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Contact:	Daniel Dhiacou / Andrew Norris
Our Ref:	P1203365JC56V03
cc.	John Toon, Matt Philpott

July 30, 2018

Independent Planning Commission NSW
Attn: Mary O'Kane
By Email

Dear Mary,

RE: INDEPENDENT PLANNING COMMISSION WATER QUALITY BRIEFING – CULBURRA WEST MIXED USE DEVELOPMENT (SSD 3846)

1. INTRODUCTION

Further to the applicant briefing meeting of 19 July 2018 at IPC offices, Martens & Associates (MA) have prepared this document to brief the IPC on the water quality matters related to the proposed Culburra West mixed-use development.

MA have prepared the water quality (MUSIC) and estuary hydrodynamic / water quality (TUFLOW AD) models and assessments for the proposed development, as well as the estuary management study and the water quality monitoring plans for the site. All assessments have been prepared in accordance with a range of industry best practice guidelines and principles. These assessments have been subject to extensive review by the NSW Department of Planning & Environment (DoPE) independent water quality experts, BMT WBM and later Alluvium.

DoPE has recommended refusal of the proposed development due, in part, to stormwater management concerns. DoPE consider that the precautionary principle has not been satisfied as there is inadequate scientific certainty that the proposal shall not cause serious or irreversible environmental damage. DoPE conclude at p54 of their EA Report:

- The potential water quality impacts of the concept proposal on the Crookhaven River estuary present an unacceptable risk to oyster aquaculture, protected wetlands, marine vegetation and fish habitat
- There is scientific uncertainty that the water quality impacts can be adequately mitigated by the proposed stormwater management system, and the Applicant has been unable to adequately demonstrate there would not be serious or irreversible impacts
- The potential water quality impacts on Lake Wollumboola are inconsistent with strategic planning objectives to protect the lake from urban development

Head Office
Suite 201, 20 George Street
Hornsby NSW 2077, Australia
Ph 02 9476 9999 **Fax** 02 9476 8767

> mail@martens.com.au
www.martens.com.au
MARTENS & ASSOCIATES P/L
ABN 85 070 240 890 ACN 070 240 890

This is a wrong assessment of the extensive water quality assessment presented as part of the application. Martens & Associates (MA) documentation supporting the application have used best practice modelling approaches to demonstrate the proposed stormwater management solution addresses and successfully ameliorates potential water quality impacts. The peer review undertaken in the development of these assessments has ensured modelling and design is consistent with industry best practice. The application has included an estuary water quality model to further assess receiving water quality impacts. This model is, we understand, a NSW first for a residential development. The approach adopted and the assessment and results presented meets the test of the precautionary principle providing scientific certainty of the conclusion that the development shall not adversely impact receiving water quality.

This document addresses water quality comments from the DoPE assessment report, the peer reviewer's last comment and the IPC's questions. It demonstrates that water quality management issues have been addressed and that the development provides scientific certainty that that the development shall cause no significant water quality impacts.

2. REFERENCE REPORTS

The reports referred to throughout this document are:

- Martens and Associates, '*Water Cycle Management Report – Mixed Use Subdivision; West Culburra, NSW';* Report reference: P1203365JR01V07; dated November 2016 (hereafter WCMR).

- Martens and Associates, '*Estuarine Management Study – Mixed Use Subdivision; West Culburra, NSW';* Report reference: P1203365JR02V04; dated November 2016 (hereafter EMS).

- Martens and Associates, '*Water Quality Monitoring Plan – Mixed Use Subdivision; West Culburra, NSW';* Report reference: P1203365JR03V04; dated November 2016 (hereafter WQMP).

- Martens and Associates, '*Estuarine Processes Modelling Report – Proposed Mixed Use Subdivision; West Culburra, NSW';* Report reference: P1203365JR04V02; dated November 2016 (hereafter EPMR).

- Eco Logical Australia, '*West Culburra Aquatic Ecology Impact Assessment: Proposed Mixed Use Subdivision Aquatic Ecology Impact Assessment*'; Report Reference 16WOL-5719; dated 4 May 2017 (hereafter AEIA).

- Martens and Associates, '*Water Cycle Management Report Addendum; Mixed Use Subdivision, West Culburra (SSD 3846)*'; Report reference P1203365JC49V01; dated 8 June 2017 (hereafter WCMRA).

3. BEST PRACTICE ENGINEERING

MA have undertaken each assessment in accordance with industry best practice standards. Assessment has addressed the requirements of a range of guidelines:

- Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC)*.

- Australian Rainfall & Runoff (AR&R) (2013), *Project 11 – Blockage of Hydraulic Structures Stage 2 Report.*

- Landcom (2004), *Managing Urban Stormwater, Soils and Construction Volume 1, 4th Edition*.

- NSW DECCW (2010), *New South Wales Natural Resources: Monitoring, Evaluation and Reporting Strategy 2010 – 2015.*

- NSW DPI (2006), *NSW Oyster Industry Sustainable Aquaculture Strategy (OISAS)*.

- NSW Government (1997), *NSW Coastal Policy 1997*.

- NSW OEH (2013), *Assessing Estuary Ecosystem Health: Sampling, data analysis and reporting protocols.*

- SEPP 62 (2011), *Sustainable Aquaculture.*

- Shoalhaven City Council (2014), *Development Control Plan*.

- Sydney Metropolitan Catchment Management Authority (SMCMA) (2010), *Draft NSW MUSIC Modelling Guidelines*.

- The neutral or beneficial effect (NorBE) design principle.

4. RESPONSES TO DOPE & PEER REVIEWER WATER QUALITY COMMENTS

Attachments A and B of this document respond in details to comments in:

- DoPE in Section 6.2 of their report 'State Significant Development Assessment: West Culburra Concept Proposal SSD 3846' (June 2018), hereafter referred to as the DoPE SSD assessment (Attachment A).

- BMT WBM and Alluvium, DoPE's water quality peer reviewers, in their submissions of July 2017 (Attachment B).

The majority of the DoPE SSD assessment repeats historical water quality issues raised by government agencies and the peer reviewers over several years of assessment and consultation. These matters have previously been addressed by the comprehensive assessment reports listed in Section 2. The DoPE SSD assessment is therefore misleading as it implies that issues noted have not been addressed by the application. However, the only water quality matters not addressed are the peer reviewer's comments of July 2017 (presented to the applicant by DoPE only in July 2018).

Between March 2014 and June 2017, MA and the peer reviewers had communicated extensively to resolve modelling and assessment matters to the peer reviewers' satisfaction. The number of issues requiring resolution were reduced with each correspondence. In May 2017 the applicant received comments from the peer reviewers and a cover letter from DoPE which noted 'the advice represents the culmination of a lengthy collaborative process between BMT WBM and Martens'. MA prepared the WCMRA (June 2017) to address these few outstanding issues, and no response was received by the applicant for over a year.

As mentioned in the applicant briefing meeting for the IPC, the applicant was only made aware of the existence of the peer reviewer's July 2017 comments after reading the DoPE

SSD assessment, and only received the comments on 17 July 2018, a full year after they were prepared and submitted to DoPE. Having only days to respond we have prepared the responses in Attachment B and summarised below.

The final response provided by the peer reviewers include a number of minor outstanding concerns, which can be summarised as:

1. A concern that inadequate development layout details are provided – DoPE has specifically required these details not be shown so this concern is not relevant.

2. Lack of information regarding elements of the proposed stormwater treatment train –the train as proposed had been documented and modelled without any such questions being raised by the peer reviewer for 3 years - the 'new concern' is therefore unreasonable.

3. A 'suspicion' (reviewer's own term) regarding the treatment train effectiveness – however the proposed configuration is supported by industry literature, and sensitivity testing demonstrates NorBE is achieved.

4. Estuary model was not rerun with the latest design solution – however previous assessment included scenarios with pollutant loads both higher and lower than the final assessed load had demonstrated negligible estuary water quality impacts. Given loads both higher and lower had no impact it is unnecessary to rerun a scenario between to confirm no impact.

The final comments from the peer reviewer presented largely unsubstantiated claims and complaints. The only 'suspected' technical deficiency is shown to be incorrect based on industry literature. Peer reviewer's comments therefore contain no reasons for refusal of the application.

In conclusion, the MUSIC and TUFLOW AD modelling undertaken are examples of industry best practice modelling and assessment with the additional benefit of a detailed peer review. The models assess the development's water quality impacts and provide scientific certainty of the modelled results thereby addressing the requirements of the precautionary principle. The modelling confirms there will be no significant impacts on receiving environment water quality, hence the development should be approved.

5. RESPONSES TO IPC WATER QUALITY COMMENTS

Several water quality questions were raised in the IPC applicant briefing agenda. These were addressed during the meeting of 19 July 2018, and a copy of the briefing notes are provided in Attachment C. Each of the water quality items raised by the IPC are addressed in the following sections.

5.1. Efficacy of Stormwater Treatment Train & Construction Phase Controls

The proposed stormwater treatment train has been developed through consultation with the peer reviewer over several years. MA have revised and refined the design to address peer reviewer requirements. The result of this consultation is a rigorous, best practice design approach which achieves the project objective of a NorBE, which is the highest level of environmental protection required for NSW developments.

Full responses to each of the latest peer reviewer comments are provided in Attachment B. As discussed at Section 4, the peer reviewer's final concerns about the treatment train can be summarised as either complaints or 'suspicion' which is demonstrated to be

incorrect based on industry literature. The peer review comments contain no reasons for the application's refusal.

The majority of the items raised in the DoPE SSD assessment report are historical comments which have since been addressed in the suite of reports prepared by MA. This is also the case with the peer reviewer comments: DoPE repeats comments from as far back as March 2014 which have since been resolved. This included comments about the construction phase stormwater controls, which have been addressed as outlined in Attachment A (refer point A9g). No further comments on the WQMP have been received for the past 4 years, and so we conclude there are no outstanding concerns about the construction phase controls.

5.2. Model Explanation

5.2.1. MUSIC Model

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is an industry standard modelling approach for the assessment of stormwater quality impacts and for the design of stormwater treatment trains to achieve desired stormwater outcomes. Site model setup and assumptions are in accordance with the industry standard *NSW MUSIC Modelling Guidelines*, and the model has been developed in consultation with the peer reviewer over a number of years.

Through a prolonged and in-depth process of review, revision, consultation, research and iteration, the MUSIC model has been refined and adjusted to address the specific requirements of the Department's peer reviewer. This has included amending the model to remove contentious inclusions and to address the peer reviewer's preferences and views.

As discussed at Section 4 and as detailed in Attachment B, the minor concerns raised by the peer reviewer do not require revision of the assessment undertaken, and the comments provided include no reasons for refusal of the proposed development.

We conclude the model, as relied on by the application, is industry best practice with the benefit of a comprehensive peer review, is fit for purpose and meets the definition of full 'scientific certainty'. Modelling demonstrates full compliance with Council water quality controls as well as the more stringent controls of NorBE adopted for the development. Model results demonstrate no impacts on receiving environments are expected, hence modelling supports approval of the development.

5.2.2. TUFLOW AD Model

To our knowledge this project is the first residential development in NSW to assess estuarine hydrodynamics and water quality impacts. TUFLOW AD was selected as an appropriate modelling system in consultation with the peer reviewer to represent the Crookhaven River and Curleys Bay estuary system.

Assessment required collection of a comprehensive data suite including water levels, Acoustic Doppler Current Profiler (ADCP) transect flows and salinity, and this data was reviewed by the peer reviewer to confirm its adequacy. The collected data was used to setup and calibrate the TUFLOW AD model, and model setup parameters were varied iteratively until calibration was confirmed as being adequate by the peer reviewer.

Following this a comprehensive scenario assessment suite of 32 models was developed. This included assessment of pre- and post-development conditions, 3 dispersion scenarios

(to account for residual calibration uncertainty) and 4 metrological scenarios (an 'average' year of rainfall, a 'dry' year of rainfall, a 'wet' year of rainfall and a 'very wet' month of local rainfall over Culburra and the development site only with no upstream inflows). Scenarios and associated parameters for each were confirmed as appropriate with the peer reviewer.

The scenario assessment suite was executed, with models taking up to 42 days to complete. Model results were assessed using a range of methods including statistical analysis, average and maximum concentration plots, and maximum concentration impact plots – this analysis methodology was also approved by the peer reviewer.

Results analysis indicated changes to estuarine concentrations due to the proposed development are negligible, even in infrequent storm events. The magnitude of changes to estuarine concentrations due to the proposed development are insignificant compared to the large natural concentration fluctuation which occurs under existing conditions (which is typical of an estuarine environment). This was demonstrated via the result output videos presented to the IPC, which show the impact of untreated runoff from the existing Culburra village and upstream areas, as well as the well flushed character of the estuary and the ability to recover from large rainfall events. Changes to estuarine water quality were categorised as very minor, and it was concluded that the proposed development will not cause any significant negative impacts on estuarine water quality.

In addition, Eco Logical Australia assessed the estuary's aquatic ecologic, particularly in seagrass, mangrove and saltmarsh environments. Eco Logical's analysis considered the changes predicted by the TUFLOW AD model and concluded that 'there is not likely to be a significant impact on threatened species, populations, ecological communities or their habitats' as a result of the proposed development.

At each stage of the assessment approval was sought and provided by the peer reviewer. The latest peer reviewer comments do not identify any model deficiencies, and as we have addressed all of the peer reviewer's comments previously raised, we conclude there are no outstanding issues with the TUFLOW AD model and estuary assessment.

The estuarine assessment is supported by a methodological approach in excess of anything previously approved for a NSW residential development and has been subject to extensive peer review. A wide range of conditions have been represented through the simulation of 32 scenarios, this sensitivity analysis removes uncertainty and demonstrates immaterial impacts even in worst case scenarios. The modelling approach therefore achieves the 'scientific certainty' required by the precautionary principle, and the extensive review demonstrates modelling is fit for purpose. Model results demonstrate no impacts on the estuary are expected, hence modelling supports approval of the development.

5.3. MUSIC Model Output Questions

5.3.1. Treated and Untreated Loads

The IPC has noted that untreated loads in the post-development scenario are less than pre-development loads. This is not the case and we are unclear how this view was formed. The loads provided in the WCMR all show untreated post-development loads (noted as 'sources' in Tables 15-19) are greater than pre-development loads (as per Tables 10-14).

The latest model results provided in the WCMRA did not include untreated post-development loads, so these have been output and are summarised in Table 1 below. All untreated post-development loads are shown as greater than the pre-development loads.

However, with treatment the post-development loads are below pre-development loads, hence the NorBE test is achieved. This outcome is achieved through the implementation of an extensive series of source and end of pipe water quality controls.

Table 1: Pre-development and post-development (treated and untreated) loads to receiving environments based on the WCMRA model.

		Receiving Environment					
Scenario	**Parameter [1]**	**SEPP 14**	**Curleys**	**Lake**	**Seagrass**	**River**	**Total**
Pre-Development Loads (kg/year) [2]	TSS	1580	9140	293	12000	13600	13900
	TN	4.7	18.0	0.9	28.9	33.6	34.5
	TP	50.5	115.0	9.3	203.0	253.0	263.0
	GP	0	899	0	899	899	899
Post-Development Untreated Loads (kg/year)	TSS	11100	8580	2020	32500	43600	45500
	TN	28.3	18.0	4.6	70.3	98.6	103.0
	TP	235.0	130.0	28.9	519.9	754.9	785.0
	GP	2410	1130	129	5290	7700	7840
Post-Development Treated Loads (kg/year) [2]	TSS	587	6960	136	8110	8670	8810
	TN	4.3	14.2	0.8	22.7	27.0	27.8
	TP	49.6	102.0	8.5	190.0	240.0	248.0
	GP	0	782	0	782	782	782

Notes
1. TSS = total suspended solids
   TN = total nitrogen
   TP = total phosphorus
   GP = gross pollutants
2. Data provided in Tables 1 and 2 of the WCMRA.

5.3.2. Capture & Reuse of Stormwater

Capture and reuse of stormwater is proposed via rainwater tanks and increased evaporation for oval irrigation, with reuse details provided in the WCMR. Whilst this reduces some of the runoff from the system, pollutant loads are not reduced due to wholesale diversion of stormwater flow through reuse.

The proposed development represents less than 0.5% of the Lake Wollumboola catchment, hence minor changes to flow volumes will not materially affect the Lake's hydrology.

6. SUMMARY

The proposed modelling and design represent an industry best practice example of an integrated water cycle management solution which achieves the protection of the receiving environments and does not introduce additional pollutant loads to Crookhaven River or Lake Wollumboola. Further, the water quality aspects of this project have been assessed more rigorously than for any residential subdivision in NSW.

In conclusion, modelling and assessment have been undertaken in accordance with a range of industry best practice guidelines, and MA have addressed all DoPE and peer reviewer comments raised. The modelling approach used to assess the water quality effects of the proposed development provide DoPE with adequate scientific certainty of the water quality outcomes. Modelled results demonstrate no detrimental impact on the estuary or Lake Wollumboola water quality. As such, the development proposal represents

best practice ecologically sustainable development, meets the requirements of the precautionary principle and therefore should be approved.

DoPE's EA report concluded that the application should be refused because:

- The potential water quality impacts of the concept proposal on the Crookhaven River estuary present an unacceptable risk to oyster aquaculture, protected wetlands, marine vegetation and fish habitat

- There is scientific uncertainty that the water quality impacts can be adequately mitigated by the proposed stormwater management system, and the Applicant has been unable to adequately demonstrate there would not be serious or irreversible impacts

- The potential water quality impacts on Lake Wollumboola are inconsistent with strategic planning objectives to protect the lake from urban development

This DoPE's conclusions are incorrect as:

- The potential water quality impacts have been assessed and found to be acceptable using both a MUSIC stormwater quality model and a detailed process of estuary water quality modelling with TUFLOW AD. The assessment has been considered by the local stakeholders and a monitoring plan developed to specifically address the issue of oyster production. A monitoring program is proposed to ensure the long-term protection of other sensitive receiving environments.

  The assessment clearly demonstrated that there shall not be serious or irreversible impacts on any of the receiving environments. The best practice modelling approach used confirms no impacts of significance, conclusions which have been confirmed by Eco Logical Australia through their assessment of the ecological implications of water quality outcomes.

  The water quality outcomes in the Crookhaven Estuary achieve the Neutral or Beneficial Effect (NorBE) test, which is the highest water quality assessment standard used in NSW. DoPE's claim that the risk posed by the development is 'unacceptable', is without any scientific or reasoned justification.

- The scientific certainty provided by the assessment completed for this project is significantly higher than for other assessments completed in NSW for residential development. The developed models (MUSIC and TUFLOW AD) have been rigorously peer reviewed and refined to ensure that the modelled solution gives the assessment process the required level of scientific certainty. In a NSW first the design process has used an estuary hydrodynamic model to assess the transportation of pollutants within the estuary to assess the water quality impacts of the development.

  The prolonged peer review process has allowed for all matters raised by agencies and the reviewer to be addressed through design and modelling revision and iteration. The final peer reviewer concerns raised in July 2017 but withheld from the Applicant by DoPE until two days prior to the IPC presentation have also been addressed. These last remaining 'issues' related to the level of development detail presented (which is as shown to address the specific requirements of DoPE) and a 'suspicion' of the peer reviewer which is refuted by the industry literature. There is

therefore more than adequate scientific certainty regarding the conclusions of the water quality assessment.

- There shall be no adverse water quality impacts on Lake Wollumboola. Proposed development within the Lake's catchment (access road and oval) impacts less than 0.5% of the total Lake catchment and have been designed with extensive water quality treatment systems. The water quality impacts of this development shall be extremely minor, but positive.

  The proposed water quality solution within the Lake's catchment achieve the strategic planning objectives by ensuring that the very minor amount of development in the catchment ensure the protection of the Lakes water quality.

In summary, DoPE's conclusions are flawed, having failed to consider the volumes of scientific assessment and review and the engineering solutions presented. Their conclusions regarding the potential risk to receiving environments are fundamentally flawed and have no scientific or engineering justification to support them. In contrast, the Application uses best practice approaches to design a water quality management solution and on going monitoring program to ensure the protection of the receiving environments. There are no valid reasons for the refusal of the application.

If you have any queries, please do not hesitate to contact our offices.

For and on behalf of

MARTENS & ASSOCIATES PTY LTD

DANIEL DHIACOU
BEng (Hons1), DipEngPrac
Civil & Environmental Engineer

ANDREW NORRIS
BSc (Hons), MEngSc, MAWA
Director/Project Manager

7. ATTACHMENT A – DOPE WATER QUALITY COMMENTS & MA RESPONSES

Table 2: Department of Planning & Environment (DoPE) water quality comments (June 2018) and MA responses.

#	DoPE Comment	MA Response
A	**Department of Planning & Environment (DoPE) 15 June 2018 (Section 6.2 of report)**	
A1	The Applicant also cited the pollution reduction criteria in the Shoalhaven Development Control Plan, 2014 (DCP) as relevant criteria for the proposed stormwater treatment system. However, Fisheries and OEH noted these criteria are less stringent than the NorBE objective and are not appropriate for the concept proposal. The Department's water quality expert BMT reiterated that the DCP requirements were not appropriate for the sensitive receiving environment of the Crookhaven estuary and Lake Wollumboola.	The Shoalhaven Council DCP pollution reduction criteria and NorBE criteria are not mutually exclusive, and the MUSIC modelling meets both sets of criteria.
A2	The WCMR also states the stormwater treatment system would achieve pollutant removal efficiency between 83% and 100%, however it is not clear how these values were calculated.	These treatment train effectiveness rates are calculated outputs from the MUSIC model and are documented in Section 4.5.3 of the WCMR. These rates are simply calculated by subtracting the residual pollutant volume (post-development after treatment) from the source pollutant volume (post-development before treatment) and dividing by the source pollutant volume.
A3	The WCMR included a brief discussion of the stormwater flows generated by the concept proposal. The assessment compared pre and post-development flows and concluded the developed area discharging to the SEPP 14 wetland must be limited to 34.9 ha to mimic pre-development flows. The assessment recommends flows outside this area be diverted and discharged to the Crookhaven River (presumably away from the SEPP 14 wetland, although this was not stated). The assessment concludes that on-site detention is not required. The WCMR did not include a plan showing the 34.9 ha area in the context of the full development.	On-site detention was confirmed as not being required by a Council officer (refer Section 6.2 of the WCMR). The 34.9 ha catchment to discharge to the SEPP14 wetland is provided in drawing SK205 in Attachment A of the WCMR. The area to the east of this catchment will be diverted to Curley's Bay (outlet 3), and the area to the west of this catchment will be diverted to Crookhaven River west of Billys Island (outlet 1).
A4	The WQMP stated there would be no sampling and analysis of stormwater runoff from the site.	Section 2.11 and 3.4.11 of the WQMP describes the proposed monitoring procedures, which includes sampling of stormwater overflows from sedimentation basins during the construction phase. In addition, thorough visual inspection of stormwater quality improvement devices is required to be undertaken on a monthly to quarterly basis by a specialist approved by Shoalhaven City Council and funded by the developer. This will ensure each of the proposed treatment train elements will continue to function as required.

#	DoPE Comment	MA Response
A5	Fisheries considered it implausible that water quality would be improved post development, given the site is currently covered in mature native vegetation with minimal pollutant sources. Fisheries identified specific inadequacies in the modelling and stated the exclusion of stormwater sampling from the monitoring plan meant that water quality decline would unlikely be detected. Fisheries remained concerned about the concept proposal's potential water quality impacts on the POAAs, seagrasses, mangroves and fish habitats.	We note that the pre-development catchment is mostly forest, but also includes agricultural areas (14% of the total catchment) as well as some commercial, industrial and road areas close to the existing Culburra Village. These areas discharge to the Crookhaven River without any treatment. The proposed development includes a range of stormwater quality treatment devices which have been designed in accordance with industry best practice to achieve a NorBE. Stormwater monitoring is proposed to be included as discussed at point A4 above, in conjunction with a thorough visual inspection regime. The EPMR detailed impacts to the estuary under a range of meteorological scenarios including extreme local rainfall conditions, and demonstrated that even under these circumstances, changes to estuarine nutrient and sediment concentrations were negligible and were not of material significance. This was further supported by the AEIA which specifically reviewed potential impacts on seagrass, mangroves and saltmarsh areas, and concluded no significant impacts on aquaculture were expected. Based on these assessments, we consider that the potential for impacts on these receivers would not be of material significance, especially considering the large degree of natural concentration fluctuation which occurs under existing conditions. This has been demonstrated via the result output clips shown to the IPC.
A6	NOW raised concerns about the potential water quality impacts of the lengthy construction phase and the NSW Food Authority advised the proposal may have localised impacts on the oyster harvest areas in close proximity to the proposal.	The sediment and erosion control plan (SECP) is detailed in the WQMP and has been designed in accordance with the design guidelines provided in Managing Urban Stormwater, Soils and Construction Volume 1, 4th Edition (Landcom, 2004, i.e. 'the Blue Book'). The SECP reflects current best management practices to mitigate the overall impact of the development during the construction phase. A range of measures are proposed including sediment detention basins, earth diversion bunds, sediment fences, energy dissipaters and stabilised site entrances, and a monitoring plan is proposed to ensure SECP measures will function as per the design intent. The SECP has been designed in accordance with best management practices, and further as discussed at point A5 the modelling and ecological assessments demonstrate that even if these controls were overwhelmed in large rainfall events, the impact to the estuary would not be of material significance.
A7	The Lake Wollumboola Protection Association raised water quality impacts on Lake Wollumboola as a key concern and Australia's Oyster Coast objected to the concept proposal on the basis of the proximity to existing oyster leases in the Crookhaven estuary.	Stormwater discharges to Lake Wollumboola and oyster leases in the Crookhaven Estuary were explicitly analysed as part of the water quality model. Modelling demonstrated that the NorBE objective was achieved for both receiving environments, hence no impacts to either the Lake or the oyster leases are expected. In addition, the EPMR tested potential estuarine water quality impacts for a wide range of scenarios and concluded the impact to the estuary would not be of material significance.

#	DoPE Comment	MA Response
A8	The majority of public submissions objecting to the concept proposal raised water quality as a key concern.	MA agrees that if unmitigated there is the potential for water quality impacts. This is the reason that MA have established comprehensive and robust water quality models and used these to design water quality treatment devices to ensure stormwater discharges are adequately treated. Design and modelling has been undertaken in accordance with best industry practice guidelines and has been subject to extensive peer review. Modelling achieves the project objectives of NorBE at all environmental receivers assessed. Further, model outcomes have been reviewed by an ecologist who concluded no significant impacts on aquaculture were expected. In addition, as far as we are aware, assessment undertaken for this site, including the estuary water quality study, represents the highest degree of modelling effort undertaken for a residential subdivision in NSW. We therefore consider that the water quality issues have been thoroughly addressed, and design has been undertaken to the highest standard.
A9a	BMT raised the following specific questions and concerns: • the suitability of using the MUSIC model for the Crookhaven estuary, given its hydrologic characteristics	This comment is perplexing because MA have been using MUSIC for water quality modelling since project inception. BMT have known this since their first peer review in March 2014 but have never raised this comment in any of our correspondence. If this is a new concern raised after 4 years of peer review we consider this is completely disingenuous as it undermines the entire peer review process. If, however, this comment is meant to refer to the use of TUFLOW AD to model estuarine processes, this is a matter which has been discussed at length and resolved with the peer reviewer. Modelling demonstrated adequate calibration to: o Water levels (5 locations over a 10.5 week monitoring period); o Acoustic Doppler Current Profiler (ADCP) transect flows (two locations over a neap and spring tidal cycle); and o Salinity (7 locations including continuous sampling over a 10.5 week monitoring period and discrete sampling). BMT WBM confirmed adequate calibration was achieved with the fixed grid model (letter of 27 November 2015, email of 29 January 2016 and email of 24 May 2016), hence there was no need to change from a fixed grid modelling approach to a flexible modelling approach. Regardless, the inclusion of this 'concern' in DoPE's SSD assessment is misleading as it implies BMT WBM have an outstanding issue where none has been communicated to the applicant.

#	DoPE Comment	MA Response
A9b	• accuracy of the assumptions used in the modelling in relation to infiltration, seepage losses, uptake of nutrients from the 100 m foreshore buffer and use of inappropriate rainfall scenarios	Infiltration into the 100 m wide foreshore buffer zone was removed from the MUSIC model as part of the WCMRA. The WCMRA demonstrates NorBE can be achieved without reliance on vegetation uptake within this zone. In his letter of 18 July 2017 Tony Weber notes 'The proposed changes to the model in terms of the assumptions regarding the vegetated zones assimilating some of the pollutant loads are supported'. Rainfall scenarios were confirmed as acceptable by the peer reviewer. The EPMR adopted 4 meteorological scenarios for assessment: o An 'average' year of rainfall (1967); o A 'dry' year of rainfall (1968); o A 'wet' year of rainfall (1969); and o A 'very wet' month of local rainfall (Oct – Nov 1969) over Culburra and the development site only, with no upstream inflows. These scenarios were developed in consultation with BMT WBM, and were confirmed as acceptable (email of 29 January 2016). See EPMR Section 12.5.
A9c	• limited assessment of construction impacts, when the risks to water quality would be greatest	As discussed at point A6 above, a detailed SECP as well as monitoring plan have been developed in accordance with best industry practice. Further, A Construction Phase Water Quality Assessment has been completed to address this concern. WBM BMT have agreed that this work has been '*well thought out*' (T. Weber, October, 2014) and therefore we consider this matter resolved. Outcomes are provided in: WCMR: Section 5. EMS: Section 3. WQMP: Section 2.6; Section 3.
A9d	• inadequate groundwater assessment including consideration of recharge rates, groundwater and surface water interactions and potential increase in nutrient discharge	We note a detailed site-specific groundwater assessment was undertaken for West Culburra and included 26 boreholes, 8 monitoring wells, 8 test pits, testing of hydraulic conductivity and laboratory analysis of water quality. Based on this testing a CLASS-U3M-1D model was run and demonstrated there would be a negligible environmental impact from the proposed development. This assessment is sufficiently detailed to demonstrate acceptability of the proposal. As discussed at point A9b above, infiltration and vegetation uptake of nutrients are no longer relied upon by water quality modelling, hence the peer reviewer's requirement for further detailed groundwater modelling is moot.
A9e	• proposed stormwater treatment devices inappropriate for the location and the types of pollutants generated by urban development	As discussed at point A9a above, this comment is also perplexing because the proposed treatment devices have not changed since August 2014. Again, if this is a new concern raised after 4 years of peer review we consider the peer review process has been subject to procedural unfairness which undermines the entire peer review process. The stormwater treatment devices proposed are very common in new developments and subdivisions across NSW, and have been accepted by Government Agencies for a large number of designs undertaken by MA.

#	DoPE Comment	MA Response
A9f	• risks to oyster leases not adequately addressed, in particular pathogen contamination	Section 4.6.3 of the WCMR describes that the proposed development shall be sewered with a system operated by Shoalhaven Water, and no onsite effluent disposal is proposed which reduces the risk of release of human pathogens to stormwater. A Sewage Management Regime (Allen Price & Associates, 2013) has been prepared to outline design measures and emergency procedures to mitigate the impacts of sewage spills / leaks on the water quality within the estuary. Based on the above and using the risk assessment approach presented in Section 2.2 of the WQMP and reviewed by the peer reviewer: o Likelihood of pathogen contamination of oyster leases from the proposed development is 'rare'. We note this likelihood is certainly lower than the likelihood of contamination from the existing Culburra village which does not have any of the water quality treatment or monitoring measures proposed as part of this application. o Consequence of pathogen contamination of oyster leases from the proposed development is 'moderate' to 'major'. o Overall risk of pathogen contamination of oyster leases from the proposed development is 'low' to 'medium'. As the hazard risk could potentially be as high as 'medium', monitoring is proposed to manage this risk. Section 2.8.3 of the WQMP details proposed faecal coliform monitoring at 4 locations monitored on either a monthly basis, after moderate rainfall events or after spills. This monitoring will complement the existing Crookhaven estuary monitoring regimes (detailed in Section 2.8.2 of the WQMP) and will ensure risk of pathogen contamination is appropriately managed.

#	DoPE Comment	MA Response
A9g	• inadequate water quality monitoring and lack of specific water quality objectives by which to measure the performance of the concept proposal	A detailed water quality monitoring regime is provided in the WQMP. Monitoring is proposed for: 1. Sedimentation basin water quality (during construction) 2. Estuary water quality 3. Shellfish 4. Secondary indicators 5. Stormwater quality improvement devices (SQIDs) 6. Groundwater quality The WQMP has been developed in consultation with local stakeholders including: o Local oyster farmers o Australia's Oyster Coast Inc o NSW Food Authority o Southern Rivers Catchment Management Authority o Shoalhaven Water o Shoalhaven City Council o NSW OEH o NSW Fisheries The WQMP has been available for peer review since October 2013. BMT WBM provided several comments on the WQMP in their review of 6 March 2014, and MA amended the WQMP to address each comment: o Wetland system discharge monitoring – recommendations and requirements related to end of line discharge monitoring and monitoring of vegetated treatment systems is included in the WQMP (Section 2 and in particular Section 2.11). We note that only a single wetland upstream of the Lake Wollumboola catchment is currently proposed as per the WCMRA. o Compliance values for monitoring programs – the WQMP includes trigger values where appropriate. In the case of shellfish and estuarine monitoring, monitoring is to be completed as part of a wider strategy and setting individual trigger values is therefore not appropriate. See WQMP Section 2. o Risk assessment – the WQMP was restructured to be in a risk assessment format. See WQMP Section 2 (particularly Section 2.2 – 2.5) and Attachment C. o Revise monitoring indicators – this is provided in the WQMP Section 2.8. As no further comments on the WQMP have been received for the past 4 years we conclude this matter resolved.
A9h	• potential to double the nitrogen and phosphorus loads to the Lake Wollumboola catchment, which is inconsistent with strategic planning objectives for protection of the lake	This is incorrect. The WCMRA demonstrates the total nitrogen and total phosphorus loads to Lake Wollumboola are reduced by 5% and 9% respectively as a result of the proposed treatment train. We are unsure where this comment comes from or what it is based on, and no details have been provided by the peer reviewer or DoPE to support this statement.

#	DoPE Comment	MA Response
A9i	• reliance on the stormwater treatment system to achieve the NorBE objective without sufficient design detail or evidence to support the claimed pollutant reductions	This is incorrect. All MUSIC model inputs have been provided in the WCMR (Section 4 as well as Attachments B, D and E). The information as provided is sufficient to enable peer review. If this were not the case, the peer reviewer has had sufficient opportunity over the past 5 years to request MUSIC models to confirm their validity, and MA have always been willing to provide these, however models were never requested. This is further evidence of procedural unfairness, a lack of robust analysis by the peer review, and a general failure of the peer review process.
A9j	• treatment performance of proposed stormfilters/envirpods [sic] may have been 'double-counted' in the modelling	This comment refers to the proposed MUSIC treatment train and the way in which bioswales discharge to Stormfilters and Enviropods (SFEP). This treatment train has been included in modelling since August 2014, and SFEPs were added to the model as discussed with the peer reviewer – the peer reviewer raising this issue now is in contrast to their previous advice. Regardless, the effectiveness of the devices in the configuration proposed is supported by industry literature. A refereed paper presented in the Water journal of the Australian Water Association in September 2011 includes detailed results of system performance, and is provided in Attachment D. Table 3 compares the range of SFEP nutrient influent and effluent concentrations as reported by the industry literature and as modelled in the WCMRA. The modelled nutrient inflow and outflow concentrations are within the range of concentrations reported in the paper (with the exception of the lower bound TP influent concentration which is only 0.01 mg/L outside of the reported range), and modelled concentrations are largely within the lowest two quartiles of the reported range. The MUSIC model is not predicting removal of nutrients which was not observed in the field trial. Comparison of TSS concentrations at SFEPs revealed the MUSIC model was predicting concentrations lower than the concentrations observed in the field trial. To address this concern we have calculated the additional TSS load if the SFEP effluent concentrations were limited to the lower bound of the field trial data (8 mg/L). For sensitivity purposes we have also calculated the additional TSS load if SFEP effluent concentrations were limited to double the lower bound of the field trial data (i.e. 16 mg/L). These additional loads were added to the TSS loads from the WCMRA, with results summarised in Table 4. Outputs demonstrate the project objective of NorBE is still met, even with these limitations on the removal efficiency. This demonstrates the peer reviewer's comment of treatment train performance being 'double-counted' is not founded in fact and must be dismissed as simply unsupported supposition. Whilst TSS concentrations were outside the documented field trial range, sensitivity analysis demonstrated NorBE is still achieved for the proposed treatment train. We maintain that the modelling is consistent with industry best practice and achieves the project objectives.

#	DoPE Comment	MA Response
A9k	• sensitivity analysis does not demonstrate with sufficient certainty that the stormwater treatment system would protect the estuary.	This comment refers to the use of vegetation uptake and infiltration within the 100 m wide foreshore buffer zone. This has been removed from modelling as discussed at point F9b above, hence this comment is moot. Further, we note that a comprehensive sensitivity analysis has been undertaken for the estuarine processes model, with 32 scenarios simulated. This analysis has demonstrated that changes to sensitivity models' estuarine concentrations due to the proposed development are considered negligible. See EPMR Section 13.
A10	BMT's latest advice in July 2017 concluded there is considerable uncertainty in the water quality impact predictions provided by the Applicant. BMT do not agree the proposed modifications to the concept proposal (reduction in industrial area and modified impervious surface assumptions) would lead to the scale of water quality improvements stated by Martens. BMT continue to question the assumptions made about the ability of the stormwater treatment system to improve water quality discharged from the developed site. BMT do not support the Applicant's conclusion that a NorBE objective would be achieved.	The BMT WBM peer review of 19 and 20 July 2017 was not provided to the applicant until 1 year later on 17 July 2018, two days prior to the IPC applicant briefing presentation. This clearly demonstrates procedural unfairness as adequate opportunity to respond to the peer reviewer comments has not been provided to the applicant. Despite this, responses have been provided in Attachment B (points B and C) to address each of the peer reviewers' comments. We conclude that NorBE has been achieved for the site.

Table 3: Nutrient concentrations in and out of SFEP devices compared based on industry literature and the MA MUSIC model.

		Range of Event Mean Concentrations (mg/L)	
Data Source	**Stormwater Sampled**	**TP**	**TN**
Water Journal Paper (Attachment D)	Influent	0.08 to 0.19	0.6 to 1.5
	Effluent	0.02 to 0.15	0.2 to 0.9
MA WCMRA MUSIC Model	Influent	0.07 to 0.11	0.61 to 0.83
	Effluent	0.04 to 0.06	0.43 to 0.65

Table 4: TSS loads (kg/yr) to receiving environments for different SFEP limiting removal efficiency scenarios.

		Post-Development – SFEP Removal Efficiency		
Receiver	**Pre-Development**	**Unlimited (WCMRA)**	**Limited to 8 mg/L [1]**	**Limited to 16 mg/L [2]**
Crookhaven River	13600	8670	9614	11081
Lake Wollumboola	293	136	136	136
Billys Island inlet (SEPP 14 Wetlands)	1580	587	896	1418
Seagrass and Oyster Leases	12000	8110	8745	9690
Curleys Bay	9140	6960	7003	7081

Notes
1. This is equivalent to the lower bound TSS effluent concentration documented in Attachment D.
2. This is equivalent to double the lower bound TSS effluent concentration documented in Attachment D.

8. ATTACHMENT B – PEER REVIEWER COMMENTS & MA RESPONSES

Table 5: Peer reviewer water quality comments (July 2017) and MA responses.

#	Peer Reviewer Comment Summary	MA Response
B	**Tony Weber, Alluvium 19 July 2017**	
B1	Lack of detailed concept plan makes it difficult to understand proposed development proposal changes and how these have led to water quality improvements	DoPE and the applicant have agreed that lot and internal road layout design should be removed from the concept approval stage. The WCMRA details the changes to the development layout and the water quality model in sufficient detail to enable review. If further details were required the MUSIC models could be reviewed by the peer reviewer, however these have never been requested. Further, for a development of this scale it is typical for a MUSIC assessment to be required at each stage of the proposed development. Full details of the proposed development layout and water quality models will be provided at each stage of the proposed development, which will be subject to Council review and approval.
B2	Road and roof impervious areas and wetland sizing in Lake Wollumboola catchment are not validated against development layout	As discussed at point B1 above, a development layout has not been provided for the concept approval stage as agreed with DoPE. The WCMRA states the project planners, Allen Price & Scarratts, 'completed a detailed assessment of subdivision design based on similar residential land releases in the Shoalhaven region' to inform roof and road impervious areas. To use local data in this way is an approach consistent with best practice. This represented a refinement of the previous model assumptions, which were not previously 'validated' by the peer reviewer, so this 'new' concern is unwarranted. No further details are considered necessary to provide at the concept approval stage. Full details of road and roof impervious areas as well as wetland sizing will be provided at each stage of the proposed development, which will be subject to Council review and approval. We note that the space required for the proposed treatment train has been considered as part of the design and modelling undertaken: • 3kL – 5kL rainwater tanks will be located on individual lots. • Bioswales have been sized to fit within road reserve corridors. • Enviropods and Stormfilters will be located underground. Based on the above the land required for stormwater treatment is minimal and is not expected to be a constraint to development. Land within the foreshore area will not be used for water quality treatment purposes.
B3	Lack of information regarding configuration of proposed treatment train	The physical configuration cannot be provided as the development layout is excluded from the concept approval stage as discussed above. The WCMRA clearly describes the revised treatment train for the Crookhaven River and Lake Wollumboola catchments. In addition, the MUSIC model layouts which include the proposed treatment train configurations for the concept approval stage are provided in the WCMR Attachment A (Figure SK203 and SK204). This is the same treatment train that had been proposed, documented and modelled without any questions being raised by the peer reviewer for 3 years.

#	Peer Reviewer Comment Summary	MA Response
B4	'Suspect' that bioswales discharging to Enviropods / Stormfilters may 'double-count' treatment performance	As discussed at point A9j above, a refereed paper in the *Water* journal of the Australian Water Association supports the proposed configuration. Sensitivity testing demonstrates NorBE is achievable even at double the lower bound field data concentration. This demonstrates the peer reviewers 'suspicion' of treatment train performance being 'double-counted' is not founded in fact and must be dismissed as simply unsupported supposition.
B5	Lake Wollumboola treatment train is 'not likely to be appropriate' for future changes due to potential increases to pollutant concentrations	This is an entirely new performance criteria not previously raised. It is totally inappropriate for the peer reviewer and hence the Department to, after 3 years of effective consultation and treatment train development, create a new assessment criterion and then, providing no opportunity to assess if the proposed solution complies to this criterion, simply conclude on the basis of a guess, that the solution shall fail to meet the criteria.
C	**Michael Barry, BMT WBM 20 July 2017**	
C1	Land-side water quality issues raised in the review of 19 July 2017 require resolution before the estuary model can be reviewed	We disagree with this statement. There are many inputs to the estuary model which could have been reviewed by the peer reviewer, even without undertaking detailed review of the land-side water quality modelling. No effort or rigour has been applied by the peer reviewer to respond to the documentation provided by MA. Regardless, no modelling issues have been identified by the peer reviewer, and as we have addressed all of the issues raised by the estuary model peer reviewer, we consider there are no outstanding issues with the EPMR.
C2	Estuary model not updated with latest land-side model outputs	If the peer reviewer comments had been provided to the applicant a year ago when it was issued to DoPE, MA could have rerun the model suite and prepared results by this time. However, if IPC desires the estuarine model can be rerun to evaluate the latest WCMRA results, noting that model runs may take up to 6 weeks. The WCMRA describes that the two vegetation uptake scenarios simulated by MA for the EPMR relied on the MUSIC outputs with and without vegetation uptake within the 100 m wide foreshore buffer zone included. The differences in the results of both models demonstrated there were negligible impacts within the Crookhaven River estuary, regardless of the vegetation uptake scenario adopted. The WCMRA was then updated to exclude vegetation uptake. The post development loads presented in the WCMRA assessment are between the loads of scenarios with and without infiltration assessed previously, as summarised in Table 6. The latest WCMRA results show loads much closer to the lower loads of the 'with vegetation uptake' scenario, and for some receivers the WCMRA results are lower than both previous scenarios assessed in the WCMR. As the previous EPMR assessment demonstrated no significant impact, and the WCMRA modifications produce results within (or even lower than) the range assessed previously, we conclude it is unnecessary to rerun the model suite to account for these changes.

Table 6: Post-development treated loads modelled by MUSIC at site receivers for the scenarios presented in the WCMR & WCMRA.

		Load (kg/yr)		
Scenario	**Receiver**	**TSS**	**TP**	**TN**
WCMR – with vegetation uptake (WCMR Table 24)	Crookhaven River	10067	22.3	162.2
	Lake Wollumboola	125	0.5	4.5
	Billys Island inlet (SEPP 14 Wetlands)	510	2.5	26.6
	Seagrass and Oyster Leases	9557	19.8	135.6
	Curleys Bay	8660	15.2	89.1
WCMR – without vegetation uptake (WCMR Table 25)	Crookhaven River	12433	42.8	345.7
	Lake Wollumboola	318	2.0	18.6
	Billys Island inlet (SEPP 14 Wetlands)	1270	9.2	88.9
	Seagrass and Oyster Leases	11163	33.6	256.8
	Curleys Bay	9140	17.7	115.0
WCMRA (WCMRA Table 2)	Crookhaven River	8670	27.0	240.0
	Lake Wollumboola	136	0.8	8.5
	Billys Island inlet (SEPP 14 Wetlands)	587	4.3	49.6
	Seagrass and Oyster Leases	8110	22.7	190.0
	Curleys Bay	6960	14.2	102.0

9. ATTACHMENT C – MA BRIEFING NOTES FOR IPC, 19 JULY 2018

IPC BRIEFING NOTES

8:00 – 9:00 am 19/07/2018

Lvl 3, 201 Elizabeth St, Sydney, 2000

INTRODUCTION

- I am Andrew Norris a Director of Martens and Associates, we have been responsible for the preparation of the water quality and estuary hydrodynamic and water quality modelling for the project and for the development of the estuary and water cycle studies as well as the water quality monitoring plan.
- The Department is recommending refusal of the proposed development in part due to stormwater management 'concerns'. In short, the Department formed the view that there is inadequate certainty that the development addresses the precautionary principle. That is, that the development will not cause serious or irreversible environmental damage.
- This is a view unsupported by the volumes of work undertaken since 2012 to assess potential water quality effects of the development and to develop a stormwater management solution which addresses those potential impacts.
- The tools used for this assessment are industry best practice with MUSIC and TUFLOW AD used for the assessment of stormwater quality and estuary hydrodynamics and water quality.
- The models have been peer reviewed and revised and refined to address all matters of substance.
- As such, the methodology meets the test of the precautionary principle, the design and assessment approach delivers, as much as is required for any such development, the 'scientific certainty' required to support the conclusions reported.
- The result of this rigorous, best practice design approach is a water quality management solution which delivers the highest levels of receiving environment protection required for NSW developments. The development achieves the Neutral or Beneficial Effect Test (NorBET) which was originally developed by the Sydney Catchment Authority for developments in Sydney's drinking water supply catchments.
- This week we have been provided with a final two-page letter by the Department's peer reviewer for the water quality model, this letter, written and submitted to the Department a year ago, notes a number of minor outstanding concerns. These shall be addressed shortly but can be summarised as a concern there is inadequate detail in the proposal (which is a function of the Departments specific requirement that less development detail be shown); the reviewer's failure to have considered information regarding reuse documented in project reports; and a 'new' 'suspicion' – the reviewer's own term – regarding the proposed treatment trains modelled performance. This is the same treatment train that had been proposed, documented and modelled without any questions being raised by the reviewer for three years!
- The development application addresses water quality using approaches which meet NSW best practice for protection of receiving environments using MUSIC to industry best practice norms. The application goes further using what we understand to be a NSW first for a residential development with an estuary water quality model to further assess receiving water quality impacts.
- In addition to the modelling assessment completed a process of stakeholder engagement was completed which led to the development of a long-term water quality monitoring program

for the development. This was developed through close consultation with a range of local stakeholders, most importantly including the local Oyster industry.

Regarding specific matters raised by the Commission in their Applicant Briefing Note

MUSIC MODEL

- MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is an industry standard modelling approach for the assessment of a storm water quality impacts and for the design of stormwater treatment trains to achieve desired stormwater outcomes.
- The MUSIC model, as it is not presented in the application, has been developed through a consultative peer review process since 2012.
- Through this process each parameter adopted in the model has been reviewed at length and is in accordance with the NSW guidelines for MUSIC modelling. All contentious inclusions in the modelling approach have been removed to address the peer reviewer's preferences and views. As such the model as relied on by the application is best practice and meets the definition of 'full scientific certainty'. Modelling developed for the application demonstrates full compliance with the Council controls as well as the more stringent controls adopted for the development's design – that is the Neutral or Beneficial Effect Test.
- Extensive consultation and model review has been undertaken with Department of Planning's appointed peer reviewer Mr Tony Weber of (initially) WBM BMT and by February 2017 of Alluvium Pty Ltd.
- Through a prolonged and in-depth process of review, revision, consultation, research and iteration the MUSIC model has been refined and adjusted to address the specific requirements of the Department's peer reviewer.
- Until mid-July this year we were of the understanding that all of the matters raised by the Department's reviewers had been fully addressed by the MUSIC model documented in Martens' correspondence of June 8, 2017.
- Having on Tuesday this week received Mr Webers correspondence dated July 19 last year we now understand that he has a number of minor concerns which remain unaddressed. They include:

  Proposal development layout modifications – the Department has requested that the applicant remove details from the proposed development layout, this has created 'uncertainty' for Mr Weber as he is unable to review a final proposed lot layout. This situation can be appropriately managed by conditions requiring a final MUSIC assessment for each stage once the lot layout is confirmed – such a condition would be typical for a development of this scale.

  Changes to roof and road area assumptions made based on Allen Price & Scarretts detailed assessment of local dwelling sizes was a refinement of modelling assumptions based on local data is considered best practice approach, Mr Webers is concern was that he could not validate this – however, the original assumption were similarly unvalidated and were not supported by local data, so the 'new' concern is unwarranted.

  Mr Weber notes he was unable to review the MUSIC model, we know no reason for this. The intervening one year since his letter provided the Department ample opportunity for Mr Weber to have access to the model and to review it if required.

Mr Weber claims he cannot review the stormwater harvesting assumptions relied on in the model – Section 4.4.1 (p33) of the WCMP details the reuse assumption and calculations, this methodology has been presented in all past versions of the report Mr Weber has reviewed. There has been no change in this assumption for many years and it is unreasonable for Mr Weber to raise this and rely on it as a reason to not support the modelling approach.

The configuration of bioswales discharging in to the Stormwater 360 devices (Enviropods and Stormfilters) is not a new configuration – this has been included in the treatment train since the Stormwater 360 devices were added in August 2014. Their use was agreed to by Mr Weber through the review process – they were a brand substitution to ensure that the devices had peer reviewed performance parameters.

Mr Weber goes on to suggest he 'suspect[s]' the configuration may be 'double-counting' the effect of the devices. This suspicion was not raised for 3 years and we have had only two days to address the concern. Regardless, the effectiveness of the devices in the configuration used is supported by industry literature from as far back as September 2011. A refereed paper presented in the Water journal of the Australian Water Association in September 2011 includes detailed results of system performance. Reviewing the inflow quality for the devices assessed in the Culburra model show inflow nutrient concentrations within the range of stormwater inflow concentrations reported in the paper. The modelled outflow concentrations from the system are also within the reported ranges. Clearly Mr Webers 'suspicion' is not founded in fact and must be dismissed as simply unsupported supposition.

Mr Weber raised concerns regarding pollutant concentrations entering Lake Wollumboola in larger events. This is an entirely new performance criteria not previously raised. It is totally inappropriate for Mr Weber and hence the Department to, after 3 years of effective consultation and treatment train development, create a new assessment criterion and then, providing no opportunity to assess if the proposed solution complies to this criterion, simply conclude on the basis of a guess, that the solution shall fail to meet the criteria.

- In summary the MUSIC model adopted for this application's design is industry best practice with the additional benefit of a detailed peer review. The last comments from the peer reviewer contain no reasons for refusal other than the reviewers unsubstantiated claims and complaints that the application does not include detail he would like to see – all of which have been removed from the application plans at the request of the Department. The only 'suspected' technical deficiency – Mr Webers term – is 'double counting' of treatment performance. Industry literature shows this suspicion to be incorrect.
- It must be therefore concluded that the MUSIC model used to assess the development is industry best practice and provides an appropriate level of scientific certainty to address the needs of the precautionary principle and, given the results show no serious or irreversible environmental harm, the modelling is adequate to support approval of the development.

TUFLOW AD MODEL

- To our knowledge this proposal is the first in NSW where an estuary hydrodynamic model has been required to allow for the assessment of water quality impacts of a proposed residential development. As such, this project is supported by a methodological approach in excess of

anything previously approved. The approach must therefore achieve the 'scientific certainty' required by the precautionary principle.

- Prior to its development the TUFLOW AD modelling approach was discussed with Mr Weber and a proposed model approach documented by Martens in June 2014 (JC09). Mr Weber at that time responded confirming, and I quote 'Great work on the letter you sent through, really like what you are proposing and think it is well thought out' – the methodology was thereby 'approved' by the Department's peer reviewer.
- The TUFLOW model was established, water quality modelling completed, documented and submitted.
- The Department then appoint a new peer reviewer Dr Michael Barry (also of WBM BMT) to address estuary modelling works.
- Dr Barry raised numerous issues with the previously approved modelling approach, all of which were addressed at considerable additional cost to the applicant.
- Calibration data not originally required by Mr Weber was developed at Dr Barry's request. This included Acoustic Doppler Current Profile (ADCP), water level and conductivity data from locations across the estuary.
- The TUFLOW model was refined further to achieve calibration to data sets developed. Residual uncertainty regarding calibration was then addressed in consultation with Dr Barry through the use of sensitivity modelling runs using a range of dispersion coefficients and rainfall conditions.
- The development has been assessed against 16 model scenarios with different combinations of rainfall data (dry, wet, average rainfall year as well as a scenario with only intense local rainfall), these are combined with three dispersion coefficients to address residual uncertainty in the model calibration.
- Analysis of the results of these models are documented in the project's Estuarine Processes Modelling Report. Results demonstrate that the proposed development will not impact on the estuary's water quality.

Video 1 – By way of example this video shows the total nitrogen concentration over a week as a result of a large rainfall event for the full model domain. It shows both the effects of pollutant runoff from the catchments extensive agricultural areas and from Culburra village. The well flushed character of the estuary is seen by the rapid recovery to pre-rainfall nitrogen levels.

Video 2 – These videos show the total nitrogen concentration over the same period for both the developed and undeveloped scenario. The effects of the largely untreated runoff from the existing village can be seen. By comparison the proposed development has no appreciable impact on water quality – this is due to the extensive water quality control measures included in the proposed development.

Models are both 1 hour per step and show one week of the design 'average' year rainfall model.

EXPLANATION OF MODELLING RESULTS

The last point raised by the Commissions applicant briefing note relates to modelling results as they are reported.

- It is not clear why the commission has formed the view that untreated pollutant loads are modelled as reduced compared to undeveloped conditions. If this was the case the proposed water quality treatment train would not have been needed.

- The increase in pollutant generation as a result of development is documented in our WCMP in tables considering treatment train efficiencies. The tabulated source loads (which refers to the generated pollutant load and is synonymous with untreated load) is greatly in excess of both treated and predevelopment loads.
- The effects of untreated urban development can be seen in the TUFLOW AD modelling results. The pulses of pollutants flowing from the existing Culburra village would be mimicked around the foreshore downslope of the development if no water quality controls were implemented.
- MUSIC results for the final assessment model show a total annual flow of 314 ML from the undeveloped site and 373 ML for the developed site. Whilst some of the generated runoff is removed from the system through internal reuse and increased evaporation through use for oval irrigation, the reduced overall pollutant loads are not due to wholesale diversion of stormwater flow through reuse.
- The proposed development comprises less than 0.5% of the Lake's total catchment. Therefore, the very minor changes in flow volume shall not materially impact the Lake's hydrology.
- Pollutant loads to the Lake are reduced as a result of the development through the treatment of proposed new road areas and through the capture, treatment and reuse of potentially polluting runoff from the proposed oval.
- Achieving the NorBET for areas draining to the Crookhaven River are similarly achieved only through the implementation of an extensive series of source and end of pipe water quality controls. The solution proposed represents a best practice example of an integrated water cycle management solution which achieves the protection of the receiving environments and adds no additional pollutant load to the River. The effectiveness of the proposed solution is seen in the estuary modelling where the impacts of the existing village contrast with no observable effects of the proposed development.

In conclusion, the modelling approach used to assess the water quality effects of the development provide the Department with adequate scientific certainty of the water quality outcomes. The modelled results demonstrate no detrimental impact on estuary or Lake water quality. As such, the development proposal represents best practice ecologically sustainable development, meets the requirements of the precautionary principle and therefore should be approved.

10. ATTACHMENT D – WATER JOURNAL PAPER, SEPTEMBER 2011

NUTRIENTS AND SOLIDS REMOVAL BY AN ENGINEERED TREATMENT TRAIN

Field evaluation of a gully pit insert and cartridge media filter

M Wicks, N Vigar, M Hannah

Abstract

The performance claims for individual stormwater treatment devices is often open to debate, as much of the data available has not been subjected to robust scrutiny and/or the claims are unable to be replicated. The following article summarises the results from a field trial of two such devices: an EnviroPod® and a StormFilter®, arranged in series (or a 'treatment train') treating runoff from a small road catchment on Streets Creek, Kuranda, west of Cairns in Far North Queensland.

This field trial complements an earlier research project undertaken on the same system by James Cook University. Data was collected from six storm events, predominantly during the dry seasons of 2008 and 2009, and includes simultaneous sampling of both the flow rate and water quality on the inflows to, and outflows from, the treatment train for a suite of particulate and soluble stormwater pollutants. Influent concentrations for both Phosphorus and Nitrogen were found to be half to one-third of concentrations reported in the literature as typical for urban catchments in Australia.

One storm was also analysed for an expanded suite of nitrogen analytes, which determined that more than half the load was in soluble form. Furthermore, results from the field trial and research project indicated that this treatment train system has the potential to achieve meaningful load reductions of Suspended Solids (up to 99%), Phosphorus (up to 70%) and Nitrogen (up to 45%) through the use of conventional screening, filtration and ion-exchange removal technologies.

Introduction

Livingston and McCarron (1992) identified that pollution loads (gross pollutants, sediment and nutrients) in stormwater increase proportionally with the degree of urbanisation in the catchment. Most consent authorities in Australia have established pollution removal efficiencies to be achieved prior to discharge from the urban catchment (eg, NSW Department of Environment and Climate Change (DECC) 2007 recommends Suspended Solids (SS) 85%, Total Phosphorus (TP) 65%, and Total Nitrogen (TN) 45%) and/or Event Mean Concentrations (EMCs) in any stormwater discharged into natural ecosystems (e.g. ANZECC 2000 recommends turbidity 2-15 Nephelometric Turbidity Units (NTU), TP 0.01 mg/L and TN 0.15 mg/L for river systems in tropical Australia).

In general, each pollutant is removed from the water column using a specific physical, chemical or biological process. Arranging these processes in sequence provides a treatment train approach that addresses and treats the whole pollutant load. There is, however, a paucity of published peer-reviewed scientific information validating the removal efficiency of each element or device used within a treatment train – let alone the performance of the treatment train itself. The research referred to herein provides information to validate the performance claims of an EnviroPod® gully trap and a StormFilter ® cartridge arranged in series as a treatment train.

Photo: ©Google, ©GeoEye ©Wherels® Sensis Pty Ltd ©Digital Globe

Figure 1. Location of the Kuranda Test Site.

Background

This field trial follows a previous research project undertaken by the School of Earth and Environmental Sciences, James Cook University (JCU), as part of a wider investigation into the impacts of road runoff on the Kuranda Range Road watershed, near Cairns (Munksgaard and Lottermoser, 2008), which discharges into the sensitive environment of Streets Creek. JCU reported on the quality of the watershed's receiving waters, the chemical characterisation of the road runoff and the performance of the system over four runoff events.

JCU found that the system "had a high retention capacity for suspended sediment and by implication particulate metals". Conversely, they reported that the "treatment train" had only a "modest retention capability for dissolved (filtered) metals". In addition, JCU identified that the treatment train system was, in fact, responsible for a significant net export of zinc. On the basis of their data, nutrient levels in the road runoff were low, and do not constitute a water quality concern at Streets Creek. However, they also reported significant retention of both TN and TP. The JCU study, which, in their own words "do[es] not constitute a full evaluation of the EnviroPod/StormFilter treatment system", found the system

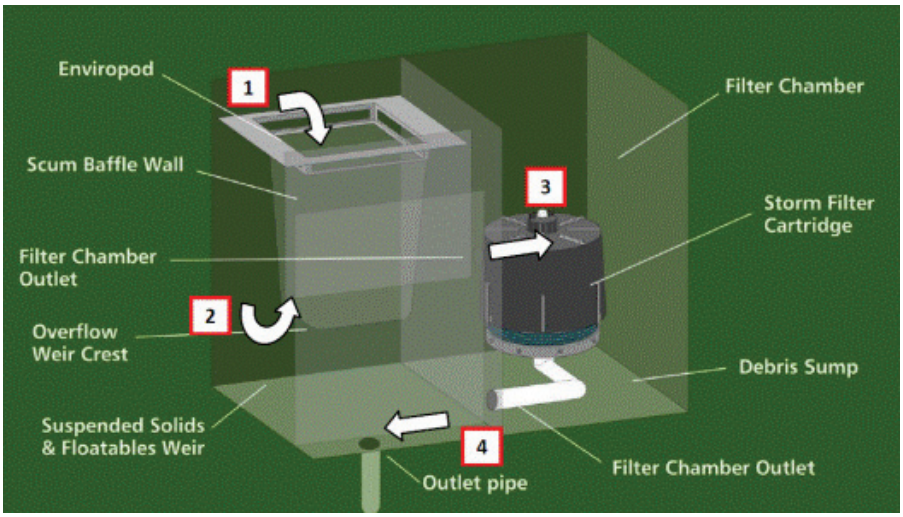

Figure 2. Schematic of the SYSTEM treatment train.

achieved substantial removal of Total Nitrogen (45%), Total Phosphorus (70%), Total Aluminium (71%), Total Nickel (73%), Total Lead (60%) and Total Copper (58%). On the other hand, it identified potential releases of Suspended Solids under 500 microns, as well as dissolved zinc and copper.

One explanation for the above-mentioned releases is that they could be related to the anaerobic conditions present in either the standing water within the wet-sump or, in the case of zinc, corrosion of the exposed galvanised protection on the steel components. Given the substantial removal of suspended solids, nutrients and total metals, it appears unlikely that the dissolved copper and zinc, observed in the outflows, was associated with a release of the under-500 micron sediment fraction.

It was largely to address these issues and better understand the sources of these copper and zinc releases that Stormwater360 undertook a further field evaluation of the treatment train system, which is the subject of this evaluation.

Table 1. Water quality analytical parameters.

Parameter	Abbreviation	Analytical Method*	Units	Limit of Reporting	Analysed by
Electrical Conductivity	EC	APHA 2510B	µS/cm	1	Cairns Water
pH	pH	APHA 4500-H+	-	0.1	Cairns Water
Suspended Solids above 500 microns	SS > 500 micron	500 micron sieve & APHA 2540B	mg/L	1	Cairns Water
Volatile Suspended Solids above 500 microns	SS Vol. > 500 micron	500 micron sieve & APHA 2540E	mg/L	0.1% Dry Solids	Cairns Water
Suspended Solids below 500 microns	SS < 500 micron	APHA 2540B; equiv. ASTM D-3977-97	mg/L	1	Cairns Water
Volatile Suspended Solids below 500 microns	SS Vol. < 500 micron	APHA 2540E	mg/L	0.1% Dry Solids	Cairns Water
Suspended Solids	SS	Calculated	mg/L	-	-
Volatile Suspended Solids	SS Vol.	Calculated	mg/L	-	-
Total Phosphorus	TP	APHA 4500-P	mg/L P	0.02	Cairns Water
Total Nitrogen	TN	APHA 4500-N	mg/L N	0.05	Cairns Water
Total Kjeldahl Nitrogen	TKN	Calculated	mg/L N	-	-
Ammonia Nitrogen (Ammonium Nitrogen)	NH3-N	APHA 4500-NH3	mg/L N	0.05	Cairns Water
Nitrate/Nitrite (Total Oxidised Nitrogen)	NO3-/NO2--N	APHA 4500-NO3	mg/L N	0.01	Cairns Water
Total Organic Carbon	TOC	APHA 5310-B	mg/L	1	ALS
Dissolved Organic Carbon	DOC	APHA 5310-B	mg/L	1	ALS
Particle Size Distribution (Laser Diffraction)	PSD	Malvern Mastersizer S	micron	0.05	QUT

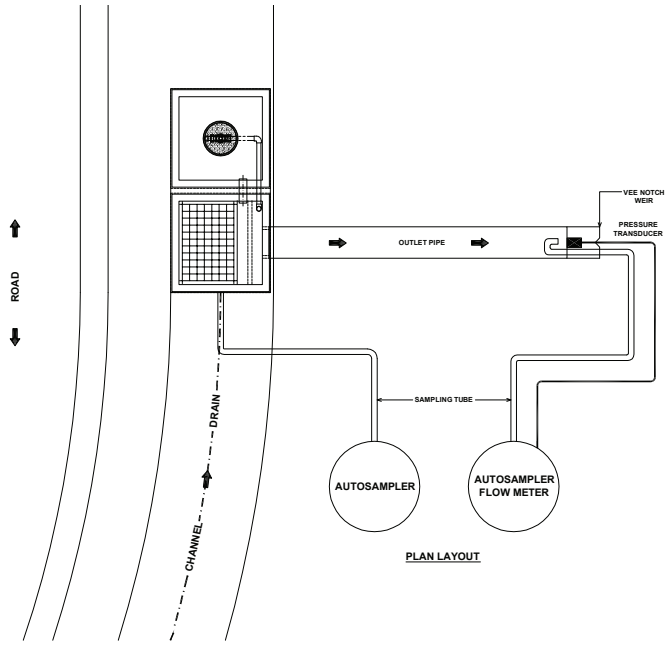

Figure 3. Schematic of the sampling location.

Sampling Procedure and Equipment

A graphical representation of the system is shown in Figure 2. The direction of flow through the gully pit insert (EnviroPod®) and into the cartridge media filter (StormFilter®) is shown in sequence from 1 to 4. The gully pit insert is intended to treat most flows and filter solids above 100 µm while containing contaminants in a dry state.

After treatment by the gully pit insert, water is filtered radially through the media cartridge (outside to inside). The media cartridge had a nominal flow rate of 0.95 L/s (at 46 cm head, when the cartridge is primed) and a peak flow rate of *ca.* 1.3 L/s (at maximum 0.88 m head prior to bypass). The ZPG™ media used was a proprietary blend containing perlite (50%), granular activated carbon (GAC, 10%) and zeolite (40%).

The system samples were collected using automated influent and effluent samplers (Figure 3), collecting continuous flow and precipitation data and water quality simultaneously. The influent sampler was programmed to send an SMS alert to Stormwater360, via the GSM cellular network, when the sampling program was triggered. A dial-up connection was then made to each sampler to download data for analysis.

To qualify as a representative sample, the following criteria were specified.

I. Collection of at least three simultaneous influent and effluent samples per storm;

II. Samples must have been collected while the treatment system operated within design flow rates (not in bypass);

III. The sampled portion of the storm event must represent at least 60% of the storm total flow volume;

IV. A minimum of six data sets must be collected for a full performance evaluation.

Antecedent dry period was not identified as a constraint, due to the impervious nature of the catchment and the absence of a base flow; however, at least a three-day antecedent dry period was preferred. If the storm was deemed to qualify, Stormwater360 would inform Cairns Water and Waste Laboratory Services (Cairns Water, NATA accreditation # 14204) that samples required collection and analysis. Analysis was performed by Cairns Water and Waste Laboratory Services, ALS Laboratory Group – Brisbane (ALS, NATA accreditation # 825). All water quality parameters for qualifying storms were sent to an independent peer reviewer at Queensland University of Technology (QUT), ensuring transparency of data. Test methods for water quality analysis used for this study are provided in Table 1.

Gross pollutants were not monitored as part of this study, although significant quantities were captured. Previous monitoring by White *et al*. (2001) demonstrated that the Enviropod® filter retained all (100%) litter up to an approach flow of 100L/sec.

Results and Discussion

The system was installed at the Streets Creek site in March 2006 and remained an active treatment and sampling site for four years until being decommissioned in March 2010. Stormwater360 monitored the system from April 2008 to December 2009. During this time, the unit was maintained annually, prior to the onset of each dry season. Complete maintenance involved removing all sediments and debris from the system, gully pit insert and replacing the cartridge media. The gully pit insert required additional manual maintenance approximately once per year.

Maintenance frequencies for the study were conducted in line with the systems standard operational lifecycle. Due to the nature of the catchment and size, there was an absence of a base flow or dry weather flows. Potential pollutant leaching of soluble contaminants was, however, still accounted for; organic debris left within the system was allowed to break down between maintenance periods and permitted to be sampled by the effluent sampler during storm events.

A summary of the principal analytes sampled is contained in Table 2.

Suspended Solids

ANZECC (2000), DECC (2007) and Fletcher *et al*. (2004) have identified suspended solids as a stressor of aquatic ecosystems. In addition, many of the other pollutants, such as metals, hydrocarbons etc, are transported attached to the suspended solids and sediment. The system achieved an SSC

Table 2. Summary of results.

Analyte	No. of events	Range of Influent EMCs (mg/L)	Median Influent EMC (mg/L)	Range of Effluent EMCs (mg/L)	Median Effluent EMC (mg/L)	Mean Removal Efficiency (Sum of Loads)
SSC	6	75 to 4384	1181	8 to 63	20	99%
SSC < 500 micron	6	48 to 180	105	8 to 62	20	78%
TP	6	0.08 to 0.19	0.123	0.02 to 0.15	0.055	47%
TN	6	0.6 to 1.5	1.045	0.2 to 0.9	0.615	44%
TKN	6	0.6 to 1.2	1.007	0.175 to 0.800	0.515	49%
NH3-N	6	0.05 to 0.15	0.050	0.05 to 0.07	0.050	31%
TOC	6	3 to 16	7	3 to 10	5	32%
DOC	6	3 to 12	7	3 to 11	6	21%

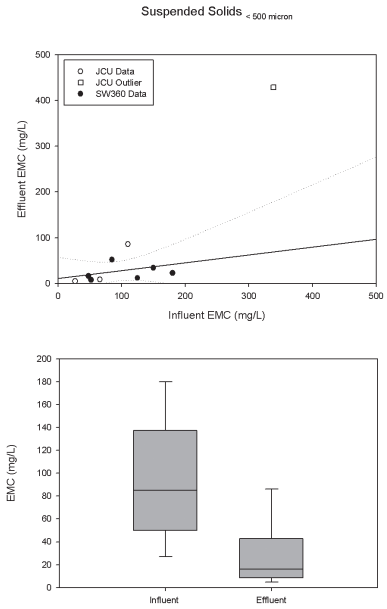

Figure 4. SS <500micron data (JCU + SW360).

aggregate load reduction of 99%. SSC (ie, SSC is defined as the sum of SS <500 micron and SS >500 micron) is 'suspended' in the sense that all these particles were sufficiently suspended to reach the system. However, SS <500 micron represents what is more commonly understood by the term 'suspended solids'. It excludes coarse settleable sediment, which, while being a management issue, does not represent such an acute threat to water quality.

Figure 4 shows influent and effluent data (Stormwater360) for SS <500 micron, together with the results published by JCU. In the scatter plot, the filled-in circles represent data from the trial reported herein, and open circles represent data from the previous JCU's research project. The exception is the JCU outlier represented as an open square, which has not been included in this evaluation. The line of best fit shown as a solid straight line was calculated by a least squares linear regression for all data points except the JCU outlier (intended to be informational only). Its relative slope provides an appreciation of the trend of the removal efficiency for the treatment train. The dotted curves represent the 95% confidence limits for these same data points. The true statistical significance of the regression lines is open to interpretation and requires further investigation, due to the limited number of data points available for this analysis.

Over the six storms analysed by Stormwater360, the influent EMC for SS <500 micron was in the range of 48 to 180 mg/L with a median influent EMC of 105 mg/L. Duncan (1999) literature review determined that the median concentration for most land uses (roofs excepted) lies between 71 mg/L (forested catchments) and 232 mg/L (urban roads). Fletcher *et al*. (2004) recommend using a value of *ca.* 120 mg/L for roads and *ca.* 100 mg/L for most other land uses. Both sources propose a median value of *ca.* 40 mg/L for forested catchments. The influent concentration of Suspended Solids at Streets Creek is within the typical range of average annual EMCs proposed within the literature; however, no data was collected during large wet-season storm events. Consequently, the median influent EMC reported herein should not be regarded as indicative of an annual median value.

Effluent EMCs recorded for SS <500 micron were in the range of 8 to 62 mg/L. The median effluent EMC was 20 mg/L. Mean removal efficiency for SS<500 micron, calculated by aggregate load reduction, was 78%. It is evident from Figure 4 that the Stormwater360 and JCU data sets are in relatively good agreement with each other, with the exception of the JCU outlier, which represents the first storm from JCU's research project. This storm was deemed an outlier for all water quality parameters due to possible sampling errors and has been removed from the analyses. The box plot in Figure 4 shows that the combined dataset is also clustered around an influent EMC of *ca.*100 mg/L and an effluent EMC of *ca.*20 mg/L. In practical terms, 10 mg/L approximates the system's irreducible EMC for under-500 micron suspended solids. The box plot in Figure 4 indicates that, over the course of two trials, the effluent EMCs from the system, were typically within the range of 10 to 40 mg/L.

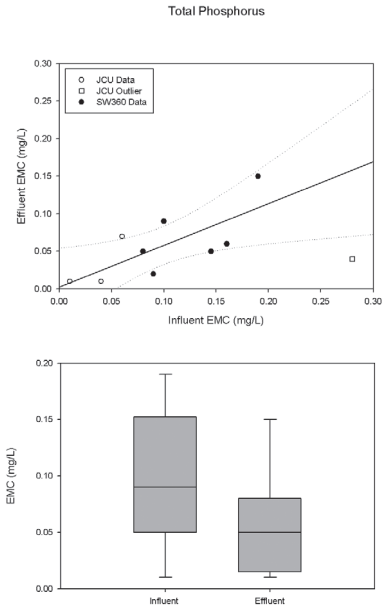

Figure 5. Total Phosphorus (SW360 and JCU combined).

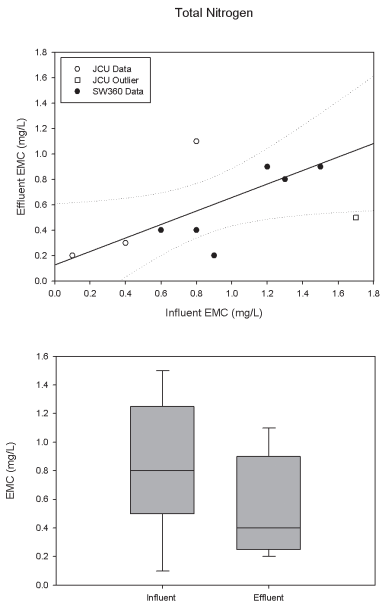

Figure 6. Total Nitrogen (SW360 and JCU combined).

Particle size distribution (PSD) by laser diffraction was performed for the SS <500 micron fraction for three storms during the Stormwater360 evaluation. Inspection of the three cases analysed consists of particles between *ca.* 10 microns and 200 microns in diameter. There is substantial variation between the three events.

- Storm 2 influent PSD centred at *ca.* 20 microns for a removal efficiency of approximately 65%;
- Storm 3 influent PSD centred at *ca.* 100 microns for a removal efficiency of approximately 85%;
- Storm 6 influent PSD centred at *ca.* 35 microns for a removal efficiency of approximately 75%.

Generally, the higher removal efficiency would be expected for the coarser samples, and this was the case for all three storms sampled.

Total Nutrients

The system achieved an aggregate load reduction for total phosphorus (TP) of 47% (note, JCU recorded a load reduction of 70%), the median influent and effluent EMCs for TP were 0.123 mg/L and 0.055 mg/L respectively (refer to Table 2). Duncan (1999) and Fletcher *et al.* (2004) recorded EMCs within a similar range and Fletcher (2004) recommends mean TP concentrations of between 0.25 and 0.50 mg/L for most land uses. Similarly, BMP Database (2010) suggests that a typical range for TP concentrations in stormwater is from 0.11 to 0.38 mg/L, across a range of land uses. In this context it is apparent that the influent TP concentration at the Kuranda site is towards the very low end of published data. Consequently, the 47%

Table 3. Nitrogen results from Storm 6.

Phase	Analyte	Influent EMC (mg/L)	Effluent EMC (mg/L)	Mean Removal Efficiency (Sum of Loads)
Total (dissolved and particulate)	TN	0.8	0.4	50%
	TKN	0.8	0.34	58%
	NH3-N	0.15	0.07	53%
	Org-N	0.65	0.27	58%
	NO3-/NO2--N	0.01	0.06	-500%
Dissolved	TN	0.4	0.3	25%
	TKN	0.39	0.23	41%
	NH3-N	0.16	0.073	54%
	Org-N	0.23	0.157	32%
	NO3-/NO2--N	0.01	0.07	-600%
Particulate (by calculation)	TN	0.4	0.1	75%
	TKN	0.41	0.11	73%
	NH3-N	0	0	N/A
	Org-N	0.41	0.11	73%
	NO3-/NO2--N	0	0	N/A

reduction recorded in the Stormwater360 trial could be related to the difficulty in removing TP at very low influent EMCs, and a much higher removal rate (similar to the 70% recorded by JCU) could be expected as the influent EMC increased.

The system achieved an aggregate load reduction for total nitrogen (TN) of 44%, while the median influent and effluent EMCs for TN were 1.045 mg/L and 0.615 mg/L respectively (Table 2). Again, this influent EMC is low with respect to most of the published data and, according to Duncan (1999), it correlates well with the median for data from forested catchments (0.95 mg/L), but is significantly lower than the median for roads (2.2 mg/L) or urban catchments (2.5 mg/L). Fletcher *et al*. (2004) recommends using a typical total nitrogen value of at least 2 mg/L for most land uses, with the exception of forested catchments.

The total nitrogen results from JCU and SW360 are presented in Figure 6. The spread of influent EMCs is broad, but removal efficiency appears relatively consistent and substantial. This is in spite of the low influent concentrations. TN is generally considered to be predominantly soluble, which is best removed by biological uptake or denitrification (in an anaerobic environment). Consequently, the consistent removal of TN exhibited by the system deserves further consideration. The majority (*ca.* 95%) of the total nitrogen load at Kuranda is TKN and a breakdown of TN species is contained in Table 3.

A small proportion of this TKN load (*ca.* 5%) is ammonia nitrogen, which implies that *ca.* 90% of the total nitrogen load is present as organic nitrogen, in either soluble or particulate forms. An expanded nitrogen suite analysis was conducted for Storm 6, and filtered (0.45 micron) and unfiltered samples were processed in order to establish whether the removal processes, for this event, involved particulate removal or removal of dissolved species. Essentially, the entire TN load was present as TKN and *ca.* 20% of this was ammonia-N (Table 3).

The entire ammonia-N load was soluble, and the treatment train system achieved 54% removal of this species. The remainder (*ca.* 80%) of the TN/TKN load was present as organic nitrogen, of which *ca.* 35% was dissolved. Overall, 73% removal of particulate organic nitrogen and 32% removal of dissolved organic nitrogen was achieved.

Given the removal efficiency for suspended solids, the high removal of particulate organic nitrogen is understandable. Removal mechanisms for dissolved organic nitrogen are less obvious. It is possible that there is some adsorption to the 'schmutzdecke' (bio-film) that develops on the cartridge; another possibility is removal under the anaerobic conditions within the standing water within the wet-zones, being the wet-sump and around the base of the cartridge.

When runoff first enters the StormFilter®, it initially displaces the standing water in the wet-zones. Any pollutants in the standing water are sampled by the effluent sampler (once they have passed through the StormFilter® cartridge), but they are not sampled by the influent sampler. Furthermore, the last of the runoff to enter the cartridge during a storm event does not necessarily pass through the filter cartridge during that event and may be retained within the wet-sump until the next storm event, whereupon it is displaced. When the (particulate or dissolved) organic nitrogen converts to ammonia in the anaerobic wet sump, it can be removed as ammonia-N by the zeolite.

Table 4. Grab samples from wet sump.

Date	Antecedent Dry Period (days)	Report #	Diss. Cu (mg/L)	Diss. Zn (mg/L)	DOC (mg/L)	Diss. N (mg/L)	Diss. NH3-N (mg/L)	Diss. NOx--N (mg/L)
07/07/2008	8	40627	0.011	0.053	17	-	-	-
20/02/2009	6	42998	0.001	0.016	-	2.4	2.39	<0.01
06/05/2009	19	43826	0.005	0.082	16	7.2	5.85	0.72
21/07/2009	79	44703	0.004	0.083	20	3.4	2.24	0.025

Periodic grab samples from the wet-sump indicate that most of the TN load in the standing water is present as ammonia-N at concentrations that are two orders of magnitude higher than typical influent ammonia-N concentrations. As such, ammonia-N is, possibly, generated in the wet-zones by anaerobic decomposition of organic nitrogen in the inter-storm event periods. This has two important implications: 1): the load of ammonia-N passed to the StormFilter® cartridge is significantly higher than is suggested by the influent EMC, which implies that the removal rates for ammonia-N removal may be an under-estimate; and 2): by converting organic nitrogen to ammonia-N in the wet-zones and then removing this ammonia, the system has the potential to remove soluble organic-N.

Discussion

The results for Storm 6 represent a snapshot of one storm, and should not be considered as comprehensive; they do suggest, however, that the main TN removal pathways for the treatment train is the efficient removal of particulate organic nitrogen, complemented by the sorptive removal of soluble ammonia-N and organic-N.

Very often TN removal is treated as a key performance benchmark for stormwater treatment practices. This is potentially problematic, given the apparent variation in the nature of the TN load. In a comprehensive study of nitrogen composition in Melbourne (Taylor *et al*., 2005), *ca.* 25% of the load was present as particulate organic nitrogen. The remainder was soluble and, of these species, oxidised nitrogen predominated over dissolved organic nitrogen and ammonia-N.

Taylor *et al*. (2005) inferred that either 'removing' the water by infiltration or denitrification (ie, in the anaerobic zone of bio-retention practices) would be necessary to achieve significant TN reduction. Fletcher *et al*. (2004) reported that the TN composition measured in wet weather samples for various land uses in the Sydney and Illawarra regions was extremely variable. For urban catchments, median oxidised nitrogen concentrations were in the range 0.09 to 0.42 mg/L, while the median TN concentration range was 0.65 to 2.32 mg/L.

The oxidised nitrogen represents a much smaller proportion of the TN load than was observed by Taylor *et al*. (2005) for Melbourne data. In a study of nutrient build-up on urban roads in the Gold Coast, Miguntanna *et al*. (2010) found that oxidised nitrogen comprised only *ca.* 10% of the TN load, across three different land uses, and most of the TN load was present as TKN and a significant proportion of this was particulate in nature. Consequently, the measured TN load from the Gold Coast catchments is similar to that measured at the Streets Creek, Kuranda site, providing applicability of Nitrogen removals to various urban land uses.

Conclusions

The results from this field trial generally correlate well with an earlier study at this site by JCU (Munksgaard and Lottermoser, 2008). The data collection from this study has been based on a rigorous and technically demanding monitoring program, which adds further credibility of the results (Goonetilleke, 2010). From an operational perspective, the system captured an appreciably large sediment load requiring annual cleaning to maintain its operational effectiveness.

The EnviroPod®/StormFilter® treatment train achieved 78% removal for suspended solids under 500 microns, which approximates the long-term environmental target recommended by NSW DECC (2007), QLD DERM (2010) for South East Queensland (SEQ) and consistent with the 80% reduction target of many consent authorities in the US.

The runoff at Streets Creek contained very low levels of phosphorus and nitrogen. Total Phosphorus removal was between 45% and 70% respectively in both the Stormwater360 field trial and the JCU research project, which approximates the NSW DECC (2007) and QLD DERM (2010) SEQ long-term environmental targets of 65% and 60% respectively, and is better than expected given the low influent EMCs. Total Nitrogen removal was consistent, substantial and in agreement with the NSW DECC (2007) and QLD DERM (2010) SEQ 45% long-term environmental target, despite the proximity of the influent EMC to the irreducible concentration of the treatment train. The removal of nitrogen was particularly noteworthy, given that the debris captured and stored within the treatment train was not included in the influent load into the system, but may have been sampled as a soluble leachate by the effluent sampler.

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The Authors



Michael Wicks (email: michaelw@stormwater360.com.au) is Technical Director of Stormwater360 Australia. **Nick Vigar** is Research Manager and **Mike Hannah** is Technical Director, both of Stormwater360 New Zealand.

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