a greater proportion of hillslope erosion, however the RC2014 model predicts a similar proportion to that of the tracing.

Table 38 Results showing surface soil tracing and contribution of hillslope predicted and Source Catchments. Table modified from Wilkinson et al. (2013)

River sediment sampling location	Catchment area (ha)	MRE[a] (%)	Surface soil contribution (tracing) %[b]	Hillslope erosion contribution (RC2013)	Hillslope erosion contribution (RC2014)
Little Bowen River	147,000	11	13(+-5)	59	27
Broken River	219,000	16	65(+14-14)	81	65
Bowen River downstream of Broken confluence	366,000	6	29(+-9)	80	
Bowen River at Myuna	704,000	7	19(+6-7)	65	27
Bowen River at Hotel	765,000	14	17(+6-%)		
Upper Burdekin River	3,480,000		~20[c]	37	17
Weany Creek	1400		~40[c]		
Keelbottom Creek	117,000	5	13(+2-2)	62	19
Thornton Creek	8400	3	20(+3-3)		

[a] Mean Relative Error of degree of agreement between observed and predicted from Wilkinson et al. (2013)
[b] Upper and lower 95% confidence intervals, respectively
[c] Estimated by linear mixing of mean ^{137}Cs and $^{210}Pb_{xs}$ activities.

Contribution by land use

Grazing (open and closed) and Conservation account for ~90% and ~5% of the BU Region respectively, and generate 99% of the fine sediment load, and over 95% of all other constituents, apart from DIN and PSII. PSII toxic load is predominantly derived from sugarcane and sugarcane accounts for ~45 % of the DIN export.

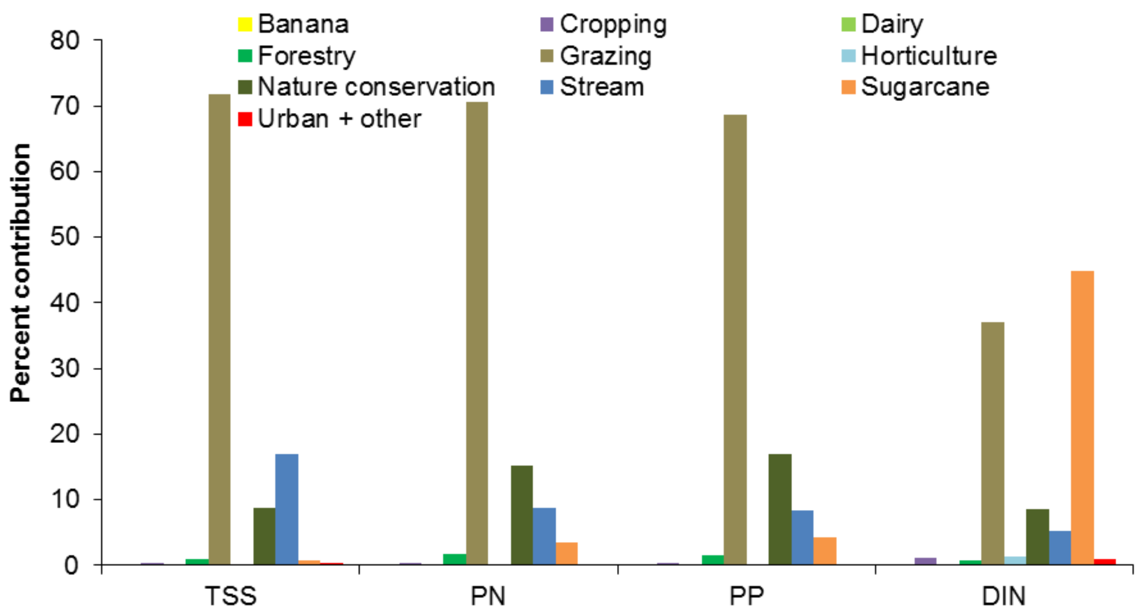


Figure 25 Contribution to fine sediment, particulate nutrient and DIN export by land use for the BU region

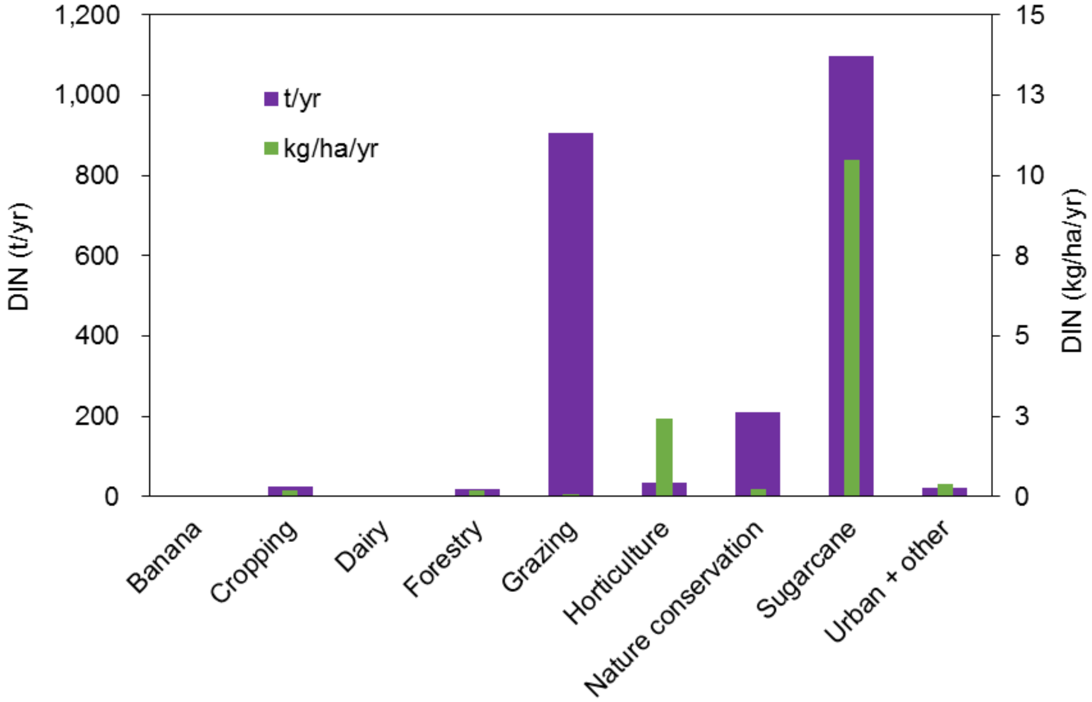


Figure 26 DIN export load and areal rate for each land use in BU

Sugarcane and grazing account for <1% and 90% of the BU area respectively, and between them generate 87% of the DIN export load (Figure 26). Sugarcane generated the largest load (1,099 t/yr). Per unit area, sugar also generates the highest average annual load (10 kg/ha/yr), while grazing has the lowest (<0.1 kg/ha) (Figure 26). The large grazing load is a function of its large area.

Sources and sinks

Of the estimated total modelled fine sediment load (6,532 kt/yr) in the BU region (Table 39), 57% is exported to the GBR lagoon with the remaining 43% largely lost to reservoir deposition (65%), floodplain deposition (26%), and the remainder lost to extractions (9%). No instream deposition of fine sediment was modelled due to a lack of supporting data to quantify the deposition component at the time of model development, though instream deposition and remobilisation could be enabled in future models if data to support it become available. For TN, 75% of the generated load is exported, while 60% of the generated TP load is exported.

Table 39 Sources and sinks of each constituent in the BU NRM Region

	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
SOURCE	**6,532**	**11,295**	**2,558**	**2,652**	**6,085**	**4,588**	**448**	**147**	**3,993**	**4,412**	**2,297**
Hillslope	1,475	3,152	126		3,026	2,271	44	11	2,215	4,412	2,297
Gully	4,110	2,632			2,632	1,515			1,515		
Streambank	946	427			427	262			262		
Channel remobilisation											
Diffuse dissolved		3,937	1,319	2,618		501	374	127			
Seepage		983	983								
Point Source		164	130	34		39	30	9			
SINK (loss)	**2,837**	**2,832**	**112**	**164**	**2,555**	**1,853**	**25**	**8**	**1,820**	**2,117**	**1,024**
Storage Deposition	1,854	1,492			1,492	1,129			1,129		
Floodplain deposition	724	656			656	399			399		
Stream Deposition									-		
Extraction and Losses	259	683	112	164	407	326	25	8	293	31	15
Stream Decay										2,086	1,008
EXPORT	**3,695**	**8,463**	**2,446**	**2,488**	**3,530**	**2,735**	**424**	**138**	**2,173**	**2,295**	**1,273**

Progress towards Reef Plan 2013 targets

For fine sediment and particulate nutrients, minor improvements in loads have occurred in RC2014, with reductions in TSS ~1.5%, PN ~1% and PP (~%1). In sugarcane a reduction of ~1% for DIN was recorded, and this is again in line with the small changes in management recorded. The PSII reduction was ~6% and this is due to the impact of recycle pits and paddock management. The management changes that led to these reductions is discussed below.

Management practice changes that occurred in grazing lands are presented in Table 40. Small changes were made in streambank and gully management, with a 1% shift from C to B practices occurring in the area of hillslope targeted practices. A 1% change in area was recorded for sugarcane soil management practice from C to B class practices (Table 40), with a relatively large change occurring in cropping (grains) soil management (Table 42) where a 5% shift from C to A and B class practices was recorded.

Collectively these changes result in small load reduction reported for fine sediment from the BU region ~1.5%.

With respect to nutrients, for sugarcane (Table 41) there was a shift from D/C classes to C/B for nutrients, while no management changes were reported from cropping (grains) (Table 42). The land management practice improvements in sugarcane resulted in a ~2% reduction in DIN from the BU region. This contributed to the 1% overall GBR reduction.

Improvements were recorded in both sugarcane and cropping (grains) land uses for pesticide use. In sugarcane there was a shift (<1%) out of B class practices into A, while for cropping areas there was a <1% shift from B to A. In addition sugarcane improvements were recorded in recycle pit management, with a 4% shift to A and B practices. These pesticide management changes resulted in a 6% reduction in PSII toxic equivalent loads from the BU region, contributing to the 1.5 % overall GBR reduction.

Table 40 BU grazing management practice change summary; values are percent of total area

Hillslope	Baseline	RC2013	Change
A	0.4	0.7	0.3
B	28.7	29.2	0.5
C	59.1	58.6	-0.5
D	11.8	11.6	-0.2
Gully	**Baseline**	**RC2013**	**Change**
A	5.5	6.0	0.5
B	20.7	20.2	-0.5
C	55.9	55.9	0
D	18.0	18.0	0
Streambank	**Baseline**	**RC2013**	**Change**
A	32.6	32.6	0
B	29.0	29.1	0.1
C	13.8	13.7	-0.1
D	10.0	9.9	-0.1

Table 41 BU sugarcane management practice change summary; values are percent of total area

Soil	Baseline	RC2013	Change
A	3	3	0
B-A	2	2	0
B	11	12	1
C-B	32	32	0
C	26	25	-1
D-C	12	12	0
D	14	14	0
Nutrients	**Baseline**	**RC2013**	**Change**
A	3	3	0
B	5	7	2
C-B	12	11	-1

C	54	53	-1
D-C	16	15	-1
D	11	10	-1
Pesticides	**Baseline**	**RC2013**	**Change**
A	7	7	0
B	19	18	-1
C	47	47	0
Df	28	28	0
Irrigation	**Baseline**	**RC2013**	**Change**
A	9	9	0
B-C	8	8	0
D	83	83	0
Recycle Pits	**Baseline**	**RC2013**	**Change**
A	19	20	1
B	16	19	3
C	27	25	-2
D	38	36	-2

Table 42 BU grains management change; values are percent of total area

Soil	Baseline	RC2013	Change
A	4	8	4
B	82	83	1
C	14	9	-5
D	0	0	0
Nutrient	**Baseline**	**RC2013**	**Change**
A	5	5	0
B	43	43	0
C	52	52	0
D	0	0	0
Pesticide	**Baseline**	**RC2013**	**Change**
A	5	6	1
B	26	26	0
C	69	69	0
D	0	0	0

Mackay Whitsunday

The results of the MW modelling are presented below, separated into hydrology and modelled loads. In the hydrology component, the results of the updated calibration process will be presented per gauge, as well as the impact on the total flow for the MW region. The modelled loads section includes the results for the total baseline, anthropogenic baseline and predevelopment loads. The validation of the MW Source Catchments modelled data is then presented using load estimates from measured data. Progress towards targets are also presented for MW in RC2014. A summary of the total baseline load by land use, and land use by basin is also reported, as well as a mass balance summary of the sources and sinks by constituent. For a full list of the MW region loads for RC2014 refer Appendix 4, Table 96.

Hydrology calibration performance

Model performance was assessed for the 10 MW gauges following recalibration with the Sacramento model. Performance was assessed for the calibration period 1970–2014. The results for the three performance criteria: daily R^2 > 0.5, daily NSE >0.5, percent bias (PBIAS) for total flow volume and high flow volume ± 20% are listed in Appendix 1, Table 72. The R^2 and NSE criteria were met at all gauges, while the PBIAS (volume difference) criteria was met at nine of 10 gauges. Flow volume was within +/-5% at nine of 10 gauges. The gauges with the greatest improvement in total volume difference since RC2013 are presented in Table 43.

Table 43 Comparison of total volume differences for five gauges that had the biggest flow bias in RC2013 and the flow bias generated from the Sacramento calibration (RC2014) (negative values indicate an underprediction)

Gauge	Basin	RC2013 total volume diff. PBIAS (%)	RC2014 total volume diff. PBIAS (%)
124002A	O'Connell	-5	-3
124003A	O'Connell	9	-0.4
125002C	Pioneer	3	-1.5
126001A	Sandy	2	-0.2

A result of the improved calibration was an increase in the average annual flow for the MW region, when comparing the same time period (1986–2009). In RC2013 the average annual flow for the region was approximately 5,103,000 ML, and this has increased to 5,500,000 ML for RC2014 for the same time period.

Modelled Loads

In the MW region, the O'Connell Basin is typically the largest contributor to constituent export load, with the exception of DIN and PSIIs. Grazing is the dominant land use for all basins, occupying 44% of the total MW area. A large proportion of the Plane Creek Basin is used for sugarcane production, which is the reason why it exports the greatest DIN, DIP and PSII loads for the MW region.

The PSII load is dominated by diuron (57%), followed by ametryn (19%), atrazine (14%) and hexazinone (10%). Sugarcane supplies >99% of the PSII load in the MW region, with Plane Creek being the major contributor.

Table 44 Contribution from MW basins to the total MW baseline load

Basin	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
Proserpine	111	1,025	304	401	320	228	80	21	128	331	416
O'Connell	245	1,277	329	383	565	351	67	18	266	971	781
Pioneer	141	705	247	227	231	143	42	11	91	985	630
Plane Creek	114	1,025	357	364	303	236	78	20	138	1,758	1,324
Total	**611**	**4,031**	**1,237**	**1,375**	**1,419**	**959**	**267**	**69**	**623**	**4,044**	**3,152**

Anthropogenic baseline and predevelopment loads

The anthropogenic baseline load was calculated by subtracting the predevelopment load from the total baseline load. The current (baseline) TSS load was 2.4 time greater than the predevelopment load for the whole of the MW region; the Pioneer and Plane basins both have a similar increase to the region, while the Proserpine had a ~1.7 increase and the O'Connell Basin had the greatest anthropogenic increase, of ~3 times the predevelopment load (Figure 27).

For DIN, the current load was four times greater than the load for predevelopment land use for the MW region. All four basins had a significant anthropogenic contribution to DIN, primarily due to sugarcane production in the area. The Proserpine Basin had the lowest increase three times, while the Plane Creek Basin exported nearly six times the predevelopment load (Figure 28).

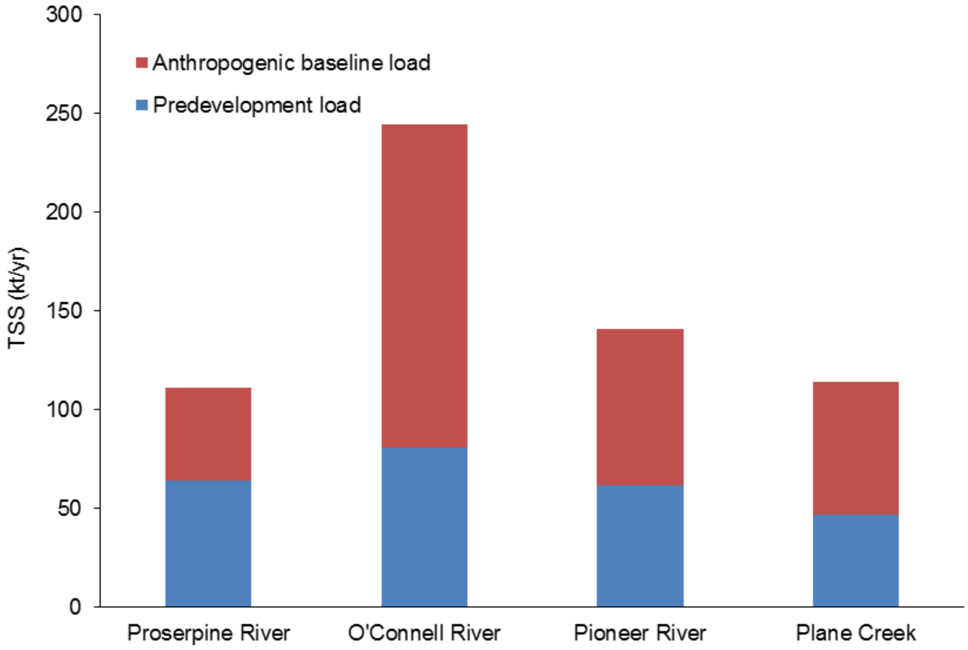


Figure 27 TSS (kt/yr) loads for the Mackay Whitsunday basins, indicating the predevelopment and anthropogenic baseline contributions

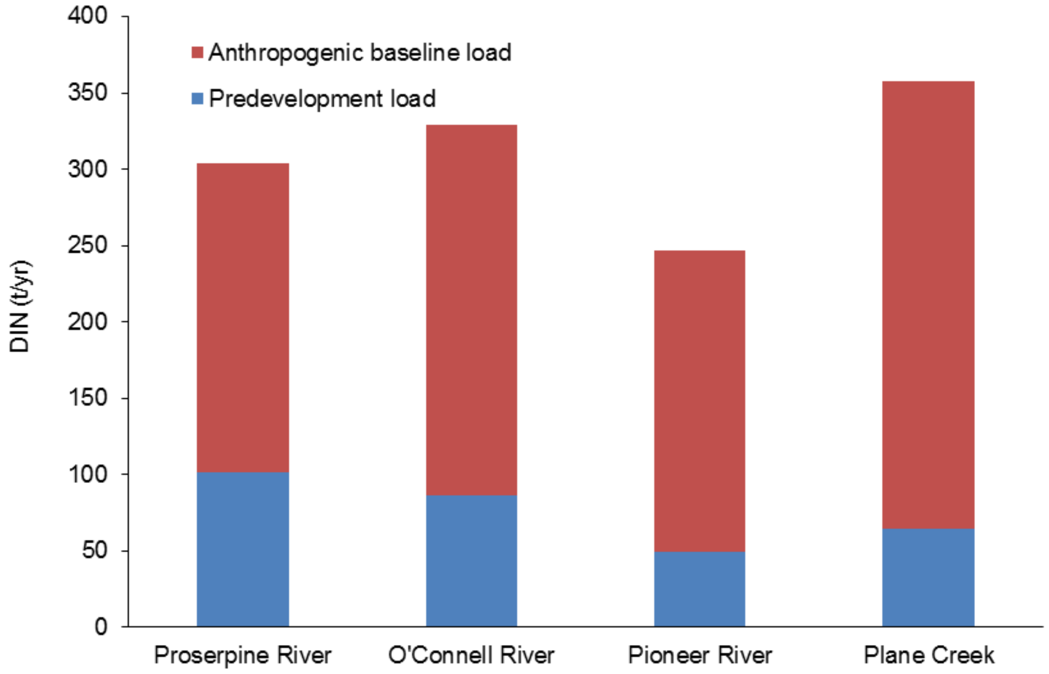


Figure 28 DIN (t/yr) loads for the Mackay Whitsunday basins, indicating the predevelopment and anthropogenic baseline contributions

Constituent load validation

Due to the extension of the modelling period from 1986–2009 through to 2014, there are now eight years of water quality monitoring data for the two sites in the MW. The monitoring data was collected under the GBR Catchment Loads Monitoring Program (GBRCLMP) (Joo et al. 2012, Turner et al. 2012, Turner et al. 2013, Garzon-Garcia et al. 2015, Wallace et al. 2015). The GBRLMP validation data is the most current data and is of high sample frequency, targeted at event sampling specifically for model validation.

A comparison was made between the mean GBRCLMP measured loads (averaged over 6–8 years, depending on data availability) and the modelled load for the same location and same time period (Figure 29 and Figure 30). The modelled constituent loads at the Pioneer River at Dumbleton Pump Station were between 4% and 65% of the measured loads. Modelled flow was within ±5% of the measured flow for the eight year monitoring period. Across the monitoring period, the model was under-predicting all constituents except for DIN, which is only slightly over-predicted. Modelled loads for Sandy Creek at Homebush are generally much closer to measured loads (Figure 24). A consistent observation is the under-prediction of particulate nutrients in many regions, including at the Pioneer River site where PN and PP are under-predicted by 64% and 54% respectively, and at the Sandy Creek site where the under-predictions are less pronounced at 30% and 6% respectively.

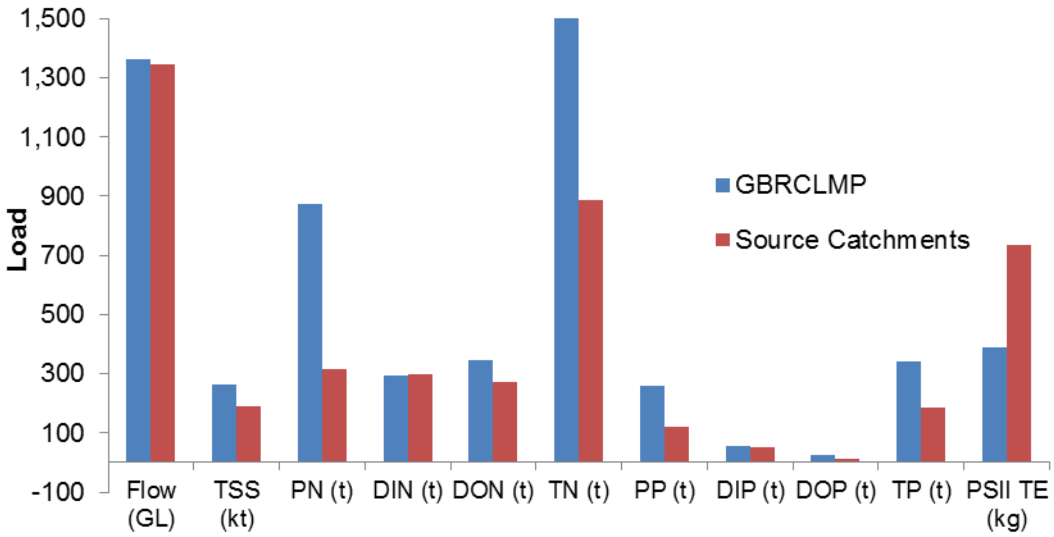


Figure 29 Comparison between average Source Catchments modelled and GBRCLMP loads for the period 2006–2014 for the Pioneer River at Dumbleton Pump Station

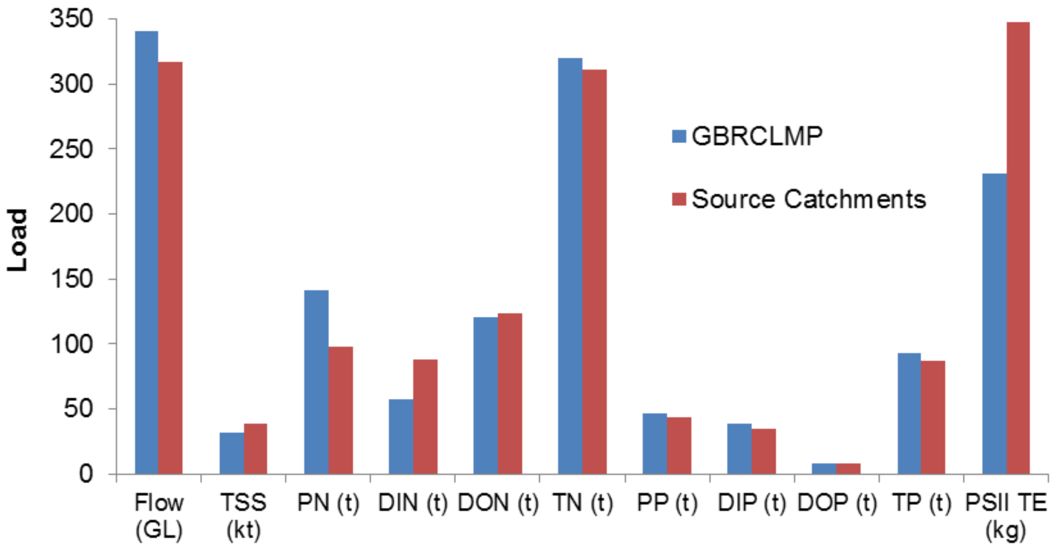


Figure 30 Comparison between average Source Catchments modelled and GBRCLMP loads for the period 2009–2014 for Sandy Creek at Homebush

The performance of the RC2014 baseline model to predict water quality across the MW region was also assessed using a number of quantitative statistics recommended in Moriasi et al. (2015). The estimated quantitative statistics and the corresponding model performance ratings are presented in Table 45 for the Pioneer River and Table 46 for Sandy Creek. For ease of presentation, 'very good' and 'good' rated sites are coloured green, while 'satisfactory' and 'indicative' are coloured orange, signalling that further work is required to improve the representation of these constituents.

At the Pioneer River site the R^2 rating was 'very good' for all constituents, except DIN (Table 45). The ratings for the RSR, PBIAS, and NSE tended to be 'indicative' for most constituents, and were generally consistent between the constituent/performance measures. Better aligning particulate nutrients, TSS and DIN loads to measured data is an area requiring further improvement in the model, while TP and TN will subsequently improve with particulate and DIN improvements. The performance of the model at the Sandy Creek site is excellent, with a 'very good' rating achieved for 85% of the constituent/performance measure combinations (Table 46). DIN was the only constituent that rated as 'indicative' across all four measures.

Table 45 RC2014 quantitative statistical analysis for 125013A Pioneer River at Dumbleton Pump Station (HW) (n = 8 years for flow and n = 8 years for WQ) against annual GBRCLMP loads

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.2	Very good	-1.5	Very good	1.0	Very good	1.0	Very good
TSS	0.6	Satisfactory	-28.0	Indicative	0.6	Satisfactory	0.9	Very good
TN	0.9	Indicative	-42.1	Indicative	0.3	Indicative	0.9	Very good
PN	1.1	Indicative	-64.0	Indicative	-0.1	Indicative	0.9	Very good
DIN	0.8	Indicative	1.0	Very good	0.3	Indicative	0.4	Satisfactory
DON	0.5	Good	-21.1	Satisfactory	0.7	Very good	0.9	Very good
TP	0.9	Indicative	-46.3	Indicative	0.3	Indicative	0.9	Very good
DIP	0.5	Very good	-3.4	Very good	0.8	Very good	0.8	Very good
PP	0.9	Indicative	-53.8	Indicative	0.1	Indicative	1.0	Very good
DOP	0.9	Indicative	-44.3	Indicative	0.3	Indicative	0.9	Very good

Table 46 RC2014 quantitative statistical analysis for 126001A Sandy Creek at Homebush, (n = 8 years for flow and n = 5 years for WQ) against annual GBRCLMP loads

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.1	Very good	-7.0	Good	1.0	Very good	1.0	Very good
TSS	0.3	Very good	21.0	Indicative	0.9	Very good	0.9	Very good
TN	0.2	Very good	-2.6	Very good	1.0	Very good	0.9	Very good
PN	0.4	Very good	-30.4	Indicative	0.9	Very good	0.9	Very good
DIN	1.0	Indicative	54.2	Indicative	-0.0	Indicative	0.2	Indicative
DON	0.2	Very good	2.5	Very good	1.0	Very good	0.9	Very good
TP	0.1	Very good	-2.5	Very good	1.0	Very good	1.0	Very good
DIP	0.2	Very good	-10.5	Very good	1.0	Very good	1.0	Very good
PP	0.2	Very good	-6.3	Very good	0.9	Very good	0.8	Very good
DOP	0.3	Very good	9.0	Very good	0.9	Very good	0.9	Very good

The same quantitative statistics were also calculated on the long-term (1986-2009) monitored monthly loads (Joo et al. 2014) versus the modelled load for the Pioneer River at Dumbleton Station. The model achieved excellent results for the NSE, R^2 and RSR measures, with a mix of results for volume difference (p-bias). Overall the model can be considered to be performing very well against the monitored monthly loads at this site.

Table 47 RC2014 quantitative statistical analysis for 125013A Pioneer River at Dumbleton Pump Station against monthly loads calculated by Joo et al. (2014) for the period 1986-2009

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.15	Very good	7.66	Good	0.98	Very good	0.98	Very good
TSS	0.30	Very good	-11.37	Good	0.91	Very good	0.95	Very good
TN	0.50	Very good	-36.89	Indicative	0.75	Very good	0.94	Very good
PN	0.63	Satisfactory	-52.21	Indicative	0.60	Good	0.93	Very good
DIN	0.45	Very good	11.95	Very good	0.80	Very good	0.81	Very good
DON	0.22	Very good	-7.91	Very good	0.95	Very good	0.97	Very good
TP	0.49	Very good	-36.96	Indicative	0.76	Very good	0.94	Very good
DIP	0.19	Very good	-6.56	Very good	0.96	Very good	0.97	Very good
PP	0.58	Good	-44.91	Indicative	0.66	Very good	0.92	Very good
DOP	0.32	Very good	32.91	Indicative	0.90	Very good	0.96	Very good

Contribution by land use

Sugarcane is the major contributor for all four constituents contributing 47% or greater for sediment and particulate nutrients, while the DIN contribution is 62% of the export load (Figure 31). Forty-two percent of the total PSII load comes from the Plane Creek Basin, and 99.9% of the PSII load is from sugarcane.

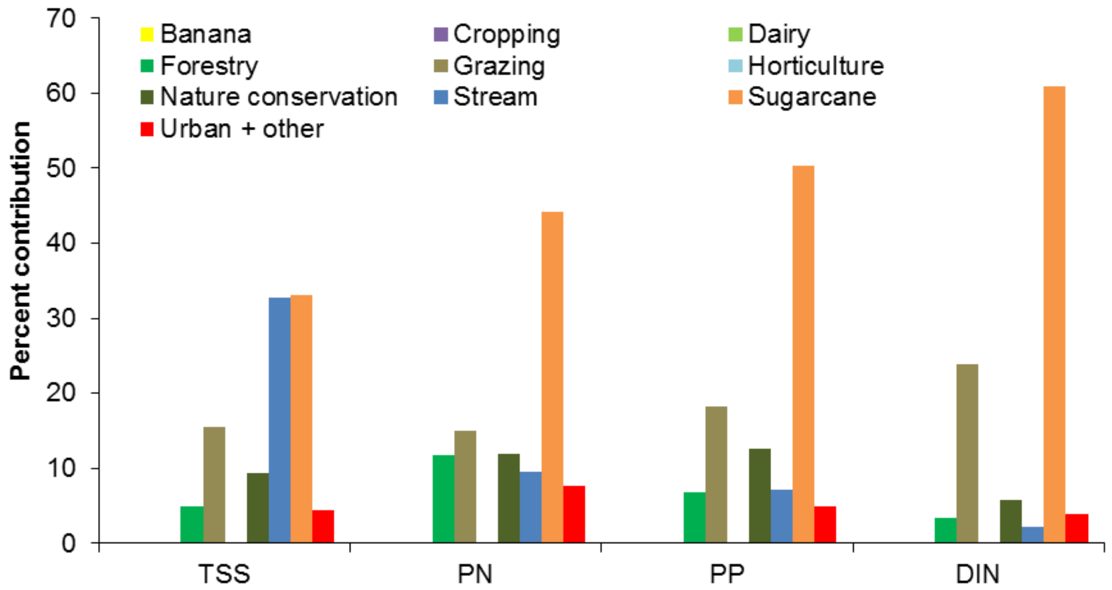


Figure 31 Contribution to fine sediment, particulate nutrient and DIN export by land use for the MW region

Sugarcane and grazing (closed and open) account for approximately 19% and 44% of the MW area respectively, and between them generate approximately 85% of the DIN export load (Figure 32). Sugarcane generated the largest load (~ 754 t/yr). Per unit area sugarcane generates the highest average annual load (~ 4.5 kg/ha/yr), followed by cropping (~ 2.7 kg/ha/yr) (Figure 32). The average DIN per unit area rate for all land uses in the MW is approximately 1.6 kg/ha/yr.

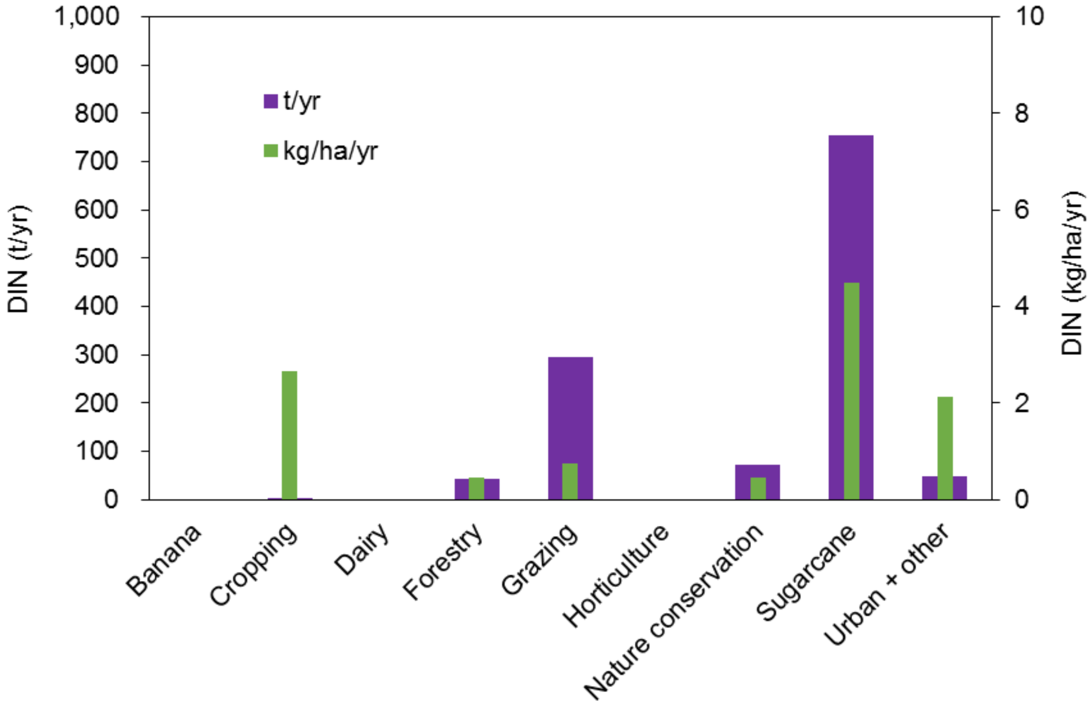


Figure 32 DIN export load and areal rate for each land use in MW

Sources and sinks

Modelled sources and sinks (losses) are given in Table 48 for all constituents. Of the total modelled fine sediment generated (715 kt/yr that is supplied to the stream) in the MW NRM region, 85% (611 kt/yr) is exported to the GBR lagoon, with 91% of the lost material being deposited in dams, and a small amount lost via extractions and floodplain deposition. As per RC2013, instream deposition and remobilisation were not enabled due the lack of data to validate this component. Modelled sources for DIN are primarily from diffuse dissolved processes (that is, DIN from sugarcane), while the only loss pathway is via extractions.

Table 48 Sources and sinks of each constituent in the MW NRM region

	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
SOURCE	**716**	**4,330**	**1,272**	**1,401**	**1,657**	**1,057**	**271**	**70**	**716**	**4,467**	**3,223**
Hillslope	451	2,818	432	915	1,470	917	209	53	655	4,467	3,223
Gully	9	5			5	2			2		
Streambank	256	183			183	59			59		
Channel remobilisation											
Diffuse dissolved		780	302	478		72	56	16			
Seepage		511	511								
Point source		34	27	7		8	6	2			
SINK (loss)	**106**	**299**	**35**	**26**	**238**	**98**	**4**	**1**	**92**	**102**	**71**
Storage deposition	97	218			218	84			84		
Floodplain deposition	4	9			9	4			4		
Stream deposition											
Extraction and Losses	4	72	35	26	11	10	4	1	4	102	71
Stream decay											
EXPORT	**611**	**4,031**	**1,237**	**1,375**	**1,419**	**959**	**267**	**69**	**623**	**4,365**	**3,152**

Progress towards Reef Plan 2013 targets

Small changes in areas (<1%) of improved practices were reported for the MW region for RC2014. Investments were made to reduce sediment loss from gullies, hillslope grazing and streambank erosion and sediment and nutrient projects were funded in a number of sugarcane areas. The modelling results suggest there was only a 0.1% reduction in average annual TSS for the MW region due to this year's investments which is not surprising given the small change in areas of improved management. No other load reductions were reported as they were less than 0.1%. The investments that led to these changes are discussed below.

With respect to grazing management changes, there was a 0.75% shift into B class practices from C and D class. This equates to an area of 9.3 km^2 where cover has been improved. Further, only a small area of gully remediation work was undertaken (0.065 km^2) which resulted in a small shift into B class practices from C class. Finally, 15 km of streambank fencing was undertaken, which is presented as a shift out of D and C class, into B class. Grazing management changes for MW are presented in Table 49.

There were no improvements, or changes in management for soil or pesticide management in sugarcane. Hence there is no PSII TE load reduction reported at all, and no sediment load reduction contribution from sugarcane. Nutrient management changes in sugarcane are minimal, with a 0.4% shift from C and D practices to B practice, which results in a 2 t/yr load reduction. This reduction is not reported as it is less than 0.1% of the total MW DIN load. Sugarcane management changes for MW are presented in Table 50.

Table 49 MW grazing management practice change summary; values are percent of total area

Hillslope	Baseline	RC2014	Change
A	8.00	8.01	0.01
B	30.00	30.75	0.75
C	25.00	24.61	-0.39
D	37.00	36.63	-0.37
Gully	**Baseline**	**RC2014**	**Change**
A	0.02	0.02	0
B	37	37	0
C	38	38	0
D	24	24	0
Streambank	**Baseline**	**RC2014**	**Change**
A	0.96	0.96	0
B	17.00	17.10	0.10
C	46.00	45.94	-0.06
D	35.00	34.96	-0.04

Table 50 MW sugarcane management practice change summary; values are percent of total area

Soil	Baseline	RC2014	Change
A	1.00	1.00	0
B-A	3.21	3.24	0.02
B	36.79	36.76	-0.02
C-B	14.00	14.00	0
C	17.00	17.00	0
D-C	8.96	9.01	0.05
D	19.04	18.99	-0.05
Nutrients	**Baseline**	**RC2014**	**Change**
A	0.00	0.00	0
B	19.45	19.89	0.44
C-B	28.50	28.34	-0.17
C	30.29	30.12	-0.17
D-C	19.68	19.57	-0.11
D	2.09	2.09	0
Pesticides	**Baseline**	**RC2014**	**Change**
A	4.13	4.13	0
B	32.48	32.48	0
C	30.81	30.81	0
D	32.58	32.58	0
Irrigation	**Baseline**	**RC2014**	**Change**
A	4.60	4.60	0
B-C	14.00	14.07	0.07
D	81.40	81.33	-0.07
Recycle Pits	**Baseline**	**RC2014**	**Change**
A	3.23	3.23	0
B	19.36	19.36	0
C	46.16	46.16	0
D	30.90	30.90	0

Fitzroy

The results of the FZ modelling are presented below, separated into hydrology and modelled loads. In the hydrology component, the results of the updated calibration process will be presented per gauge, as well as the impact on the total flow for the FZ region. The modelled loads section includes the results of the total baseline, anthropogenic baseline and predevelopment loads. The validation of the FZ Source Catchments modelled data is then presented using load estimated from measured data. Progress towards targets are also presented for FZ in RC2014. A summary of the total baseline load by land use, and land use by basin is also reported, as well as a mass balance summary of the sources and sinks by constituent. For a full list of the FZ region loads for RC2014 refer Appendix 4, Table 96.

Hydrology calibration performance

For the RC2014 model run period (1986-2014) the average annual flow for the FZ region is ~9,270,000 ML/yr, an increase of approximately 3,400,000 ML/yr from the previous modelling period (1986-2009). The difference in average flow bias between measured and modelled flows at calibration gauges improved from being 18% under-predicted for RC2013 to 1% under prediction for RC2014. Average annual flow increased for all basins with the extended model run period, with the greatest increase from RC2013 occurring in the Fitzroy Basin with an increase of ~1,450,000 ML/yr (31%). Table 51 lists the improvements in the total volume difference for a selection of gauges in the FZ region.

Table 51 Comparison of total flow difference between modelled flow and gauge flow (negative values indicate an underprediction)

Gauge	Basin	RC2013 total volume difference PBIAS (%)	RC2014 total volume difference PBIAS (%)
130005A	Fitzroy River at The Gap	-2%	-1%
129001A	Waterpark Creek at Byfield	-27%	0%
132001A	Calliope River at Castlehope	-25%	0%
133001B	Boyne River at Riverbend	-17%	-2%

Modelled loads

Generally, the FZ region is one of the top three contributors for all constituents to the GBR, due mostly to the large catchment area of the basin. The FZ is the second highest contributor of fine sediment to the GBR contributing 19% of total TSS behind the BU, and also second highest for TN at 20% and PN 20% of total export to the GBR. It is third highest for DIN (16%) behind the two major sugarcane cane areas, the BU and WT regions, and third for DON export at 20% behind the CY and WT regions, which have considerable areas of nature conservation delivering high DON loads. For TP, DIP, and DOP the FZ contributes the highest load to the GBR at 32%, 51% and 27% of total GBR load respectively. The FZ is only second to the WT for PP at 28%. In terms of total PSII load the FZ is the third highest contributor (18%), but when this is converted to toxic equivalent load the contribution is less than 1% with the majority of the pesticide used being atrazine which has a low toxicity relative to diuron.

Within the FZ NRM region, the Fitzroy River Basin is the largest contributor to the regions load, contributing 84% of the TSS, 67% of the TN, and 70% of the TP load (Table 52). This result is not surprising when you consider that area of the Fitzroy River Basin is 93% of the total NRM region.

Table 52 Contribution from FZ basins to the total FZ baseline load

Basin	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
Styx	105	901	168	340	393	340	111	21	208	240	5
Shoalwater	57	714	148	300	266	248	98	19	131	126	2
Water Park	37	748	88	178	482	263	58	11	194	17	<1
Fitzroy	1,497	6,404	1,275	2,498	2,632	2,714	796	154	1,763	1,812	40
Calliope	75	543	93	188	262	210	62	12	137	122	2
Boyne	21	259	71	144	45	81	47	9	25	49	1
Total	**1,793**	**9,568**	**1,842**	**3,646**	**4,080**	**3,856**	**1,171**	**226**	**2,459**	**2,367**	**51**

Anthropogenic baseline and predevelopment loads

The predevelopment and anthropogenic baseline load for fine sediment for each of the major basins in the FZ region are presented in Figure 33. The baseline TSS was six times the predevelopment load. Each of the six basins have significant anthropogenic TSS loads (4 to 7 times increase), making TSS and particulate nutrients the key constituents requiring targeted management to reduce their relative contributions to the GBR loads. The increase factors for other constituents can be found in Appendix 4, Table 100.

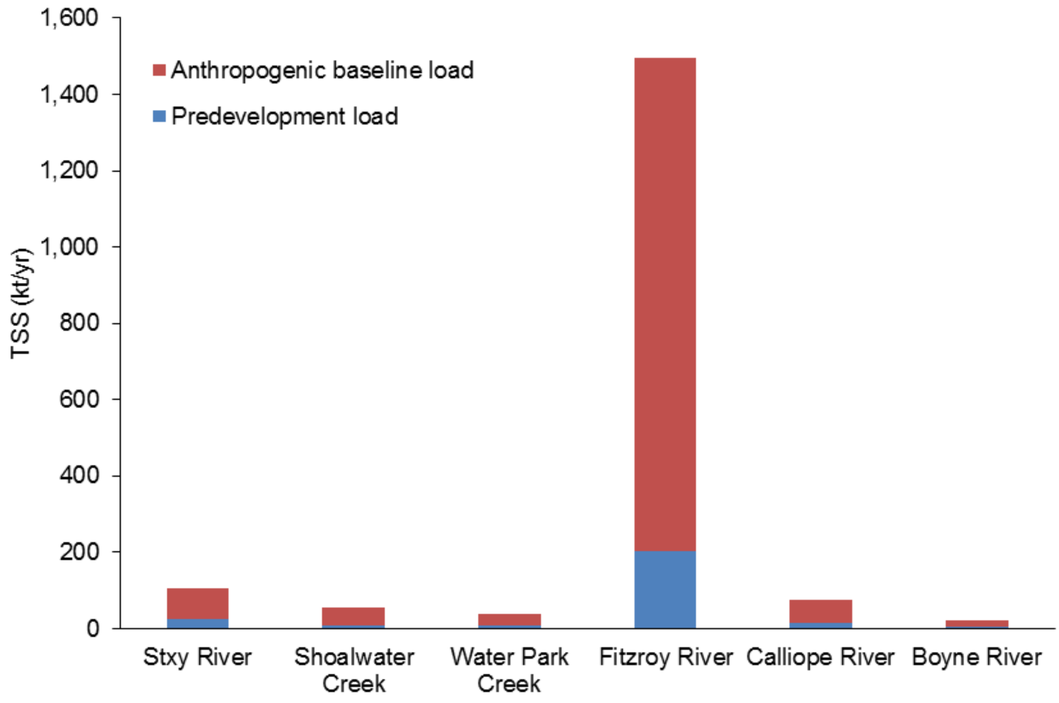


Figure 33 TSS (kt/yr) load for the FZ basins, indicating the predevelopment and anthropogenic baseline contributions

Constituent load validation

A range of sources were used to assess model performance. The two key sources are the GBRCLMP 2006–2014 monitoring program established by the Qld State Government (Turner et al. 2012) and the long-term loads (1986–2009) using the FRCE method (Joo et al. 2014).

Due to the extension of the modelling period from 1986-2009 through to 2014, there are now up to eight years of water quality monitoring data for the FZ region monitoring sites. The monitoring data was collected under the GBR Catchment Loads Monitoring Program (GBRCLMP) (Joo et al. 2012, Turner et al. 2012, Turner et al. 2013, Garzon-Garcia et al. 2015, Wallace et al. 2015). At the Rockhampton gauge there is eight years of water quality monitoring data, five years of data at the Comet Weir gauge, three years at the Taroom site and only two years of data at the Theresa Creek site.

The load estimates derived from the GBRCLMP measured data were compared against the modelled loads at all four sites for the same time periods. Figure 34 to Figure 36 compare the average annual GBRCLMP load estimates against the average annual modelled loads for TSS, PN and PP for eight years. Figure 34 shows that at the Rockhampton gauge, the model is performing well with the model estimate within 5% of the TSS for the eight year monitoring period. Model predictions at the remaining sites do not match the GBRCLMP load estimates as well with the Taroom modelled load being twice the measured TSS load, the Comet modelled load is under predicted by 40% and the Theresa Creek site overestimates the GBRCLMP measured load by 2.5 times. However it is important to note that there are a much smaller number of years of monitored data at all sites upstream of the Rockhampton gauge.

A similar pattern occurs for the particulate nutrients, with the models load at Rockhampton the closest estimate to the GBRCLMP estimate. Figure 35 shows that the PN load is underestimated by 20% at Rockhampton while Figure 36 shows that the model over estimates the PP load by 5% at the same location.

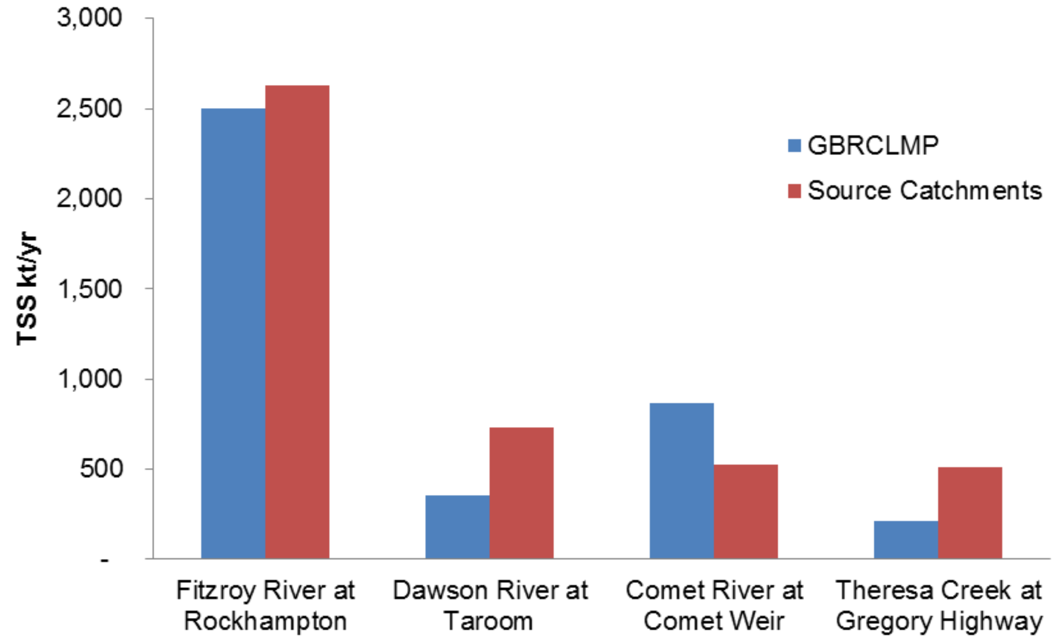


Figure 34 Comparison between average Source Catchments modelled and GBRCLMP monitored loads for TSS at the four FZ sites

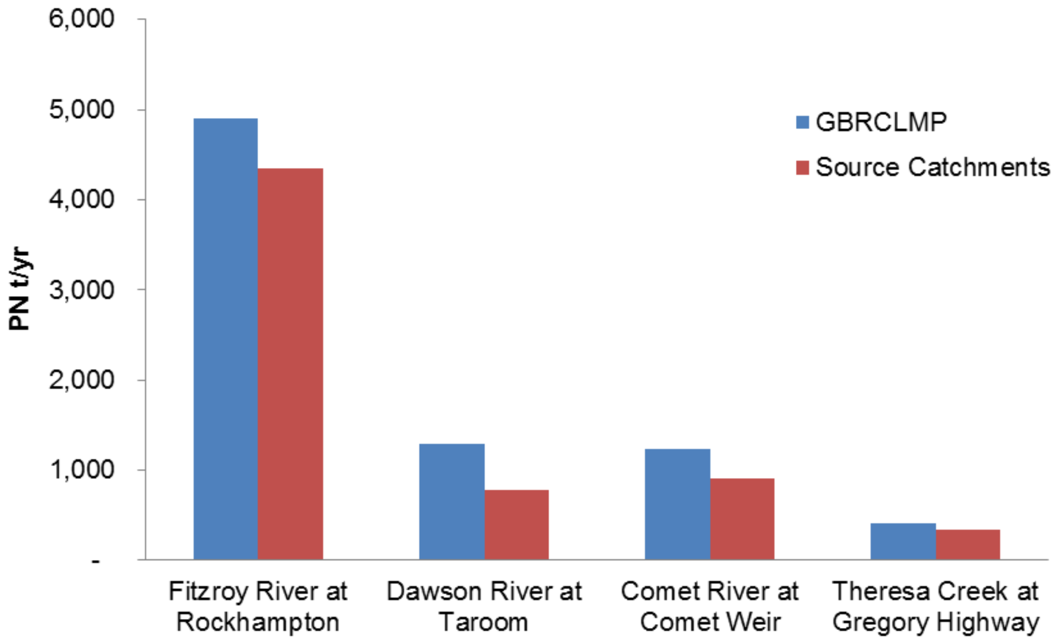


Figure 35 Comparison between average Source Catchments modelled and GBRCLMP monitored for PN at the four FZ sites

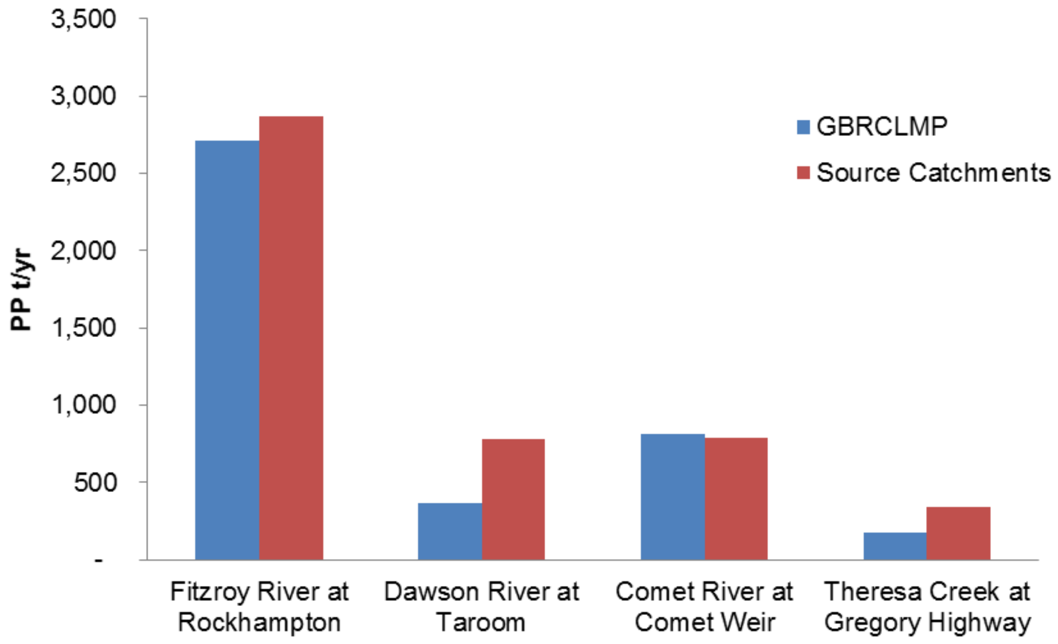


Figure 36 Comparison between average Source Catchments modelled and GBRCLMP monitored loads for PP at the four FZ sites

Comparisons against the long-term loads report (1986–2009) (Joo et al. 2014) was only possible at one location within the FZ region, the Fitzroy River at The Gap gauging station. This was considered a secondary validation dataset and not as important as the comparison against the GBRCLMP data. There is lower confidence in this dataset due to the much smaller number of samples used generate the loads often collected in low flow conditions. However because monitoring data was available over 23 years it was still considered a worthwhile comparison. Figure 37 shows the modelled TSS load was within 1% of the Joo et al. (2014) loads, and 10% and 6% respectively of the PN and PP estimated loads.

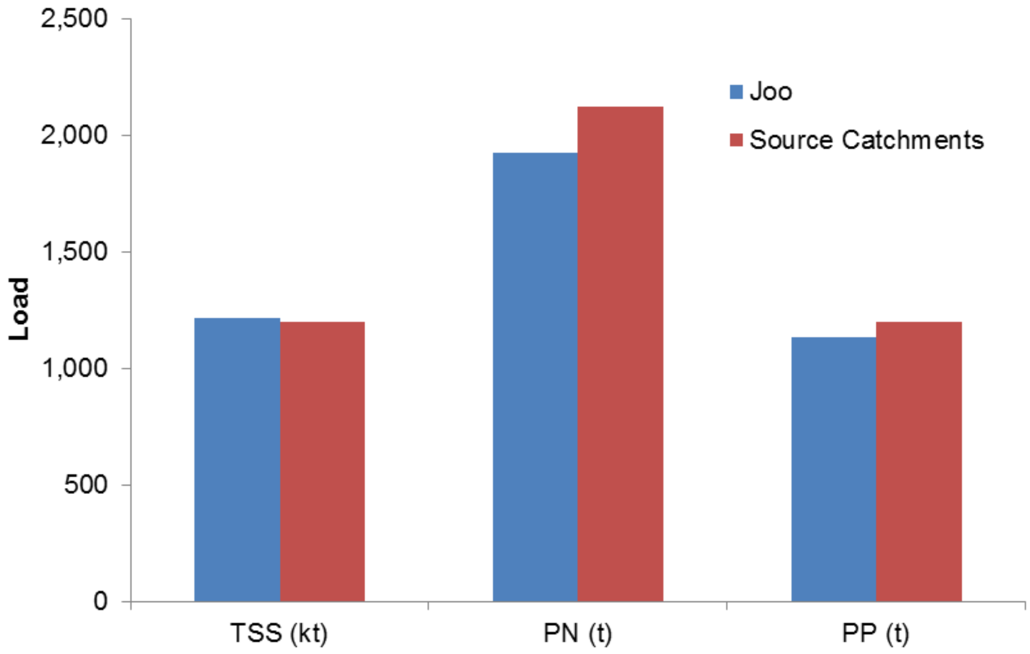


Figure 37 Comparison between average Source Catchments modelled and long-term loads report for the period 1986–2009 for TSS, PN and PP at Fitzroy River at The Gap gauging station

The performance of the RC2014 baseline model to predict water quality across the FZ region was also assessed using a number of quantitative statistics recommended in Moriasi et al. (2015). The estimated quantitative statistics and the corresponding model performance ratings are presented below for the Fitzroy River at Rockhampton (Table 53) and Comet River at Comet Weir (Table 54) sites, in comparison to the GBRCLMP calculated annual loads. For ease of presentation, ‘very good’ and ‘good’ rated sites are coloured green, while ‘satisfactory’ and ‘indicative’ are coloured orange, signalling that further work is required to improve the representation of these constituents.

At the Fitzroy River Rockhampton site, 78% of constituents/statistical measure ratings were ‘good’ or ‘very good’, with much agreement between measures (Table 53). For example flow, TSS, TN, DON, TP, DIP and PP were all rated as ‘good’ or ‘very good’ for all four statistical measures. PN was also consistent across all measures, though the mix of ‘satisfactory’ and ‘indicative’ ratings indicate room for improvement for this constituent. Also, DIN is rated as ‘indicative’ for RSR, PBIAS and NSE ratings, though it is rated as ‘very good’ for R^2. Similarly, DOP is rated as ‘satisfactory’ for two measures, and ‘good’ or ‘very good’ for the remaining two. Overall the performance of the model at this site can be considered a significant improvement on previous FZ models, and overall a ‘very good’ representation in comparison to monitored data.

Table 53 RC2014 quantitative statistical analysis for for site 1300000 Fitzroy River at Rockhampton (n = 7 years for flow and n = 7 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.2	Very good	0.6	Very good	1.0	Very good	1.0	Very good
TSS	0.3	Very good	4.9	Very good	0.9	Very good	0.9	Very good
TN	0.3	Very good	-3.2	Very good	0.9	Very good	1.0	Very good
PN	0.7	Indicative	-21.9	Satisfactory	0.5	Satisfactory	0.5	Satisfactory
DIN	0.9	Indicative	62.7	Indicative	0.1	Indicative	0.9	Very good
DON	0.3	Very good	-1.6	Very good	0.9	Very good	1.0	Very good
TP	0.5	Very good	-3.6	Very good	0.8	Very good	0.9	Very good
DIP	0.3	Very good	3.0	Very good	0.9	Very good	0.9	Very good
PP	0.5	Good	-6.5	Very good	0.7	Very good	0.7	Good
DOP	0.6	Satisfactory	-21.2	Satisfactory	0.6	Good	0.9	Very good

At the Comet River site, 85% of constituent/statistical measure combinations were ‘good’ or ‘very good’ with the majority being the latter. Only PBIAS measures reported ‘satisfactory’ or ‘indicative’ results for six constituents, indicating some room for improvement. TN, DIN, TP and PP were consistent across all four measures. PN and DOP are the two constituents that both have scope for improvement as shown by the statistical analyses at both monitoring locations.

Table 54 RC2014 quantitative statistical analysis for site 130504B Comet River at Comet Weir (n = 5 years for flow and n = 5 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.2	Very good	-11.2	Satisfactory	1.0	Very good	1.0	Very good
TSS	0.5	Very good	-39.2	Indicative	0.8	Good	0.8	Good
TN	0.2	Very good	-14.5	Very good	1.0	Very good	1.0	Very good
PN	0.4	Very good	-26.4	Satisfactory	0.8	Very good	0.9	Very good
DIN	0.4	Very good	19.0	Good	0.8	Very good	1.0	Very good
DON	0.3	Very good	-24.0	Satisfactory	0.9	Very good	1.0	Very good
TP	0.3	Very good	-19.0	Good	0.9	Very good	0.9	Very good
DIP	0.6	Good	-54.2	Indicative	0.7	Very good	0.9	Very good
PP	0.2	Very good	-2.6	Very good	0.9	Very good	0.9	Very good
DOP	0.6	Good	-30.2	Indicative	0.7	Very good	0.6	Good

The same quantitative statistics were also calculated on the long-term monitored monthly loads (Joo et al. 2014) versus the modelled loads, with the overall ranking for each constituent at the Fitzroy River at Rockhampton site (Table 55). Of the 10 modelled constituents (flow, sediments and nutrients) most achieved a ‘good’ or better rating (65%). There were only 20% of measures that resulted in an ‘indicative’ rating, mainly particulate nutrients, DOP, and DIP.

Table 55 RC2014 quantitative statistical analysis for monthly ratings of performance at the Fitzroy River at Rockhampton (1986–2009)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.2	Very good	12.3	Satisfactory	1.0	Very good	1.0	Very good
TSS	0.6	Good	-18.3	Satisfactory	0.6	Satisfactory	0.7	Good
TN	0.4	Very good	2.9	Very good	0.9	Very good	0.9	Very good
PN	0.8	Indicative	-2.5	Very good	0.3	Indicative	0.3	Satisfactory
DIN	0.3	Very good	8.0	Very good	0.9	Very good	0.9	Very good
DON	0.3	Very good	8.9	Very good	0.9	Very good	0.9	Very good
TP	0.5	Good	12.9	Very good	0.7	Very good	0.8	Very good
DIP	0.5	Very good	60.6	Indicative	0.7	Very good	1.0	Very good
PP	0.8	Indicative	13.3	Very good	0.3	Indicative	0.3	Satisfactory
DOP	1.2	Indicative	55.7	Indicative	-0.5	Indicative	0.6	Satisfactory

Contribution by land use

The contribution by land use for the major constituents in presented in Figure 38. The largest land uses contributing to the TSS load were from grazing. Grazing occupies the largest area within the FZ region (78%) and produces 81% of the FZ region TSS load exported to the GBR. The particulate nutrient contribution was also dominated by grazing, contributing 65% of the PN and PP loads. This result is as expected because particulate nutrients are a function of sediment. Nature conservation, forestry, and dryland cropping also contribute significant loads, with the remainder of the particulate nutrient load coming from these land uses.

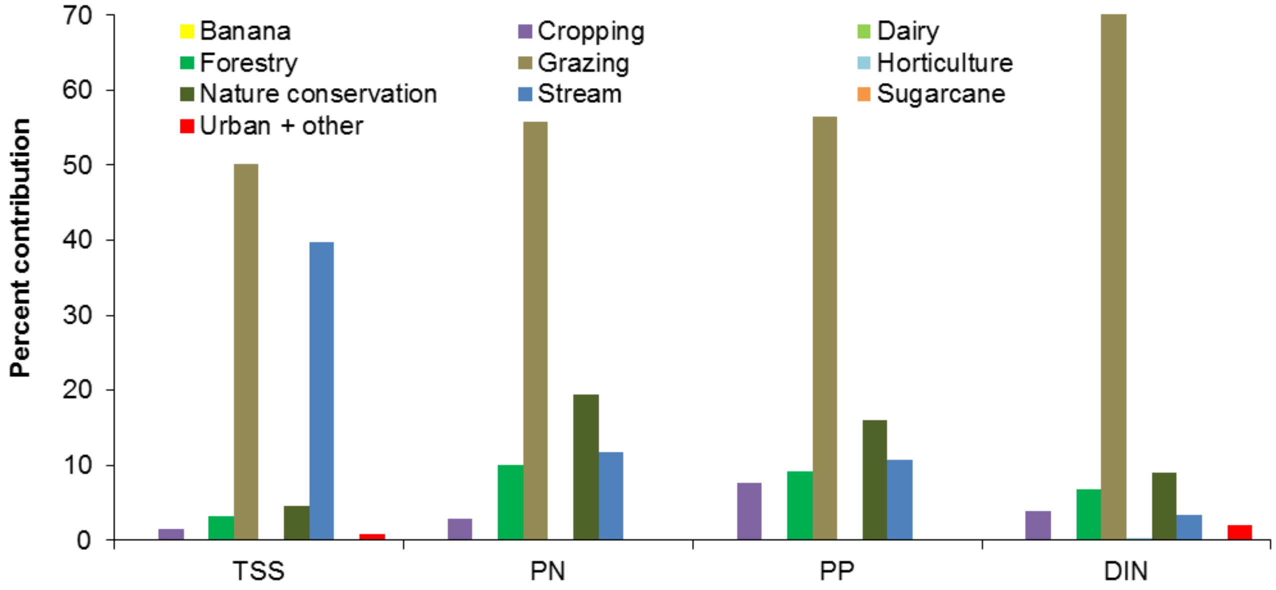


Figure 38 Contribution to fine sediment, particulate nutrient and DIN export by land use for the FZ region

Eighty-five percent of the atrazine exported from the FZ region came from the dryland cropping land use, with only a small contribution from irrigated cropping. Tebuthiuron loads are produced solely within open grazing areas.

Sources and sinks

The total fine sediment load generated within the FZ region was 7,250 kt/yr, of which 55% was generated from gully erosion, 24% from streambank erosion and the remaining 21% from hillslope erosion. Sediment was lost throughout the system to floodplain deposition (58% of losses), reservoir deposition (20%) and the remainder was lost to irrigation extractions. Instream deposition and remobilisation of fine sediments were not modelled, due to a lack understanding of these in stream processes within the FZ region. Of the total fine sediment load generated, 25% (1793 kt/yr) is exported to the GBR lagoon (Table 56).

A higher proportion of nutrients supplied to the stream was exported to the GBR in comparison to the proportion of supplied TSS. So whilst particulate nutrients and fine sediment losses may have been similar there were only small loss of dissolved nutrients. Forty seven percent of the total nitrogen load generated and 37% of the total phosphorus load generated was exported to the GBR lagoon. For both TN and TP, particulate nutrients derived from hillslope erosion were the largest contributor. Particulate nitrogen makes up 65% of the total nitrogen load generated however a large portion is lost throughout the system as deposition. As a result, DON contributes a similar proportion to the total N load exported as PN. Combined PN and DON contribute approximately 80% of the total exported N load. DIN is the smallest contributor to the generated and exported nitrogen load. Particulate phosphorus contributes 83% to the total generated phosphorus load. A large proportion of PP is lost throughout the system to floodplain and reservoir deposition however it still contributes the largest proportion to the total exported phosphorus load at 64%. DOP is the next largest contributor to the total exported phosphorus load at 30% and DIP is the smallest contributor at only 6%.

Table 56 Sources and sinks of each constituent in the FZ

	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSIIs (kg/yr)	PSII TE (kg/yr)
SOURCE	**7,250**	**20,258**	**2,334**	**4,616**	**13,309**	**10,439**	**283**	**1,467**	**8,743**	**3,569**	**77**
Hillslope	1,533	10,221			10,221	6,548			6,548	3,569	77
Gully	3,954	1,869			1,869	1,451			1,451		
Streambank	1,764	1,191			1,191	743			743		
Point source		81	64	17		43	10	34			
Diffuse dissolved		6,868	2,270	4,599		1,707	274	1,434			
SINK (loss)	**5,457**	**10,690**	**491**	**970**	**9,229**	**6,637**	**57**	**296**	**6,284**	**1,202**	**26**
Extraction	1,490	5,205	474	935	3,797	2,978	55	286	2,638	737	17
Floodplain deposition	2,875	2,439			2,439	1,624			1,624		
Storage deposition	1,083	2,971			2,971	2,007			2,007		
Stream decay										438	8
Residual (instream)	9	75	17	35	22	28	2	11	15	27	1
EXPORT	**1,793**	**9,568**	**1,842**	**3.646**	**4,080**	**3,856**	**226**	**1,171**	**2,459**	**2,367**	**51**

Progress towards Reef Plan 2013 targets

Limited management changes were reported for the FZ region for RC2014. Investments were made to improve gully, grazing, streambank and cropping management practices. The modelling results suggest there was only a 0.3% reduction in average annual TSS for the FZ region. A reduction of 0.2% occurred for TP, PP, TN and PN. Atrazine was the only pesticide that change data was supplied for and the corresponding reduction resulted in a 0.15% decrease in the PSII toxic load. The investments that led to these changes are discussed below.

Two-thirds of funded cropping projects occurred in the FZ region. Soil management accounted for the largest management change with improvements to contour bank construction accounting for 76% of the cropping change. The remainder of the change resulted in improved controlled traffic and improved management practices for pesticides. Practice management improvements for cropping in the FZ are listed in Table 57.

Hillslope, gully and streambank management practice changes for grazing are listed in Table 58. Almost half of all hillslope management change projects were implemented in the FZ Basin (86,349 ha). Of these, the greatest change occurred in the transitioning of C to B class management (87%).

One-fifth of gully projects undertaken in the whole GBR occurred in the FZ region. These projects resulted in a small change in land that transferred from D class management to A, B and C class management practices. The largest transfer resulted in land transitioning to A class management (7,893 ha), followed by a transition to B class management (6,865 ha) and the smallest was the change to C class management (2,852 ha).

Approximately three-quarters of all streambank fencing undertaken in the GBR occurred in the FZ region. The total 336 km of fencing projects was significantly more than for other regions. Changes resulted in land transitioning from D class management to C and A class management.

Table 57 FZ cropping management change; values are percent of total

Soil	Baseline	RC2014	Change
A	12.74	12.74	0
B	29.13	29.57	0.44
C	56.14	55.79	-0.35
D	1.99	1.90	-0.09
Nutrient	**Baseline**	**RC2014**	**Change**
A	1.28	1.28	0
B	52.26	52.26	0
C	40.11	40.11	0
D	6.35	6.35	0
Pesticide	**Baseline**	**RC2014**	**Change**
A	2.90	2.90	0
B	67.13	67.36	0.2
C	28.52	28.32	-0.2
D	1.45	1.42	0

Table 58 FZ grazing management change; values are percent of total

Hillslope	Baseline	RC2014	Change
A	7.9	7.9	0.01
B	13.3	13.9	0.66
C	49.2	48.6	-0.59
D	29.6	29.6	-0.08
Gully	**Baseline**	**RC2014**	**Change**
A	3.9	4.0	0.06
B	16.2	16.3	0.05
C	54.6	54.7	0.02
D	25.2	25.1	-0.14
Streambank	**Baseline**	**RC2014**	**Change**
A	18.0	18.1	0.14
B	17.3	17.3	0
C	16.7	16.9	0.26
D	35.6	35.2	-0.39
NA	12.5	12.5	0

Burnett Mary

The results of the BM modelling are presented below, separated into hydrology and modelled loads. In the hydrology component, the results of the updated calibration process will be presented per gauge, as well as the impact on the total flow for the BM region. The modelled loads section includes the results of the total baseline, anthropogenic baseline and predevelopment loads. The validation of the BM Source Catchments modelled data is then presented using measured load data. Progress towards targets are also presented for BM in RC2014. A summary of the total baseline load by land use, and land use by basin is also reported, as well as a mass balance summary of the sources and sinks by constituent. For a full list of the BM region loads for RC2014 refer Appendix 4, Table 96.

Hydrology calibration performance

As a result of the extended model run period, and recalibration of hydrology using the Sacramento rainfall runoff model, the total average annual flow for BM was increased by approximately 2,415,000 ML/yr, with the total average annual flow for the region estimated to be 4,830,717 ML/yr. The greatest increase in average annual flow was for the Burnett Basin where it increased by over five times (Table 59), and over four times for the Kolan Basin. Over fifty percent of the total flow for the 28 year model run period is from the two extreme flood years of 2010/11 and 2012/13.

Table 59 Comparison of average annual flow for the BM basins between RC2013 and RC2014

Basin	RC2013 ML/yr	RC2014 ML/yr	x increase
Baffle	491,201	798,419	1.6
Kolan	74,321	325,267	4.4
Burnett	193,141	1,063,665	5.5
Burrum	258,813	496,200	1.9
Mary	1,400,239	2,147,166	1.5

Model performance was assessed for the 29 BM gauges used in the recalibration process. Performance was assessed for the calibration period 1970 – 2014. The results for the three performance criteria: daily $R^2 > 0.5$, daily NSE >0.5, volume difference (p-bias) for total flow volume and high flow volume ± 20% are listed in Appendix 1,Table 75. All gauges met all performance criteria. The flow bias (volume difference) for all of the calibration gauges in the BM improved substantially compared to the previous calibration. The total flow bias for the five most improved gauging stations in BM region are listed in Table 60. The six gauges with the most improved total volume difference are listed in Table 60. Significant improvements were recorded in the Burnett Basin in particular, with gauging station 136306A improving from a 51.5% over-prediction to a 0.3% under-prediction of flow.

Table 60 Comparison of total volume differences for the five most improved calibration gauges between RC2013 and RC2014 (negative values indicate an negative prediction)

Gauge	Basin	RC2013 total volume diff. PBIAS (%)	RC2014 total volume diff. PBIAS (%)
135004A	Kolan	-19.9	-1.2
136094A	Burnett	26.3	0.1
136207A	Burnett	-34.7	0.0
136207A	Burnett	-34.7	0.0
136306A	Burnett	51.5	-0.3
138010A	Mary	23.3	-6.4

An example of the improvement in the hydrographs is shown in Figure 39. The hydrograph from RC2014 using Sacramento more closely matching the observed hydrograph, than the hydrograph from RC2013 using SimHyd.

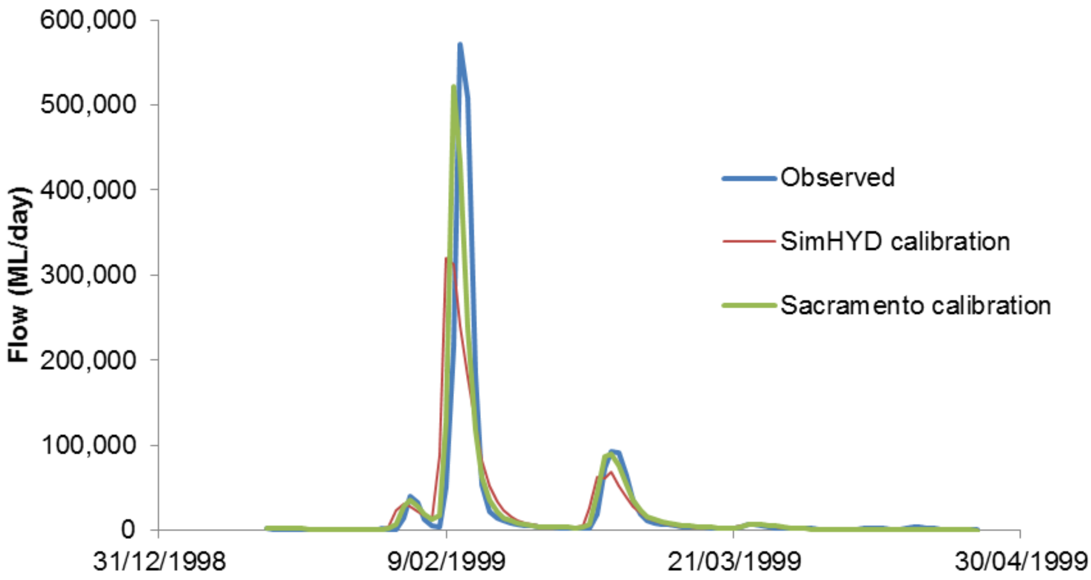


Figure 39 An example hydrograph at a gauging station 138014A showing improvement gained as the result of the Sacramento calibration in RC2014

Modelled Loads

Model results indicate that the BM is the second lowest contributor to the total GBR load for all constituents. This is consistent with the RC2013 results. The BM contributes 13% of the fine sediment load to the GBR, while for all remaining constituents the contribution is less than 10%. Within the BM region, the Burnett and Mary basins are the greatest contributors to the regional loads (Table 61), again this is constituent with the RC2013 results. The Burnett Basin is the greatest contributor for fine sediment and PSII, while the Mary Basin is the greatest contributor for all remaining constituents including PSII toxic equivalent (TE) load. The Burnett Basin is the largest in the BM region (63%) while the Mary Basin (18% of total BM area) is the wettest, and alone contributes almost half the BM average annual flow. The extension of the model run period, which included the two extreme flood events in

2010/11 and 2012/13 significantly increased the average annual flow in the Mary River Basin resulting in the Mary Basin becoming the major contributor for most constituents.

Table 61 Contribution from BM basins to the total BM baseline load

Basin	TSS (kt/y)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/y)	PSII TE (kg/yr)
Baffle	125	495	59	221	215	122	14	9	99	12	5
Kolan	44	310	100	139	71	40	7	4	28	116	51
Burnett	544	1,172	227	440	505	255	31	16	207	165	45
Burrum	48	445	174	183	88	63	13	7	43	132	52
Mary	504	1,835	314	857	664	321	50	30	241	137	57
Total	1,264	4,257	874	1,839	1,543	800	116	66	618	563	210

Anthropogenic baseline and predevelopment loads

The Source Catchments modelled TSS, PN and PP exported loads from the Burnett Mary region have increased three-fold from predevelopment land use loads (Figure 40) while DIN loads increased two-fold (see Figure 41). The variability in DIN load increases between basins is attributed to the difference in the degree of change from predevelopment. For example, the increase factor in the Baffle is clearly less than the other basins reflecting the fact that this basin is less disturbed than the other four basins. The estimated increase in loads is much smaller than previous modelled increases of approximately 12, 15, and 9-fold for TSS, TP and TN (Kroon *et al*., 2012). This difference may partially be explained by the lack of water storages in the model used for load estimates reported in Kroon *et al*. (2012), while the current modelling includes all trapping in all major water storages and removal of constituents due to water extraction.

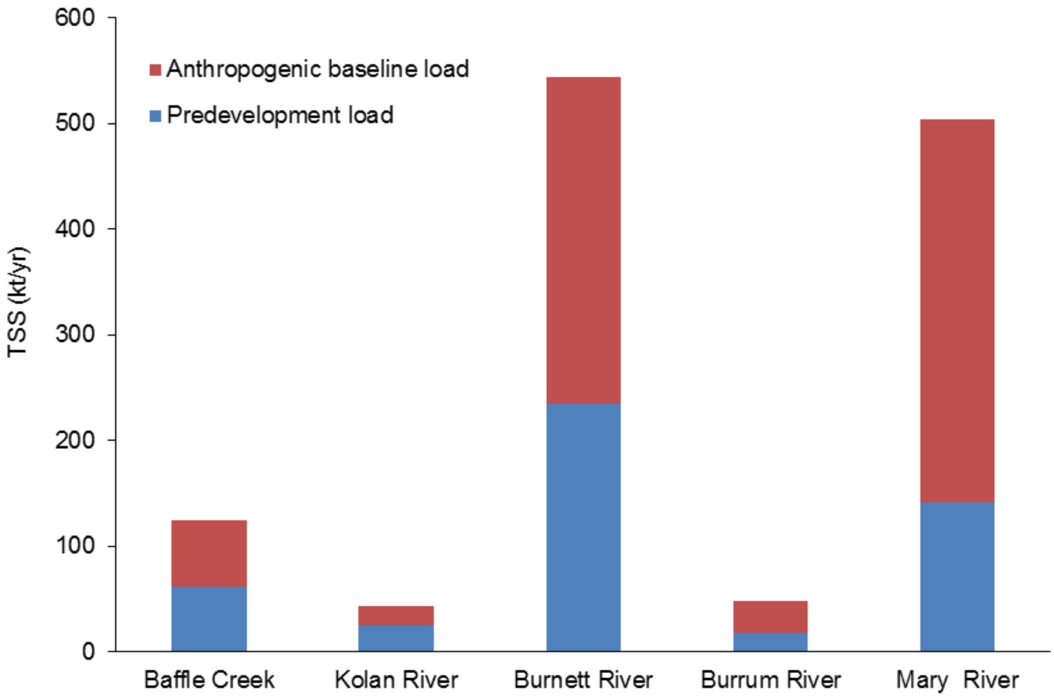


Figure 40 TSS (kt/yr) load for the Burnett Mary basins, indicating the predevelopment and anthropogenic baseline contributions

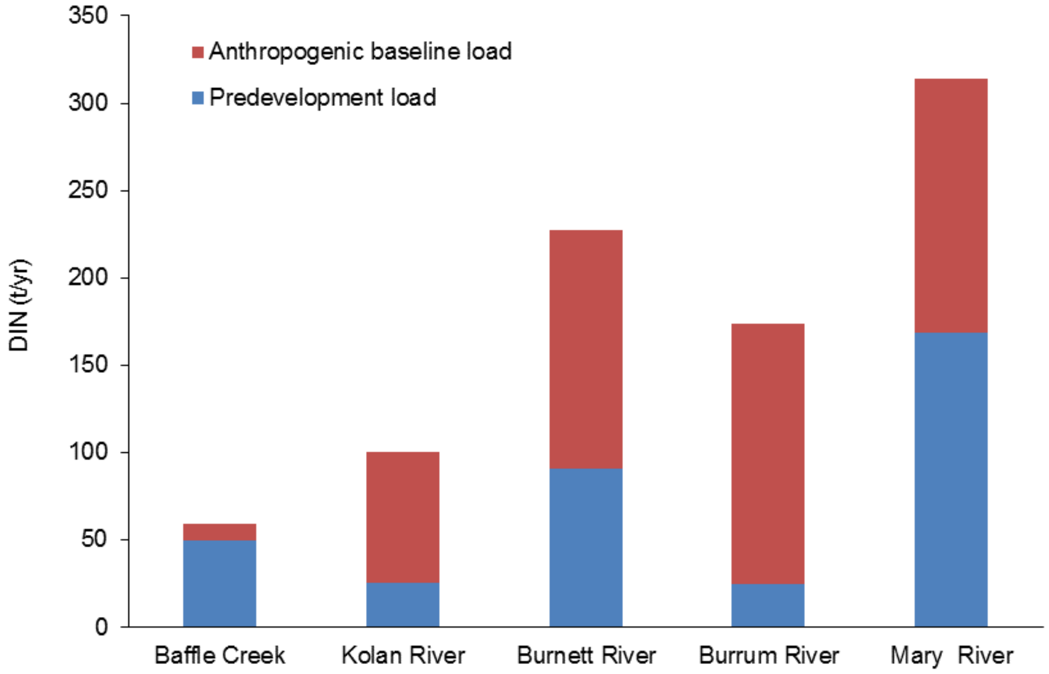


Figure 41 DIN (t/yr) load for the Burnett Mary basins, indicating the predevelopment and anthropogenic baseline contributions

Constituent load validation

The GBR Source Catchments loads and flow for the BM region were validated against load estimates from catchment monitoring at four sites in the Burnett Basin and two sites in the Mary Basin (Figure 42 to Figure 45), between the period 2006–2014, using data from GBR Catchment Loads Monitoring Program (GBRCLMP) (Joo et al. 2012, Turner et al. 2012, Turner et al. 2013, Garzon-Garcia et al. 2015, Wallace et al. 2015).

At the Burnett Basin end of system (EOS) site (Burnett River at Ben Anderson Barrage, Figure 42), the model overestimated flow, TSS and PSII pesticides (atrazine and diuron) while loads were underestimated for the remaining constituents. Differences in flow at this site may be attributed to the fact that monitored flow volume is an approximation by summing flows from upstream gauging stations (Garzon-Garcia et al. 2015) whereby:

Flow at Burnett River at Ben Anderson Barrage Head Water = Flow at Fig Tree + Flow at Degilbo + Flow at Perry.

Hence the model may be providing a better estimate of the actual flow at the Barrage.

The large differences between monitored and modelled loads for both atrazine and diuron (Figure 42) may be due to the fact that only two years of monitoring data has been collected during the 2009–2010 to 2013–2014 period and the fact that modelled application rates of pesticides are only typical rates for the area not those that are actually applied on any given day.

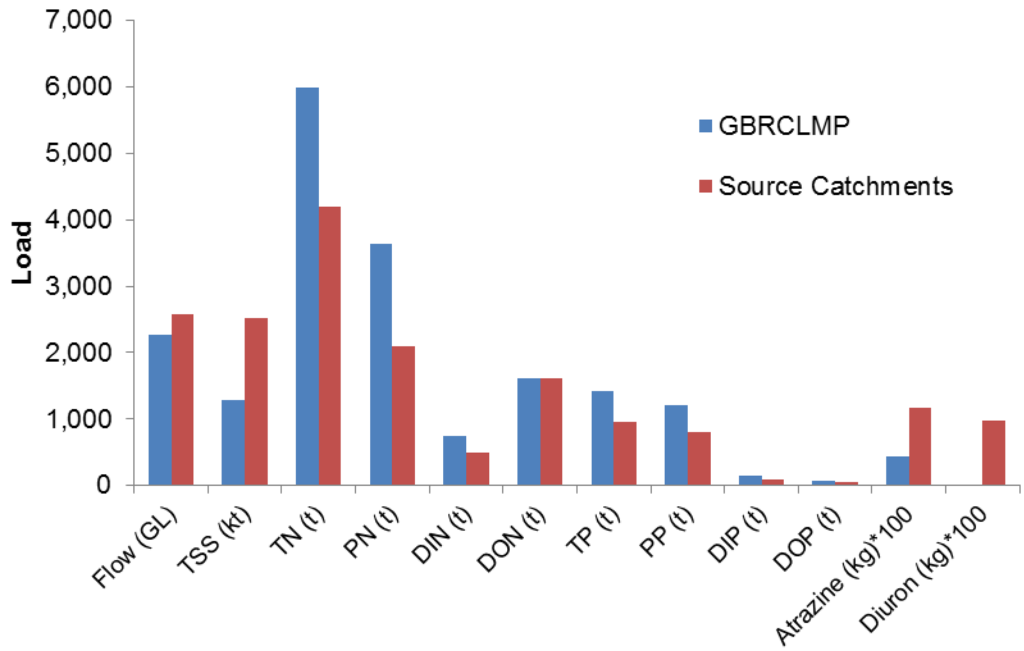


Figure 42 Comparison of monitored and modelled average annual flow (2006–2014) and constituent loads (2009–2014) in the Burnett Basin, as the Ben Andersen Barrage gauge (136014A)

At the Burnett River at Eidsvold gauge (Figure 43) most constituents are under-predicted, including flow and dissolved nutrients. Fine sediment and PP are both over-predicted, but PN compares well to the monitored load. No pesticides have been monitored at this site. TSS is also over-predicted at the Jones Weir tail water gauge (Figure 44), while most other constituents are under-predicted. Again, no pesticides were monitored at this site. TSS is under-predicted at the Mount Lawless gauge (Figure 45), which is in contrast to the other three monitoring sites.

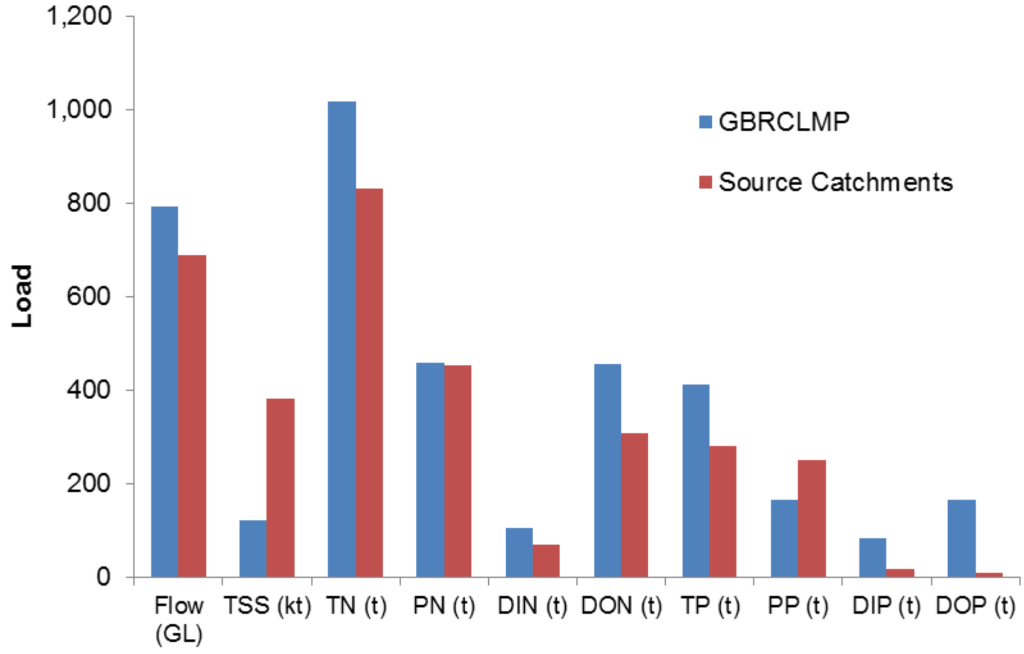


Figure 43 Comparison of monitored and modelled mean annual flow (2007–2013) and constituent loads (2009-2012) in the Burnett Basin, at the Burnett River at Eidsvold gauge (136106A)

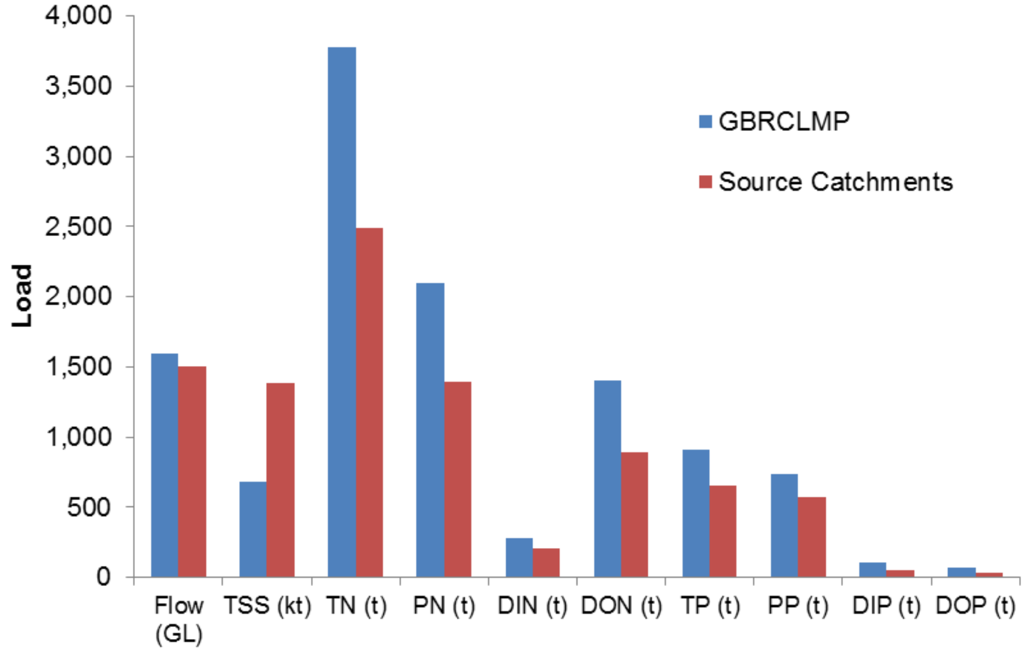


Figure 44 Comparison of monitored and modelled mean annual flow (2006–2013) and constituent loads (2009-2012) in the Burnett Basin, at the Burnett River at Jones Weir tail water gauge (136094A)

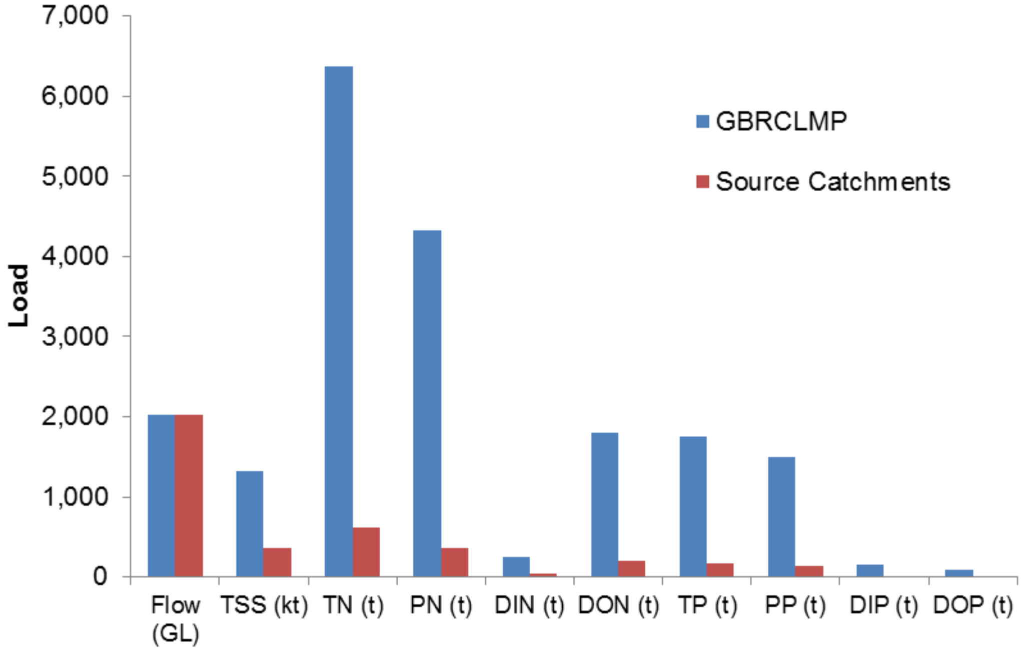


Figure 45 Comparison of monitored and modelled mean annual flow (2006–2014) and constituent loads (2007–2013) in the Burnett Basin, at the Burnett River at Mount Lawless gauging station (136002D)

The annual variability of TSS loads at the Burnett EOS gauging station is shown in Figure 46. The two extreme flood years of 2010/11 and 2012/13 account for 87% of the modelled TSS load for the whole modelling period of 28 years ().

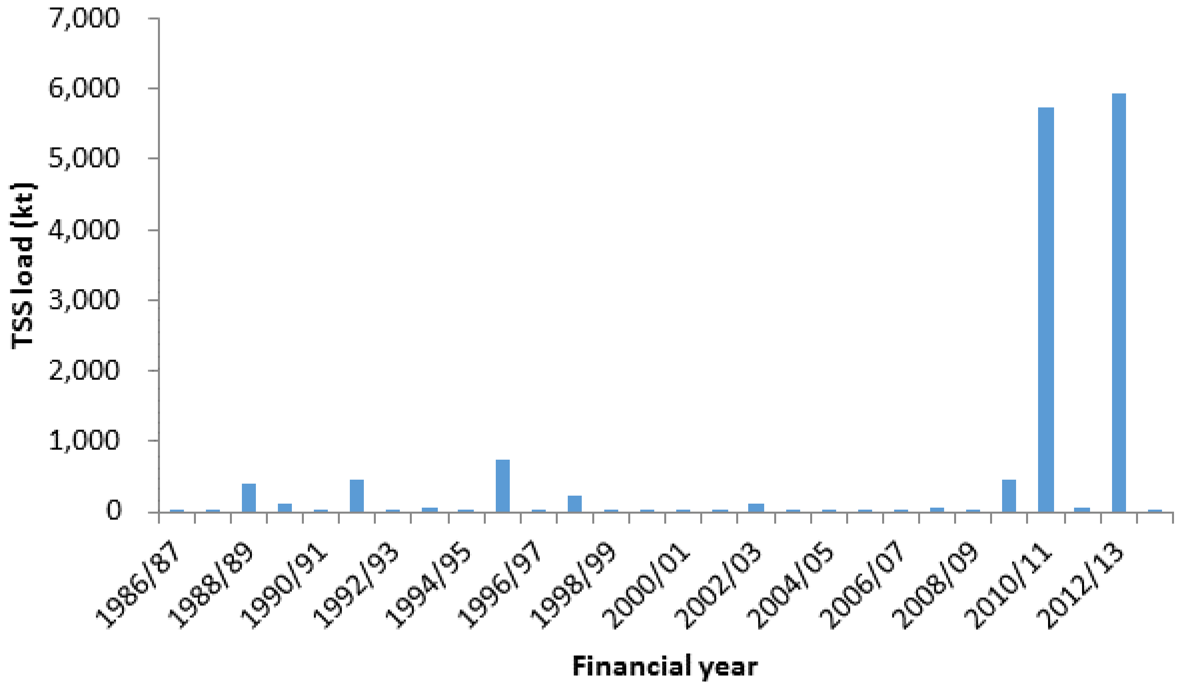


Figure 46 Annual variability in modelled TSS load at Burnett EOS site (136014A)

The performance of the RC2014 baseline model to predict the water quality processes across the BM region was also assessed using a number of quantitative statistics recommended in Moriasi et al.

(2015). The estimated quantitative statistics and the corresponding model performance ratings are presented in for the Burnett River. An overall performance rating was established as recommended quantitative statistics revealed conflicting/unbalanced performance ratings for most of the constituents. The overall performance was described conservatively using the least rating of the recommended statistics. For ease of presentation, 'very good' and 'good' rated sites are coloured green, while 'satisfactory' and 'indicative' are coloured orange, signalling that further work is required to improve the representation of these constituents.

As shown in Table 62, the RSR, R^2 and NSE yield similar results for all constituents, with a mix of 'good' or better rankings and some 'indicative' rankings a the Burnett end of system site. Using the PBIAS measure most constituents achieved an 'indicative' result suggesting further work is required to improve these estimates. Flow was ranked as 'very good' across three measures; TP, DOP and DIP also ranked 'good' or better, while TSS was only ranked very 'good' through the PBIAS measure, and 'indicative' for the remainder. DIN was better than 'good' for three measures while TN, PN and DON achieved similar results. Statistics could not be calculated at the daily or monthly time-step due to the load calculation method used in the GRBCLMP data.

Table 62 RC2014 quantitative statistical analysis for site 136014A Burnett River at Ben Anderson Barrage (HW), (n = 8 years for flow and n = 5 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.12	Very good	13.60	Satisfactory	0.99	Very good	1.00	Very good
TSS	0.98	Indicative	95.13	Indicative	0.04	Indicative	0.98	Very good
TN	0.39	Very good	-29.72	Satisfactory	0.85	Very good	0.98	Very good
PN	0.52	Good	-42.57	Indicative	0.73	Very good	0.93	Very good
DIN	0.53	Good	-33.45	Indicative	0.72	Very good	0.80	Very good
DON	0.14	Very good	0.47	Very good	0.98	Very good	0.97	Very good
TP	0.41	Very good	-31.28	Indicative	0.84	Very good	0.96	Very good
DIP	0.51	Good	-39.40	Indicative	0.74	Very good	0.98	Very good
PP	0.40	Very good	-32.29	Indicative	0.84	Very good	0.96	Very good
DOP	0.60	Good	-33.60	Indicative	0.64	Good	0.72	Very good

Overall, at the Burnett end of system site (136014A) Source Catchments modelled loads compared well with the corresponding loads estimated from catchment monitoring data. The majority of statistics were rated as good or very good (Table 62). Further investigation will be undertaken to improve the TSS estimates. Unfortunately, there has not been enough data collected in the in the Mary Basin to do a similar analysis. However, there are now two monitoring sites in the Mary Basin that may allow a similar analysis in the future.

Contribution by land use

The contribution of land uses to TSS, PN, PP and DIN export in the BM region are shown in Figure 47. Grazing occupies over 68% of the region and was by far the largest contributor to TSS, PN and PP export while most of the DIN was exported from the sugarcane land use. Streambank erosion was also a significant contributor for TSS, PN and PP. The annual contribution of each land use per unit area to TSS export from each of the five basins in the BM region is shown in Table 102, Appendix 4.

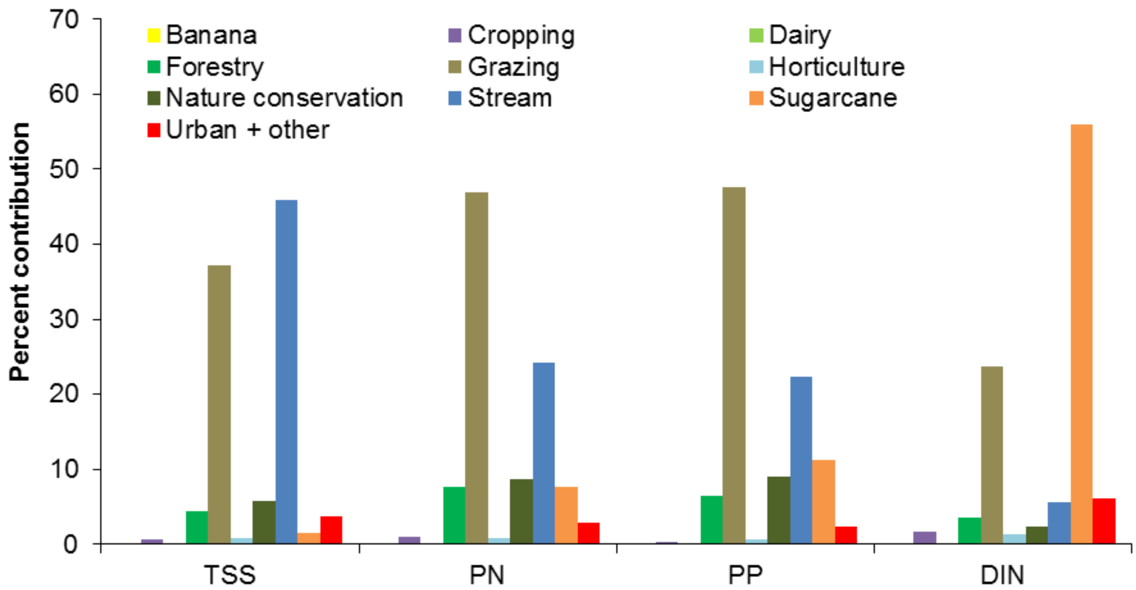


Figure 47 Contribution to fine sediment, particulate nutrient and DIN export by land use for the BM region

Despite accounting for less than 2% of the BM region area, sugarcane contributes 59% of the DIN export from the region. Grazing is the dominant land use accounting for 69% of the region and contributes 25% of the DIN export from the region (Figure 48). In terms of areal rates, sugarcane at 5.6 kg/ha/y, urban at 0.39 kg/ha/y and horticulture at 0.37 kg/ha/y are the dominant sources of DIN in the BM region. The average DIN per unit area rate for all land uses in the BM is 0.16 kg/ha/yr.

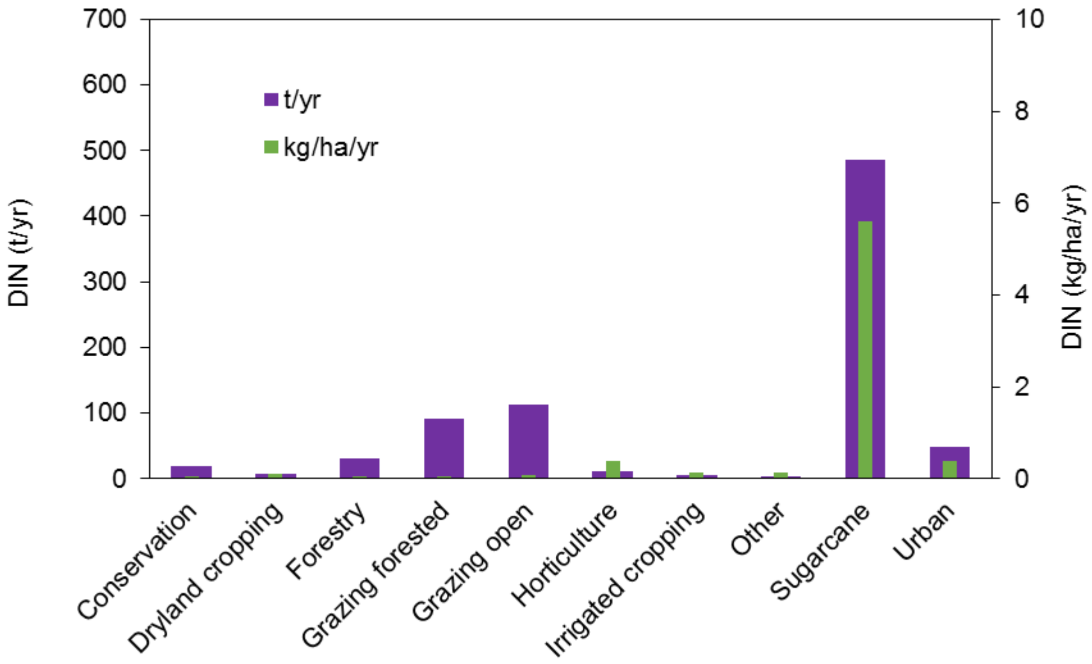


Figure 48 DIN export load and areal rate for each land use in BM

Sources and sinks

Modelled sources and sinks (losses) are given in Table 63 for all constituents. Of the total modelled fine sediment generated, 2,497 kt/yr was supplied to the streams in the BM NRM region of which 1,262 kt/yr (51%) was exported to the GBR lagoon while the remaining 49% was mainly trapped in reservoirs, lost through water extraction or deposited in floodplains. With a contribution of about 42% of the total supply, streambank erosion is the major source of TSS followed by hillslope erosion at 38% and gully erosion at 20%.

Table 63 RC2014 constituent budgets in the BM region

	TSS (kt/yr)	TN (t/yr)	DIN (t/yr)	DON (t/yr)	PN (t/yr)	TP (t/yr)	DIP (t/yr)	DOP (t/yr)	PP (t/yr)	PSII (kg/yr)	PSII TE (kg/yr)
SOURCE	**2,497**	**7,570**	**1,110**	**2,442**	**4,018**	**1,827**	**158**	**89**	**1,580**	**708**	**248**
Hillslope	943	2,893	19		2,875	1,128	7	2	1,120	708	248
Gully	495	288			288	121			121		
Streambank	1,058	856			856	339			339		
Channel remobilisation											
Diffuse dissolved		2,920	496	2,424		216	134	83			
Seepage		529	529								
Point Source		84	66	18		23	18	5			
SINK (loss)	**1,235**	**3,337**	**235**	**628**	**2,474**	**1,031**	**44**	**25**	**963**	**142**	**38**
Storage deposition	654	1,146			1,146	461			461		
Floodplain deposition	98	80			80	34			34		
Stream deposition											
Extraction and Losses	488	2,111	238	628	1,246	539	44	25	468	45	18
Stream decay										97	23
Export	**1,262**	**4,233**	**875**	**1,814**	**1,544**	**796**	**115**	**65**	**617**	**566**	**210**

Progress towards Reef Plan 2013 targets

Limited management changes were reported for the BM region for RC2014. Investments were made to improve sugarcane, gully, streambank and grazing management practices. The modelling results suggest there was <0.1% reduction in average annual TSS for the BM region, taking cumulative progress to 3%, with 0.1% reductions reported in the Baffle Creek and Mary basins. A reduction of 0.1% occurred for PP and PN, taking the cumulative PP reduction to 12% and PN to 6%; while a reduction of 0.4% was reported for DIN. The cumulative reduction of 31.5% is classed as a ‘very good’ ranking. A small amount of investment into improved pesticide management resulted in a 0.2% decrease in the PSII TE load, with the cumulative reduction now 33%. The investments that led to these changes are discussed below.

Table 64 BM sugarcane management practice change summary; values are a percent of total area

Soil	Baseline 2013	RC2014	Change
A	7.75	7.79	0.04
B-A	13.95	14.24	0.29
B	16.55	16.59	0.04
C-B	16.28	16.41	0.13
C	31.47	30.97	-0.50
D-C	12.18	12.18	0.00
D	1.82	1.82	0.00
Nutrients	**Baseline 2013**	**RC2014**	**Change**
A	1.00	1.00	0
B	12.00	12.14	0.14
C-B	38.00	37.99	-0.01
C	21.60	21.53	-0.07
D-C	14.40	14.35	-0.05
D	13.00	13.00	0
Pesticides	**Baseline 2013**	**RC2014**	**Change**
A	18.00	18.53	0.53
B	29.00	28.95	-0.05
C	48.00	47.51	-0.49
Df	5.00	5.00	0
Irrigation	**Baseline 2013**	**RC2014**	**Change**
A	6.00	6.00	0
B-C	28.50	28.54	0.04
D	65.50	65.46	-0.04
Recycle Pits	**Baseline 2013**	**RC2014**	**Change**
A	14.00	14.04	0.04
B	11.00	11.05	0.05
C	44.00	43.92	-0.08
D	29.00	29.00	0

Table 65 BM grazing management change; values are percent of total area

Hillslope	Baseline	RC2014	Change
A	1.66	1.68	0.02
B	44.04	44.14	0.10
C	54.27	54.16	-0.11
D	0.02	0.02	0
Gully	**Baseline**	**RC2014**	**Change**
A	8.76	8.76	0
B	20.98	20.99	0.01
C	54.12	54.12	0.01
D	16.14	16.12	-0.02
Streambank	**Baseline**	**RC2014**	**Change**
A	28.98	28.98	0.01
B	14.61	14.65	0.04
C	18.40	18.39	-0.02
D	27.54	27.51	-0.02
NA	10.47	10.47	0

Discussion

The modelled estimates of constituent loads exported to the GBR for Report Card (2014) are a major improvement on the previous Source Catchments modelling. A scheduled, major rebuild occurred following the completion of RC2013 modelling. Updates included an extension of the climate simulation period, and hydrology recalibration; improvement in hillslope erosion inputs; updates to the sugarcane paddock model and a major restructure in the way management practice adoption data was represented.

Prior to the extension of the climate period, models were parameterised with minimal calibration, given only four years of monitoring data to draw on. The inclusion of improved input data layers (e.g. gully mapping), utilising eight years of monitoring data and sediment tracing data has allowed for a degree of manual calibration of parameters, This manual calibration has not only better align modelled loads with monitoring data and ultimately achieve an improved baseline load. But improved the alignment of sediment budgets to literature (e.g. Normanby and Burdekin basins).

It is important not to lose sight of the main objective of the modelling, to report the water quality benefits as a result of management changes. Therefore the relativity between scenarios is important not the absolute load. However the goal of the modelling program is for continual improvement of modelled load predictions. This approach will continue.

The new management practice adoption framework combined with smaller regional investment has seen load reductions of less than 1% this report card. Such small changes would be difficult to detect through monitoring alone, highlighting the value of modelling to provide the best estimate of the relative magnitude of the change in water quality where many small changes in practices are made across a landscape.

The extension to the model run period has provided an additional five years of loads monitoring data to be included for model validation. The extended period includes the extreme flood events of 2010/11 and 2011/12. The two extreme wet years provides additional calibration points at the high flow end, important for improving load predictions. The inclusion of the wetter years has also contributed to the increased average annual loads when compared to the previous Report Card estimates. This was particularly true for the Burnett Mary, where over 50% of the generated sediment load for the model period occurred during these two years.

The updated hydrology calibration approach has seen the flow bias for the calibration period improve from approximately +/- 30% of observed flows across the GBR basins to now being with approximately +/-5% of observed average annual flows. The improvements also translated through to better representation of the inter-annual flow volumes and timing of event peaks. Improved flow predictions have led to better load estimates. Load estimates across the GBR have remained at approximately +/-50% of observed load estimates.

The inclusion of seasonal ground cover into the hillslope erosion model has accounted for the lack of ground cover response to wet season storms previously observed in the models. Representation of the inter-annual variability is important given the correlation between cover and erosion particularly in grazing lands across the GBR (Silburn 2011).

The two refinements to the sugarcane DIN modelling are important additions to the modelling framework. The modification to surface DIN generation in the APSIM modelling (Fraser et al. 2016) has resulted in smaller DIN loads in surface runoff than previously modelled. However the surface runoff loads better reflect experimental data. The change to modelled surface runoff DIN, resulted in an under prediction at gauges where measured DIN loads were available. The inclusion of subsurface DIN not only improved load estimates at the gauges, but better reflected the transport processes occurring in a number of irrigated cane areas, namely the return of runoff and associated loads of constituents to stream via subsurface pathways (Armour, Nelson, et al. 2013, Rasiah et al. 2013). Importantly the new approach now enables improved management of DIN via reduced fertiliser inputs to be expressed in stream water quality.

The updated management practice framework has enabled more combinations of management practices to be reflected in the practice adoption framework. Better alignment of induvial practices to water quality benefits within the model have resulted in more conservative but more realistic load reductions being reported compared to previous report cards.

The current modelling framework is flexible and has improved the capacity to model management practice change when compared to previous GBR catchment modelling approaches. It is a substantial improvement on previous GBR load modelling applications utilising a consistent methodology across all NRM regions. The model has shown that it is an appropriate tool for assessing load reductions due to on-ground land management change across the GBR.

Cape York

The results from RC2014 are an improved representation of constituent generation and runoff to the GBR compared to all previous CY modelling. The major enhancements that have achieved this include: recalibration of hydrology, an improved methodology for converting remotely sensed cover to a c-factor used in the hillslope erosion model, shifting from annual to seasonal cover for estimating hillslope erosion, an improved gully map product for the Normanby Basin, and in-stream deposition and remobilisation functionality being enabled in the model. Another significant factor to note is that this is the first CY modelling that had a useful amount of water quality monitoring data available for model evaluation and calibration. Following is a discussion of each of these factors and how they have influenced the modelling results, providing an improved estimate of constituent loads from CY.

Hydrology

The recalibration of the hydrology model for CY has seen a significant improvement in modelled total flow volumes. Total flow difference was improved at all gauges, however the biggest improvement occurred at the Kalpowar Gauge in the Normanby Basin. This gauge has the largest catchment area and the shortest gauging record (commenced late 2005). The extension of the model run period enabled five extra years of flow data to be incorporated into the calibration, a likely contributor to the improved flow bias at this location. Total flow bias was previously 25.4% in the 2010–2013 Report Cards, and this was reduced to 3.8% in the current Report Card. This is an important improvement because this is currently the only location in CY where water quality data is collected (where the number of samples collected is sufficient for load calculations), providing a critical validation dataset for Source Catchments loads. Other gauges where total flow bias was improved are in the Endeavour Basin where gauge 107002A was previously under-predicted by ~18% and is now over-predicted by <1%; also there were three gauges (two in the Normanby and one in the Pascoe Basin) where flow bias has been improved by almost 10%. An implication of the reduced flows is a corresponding reduced constituent load estimates. The reduced loads will be particularly obvious and directly proportional to flow where constituent generation is via an EMC/DWC model (product of flow by concentration). It was noted that a number of the recalibrated gauges had a higher than expected baseflow contribution. Further investigation of the portions will be undertaken for RC2015.

Fine sediment generation, sources and sinks

Average annual hillslope erosion generation increased in RC2014 due to the decrease in cover, as described on page 38. The hillslope delivery ratio (HSDR) and the Dry Weather Concentrations (DWC) were both reduced to account for the increased generation to align with monitored data. The reduction of the hillslope delivery ratio is supported in the literature by Rustomji et al. (2010), who report that a HSDR as low as 1% is an appropriate value in the neighbouring Mitchell River catchment. Rustomji et al. (2010) also support use of spatially variable HSDR, which is an improvement that will be explored in future CY modelling.

In the previous CY baseline model, hillslope sources were the greatest source of sediment (supply). This has changed in the new baseline model and gullies are now the largest source. This is due to the empirical National Land and Water Audit gully density layer for the Normanby Basin being replaced with an actual mapped gully layer (Brooks et al. 2013). The modelled streambank contribution is generally low because the streambank erosion is largely representing trunk stream erosion. Secondary channel erosion as described by Brooks et al. (2013) is effectively incorporated into the gully load for the Source model due to the different spatial scales at which the Source and Brooks et al. (2013) Normanby models operate. That is, there are 150 subcatchments in the Source Normanby Basin model, while there are 9,000 in the Brooks et al. (2013) work. Each subcatchment represents a single stream. The additional 8,850 streams modelled by Brooks et al. (2013) are potentially modelled as gullies in the Source Catchments model.

Table 66 Sources of sediment in the current and previous Report Card, and the comparison between Source Catchments modelling and Brooks et al. (2013)

Erosion process	RC2013	RC2014	Brooks et al. (2013) Normanby	RC2014 Normanby
Hillslope (%)	66	36	<1	22
Gully (%)	21	57	37	70
Streambank (%)	13	7	62*	4
Channel remobilisation	0			4

* Note, this estimate includes sediment generation in both main trunk streams and secondary channels

Cape York is the first of the Source Catchments models to have in-stream deposition and remobilisation enabled. In previous Report Cards this functionality has not been used. These processes are in a state of continuous flux between deposition and remobilisation (Wilkinson et al. 2010). The algorithm representing in-stream deposition and remobilisation has not changed, however recently published research highlights these processes as an important part of the sediment budget story (Brooks et al. 2013), and thus they've been enabled for RC2014. To validate this component of the model it was assumed that the net balance of in-stream deposition and remobilisation would be approximately the same. The model could then be used to achieve a similar apportioning of floodplain and in-stream deposition to the findings of Brooks et al. (2013). The main parameters that were adjusted in this process were the proportion of streambank for deposition and the initial store, the floodplain and in-stream settling velocity, the annual recurrence interval for bankfull flow (ARI), and the bank erosion coefficient. In previous Report Cards most of these parameters were set to default values, thus the RC2014 values now represent a CY specific set up and provide a base for other regions to enable this functionality/process in future Report Cards.

Of the generated fine sediment load, 40% is now stored as floodplain or in-channel deposition across the CY model. In the Normanby this figure was 51% of generated sediment being stored. This is in line with Brooks et al. (2013) research that suggests approximately 55% is stored. Further to this, of the load that is being stored across CY, 85% is stored on the floodplain and 15% in-stream. In the Normanby Basin this changes to 87% floodplain and 13% in-stream (of the total *supply*, 45% is stored on the floodplain and 7% instream). Brooks et al. (2013) research suggests 75% floodplain and 25% in-stream deposition for the Normanby Basin.

The average annual modelled fine sediment load is still 46% higher than the monitored load (142 kt/yr versus 208 kt/yr) in the Normanby. In terms of concentration, the average long term monitored TSS concentration at the gauge is 51 mg/L, and the modelled average concentration at the gauge is 79 mg/L. Shellberg (pers comms), suggests that there is little difference in concentration between the Kalpowar gauge and the Normanby River end of system. The modelled concentration at the EOS is 59 mg/L, of a similar order to the Kalpowar monitored data.

There was no management data reported for CY in RC2014. The cumulative reduction for TSS and PN remains at 8%, and at 7% for TP. The PP reduction is 12%, and 6% for TN. As there is no sugarcane modelled in CY there are no DIN reductions.

In summary, the extension of the modelled period, hydrology recalibration and multiple changes to input datasets are the main reason for an increase in constituent loads. There is no load reduction due to improved management practice, as no changes were reported.

Wet Tropics

The results from RC2014 are an improved representation of constituent generation and runoff to the GBR compared to all previous WT modelling. The major enhancements that have achieved this include: recalibration of hydrology, an improved methodology for converting cover to c-factor and a shift to seasonal cover for estimating hillslope erosion. The inclusion of subsurface drainage DIN for sugarcane, and the use of HowLeaky for banana modelling as opposed to an EMC/DWC approach provide a better reflection of runoff processes. Following is a discussion of each of these factors and how they have influenced the modelling results. There was an increase in all pollutant loads compared to RC2013, except for PSIIs.

Hydrology

The recalibration of the hydrology in the WT model has seen a significant improvement in the three performance measures and better alignment of peak flows between modelled and observed runoff. A number of changes were made to the underlying hydrology model which resulted in the improved calibration. In summary, the modifications included the change in rainfall runoff models from SIMHYD to Sacramento, an increase in the number of gauging stations used in calibration and an increase in the temporal extent. The increase in climate period (2009–2014) allowed the inclusion of a number of more recent above average rainfall years.

A rainfall scaling exercise was undertaken for the WT. Through the rainfall scaling, the total volume difference for the RC2013 calibration was -31% which has improved to 0%. The changes combined, increased the WT average annual flow by approximately 9%, even when additional irrigation extractions were included in the model (up from five to 35). An obvious implication of the increased flow is a corresponding increase in constituent loads, particularly for EMC/DWC models because load calculations EMC/DWC models are just the product of concentration and flow (before other input and methodology changes are taken into consideration). A significant proportion of the WT area uses EMC/DWC models for load generation. Adding an additional four years to the modelling period (2009–2014) saw the average annual flow increase by 3% when compared to the 1986–2009 period using the Sacramento calibration.

Fine sediment and particulate nutrient sources and sinks

In comparison to RC2013, hillslope fine sediment erosion supply doubled, while there were slight reductions in both gully and streambank erosion. The erosion increases occurred mainly in sugarcane and nature conservation FUs. There were smaller increases in most of the other FUs. For sugarcane, the increase in soil erosion was related to the increase in runoff (by extending the model run period) as well as the incorporation of poorly drained soils, the changes in the baseline distribution for soil management, changes in tillage practices, and the increase from four to 39 management scenarios. For nature conservation, the increase is primarily due the increased runoff across the model period, and adjustments to the EMC/DWC values. The decreases in gully and streambank erosion were due to gully erosion being restricted to grazing lands (gully erosion was effectively set to zero in sugarcane, irrigated and dryland cropping FUs) and a slight change made to components of the streambank model undertaken from a desktop GIS assessment.

The change in the algorithm used to convert remotely sensed cover to c-factor in the RUSLE model decreased the average predicted ground cover by 17% in RC2014, thus increasing hillslope generation. The maximum annual load was adjusted to account for the increased generation, as evaluation against monitored data showed the fine sediment load to be well over-predicted. Once the maximum annual erosion rate was set to 50 t/ha, the average modelled load in Rudd creek (2011–2014) was ~14,000 t/yr and the measured load was ~7,900 t/yr (O'Brien 2015).

The WT is the largest contributor of particulate nutrients in GBR compared to the other NRM regions. Issues have been identified in all regions regarding the observed lack of nutrients in subsurface layers and the under prediction of particulate N and P loads compared to measured estimates from these areas. This issue will be investigated before the next Report Card and it is envisaged that the larger drier regions will contribute larger particulate loads therefore, the proportion derived from the WT will be smaller at the GBR scale.

The modelled loads of TSS and particulate nutrients had overall better performance ratings at the long-term monthly scale dataset (data from 1986-2009) compared to the shorter term annual scale dataset (data from 2005–2010). The larger drier Herbert River performed the best overall compared to other sites for TSS and particulate nutrients at the monthly scale.

Nutrients

The WT was the highest contributor of DIN (42%) to the total GBR DIN export load, which is consistent with previous Report Cards. The WT DIN export load increased by 12% compared to RC2013, partly due to the increase in average annual flow. The Herbert Basin is the largest contributor of DIN, followed by the Johnstone and Mulgrave–Russell basins. In previous Report Cards, the highest contributor was the Johnstone, followed by the Herbert and Tully. One reason for the change in order of ranking is the revision of the sugarcane DIN delivery ratio (DR) applied in the Herbert. In RC2013, the delivery ratio was applied to the entire Herbert Basin. In RC2014, delivery ratios differed based on the location of sugarcane upstream or downstream of the EOS gauge. A 50% DR was applied to sugarcane upstream of the EOS, and 100% downstream. The 50% DR was applied to more closely align the DIN modelled load with the measured load at the Herbert EOS gauge. A spatial DR was also applied in the Barron Basin, where a 15% DR was applied upstream of the EOS gauge and 100% below the EOS gauge. The DR for all other basins didn’t change from RC2013 (100%). Changes in hydrology and the revision of the management practice frameworks for sugarcane would have also influenced the changes in loads from each basin, and the ranking of each basin.

As described, a daily timeseries of DIN in deep drainage (below the root zone) from APSIM was supplied as an additional pathway for DIN in sugarcane. Further to this, an important change has been that management of nutrients in sugarcane (DIN) now affects surface and subsurface (seepage) runoff. In previous Report Cards, management only affected the surface runoff component. The majority of the sugarcane DIN export load was from seepage (a proportion of the DIN escaping the root zone as deep drainage) (89%) and the remaining 11% from surface runoff. The majority of the deep drainage component was returned to the stream as seepage (91%). Seepage DRs were 100% in all basins except Herbert (50% above EOS gauge) and Barron (15% above EOS gauge).

A study of runoff and deep drainage in sugarcane farming in the Murray Basin showed that the major loss pathway was from deep drainage from a permeable soil type (Armour, Nelson, et al. 2013). Deep drainage from this study accounted for between 23-42% of annual rainfall (from two sites). The modelled average areal rate of DIN export from sugarcane across the WT was 12 kg/ha/yr. Armour, Nelson, et al. (2013) found that the inorganic N loss (mainly nitrate) was up to 13 kg N/ha/yr. The modelled areal rate for DIN sugarcane export from the Murray Basin was also 12 kg/ha/yr (modelled basin range 7–17 kg/ha/yr). Lower nitrogen leaching loads were reported at a different sugarcane site (<1–9 kg/ha/yr), possibly due to a better match between fertiliser and crop demand, and the number of days from application to deep drainage (Armour, Davis, et al. 2013).

There were slight increases in the DIN export load for all land uses compared to RC2013, except for bananas, where there was a slight decrease. The increases in export load for nature conservation, forestry and grazing FUs was from increasing the EMC/DWC values along with the increase in flow to align more closely with EOS monitored loads. The majority of the DIN export load was from sugarcane (41%) and nature conservation (34%) with areal rates of 12 kg/ha/yr and 2 kg/ha/yr respectively.

For bananas, the change in models from the EMC/DWC approach to the HowLeaky model allowed for the inclusion of management practices for soil and nutrients to be modelled. Surface runoff was the only pathway modelled for bananas for RC2014. The DWC for bananas was set to 1.5 mg/L to represent the deep drainage component. Armour, Nelson, et al. (2013) found that for the banana plant crop drainage was 65% of rainfall, and for the ratoon 37% of rainfall. For two contrasting N fertiliser applications (710 and 1,065 N kg/ha), the loss of fertiliser N below the root zone was 37% and 63% respectively (Armour et al 2013). The incorporation of DIN in deep drainage from banana land use is planned for future Report Cards.

Similar to sediments and particulates, dissolved nutrients performed better compared to long-term monthly monitoring than for the shorter record of annual monitoring. The North Johnstone overall had the better performance rankings of ‘very good’ for all dissolved nutrients at the monthly scale.

Herbicides

The WT contributes approximately a quarter of the PSII herbicide load to the GBR. There was a decrease in the RC2014 PSII load compared to the RC2013 PSII load (8,596 kg/yr to 3,694 kg/yr). This change is the result of a review of the management practice adoption data for a 2013 baseline year (updated from a 2008-2009 baseline year), a review of the pesticide application profiles by local experts including a separate profile for the Herbert region and a review of the sugarcane modelling in APSIM.

Progress towards targets

The progress towards the targets for RC2014 in the WT were small. Overall, limited management changes were reported for the WT region for RC2014. Investments were made to improve soil and nutrient management in sugarcane and bananas, and pesticide management in sugarcane. The modelling results suggest there was a 0.35% reduction in average annual TSS load for the WT region, a 1.29% reduction for DIN and a 1.72% reduction for PSIIs. No management practice changes were reported for hillslope, streambank or gully management in grazing areas. The modelled cumulative reduction in loads (2010–2014) for TSS is 12.9%, 13.9% for DIN and 27.6% for PSIIs.

A number of factors have contributed to the smaller reductions compared to previous Report Cards, which have been discussed above. For sugarcane, 10% of the sugarcane area had a soil management change (mostly partial steps), 6% of the area for nutrient management (shared equally between partial and a full step change) and 8% of the area for pesticide management (mostly a partial step change C full to B partial). However, the modelling currently represents four levels of pesticide management actions applications (Af, Bf, Cf and Df) and there is no improvement modelled unless a full step change has been achieved.

Only full step changes were reported for the banana management framework. For soil management 9% of the banana area underwent a change and for nutrients 11% of the area. Overall, sugarcane and banana represent 8% and 0.7% of the WT area. The overall percent reductions in the export loads are sensible given that the area of management change is small.

Burdekin

Overall, the results from RC2014 for the BU region show an improved representation of land use practice, runoff and constituent generation and export to the GBR compared to previous Report Cards. The improved version provides the platform for a more refined assessment of progress towards Reef Plan targets. The major Source modelling enhancements and datasets that have enabled this improvement in the BU region are: extended climate period for hydrology calibration and model run period, use of Sacramento rainfall runoff model, several changes to hillslope, gully and streambank parameters to affect fine sediment loads, improved APSIM simulations, and the availability of extra data against which to compare the model results.

Hydrology

The recalibration of the hydrology in the BU model has seen a significant improvement in the three performance measures and better alignment of peak flows between modelled and monitored runoff.

The RC2014 hydrology modelling results show that key sites in the BU and coastal basins (as described in the BU Results) produced very good agreement with gauged flow data, at the daily scale. For the key sites the Daily Nash Sutcliffe Coefficient of Efficiency and total volume error showed a large improvement from RC2013 to RC2014. Using the Moriasi et al. (2007) classification (for NSE and PBIAS) all gauges are now classed as “good” to “very good” for RC2014 at the daily scale. NSE is a good measure for predicting overall fit of hydrograph shape (Servat and Dezetter 1991), with average NSE improving from 0.61 to 0.81. At the sub-catchment scale the RC2014 results show a similar improvement in NSE for the “key site scale”. Comparatively the flow difference (p-bias) measure had a larger improvement, with only one gauge being outside the Moriasi range.

The improved RC2014 hydrology allowed the assessment of whole of catchment hydrologic performance at the event scale (sub monthly). Event performance was assessed for PBIAS at EOV using the event definition of Dougall and Carroll (2013). Performance was found to be good with total volume for all events being within 1% of observed. However events defined as “below dam” in origin were, on average, over-predicted by 14%. In terms of individual event performance, PBIAS was satisfactory for 65% of the events, with the statistical measure decreasing as the size of the event decreased. This is to be expected as there is more uncertainty in the representation of rainfall events, when event size decreases. It should be noted that a proportion of these events had well sampled water quality, and now that hydrology calibration is improved these data will be more useful for testing performance of water quality modelling.

Several methods are available for improving event prediction, including the sourcing of better rainfall datasets and or rainfall scaling (Hateley et al. 2014). Also there is work that shows improved hydrologic prediction through the assimilation of remotely sensed soil water in data sparse regions (López López et al. 2016). Nonetheless it is encouraging to see model performance being well represented at this finer temporal scale.

Fine sediment and particulate nutrient generation

Hillslope erosion

As described in the Methods on page 38, the changes to the USLE inputs has significant impacts on hillslope derived load in the BU region. The Fractional Cover Index (FCI) generates better performance statistics for cover prediction and its ability to estimate cover in treed areas over the Bare Ground Index (BGI) products are major improvements. The FCI is a particularly valuable addition in the BU due to its high proportion of area of treed cover.

The change in cover, cover to c-factor calculation and the move to seasonal cover decreased average predicted cover by ~20% compared to the previous BU model. This resulted in a large increase in modelled hillslope sediment supply. In response, the hillslope delivery ratio (HSDR) was reduced to account for the increased generation, as evaluation against monitored data and sediment tracing showed the fine sediment load to be well over-predicted.

During parameterisation, mountainous areas were found to be generating particularly high loads of sediment from hillslope erosion. Many of these areas have very steep slopes and high rainfall and also contain large areas of rock outcrops and stony soils. McIsaac et al. (1987) and McCool et al. (1987) found that the RUSLE over predicts soil loss for steep slopes. Risse et al. (1993) found that the RUSLE tended to over predict soil loss on plots with lower erosion rates and that the RUSLE has a poorer predictive capability on rangeland settings compared to agricultural conditions. Lu et al. (2003) added to this by stating that erosion rates can be overestimated in steep arid tropical mountain ranges when using the RUSLE to estimate hillslope erosion.

Annual hillslope erosion was capped within the BU region at a maximum of 1.4 t/ha/day and potentially could have been lowered further to reduce the hillslope erosion rate, however lowering the cap further adversely affected erosion rates for high runoff events and narrowed the difference between erosion rates for extreme, moderate and low runoff events. Lowering the delivery ratio was considered a better option than a further lowering of the hillslope erosion rate cap as it would not distort the difference in erosion rates between events of different magnitudes. The default delivery ratio was lowered from 10% to 5% in all catchment except the Upper Burdekin and Bowen. This provided a better match to sediment tracing and annual load estimates.

Gully erosion

The gully density layer used for this report card has changed significantly compared to the data used within the previous models. The hybrid layer, which is a combination of grid based gully erosion presence mapping for the Burdekin's coastal catchments (Darr et al., unpublished data) and the work of DSITI (Tindall et al. 2014) for the Burdekin proper, provided improved spatial resolution and accuracy and more significantly increased the range of density values that occurred across the BU region. This combined with other new lines of evidence considered in the parametrisation has resulted in gully erosion being the dominate sediment source (~65%) at the NRM region scale, with streambank (~15%) and hillslope (~20%) providing the remainder.

In RC2013, and prior, the initial, default model parametrisation showed a potential under-prediction of sediment supply from either gully and/or hillslope erosion at the average annual scale, when compared against monitored catchment loads (Dougall, Ellis, et al. 2014). Notably these results indicated that the spatial inputs for gully and hillslope erosion could be improved to better resolve monitored loads. The potential deficiencies in the gully modelling were later highlighted by independent evidence in the form of the sediment source tracing of Wilkinson et al. (2013) and more recently the work of Wilkinson et al. (2015). These studies suggested that sub surface sediment was the dominate source of eroded material measured in streams. However, it should be noted that the delineation of erosion process across the GBR has been complicated by erosion source definition (proportion of sub surface and surface soil) as compared to erosion processes as defined in recent sediment tracing work (Hancock et al. 2013, Bartley et al. 2013). The work of Hancock et al. (2013) identifies scalds and rill (in Hancock et al. (2013) defined as 'horizontal subsoils', due to the removal of surface soil via erosion) as a high contributor to the sediment budget in the Bowen catchment. Notably the different conclusions have led to some uncertainty, especially with stakeholder communication.

During the above period of sediment tracing work in the Burdekin, a gully mapping project was also undertaken in the region with the aim of providing better spatial inputs for catchment modelling. This project produced a range of spatial layers and these are extensively reported in Tindall et al. (2014). In addition the BU regions coastal catchments were manually mapped with high resolution imagery (Darr et al., unpublished data). These layers proved to have higher gully destines than the prior layer of Kuhnert et al. (2007).

RC2014 modelled sediment sources are dominated by gully and streambank erosion and this better matches the surface/subsurface results outlined by the sediment tracing in the region (~80% subsurface mainly gully and ~20% hillslope).

Streambank

There has been a relatively slow improvement in the modelling of bank erosion since the first application of the SedNet bank erosion model in the BU. For the Reef Plan 2009 catchment modelling (RC2010–RC2013), a better streambank erosion vegetation map was produced than that of prior models (Fentie, Duncan, et al. 2006, Kinsey-Henderson et al. 2007), along with minor improvements in other spatial parameters such as bank height. Evaluation of the modelling showed expectable rates of stream bank erosion in the upper Burdekin when compared to (Bainbridge 2004). However more recent work identified several areas for improvement (Bartley et al. 2015) and these were already being addressed in part by the modelling team for the RC2014 model.

To further constrain the modelling, a rapid appraisal of bank erosion rates with historical air-photos for the Lower Burdekin was performed. Little evidence of large scale erosion was present, however due to limited time and the inherent complexities in measuring change using this technique the measurement error was considered to be high. As such the most conservative approach was used, where the erosion rates were constrained to match the lower end of those outlined in Wilkinson et al. (2004) and Prosser et al. (2001). In addition links were manually inspected for the presence for a high proportion of rock and gorge like characteristics and erosion rates were set to zero for these links.

These changes have resulted in a lower predictions of streambank erosion than in previous modelling, in particular in the Lower Burdekin basin and areas directly downstream of the Burdekin falls dam.

Sugarcane DIN loads

Changes in hydrology and the revision of the management practice frameworks for sugarcane have created minor changes compared to previous report cards. For example the BU region DIN export load decreased by 8% compared to RC2013, which is well within the uncertainty boundaries of the monitoring data. The BU region was the second highest contributor of DIN (21%) to the total GBR DIN export load, which is consistent with previous Report Cards. At the regional scale the BU Basin is the largest contributor of DIN, followed by the Haughton and this ranking is the same as previous report cards.

An important change in RC2014 has been that management of nutrients in sugarcane (DIN) now affects surface and subsurface (seepage) runoff. In previous Report Cards, management only affected the surface runoff component and seepage was modelled with DWC's. The majority of the DIN loss at FU scale for sugarcane was from deep drainage (90%) and the remaining 10% from surface runoff. The majority of the deep drainage component was returned to the stream as seepage (91%), averaged across the BU sugarcane FU area. Seepage DRs were set at 100% to better match the limited monitoring data at Barratta Creek.

There were small changes in the DIN export load for all land uses compared to RC2013. The changes in export load for nature conservation, forestry and grazing FUs were from changes in hydrology. The majority of the DIN export load was from sugarcane (45%) with the rest of the load comprised from grazing and nature conservation.

Herbicides

The BU contributes approximately a fifth of the PSII pesticide load to the GBR. There was a minor decrease in the RC2014 PSII load compared to the RC2013 PSII load. The development of more specific pesticide profiles for sugarcane in the BU was the main reason for the lower PSII load.

Progress towards targets

For fine sediment and particulate nutrients, minor improvements in loads have occurred in RC2014, with reductions in TSS ~1.5%, PN ~1% and PP (~%1). It is important to acknowledge the considerable difficulties in reporting small changes in grazing land management across the large BU region. In general, the scale of investment in terms of area are logical in terms of expectations from investments, with considerable variation in area to reduction ratios to be expected. However as the modelling further improves confidence at these smaller scales should increase. Importantly cumulative change over many years is a better indicator than annual. In sugarcane a reduction of ~1% for DIN was recorded, and this is again in line with the small changes in management recorded. The PSII reduction was ~6% and this is due to the impact of recycle pits and paddock management.

Mackay Whitsunday

The results from RC2014 are an improved representation of runoff and constituent generation to the GBR compared to previous MW modelling. The major enhancements that have achieved this include: recalibration of hydrology, an improved methodology for cover to c-factor conversion and a shift to seasonal cover for estimating hillslope erosion, an improved representation of constituent generation from sugarcane and the ability for sugarcane derived DIN to be included in DIN loads to the stream via subsurface pathways. Following is a discussion of each of these factors and how they have influenced the modelling results, producing in an improved estimate of constituent loads from MW.

Hydrology

The extended climate and model simulation period increased the average annual flow by over 1 million ML from 5,103,000 ML/yr to 6,276,218 ML/yr, as four of the five additional years had above average flows, including the second wettest year on record (2010/2011) for the model run period. An expected implication of the increased average annual flow is an increase in average annual constituent loads, hence the average annual baseline loads in RC2014 are higher than previous Reef Report Cards.

Fine sediment and particulate nutrient generation

Hillslope erosion was the major contributor to fine sediment loads exported (hillslope 62%, streambank 36%, and gullies 2%) in RC2014. This is consistent with RC2013, where hillslope erosion was dominant (51%), followed by streambank erosion (46%) and gullies (3%). The changes to sediment sources in RC2014 are a function of several model changes including: using seasonal cover inputs, generated via the new algorithm that better converts cover to c-factor, which combined have reduced average cover by 10% and thus increase hillslope erosion; also, gullies were disabled in sugarcane and cropping FUs; an increase in sugarcane farmers in D class soil management from 5% in RC2013 to 19% in RC2014; finally, the increase in modelled flows, due to the additional five years of data, will naturally result in an increase in constituent loads.

Until recently there was a lack of empirical data for streambank erosion rates in the MW region. Alluvium (2014) were recently engaged by the MW NRM body to undertake a stream stability assessment in the Rocky Dam Creek catchment. Although the results of this weren't available until after the completion of the RC2014 MW model, this type of information is required to validate the streambank component of the MW model. It is likely that the streambank contribution is underestimated, and this will be investigated further in the next round of modelling.

Particulate nutrient loads were under-predicted in MW by up to 65% in early iterations of RC2014 (when compared with monitored data). Enrichment ratios were increased for grazing and sugarcane FUs in line with recent research from BU and WT basins (Burton et al. 2015). Adjusting these values only affects the hillslope load of particulate nutrients, and does not impact the gully or streambank load. Given that streambank sources are ~40% of the fine sediment supply in MW further investigation of the streambank parameterisation will be considered.

Sugarcane DIN and PSIIs

The delivery ratio for seepage DIN (DIN lost below the root zone but returned to the stream) was adjusted in consultation with the paddock trial authors (Rohde et al. 2008, Masters et al. 2013). A spatially variable approach was taken, and seepage was set to 20% for the Plane Creek Basin and 10% was used in other basins. In the MW model, 92% of DIN generated from sugarcane is transferred to deep drainage, though only 14% is returned to the stream via seepage. The remaining 8% is from surface runoff. Seepage delivery ratios in MW were adjusted to better match monitored instream loads in consultation with local experts (Rohde et al. 2008, Masters et al. 2013). Recent research from the Wet Tropics indicates that up to 90% of DIN losses from sugarcane is via deep drainage, or lost below the root zone (Armour, Nelson, et al. 2013). This important pathway was not modelled in previous Report Cards, and a DWC value was used. This component of the MW modelling requires further investigation, coupled with on-ground monitoring data.

In-stream decay of pesticides was disabled as PSII loads were initially low when compared to measured data. Deactivating in-stream decay and increasing the dissolved delivery ratio to 90% (from 50% in RC2013) resulted in a better representation of modelled versus measured data. PSII loads have been modelled using typical scenarios of herbicide application defined by local technical experts. Actual practices will vary between growers and between years. Differences in the products selected and the timing of application of these products relative to the following runoff event will affect the predicted load compared to the measured. These results are consistent across all the GBR models and pesticide application rates used in the paddock model runs will be reviewed for future Report Cards in consultation with local technical experts.

Progress towards targets

Progress towards the Reef Plan 2009 targets were small for the MW region in RC2014. This is due to the low level of investment in management changes for this report card and the new ABCD framework which is more conservative in terms of the management changes required to shift from one management class to the next. Minor investments were made to improve gully, grazing, streambank and sugarcane management practices. The modelling results suggest there was only a 0.1% reduction in average annual TSS for the MW region, which takes the MW cumulative reduction to 9% or 'moderate' progress. No other load reductions were reported as they were less than 0.1%. Particulate phosphorus and nitrogen progress remain at 'very good' and 'good' levels, while for DIN the cumulative reduction for RC2014 is 24% or 'moderate'. PSII TE reduction remains at 41%, which is the greatest reduction across the GBR to date.

Fitzroy

Overall, the results from RC2014 for the FZ region are an improved representation of constituent generation and runoff to the GBR compared to previous Report Cards. The major enhancements that have achieved this include: extended climate period for hydrology calibration and model run period, improved recalibration of hydrology, shifting from annual to seasonal cover for estimating hillslope erosion, a combination of improved gully map products for the FZ region, several changes to hillslope, gully and streambank parameters to affect fine sediment loads, and the availability of extra data against which to compare the model results.

Hydrology

The recalibration of the FZ region resulted in improved modelling of high flow events and improved volumetric differences between the model and monitored data. This has been achieved primarily through the recalibration of hydrology using the Sacramento rainfall-runoff model and to a lesser extent improved modelling of storages and environmental flows and updated extraction data.

The updated calibration has resulted in modelled flow improving from an average 18% under prediction in RC2013 to being within 1% of the gauged flow at the regional scale for RC2014. At a basin and sub-basin scale the modelled flow has improved similarly. For example, the difference between the model flow and observed flow at the Calliope River at Castlehope has improved from a 27% under prediction of the gauged flow to no difference and the Isaac River at Yatton has improved from an 11% under prediction to a 3% under prediction.

Fine sediment generation, sources and sinks

A large number of changes that affect the sediment budget were introduced for RC2014. These changes have improved the models predicted loads compared to the previous report cards. The sediment load is now within 5% of the GBRCLMP load estimates for the Fitzroy River at Rockhampton compared 35% over estimate for the previous report card.

The RC2014 modelling has improved the relative contribution from the different erosion. For example, tracing data for the FZ Basin suggests that 80% of sediment is derived from subsoil sources (Hughes et al. 2009). Wilkinson et al. (2012) found that in the neighbouring Burdekin Basin subsurface or channel erosion contributes 60–80% of fine sediment loads. The combined modelled export load from streambank and gully erosion, the dominant sources of subsurface erosion, is 73% for this report card compared to 65% for the previous report card. Changes to individual sediment models are discussed below.

Hillslope Model

The FZ region hillslope model was altered for this report card by applying a variable hillslope erosion delivery ratio. Due to the generally flat terrain and long hillslope lengths of dry-tropical catchments of the GBR, a delivery ratio of 5% is considered appropriate (Lu et al. 2003a; Rustomji et al. 2010) and was applied to the majority of the FZ Basin. The original 10% delivery ratio was retained for the coastal basins.

For steep nature conservation and forestry areas, a 2.5% delivery ratio was applied to reduce the high erosion rates that were being generated in these areas. During parameterisation, nature conservation and forestry areas were found to be generating much higher sediment loads from hillslope erosion than were expected. Many of these areas have very steep slopes, high rainfall, and contain large areas of rock outcrops and stony soils. McIsaac et al. (1987) and McCool et al. (1987) found that the RUSLE over predicts soil loss for steep slopes. Risse et al. (1993) found that RUSLE tended to over predict soil loss on plots with lower erosion rates and the RUSLE has a poorer predictive capability on rangeland settings compared to agricultural conditions. Lu et al. (2003) added to this by stating that erosion rates can be overestimated in steep arid tropical mountain ranges when using the RUSLE to estimate hillslope erosion. Studies of hillslope erosion in Queensland and northern NSW have consistently found that the RUSLE cover/soil loss relationship underestimates the effectiveness of cover (Freebairn et al. 1989, Rosewell 1990, Loch 2000, Silburn 2011) and the relative difference is large at higher covers. Use of alternative cover/soil loss relationships for hillslope erosion should be tested in future modelling. The delivery ratio of 2.5% was selected as it resulted in similar loads being generated for the conservation and forestry areas as surrounding land uses in the neighbouring catchments. Work has been initiated on quantifying the extent of rock outcrops and surface course fragments within GBR catchments and will be used in future models to modify K-factors in the RUSLE calculation of hillslope erosion. This will reduce the need to use artificially low delivery ratios in areas of steep slopes with large areas of rock outcrops.

Gully Model

The gully density layer used for this report card has changed significantly compared to the data used within the previous models. The hybrid layer, which is a combination of grid based gully erosion presence map (Darr et al., unpublished data) and modelled data (Trevithick et al. 2008), provided improved spatial resolution and accuracy and more significantly increased the range of density values that occurred across the FZ region. The previous NLWRA gully density mapping had a range of values from 0 to 3.1 km/km^2 with an average of 0.2 km/km^2. The new mapping used for this report card had a range from 0 to 8.4 km/km^2 with an average of 1.0 km/km^2.

The significant increase in gully density in the new layer required a reassessment of other parameters used in the gully model. A visual assessment using aerial photos was conducted to estimate gully widths, this assessment led to the average gully cross section being reduced from 10 m^2 to 5 m^2.

Overall, these changes resulted in a significant increase in the gully fine sediment load generated in the FZ region. The generated TSS load (as opposed to the contribution to export) from gully erosion more than doubled from the previous report (1,930 kt/y) to this report card (3,956 kt/y). For RC2014 gully erosion contributes 55% to the total generated TSS load. After travelling through the stream network and after floodplain and reservoir deposition and extractions have occurred, gully erosion contributed 33% of the exported TSS load.

Streambank Model

Loads generated from streambank erosion increased significantly due to changes to the hydrology models. The improved modelling of high flow events and increased flow volumes produced significantly larger fine sediment loads from streambank erosion. Streambank erosion for this report card almost doubled from the previous report card to 1,764 kt/yr.

The riparian vegetation layer used for this report card was changed after making a comparison against historical aerial photography. The layer used in the previous model (Qld 2009 Foliage Projective Cover (FPC)) and an alternative layer produced at a later date (Qld 2013 FPC) were compared against historical imagery over a range of dates from 1953 through to 2012. The 2009 FPC data was found to generally underrepresent the riparian vegetation and in some areas it significantly under represented it, while the 2013 FPC layer on average slightly over represented the riparian vegetation. The difference between the two layers is highlighted by comparing their cover within the 100 m stream buffer used by the stream bank erosion model to represent riparian vegetation. The 2009 FPC data had a mean cover of 41% while the 2013 FPC data had a mean cover of 70%. Overall the 2013 FPC data provided a better estimate of riparian vegetation based on the assessment of aerial photography at the sites sampled and was used to represent riparian vegetation for RC2014. The change in riparian vegetation layer reduced the overall sediment generated from streambank erosion for RC2014, offsetting some of the increase cause by higher flows.

The proportion of sediment deposited on the floodplain increased from 36% of the generated load for the previous report card to 40% for RC2014. Overall the changes to the model increased the streambank erosion contribution to the total generated load from 20% for the previous report card to 24% for this report card. Streambank erosion contributes 40% of the total exported TSS load to the Reef.

A large portion of the streambank fencing that occurred in the GBR happened in the FZ region. However this investment did not generate a significant reduction in loads. A large portion of the fencing occurred in areas within the model that had significant riparian cover, in many cases the cover was greater than 90%. This high riparian vegetation cover limited the improvement that the investments could achieve within the model.

Storage Trapping Model

The application of the storage trapping model (Lewis et al. 2013) to a larger number of storages in the RC2014 model, combined with increased sediment supply from hillslope erosion, increased storage deposition significantly. Overall there was almost a fourfold increase in sediment deposition to 1,083 kt/yr. Particulate nitrogen and phosphorus recorded larger increases in reservoir deposition with both recording 16 times more deposition for this report card. While there are no data in the FZ to validate the storage sediment trapping calculations, data from the Burdekin falls dam (Lewis et al. 2013) suggest that trapping efficiencies are of the correct order.

Other land uses: Event Mean Concentration (EMC)/Dry Weather Concentration (DWC)

The changes to EMC/DWC values improved model predictions when compared to monitored data. Comparing modelled loads to the average annual GBRCLMP loads at Rockhampton the modelled load for DON is within 1% of the measured load, DIP is 4% above and DOP is 20% below. The EMC/DWC values for DIN were not adjusted and the model over predicts the GBRCLMP monitored loads by 60% and concentrations are over predicted by 30%. For the next report card consideration will be given to reducing the EMC/DWC values for DIN to improve the models prediction. The large increase in the tebuthiuron EMC/DWC values has greatly improved the modelled load compared to the GBRCLMP monitored data. For this report card the tebuthiuron modelled load is within 3% of the monitored load and mean concentration was within 3%.

Nutrients

The doubling of enrichment ratios for particulate nutrients resulted in improved prediction of loads. Previously particulate nutrient loads for N and P were significantly under-estimated by the model. The increases in particulate nutrients loads for this report card have resulted in particulate nitrogen being underestimated by 20% when compared to the eight years of GBRCLMP monitored loads at Rockhampton and the particulate phosphorus load being underestimated by 5%.

Progress towards targets

Limited progress was made towards targets in RC2014 compared to past improvements. Small reductions occurred for TSS (~0.3%), PN (~0.2%) PP (~0.2%) and PSII toxic load (~0.15%). This is due to the low level of investment in management changes for this report card and the new ABCD framework which is more conservative in terms of the management changes required to shift from one management class to the next. Changes in loads are of a similar magnitude to the areas of reported improvements in management practice. The area managed under A and B class practices for hillslope erosion increased by 0.67% and the area managed under A and B class practices for gully and streambank had smaller increases of 0.12% and 0.14% respectively. For streambank fencing investments (as discussed above), many occur where riparian cover is already high and do not contribute to a modelled water quality improvements, although they may be useful in preventing degradation of riparian land currently in good condition.

Burnett Mary

Overall, the results from RC2014 for the BM region are an improved representation of constituent generation and runoff to the GBR compared to previous Report Cards. The major enhancements that have achieved this include: extended climate period for hydrology calibration and model run period, improved recalibration of hydrology, shifting from annual to seasonal cover for estimating hillslope erosion, several changes to hillslope, gully and streambank parameters to affect fine sediment loads, and the availability of extra data against which to compare the model results.

Hydrology

An improved spatial and temporal representation of hydrology has been a critical enhancement of the catchment modelling undertaken. In the BM region the updated hydrology model calibration produced improved agreement with gauged flow data compared to RC2013. Out of the 29 gauges used in the hydrology calibration for the region, 60% met the daily Nash-Sutcliffe criterion (>0.75) compared to none in RC2013, 100% met the total volume error criterion (PBIAS ± 20%) compared to 86% in RC2013.

Baseflow indices (BFI, the ratio of annual baseflow in a river to the total annual flow) for the modelled hydrology for each subcatchment/FU intersection were calculated. Fifty percent of subcatchment/FU intersections had BFI values greater than 43%, and 25% of had BFI values greater than 75%. So, when considering re-calibration of the Sacramento model, it may be more appropriate to constrain BFI values at the subcatchment/FU intersection level as models are assigned at this level. The implication of overestimated BFI values by the model is that the contribution of the baseflow and DWC to constituent loads will be correspondingly overestimated. This will be addressed in the modelling for RC2015.

The accuracy of the SILO rainfall grid is generally expected to be lower in areas where there is a low density of rainfall gauges (Zhang and Chiew 2009) relative to the climate gradients (Chiew et al. 2008). The SILO climate database is continually expanding and updated through time. With this in mind, the most up-to-date SILO data available at the time of building this model have been used, and this is expected to have contributed to the improvement in the hydrology model results presented here

Constituent Loads

The major change in RC2014 compared to previous report cards is the inclusion of the two extreme flood events in 2010/11 and 2012/13 which, according to both the model results and load estimates from monitoring, accounted for over 92% of TSS, PN and PP loads for the 2006-2014 period. Therefore, differences between RC2014 modelling results and previous report cards are mainly due to the inclusion of these two extreme flood events in RC2014 modelling period.

Anthropogenic baseline loads

The Mary and Burnett basins are the dominant contributors of anthropogenic baseline TSS export loads in the BM region while the Mary and the Burrum basins are dominant sources of DIN anthropogenic baseline load. The anthropogenic baseline exports for DIN and PSII inhibiting herbicides are associated with the prevalence of sugarcane land use in each catchment in the region.

TSS export has increased 1.7 fold in the Kolan Basin to 3.6 fold in the Mary Basin with an overall 2.6 fold increase for the Burnett Mary region compared with predevelopment land use. These increases in loads from predevelopment are less than those in the previous report card, because the two extreme flood years in 2010/11 and 2012/13 which dominated sediment export in RC2014 were not included in the previous report card modelling.

Constituent generation and export

Despite being the third largest GBR regional area (13%), the BM region contributes a relatively small amount of the total constituent load to the GBR lagoon, with approximately 11, 10 and 3% of the TSS, DIN and PSII baseline load export and 7% of the end of system flow to the GBR lagoon. The relatively low contributions in TSS, TP, PP, TN, and PN export are attributed to the lesser extreme rainfall in the region (when compared to the other GBR NRM regions), generally higher cover, and constituent trapping in the 11 storages included in the BM model compared to the other five regions. The model estimated over 42% of trapping of TSS and particulate nutrients by storages in RC2013 and just over 26% in RC2014. The reduction in modelled trapping efficiency in RC2014 is attributed to the inclusion of the two extreme flood years of 2010/11 and 2012/13 in the modelling period, which would have resulted in substantial flow through the dams and weirs during the floods reducing trapping efficiency. Future verification and investigation of the trapping efficiency algorithm will be undertaken.

The modelled TSS load exported from the region to the coast is 39% hillslope erosion, 15% gully, with the largest contribution of 46% coming from streambank erosion. This is reasonably similar to results from RC2013 where contributions to TSS export were 36%, 9% and 56% from hillslope, gully and streambank erosion, respectively but in contrast to model outputs from Fentie *et al*. (2006) where hillslope was the major contributor to exported TSS (55%), gullies 20%, with streambank erosion 27%. Changes since the Fentie, Esslemont, et al. (2006) modelling are in part related to improvements such as gully mapping. Nevertheless, in both RC2013 and RC2014 the Mary catchment had the greatest contribution of streambank erosion from the region, and this was the case from earlier modelling undertaken by DeRose et al. (2002) and the National Land and Water Audit (NLWRA,2001). Whilst there is a general lack of measured data to evaluate the extent and severity of streambank erosion in the GBR as whole (Bartley et al. 2015), there is evidence that streambank erosion is a very important issue in the region (Simon, 2014 and Department of Natural Resources and Mines, 2015).The Mary catchment accounts for more than 53, 44 and 20%, respectively, of the TSS, DIN and PSII export loads. Most of the TSS from the Mary catchment is sourced from streambank erosion, which is the dominant source of sediment in this catchment accounting for 55% of the sediment export from the catchment itself and 22% of the regional TSS export. Within the BM region, the Mary catchment is the greatest contributor to export of all constituents (except TSS and PSII herbicides for which the Burnett Basin contributes slightly higher) due mainly to the high rate of streambank erosion in this catchment. A project is currently underway to improve mapping of streambank erosion in the Mary Basin (P. Binns, DNRM, pers. Comm.). The presence of fewer and smaller water storages in the Mary catchment (three out of

11 storages that trap TSS and particulate nutrients) can explain the large contribution of TSS export from this basin.

In RC2013, the Burnett Basin, which is the largest basin in the BM region, generated almost 51% of the regional TSS to the stream network, with just 4% exported from the region compared to 53% and 43% of the TSS supply and export, respectively, in RC2014. The relatively small TSS per cent contribution to export from the Burnett Basin in RC2013 is a result of the high sediment trapping efficiency of six of the 11 sediment water storages in the lower reaches of the catchment, particularly the Burnett River Dam, and losses associated with water extractions. In contrast, RC2014 included the two extreme flood years of 2010/11 and 2012/13 when storage trapping was less effective. In terms of the overall constituent budget, it is worth noting that sediment deposition in storages is the major sink of TSS within the region. The very high trapping efficiency of most of the storages included in the model in part explains the relatively small contribution to TSS export from the Burnett catchment to the GBR lagoon. Losses associated with water extraction account for almost all the sink budget of dissolved constituents as zero decay and no storage deposition of dissolved constituents are assumed in the current modelling.

Contribution by source

Streambank erosion and hillslope erosion from grazing contributed 62% and 19%, respectively, of the anthropogenic TSS export from the region. Therefore, on ground management intervention to reduce export of TSS to the GBR lagoon should target these sources. The dominance of streambank erosion as a source of TSS export is a consequence of relatively high channel capacity and stream power, as a result of large historical channel incision and widening coupled with localised clearing of riparian vegetation. The constituent budget presented in Table 63 shows that for the BM region as a whole, hillslope erosion contributes 38% of total supply and 20% of the TSS export. Gully erosion contributes 20% of supply and 7% of the TSS export. Streambank erosion contributes 42% of supply and 23% of the TSS export. Given two processes that supply similar amounts of TSS, it is the process that exports high proportion (i.e. have the highest delivery) of TSS that should be targeted for maximum reduction in TSS export to the reef lagoon. These percentage differences in supply and export contributions by a particular process is attributed to the extent and location of losses and sinks in relation to the location of TSS generation from the process of concern. In terms of sediment budget by basin, the Burnett and Mary Basins have a similar breakdown of sediment sources, with streambanks contributing 22% of the exported loads for both basins, while the Burnett Basin had a slightly higher gully contribution (9% to 2%, and the Mary Basin a higher hillslope contribution 16% to 12%).

The constituent budget also shows that 26% of the TSS supplied to the stream network is trapped in storages and 13% is taken out of the stream network through water extractions for different uses. Given the significance of these terms in the constituent budget, it is important that these losses are verified by future monitoring data which has been lacking to date in the region.

Sugarcane land use followed by streambank erosion and urban land use in the Mary contribute most of the TN export. Grazing and streambank erosion contribute 48% and 22% of the PP and 47% and 24% of the PN export from the Burnett Mary region, respectively. Sugarcane and grazing contributed 59% (with 15% from Burnett, 16% from Burrum and 17% from Mary) and 22% of the DIN export from the region, respectively.

Most of the DIN export is associated with fertiliser losses in sugarcane growing areas. Adoption of improved nutrient management practice is expected to result in major contribution to reduction in DIN export. Similarly, most of the PSII export is due to the application of these chemicals to control weeds in sugarcane farms. The sugarcane industry in the Burrum and Mary basins contributes most of the PSII export. Therefore, management actions to reduce PSII export from this region should focus on the sugarcane industry in those basins. All of the PSII inhibiting herbicides export is from the sugarcane land use. Therefore, management actions to reduce export of PSII inhibiting herbicides from the region should target sugarcane management.

Progress towards targets

There has been little progress towards meeting the reef targets in RC2014 compared to previous report cards. This is due to the very low level of investment in management changes for this report card and the new ABCD framework which is more conservative in terms of the management changes required to shift from one management class to the next. Percentage load reductions of all constituents from the BM region are less than 0.5% for this report card. Since most sugarcane farms are in close proximity to the coast, DIN and PSII export and reductions due to management interventions are greater than TSS and particulate nutrients which are predominantly trapped upstream of cane growing areas in storages. Mary and Kolan were the only basins where there were some DIN load reductions as management interventions were limited to these areas for this report card. There was only a 0.14% shift in area to B practice from C-B, C and D-C nutrient management practices.

The less than 0.1% TSS export reduction from the BM compared is less than 1% from the GBR as a whole. There has also been a low reduction in DIN export of about 0.5% from the BM compared to 1% from the GBR as a whole. The story is similar for PSII herbicides with a reduction of less than 0.1% from the BM region compared to 1% from the GBR as a whole.

Continual improvement is an important aspect of numerical modelling to simulate catchment systems. A number of improvements are planned for future GBR Source Catchment models. The two priority areas for further model development are improving the model hydrology (to better match modelled and monitored baseflow proportions) and better representation of sediment sources that is, determination of hillslope, streambank and gully supply. In addition, more spatially explicit management practice change data is critical to potentially improve the relative change in exported constituent loads from the regional basins.

In summary, the inclusion of the two flood years of 2010/11 and 2012/13 in the modelling period for RC2014 is the main reason for the increase in constituent loads from all scenarios modelled for this Report Card. The low level of investment in management changes resulted in small load reductions across all constituents in RC2014.

Conclusion

The catchment scale water quality modelling described in this report is one of multiple lines of evidence used to report on progress towards Reef Plan 2013 targets. Investments in improved land management practices between 2008 and 2014 have resulted in an estimated fine sediment load reduction of 12%. Particulate nitrogen and phosphorus estimated loads have declined by 11.5% and 14.5% respectively. Progress towards meeting the 50% DIN target by 2018 has been poor, with an estimated 17% reduction reported to date. Pesticide PSII toxic equivalent load, however, is over halfway to its 60% reduction target, with an estimated 30.5% reduction reported.

The baseline loads presented in this report are typically higher than for previous Source Catchments sediment and nutrient loads. The reasons for the higher loads are: updated hydrology, extended model run period to 2014 which captures two very wet years, thus the average annual load has increased because the loads reported from these two years were very high; and methodological changes such as improved cover representation and frequency of cover imagery. The extended model run period allows for the inclusion of additional monitored data against which to validate the model. In data poor areas, such as Cape York, this is a major improvement. The model development process occurs on a five-year cycle, and it is likely that modelled outputs from all regions will change due to monitoring and modelling feedback, and model improvements. For example, land use datasets are updated, superior input datasets are developed such as gully mapping in all regions, and our understanding of the processes improves.

Overall, the catchment scale water quality modelling has been successful, and the aim of reporting towards Reef Plan 2013 targets had been achieved. The results show that while progress is being made towards meeting the sediment, nutrient and pesticide targets, further work still needs to occur to ensure the targets are reached by 2018.

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Appendix 1 – Hydrology calibration parameters and results

The simulated daily flows with the optimised parameters for each gauging station were compared with the observed flows statistically to assess the calibration results. The statistics that were analysed included the coefficient of determination of linear regression (R^2) and the Nash-Sutcliffe coefficient of efficiency (NSE) for daily flow volumes. The R^2 value describes the proportion of the variance of the observed flow by the simulations. The NSE indicates how well the simulated flow versus the observed against a 1:1 line. The Percent Bias which is calculated as the percentage difference between the predicted and observed flow for the total observed flow volume was used to assess the accuracy of simulations for total and high flow volume. The model performance was assessed against observed flow data using the following criteria:

- The coefficient of determination of linear regression (R^2) for daily flow >0.5
- Daily Nash Sutcliffe Coefficient of Efficiency (NSE) >0.5
- Percent Bias (Percentage Volume Difference) for total flow volume and for high-range (0-10% percentile) flow volume within ± 20%

Table 67 Hydrological parameters of the 'Sacramento Lag Unit Hydrograph' model and 'Storage Routing with Length Modifier'

Parameter	Description	PEST Range	Initial Value
UZTWM	Upper Zone Tension Water Storage Maximum (mm)	12 – 180	97.7
UZFWM	Upper Zone Free Water Storage Maximum (mm)	5 – 155	68.2
UZK	Upper Zone Lateral Drainage Rate	0.1 – 1.0	0.9
ZPERC	The potential increase in percolation from saturated to dry conditions	1.0 – 600	76.8
REXP	Exponent in Percolation Relationship	1.0 – 6.0	1.96
PCTIM	Permanently impervious fraction of the basin	1.0E-5 – 0.11	0.10257
SARVA	Fraction of the basin covered by streams, lakes, and riparian vegetation	1.0E-5 – 0.11	0.10965
SSOUT	Subsurface outflow along the channel (mm/day)	1.0E-5 – 0.11	0.0454
ADIMP	Fraction of the basin becomes impervious as all tension water are met	1.0E-5 – 0.15	0.14787
PFREE	Proportion of percolated water directly enters Free Water Storage	1.0E-2 – 0.5	0.17221
LZTWM	Lower Zone Tension Water Storage Maximum (mm)	1.0E-10 – 600	269.71
L_RAT	Ratio of LZTWM for non-forest land use to the forest	1.0E-2 – 0.95	0.48
LZFSM	Lower Zone Free Water Supplementary Storage Maximum (mm)	1.0 – 350	19.20
LZFPM	Lower Zone Free Water Primary Storage Maximum (mm)	1.0 – 300	16.69
LZSK	Lower Zone Supplementary Drainage Rate	1.0E-3 – 0.9	0.6421
LZPK	Lower Zone Primary Drainage Rate	1.0E-3 – 0.6	0.5167
RSERV	Proportion of lower zone free water that directly enters Free Water Storage	0.3 – 0.3	0.3
SIDE	Ratio of non-channel subsurface outflow to channel base flow	1.0E-5 – 0.1	0.0582
LAUH	Index for modifying hydrograph unit parameters	1.0E-10 – 4.0	0.1
ROPW	Routing parameter power	0.6 – 1.0	0.6
RECO	Regional constant calculated from reach length	1.0E-15 – 1.0E+6	1.0

Cape York

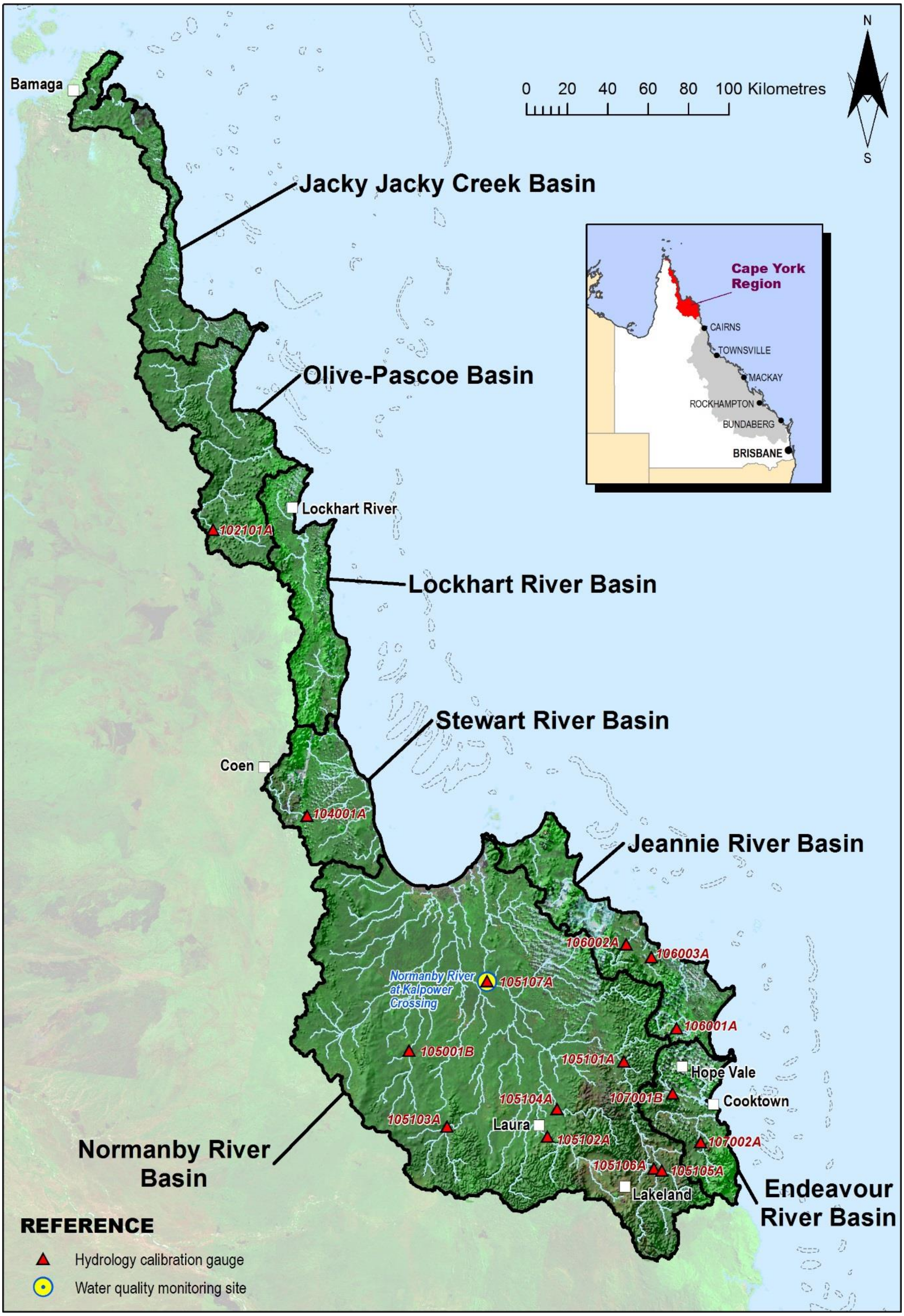

Figure 49 CY gauging stations used in hydrology calibration and for water quality monitoring

Table 68 Cape York hydrology calibration performance results (1970-2014)

Gauge	Gauge name	Catchment area (km^2)	Years of record^	R^2	NSE	Total flow volume p-bias (%)	High flow volume p-bias (%)
102102A	Pascoe R. at Garraway Creek	1,313	44	0.81	0.64	-5.4	-7.5
104001A	Stewart R. at Telegraph Road	470	44	0.75	0.5	1.2	0.5
105001B	Hann R. at Sandy Creek	984	44	0.86	0.72	0.4	0.3
105101A	Normanby R. at Battle Camp	2,302	44	0.82	0.63	0.1	0.6
105102A	Laura R. at Coalseam Creek	1,316	44	0.72	0.46	0.6	0.6
105103A	Kennedy R. at Fairlight	1,083	18	0.72	0.47	-0.6	-0.9
105104A	Deighton R. at Deighton	590	18	0.82	0.64	-1.5	-2.0
105105A	East Normanby R. at Mulligan Highway	297	44	0.79	0.57	-0.5	-0.6
105106A	West Normanby R. at Sellheim	839	19	0.74	0.46	0.8	0.9
105107A	Normanby R. at Kalpowar Crossing	12,934	9	0.91	0.81	3.8	1.3
106001A	McIvor R. at Elderslie	175	18	0.66	0.34	3.2	2.0
106002A	Jeannie R. at Wakooka Road	323	18	0.71	0.42	4.2	3.4
106003A	Starcke R. at Causeway	192	18	0.69	0.38	4.3	3.5
107001B	Endeavour R. at Flaggy	337	44	0.71	0.41	1.2	0.5
107002A	Annan R. at Mt Simon	373	21	0.79	0.57	0.8	0.2

NSE (Nash Sutcliffe coefficient of Efficiency)
^ Years of record = number of years of flow data that was within the hydrology calibration period (1972–2014).
(EOS) end-of-system. It refers to the furthest downstream gauge on a stream or river

Table 69 Comparison of total volume differences for all calibration gauges between RC2013 and RC2014

Gauge	Basin	RC2013 total volume diff. (%)	RC2014 total volume diff. (%)
102102A	Pascoe	-13	-5.4
104001A	Stewart	-5.9	1.2
105001B	Normanby	-2.7	0.4
105101A	Normanby	5.9	0.1
105102A	Normanby	-2.7	0.6
105103A	Normanby	-7.8	-0.6
105104A	Normanby	-1.6	-1.5
105105A	Normanby	-0.1	-0.5
105106A	Normanby	8.3	0.8
105107A	Normanby	25.4	3.8
106001A	Jeannie	0.9	3.2
106002A	Jeannie	3.3	4.2
106003A	Jeannie	-5.7	4.3
107001B	Endeavour	-0.4	1.2
107002A	Endeavour	-17.6	0.8

Wet Tropics

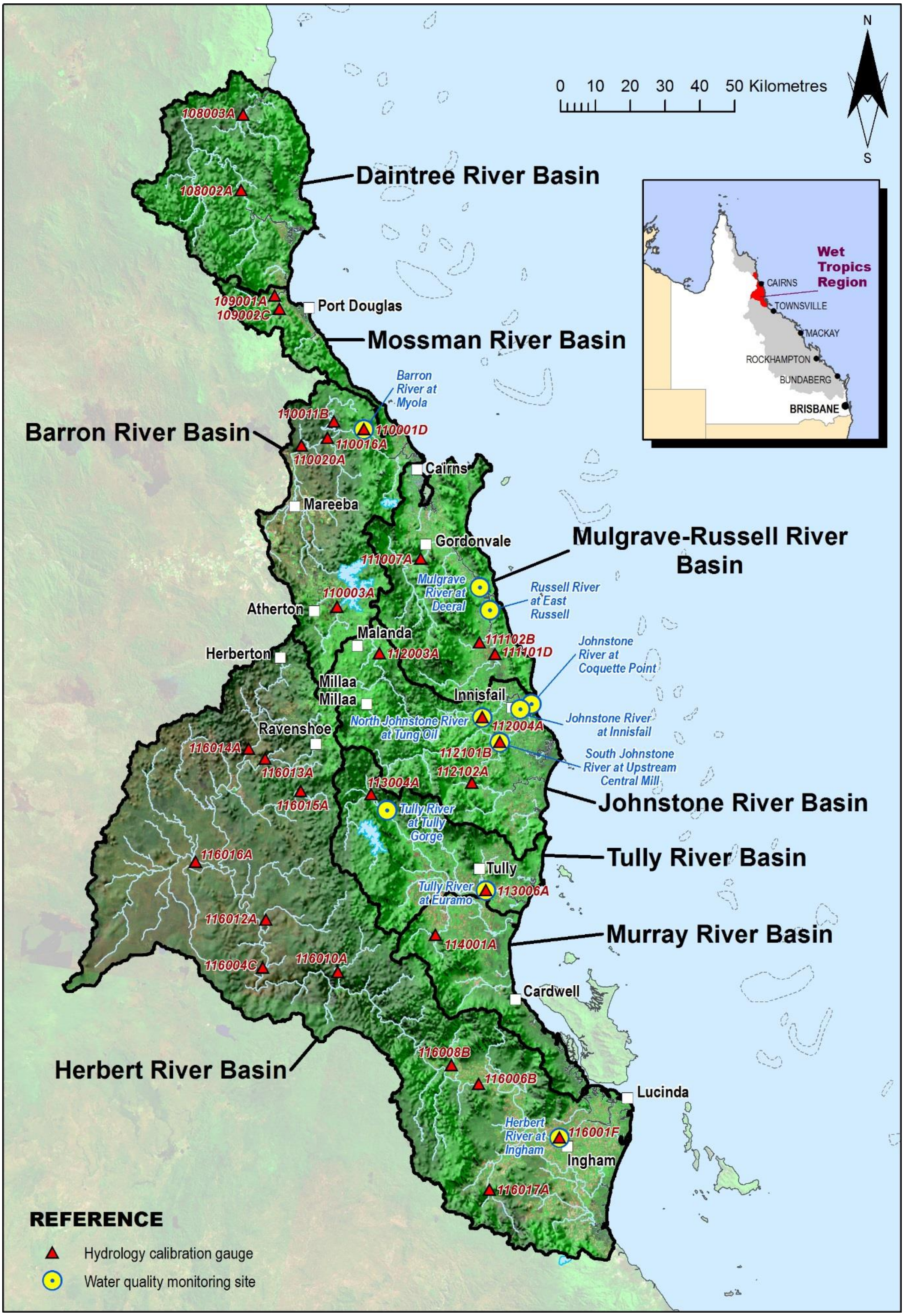

Figure 50 WT gauging stations used in hydrology calibration and for water quality monitoring

Table 70 Wet Tropics hydrology calibration results (1970-2014)

Gauge	Gauge name	Catchment area (km^2)	Years of record^	R^2	NSE	Total flow volume bias	High flow volume bias
108002A	Daintree River at Bairds (EOS)	911	42	0.85	0.71	0.0	-0.6
108003A#	Bloomfield River at China camp	264	42	0.86	0.73	0.0	-0.2
109001A#	Mossman River at Mossman (EOS)	106	41	0.85	0.62	-2.0	7.4
109002B-C#	South Mossman River at Loco Bridge	54	20	0.90	0.80	-7.3	-4.6
110001A-D	Barron River at Myola (EOS)	1,945	42	0.95	0.90	4.7	4.5
110003A	Barron River at Picnic Crossing	228	42	0.92	0.85	-0.1	-0.1
110011B	Flaggy Creek at Recorder	150	42	0.88	0.77	-3.0	-3.9
110016A	Barron River @ Koah	1,434	13	0.94	0.86	4.6	11.4
110020A	Barron River at Bilwon	1,258	22	0.92	0.85	0.0	-3.0
111007A	Mulgrave River at the Fisheries (EOS)	520	42	0.91	0.83	0.0	-0.8
111101A-D#	Russell River at Buckland's (EOS)	315	34	0.94	0.89	-2.5	-3.3
111102A-B#	Babinda Creek at Babinda	82	16	0.90	0.81	-6.2	-4.5
112001A*	North Johnstone River at Tung Oil (EOS)	936	42	0.75	0.52	0.5	1.1
112003A	North Johnstone River at Glen Allyn	165	42	0.96	0.92	-1.0	-1.7
112101A-B	South Johnstone River at Upstream Central Mill (EOS)	401	42	0.94	0.87	-0.1	-0.9
112102A	Liverpool Creek at Upper Japoonvale	78	42	0.90	0.81	0.7	1.2
113004A#	Cochable Creek at Powerline	95	42	0.88	0.76	0.0	0.4
113006A	Tully River at Euramo (EOS)	1,450	42	0.92	0.84	-4.5	-4.5
114001A	Murray River at Upper Murray (EOS)	156	42	0.87	0.75	-3.3	-6.0
116001A-D	Herbert River at Ingham (EOS)	8,581	42	0.94	0.87	-5.2	-7.3
116004A-C	Herbert River at Glen Eagle	5,236	42	0.92	0.85	3.3	-0.6
116006A	Herbert River at Abergowrie College	7,440	42	0.93	0.87	-0.1	-2.3
116008B#	Gowrie Creek at Abergowrie	124	42	0.78	0.61	-4.8	-6.9
116010A	Blencoe Creek at Blencoe Falls	226	42	0.88	0.77	-1.0	-2.1
116012A	Cameron Creek at 8.7 km	360	42	0.77	0.59	-7.7	-10.3
116013A	Milstream at Archer Creek	308	42	0.92	0.84	0.0	0.0

Gauge	Gauge name	Catchment area (km^2)	Years of record^	R^2	NSE	Total flow volume bias	High flow volume bias
116014A	Wild River at Silver Valley	591	42	0.90	0.80	1.7	1.3
116015A	Blunder Creek at Wooroora	127	42	0.85	0.70	-0.3	-0.1
116016A	Rudd Creek at Gunnawarra	1,450	42	0.88	0.75	-0.1	0.3
116017A	Stone Creek at Running Creek	157	42	0.89	0.79	0.1	0.4

NSE (Nash Sutcliffe coefficient of Efficiency)
* The flow from 112004A was added onto flow from 112001A.
^ Years of record = number of years of flow data that was within the hydrology calibration period (1972–2014).
(EOS) end-of-system. It refers to the furthest downstream gauge on a stream or river
#rainfall data for the sub-catchment draining to the gauge were scaled

Burdekin

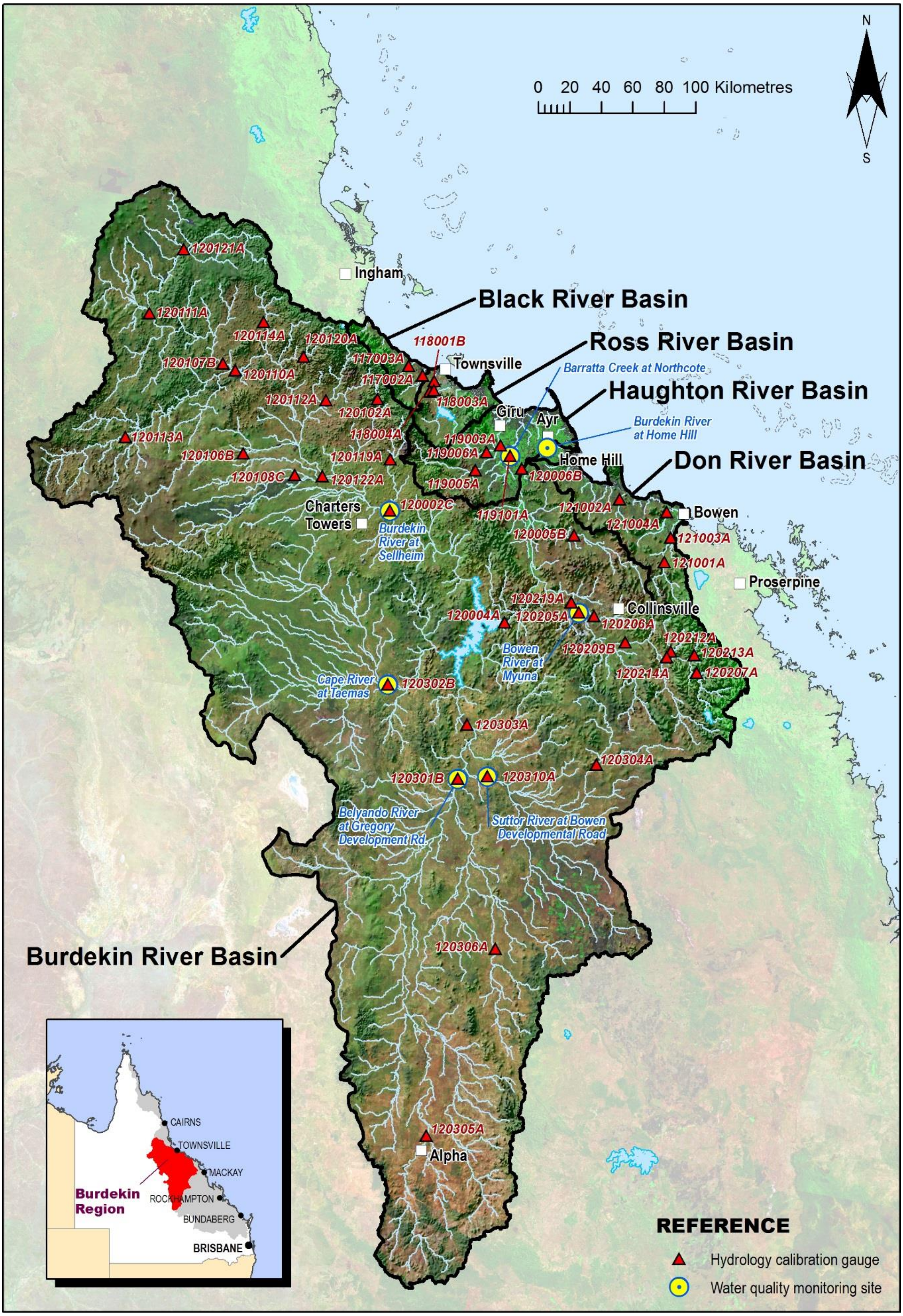

Figure 51 BU gauging stations used in hydrology calibration and for water quality monitoring

Table 71 BU hydrology calibration results (1970-2014)

Gauge	Gauge name	Catchment area (km^2)	Years of record	R^2	NSE	Total flow volume bias	High flow volume bias
117002A	Black River at Bruce Highway	256	41	0.85	0.7	1.3	1.2
117003A	Bluewater Creek at Bluewater	86	41	0.85	0.7	-3.3	-3.9
118001B	Bohle River at Mount Bohle	183	29	0.89	0.8	28.4	23.3
118003A	Bohle River at Hervey Range Road	143	29	0.89	0.8	-6.4	-7.6
118004A	Little Bohle River at Middle Bohle River junction.	54	24	0.88	0.8	-0.1	0.2
119003A	Haughton River at Powerline	1,773	42	0.86	0.7	0	1.1
119005A	Haughton River at Mount Piccaninny	1,133	42	0.9	0.8	0	-0.1
119006A	Major Creek at Damsite	468	36	0.79	0.6	-2.8	-3.3
119101A	Barratta Creek at Northcote	753	40	0.88	0.8	-0.1	0
121003A	Don River at Reeves	1,016	30	0.89	0.8	0.1	0.1
121001A	Don River at Ida Creek	604	42	0.74	0.5	-1.1	-0.9
121004A	Euri Creek at Koonandah	429	16	0.82	0.7	-7.5	-7.6
121002A	Elliot River at Guthalungra	273	41	0.86	0.7	-4.8	-4.8
120002C	Burdekin River at Sellheim	36,260	42	0.96	0.9	0	-0.5
120122A	Burdekin River at Gainsford	26,316	10	0.95	0.9	1.8	0.6
120110A	Burdekin River at Mount Fullstop	17,299	42	0.96	0.9	0	0.6
120107B	Burdekin River at Blue Range	10,528	42	0.95	0.9	-0.1	-0.2
120111A	Burdekin River at Lucky Downs	6,277	17	0.78	0.5	-0.3	6.1
120121A	Burdekin River at Lake Lucy Dam Site	2,216	38	0.85	0.7	-4.3	-5.9
120113A	Clarke River at Wandovale	1,802	22	0.85	0.7	0.1	-0.4
120106B	Basalt River at Bluff Downs	1,301	42	0.83	0.7	0	0.4
120112A	Star River at Laroona	1,212	42	0.78	0.6	-6.8	-7.8
120118A	Burdekin River at Lake Lucy	1,087	17	0.92	0.8	0	-1
120108C	Fletcher Creek at Fletchervale	1,034	17	0.91	0.8	-2.9	-1.4
120114A	Douglas Creek at Kangaroo Hills	663	17	0.89	0.8	0.1	-0.3
120119A	Fanning River at Fanning River	498	19	0.64	0.4	-1.8	-2
120120A	Running River at Mt. Bradley	490	39	0.85	0.7	-0.6	-0.8
120102A	Keelbottom Creek at Keelbottom	193	42	0.8	0.7	-3.8	-5.1

Gauge	Gauge name	Catchment area (km²)	Years of record	R^2	NSE	Total flow volume bias	High flow volume bias
120302B	Cape River at Taemas	16,074	42	0.93	0.9	0	0.1
120303A	Suttor River at St Anns	50,291	42	0.88	0.8	3.2	0.7
120301B	Belyando River at Gregory Development Rd.	35,411	38	0.82	0.7	-3.6	-4.8
120305A	Native Companion Creek at Violet Grove	4,065	42	0.93	0.9	0	0
120306A	Mistake Creek at Charlton	2,583	22	0.79	0.6	-0.1	0
120310A	Suttor River at Bowen Developmental Road	10,758	8	0.85	0.7	0	0
120304A	Suttor River at Eaglefield	1,915	42	0.77	0.5	0	-0.1
120219A	Bowen River at Red Hill Creek	8,280	14	0.91	0.8	0	-1.1
120205A	Bowen River at Myuna	7,104	42	0.91	0.8	0	-0.1
120209A	Bowen River at Jacks Creek	4,305	42	0.89	0.8	0.2	1.5
120214A	Broken River at Mt. Sugarloaf	2,269	22	0.88	0.7	0.4	-0.7
120207A	Broken River at Urannah	1,103	42	0.83	0.6	5.4	7.2
120206A	Pelican Creek at Mt Jimmy	545	34	0.81	0.6	-0.1	-0.4
120212A	Emu Creek at The Saddle	431	17	0.69	0.4	-0.1	0.6
120213A	Grant Creek at Grass Humpy	325	17	0.72	0.5	0	0.8
120004A	Burdekin River at Burdekin Falls D/S	114,654	11	0.96	0.9	-2.8	-4.4
120005B	Bogie River at Strathbogie	1,031	23	0.88	0.8	-0.1	-0.6
120006B	Burdekin River at Clare	129,876	24	0.97	0.9	-0.6	-2.4

NSE (Nash Sutcliffe coefficient of Efficiency).
^ Years of record = approximate number of years of flow data that was within the hydrology calibration period (1970–2014).
(EOS) end-of-system. It refers to the furthest downstream gauge on a stream or river.

Mackay Whitsunday

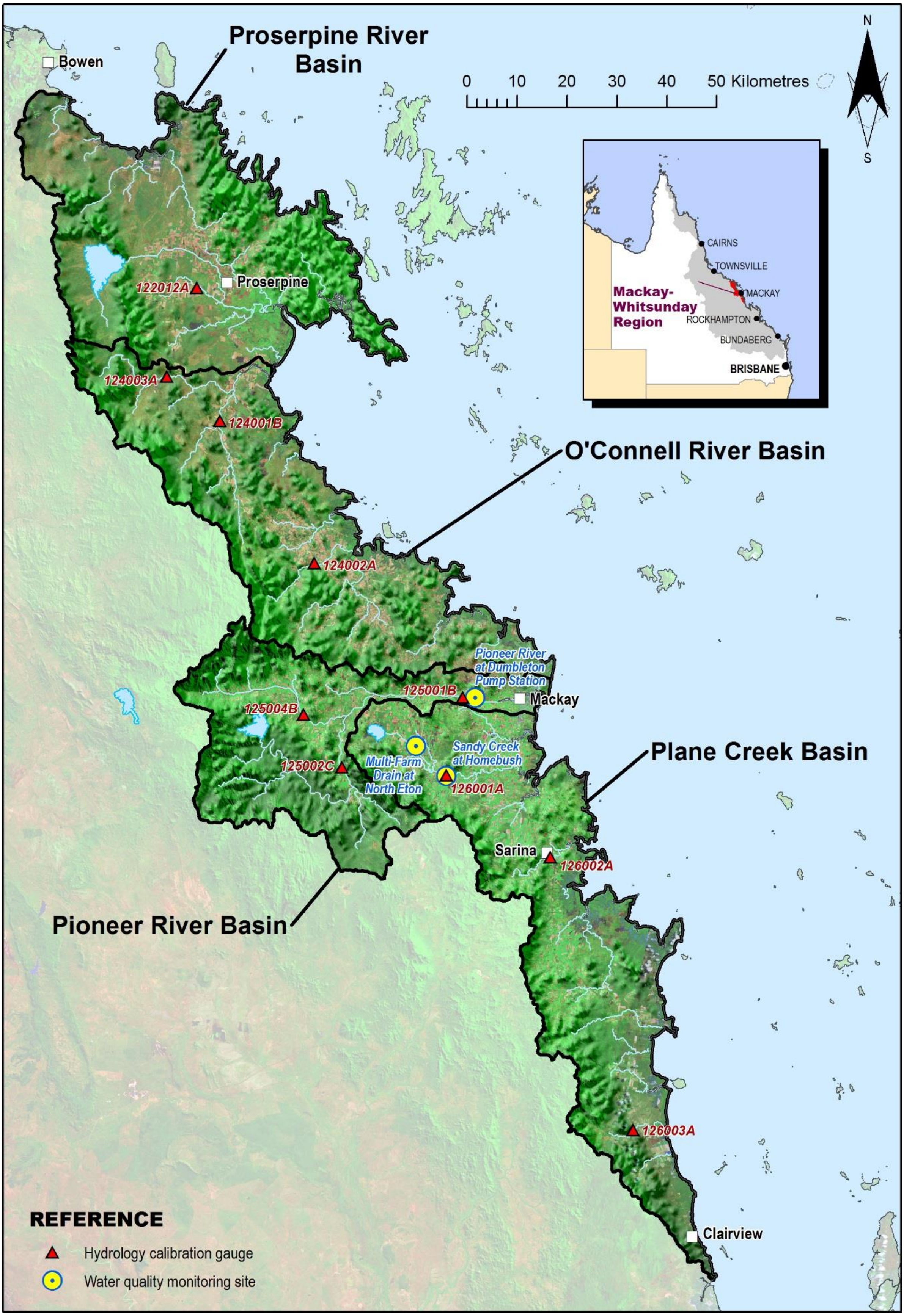

Figure 52 MW gauging stations used in hydrology calibration and for water quality monitoring

Table 72 Mackay Whitsunday hydrology calibration results (1970-2014)

Gauge	Gauge name	Catchment area (km^2)	Years of record^	R Squared	NSE	Total flow volume bias	High flow volume bias
122012A [C]	Lethe Brook at Hadlow Road	89	13	0.79	0.62	-23.3	-25
124001B	O'Connell River at Staffords Crossing	342	44	0.9	0.8	-1.9	-2.1
124002A	St.Helens Creek at Calen	118	41	0.92	0.85	-3	-4
124003A	Andromache River at Jochheims	230	38	0.91	0.82	-0.4	-0.5
125001B [C]	Pioneer River at Pleystowe Recorder	1434	12	0.94	0.88	-0.1	-0.4
125002C	Pioneer River at Sarichs	757	44	0.91	0.82	-1.5	-1.9
125004B	Cattle Creek at Gargett	326	44	0.94	0.89	-0.7	-0.9
126001A	Sandy Creek at Homebush (EOS)	326	44	0.92	0.84	-0.2	-0.2
126002A [C]	Plane Creek at Sarina	92	16	0.85	0.68	1	1.2
126003A	Carmila Creek at Carmila	84	41	0.79	0.62	-4.4	-4.7

NSE (Nash Sutcliffe coefficient of Efficiency).
[C] closed/historic gauging station.
^ Years of record = approximate number of years of flow data that was within the hydrology calibration period (1970–2014).
(EOS) end-of-system. It refers to the furthest downstream gauge on a stream or river.

Table 73 Comparison of total volume differences for all calibration gauges between RC2013 and the RC2014

Gauge	Basin	RC2013 total volume diff. (%)	RC2014 total volume diff. (%)
122012AC	O'Connell	-27	-23.3
124001B	O'Connell	3	-1.9
124002A	O'Connell	-5	-3
124003A	O'Connell	9	-0.4
125001BC	Pioneer	2	-0.1
125002C	Pioneer	3	-1.5
125004B	Pioneer	2	-0.7
126001A	Plane	2	-0.2
126002AC	Plane	2	1
126003A	Plane	2	-4.4

Fitzroy

Figure 53 FZ gauging stations used in hydrology calibration and for water quality monitoring

Table 74 FZ NRM region hydrology calibration results (1970-2014)

Gauge	Gauge name	Catchment area (km^2)	Years of record^	R Squared	NSE	Total flow volume bias	High flow volume bias
129001A	Waterpark Creek at Byfield	213	44	0.84	0.7	0	-0.9
130003B	Fitzroy River at Riverslea	131413	44	0.89	0.75	-1	-0.3
130004A	Raglan Creek at Old Station	389	44	0.78	0.56	0	0.4
130005A	Fitzroy River at The Gap	135788	44	0.9	0.79	-0.7	-2.3
130008A	Neerkol Creek at Neerkol	505	25	0.91	0.82	-1.8	-2
130009A	Marlborough Creek at Slopeaway	679	16	0.95	0.9	-2	-2.9
130103A	Mackenzie River at Carnangarra	45367	29	0.91	0.78	6.6	8.7
130105A	Mackenzie River at Coolmaringa	76659	43	0.94	0.89	-6.1	-6.7
130106A	Mackenzie River at Bingegang	50851	43	0.89	0.79	0.2	1.2
130108B	Blackwater Creek at Curragh	776	37	0.82	0.64	-0.1	0.3
130109A	Mackenzie River at Tartrus Weir Headwater	75182	26	0.95	0.84	13.3	13.5
130206A	Theresa Creek at Gregory Highway	8485	44	0.9	0.81	-0.2	0.2
130208A	Theresa Creek at Ellendale	758	35	0.83	0.66	0.1	0.3
130209A	Nogoa River at Craigmore	13871	42	0.85	0.71	0.7	-2.7
130210A	Theresa Creek at Valeria	4421	43	0.76	0.47	-0.3	-1.7
130219A	Nogoa River at Duck Ponds	27146	21	0.92	0.85	-1.8	-2.7
130302A	Dawson River at Taroom	15847	44	0.86	0.74	-0.1	-0.3
130305A	Dawson River at Theodore	27332	32	0.81	0.52	1.4	5.3
130306B	Don River at Rannes Recorder	6806	44	0.96	0.93	-1.5	-1.6
130313A	Palm Tree Creek at La Palma	2660	44	0.78	0.56	0	-0.5
130315C	Callide Creek at Stepanoffs	547	32	0.84	0.68	0	-1.8
130316A	Mimosa Creek at Redcliffe	2487	44	0.81	0.63	-0.2	-0.7
130317B	Dawson River at Woodleigh	28503	44	0.91	0.79	2	2.1
130322A	Dawson River at Beckers	40501	44	0.93	0.85	0	0
130324A	Dawson River at Utopia Downs	6039	44	0.76	0.51	-0.2	-0.8
130327A	Callide Creek at Goovigen	4468	43	0.91	0.75	0.1	0.3
130344A	Juandah Creek at Windamere	1679	40	0.82	0.65	0	0.1
130349A	Don River at Kingsborough	594	38	0.85	0.69	0	1.2
130401A	Isaac River at Yatton	19736	44	0.93	0.87	2.4	2.7

Gauge	Gauge name	Catchment area (km^2)	Years of record^	R Squared	NSE	Total flow volume bias	High flow volume bias
130403A	Connors River at Mount Bridget	1292	44	0.83	0.68	-5.3	-5.8
130404A	Connors River at Pink Lagoon	8741	44	0.95	0.9	0.2	-1.5
130406A	Funnel Creek at Main Road	1065	44	0.92	0.84	0.1	0.4
130407A	Nebo Creek at Nebo	257	44	0.88	0.78	0	-0.1
130410A	Isaac River at Deverill	4091	44	0.88	0.75	-4.2	-3.6
130413A	Denison Creek at Braeside	757	43	0.88	0.77	-0.3	-0.3
130414A	Isaac River at Goonyella	1213	31	0.71	0.41	-0.1	-0.6
130504B	Comet River at Comet Weir	16423	43	0.92	0.83	0.2	0.3
130506A	Comet River at The Lake	10188	42	0.94	0.88	-4.5	-3.9
130509A	Carnarvon Creek at Rewan	351	29	0.82	0.64	0	0.6
132001A	Calliope River at Castlehope	1288	44	0.91	0.83	0	0.1
132002A	Calliope River at Mount Alma	165	18	0.9	0.79	2.1	2.7
133001B	Boyne River at Riverbend	2258	18	0.77	0.59	-1.7	-3.9
133003A	Diglum Creek at Marlua	203	42	0.88	0.76	-0.1	0.3
133004A	Boyne River at Milton	1170	21	0.93	0.86	-0.8	-1.2

Burnett Mary

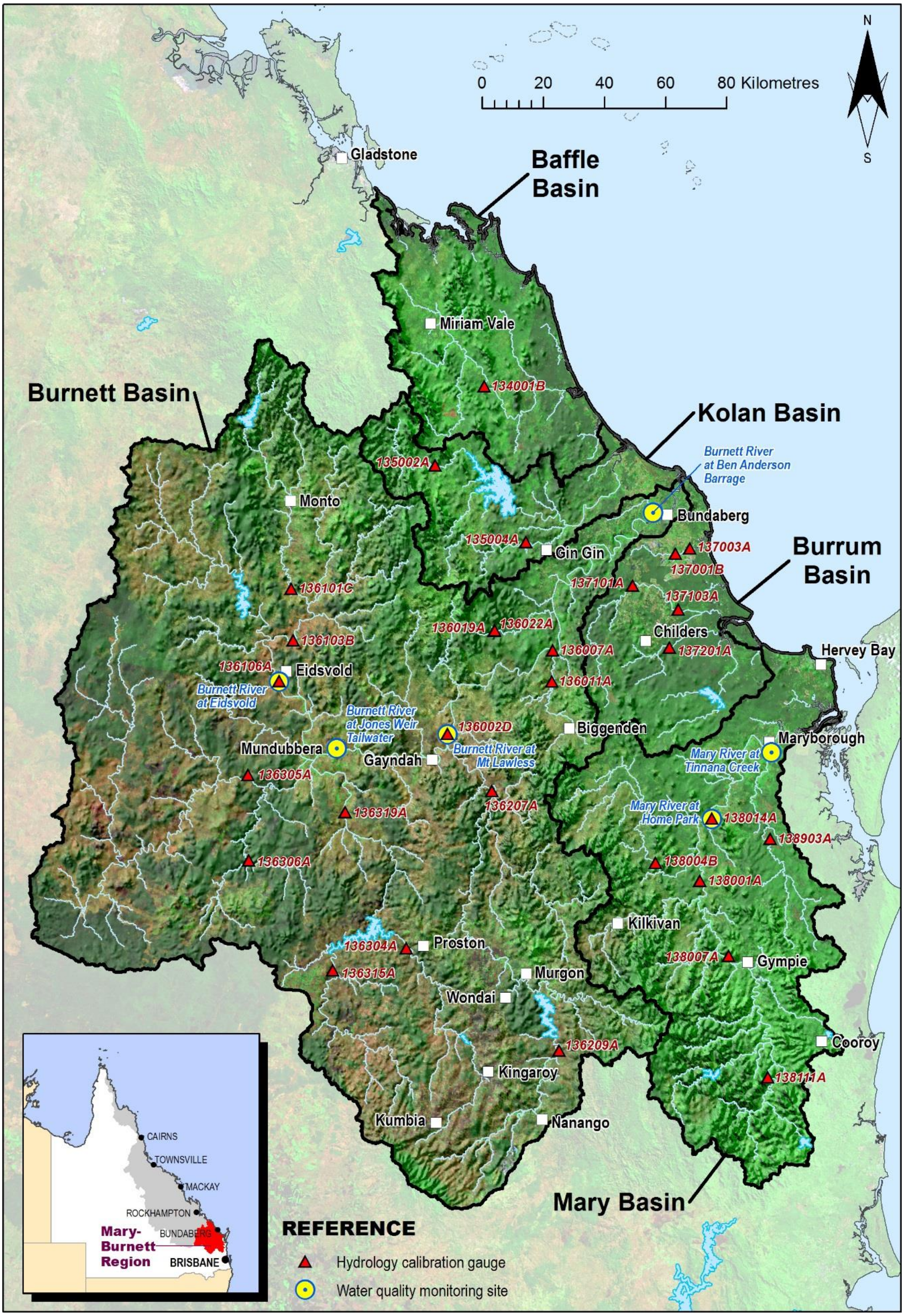

Figure 54 BM gauging stations used in hydrology calibration and for water quality monitoring

Table 75 Burnett Mary NRM region hydrology calibration results (1970-2014)

Gauge	Gauge name	Catchment area (km2)	Years of record^	R Squared	NSE.	Total flow Volume Bias	High Flow Volume Bias
134001B	Baffle Creek at Mimdale	1,401	46	0.917	0.833	0.00	-0.01
135002A	Kolan River at Springfield	548	49	0.915	0.834	-0.28	-0.31
135004A	Gin Gin Creek at Brushy Creek	537	49	0.856	0.732	-1.18	-1.39
136002D	Burnett River at Mount Lawless	2,130	39	0.901	0.81	-0.04	0.62
136007A	Burnett River at Figtree Creek	1,318	18	0.757	0.553	-0.04	-0.40
136011A	Degilbo Creek at Coringa	686	28	0.94	0.879	-0.02	0.36
136094A	Burnett River at Jones Weir Tailwater	2,817	33	0.96	0.92	0.06	-0.05
136101C	Three Moon Creek at Abercorn	1,537	50	0.894	0.79	-0.63	-9.35
136103B	Burnett River at Ceratodus	2,349	54	0.97	0.941	0.08	-2.85
136106A	Burnett River at Eidsvold	3,208	54	0.942	0.885	-2.35	1.24
136207A	Barambah Creek at Ban Ban	4,154	48	0.823	0.675	-0.02	-0.34
136209A	Barker Creek at Glenmore	1,366	27	0.878	0.728	4.50	2.34
136304A	Stuart River at Proston Rifle Range	1,555	49	0.751	0.516	-0.12	0.18
136305A	Auburn River at Dykehead	5,287	49	0.94	0.878	-0.04	0.15
136306A	Cadarga Creek at Brovinia Station	1,288	49	0.792	0.614	-0.29	0.05
136315A	Boyne River at Carters	1,619	35	0.926	0.855	-0.05	0.69
136319A	Boyne River at Cooranga	2,103	20	0.903	0.797	-4.04	-6.02
137003A	Elliott River at Dr Mays Crossing	25	41	0.767	0.537	1.36	5.62
137201A	Isis River at Bruce Highway	457	49	0.805	0.621	-0.03	0.62
138001A	Mary River at Miva	1,713	105	0.93	0.864	2.12	-0.24
138004B	Munna Creek at Marodian	1,190	40	0.83	0.686	-1.77	-2.27
138007A	Mary River at Fishermans Pocket	2,246	46	0.96	0.913	-0.28	2.36
138014A	Mary River at Home Park	897	32	0.91	0.825	-6.37	-6.06
138111A	Mary River at Moy Pocket	813	51	0.859	0.725	-0.17	0.00
138903A	Tinana Creek at Bauple East	756	33	0.944	0.892	-1.23	-1.59

NSE (Nash Sutcliffe coefficient of Efficiency)
^ Years of record = number of years of flow data that was within the hydrology calibration period (1972–2014).

Table 76 Comparison of total volume differences for all BM calibration gauges between RC2013 and the RC2014

Gauge	Basin	RC2013 total volume diff. (%)	RC2014 total volume diff. (%)
134001B	Baffle	-9.5	0.0
135002A	Kolan	2.4	-0.3
135004A	Kolan	-19.9	-1.2
136002D	Burnett	6.5	0.0
136007A	Burnett	3.1	0.0
136011A	Burnett	2.7	0.0
136094A	Burnett	26.3	0.1
136101C	Burnett	10.0	-0.6
136103B	Burnett	9.4	0.1
136106A	Burnett	-7.7	-2.4
136207A	Burnett	-34.7	0.0
136209A	Burnett	-1.2	4.5
136304A	Burnett	-9.0	-0.1
136305A	Burnett	11.8	0.0
136306A	Burnett	51.5	-0.3
136315A	Burnett	14.5	-0.1
136319A	Burnett	0.6	-4.0
137003A	Burrum	3.9	1.4
137201A	Burrum	-4.4	0.0
138001A	Mary	3.5	2.1
138004B	Mary	-9.9	-1.8
138007A	Mary	-3.4	-0.3
138010A	Mary	23.3	-6.4
138014A	Mary	1.0	-0.2
138903A	Mary	6.7	-1.2

Appendix 2 – Dynamic SedNet global parameters and global requirements

For the definition of parameters and the full equations for model components, please refer to: Ellis and Searle (2014), and the catchment modelling technical reports for Report Cards 2010 to Report Card 2013 (Dougall, Ellis, et al. 2014, Dougall, McCloskey, et al. 2014, Fentie et al. 2014, Hateley et al. 2014, McCloskey et al. 2014, Packett et al. 2014, Waters et al. 2014).

Spatial Projection

Spatial data was projected in the Australian Albers projection. This was modified from previous modelling where the DNRM Albers Equal-Area projection was used. The details of the Australian Albers projection are:

- Central Meridian: 132
- Standard Parallel 1: -18
- Standard Parallel 2: -36
- Latitude of Origin: 0

Grazing constituent generation

Table 77 Hillslope erosion parameters *where two values are supplied it indicates that these two values have been applied spatially in the model

Parameter	CY	WT	BU	MW	Fitzroy	BM
TSS delivery ratio	5	20/30*	5/10*	15	2.5/5/10*	20
Max. annual load (t/ha)*	50/25*	50	500	35	500	50
DWC (mg/L)	0	20	0	100	0	100

Table 78 Gully erosion parameters *where two values are supplied it indicates that these two values have been applied spatially in the model

Parameter	CY	WT	BU	MW	FZ	BM
Daily runoff power factor	1.4	1.4	1.4	1.4	1.4	1.4
Gully model type	DERM	DERM	DERM	DERM	DERM	DERM
TSS DR %	100	100	100/25	100	100	100
Gully cross-sectional area (m^2)	7.5	5	16/8*	5	5	10
Average gully activity factor	1	1	1	1	0.5	1
Management practice factor	Variable	Variable	Variable	Variable	Variable	Variable
Default gully start year	1870	1870	1870	1861	1870	1900
Gully full maturity year	2010	2014	2014	2010	2010	2007
Density raster year	2001	2001	2003	2001	2013	2003

Table 79 Particulate nutrient generation parameter values *where two values are supplied it indicates that these two values have been applied spatially in the model

Parameter	CY	WT	BU	MW	FZ	BM
PP/PN enrichment ratio	4/2.4	4/2	2/1.2	6/3.6	4/2.4	5/4
Hillslope DR %	5	20/30	20	20	20	20
Gully DR %	100	100	100/20*	100	100	100

Sugarcane and cropping constituent generation

Table 80 A summary of changes for the 2014 Report Card changes for cropping and sugarcane (**changes** from 2013 Report Card)

Change	CY	WT	BU	MW	Fitz	BM	Possible effect
Updated rainfall	To 2014	To 2014	To 2014	To 2014	To 2014	To 2014	
Dryland grains cropping - HowLeaky							
Area	20 km^2 (<1%)	142 km^2 (0.7%)	1336 km^2 (0.9%)	3 km^2 (<1)	7934 km^2 (5%)	820 km^2 (1.6%)	
Management Scenarios	No change	No change	Additional management scenarios modelled; from 4 (ABCD) to 15	No change	Additional management scenarios modelled; from 4 (ABCD) to 15	Additional management scenarios modelled; from 4 (ABCD) to 15	Incremental water quality improvements modelled as additional management scenarios were available
Pesticides	No change	No change	Additional pesticide products modelled, locally derived degradation parameters applied	No change	Additional pesticide products modelled, locally derived degradation parameters applied	Additional pesticide products modelled, locally derived degradation parameters applied	
Irrigated grains cropping - HowLeaky							
Area	31 km^2 (<1%)	8 km^2 (<0.05%)	70 km^2 (<0.0%)	<1 km^2 (<1%)	1213 km^2 (1%)	466 km^2 (0.9%)	
Management Scenarios (modelled exactly the same as non-irrigated)	No change	No change	Additional management scenarios modelled; from 4 (ABCD) to 15	No change	Additional management scenarios modelled; from 4 (ABCD) to 15	Additional management scenarios modelled; from 4 (ABCD) to 15	Incremental water quality improvements modelled as additional management scenarios were available
Bananas - HowLeaky							
Management Scenarios	New model implemented	New model implemented	---	---	---	---	Management effect possible in catchment model
Sugarcane - APSIM							
Management Scenarios	---	Additional management scenarios modelled; from 4 (ABCD) to 39	Additional management scenarios modelled; from 4 (ABCD) to 112	Additional management scenarios modelled; from 4 (ABCD) to 39	---	Additional management scenarios modelled; from 4 (ABCD) to 39	Incremental water quality improvements modelled as additional management

Change	CY	WT	BU	MW	Fitz	BM	Possible effect
							scenarios were available
Soil file params	---	Heavily revised, incl poorly drained soils	Heavily revised, incl poorly drained soils	Heavily revised, incl poorly drained soils	---	Heavily revised, incl poorly drained soils	
Irrigation modelling	---	No change	Revised to include A,B,C and D management	Additional irrigation in drier parts of MW	---	Irrigation rate change	Change in runoff, drainage, DIN
Recycling pits	---	No pits	Modelled, A, B, and C levels of management	No pits	---	Modelled one level of management	Reduction in total loads of all constituents
Pesticides	---	Additional pesticide products modelled, locally derived degradation parameters applied	Additional pesticide products modelled, locally derived degradation parameters applied	Additional pesticide products modelled, locally derived degradation parameters applied	---	Additional pesticide products modelled, locally derived degradation parameters applied	
Nitrogen	---	Changed DIN runoff model, applications timed according to coming rainfall and management	Changed DIN runoff model, applications timed according to coming rainfall and management	Changed DIN runoff model, applications timed according to coming rainfall and management	---	Changed DIN runoff model, applications timed according to coming rainfall and management	Overall reduction in DIN lost to runoff

Other land uses (EMC/DWC values)

Although not all FUs have an EMC/DWC model applied, there are some constituents that use this approach, as well as those FUs that have an EMC/DWC model applied for all constituents (commonly, urban, other, and horticulture with some exceptions). During the development of the appropriate EMC/DWC values all land uses were considered and a concentration value determined. This was important for the predevelopment model as nature conservation values were applied to all FUs, excluding those where the RUSLE approach was taken in the baseline model, and maintained in the predevelopment model (commonly, open and closed grazing, forestry, and nature conservation areas with some exceptions).

Table 81 Event Mean Concentrations/Dry Weather Concentrations (mg/L) for Cape York

Functional unit	TSS EMC	TSS DWC	PN EMC	PN DWC	PP EMC	PP DWC	DIN EMC	DIN DWC	DON EMC	DON DWC	DOP EMC	DOP DWC	DIP EMC	DIP DWC
Nature conservation	USLE	0	USLE	0.040	USLE	0.005	0.032	0.016	0.35	0.175	0.010	0.005	0.005	0.0025
Forestry	USLE	0	USLE	0.075	USLE	0.0175	0.040	0.020	0.30	0.150	0.020	0.010	0.010	0.0050
Closed grazing	USLE	0	USLE	0.060	USLE	0.014	0.032	0.016	0.30	0.150	0.016	0.008	0.008	0.0040
Open grazing	USLE	0	USLE	0.075	USLE	0.0175	0.050	0.025	0.35	0.175	0.020	0.010	0.010	0.0050
Other	40	20	0.15	0.075	0.035	0.0175	0.040	0.020	0.30	0.150	0.020	0.010	0.010	0.0050
Urban	40	20	0.15	0.075	0.035	0.0175	0.040	0.020	0.30	0.150	0.020	0.010	0.010	0.0050
Horticulture	60	30	0.225	0.1125	0.53	0.02625	0.060	0.030	0.45	0.225	0.030	0.015	0.015	0.0075
Dryland cropping	HowLeaky	30	HowLeaky	0.1125	HowLeaky	0.000	0.060	0.030	0.45	0.225	HowLeaky	0.000	HowLeaky	0.0000
Irrigated cropping	HowLeaky	30	HowLeaky	0.1125	HowLeaky	0.000	0.060	0.030	0.45	0.225	HowLeaky	0.000	HowLeaky	0.0000
Banana	HowLeaky	30	HowLeaky	0.1125	HowLeaky	0.000	0.060	0.030	0.45	0.225	HowLeaky	0.000	HowLeaky	0.0000
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 82 Event Mean Concentrations/Dry Weather Concentrations (mg/L) for Wet Tropics

Functional unit	TSS EMC	TSS DWC	PN EMC	PN DWC	PP EMC	PP DWC	DIN EMC	DIN DWC	DON EMC	DON DWC	DOP EMC	DOP DWC	DIP EMC	DIP DWC
Nature conservation	30	15	0.17	0.03	0.02	0.01	0.16	0.08	0.12	0.06	0.01	0.01	0.01	0.00
Forestry	40	20	0.18	0.04	0.03	0.02	0.20	0.10	0.72	0.36	0.01	0.01	0.01	0.01
Closed grazing	USLE	20	USLE	0.48	USLE	0.02	0.16	0.08	0.30	0.15	0.02	0.01	0.02	0.01
Open grazing	USLE	20	USLE	0.48	USLE	0.02	0.16	0.08	0.30	0.15	0.02	0.01	0.02	0.01
Dairy	150	75	0.48	0.24	0.04	0.02	0.19	0.09	0.12	0.06	0.02	0.01	0.02	0.01
Other	105	35	0.48	0.24	0.04	0.02	0.76	0.38	0.27	0.14	0.01	0.01	0.04	0.02
Urban	105	35	0.48	0.24	0.04	0.02	0.76	0.38	0.27	0.14	0.01	0.01	0.04	0.02
Horticulture	120	60	0.50	0.25	0.10	0.05	0.41	0.21	0.21	0.11	0.03	0.02	0.05	0.02
Dryland cropping	HowLeaky	60	HowLeaky	0.25	HowLeaky	0.05	0.50	0.25	0.50	0.25	HowLeaky	0.01	HowLeaky	0.01
Irrigated cropping	HowLeaky	60	HowLeaky	0.25	HowLeaky	0.05	0.50	0.25	0.50	0.25	HowLeaky	0.01	HowLeaky	0.01
Banana	HowLeaky	60	HowLeaky	0.55	HowLeaky	0.05	HowLeaky	1.50	0.21	0.11	HowLeaky	0.02	HowLeaky	0.01
Sugarcane	APSIM	72	APSIM	0.30	APSIM	0.02	APSIM	0.00	0.50	0.30	APSIM	N/A	APSIM	N/A
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 83 Event Mean Concentrations/Dry Weather Concentrations (mg/L) for BU

FU	TSS EMC	TSS DWC	PN EMC	PN DWC	PP EMC	PP DWC	DIN EMC	DIN DWC	DON EMC	DON DWC	DOP EMC	DOP DWC	DIP EMC	DIP DWC
Nature Conservation	USLE	0	USLE	0	USLE	0	0.1	0.1	0.2	0.2	0.01	0.01	0.03	0.03
Forestry	USLE	0	USLE	0	USLE	0	0.1	0.1	0.2	0.2	0.01	0.01	0.03	0.03
Grazing Forested	USLE	0	USLE	0	USLE	0	0.1	0.1	0.2	0.2	0.01	0.01	0.03	0.03
Grazing Open	USLE	0	USLE	0	USLE	0	0.1	0.1	0.2	0.2	0.01	0.01	0.03	0.03
Horticulture	80	0	USLE	0	USLE	0	0.74	0.74	0.25	0.25	0.02	0.02	0.01	0.01
Dryland Cropping	HowLeaky	0	HowLeaky	0	HowLeaky	0	0.5	0.5	0.37	0.37	HowLeaky	0	HowLeaky	0
Irrigated Cropping	HowLeaky	0	HowLeaky	0	HowLeaky	0	0.5	0.5	0.37	0.37	HowLeaky	0	HowLeaky	0
Other	120	0	USLE	0	USLE	0	0.1	0.1	0.2	0.2	0.01	0.01	0.03	0.03
Sugarcane	APSIM	0	APSIM	0	APSIM	0	APSIM	0	0.25	0.25	APSIM	N/A	APSIM	N/A
Urban	120	0	USLE	0	USLE	0	0.16	0.16	0.26	0.26	0.02	0.02	0.01	0.01
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 84 Event Mean Concentrations/Dry Weather Concentrations (mg/L) for Mackay Whitsunday

Functional unit	TSS EMC	TSS DWC	PN EMC	PN DWC	PP EMC	PP DWC	DIN EMC	DIN DWC	DON EMC	DON DWC	DOP EMC	DOP DWC	DIP EMC	DIP DWC
Nature conservation	50	25	0.15	0.075	0.07	0.035	0.058	0.029	0.092	0.046	0.003	0.002	0.011	0.005
Forestry	70	35	0.4	0.2	0.1	0.05	0.077	0.039	0.122	0.0061	0.004	0.002	0.015	0.007
Closed grazing	USLE	100	USLE	0	USLE	0	0.097	0.048	0.153	0.076	0.005	0.003	0.018	0.009
Open grazing	USLE	100	USLE	0	USLE	0	0.193	0.097	0.306	0.153	0.01	0.005	0.036	0.018
Other	109	55	0.448	0.224	0.127	0.064	0.193	0.097	0.306	0.153	0.01	0.005	0.036	0.018
Urban	218	109	0.895	0.448	0.255	0.127	0.386	0.193	0.611	0.306	0.021	0.01	0.073	0.036
Horticulture	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryland cropping	HowLeaky	70	HowLeaky	0	HowLeaky	0	0.58	0.29	0.917	0.458	HowLeaky	0	HowLeaky	0
Irrigated cropping	HowLeaky	70	HowLeaky	0	HowLeaky	0	0.483	0.242	0.764	0.382	HowLeaky	0	HowLeaky	0
Sugarcane	APSIM	70	APSIM	0.56	APSIM	0.159	APSIM	0	0.65	0.33	APSIM	N/A	APSIM	N/A
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 85 Event Mean Concentrations/Dry Weather Concentrations (mg/L) for the FZ

Functional unit	TSS EMC	TSS DWC	PN EMC	PN DWC	PP EMC	PP DWC	DIN EMC	DIN DWC	DON EMC	DON DWC	DOP EMC	DOP DWC	DIP EMC	DIP DWC
Nature conservation	50	25	0.15	0.075	0.07	0.035	0.058	0.029	0.092	0.046	0.003	0.002	0.011	0.005
Forestry	70	35	0.4	0.2	0.1	0.05	0.077	0.039	0.122	0.0061	0.004	0.002	0.015	0.007
Closed grazing	USLE	100	USLE	0	USLE	0	0.097	0.048	0.153	0.076	0.005	0.003	0.018	0.009
Open grazing	USLE	100	USLE	0	USLE	0	0.193	0.097	0.306	0.153	0.01	0.005	0.036	0.018
Other	109	55	0.448	0.224	0.127	0.064	0.193	0.097	0.306	0.153	0.01	0.005	0.036	0.018
Urban	218	109	0.895	0.448	0.255	0.127	0.386	0.193	0.611	0.306	0.021	0.01	0.073	0.036
Horticulture	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryland cropping	HowLeaky	70	HowLeaky	0	HowLeaky	0	0.58	0.29	0.917	0.458	Howleaky	0	Howleaky	0
Irrigated cropping	HowLeaky	70	HowLeaky	0	HowLeaky	0	0.483	0.242	0.764	0.382	Howleaky	0	Howleaky	0
Sugarcane	APSIM	70	APSIM	0.56	APSIM	0.159	APSIM	0	0.65	0.33	APSIM	N/A	APSIM	N/A
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 86 Event Mean Concentrations/Dry Weather Concentrations (mg/L) for the Burnett Mary

Functional unit	TSS EMC	TSS DWC	PN EMC	PN DWC	PP EMC	PP DWC	DIN EMC	DIN DWC	DON EMC	DON DWC	DOP EMC	DOP DWC	DIP EMC	DIP DWC
Conservation	USLE	100	USLE	0.078	USLE	0.023	0.038	0.019	0.166	0.083	0.007	0.003	0.011	0.005
Forestry	USLE	100	USLE	0.104	USLE	0.031	0.051	0.025	0.222	0.111	0.009	0.004	0.014	0.007
Grazing Forested	USLE	100	USLE	0.099	USLE	0.025	0.064	0.073	0.270	0.227	0.011	0.005	0.018	0.004
Grazing Open	USLE	100	USLE	0.260	USLE	0.078	0.127	0.064	0.554	0.277	0.022	0.011	0.036	0.018
Other	82.5	55	0.521	0.260	0.156	0.078	0.127	0.064	0.554	0.277	0.022	0.011	0.036	0.018
Urban	165	110	1.041	0.521	0.312	0.156	0.254	0.127	1.108	0.554	0.044	0.022	0.072	0.036
Horticulture	206.25	137.5	1.302	0.651	0.390	0.195	0.318	0.159	1.385	0.693	0.055	0.028	0.09	0.045
Dryland Cropping	HowLeaky	0	HowLeaky	0	HowLeaky	0	0.381	0.191	1.662	0.831	HowLeaky	0.033	HowLeaky	0.054
Irrigated Cropping	HowLeaky	0	HowLeaky	0	HowLeaky	0	0.3175	0.159	1.385	0.693	HowLeaky	0.028	HowLeaky	0.045
Sugarcane	APSIM	0	APSIM	0	APSIM	0	APSIM	0	2	0	APSIM	N/A	APSIM	N/A
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 87 Event Mean Concentrations/Dry Weather Concentrations (mg/L) for the predevelopment model, all regions

Basin	TSS EMC	TSS DWC	PN EMC	PN DWC	PP EMC	PP DWC	DIN EMC	DIN DWC	DON EMC	DON DWC	DOP EMC	DOP DWC	DIP EMC	DIP DWC
Cape York	USLE	0	USLE	0.040	USLE	0.005	0.032	0.016	0.35	0.175	0.010	0.005	0.005	0.0025
Wet Tropics	30	15	0.170	0.030	0.020	0.010	0.160	0.080	0.119	0.060	0.010	0.005	0.007	0.003
Burdekin	USLE	0	USLE	0	USLE	0	0.100	0.100	0.200	0.200	0.010	0.010	0.030	0.030
Mackay Whitsunday	50	25	0.150	0.075	0.070	0.035	0.058	0.029	0.092	0.046	0.003	0.002	0.011	0.005
Fitzroy	USLE/40	20	USLE	0	USLE	0	0.150	0.075	0.304	0.152	0.019	0.010	0.100	0.050
Burnett Mary	USLE/33	16.5	USLE/0.156	0.078	USLE/0.047	0.023	0.038	0.019	0.166	0.083	0.007	0.003	0.011	0.005

Table 88 Parameter changes for in-stream models in CY

Parameter	CY
Bank height proportion for fine sediment deposition (%)	0.05
Initial proportion of fine bed store (%)	0.01
Floodplain sediment settling velocity	0.002
Sediment settling velocity for remobilisation	0.5
Sediment settling velocity for instream deposition	0.002

Appendix 3 – Management practice data frameworks

P2R management practice and management system benchmarks have been developed for each agricultural industry sector, and in each major river basin within each region. There are varying levels of uncertainty or confidence in these benchmarks, for many reasons, and these are described in Table 89.

Table 89 Summary of data sources and uncertainty around management system baselines developed for Reef Plan 2013

Industry	Primary data sources	Confidence in management system baselines	Sources of uncertainty
Bananas	• 1:1 growers survey • Banana BMP Guide (anonymous, aggregated) • Reef Programme grant applications (anonymous)	Good	• High level of heterogeneity within the industry, particularly with respect to farm size. There are a relatively small number of very large farms which can skew results.
Grains	• Grains BMP program (anonymous) • Expert agronomist workshops	High	• Over 80% of industry represented in baseline sample. However there are some Grains BMP questions which do not allow discrimination of practices at a fine level.
Grazing	• Grazier 1:1 survey	Good	• Survey has enabled an excellent appreciation of farm management. However there is an assumption that good management is analogous to good resource condition. • Some river basins have insufficient sample size to develop a baseline that is specific to that basin. In these instances the broader regional baseline is employed.
Horticulture	• Growcom Farm Management System (anonymous)	High	• Very large proportion of industry represented in baseline sample (depending on region). However there are some Horticulture FMS questions which do not allow discrimination of practices at a fine level.
Sugarcane	• 1:1 grower surveys • Smartcane BMP program (anonymous, aggregated) • Reef Programme grant applications (anonymous)	High	• Uncertainty around management related to timing of fertiliser and herbicide applications. Mostly relates to variance in interpretation from field staff capturing data on-farm. • Alternate lines of evidence validate baseline distributions for key practices.

Grazing

The prevalence of different management practices utilised in grazing businesses was determined through surveying of commercial-scale graziers between late 2011 and early 2014. Surveys took the form of one on one, semi-structured interviews conducted on-farm by experienced professional grazing extension officers. Survey questions were designed to align with the practices articulated in the Grazing Water Quality Risk framework, i.e. the responses recorded align with varying degrees of water quality risk associated with that management. The framework further aligns these practices with the erosion process that is most directly influenced by those practices. While the key management categories remained consistent, the questions and practice descriptions used in wet coastal landscapes were different to those used in rangelands grazing systems.

For reporting and P2R modelling purposes the specific management practice data was analysed to develop management system ratings (from Low to High risk) that reflect the water quality risk of the mix of individual practices on a farm. Survey responses to individual questions (practice descriptions) were weighted and aggregated to develop a water quality risk score for the practices associated with each erosion process (surface (hillslope) erosion, streambank erosion, and gully erosion). Table 90 below provides an example for one question that relates to the objective determination of long term carrying capacity.

Table 90 Grazing land management survey question 11 - the categories of response and the water quality risk score allocated for each category of response

Survey Question: For long term planning what do you base your average carrying capacity on?	Score	Risk level
Historical experience and/or anecdotal advice (not documented)	0	High
Long term stock and stocking rate records (documented in diaries, paddock records etc.)	4	Moderate
Some objective measure of safe stocking rate calculations, including property map and based on historical data, subjective assessment of resource condition	7	Low-moderate
Documented records, including property map and safe stocking rate calculations based on land type, property infrastructure and objective assessments of land condition.	10	Low

This survey question (Table 90) accounts for 10% of the total water quality risk score for practices related to hillslope erosion risk. The ‘best practice’ response is allocated a score of 10, and the least sophisticated management is allocated a score of zero. A total water quality risk score for the practices related to hillslope erosion was derived through combining scores for all relevant questions.

Scores for each erosion process were then assigned a management risk rating (Table 91), based on expert review of specific combinations of management practice.

Table 91 Water quality risk scores used to categorise management risk ratings

Erosion process	Water Quality Risk Rating			
	Low	Low-Moderate	Moderate	High
Hillslope	81-100	59-80	33-58	0-32
Streambank	100	66-99	33-65	0
Gully	85-100	62-84	32-61	0-31

In Table 92 some key grazing management categories and their weighting in developing water quality risk scores are presented.

Table 92 Key grazing management categories and their weightings in developing water quality risk scores and ratings

Erosion Process	Management category (each informed by a suite of practices)	P2R Weighting
Hillslope erosion	**1.** Average stocking rates imposed on paddocks are consistent with district long-term carrying capacity benchmarks for comparable land types, current land condition, and level of property development	20%
	2. Retention of adequate pasture and groundcover at the end of the dry season, informed by (1) knowledge of groundcover needs and (2) by deliberate assessment of pasture availability in relation to stocking rates in each paddock during the latter half of the growing season or early dry season.	40%
	3. Strategies implemented to recover any land in poor or very poor condition (C or D condition)	25%
	4. The condition of selectively-grazed land types is effectively managed	15%
	Hillslope erosion assessment	100%
Streambank erosion	**5.** Timing and intensity of grazing is managed in frontages of rivers and major streams (including associated riparian areas) and wetland areas.	100%
Gully erosion	**6.** Strategies implemented, where practical and affordable, to remediate gullied areas	30%
	7. Linear features (roads, tracks, fences, firebreaks, and water points located and constructed to minimise their risk of initiating erosion	40%
	1 – 4 Hillslope erosion assessment	30%
	Gully erosion assessment	100%

Grazing management system baselines for Reef Plan 2013 were based on management system ratings for individual businesses, aggregated to form baselines for representative river basins within NRM regions. These individual ratings and baselines were reviewed by regional experts and compared with congruent data (where available; such as aggregated, anonymous assessments conducted by graziers participating in the Grazing BMP program). Where insufficient samples were available to discriminate management at the level of river basins, the baseline for the entire NRM region is used.

Sugarcane

Key management practices relevant to water quality risk of sugarcane farming systems were articulated in a Water Quality Risk framework for sugarcane in 2013, and is presented in Table 93.

Table 93 Key management categories articulated in the P2R Water Quality Risk framework for sugarcane

Management category	Weighting
Sediment (runoff and soil loss)	
Crop residue cover (green cane trash blanketing)	30%
Controlled Traffic Farming	25%
Land management during cane fallow	25%
Tillage in plant cane (land preparation)	20%
Nutrients (nitrogen)	
Matching nitrogen supply to crop nitrogen requirements	60%
Timing of fertiliser application with respect to rainfall or irrigation	30%
Application method (surface or subsurface)	10%
Pesticides	
Timing application of residual herbicides	40%
Targeting application to reduce the volume of herbicide applied	40%
Residual herbicide use in ratoons	20%
Water	
Calculating the amount of water to apply	70%
Managing surface runoff	30%

The prevalence of each of these key management practices in the sugarcane industry was estimated through a benchmarking process conducted throughout 2013-14.

- A suite of questions directly relating to the P2R Water Quality Risk framework was the basis of a survey conducted by regional NRM organisations on behalf of P2R. Sampling was targeted as much as possible to ensure that up to 50% of the growers sampled had not previously had high levels of engagement with Reef Plan initiatives. In each region there was a target of a minimum of 100 randomly selected growers across catchments.
- Congruent datasets were obtained through the Smartcane BMP program and recent applications (2012-13 and 2013-14 where available) for the Australian Government's incentive programs.
- In each region small expert panels were convened to review the adoption levels indicated by the various source data and confirm adoption estimates for each practice level, for each management issue. The proportion of growers and area at each level were checked for sensibility and modified if sufficient supporting evidence was available. Supporting evidence was in the form of discrete data (mills, local productivity service organisations, specific project data, other P2R data on rates and volumes of nutrient and pesticide use) and weight of local opinion.

Best management practice systems for sediment, nutrient, or pesticide management are described through aggregating the adoption levels of each practice according to their framework weighting.

Bananas

The P2R Water Quality Risk framework for bananas is based on the Australian Banana Grower's Association (ABGC) *Banana BMP Guide* (http://bmp.abgc.org.au/). The specific practices that are most relevant to water quality risk of the banana farming system were collated into a focused framework that also aligns with the management practice monitoring system utilised by Terrain NRM (the regional NRM organisation in the Wet Tropics). Prioritising and weighting these practices for relative water quality risk occurred through consultation with Queensland government scientists, officers from the ABGC, Terrain NRM and extension officers from the Queensland Department of Agriculture and Fisheries, and is presented in Table 94.

The pollutants of most concern with respect to the banana industry are sediments and nutrients. There is little to no use of the residual herbicides (with relatively high ecological toxicities) that are common in other cropping sectors. Herbicides that are commonly used in bananas have relatively low ecological toxicity and are not priorities for Reef Plan 2013. Offsite movement of these products - when it occurs - is largely a function of runoff and soil loss, which is a focal area in the framework.

Table 94 Key management categories articulated in the P2R Water Quality Risk framework for bananas

Management category	Weighting
Sediment (runoff and soil loss)	
Crop removal	10%
Fallow management	20%
Tillage – plant crop	15%
Ground cover (inter-rows and headlands)	35%
Controlling runoff (contouring)	10%
Controlling runoff (drains)	5%
Sediment traps	5%
Nutrients	
Timing application of residual herbicides	40%
Targeting application to reduce the volume of herbicide applied	40%
Residual herbicide use in ratoons	20%
Water	
Calculating the amount of water to apply	70%
Managing surface runoff	30%

The prevalence of each of these key management practices in the Wet Tropics was estimated through a benchmarking process conducted during 2013-14. There was no data available to support baseline development in the banana production areas of southern Cape York, although this may change during 2015. Anonymous data sources for the Wet Tropics included:

- A grower survey conducted in 2012 by Terrain NRM and the ABGC, representing 125 growers and approximately 75% of the cropped area of bananas.
- Management practice data collected by Terrain NRM as a component of 2012–13 applications for the Australian Government's Reef Rescue program.

- Aggregated anonymous data from the Banana BMP Guide, available for discussion while reviewing adoption benchmarks with experienced extension officers.

Grains

The P2R Water Quality Risk framework for the grain farming industry is based on a range of key management areas selected from four modules of the Grains BMP program (www.grainsbmp.com.au). Eighteen management issues were assigned weightings according to their potential for influencing offsite water quality. These weightings were developed through a review process including Queensland government scientists and experienced Central Queensland agronomists and agricultural consultant, and is presented in Table 95.

Table 95 Grains BMP program modules and management questions used in developing the Reef Plan 2013 management baseline

BMP Module	Management category	Weighting
Sediment (runoff and soil loss)		
Property Design Layout	Use of contour and diversion banks in sloping cropping areas	15%
Property Design Layout	Sediment trapping devices	5%
Property Design Layout	Waterways and drainage lines	5%
Making Best Use of Rainfall	Stubble volume and persistence	15%
Making Best Use of Rainfall	Retain stubble during the fallow	20%
Making Best Use of Rainfall	Cropping frequency	10%
Making Best Use of Rainfall	Need for tillage	20%
Making Best Use of Rainfall	Wheel traffic	10%
Pesticides		
Pesticide Application	Pest identification	5%
Pesticide Application	Resistance management	10%
Pesticide Application	Product selection	5%
Pesticide Application	Risk of residual pesticide movement	40%
Property Design Layout	Pesticide and sediment movement	40%
Nutrients		
Crop Nutrition	Records of crop yield and quality	10%
Crop Nutrition	Frequency of soil testing for N	30%
Crop Nutrition	Influence of stored soil moisture on yield and fertiliser decisions	30%
Crop Nutrition	Impact of seasonal outlook on making fertiliser decisions	20%
Crop Nutrition	Application timing to minimise potential losses and maximise uptake	10%

Appendix 4 – 2014 Report Card modelling results

Table 96 Constituent loads for RC2014 predevelopment, baseline and change model runs for the CY NRM Region

Total fine sediment (kt/yr)						
	Predevelopment	Baseline (12/13)	Anthropogenic Baseline	Increase Factor	Total (13/14)	Total Change (%)
Jacky Jacky	14	16	3	1.14	16	0.0
Olive Pascoe	26	35	9	1.35	35	0.0
Lockhart	18	18	0	1.00	18	0.0
Stewart	20	25	5	1.25	25	0.0
Normanby	68	230	162	3.38	230	0.0
Jeannie	22	26	3	1.18	26	0.0
Endeavour	14	21	7	1.50	21	0.0
TOTAL	**181**	**371**	**190**	**2.05**	**371**	**0.0**
Total phosphorus (t/yr)						
	Predevelopment	Baseline (12/13)	Anthropogenic Baseline	Increase Factor	Total (13/14)	Total Change (%)
Jacky Jacky	44	54	10	1.23	54	0.0
Olive Pascoe	67	101	34	1.51	101	0.0
Lockhart	51	51	1	1.00	51	0.0
Stewart	25	27	1	1.08	27	0.0
Normanby	191	358	167	1.87	358	0.0
Jeannie	30	39	8	1.30	39	0.0
Endeavour	29	51	22	1.76	51	0.0
TOTAL	**438**	**680**	**242**	**1.55**	**680**	**0.0**
Particulate phosphorus (t/yr)						
	Predevelopment	Baseline (12/13)	Anthropogenic Baseline	Increase Factor	Total (13/14)	Total Change (%)
Jacky Jacky	10	18	8	1.80	18	0.0
Olive Pascoe	18	45	28	2.50	45	0.0
Lockhart	28	28	0	1.00	28	0.0
Stewart	11	12	1	1.09	12	0.0
Normanby	150	299	149	1.99	299	0.0
Jeannie	16	22	7	1.38	22	0.0
Endeavour	10	27	16	2.70	27	0.0
TOTAL	**243**	**451**	**209**	**1.86**	**451**	**0.0**
Dissolved inorganic phosphorus (DIP) (t/yr)						
	Predevelopment	Baseline (12/13)	Anthropogenic Baseline	Increase Factor	Total (13/14)	Total Change (%)
Jacky Jacky	11	12	1	1.09	12	0.0
Olive Pascoe	17	19	2	1.12	19	0.0

Lockhart	8	8	0	1.00	8	0.0
Stewart	5	5	0	1.00	5	0.0
Normanby	14	20	6	1.43	20	0.0
Jeannie	5	5	0	1.00	5	0.0
Endeavour	6	8	2	1.33	8	0.0
TOTAL	**65**	**76**	**11**	**1.17**	**76**	**0.0**
Dissolved organic phosphorus (DOP) (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Jacky Jacky	23	24	1	1.04	24	0.0
Olive Pascoe	33	37	4	1.12	37	0.0
Lockhart	15	15	0	1.00	15	0.0
Stewart	9	10	0	1.11	10	0.0
Normanby	27	39	12	1.44	39	0.0
Jeannie	10	11	1	1.10	11	0.0
Endeavour	13	16	4	1.23	16	0.0
TOTAL	**130**	**153**	**22**	**1.18**	**153**	**0.0**
Total nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Jacky Jacky	585	955	370	1.63	955	0.0
Olive Pascoe	852	1,432	579	1.68	1,432	0.0
Lockhart	512	739	228	1.44	739	0.0
Stewart	253	398	145	1.57	398	0.0
Normanby	1,695	2,299	604	1.36	2,299	0.0
Jeannie	306	482	177	1.58	482	0.0
Endeavour	329	601	272	1.83	601	0.0
TOTAL	**4,531**	**6,907**	**2,375**	**1.52**	**6,907**	**0.0**
Particulate nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Jacky Jacky	58	97	39	1.67	97	0.0
Olive Pascoe	83	195	112	2.35	195	0.0
Lockhart	159	161	1	1.01	161	0.0
Stewart	33	36	3	1.09	36	0.0
Normanby	1,060	1,310	250	1.24	1,310	0.0
Jeannie	78	115	37	1.47	115	0.0
Endeavour	37	144	107	3.89	144	0.0
TOTAL	**1,507**	**2,057**	**550**	**1.36**	**2,057**	**0.0**
Dissolved inorganic nitrogen (DIN) (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**

Jacky Jacky	73	73	0	1.00	73	0.0
Olive Pascoe	106	107	1	1.01	107	0.0
Lockhart	49	49	0	1.00	49	0.0
Stewart	30	30	0	1.00	30	0.0
Normanby	88	96	8	1.09	96	0.0
Jeannie	31	32	0	1.03	32	0.0
Endeavour	40	41	1	1.03	41	0.0
TOTAL	**417**	**427**	**10**	**1.02**	**427**	**0.0**
Dissolved organic nitrogen (DON) (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Jacky Jacky	454	785	331	1.73	785	0.0
Olive Pascoe	664	1,130	467	1.70	1,130	0.0
Lockhart	304	530	226	1.74	530	0.0
Stewart	190	331	141	1.74	331	0.0
Normanby	548	894	346	1.63	894	0.0
Jeannie	196	336	140	1.71	336	0.0
Endeavour	252	416	164	1.65	416	0.0
TOTAL	**2,607**	**4,422**	**1,815**	**1.70**	**4,422**	**0.0**
PSII Load (kg/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Jacky Jacky	0	0	0	NA	0	0.0
Olive Pascoe	0	0	0	NA	0	0.0
Lockhart	0	0	0	NA	0	0.0
Stewart	0	0	0	NA	0	0.0
Normanby	0	12	12	NA	12	0.0
Jeannie	0	1	1	NA	1	0.0
Endeavour	0	6	6	NA	6	0.0
TOTAL	**0**	**18**	**18**	**NA**	**18**	**0.0**

Table 97 Constituent loads for RC2014 predevelopment, baseline and change model runs for the WT NRM Region

Total fine sediment (kt/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	85	108	23	1.3	108	0.0
Mossman	11	21	10	1.9	21	0.1
Barron	37	80	43	2.2	80	0.0
Mulgrave-Russell	106	265	159	2.5	264	0.8
Johnstone	132	409	277	3.0	408	0.3

Tully	76	177	101	2.0	176	0.7
Murray	39	89	50	2.3	89	0.4
Herbert	189	515	326	2.7	515	0.1
TOTAL	**675**	**1,665**	**989**	**2.5**	**1,661**	**0.3**
Total phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	88	135	47	1.5	135	0.1
Mossman	13	34	22	2.6	34	0.2
Barron	38	96	58	2.5	96	0.1
Mulgrave-Russell	121	453	332	3.7	450	0.9
Johnstone	194	1,268	1,074	6.5	1,263	0.4
Tully	84	329	245	3.9	327	1.0
Murray	42	189	147	4.5	188	0.6
Herbert	181	512	332	2.8	511	0.3
TOTAL	**761**	**3,016**	**2,255**	**3.9**	**3,004**	**0.52**
Particulate phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	50	87	37	1.7	87	0.1
Mossman	7	26	19	3.7	26	0.2
Barron	26	74	48	2.9	74	0.1
Mulgrave-Russell	65	365	300	5.6	362	1.0
Johnstone	136	1,186	1,050	8.7	1,182	0.4
Tully	43	271	228	6.3	269	1.1
Murray	20	156	136	7.8	156	0.6
Herbert	112	412	300	3.7	412	0.3
TOTAL	**459**	**2,578**	**2,118**	**5.6**	**2,566**	**0.55**
Dissolved inorganic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	15	24	9	1.6	24	0.0
Mossman	2	5	3	2.5	5	0.0
Barron	5	13	8	2.6	13	0.0
Mulgrave-Russell	23	50	28	2.8	50	0.0
Johnstone	23	43	20	1.9	43	0.0
Tully	17	32	16	1.9	32	0.0
Murray	9	19	10	2.1	19	0.0
Herbert	28	54	26	1.9	54	0.0
TOTAL	**122**	**240**	**118**	**2.0**	**240**	**0.0**
Dissolved organic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**

Daintree	23	24	1	1.0	24	0.0
Mossman	3	4	0	1.3	4	0.0
Barron	7	9	2	1.3	9	0.0
Mulgrave-Russell	33	38	4	1.2	38	0.0
Johnstone	35	39	4	1.1	39	0.0
Tully	25	26	1	1.0	26	0.0
Murray	13	13	1	1.0	13	0.0
Herbert	41	46	5	1.1	46	0.0
TOTAL	**180**	**199**	**19**	**1.1**	**199**	**0.0**
Total nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	955	1,688	733	1.8	1,687	0.0
Mossman	137	272	135	2.0	272	0.0
Barron	263	641	378	2.4	638	0.7
Mulgrave-Russell	1,358	2,487	1,129	1.8	2,476	1.0
Johnstone	1,467	3,616	2,149	2.5	3,608	0.3
Tully	963	1,815	853	1.9	1,806	1.0
Murray	502	1,027	525	2.1	1,022	0.8
Herbert	1,611	3,504	1,893	2.2	3,498	0.4
TOTAL	**7,255**	**15,049**	**7,794**	**2.1**	**15,008**	**0.53**
Particulate nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	318	398	80	1.3	398	0.0
Mossman	41	77	36	1.9	77	0.1
Barron	107	265	158	2.5	265	0.0
Mulgrave-Russell	425	969	545	2.3	965	0.8
Johnstone	490	1,896	1,406	3.9	1,893	0.3
Tully	275	665	391	2.4	663	0.6
Murray	146	332	186	2.3	332	0.4
Herbert	475	1,203	728	2.5	1,201	0.2
TOTAL	**2,277**	**5,807**	**3,529**	**2.5**	**5,794**	**0.36**
Dissolved inorganic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	365	481	116	1.3	481	0.0
Mossman	55	134	78	2.4	134	0.0
Barron	71	159	88	2.2	156	2.8
Mulgrave-Russell	535	918	384	1.7	911	1.9
Johnstone	559	989	430	1.8	986	0.8

Tully	394	678	284	1.7	672	2.3
Murray	204	388	184	2.0	385	2.0
Herbert	651	1,294	643	2.0	1,289	0.8
TOTAL	**2,834**	**5,041**	**2,207**	**1.9**	**5,012**	**1.3**
Dissolved organic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	272	809	537	3.0	809	0.0
Mossman	41	62	20	1.5	62	0.0
Barron	85	217	132	2.6	217	0.0
Mulgrave-Russell	399	600	201	1.5	600	0.0
Johnstone	417	730	313	1.7	730	0.0
Tully	294	472	178	1.6	472	0.0
Murray	152	306	154	2.0	306	0.0
Herbert	485	1,007	523	2.1	1,007	0.0
TOTAL	**2,144**	**4,202**	**2,058**	**2.0**	**4,202**	**0.0**
PSII Load (kg/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Daintree	0	104	104	NA	104	0.6
Mossman	0	64	64	NA	64	0.1
Barron	0	160	160	NA	154	3.5
Mulgrave-Russell	0	678	678	NA	666	1.8
Johnstone	0	928	928	NA	894	3.7
Tully	0	502	502	NA	496	1.1
Murray	0	389	389	NA	387	0.4
Herbert	0	868	868	NA	865	0.4
TOTAL	**0**	**3,694**	**3,694**	**NA**	**3,630**	**1.7**

Table 98 Constituent loads for RC2014 predevelopment, baseline and change model runs for the BU NRM Region

Total fine sediment (kt/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	36	67	30	1.86	67	0.0
Ross	14	46	32	3.29	46	0.0
Haughton	33	160	127	4.85	159	0.3
Burdekin	512	3,222	2,711	6.29	3,183	1.5
Don	31	200	168	6.45	200	0.1
TOTAL	**625**	**3,695**	**3,069**	**5.91**	**3,654**	**1.3**
Total phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**

Black	107	119	11	1.11	119	0.0
Ross	35	71	36	2.03	71	0.0
Haughton	80	244	164	3.05	243	0.9
Burdekin	686	2,104	1,418	3.07	2,094	0.7
Don	73	197	124	2.70	196	0.7
TOTAL	**982**	**2,735**	**1,753**	**2.79**	**2,722**	**0.7**
Particulate phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	79	91	12	1.15	91	0.0
Ross	13	27	13	2.08	27	0.0
Haughton	41	163	122	3.98	162	1.2
Burdekin	328	1,733	1,405	5.28	1,723	0.7
Don	37	159	122	4.30	158	0.7
TOTAL	**498**	**2,173**	**1,675**	**4.36**	**2,160**	**0.8**
Dissolved inorganic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	22	21	0	0.95	21	0.0
Ross	16	33	17	2.06	33	0.0
Haughton	29	63	33	2.17	63	0.0
Burdekin	269	279	10	1.04	279	0.0
Don	27	28	1	1.04	28	0.0
TOTAL	**363**	**424**	**61**	**1.17**	**424**	**0.0**
Dissolved organic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	7	7	0	1.00	7	0.0
Ross	5	11	6	2.20	11	0.0
Haughton	10	18	8	1.80	18	0.0
Burdekin	90	92	2	1.02	92	0.0
Don	9	10	1	1.11	10	0.0
TOTAL	**121**	**138**	**17**	**1.14**	**138**	**0.0**
Total nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	347	402	55	1.16	402	0.0
Ross	189	376	187	1.99	376	0.0
Haughton	353	1,310	957	3.71	1,289	2.3
Burdekin	3,159	5,737	2,578	1.82	5,712	1.0
Don	333	637	304	1.91	635	0.7
TOTAL	**4,382**	**8,463**	**4,082**	**1.93**	**8,414**	**1.2**
Particulate nitrogen (t/yr)						

	Predevelopment	Baseline (12/13)	Anthropogenic Baseline	Increase Factor	Total (13/14)	Total Change (%)
Black	130	157	27	1.21	157	0.0
Ross	28	55	27	1.96	55	0.0
Haughton	60	243	183	4.05	241	1.0
Burdekin	471	2,791	2,321	5.93	2,767	1.0
Don	62	283	221	4.56	282	0.5
TOTAL	**750**	**3,530**	**2,779**	**4.71**	**3,502**	**1.0**
Dissolved inorganic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	72	98	26	1.36	98	0.0
Ross	54	178	125	3.30	178	0.0
Haughton	98	855	757	8.72	835	2.6
Burdekin	896	1,144	248	1.28	1,143	0.4
Don	90	170	80	1.89	169	1.3
TOTAL	**1,210**	**2,446**	**1,236**	**2.02**	**2,424**	**1.8**
Dissolved organic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	145	147	2	1.01	147	0.0
Ross	107	142	35	1.33	142	0.0
Haughton	195	212	17	1.09	212	0.0
Burdekin	1,792	1,802	10	1.01	1,802	0.0
Don	181	184	3	1.02	184	0.0
TOTAL	**2,421**	**2,488**	**67**	**1.03**	**2,488**	**0.0**
PSII load (kg/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Black	0	16	16	NA	16	0.0
Ross	0	2	2	NA	2	0.0
Haughton	0	1,591	1,591	NA	1,502	5.6
Burdekin	0	533	533	NA	505	5.1
Don	0	154	154	NA	132	14.1
TOTAL	**0**	**2,295**	**2,295**	**NA**	**2,157**	**6.0**

Table 99 Constituent loads for RC2014 redevelopment, baseline and change model runs for the Mackay Whitsunday NRM Region

Total fine sediment (kt/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	64	111	47	1.73	111	0.2
O'Connell	81	245	164	3.02	245	0.1
Pioneer	61	141	79	2.31	141	0.0
Plane	47	114	67	2.43	114	0.0

TOTAL	**254**	**611**	**357**	**2.41**	**610**	**0.1**
Total phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	88	228	141	2.59	228	0.0
O'Connell	86	351	265	4.08	351	0.0
Pioneer	55	143	89	2.60	143	0.0
Plane	50	236	186	4.72	236	0.0
TOTAL	**279**	**959**	**680**	**3.44**	**959**	**0.016**
Particulate phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	63	128	65	2.03	128	0.0
O'Connell	66	266	201	4.03	266	0.0
Pioneer	43	91	48	2.12	91	0.0
Plane	34	138	103	4.06	138	0.0
TOTAL	**206**	**623**	**417**	**3.02**	**623**	**0.0**
Dissolved inorganic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	19	80	60	4.21	80	0.0
O'Connell	16	67	51	4.19	67	0.0
Pioneer	9	42	32	4.67	42	0.0
Plane	12	78	66	6.50	78	0.0
TOTAL	**57**	**267**	**210**	**4.68**	**267**	**0.0**
Dissolved organic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	5	21	15	4.20	21	0.0
O'Connell	5	18	13	3.60	18	0.0
Pioneer	3	11	8	3.67	11	0.0
Plane	3	20	17	6.67	20	0.0
TOTAL	**16**	**69**	**53**	**4.31**	**69**	**0.0**
Total nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	399	1,025	626	2.57	1,025	0.0
O'Connell	359	1,277	918	3.56	1,277	0.0
Pioneer	224	705	481	3.15	705	0.1
Plane	235	1,025	790	4.36	1,024	0.1
TOTAL	**1,218**	**4,031**	**2,813**	**3.31**	**4,031**	**0.0**
Particulate nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	137	320	183	2.34	320	0.0

O'Connell	135	565	430	4.19	565	0.0
Pioneer	95	231	136	2.43	231	0.0
Plane	69	303	234	4.39	303	0.0
TOTAL	**436**	**1,419**	**983**	**3.25**	**1,419**	**0.0**
Dissolved inorganic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	101	304	203	3.01	304	0.0
O'Connell	87	329	243	3.78	329	0.0
Pioneer	50	247	197	4.94	247	0.0
Plane	64	357	293	5.58	357	0.1
TOTAL	**302**	**1,237**	**935**	**4.10**	**1,237**	**0.0**
Dissolved organic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	161	401	240	2.49	401	0.0
O'Connell	137	383	246	2.80	383	0.0
Pioneer	79	227	148	2.87	227	0.0
Plane	102	364	262	3.57	364	0.0
TOTAL	**479**	**1,375**	**896**	**2.87**	**1,375**	**0.0**
PSII load (kg/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Proserpine	0	569	569	NA	569	0.0
O'Connell	0	1,080	1,080	NA	1,080	0.0
Pioneer	0	876	876	NA	876	0.0
Plane	0	1,840	1,840	NA	1,840	0.0
TOTAL	**0**	**4,365**	**4,365**	**NA**	**4,365**	**0.0**

Table 100 Constituent loads for RC2014 predevelopment, baseline and change model runs for the FZ NRM Region

Total fine sediment (kt/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	24	105	81	4.38	105	0.0
Shoalwater	10	57	47	5.70	57	0.0
Water Park	7	37	30	5.29	37	0.0
Fitzroy	204	1,497	1,293	7.34	1,493	0.3
Calliope	14	75	62	5.36	75	0.0
Boyne	5	21	17	4.20	21	0.7
TOTAL	**263**	**1,793**	**1,530**	**6.82**	**1,788**	**0.3**
Total phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**

Styx	90	340	250	3.78	340	0.0
Shoalwater	61	248	187	4.07	248	0.0
Water Park	51	263	213	5.16	263	0.0
Fitzroy	578	2,714	2,136	4.70	2,709	0.2
Calliope	48	210	162	4.38	210	0.0
Boyne	23	81	58	3.52	81	0.1
TOTAL	**850**	**3,856**	**3,006**	**4.54**	**3,851**	**0.2**
Particulate phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	52	208	156	4.00	208	0.0
Shoalwater	27	131	104	4.85	131	0.0
Water Park	30	194	164	6.47	194	0.0
Fitzroy	280	1,763	1,484	6.30	1,758	0.3
Calliope	27	137	110	5.07	137	0.0
Boyne	7	25	18	3.57	25	0.3
TOTAL	**422**	**2,459**	**2,037**	**5.83**	**2,454**	**0.2**
Dissolved inorganic phosphorus (DIP) (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	32	111	78	3.47	111	0.0
Shoalwater	29	98	69	3.38	98	0.0
Water Park	17	58	41	3.41	58	0.0
Fitzroy	250	796	546	3.18	796	0.0
Calliope	18	62	44	3.44	62	0.0
Boyne	14	47	33	3.36	47	0.0
TOTAL	**360**	**1,171**	**811**	**3.25**	**1,171**	**0.0**
Dissolved organic phosphorus (DOP) (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	6	21	15	3.50	21	0.0
Shoalwater	5	19	13	3.80	19	0.0
Water Park	3	11	8	3.67	11	0.0
Fitzroy	48	154	106	3.21	154	0.0
Calliope	3	12	8	4.00	12	0.0
Boyne	**3**	**9**	**6**	**3.00**	**9**	**0.0**
TOTAL	**68**	**226**	**158**	**3.32**	**226**	**0.0**
Total nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	515	901	386	1.75	901	0.0
Shoalwater	419	714	294	1.70	714	0.0
Water Park	291	748	456	2.57	748	0.0

Fitzroy	3,342	6,404	3,062	1.92	6,397	0.2
Calliope	279	543	263	1.95	543	0.0
Boyne	186	259	73	1.39	259	0.1
TOTAL	**5,033**	**9,568**	**4,536**	**1.90**	**9,561**	**0.2**
Particulate nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	103	393	290	3.82	393	0.0
Shoalwater	55	266	211	4.84	266	0.0
Water Park	76	482	407	6.34	482	0.0
Fitzroy	451	2,632	2,181	5.84	2,624	0.3
Calliope	51	262	211	5.14	262	0.0
Boyne	12	45	33	3.75	45	0.3
TOTAL	**747**	**4,080**	**3,333**	**5.46**	**4,072**	**0.2**
Dissolved inorganic nitrogen (DIN) (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	167	168	1	1.01	168	0.0
Shoalwater	148	148	0	1.00	148	0.0
Water Park	88	88	0	1.00	88	0.0
Fitzroy	1,197	1,275	78	1.07	1,275	0.0
Calliope	93	93	0	1.00	93	0.0
Boyne	71	71	0	1.00	71	0.0
TOTAL	**1,764**	**1,842**	**79**	**1.04**	**1,842**	**0.0**
Dissolved organic nitrogen (DON) (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	245	340	95	1.39	340	0.0
Shoalwater	216	300	83	1.39	300	0.0
Water Park	128	178	50	1.39	178	0.0
Fitzroy	1,694	2,498	804	1.47	2,498	0.0
Calliope	136	188	53	1.38	188	0.0
Boyne	103	144	40	1.40	144	0.0
TOTAL	**2,522**	**3,646**	**1,125**	**1.45**	**3,646**	**0.0**
PSII Load (kg/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Styx	0	240	240	NA	240	0.0
Shoalwater	0	128	128	NA	128	0.0
Water Park	0	17	17	NA	17	0.0
Fitzroy	0	1,812	1,812	NA	1,812	0.0
Calliope	0	122	122	NA	122	0.0
Boyne	0	49	49	NA	49	0.0

TOTAL	**0**	**2,368**	**2,368**	**NA**	**2,368**	**0.0**

Table 101 Constituent loads for RC2014 predevelopment, baseline and change model runs for the Burnett Mary NRM Region

Total fine sediment (kt/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	62	125	63	2.02	125	0.1
Kolan	26	44	18	1.69	44	0.0
Burnett	235	544	309	2.31	544	0.0
Burrum	18	48	30	2.67	48	0.0
Mary	141	504	362	3.57	503	0.1
TOTAL	**482**	**1,264**	**782**	**2.62**	**1,264**	**0.0**
Total phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	60	122	61	2.03	122	0.1
Kolan	22	40	18	1.82	40	0.0
Burnett	107	255	148	2.38	255	0.0
Burrum	18	63	45	3.50	63	0.0
Mary	144	321	177	2.23	320	0.2
TOTAL	**351**	**800**	**449**	**2.28**	**799**	**0.1**
Particulate phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	38	99	61	2.61	99	0.1
Kolan	10	28	18	2.80	28	0.0
Burnett	71	207	136	2.92	207	0.0
Burrum	7	43	36	6.14	43	0.0
Mary	68	241	172	3.54	240	0.2
TOTAL	**194**	**618**	**424**	**3.19**	**617**	**0.1**
Dissolved inorganic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	14	14	0	1.00	14	0.0
Kolan	7	7	0	1.00	7	0.0
Burnett	22	31	9	1.41	31	0.0
Burrum	7	13	6	1.86	13	0.0
Mary	47	50	4	1.06	50	0.0
TOTAL	**97**	**116**	**20**	**1.20**	**116**	**0.0**
Dissolved organic phosphorus (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	9	9	0	1.00	9	0.0
Kolan	4	4	0	1.00	4	0.0

Burnett	14	16	3	1.14	16	0.0
Burrum	4	7	2	1.75	7	0.0
Mary	29	30	1	1.03	30	0.0
TOTAL	**60**	**66**	**6**	**1.10**	**66**	**0.0**
Total nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	351	495	143	1.41	494	0.2
Kolan	166	310	144	1.87	309	0.5
Burnett	672	1,172	500	1.74	1,172	0.0
Burrum	153	445	292	2.91	445	0.0
Mary	1,095	1,835	739	1.68	1,832	0.3
TOTAL	**2,438**	**4,257**	**1,819**	**1.75**	**4,253**	**0.2**
Particulate nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	87	215	128	2.47	215	0.1
Kolan	30	71	40	2.37	71	0.0
Burnett	186	505	319	2.72	505	0.0
Burrum	22	88	66	4.00	88	0.0
Mary	195	664	469	3.41	663	0.2
TOTAL	**521**	**1,543**	**1,023**	**2.96**	**1,542**	**0.1**
Dissolved inorganic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	49	59	10	2.47	59	0.4
Kolan	25	100	75	2.37	100	0.9
Burnett	91	227	137	2.72	227	0.0
Burrum	24	174	149	4.00	174	0.0
Mary	168	314	145	3.41	312	1.0
TOTAL	**358**	**874**	**516**	**2.96**	**872**	**0.4**
Dissolved organic nitrogen (t/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	215	221	5	1.03	221	0.0
Kolan	110	139	28	1.26	139	0.0
Burnett	395	440	45	1.11	440	0.0
Burrum	106	183	77	1.73	183	0.0
Mary	732	857	125	1.17	857	0.0
TOTAL	**1,559**	**1,839**	**280**	**1.18**	**1,839**	**0.0**
PSII load (kg/yr)						
	Predevelopment	**Baseline (12/13)**	**Anthropogenic Baseline**	**Increase Factor**	**Total (13/14)**	**Total Change (%)**
Baffle	0	12	12	NA	12	0.0

Kolan	0	116	116	NA	116	0.0
Burnett	0	165	165	NA	165	0.0
Burrum	0	132	132	NA	132	0.0
Mary	0	137	137	NA	136	0.7
TOTAL	**0**	**563**	**563**	**NA**	**562**	**0.2**

Table 102 BM TSS export (t/ha/yr) by land use

Basin	Conservation	Dryland Cropping	Forestry	Grazing	Horticulture	Irrigated Cropping	Other	Sugarcane	Urban
Baffle	0.29	0.24	0.25	0.31	0.46	0.20	0.23	0.35	0.39
Burnett	0.08	0.22	0.06	0.10	0.31	0.23	0.19	0.18	0.24
Burrum	0.07	0.06	0.03	0.08	0.11	0.08	0.07	0.22	0.08
Kolan	0.08	0.22	0.07	0.12	0.21	0.25	0.16	0.17	0.26
Mary	0.19	0.14	0.16	0.24	0.65	0.15	0.29	0.33	0.59
BM	0.15	0.22	0.09	0.15	0.36	0.22	0.20	0.23	0.38

Appendix 5 – Model validation

Wet Tropics

Table 103 Comparison of Source Catchments modelled and GBRCLMP monitored load at each of the six WT monitoring sites for TSS

Site	TSS (t/yr)		
	Measured	Modelled	% diff
Barron River at Myloa	208,770	90,799	-57
Nth Johnstone River at Tung Oil	166,495	119,678	-28
Sth Johnstone River at Upstream Central mill	77,850	44,789	-42
Tully River at Tully Gorge	25,522	20,408	-20
Tully River at Euramo	110,901	168,993	52
Herbert River at Ingham	566,999	434,100	-23

Table 104 Comparison of Source Catchments modelled and GBRCLMP monitored load at each of the six WT monitoring sites for particulate nutrients

Site	PN (t/yr)			PP (t/yr)		
	Measured	Modelled	% diff	Measured	Modelled	% diff
Barron River at Myloa	656	297	-55	143	88	-39
Nth Johnstone River at Tung Oil	924	649	-30	294	246	-16
Sth Johnstone River at Upstream Central mill	367	209	-43	140	119	-15
Tully River at Tully Gorge	179	86	-52	39	13	-67
Tully River at Euramo	475	641	35	129	294	129
Herbert River at Ingham	1,764	1,015	-42	438	313	-29

Table 105 Comparison of Source Catchments modelled and GBRCLMP monitored load at each of the six WT monitoring sites for DIN and DON

Site	DIN (t/yr)			DON (t/yr)		
	Measured	Modelled	% diff	Measured	Modelled	% diff
Barron River at Myloa	57	89	58	294	241	-18
Nth Johnstone River at Tung Oil	311	278	-11	229	250	9
Sth Johnstone River at Upstream Central mill	160	121	-24	93	95	2
Tully River at Tully Gorge	148	100	-32	119	88	-26
Tully River at Euramo	778	583	-25	459	414	-10
Herbert River at Ingham	1,055	705	-33	1,190	861	-28

Table 106 Comparison of Source Catchments modelled and GBRCLMP monitored load at each of the six WT monitoring sites for DIP and DOP

Site	DIP (t/yr)			DOP (t/yr)		
	Measured	Modelled	% diff	Measured	Modelled	% diff
Barron River at Myloa	10	10	-8	17	9	-45
Nth Johnstone River at Tung Oil	15	15	-3	49	18	-64
Sth Johnstone River at Upstream Central mill	10	6	-43	18	7	-63
Tully River at Tully Gorge	3	4	70	20	6	-68
Tully River at Euramo	22	30	37	63	24	-62
Herbert River at Ingham	51	44	-14	111	43	-61

Table 107 RC2014 (110001D: Barron River at Myola, n = 8 years for flow and n = 8 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	1.26	Indicative	53.63	Indicative	-0.58	Indicative	0.24	Indicative
TSS	1.72	Indicative	82.24	Indicative	-1.94	Indicative	0.53	Satisfactory
TN	1.57	Indicative	74.50	Indicative	-1.46	Indicative	0.27	Indicative
PN	1.61	Indicative	81.66	Indicative	-1.58	Indicative	0.23	Indicative
DIN	1.20	Indicative	35.28	Indicative	-0.44	Indicative	0.15	Indicative
DON	1.44	Indicative	66.48	Indicative	-1.08	Indicative	0.48	Satisfactory
TP	1.39	Indicative	74.18	Indicative	-0.94	Indicative	0.24	Indicative
DIP	1.23	Indicative	62.26	Indicative	-0.51	Indicative	0.18	Indicative
PP	1.39	Indicative	75.49	Indicative	-0.94	Indicative	0.27	Indicative
DOP	1.33	Indicative	77.43	Indicative	-0.78	Indicative	0.02	Indicative

Table 108 RC2014 (112101B South Johnstone River at Upstream Central Mill, n = 8 years for flow and n = 8 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.30	Very good	8.25	Good	0.91	Very good	0.98	Very good
TSS	0.92	Indicative	42.47	Indicative	0.16	Indicative	0.96	Very good
TN	0.80	Indicative	31.19	Indicative	0.36	Satisfactory	0.96	Very good
PN	0.95	Indicative	42.96	Indicative	0.09	Indicative	0.95	Very good
DIN	0.89	Indicative	24.72	Satisfactory	0.21	Indicative	0.59	Satisfactory
DON	0.23	Very good	-1.76	Very good	0.95	Very good	0.95	Very good
TP	0.56	Good	16.91	Good	0.69	Very good	0.92	Very good
DIP	1.29	Indicative	45.40	Indicative	-0.66	Indicative	0.85	Very good
PP	0.56	Good	15.19	Good	0.69	Very good	0.87	Very good
DOP	1.09	Indicative	62.63	Indicative	-0.19	Indicative	0.82	Very good

Burdekin

Table 109 RC2014 120302B Cape River at Taemas, (n = 7 years for flow and n = 7 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.22	Very good	-0.66	Very good	0.95	Very good	0.93	Very good
TSS	0.94	Indicative	47.37	Indicative	0.11	Indicative	0.53	Satisfactory
TN	0.91	Indicative	50.51	Indicative	0.18	Indicative	0.77	Very good
PN	1.26	Indicative	75.93	Indicative	-0.60	Indicative	0.21	Indicative
DIN	2.60	Indicative	-194.73	Indicative	-5.75	Indicative	0.06	Indicative
DON	0.71	Indicative	40.19	Indicative	0.50	Satisfactory	0.89	Very good
TP	0.74	Indicative	0.49	Very good	0.45	Satisfactory	0.29	Indicative
DIP	4.78	Indicative	-281.59	Indicative	-21.87	Indicative	0.78	Very good
PP	0.90	Indicative	17.76	Good	0.20	Indicative	0.07	Indicative
DOP	0.92	Indicative	54.52	Indicative	0.15	Indicative	0.72	Very good

Table 110 RC2014 119101A Barratta Creek at Northcote, (n = 5 years for flow and n = 5 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.47	Very good	37.00	Indicative	0.78	Good	0.95	Very good
TSS	0.80	Indicative	42.94	Indicative	0.35	Indicative	0.76	Good
TN	0.73	Indicative	56.05	Indicative	0.46	Satisfactory	0.90	Very good
PN	0.84	Indicative	61.90	Indicative	0.30	Indicative	0.79	Very good
DIN	0.59	Good	-1.72	Very good	0.65	Good	0.23	Indicative
DON	0.89	Indicative	73.86	Indicative	0.21	Indicative	0.90	Very good
TP	0.71	Indicative	46.40	Indicative	0.50	Good	0.83	Very good
DIP	0.57	Good	44.96	Indicative	0.67	Very good	0.74	Very good
PP	0.62	Satisfactory	26.81	Satisfactory	0.62	Good	0.82	Very good
DOP	0.88	Indicative	71.92	Indicative	0.22	Indicative	0.90	Very good

Table 111 RC2014 120301B Belyando River at Gregory Development Road, (n = 7 years for flow and n = 6 years for WQ)

Parameter	RSR		PBIAS		NSE		R^2	
	Value	Rating (Moriasi 2007)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)	Value	Rating (Moriasi 2015)
Flow	0.21	Very good	0.13	Very good	0.95	Very good	0.95	Very good
TSS	1.36	Indicative	-66.98	Indicative	-0.85	Indicative	0.26	Indicative
TN	0.50	Very good	29.79	Satisfactory	0.75	Very good	0.91	Very good
PN	0.56	Good	23.49	Satisfactory	0.69	Very good	0.81	Very good
DIN	5.63	Indicative	-374.44	Indicative	-30.72	Indicative	0.90	Very good
DON	0.72	Indicative	55.32	Indicative	0.47	Satisfactory	0.95	Very good
TP	0.51	Good	-2.36	Very good	0.74	Very good	0.61	Good
DIP	0.70	Indicative	44.82	Indicative	0.50	Good	0.61	Good
PP	0.58	Good	-25.03	Satisfactory	0.66	Very good	0.61	Good
DOP	0.75	Indicative	53.34	Indicative	0.43	Satisfactory	0.73	Very good