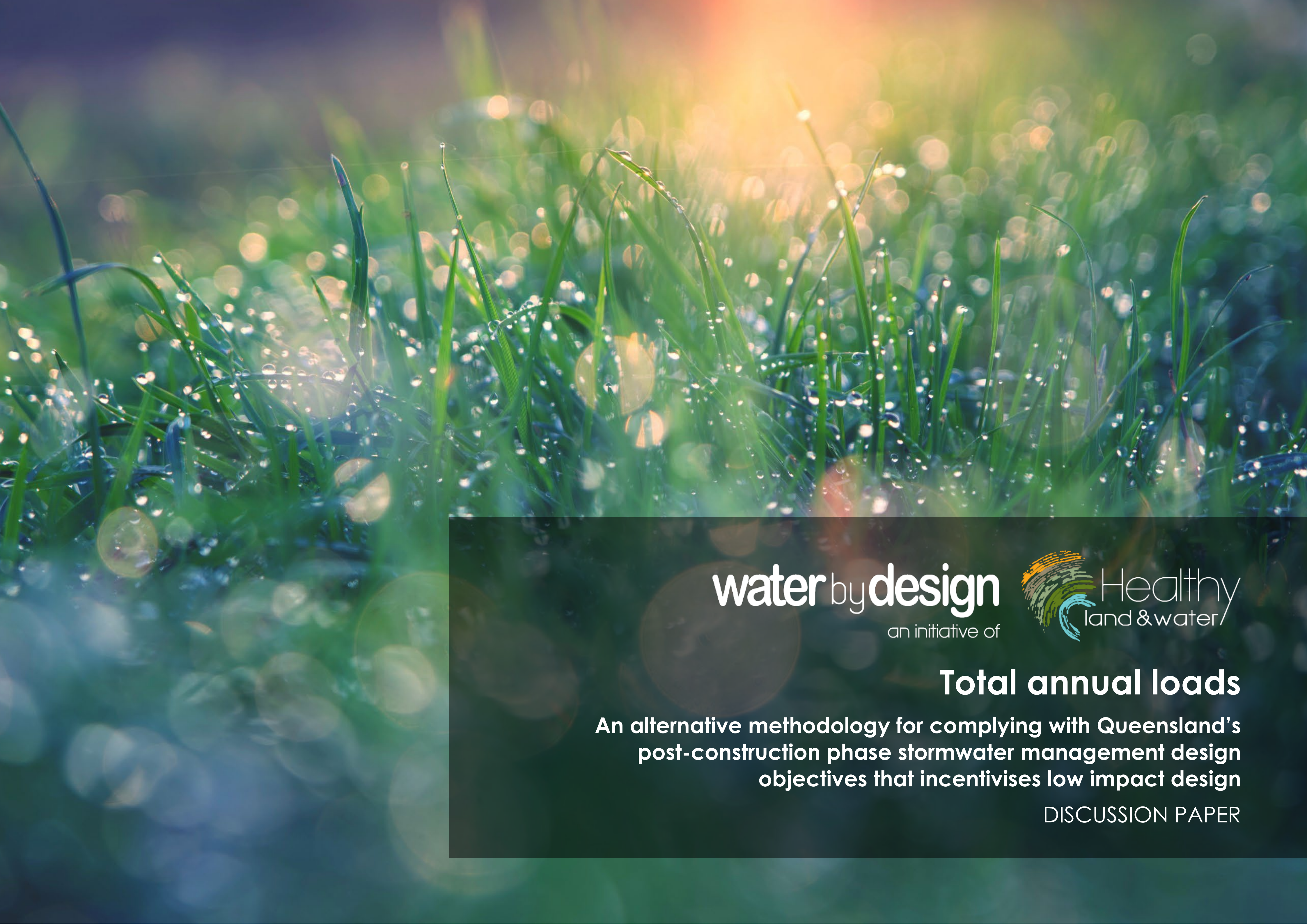

water by design
an initiative of
Healthy land & water

Total annual loads

An alternative methodology for complying with Queensland's post-construction phase stormwater management design objectives that incentivises low impact design

DISCUSSION PAPER

Total annual loads: an alternative methodology for complying with Queensland's post-construction phase stormwater management design objectives that incentivises low impact design

Version 1.1 | October 2022

Version history

Version	Date	Title	Contributors
1.0	October 2022	Total annual loads	Technical content provided by Glenn Browning. Reviews provided by Adrian Crocetti and Rachael Nasplezes, with significant input from Dr Dale Browne, Jack Mullaly, Juliette Monetti, Sally Boer, and Tony Weber. Images provided by Glenn Browning.
1.1	September 2022	Total annual loads: An alternative methodology for complying with Queensland's post-construction phase stormwater management design objectives that incentivises low impact design	Technical content provided by Ben Penhallurick, Dr Dale Browne, Chris Tanner, Glenn Browning, Juliette Monetti, Penny Galbraith, Sally Boer, and Shaw Abrey. Reviews provided by Leigh Bennett, Matthew Roetteler and Rachael Nasplezes. Images provided by Dr Dale Browne and Glenn Browning. Design by Georgia Glidden.

Citation

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Disclaimer

Purpose

The discussion paper has been prepared for consideration by the Queensland stormwater industry. It presents an alternative approach for complying with Queensland's post-construction phase stormwater management design objectives that incentivise low impact design. Industry stakeholders will have opportunities to provide feedback in workshops, subsequent to its release.

About Water by Design

Healthy Land & Water's Water by Design initiative works with individuals and organisations to identify and fill knowledge gaps and facilitate the uptake of improved practice in sustainable water management.

About Healthy Land & Water

Healthy Land & Water is the **peak environmental group** for South East Queensland. For over 20 years it has been dedicated to investing in and leading initiatives to build the prosperity, liveability, and sustainability of our 'future region'. Healthy Land & Water is focused on **delivering an environment for future generations to thrive**.

Our success and strength stems from our extensive knowledge, science and evidence which informs investment in our environment. We are experts in research, monitoring, evaluation and project management. Our team has led many thousands of projects to restore waterways and landscapes, improve native habitats, manage weeds, protect native species, inform policy and educate communities on the best ways to improve and protect the environment.

Working in partnership with Traditional Owners, government, private industry, utilities and the community, Healthy Land & Water delivers innovative and science-based solutions to challenges affecting the environment. Through a combination of scientific expertise and on-ground management works, Healthy Land & Water lead and connect through science and actions that will preserve and enhance our natural assets and support resilient regions long into the future.

Traditional Owner acknowledgement

We acknowledge that the place we now live in has been nurtured by Australia's First Nations' Peoples for tens of thousands of years. We believe the spiritual, cultural and physical consciousness gained through this custodianship is vital to maintaining the future of our region.

Queensland Government

Funding acknowledgement

The Urban Stormwater and Erosion and Sediment Control Capacity Building program is funded through the Queensland Government's Investing in Our Environment for the Future Program and delivered by the Department of Environment and Science (DES).

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List of abbreviations and acronyms

BaU	Business as usual
BCA	Benefit cost analysis
BCR	Benefit cost ratio
DES	Department of Environment and Science
GPs	Gross pollutants
LID	Low impact design
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NPV	Net present value
SMDOs	Stormwater management design objectives
SPP	State Planning Policy 2017
TAL	Total annual load
TN	Total nitrogen
TP	Total phosphorous
TSS	Total suspended solids
WSUD	Water sensitive urban design

EXECUTIVE SUMMARY

Post-construction phase stormwater management design objectives in the *State Planning Policy 2017* (State interest – water quality) have been successful in driving investment in stormwater treatment in Queensland. However, a few issues affect their ability to protect receiving waters from the impacts of urban development. Recognising these issues, Healthy Land & Water's Water by Design initiative has investigated the feasibility of alternative methodologies to Policy 5a and 5b of the *State Planning Policy 2017* that can be used to comply with the objectives. This discussion paper reports on the findings of that investigation, proposes a new compliance methodology that addresses the issues affecting the current objectives, and recommends steps to support the use of the proposed methodology by the Queensland stormwater industry.

The total annual loads approach is currently considered an alternative pathway to the current business as usual approaches that enables and incentivises a greater diversity of Water Sensitive Urban Design (WSUD) responses. It is this alternative pathway that is considered within this discussion paper as a workable solution that can incentivise developers to avoid generative stormwater pollution. These alternative design objectives align strongly to the stormwater management hierarchy that seeks to avoid, reduce, reuse, treat or discharge stormwater flows and pollutants, and improve the quality of water flowing to receiving waters.

The discussion paper has been prepared for consideration by the Queensland stormwater industry.

Industry stakeholders will have opportunities to provide feedback in workshops subsequent to its release.

INTRODUCTION

Post-construction phase stormwater management design objectives

The *State Planning Policy 2017* (SPP) outlines the Queensland Government's interest in protecting receiving waters from the impacts of urban development. To achieve this interest, the SPP requires development to achieve post-construction phase stormwater management design objectives either on-site (Policy 5a) or off-site (Policy 5b). These objectives are expressed as percentage reductions in the mean annual loads of typical stormwater pollutants generated by development after construction and with no stormwater treatment in place. The pollutants include total suspended solids (TSS), total phosphorous (TP), total nitrogen (TN), and gross pollutants (GPs) (Table 1).

Climatic region	TSS	TP	TN	GPs
South East Queensland	80%	60%	45%	90%
Central Queensland (South)	85%	60%	45%	90%
Central Queensland (North)	75%	60%	40%	90%
Cape York, Wet and Dry Tropics	80%	60%	40%	90%
Western Queensland	85%	60%	45%	90%

Table 1. Differences in the objectives between climatic regions.

The objectives vary across Queensland's climatic regions owing to differences in the relationships between climate, land uses, and pollution generation (Figure 1).

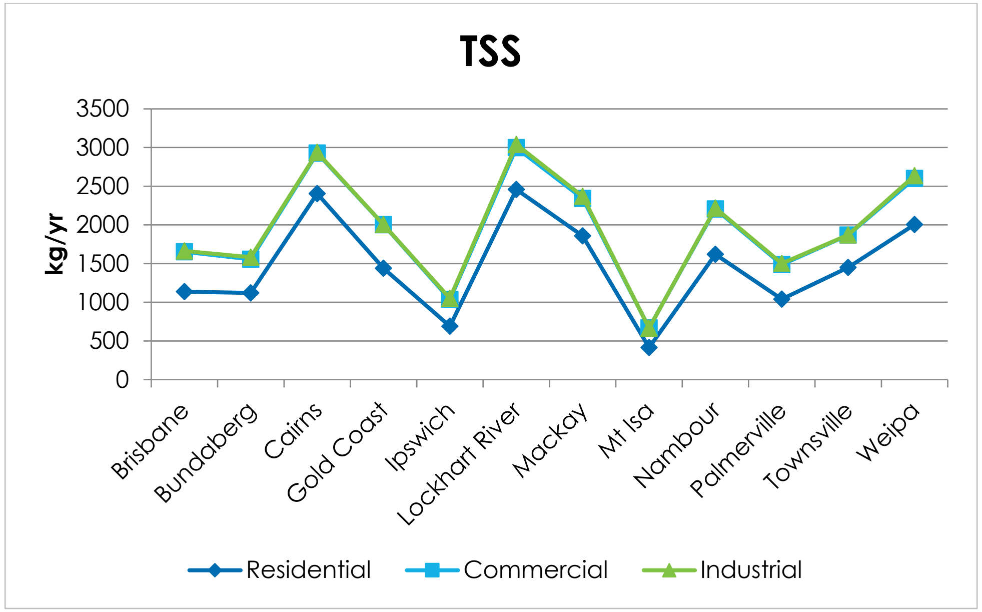


Figure 1. Differences in TSS generation between climatic regions.

The objectives apply to development as defined below:

1. A material change of use for an urban purpose that involves premises 2500m^2 or greater in size, and;
   a. Will result in six or more dwellings, or;
   b. An impervious area greater than 25% of the net developable area.
2. Reconfiguring a lot for urban purposes that involves premises 2500m^2 or greater in size and will result in six or more lots.

Current compliance methodology

Currently, complying with the objectives involves demonstrating percentage reductions in pollution loads using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) or an equivalent modelling software. Figure 2 describes the steps involved in this methodology, including how MUSIC is used. Note that this methodology may differ depending on the requirements of the local authority.

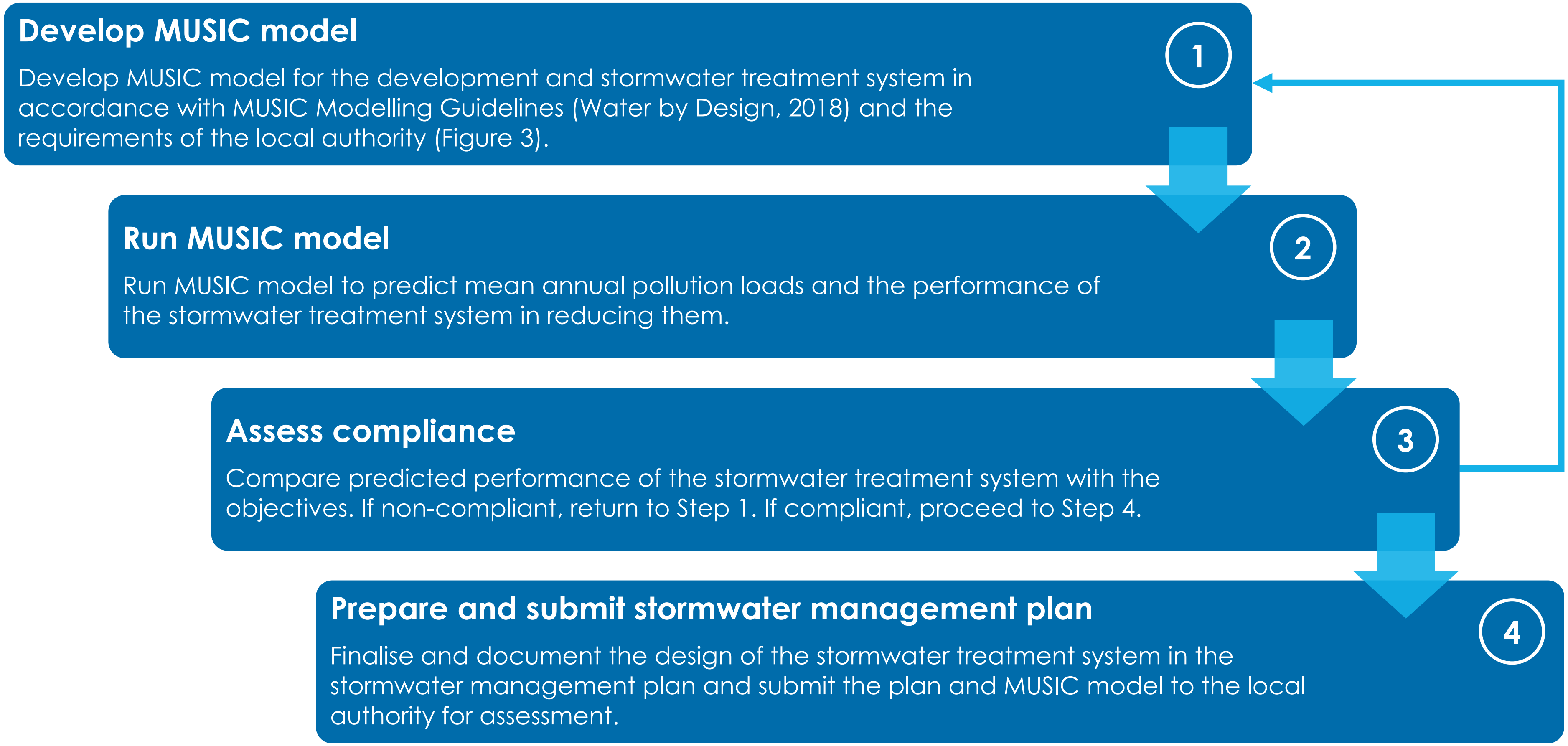


Figure 2. Current compliance methodology.

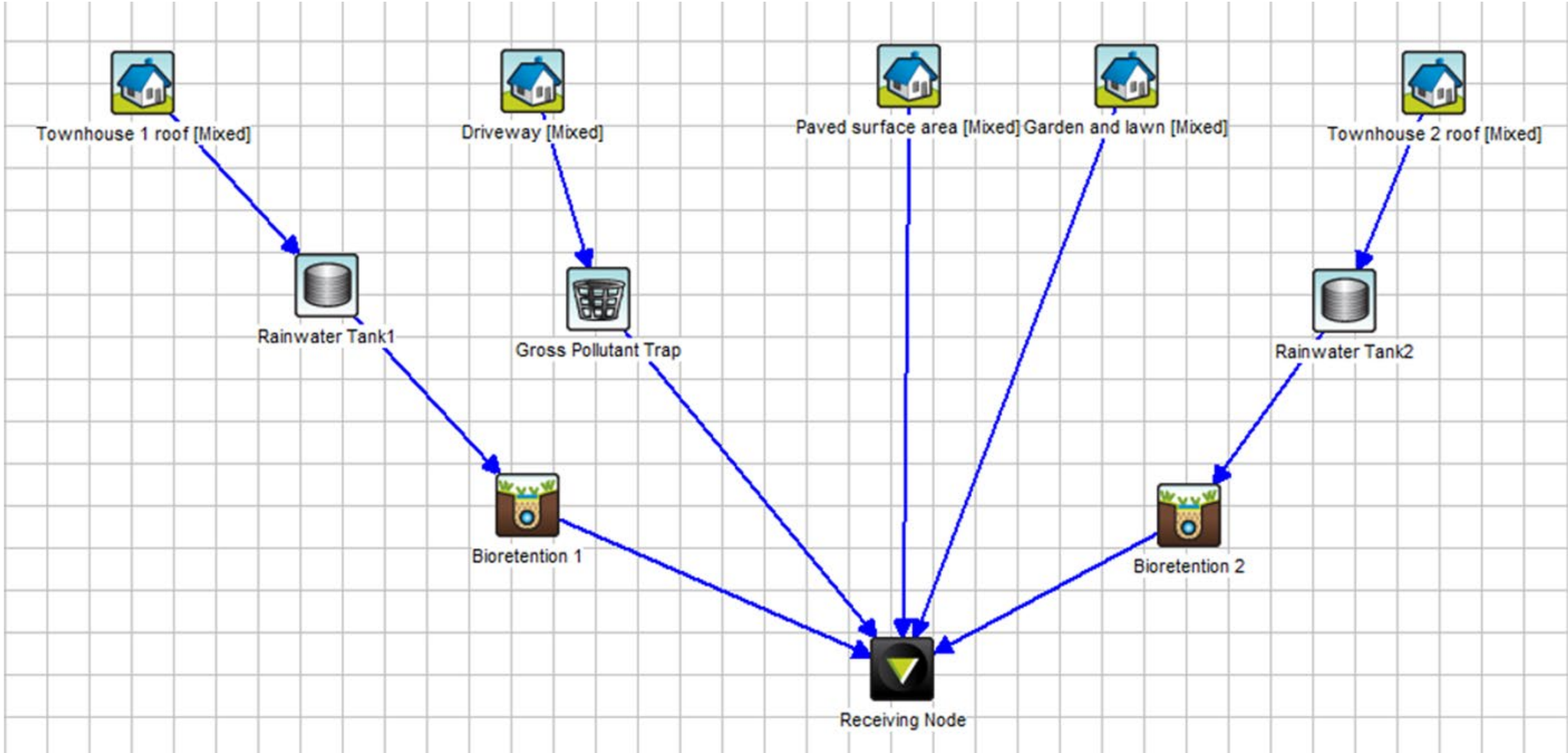


Figure 3. Current MUSIC modelling methodology.

Current approaches to urban design

There are several approaches to the design of urban developments that comply with the objectives. Broadly speaking, these may be divided into the two approaches presented in Figure 4. Note that most developments are a blend of these two approaches.

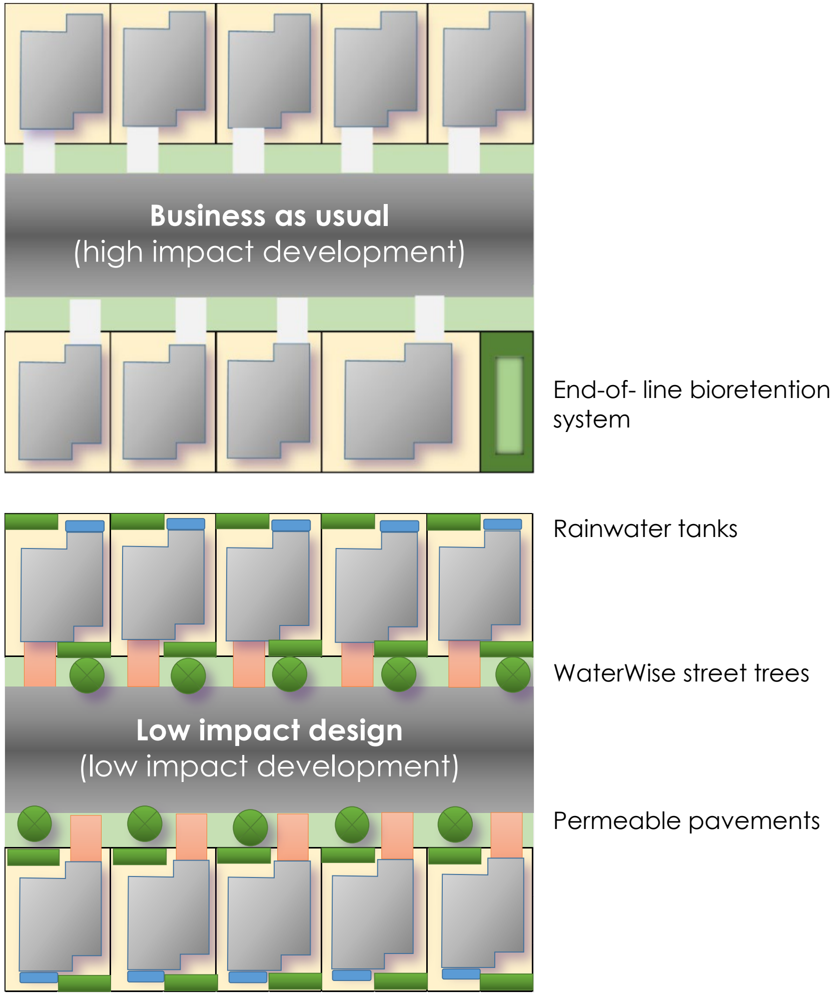


Figure 4. Current approaches to urban design.

Business as usual

Business as usual (BaU) involves providing little to no low impact approaches or at-source stormwater treatment in a development. Instead, a large end-of-line bioretention system (i.e. a bioretention system at the end of the stormwater catchment) is used as the only stormwater treatment measure. This approach results in more pollution and has higher impacts

Low impact design

Low impact design (LID) is less common, and involves minimising imperviousness in the development and using stormwater treatment measures to avoid, reduce, and reuse stormwater. **LID approaches can achieve greater liveability benefits than BaU, including increased urban amenity and cooling**. They result in less pollution and have lower impacts on the environment, or a low impact development. Refer to Water by Design's discussion paper on LID for more information (Water by Design, 2021).

ISSUES

While the current percentage reduction objectives have been successful in driving investment in stormwater treatment, a few issues affect their ability to protect Queensland's receiving waters from the impacts of urban development.

To illustrate these issues, consider the TSS loads and stormwater treatment requirements for two equivalent, hypothetical developments. The first development is high impact and generates 100 tonnes of pollution per year, while the second development is low impact and generates only 60 tonnes of pollution per year.

In both cases, to comply with the objectives for South East Queensland (Table 1), the developments would be required to reduce their pollution loads by 80%. For the high impact development, this would mean removing 80 tonnes of pollution per year and continuing to discharge 20 tonnes. For the low impact development, this would mean removing 48 tonnes of pollution per year and continuing to discharge 12 tonnes (Figure 5).

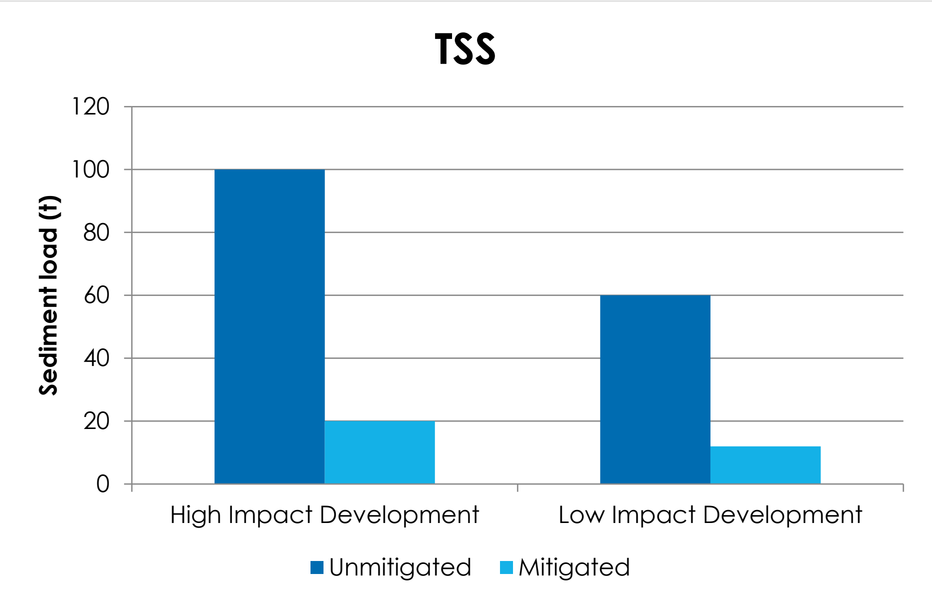


Figure 5. Differences in TSS between urban design approaches.

Residual pollution loads

Despite both developments complying with the objectives, the high impact development will discharge 8 tonnes of pollution per year more than the low impact development (i.e. will have a higher residual pollution load). This is due to the form of the objectives as percentage reductions which does not account for differences in approaches to urban design, including how much pollution is generated. Consequently, under the current objectives, stormwater is not being treated according to the impact of development.

Needs of receiving waters

Currently, high impact developments employing a BaU approach comply with the objectives and can be approved anywhere in Queensland. As demonstrated above, these developments can have significantly higher residual pollution loads than low impact developments. Unless there is stormwater treatment downstream, the additional pollution will not be mitigated and will enter and degrade receiving waters. Consequently, under the current objectives, stormwater is not being treated based on what's needed to protect receiving waters.

Disincentive for best practice

To comply with the objectives, a low impact development may require a disproportionately large stormwater treatment system, despite generating far less pollution (Figure 5). This is because the treatment of stormwater pollution follows an exponential decay curve in MUSIC, resulting in decreasing stormwater treatment performance with increasing stormwater treatment effort (i.e. diminishing returns) (Figure 6).

In simpler terms, reducing pollution becomes progressively harder the smaller the load. Given the significant costs of purchasing land and delivering stormwater treatment measures, it can be financially harder for low impact developments to achieve compliance with the objectives relative to high impact developments. In fact, in some cases, higher impact developments can have similarly sized or even smaller stormwater treatment measures than lower impact developments. Consequently, under the current objectives, **LID approaches are disincentivised compared to BaU**. Conversely, BaU approaches are incentivised.

This approach drives outcomes that are inconsistent with the best practice stormwater management hierarchy by incentivising the generation and treatment of stormwater over its avoidance, reduction, and reuse (Figure 7) (adapted from ARMCANZ & ANZECC, 2000).

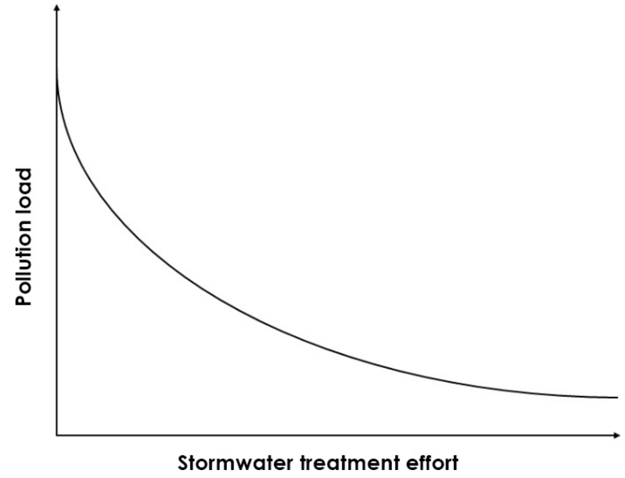


Figure 6. Diminishing returns of stormwater treatment effort.

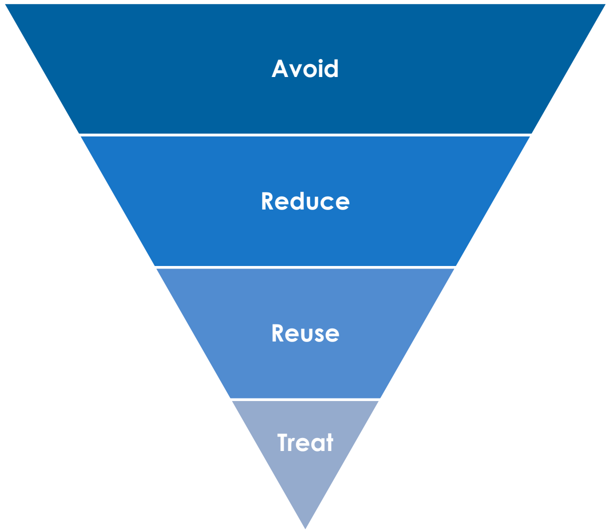


Figure 7. Best practice stormwater management hierarchy.

SOLUTIONS

Healthy Land & Water's Water by Design initiative has investigated the feasibility of alternative methodologies for complying with the current percentage reduction objectives. To address the issues described above, a total annual load approach has been identified as offering the most cost effective and workable solution.

Total annual load objectives

The term total annual load (TAL) refers to an objective that specifies the total amount of stormwater pollution that may be discharged from a given area over a given amount of time. In other places (e.g. the United States of America), the term total maximum daily load is used to refer to similar volume-based pollution discharge limits (United States Environmental Protection Agency, 2021).

TAL objectives are being used in other parts of the world to protect receiving waters

TAL objectives address the issues described above in the following ways:

- By setting a total amount of stormwater pollution that may be discharged from developments, rather than a percentage reduction.
- By allowing authorities to set objectives based on what's needed to protect receiving waters. This can be used to limit development in catchments with sensitive receiving waters or conversely, allowing more development where minimal harm can occur.
- By creating a level playing field for LID approaches. Where TAL objectives are relatively small (e.g. because of the high environmental or ecological value of a receiving water), an LID approach may represent the only feasible option.

Another benefit of TAL objectives is that they allow for low impact developments to generate water quality credits when more pollution is treated than is required. These credits could be used to offset the impacts of development in catchments where minimal harm can occur to receiving waters, further incentivising LID approaches.

Another important benefit is that it makes it easier to implement Living Waterways. A lot of this work was proposed in the background document for living waterways in 2013.

Proposed compliance methodology

Establishing TAL objectives based on what's needed to protect receiving waters would likely require significant work including changes to existing policy and practice. As such, Healthy Land & Water's Water by Design initiative has identified a compliance methodology that uses the current percentage reduction objectives and MUSIC modelling software to calculate and achieve the benefits of TAL objectives.

The methodology represents a hybrid of the current compliance methodology and TAL objectives, specifically by using:

- Percentage reduction objectives to calculate TAL objectives from mean annual pollution loads.
- MUSIC to demonstrate compliance with TAL objectives through a LID approach.

Figure 8 describes the steps involved in the TAL compliance methodology, including how MUSIC is used. Note that the methodology is likely to be refined based on feedback from the Queensland stormwater industry obtained through workshops subsequent to the release of this discussion paper.

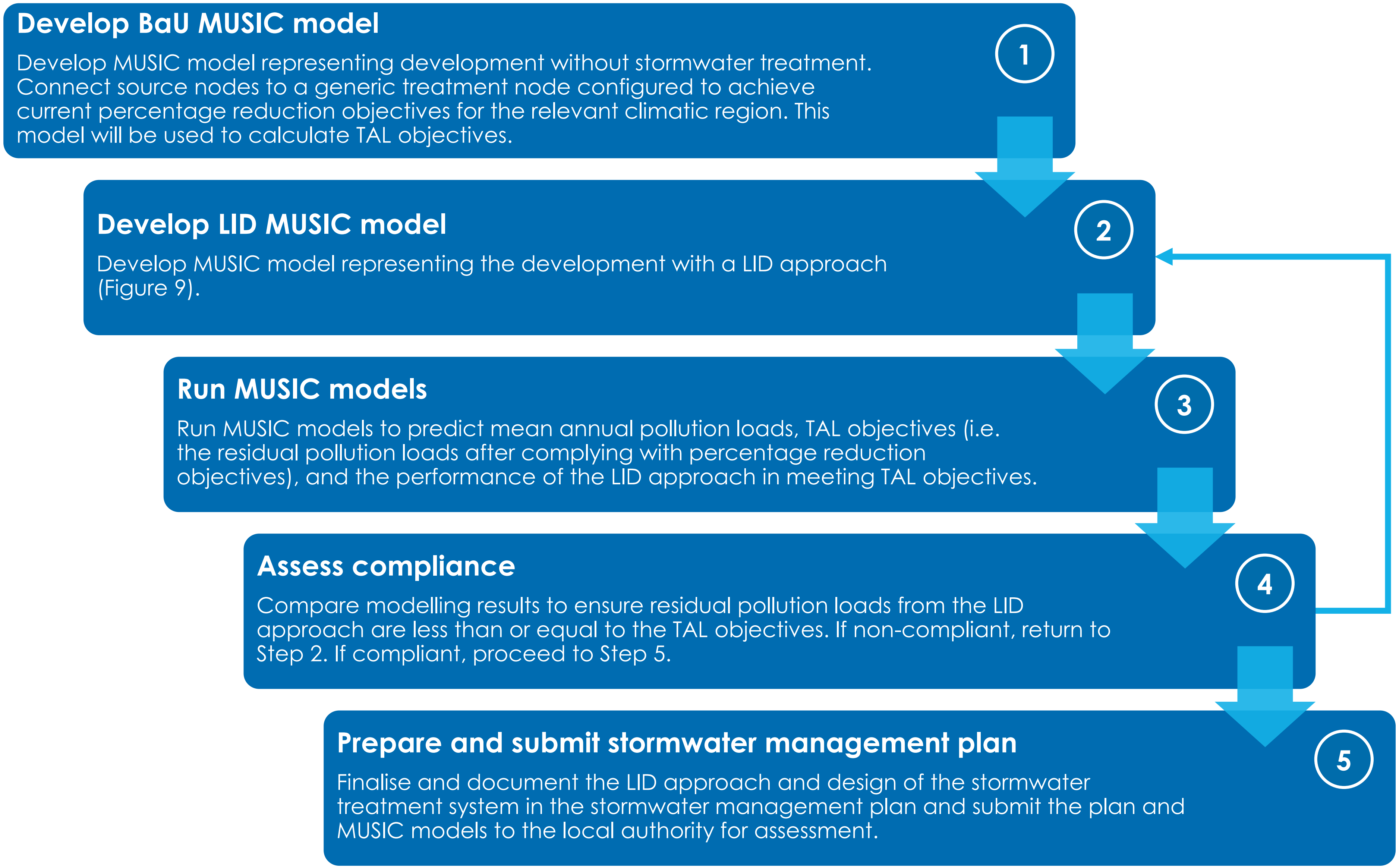


Figure 8. Proposed compliance methodology.

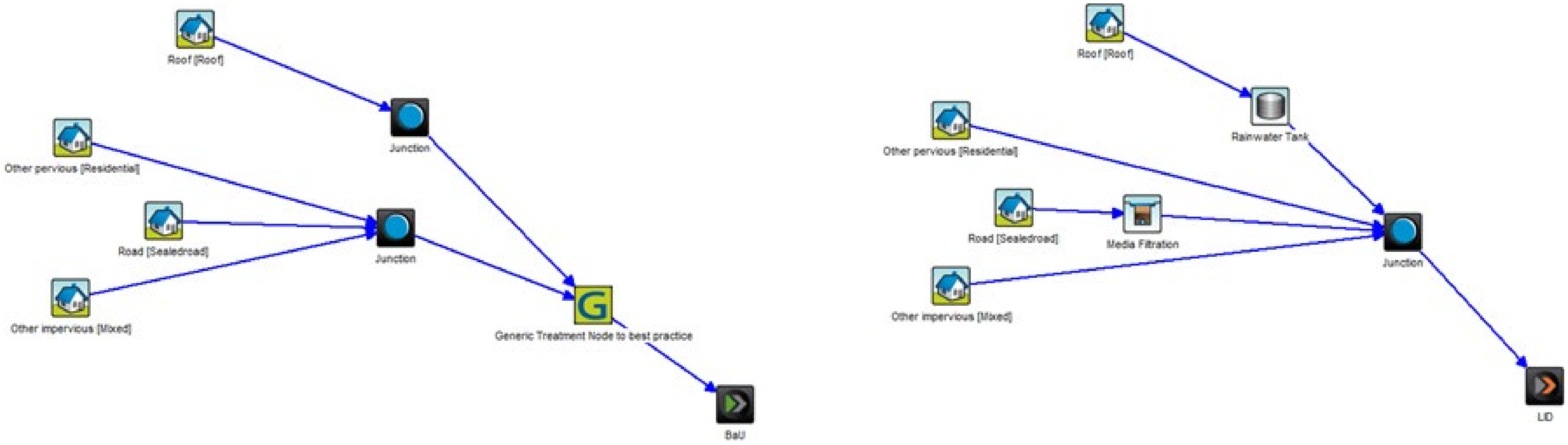


Figure 9. Proposed MUSIC modelling methodology.

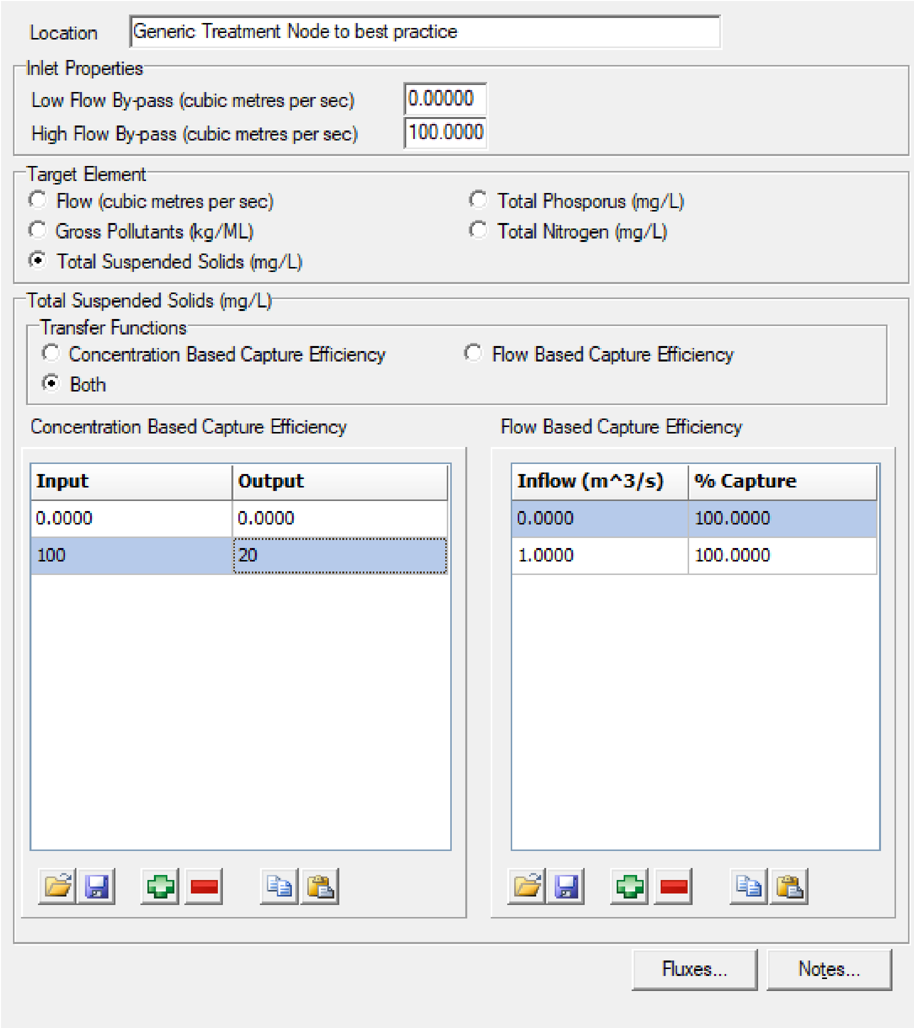


Figure 10. Input and output concentrations in generic treatment node.

Developing the BaU MUSIC model

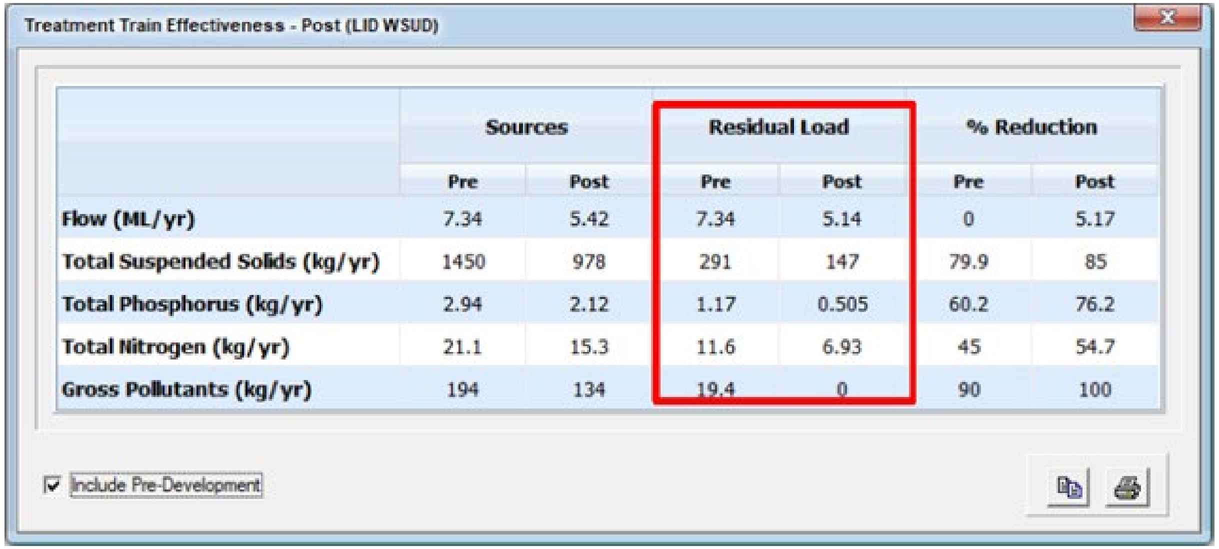
The BaU MUSIC model allows for the calculation of TAL objectives which are expressed as the residual pollution loads from the development after complying with current percentage reduction objectives.

The model should be developed to represent the development without LID or stormwater treatment. Source nodes should be connected to a generic treatment node configured to achieve percentage reduction objectives for the relevant climatic region. This requires the modeller to set the input and output concentrations of target pollutants based on the percentage reduction objectives in the generic treatment node, as presented in Figure 10.

Table 2 provides an example of the input and output concentrations for South East Queensland.

Pollutant	Percentage reduction objective	Input concentration	Output concentration
TSS	80%	100 mg/L	20 mg/L
TP	60%	100 mg/L	40 mg/L
TN	45%	100 mg/L	55 mg/L
GPs	90%	100 mg/L	10 mg/L

Table 2. Input and output concentrations in generic treatment node.



Treatment Train Effectiveness - Post (LID WSUD)

	Sources		Residual Load		% Reduction	
	Pre	Post	Pre	Post	Pre	Post
Flow (ML/yr)	7.34	5.42	7.34	5.14	0	5.17
Total Suspended Solids (kg/yr)	1450	978	291	147	79.9	85
Total Phosphorus (kg/yr)	2.94	2.12	1.17	0.505	60.2	76.2
Total Nitrogen (kg/yr)	21.1	15.3	11.6	6.93	45	54.7
Gross Pollutants (kg/yr)	194	134	19.4	0	90	100

Include Pre-Development

Figure 11. Performance of LID model in meeting TAL objectives.

Assessing compliance with TAL objectives

After running the models, open the 'Treatment Train Effectiveness' box and ensure the 'Include Pre-Development' checkbox has been checked (Figure 11). Compare the modelling results to ensure residual pollution loads from the LID approach (Post) are less than or equal to the TAL objectives (Pre). If non-compliant, revise the LID model.

Benefits of the generic treatment node

The key benefit of using the generic treatment node in the BaU model is that results can be reported and compared in MUSIC, allowing for models to be efficiently modified and iterated in the event of non-compliance. Alternatively, modellers may export results to calculate TAL objectives and assess compliance for themselves.

The proposed TAL methodology complies with the current percentage reduction objectives while requiring only one additional step compared to the current methodology (Figure 2). It addresses the issues of residual pollution loads and removes the disincentive to pursue LID approaches.

However, as noted above, it does not establish TAL objectives based on what's needed to protect receiving waters. Incorporating stronger protections for high ecological value and sensitive receiving waters in the SPP and other environmental policy should be a medium to long-term objective for the Queensland Government (Alluvium & Water by Design, 2018; Water by Design, 2020), and TAL objectives may play a part in achieving this.

Benefit cost analysis

A benefit cost analysis (BCA) was undertaken by E2DesignLab to investigate the benefits and costs of a LID approach achieved through the TAL methodology (Figure 12).

The BCA used a greenfield development case study in Logan, Queensland.

The BaU approach included:

- 872 lots with an average area of 387 m^2.
- 74.5 ha combined development area.
- 80% imperviousness.
- An end-of-line bioretention system with a combined area of 4,690 m^2.

The LID approach included:

- The same number of lots, average lot area and combined development area.
- 50% imperviousness.
- 1 rainwater tank and WaterWise street tree per lot.
- A smaller end-of-line bioretention system with a combined area of 2,500 m^2.

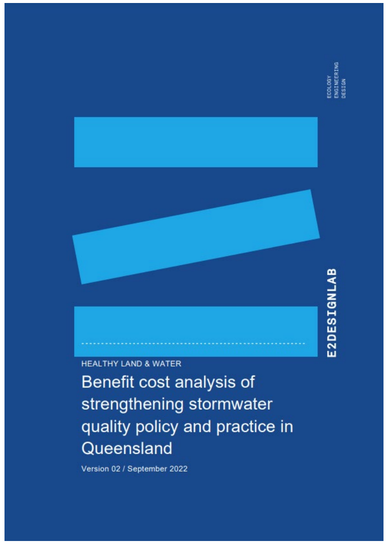


Figure 12. Benefit cost analysis of TAL methodology.

The BCA estimated benefits and costs for different stakeholder groups, including the developer, local authority, and property owner. Benefits analysed included:

- Improvements in stormwater quality through the use of bioretention systems and WaterWise street trees.
- Reductions in drinking water use through the use of rainwater tanks.
- Increases in property values through improved aesthetics from WaterWise street trees and bioretention systems.
- Increases in developable land through reductions in end-of-line bioretention area.
- Avoided street tree replacement costs through the use of WaterWise street trees.

Costs were drawn from available sources, including Melbourne Water's Water Sensitive Urban Design Lifecycle Costing Data (Melbourne Water, 2013) and adjusted for inflation to Australian dollars in 2022. The BCA was undertaken over 20 years using the

Cooperative Research Centre for Water Sensitive Cities' Investment Framework for Economics of Water Sensitive Cities (INFFEWS) tool.
Table 3 presents the benefits, costs, and net present value (NPV) for the different stakeholder groups.

Stakeholder	Benefits					Total benefits	Total costs	NPV
	Stormwater quality	Drinking water use	Property values	Developable land	Street trees			
Developer	$0	$0	$0	$881,475	$0	$881,475	$9,096,200	-$8,214,725
Local authority	$11,624,653	$0	$0	$0	$241,482	$11,866,135	$3,876,774	$7,989,361
Property owner	$0	$1,878,353	$8,688,299	$0	$0	$10,566,653	$593,078	$9,973,575
Totals	**$11,624,653**	**$1,878,353**	**$8,688,299**	**$881,475**	**$241,482**	**$23,314,263**	**$13,566,052**	**$9,748,211**

Table 3. Benefit cost analysis of TAL methodology.

The results show an overall positive outcome for the LID approach resulting in a strong benefit cost ratio of 2.0, with the developer bearing most of the costs and the local authority and property owner receiving most of the benefits, particularly through improved stormwater quality and reductions in drinking water use. These findings support work undertaken by Water by Design which indicate that LID approaches can have lower overall costs when compared to BaU (Water by Design, 2015).

LID approaches can have greater benefits than costs relative to BaU

Industry peer review

To ensure the TAL methodology is technically feasible, an expert peer review was undertaken by E2DesignLab (Figure 13).

The review used a greenfield development case study in the Sunshine Coast, Queensland. It focussed on determining if the methodology was appropriate and acceptable through trial applications of different LID approaches (Figure 14).

Overall, it found that the TAL methodology:

- Complies with the current percentage reduction objectives.
- Enables and incentivises a greater diversity of LID approaches while achieving the same or better stormwater management outcomes than BaU.
- Is appropriate and acceptable, making use of readily available modelling tools and the current knowledge and skills of stormwater industry practitioners.

Figure 13. Technical review of TAL methodology.

The TAL methodology enables and incentivises a greater diversity of LID approaches

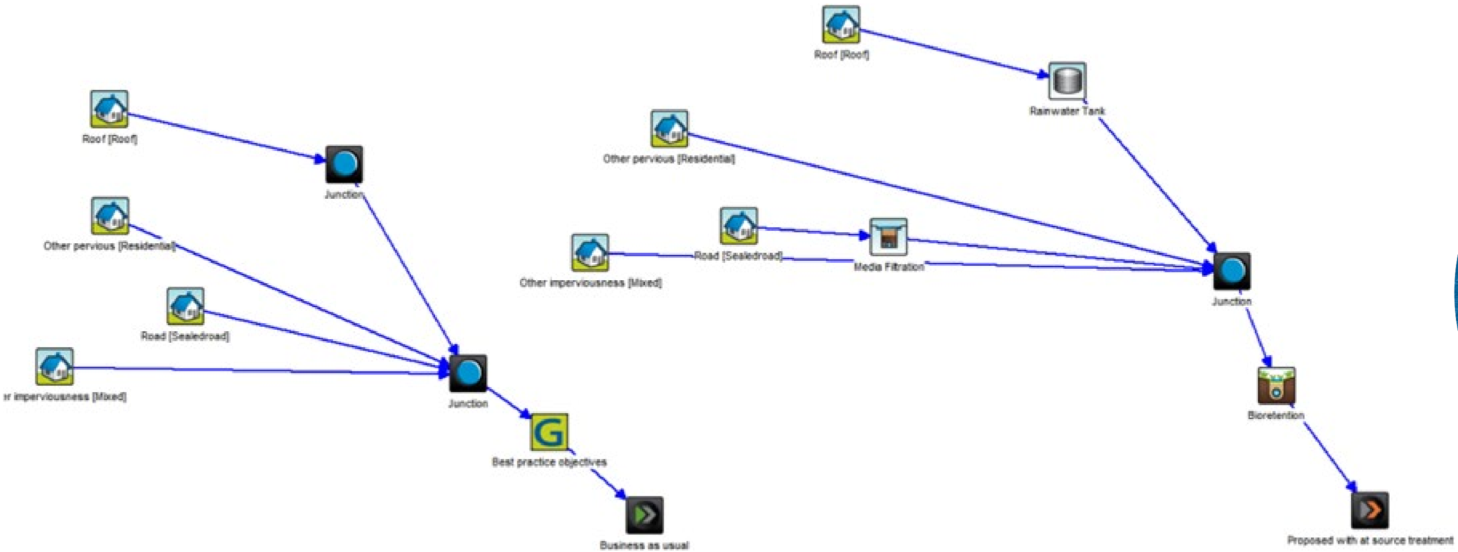


Figure 14. Trial applications of TAL methodology.

The methodology presented in Figure 8 was refined based on recommendations from the review.

The TAL methodology uses readily available modelling tools and the skills and knowledge of practitioners

The review also found that the methodology represented the path of least resistance to achieving outcomes that align with the best practice stormwater management hierarchy (Figure 7). For example, the TAL methodology would not require substantial changes to existing environmental policy including the SPP and current percentage reduction objectives. However, it was identified that the proposed methodology is more complex than what is currently in place (Figure 2).

Additionally, some potential technical challenges were identified:

- MUSIC modellers may misrepresent the imperviousness and other characteristics of developments to falsely reduce stormwater pollution generation and stormwater treatment requirements.
- There may be some divergence of modelling results between the BaU and LID models owing to the stochastic method used to model stormwater pollution generation in MUSIC.
- There is a lack of MUSIC modelling guidance to avoid inconsistent and unrealistic modelling results, including, but not limited to, how to account for baseflows and the permeability of different surfaces.

It was recommended that further industry consultation and research be undertaken to develop guidance and requirements to address these issues.

Industry consultation

Industry feedback on the TAL methodology was obtained through a series of in-person and online workshops with industry representatives and through a Communities of Practice in late 2021. The purpose of the workshops was to present and discuss the LID and the TAL methodology, with a particular focus on determining if the TAL methodology was appropriate and acceptable to industry stakeholders. Three events were held with over 70 attendees.

Overall, there was general support for the TAL methodology. However, attendees noted that further work needs to be undertaken, including:

- Establishing an industry working group to advance LID and the TAL methodology.
- Incorporating an additional policy in the SPP to support the use of the TAL methodology as an alternative for complying with the current percentage reduction objectives.
- Consistent with the recommendation from the expert peer review, undertaking further consultation and research to develop guidance and requirements for the TAL methodology.

CONCLUSION

The current post-construction phase stormwater management design objectives have been successful in driving investment in stormwater treatment in Queensland. However, their ability to protect receiving waters from the impacts of urban development is limited, largely owing to the form of the stormwater design objectives as percentage reductions. Consequently, developments can be approved irrespective of differences between their residual pollution loads and what's needed to protect receiving waters. Additionally, the objectives can disincentivise best practice approaches to urban design, resulting in the generation and treatment of pollution rather than the avoidance, reduction, and reuse of stormwater.

Recognising these issues, Healthy Land & Water's Water by Design initiative has investigated the feasibility of alternative methodologies for complying with the objectives. Through the investigation, TAL objectives were identified as offering solutions. Together with E2DesignLab, Healthy Land & Water's Water by Design initiative has proposed a compliance methodology that makes use of current policy and practice to calculate and achieve the benefits of TAL objectives. The methodology represents a hybrid of the current compliance methodology and TAL objectives, specifically by using:

- Percentage reduction objectives to calculate TAL objectives from mean annual pollution loads.
- MUSIC to demonstrate compliance with TAL objectives through a LID approach.

The TAL methodology complies with the current percentage reduction objectives while requiring only one additional step compared to the current methodology. It addresses the issues of residual pollution loads and the disincentive for best practice. However, it does not establish TAL objectives based on what's needed to protect receiving waters (i.e. as the objectives are not based on an understanding of the environmental values or quality of receiving waters and how development should be controlled to protect and enhance them).

An expert peer review undertaken by E2DesignLab supports the above and found that the TAL methodology:

- Enables and incentivises a greater diversity of LID approaches while achieving the same or better stormwater management outcomes than BaU.
- Is appropriate and acceptable and makes use of readily available modelling tools and the current knowledge and skills of stormwater industry practitioners.

However, it was identified that the proposed methodology is more complex than what is currently in place. Additionally, some technical challenges were identified:

- MUSIC modellers may misrepresent the imperviousness and other characteristics of developments to falsely reduce stormwater pollution generation and stormwater treatment requirements.
- There may be divergence of modelling results between the BaU and LID models owing to the stochastic method used to model stormwater pollution generation in MUSIC.
- There is a lack of MUSIC modelling guidance to avoid inconsistent and unrealistic modelling results, including, but not limited to, how to account for baseflows and the permeability of different surfaces.

Feedback obtained through the expert peer review and industry workshops indicated that the TAL methodology represents a promising way forward. However, further work is needed to ensure effective uptake and adoption by the Queensland stormwater industry.

Next steps

Healthy Land & Water's Water by Design initiative recommends the following next steps:

- Establish a long-term industry working group to advance LID and the TAL methodology.
- Through the working group, undertake further consultation and research to address the issues identified through the expert peer review (e.g. by developing guidance and requirements for the TAL methodology).
- When the above steps have been undertaken, add the following statement under Policy 5 (b) of the SPP to support the use of the TAL methodology as an alternative for complying with the current percentage reduction objectives.
- Using the total annual load methodology, achieves an alternative locally appropriate solution that achieves an equivalent or improved water quality outcome to the relevant stormwater management design objectives in Table B, Appendix 2.

Healthy Land & Water's Water by Design initiative also recommends the following steps for long-term consideration by the working group and Queensland stormwater industry:

- Investigate the use of TAL objectives as a means to generate water quality credits for LID approaches that treat more stormwater pollution than is required. These credits could be used to offset the impacts of development in catchments where minimal harm can occur to receiving waters, further incentivising LID approaches.
- Investigate stronger protections for high ecological value and sensitive receiving waters and, where appropriate, incorporate them into policy such as the SPP State interest – water quality. TAL objectives may be a plausible option for achieving stronger protections if they are based on what's needed to protect receiving waters.

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