LTR-001-Queries-Response_Rev0
13 February 2020

Lendlease
Level 3, Kings Gate, 2 King Street, Bowen Hills
QLD 4006 Australia

Dear Lendlease,

RE: Tweed Valley Hospital - TSA-RFI-000206: Re: SSD 2 - Response to Submissions

In reference to your emails on the other 11 November 2019, please find below our responses to the Department of Planning, Industry and Environment (DPIE) queries letter (reference DOC19/876417) regarding stormwater and impacts on coastal wetland. In addition to the above request a response to flow regime analysis dated 21/11/2019.

Based on comments provided by Biodiversity Conservation Division (DPIE), this letter has been updated and the following conclusions have been made:

- Stormwater volumes entering the basin cannot be further reduced than 17 ML due to geotechnical risks. Please refer Table 1, reference number 1a for more information
- The impact of refining the basin outflow design for the more frequent wetting events (1EY, 4EY and 50% AEP) have minimal benefit and is not necessary for the protection of the wetland. Please refer Table 1, reference number 1b for more detail.

Table 1: SMEC Response (reference DOC19/876417)

REF NO.	BIODIVERSITY CONSERVATION DIVISION (BCD) COMMENT	SMEC RESPONSE
1a	Greater effort should be given to reducing the stormwater volumes entering the basins, such as including more storage and reuse of runoff and more use of swales and raingardens in suitable locations.	As per SMEC recommendations, a 400KL rainwater reuse tank was modelled to collect and store rainwater from the hospital roof to use for irrigation and cooling tower. The results showed that the reusing stormwater will reduce the total stormwater discharge by approximately by 17ML per year on average. RBG confirmed that the other SMEC recommendation for use of infiltration treatment devices such as infiltration trenches, swales, rain gardens and permeable pavements etc could not be implemented due slope slip failure on the steep batters around the site due to waterlogged subsoil. Because of the geotechnical risks, infiltration devices will not be feasible. Also, the recommendation to remove the basin liner will not be feasible due to the same geotechnical risks mentioned above. The stormwater volumes entering the basin will not be further reduced than the existing limitation stated above of 17ML per year.

REF NO.	BIODIVERSITY CONSERVATION DIVISION (BCD) COMMENT	SMEC RESPONSE
1b	The recommendations outlined in the SMEC report for refinements to the basin outflow design and for greater channel infiltration to ensure stormwater discharge is managed to reduce impacts on the wetland should be incorporated into final engineering designs and documentation.	The basins were designed to cater 1% AEP (100 year ARI) major event and 20% AEP (20 year ARI) minor event in accordance with the basin design criteria. As per section 2.4.1.3 of Coastal Wetland Assessment (SMEC, August 2019), SMEC carried out additional model runs for frequent events such as 1EY, 4EY and 50% AEP and recommendations were provided to incorporate multiple outlets. However, as part of SMEC assessment more frequent events were evaluated to quantify the impact of the increase in flows to the wetland. Section 3.3 of Coastal Wetland Assessment (SMEC, August 2019) stated that the development site has minimal impact on coastal wetland levels, and effectively only fills the local depressions. Therefore, refining the basin outflow design for the 1EY, 4EY and 50% AEP would have minimal benefit and is not necessary for the protection of the Wetland According to the report (Morrison Geotech – Clarification on General Drainage Comments – Tweed Valley Hospital – Cudgen Road, Kingscliff), the groundwater in the existing condition is connected to the wetland and therefore adding infiltration provides limited practical benefit.
1c	Following the above actions 1(a) and 1(b), the SMEC report should be revised to better demonstrate that the impact of more frequent wetting events will be negligible or can be satisfactorily mitigated.	Based on comments provided by Department of Planning, Industry and Environment (BCD) on the 7th November 2019, the sections 2.2 MUSIC Model Review, 3.4 Groundwater and 3.4.1 Recommendation of the SMEC report dated 31st January 2020 have been updated to demonstrate the item 1a and 1b above.
1d	Regular routing maintenance of the bioretention systems and Enviropod should be included in an operational procedures plan.	n/a for SMEC
1e	A condition of consent be included to ensure there is an emergency procedure in place to prevent contamination spills (such as diesel or other fuels) entering the sensitive receiving environment.	n/a for SMEC

Ecologist Response to flow regime analysis

Question:

Flow regime analysis – SMEC has estimated impacts from discrete storm events on the wetland only. The consent conditions require consideration of changes to flow regimes over a much longer time period to include consideration of seasonal changes to wetland hydrology (and wetland ecology). We understand that the consent authority (and other government agencies) is interested in how the additional estimated 36 ML/yr (50 – 14 ML/yr harvested) of additional runoff volume is distributed into the wetland over the year. Based on estimates by SMEC, an individual 4 EY event would only contribute approximately 0.2 ML/yr of additional inflow (i.e. approximately 0.5% of the total estimated increase).

SMEC Response:

Seasonality

The Northern NSW area has a strongly seasonal rainfall pattern with the majority of rainfall falling over the summer and early Autumn period. The nearest meteorological station (Coolangatta Airport) is located approximately 17Km north of the site and this location received approx. 45% of its annual rainfall over a 4-month period between December and the end of March (BoM, 2020). Distribution of rainfall at the hospital site can be expected to be similar.

Rainfall volumes are similarly distributed with the Coolangatta Station averaging about 52 days a year with > 10mm of rain and 16 days with rainfall > 25mm (BoM, 2020). The vast majority of these events occur in the warmer months.

The increase in storm water discharge volumes associated with the hospital development will be distributed in line with this seasonal rainfall pattern. Larger volumes of stormwater will be present during the higher rainfall periods (Summer/Autumn) and lesser volumes during the Winter and Spring period. The treatment options proposed will not alter this pattern and more water will reach the wetland area in the warmer period when vegetative growth is at its most peak and many species (both fauna and flora) are actively reproducing.

Vegetation and Hydroperiod

A predominant factor in the ecological makeup and function of wetlands is the duration of hydroperiod. The coastal wetland adjacent to the hospital site is a forested wetland. Forested wetlands are defined as naturally flooded or saturated areas that support an important component of woody vegetation adapted to poorly aerated and/or saturated soil (Lugo et al. 1990).

The community within the mapped extent of the coastal wetland has previously been identified as predominately being Broad-leaved Paperbark (Melaleuca quinquenervia) Closed Forest to Woodland (TSC LGA Mapping, 2012). While Broad leaved paperbark cannot survive permanent inundation, they do have adaptations such as fibrous or adventitious roots around their lower trunk that are thought to function as breathing roots, helping the tree to survive during long periods of submersion (McJannet, 2008). Similarly the composition and diversity of the mid and understorey will vary with latitude and the length of time the swamp contains water, but can typiclly include shrubs such as quinine berry Petalostigma pubescens, and Banksia sp. on the margins; sedges such as soft twigrush Baumea rubiginosa, Lepironia articulata and bogrush Schoenos breviofolius; saw-sedges such as Gahnia sieberiana; reeds such as the common reed Phragmites australis; other grasses such as Ischaemum spp., swamp rice grass Leersia hexandra, blady grass Imperata cylindrica and saltwater couch Sporobolus virginicus (DERM, 2010).

The composition of this community is primarily determined by the frequency and duration of waterlogging and the texture, salinity nutrient and moisture content of the soil, and latitude. The composition and structure of the understorey is influenced by grazing and fire history, changes to hydrology and soil salinity and other disturbance, and may have a substantial component of exotic grasses, vines and forbs (NSW OEH, 2019).

An assessment of flow depth increase due to 36ML/year was carried out and the results are shown in Tabl*e 2*. Given these factors the addition of approximately 4 to 11cm of additional inflow from the developed site during significant events for parts of the wetland, is unlikely to result in any significant structural change to the dominant floristics of this community.

It is noted that flooding from Tweed River (BMT, 2018) indicates inundation depths for the wetland of approximately 2m for the 5% AEP event and 3m for the 1% AEP event. This suggests that the existing, long established, coastal wetland area has proved resilient throughout numerous inundation event well in excess of anything likely to result from the inflows from the proposed development.

Tabl*e 2: Summary of flow depth calculations*

DISCRIPTION	BIODIVERSITY AND CONVERATION DEPARTMENT (BCD) COMMENT	UNITS
Wetland area	30.7	ha
	307000	m^2
Flow increase	36	ML/yr
	36000	m^3/s

DISCRIPTION	BIODIVERSITY AND CONVERATION DEPARTMENT (BCD) COMMENT	UNITS
Increase in depth of water if 36ML at one time a year	11	cm
Increase in depth of water if 36ML at two times a year	6	cm
Increase in depth of water if 36ML at three times a year	4	cm

Summary:

The existing, long established, coastal wetland area has proved resilient throughout numerous inundation event well in excess of anything likely to result from the inflows from the proposed development. Therefore, it is unlikely to result in any significant structural change to the coastal wetland (dominant floristics of this community) due to annual flow increase of 36ML/yr.

Reference:

BMT (2018), Tweed Valley Hospital – Flooding and Coastal Hazards Assessment, Ref R.B22945.003.02.docx

BoM (2019), Bureau of Meteorology Climate Data Online. http://www.bom.gov.au/climate/data/

DERM (2010), Wetland Management Profile, Coastal and Subcoastal Tree Swamps. Queensland Wetlands Program

Greencap (2019), Biodiversity Development Assessment Report – Tweed Valley Hospital. Greencap Pty Ltd, Brisbane.

TSC, (2012), Tweed Shire Council Tweed LGA Vegetation Mapping.

Lugo, AE, Brown, S and Brinson, MM. 1990. "Concepts in wetland ecology". In Ecosystems of the world 15: Forested wetlands, Edited by: Lugo, AE, Brinson, MM and Brown, S. 53–85. Amsterdam: Elsevier.

If you have any queries or wish to discuss the submission further, please do not hesitate to contact myself on (02) 9925 5408 or Matt.Box@smec.com.

Yours sincerely,

Matthew Box

Manager – Water Resources Sydney

Member of the Surbana Jurong Group

local people
global experience

Final

Tweed Valley Hospital Hydrology Assessment

Reference No.
Prepared for **Lendlease**
31 January 2020

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EXECUTIVE SUMMARY

This report has been undertaken for Lendlease to assesses the hydrology impact of the proposed Tweed Valley Hospital development on the adjacent coastal wetland

The existing site was agricultural and horticultural land immediately adjacent to a coastal wetland with a small dam in the north west corner of the site. The proposed development utilises Water Sensitive Urban Design structures to control peak flows and improve water quality of discharge from site.

Central to the review is the Robert Bird Group (RBG) Stormwater Management Plan, which has been used as a base to undertake the assessment. The water quality (MUSIC) and water quantity (DRAINS) models were reviewed for suitability and then used to provide information relating to discharges into the coastal wetland. The stormwater design incorporates four basins to capture and treat development site rainfall runoff.

This report shall feed back into the ongoing design and submissions related to the overall water and ecological impact of the hospital development.

Key findings of the review are as follows:

- The proposed RBG stormwater management reduces 1% AEP (100 year Average Recurrence Interval) peak flows from the development to below existing levels for the whole of site, and with minor basin modification, the 20% AEP for all basins. This reduction of peak 1% and 20% peak flows to below existing levels is a design requirement
- During frequent rain events (more frequent than the 20% AEP) the developed stormwater discharge is above existing levels. The impact of increased and more frequent flows on the wetland is assessed as minimal benefit and is not necessary for the protection of the Wetland
- Stormwater management for the site incorporates 400 KL rainwater tanks and re-use of rainwater for irrigation
- The annual flow volumes for the current design are higher post development than pre development. The stormwater volumes entering the basin will not be further reduced than the 17ML per year as the use of infiltration treatment devices such as infiltration trenches, swales, rain gardens and permeable pavements etc could not be implemented due slope slip failure on the steep batters around the site due to waterlogged subsoil. Because of the geotechnical risks confirmed by RBG.
- According to the report dated 3rd December 2019 (Morrison Geotech – Clarification on General Drainage Comments – Tweed Valley Hospital – Cudgen Road, Kingscliff), the groundwater in the existing condition is connected to the wetland and therefore adding infiltration provides limited practical benefit.
- Infilling of the existing dam was assessed for a range of flood events and found to have no material impact on wetland flood levels, except a minor local affect for the frequent 4EY (four exceedance per year on average), due to the runoff filling in the local depressions
- Ecological impact from development outflows and more frequent wetting events has been assessed as having minimal impact, with the change in flood level being very small (<50mm), especially when compared to existing frequent flood inundation from Tweed River
- The increase in frequent flows and improved water quality through reduction of sediment load and nutrients, may be of ecological benefit to the wetland species
- The existing, long established, coastal wetland area has proved resilient throughout numerous inundation event well in excess of anything likely to result from the inflows from the proposed development. Therefore, it is unlikely to result in any significant structural change to the coastal wetland (dominant floristics of this community) due to annual flow increase of 36ML/yr

Based on comments provided by Department of Planning, Industry and Environment (DPIE) on the 7th November 2019, the following sections of the report have been updated

  - 2.2 MUSIC Model Review, 3.4 Groundwater and 3.4.1 Recommendation

1 Introduction

1.1 Purpose

The purpose of this report is to undertake a desktop review of the Stormwater Management Plan for the Tweed Valley Hospital undertaken by Robert Bird Group, and then extend the hydrology modelling to assess hydrological impacts on the adjacent coastal wetland from the stormwater measures.

The report also considers the impact of infilling an agricultural dam in the north western corner of the site.

The RBG Stormwater Management Plan does not include detailed components of the stormwater design and this review scope does not undertake an assessment of detailed design of the proposed water quality basins or stormwater network, rather to confirm that the RBG MUSIC water quality modelling and DRAINS water quantity modelling of the stormwater network are consistent with the Stormwater Management Plan in terms of hydrological aspects affecting the coastal wetland.

1.2 Scope

The scope of work incorporates the following:

- Desktop review of the RBG Stormwater Management Plan
- Hydrological assessment of the potential change to the downstream coastal wetland, due to the development
- Dam decommissioning (infilling) option assessment

In accordance with the proposal, the following steps were undertaken to review the hydrological impact of the development:

1. Review supplied background documentation relevant to the stormwater and water quality outputs to the wetland;
2. Develop a hydrologic model to determine the peak discharge for the 50%, 20% and 1% Annual Exceedance Probability (AEP) events, and compare to the pre-development case;
3. Develop a two-dimensional (2D) hydraulic model to determine the effect of the dam decommissioning option provided by RBG (existing and developed scenarios);
4. Assess the impact of changes in flow regimes on the wetland and communicate the outcomes for ecological assessment; and
5. Provide information for Input into the RBG Design Report and Design Drawings.

2 Review of Stormwater Management

2.1 Methodology

A desktop review was undertaken of the Stormwater Management Plan developed by Robert Bird Group. The review was assessed against standard industry practise and the requirements indicated to satisfy the respective draft conditions of consent from the NSW Department of Planning and Environment for Section B3.b.ii, and iii.

2.1.1 Summary of stormwater treatment

- The pre-development site was used for agriculture (mainly horticulture) with associated soil disturbance and potential for increased pollutant loads such as sediment and nutrients discharging into the coastal wetland. Previous site discharge had no significant water quality treatment that we are aware of, apart from a portion draining into an existing dam.
- The post development case aims to improve runoff water quality through the use of water sensitive urban design structures such as bio-retention systems and gross pollutant traps. Capture and re-use of rainwater is proposed with roof runoff rainwater tanks (400ML) and recycling for on-site irrigation.

2.2 MUSIC model review

Proposed water quality treatment design is tested using a comparison of pre and post development condition modelled using the industry standard MUSIC model (eWater, 2018).

The MUSIC model assesses the conceptual design of Water Sensitive Urban Design (WSUD) components and is the standard specified by most development codes in eastern Australia. Parameters to be used in each model are usually specified within design guidelines, however most are reasonably consistent unless site specific data is available.

No site specific water quality data has been provided for the Tweed area, and therefore the Tweed Shire Council Design Specifications and Queensland Urban Drainage Manual (2013) are relevant, with MUSIC pollutant parameter data in accordance with Water by Design MUSIC Modelling Guidelines (Nov, 2018) being the latest guideline, and considered applicable as used by RBG.

Rainfall data for the RBG MUSIC model was based on the data available for download from the eWater on-line Rainfall Data Tool (eWater, 2019). Data on the website has been assessed by eWater as suitable for MUSIC modelling of WSUD options. The recommendation by OEH is to assess data of 20 years minimum, however this length of record was not available at the 6-minute time increment recommended for this size site. A longer period of data (2003-2017) was obtained from the Bureau of Meteorology Climate Data Online (BoM, 2019), via purchase.

Table 1 shows the data available from a check of the Bureau of Meteorology database. The first site is the eWater MUSIC available data set which is under nine years in length. A second nearby site was found at Coolangatta with just over 14 years of data, and a third site at Gold Coast Seaway having 19 years of record (but 38km away), however it had several data gaps that significantly limit its use. Therefore, the Coolangatta site 040717 was used for analysis, being a longer period than Coolangatta Bowls, and also more recent and continuous.

Table 1: Available rainfall data for MUSIC modelling

Site	Data Start- Finish	Annual Rainfall	Comment
040052 Coolangatta Bowls (9.9km from site)	9/1972-6/1981	1934	MUSIC website data
040717 Coolangatta (12.2 km from site)	9/2003-1/2018	1438	Good quality recent data set, also used in this review
040764 Gold Coast Seaway (38.4 km from site)	3/2000-7/2019	1163	Significant data gaps and reasonable distance away

The MUSIC model catchment review is included with the DRAINS model review in the next section.

MUSIC model water quality objectives set by Tweed Shire Council (TSC, D7, 2016) are for the following pollutant load reductions:

Total Suspended Solids (TSS) 80%,
Total Phosphorous (TP) 60%
Total Nitrogen (TN) 45%
Gross Pollutants 90%

Analysis using alternative recent rainfall data from 2003-2017 was undertaken for comparison and results shown in Figure 1 (1972-1981 data) and Figure 2(2003-2017 data). The basins in the model are lined which reduces infiltration.

	Pre-development Annual Load	Post-development Annual Load (Untreated)	Post-development Annual Load (Treated)	% Reduction	TSC Target
Total Flow	78.7	136	134	1.7	N/A
TSS	29,900	32,200	5,580	82.7	80%
TP	31,500	71.6	21.3	70.3	60%
TN	183	429	201	53.2	45%
GP	415	2100	0.054	100	90%

Figure 1: Water Quality (MUSIC modelling) results copied from RBG (2019), MUSIC 1972-1981 data

	Sources		Residual Load		% Reduction	
	Pre	Post	Pre	Post	Pre	Post
Flow (ML/yr)	90.6	142	90.6	140	0	1.41
Total Suspended Solids (kg/yr)	35600	33800	35600	7000	0	79.3
Total Phosphorus (kg/yr)	37.2	75.2	37.2	26.4	0	64.9
Total Nitrogen (kg/yr)	207	454	207	236	0	48
Gross Pollutants (kg/yr)	412	1930	412	0.19	0	100

Figure 2: Water Quality (MUSIC modelling) results screenshot using more recent BoM 2003-2017 data

The results support the RBG (2019) assessment for pollutant load reduction to the required levels for TP and TN, however the TSS reduction using 2003-2017 data is shown as being just under the 80% level at 79.3%. This reduction could be easily improved to 80% with slight design modification, if required.

With regard to the mean total annual flow volume from site, this is shown as increasing by just over 50% from pre-development (90.6ML/yr) to post development (140 ML/yr) for 2003-2017 data. This is similar to, but lower than the 70 % increase indicated in RBG (2019, Table 5.2) annual load assessment of 78.7 ML/yr pre-development to 134 ML/yr post development using 1972 to 1981 data. The reason for the large increase is that the development has a significant area that has become impervious (roofs, carparks, roads, paths) compared to the original agricultural land that readily allowed infiltration. An option for reducing this is discussed later.

In terms of changes to total pollutant load, Total Suspended Solids (TSS) and Total Phosphorus (TP) are reduced below pre-development levels, while Total Nitrogen has increased by approximately 14% (207 kg/yr to 236 kg/yr). This result is consistent with an increase in TN found by the RBG assessment using 1972-1981 data. Again, this increase in total load can be reduced with some design modification. It is noted that the Landscape proposal in the SSD 9575 approval drawings included potential rain gardens.

Reducing the post development flow volumes to pre-development levels is difficult without a significant increase in storage, and mechanisms of transferring this to groundwater, which would also likely make its way to the adjacent wetland over a delayed period.

The impact on the wetland water levels is minimal and discussed later in the dam filling option, Section 4.
The ecological impact of this has been assessed in Section 5.

Following submission of revision 02 of this report to DPIE, the department requested changes to the design MUSIC model (RBG model). The model has been updated to include the following changes and has been provided to SMEC for review:

- Commercial land use run-off parameters from 2018 Water By Design guidelines have been amended in respect of rainfall run-off and field capacity values. The updated model adopts the parameters as outlined in the 2015 NSW Music modelling guidelines.
- Rainfall data has been updated to use the 10 year (01/1989 to 12/1998) 6-minute rainfall data from the Elanora rainfall station (40609), obtained from the e-Water online rainfall Data Tool.
- A "natural" (bush/forest) sub-model has been created as well as the pre-development and post-development sub-models for comparison with the natural state.
- A proposed 400KL rainwater reuse tank has been included in the model.

The following results have been obtained from the updated mode (refer Table 2)l:

Table 2: MUSIC modelling results (December 2019)

Mean Annual Load	Natural state (bush / forest)	Pre-development (agricultural land use)	Post-development (without treatment)	Post-development (with treatment)
Flow (ML/Yr)	63.7	69.6	113	99.6
Total Suspended Solids (kg/yr)	3,750	19,000	25,000	2,880
Total Phosphorus (kg/yr)	4.23	21.7	58.6	13.7
Total Nitrogen (kg/yr)	48.4	127	355	134

The updated MUSIC model demonstrates compliance with the TSC development control plan requirement to reduce the post development flows by the following reduction targets (compared with post development loads without treatment). Suspended solids 80%, Phosphorus 60%, Nitrogen 45%, gross pollutants 90%. It also demonstrates a significant overall improvement in water quality compared with the modelled pre-development state (other than a very small increase in nitrogen). It is noted that the MUSIC model has only accounted for a reduction in total flows of approximately 11ML for the rainwater tank (compared to the 17ML calculated by the project hydraulic engineer).

2.3 Reducing post development flow volume

A 400KL rainwater reuse tank was modelled to collect and store rainwater from the hospital roof to use for irrigation and cooling tower. The results showed that the reusing stormwater will reduce the total stormwater discharge by approximately by 17ML per year on average.

Using the recommended MUSIC model parameters indicates that reducing post development annual flow volume to pre-development levels is not feasible due to geotechnical limitations on use of range of other water quality treatment devices such as infiltration trenches, raingardens and permeable pavements etc (refer Morrison Geotech – Clarification on General Drainage Comments – Tweed Valley Hospital – Cudgen Road, Kingscliff). The stormwater volumes entering the basin will not be further reduced than the existing limitation stated above of 17ML per year.

2.4 DRAINS model review

2.4.1.1 Model Parameters

A review of model parameters used for both MUSIC and DRAINS models was carried out as part of the review process to check consistency of the modelling data.

Table 3 and Table 4 show the model parameters used by RBG (2019) DRAINS and MUSIC models.

Table 3: RBG DRAINS model parameters for basins

	Basin A	Basin B	Basin C	Basin D
Total Catchment (ha)	7.385	0.3	1.44	3.41
% Impervious	60	50	85	50
% Pervious	40	50	15	50

Table 4: RBG MUSIC model parameters for basins

	Basin A	Basin B	Basin C	Basin D
Total Catchment (ha)	6.77	0.21	1.25	3.30
% Impervious	62	26	65	25
% Pervious	38	74	35	75

The SMEC review confirmed that the parameters used in the MUSIC models were more accurate, hence the DRIAN model parameters were changed to replicate MUSIC model parameter.

ARR2019 data hub parameters for the Tweed Hospital Site was downloaded in August 2019 based on the latitude and longitudes shown in Table 5.

Table 5: Co-ordinate details used for ARR2019 Data hub request

	Requested	Nearest grid cell
Latitude	28.2639	28.2625
Longitude	153.5655	153.5625

The rainfall intensity parameters used by RBG were compatible with the data extracted by SMEC.

2.4.1.2 Modelling Methodology and results

The development of the RBG DRAINS models was carried out using Horton/ILSAX type hydrological model with less abbreviated data for time of concentration of 5 mins for each basin. The Table 6 shows the individual outflow from each basin.

Table 6: RBG DRAINS model runs with 2016 - ILSAX

Basin	Catchment Area (ha)	1% AEP Flow (m^3/s)		20% AEP Flow (m^3/s)		50% AEP Flow (m^3/s)		1EY (m^3/s)		4EY (m^3/s)	
		EXST	DEV	EXST	DEV	EXST	DEV	EXST	DEV	EXST	DEV
Basin A	6.77	4.45	1.61	3.09	1.41	1.44	1.13	1.24	0.67	0.56	0.35
Basin B	0.21	0.19	0.18	0.13	0.12	0.06	0.06	0.05	0.05	0.03	0.03
Basin C	1.25	1.11	0.44	0.68	0.38	0.36	0.27	0.30	0.25	0.15	0.12
Basin D	3.30	2.40	1.17	1.75	0.99	0.83	0.61	0.70	0.54	0.33	0.29

SMEC developed a XP-RAFTS hydrology model to verify the DRAINS flows. ARR2016 Initial Continuous Loss (IL/CL) method was adopted for both the XPRAFTS and the DRAINS modelling.

Table 7 shows the individual outflow from each basin. The results revealed that the developed flows for the 1% AEP event are reduced to below existing levels. However, for frequent events 50% AEP (Basins A and B), and all basins in the 1EY and 4EY events are significantly higher than the existing flows. It is expected these outflows could be reduced to pre-development levels for each basin through additional modifications to the outlet design.

Table 7: SMEC DRAINS model runs with 2016 IL/CL numbers used for rafts modelling.

Basin	Catchment Area (ha)	1% AEP Flow (m^3/s)		20% AEP Flow (m^3/s)		50% AEP Flow (m^3/s)		1EY (m^3/s)		4EY (m^3/s)	
		EXST	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**
Basin A	6.77	2.97	1.61	1.13	1.22	0.53	*0.65*	0.39	*0.54*	0.06	*0.26*
Basin B	0.21	0.12	0.14	0.05	0.07	0.02	*0.04*	0.02	*0.03*	0.00	*0.01*
Basin C	1.25	0.71	0.43	0.32	0.30	0.12	*0.24*	0.10	*0.20*	0.01	*0.10*
Basin D	3.30	1.75	1.12	0.80	0.73	0.30	*0.47*	0.23	*0.40*	0.03	*0.12*

A further assessment was carried out by SMEC to assess the combined flows at the outlet downstream of the dam for the development as a whole. Table 8 shows the combined outflows downstream of the dam. The results confirmed that the developed flows are greater than the existing flows for the 50% AEP, 1EY and 4EY rainfall events.

Refer Appendix A for hydrographs extracted from the DRAINS model for comparison.

Table 8: SMEC DRAINS model runs with 2016 IL/CL – Combined flows at the outlet.

Rainfall Event	Catchment Area (ha)	AEP OutFlow (m^3/s)	
		EXISTING	**DEVELOPED**
1% AEP	11.53	4.10	2.70
20% AEP	11.53	2.30	2.10
50% AEP	11.53	0.70	*1.20*
1EY	11.53	0.65	*1.10*
4EY	11.53	0.10	*0.30*

2.4.1.3 Recommendation

The developed flows for the more common 50% AEP, 1EY and 4EY rainfall events are greater than the existing outflows. The impact of increased and more frequent flows on the wetland is assessed as minimal benefits. Therefore, refining the basin outflow design for the 1EY, 4EY and 50% AEP would have minimal benefit and is not necessary for the protection of the Wetland.

3 Coastal Wetland Assessment

3.1 Rainfall data assessment

As indicated in the previous section, the 6 minute rainfall data for MUSIC has a maximum term of approximately 14.7 years, from May 2013 to Jan 2018. To consider 20 years' worth of data, daily rainfall records are required. Site 04717 Coolangatta (~12 km from the site) was used which contains data from December 1982 to 2019, with a 17 month gap from January 1993 to end June 1994. (25 years continuous from 1994).

A summary of the rainfall data statistics is shown in Table 9 below. It shows that there is no significant difference whether considering the rainfall from 1982, or from 1994, noting that the days of rainfall have reduced. Therefore, daily data from 1994 and continuous data from 2003 for MUSIC modelling is supported.

Table 9: Summary of min 20 years rainfall data, site 04717 Coolangatta.

Statistic	1982-2018 -data gap 1/1993-6/94 (35 yrs)	1994-2019 (25 yrs)
Total days data	12,869	9,171
Average dry days between rain	4.79	4.80
Days of rainfall >1mm	3469 (27.1%)	2436 (18.9%)
Average rainfall (on a rainday (>0.2)	11.56 mm	11.46 mm
Average rainfall when >1mm per rainday,	14.6 mm	14.7 mm
Average rainday duration >1mm	2.29 days	2.28 days
Max days without any rain	54 (2012)	54 (2012)

3.2 Increase in flow to wetland from development

Frequent events (more frequent than the 50% AEP) have been shown by the MUSIC modelling to increase the annual flow volume to the wetland by approximately 50%. For the high flow events of 20% AEP and 1% AEP, the proposed bio-retention basins by RBG have been shown to reduce peak flow to below the existing level for the site overall.

The basin outlets are designed with scour protection (from the RBG SWMP), however a detailed design was not yet available. The outlet channel is straight forward to design to reduce scour potential, particularly where the outflow channel connects to the wetland.

As an example, using Manning's formula, for a peak 1% AEP discharge of 1.61 m^3/s from Basin A, assuming a maximum channel depth of 0.3m, slope of 1% and maximum velocity of 1m/s, the flow could be accommodated with a 5m wide base width, 1:4H side slope, rock channel (n=0.045).

The channel from the basin to the outlet point could be made narrower and deeper, with flow slowed down and spread out where it discharges to the wetland. The other basins have smaller outflows and would require smaller channels as a result. The channels could also be designed for additional infiltration as discussed in the groundwater, Section 3.4. RBG confirmed that the infiltration trenches are not feasible doe to geotechnical risks.

3.3 Comparison of pre and post development flows to wetland

A comparison of flow discharge from the developed bio-retention basins was undertaken in the DRAINS model review (Section 2.3) with hydrographs provided in Appendix A.

It was shown that for the more frequent events the developed flow and volumes exceeded the existing case.

Determining the impact on the coastal wetland is made difficult by the very flat nature of the area and the disconnected low flow points.

The coastal wetland is flooded on a regular basis from the Tweed River (BMT, 2018) with a 5% AEP flood depth of approximately 2m (correlating to RL 2.5-3.0 m AHD) and 1% AEP flood depth of approximately 3.0 m

Outflow from the 4EY and 1EY events from the development site, although higher than the existing flows, effectively only fill some of the localised depressions. This is shown in the later dam filling assessment, Section 4.

Table 10: Approximate flood levels in the wetland for frequent events.

Minor flood Event (development site only)	Estimated Water level m AHD
Existing dam water level (at time of RBG survey)	0.27
Surrounding ground level	0.6-0.8
4EY (avge 4 exceedances per year)	0.6
1EY (avge 1 exceedance per year)	0.7
20% AEP	0.75

The results from the table indicate that outflow from the development site has minimal impact on coastal wetland levels, and effectively only fills the local depressions. The assessment only considers the impact from the development site, as a worst case or conservative assessment.

It should be recognised that if a rain event occurs on the development site then it will also very likely occur on the wetland and therefore the rise in water level could actually be much more significant. There are no initial or continuing rainfall losses when rainfall occurs directly onto a water surface, and therefore the water level increase to the wetland may be higher than due to discharge from the development.

It is noted that the frequency of minor runoff events into the wetland may increase significantly due to the development, however the change in wetland flood level is expected to be less than 50mm from these events, and return to normal level within a day or so, if connectivity between wetland depressions and the natural outlet remain.

3.4 Groundwater

Geotechnical assessment by Wood and Grieve (W&G, 2018), indicates the site material to be Silty Clay overlaying basalt at depth. At the lower end of site permeability percolation tests (Bore Hole 22 and 23) were undertaken to depths of 0.5m within the proposed bio-retention area.

The results are shown in Table 11 and indicate high permeability values. The testing shows than rainfall readily infiltrates into the ground in the lower elevations of the site.

Table 11: Permeability values (taken from W&G, 2018)

Test number	Borehole 22 (Permeability (mm/hr)	Borehole 23 (Permeability (mm/hr)
Test 1	670.3	203.5
Test 2	83.5	60.9
Test 3	149.0	77.6
Average of Test 2 and 3	116.3	69.3

The result for Test 1 appears very high and may be a result of other issues. Therefore, to be conservative the lowest average permeability of 69 mm/hr was used for testing in the MUSIC model to assess the impact of infiltration. MUSIC model representative infiltration rates for medium clay are 0.36-3.6mm/hr, or up to 36mm/hr for sandy clay.

The W&G geotechnical report indicated that seepage may occur at the natural soil/weathered rock interface, especially following rain events, and that the groundwater level is dependent on rainfall, subsurface material and permeability of the ground, and proximity and type of vegetation.

Given the slope of the site is perpendicular to, and direct connected to the wetland, it is expected that any infiltration on site in pre and post development conditions would be a source of groundwater inflow to the wetland.

According to the report (Morrison Geotech – Clarification on General Drainage Comments – Tweed Valley Hospital – Cudgen Road, Kingscliff), the groundwater in the existing condition is connected to the wetland and therefore adding infiltration provides limited practical benefit.

RBG confirmed that the other SMEC recommendation for use of infiltration treatment devices such as infiltration trenches, swales, rain gardens and permeable pavements etc could not be implemented due slope slip failure on the steep batters around the site due to waterlogged subsoil. Because of the geotechnical risks, infiltration devices will not be feasible.

Also, the recommendation to remove the basin liner will not be feasible due to the same geotechnical risks mentioned above.

Therefore, the MUSIC model is run with the basins lined and water recycling via 400KL rainwater tank (from RBG). Refer Table 12 for the flow volumes.

Table 12: Flow Volumes (including rainwater tank)

Infiltration option tested (using 2003-2017 data)	Pre-development flow volume ML/yr average	Post Development flow volume ML/yr average
Current stormwater model with the four basins lined and water recycling via 400KL rainwater tank	63.7	99.6

3.4.1 Recommendation

The use of infiltration treatment devices such as infiltration trenches, swales, rain gardens and permeable pavements etc could not be implemented. The stormwater volumes entering the basin will not be further reduced than the volumes mentioned in Table 12. The existing, long established, coastal wetland area has proved resilient throughout numerous inundation event well in excess of anything likely to result from the inflows from the proposed development. Therefore, it is unlikely to result in any significant structural change to the coastal wetland (dominant floristics of this community) due to annual flow increase of 36ML/yr.

4 Dam filling options

4.1 Methodology

A TUFLOW hydrodynamic model was built for the purposes of assessing the flood level and flow impacts of the proposed dam infilling. The outlet flow from each of the four basins was extracted from the DRAINS model and utilised as inflows in the TUFLOW model. The TUFLOW model DEM was on a 2 metre grid resolution based off the provided survey and sourced LiDAR data. To model the dam infill an elevation of 0.3 mAHD was assumed for the surface level of the dam.

A rain on grid model of the existing case was modelled to determine flow paths surrounding the wetland and the dam. It was determined that very minor flows from the wetland reach the dam and therefore only the proposed development basin outflows were considered for this assessment.

4.2 Option 1: Impact of filling the dam to match surrounding ground level

The dam filling option has been assessed based on the Basin outflow for the two extremes of discharge, being the 1% AEP and 4EY events.

Figure 3 and 4 below show the difference in peak flood levels for the 4EY and 1% AEP event respectively. The grey shading indicates an impact of less than 10mm.

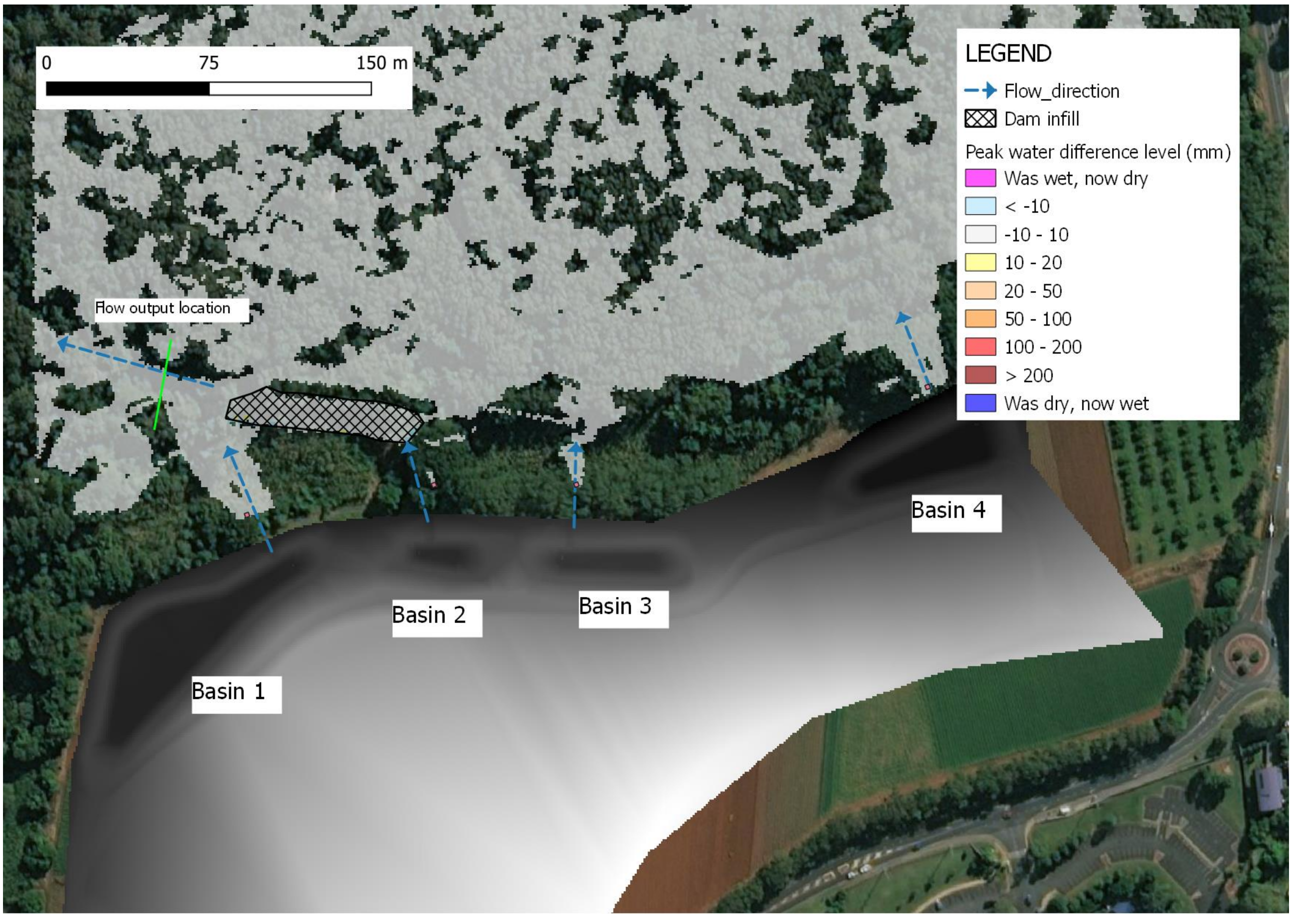

Figure 3: 1% AEP Peak flood level impact map

The impacts from in the infilling are larger for the 4EY event where the loss of storage is more significant relative to the storm volume. For the 4EY event the flood levels increase approximately 50 mm at the outlet of the dam. It is noted there is no increase in inundation extent from the dam infilling for any design event.

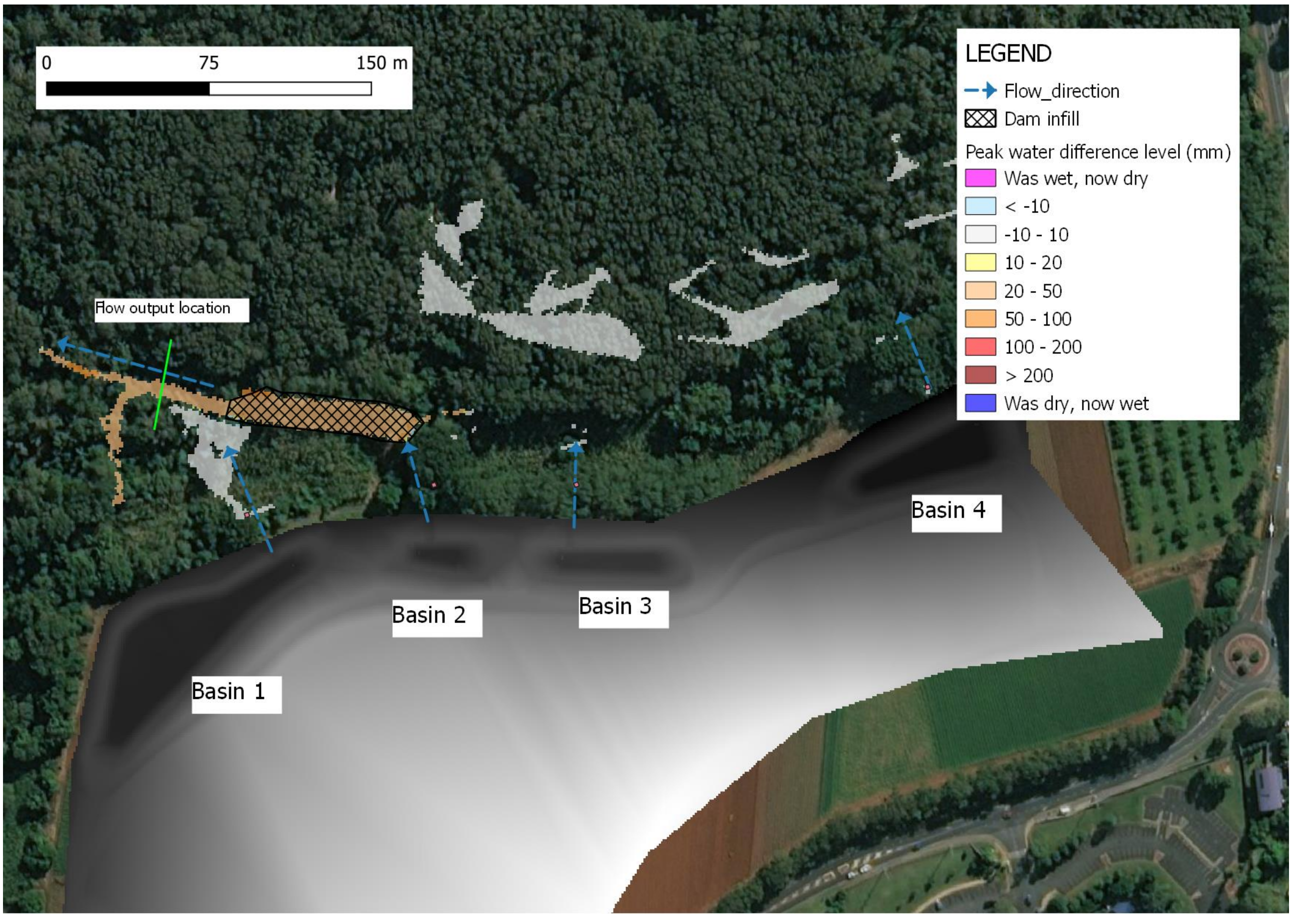

Figure 4: 4EY Peak flood level impact map

Figure-5 below shows the hydrograph plots for the outlet of the dam for the respective scenarios in the 1% AEP event. The loss of storage is seen early in the hydrograph although at the peak of the storm the loss of storage volume of the dam is negligible with peak discharges similar.

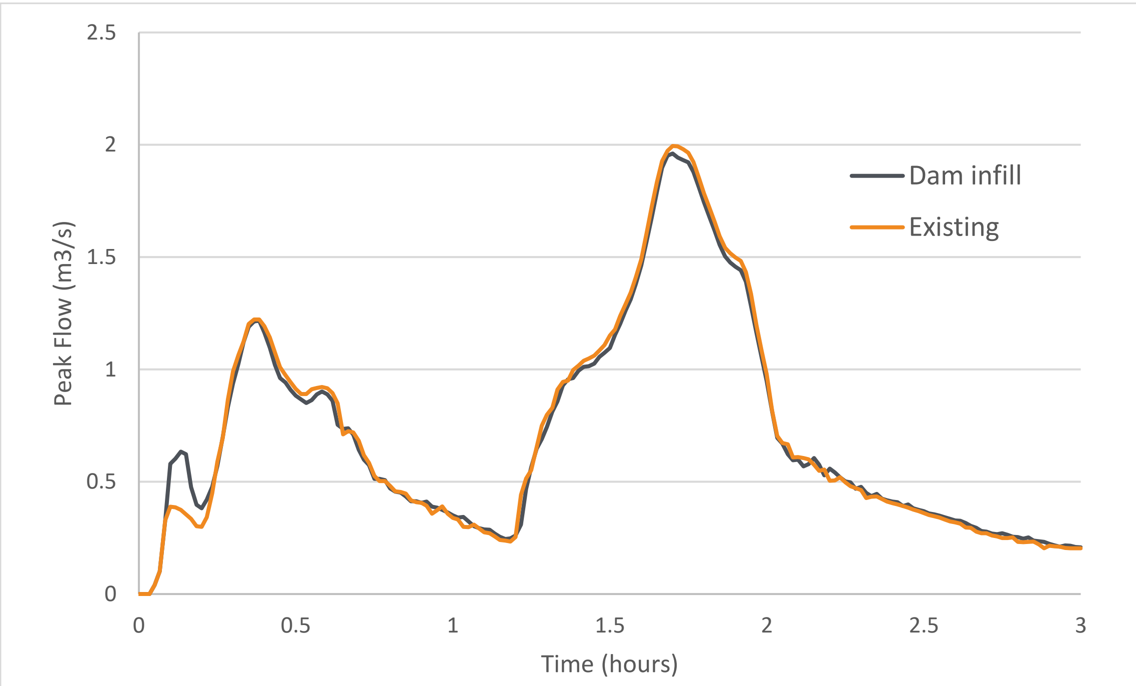

Figure 5: 1% AEP dam outflow hydrograph

Figure 6 below shows hydrograph plots for the outlet of the dam for the respective scenarios in the 4EY event. The peak flow is only 0.125 m3/s, and when compared to the volume of the wetland with an area of 30.7ha is almost negligible.

The change in flows and volume has not resulted in any increased inundation extent and from a flooding perspective is considered to have no impact on the 1% and 20% AEP flood levels, and no material impact from more frequent events from a hydrology perspective. Ecological impact should be assessed for the frequent events

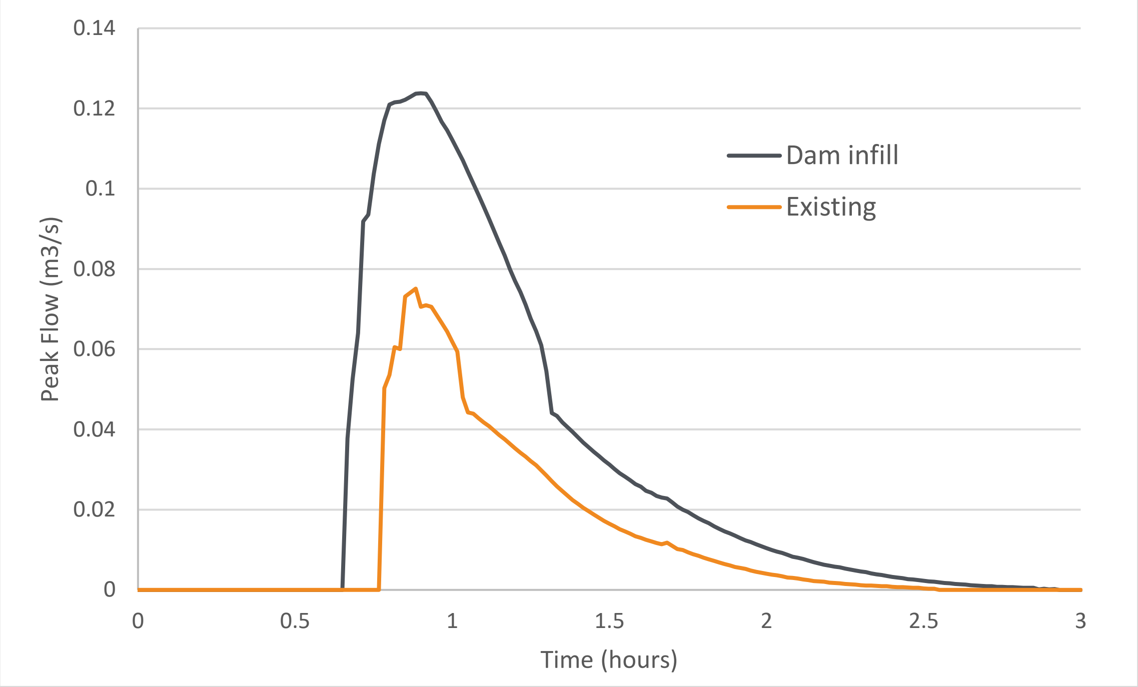

Figure 6: 4EY dam outflow hydrograph

4.3 Option 2: Impact of filling the dam with low flow channel

Although the dam filling has no impact from a flood perspective, it would be considered prudent to provide some form of low flow channel or path to allow low flows to drain, minimising isolated pools and soft spots that could affect maintenance access to the area for removal of Salvinia.

5 Ecological Values associated with the Coastal Wetland

Previous ecological assessment of the site (Greencap, 2019) identified a number of threatened species and ecological communities within and adjacent to the 36ha of mapped coastal wetland area.

These include:

- Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC;
- Lowland rainforest on floodplain in the NSW North Coast Bioregion EEC;
- Mitchell's rainforest snail *Thersites mitchellae* specimens were detected during BDAR threatened species surveys, however, all of these were recorded outside the Project Site boundary in the northern portion of former Lot 102 DP 870722 (Greencap 2019); and
- Two pH dependent amphibians were identified by the BAM Calculator as candidate threatened species – Wallum froglet *Crinia tinnula* and Olongburra frog *Litoria olongburensis.* There are records for these species within the 1,500 m assessment area and within the receiving catchment (Greencap, 2019).

As noted earlier in the report current modelling predicts a mean total annual flow from site to increase by almost 50% from pre-development (90.6 ML/yr) to post development (140 ML/yr), although previous discussion considers mitigation of these flow volumes.

The potential impacts considering the current additional flows is assessed in the following sections by a suitably qualified professional (Jon Alexander, Ecologist, CV in Appendix B).

5.1 Impacts on vegetation communities

5.1.1 Swamp sclerophyll forest on coastal floodplains

The composition of this community is primarily determined by the frequency and duration of waterlogging and the texture, salinity nutrient and moisture content of the soil, and latitude. The composition and structure of the understorey is influenced by grazing and fire history, changes to hydrology and soil salinity and other disturbance, and may have a substantial component of exotic grasses, vines and forbs (NSW OEH, 2019).

The vegetation within the mapped extent of the coastal wetland has previously been identified as predominately being Broad-leaved Paperbark (*Melaleuca quinquenervia*) Closed Forest to Woodland (TSC LGA Mapping, 2012). While Broad leaved paperbark cannot survive permanent inundation, they do have adaptations such as fibrous or adventitious roots around their lower trunk that are thought to function as breathing roots, helping the tree to survive during long periods of submersion (McJannet, 2008). Similarly the composition and diversity of the mid and understorey will vary with latitude and the length of time the swamp contains water, but can typiclly include shrubs such as quinine berry *Petalostigma pubescens*, and *Banksia sp.* on the margins; sedges such as soft twigrush *Baumea rubiginosa*, *Lepironia articulata* and bogrush *Schoenos breviofolius*; saw-sedges such as *Gahnia sieberiana*; reeds such as the common reed *Phragmites australis*; other grasses such as *Ischaemum spp*., swamp rice grass *Leersia hexandra*, blady grass *Imperata cylindrica* and saltwater couch *Sporobolus virginicus (DERM, 2010).*

Given these factors the addition of approximately 10 to 20mm of additional inflow from the developed site during significant events for parts of the wetland, and 10-50mm within the dam, is unlikely to result in any significant structural change to the dominant floristics of this community.

It is noted that flooding from Tweed River (BMT, 2018) indicates inundation depths for the wetland of approximately 2m for the 5% AEP event and 3m for the 1% AEP event. This suggests that the existing, long established, coastal wetland area has proved resilient throughout numerous inundation event well in excess of anything likely to result from the inflows from the proposed development.

5.1.2 Lowland rainforest on floodplain

The occurrence of this community appears to be limited to the slightly elevated margins of the Broad-leafed paperbark community and is probably closely linked to the localised limits of the volcanically derived soils in the area. Given its occurrence in these slightly elevated locations it is considered unlikely to be materially impacted by the additional inflows expected and, given the seasonality of rainfall in the region, may in fact benefit from additional inflows during the drier winter period.

5.2 Impacts on Fauna Species

5.2.1 Mitchells Rainforest Snail *(Thersites mitchellae)*

Mitchell's Rainforest Snail is restricted to lowland subtropical rainforest and swamp sclerophyll forest with a rainforest understorey, typically on alluvial soils with a basaltic influence. It is apparently absent from other rainforest types in the area, such as littoral rainforest (Stanisic 1998). This type of correlation with particular rainforest communities is common in many land snail species in eastern Australia (Stanisic 1994). The limited research available suggests the species is dependent on high moisture levels, low fire frequency, and a well-developed leaf litter layer. With consideration of those habitat preferences it seems unlikely that a minor increase in inflow levels will negatively impact the development or maintenance of existing habitat.

There may be potential positive impacts for this species associated with the reduction in sediments coming from the hospital site as the landuse is transferred from agricultural/horticultural use with exposed soils, to the proposed end use where all pervious areas are vegetated, and stormwater treated.

5.2.2 Wallum froglet *Crinia tinnula* and Olongburra frog *Litoria olongburensis*

Records of these two species exist within the 1,500 m assessment area and within the receiving catchment (Greencap, 2019). Survey was not undertaken to detect these species for the BDAR, as the directly impacted windrow vegetation was considered too degraded and/or did not represent suitable habitat for these species (Greencap, 2019).

Both species of frogs are more commonly associated with coastal sandplain swamps than with the Broad-leaved paperbark which is predominate in the mapped extent of the coastal wetland area. Wallum froglet has been recorded in swamp sclerophyll forests but is more typically associated with sedgelands and wet heathlands (Anstis, 2013). This habitat preference is also true of the Olongburra frog which has a strong preference for inundated areas characterised by the presence of emergent sedges, with upright species such as *Baumea* spp. and *Schoenus* spp. preferred by adult frogs for perching (Shuker, J.D. and Hero, J. (2012) .

Given the uncertainty of the presence of these species in the mapped coastal wetland area and their preference for generally different habitat, including inundated areas with the presence of emergent sedge species, there is no obvious likelihood of a negative impact on these species as a consequence of changed inflows associated with the development.

If the species are present, the reduction in sediment load and residual agricultural chemicals, resulting from the changed landuse and improved stormwater management is likely to be beneficial to these species.

6 References

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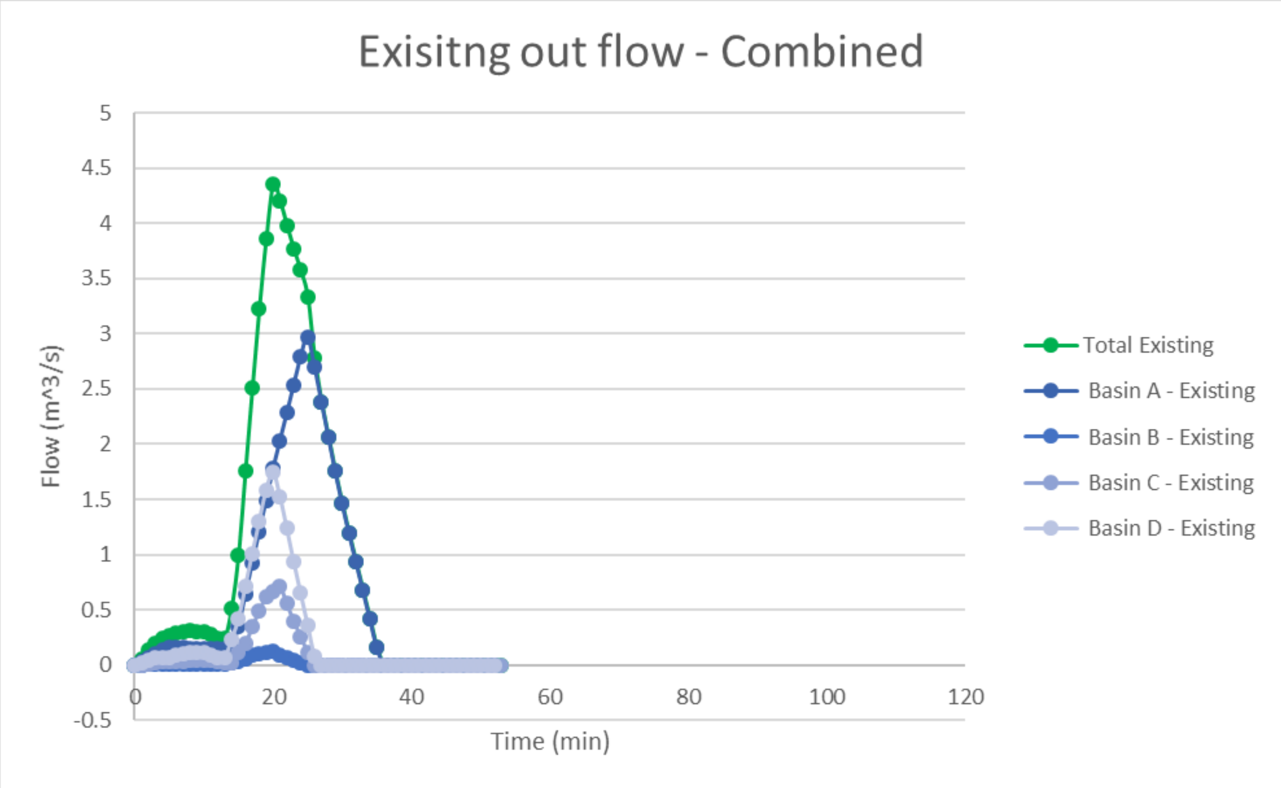
Shuker, J.D. and Hero, J. (2012) Perch substrate use by the threatened Wallum Sedge Frog (*Litoria olongburensis*) in wetland habitats of mainland eastern Australia. *Australian Journal of Zoology* 60: 219–224.

TSC, (2012), Tweed Shire Council Tweed LGA Vegetation Mapping.

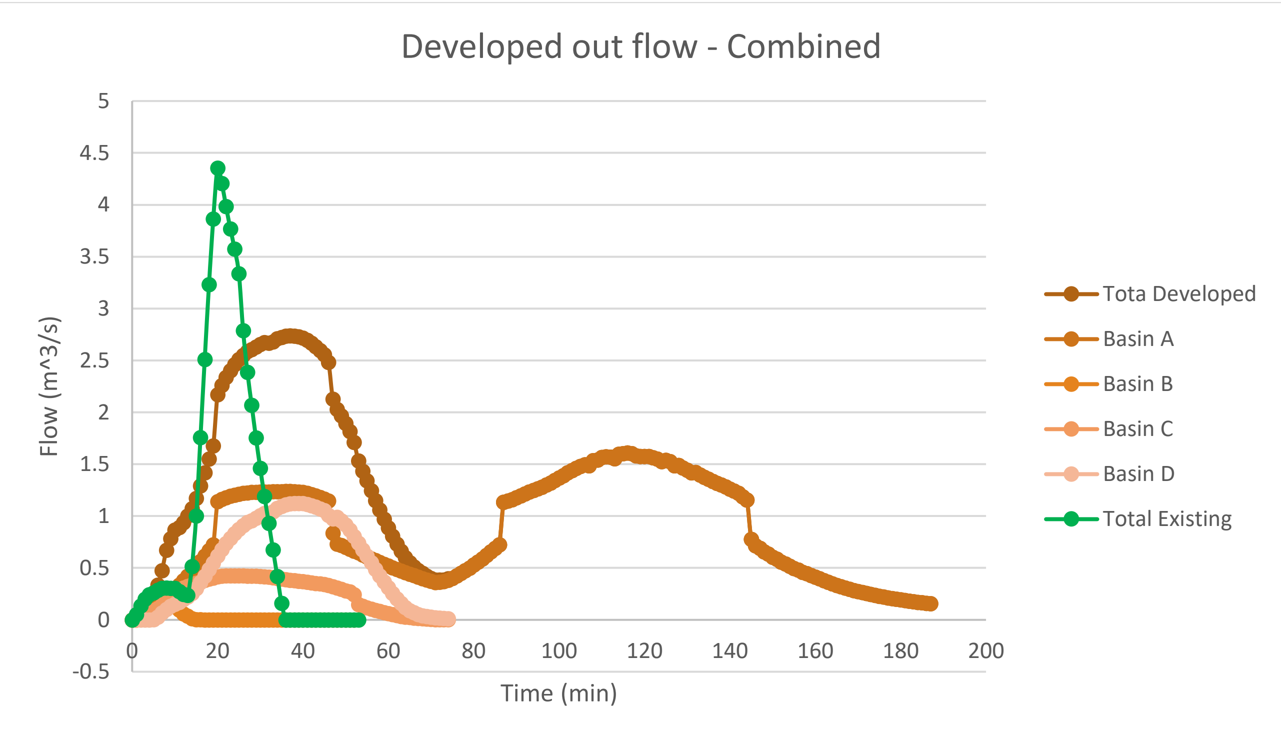
W&G (2018), Wood and Grieve Engineers Pty Ltd, Additional Geotechnical Investigation - proposed Tweed Valley Hospital, by Morrison Geotechnic.

Appendix A DRAINS – Hydrograph outputs

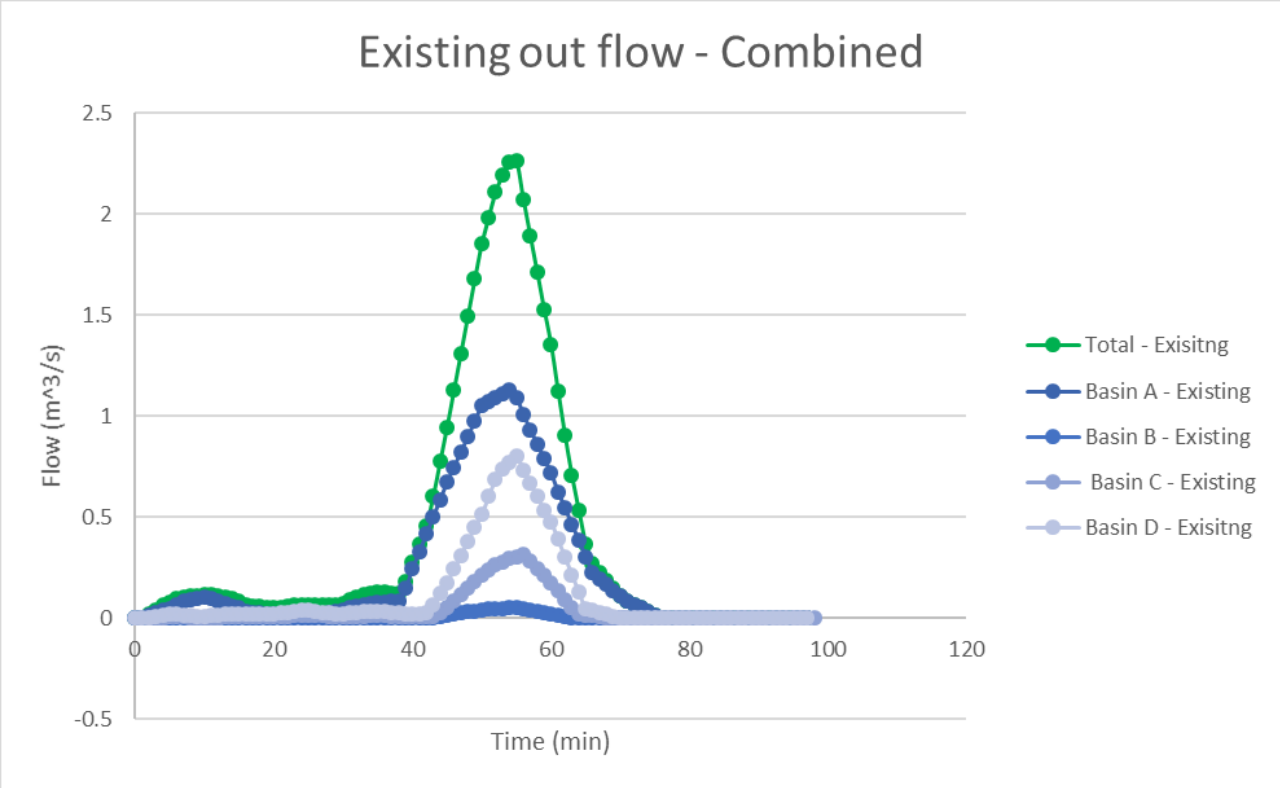
1% AEP – Existing



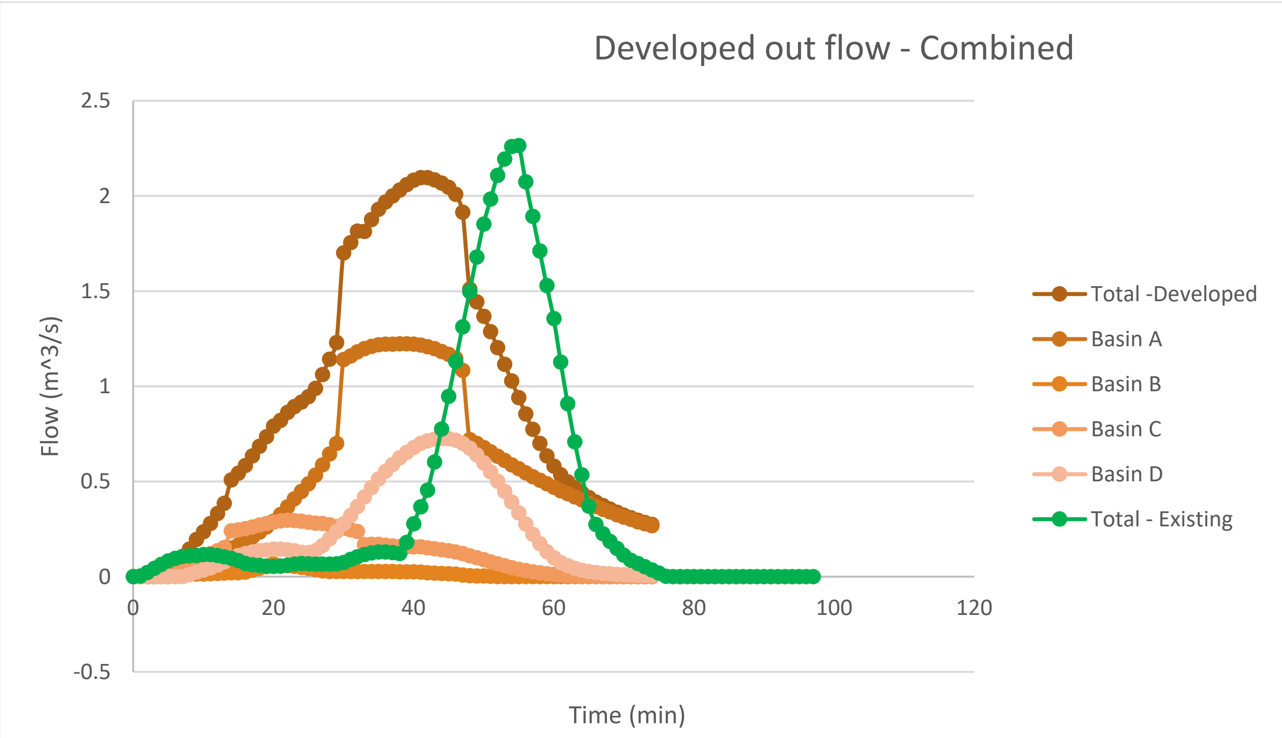
1% AEP – Developed



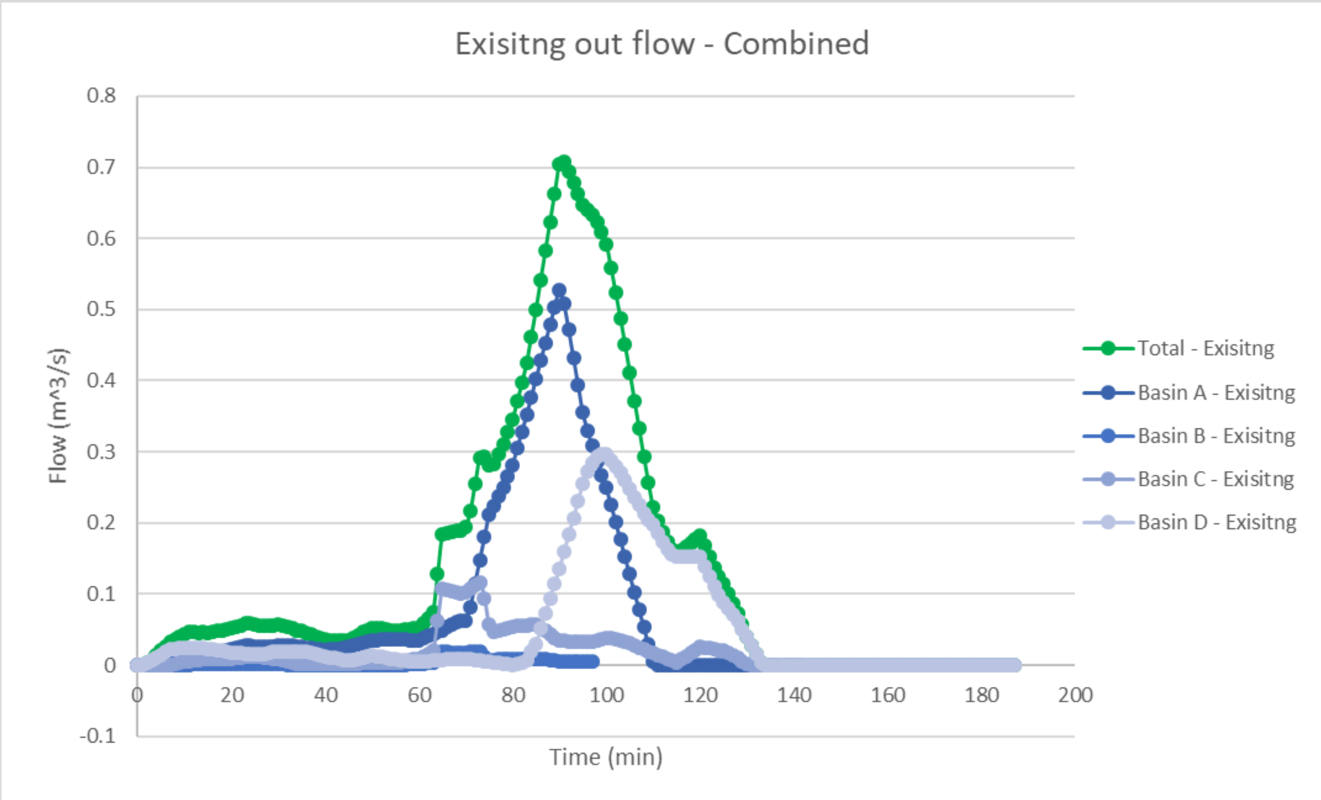
20% AEP – Existing



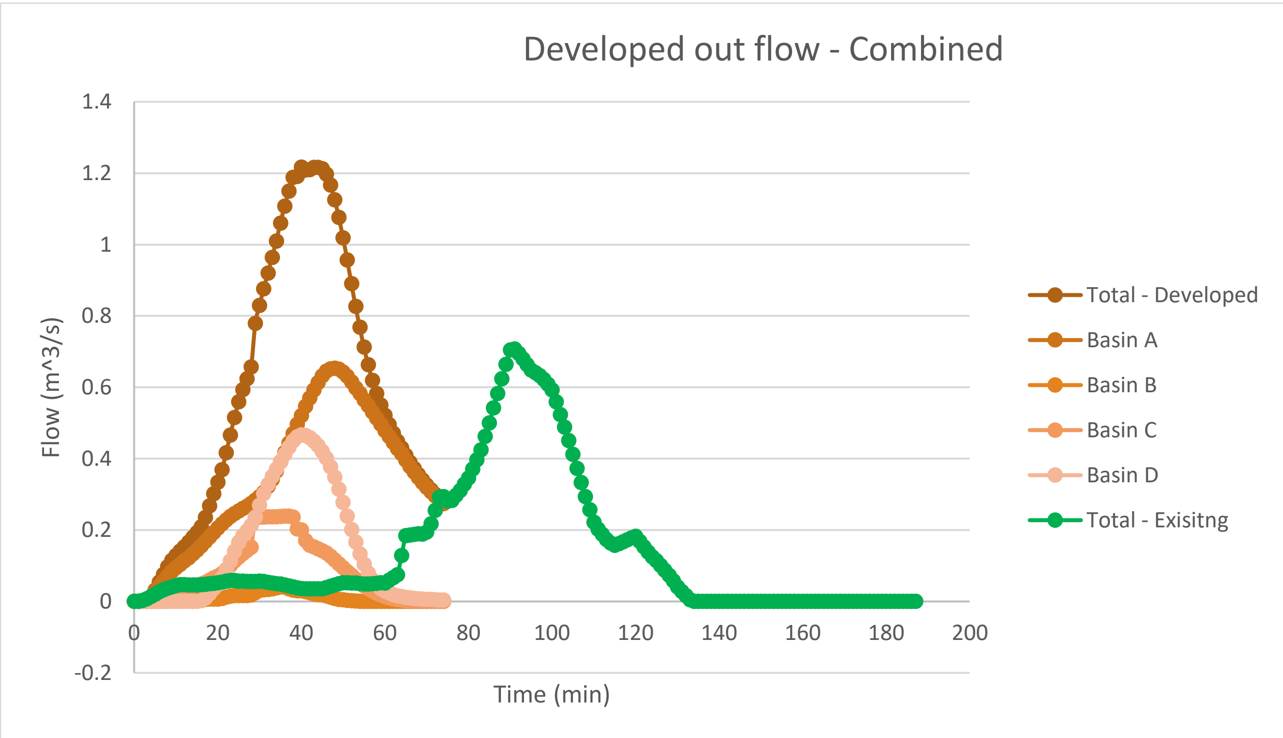
20% AEP – Developed



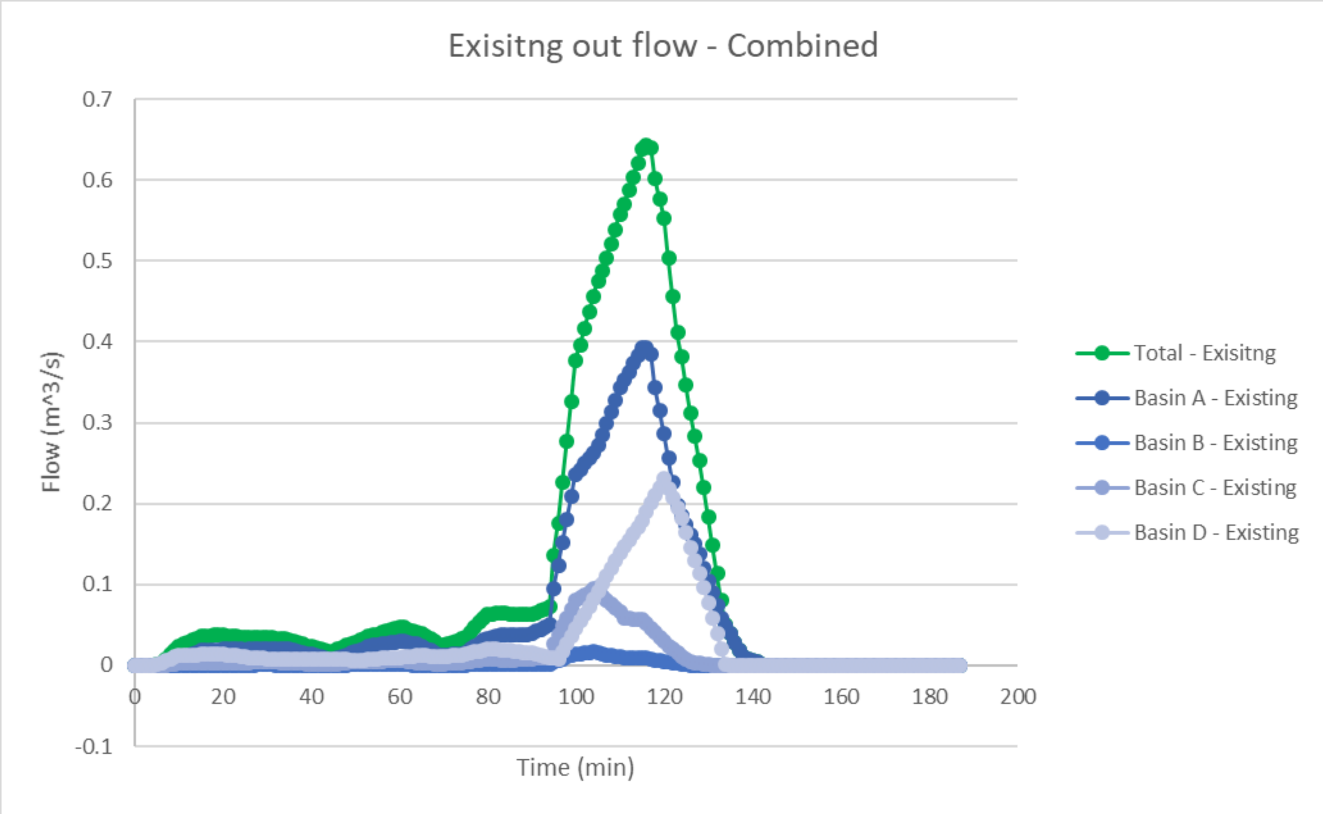
50% AEP – Existing



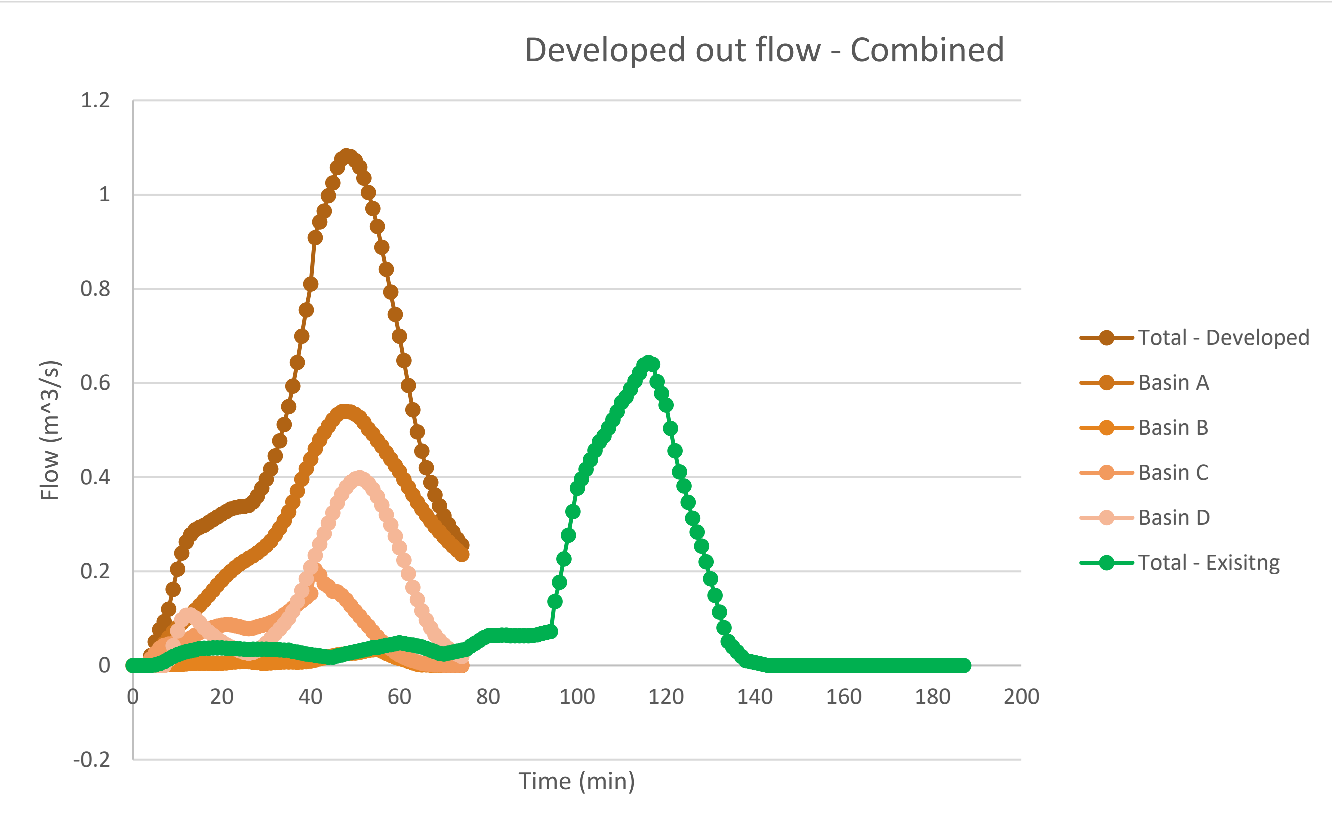
50% AEP – Developed



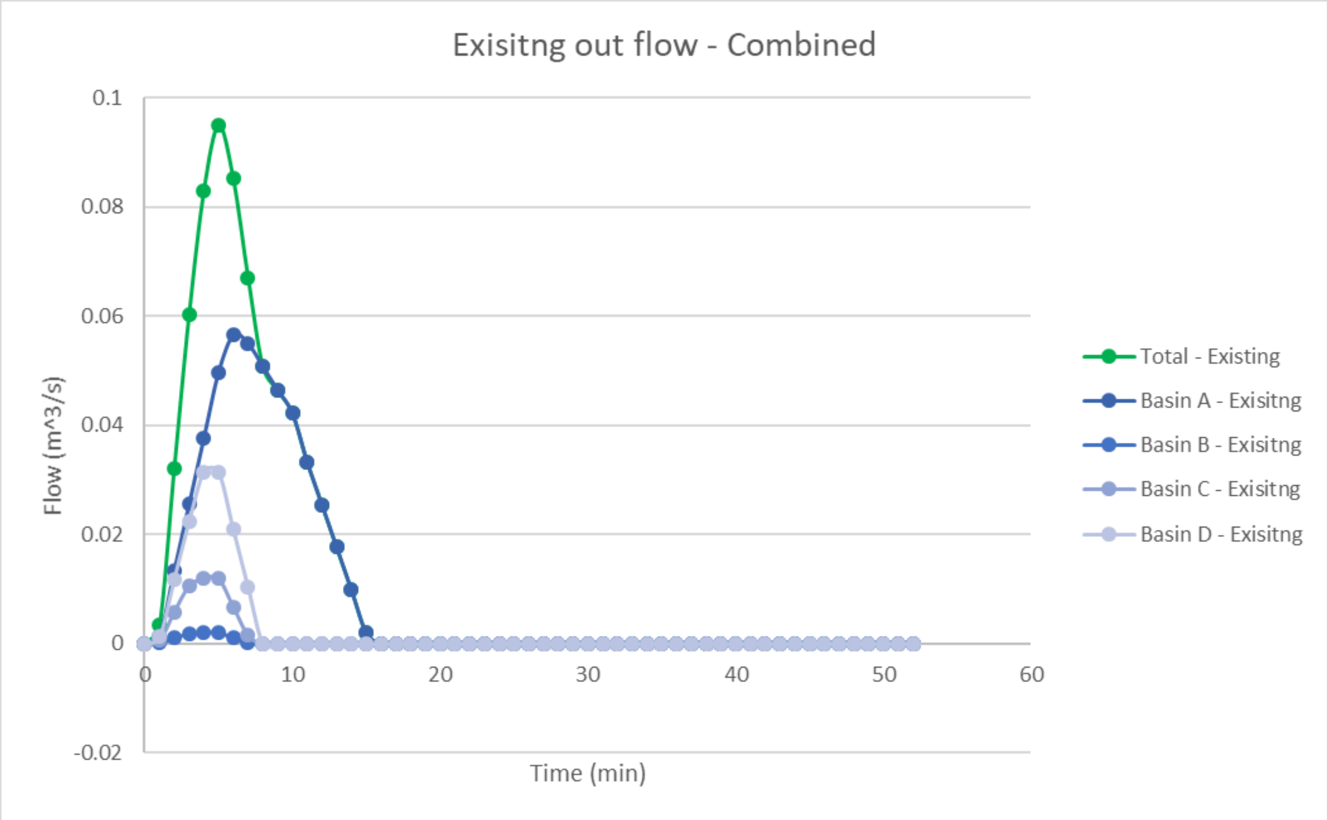
1EY – Existing



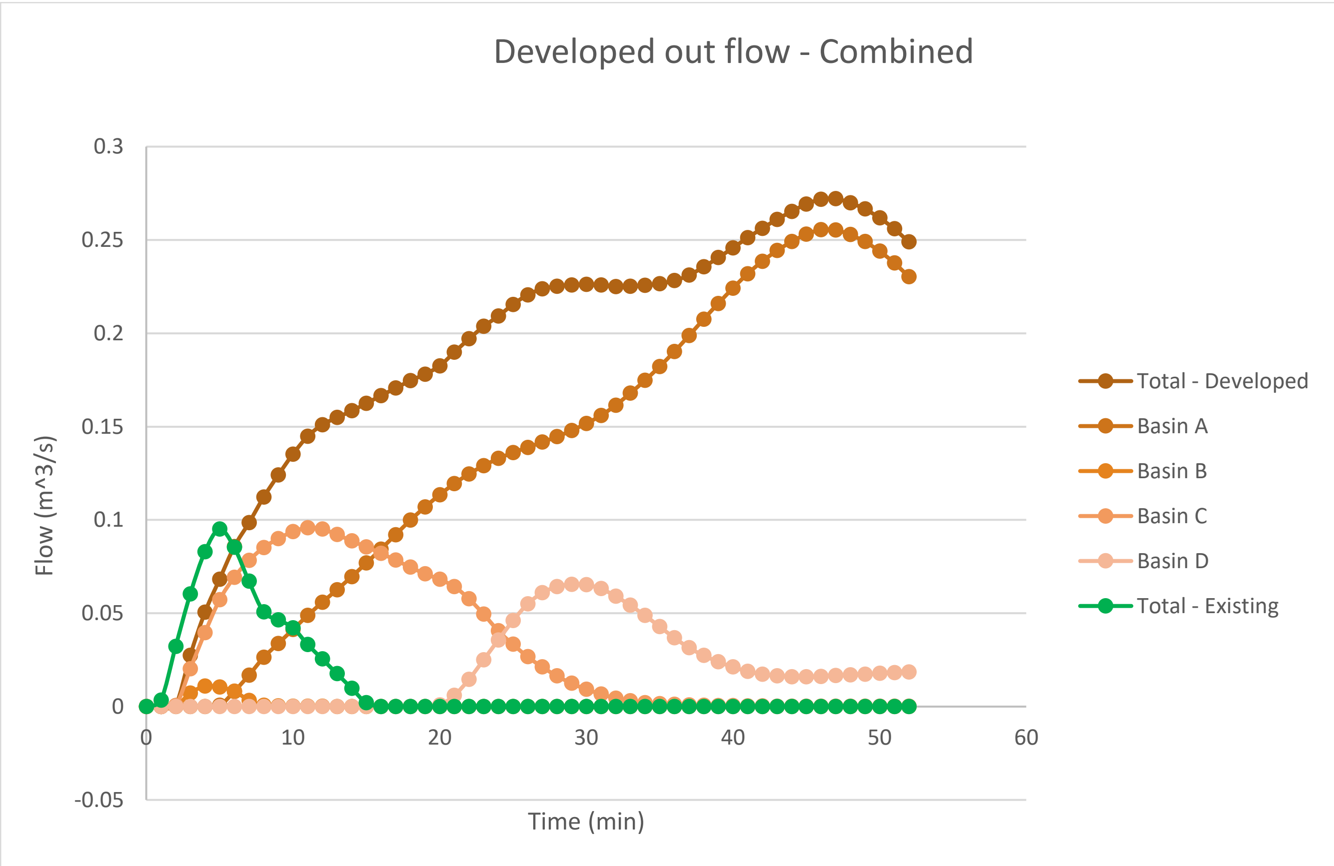
1EY – Developed



4EY – Existing



4EY – Developed



Appendix B CV: Jon ALEXANDER, Ecologist

Jon Alexander

Principal Ecologist

Professional Overview

Jon has over 25 years' experience in Ecological Assessment, Management and Planning with particular expertise in terrestrial vegetation ecology, Threatened species survey and conservation, vegetation rehabilitation and biodiversity related impact assessment.
Jon has been with SMEC for over 11 years and his areas of responsibility include assessment of environmental impacts on a diverse range of projects ranging from open cut mining and large scale linear infrastructure projects to ecotourism resorts and residential subdivisions.

Relevant Project Experience

Tugun Bypass Project Value (Construction) $500 Million.
Client: QLD DTMR/NSW RMS
Environment Manager of the operational component of the Tugun Bypass project. Responsible for delivery of an extensive post construction environmental monitoring program including survey of ENVT flora species and monitoring of ENVT Flora Translocation sites and detailed reporting to multiple stakeholders.

Cobaki Estate – Saltmarsh Rehabilitation Plan
Client: LEDA Manorstead Role: Project Manager
Preparation of a rehabilitation management plan and conducting of a baseline monitoring plan for a 75 ha saltmarsh rehabilitation project. This includes detailed vegetation mapping and ongoing monitoring of the site once rehabilitation has been undertaken.

Groundtruthing of Vegetation Mapping (Tamworth region)
Client: NSW National Parks & Wildlife Service
As part of a State wide Vegetation mapping exercise acted as a consultant botanist conducting Floristic survey and groundtruthing of NPWS vegetation mapping of the Tamworth area, North NSW. Project required survey of 96 full floristic sites.

Targeted Threatened Species Survey (*Grevillea beadleana*)
Client: NSW NPWS Northern Directorate
Conducted a targeted 2 week survey for the nationally endangered species Grevillea beadleana on the NSW northern tablelands and northwest slopes and plains.

Targeted Threatened Species Survey (*Hakea pulvinifera*)
Client: NSW NPWS Northern Directorate
Conducted a targeted 2 week survey for the nationally endangered species Hakea pulvinifera on the NSW northwest slopes and plains.

Groundtruthing of Vegetation Mapping (Blackville, NSW)
Client: Department of Land and Water Conservation
Floristic survey and groundtruthing of DLWC vegetation mapping of the Blackville Area, Central Western NSW. 120 full floristic sites.

Years of Industry Experience

25+ years

Qualifications and Memberships

- Bachelor of Applied Science (Hons). (Environmental Planning Major) Southern Cross University, Lismore. N.S.W.
- Bachelor of Applied Science. (Natural Resources) Southern Cross University, Lismore. N.S.W.
- Associate Diploma of Horticulture, Hawkesbury Agricultural College, Richmond. N.S.W
- Member of the Ecological Society of Australia
- Member of the Environment Institute of Australia and New Zealand

Key Skills and Competencies

- Flora Survey & Vegetation Assessment
- Terrestrial Ecology
- Vegetation Rehabilitation
- Bushfire Management
- Environmental Monitoring, Survey and Design
- Environmental Impact Assessment

Dunngir National Park Pest Management Planning
Client: NSW National Parks & Wildlife Service

Project involved survey and mapping of significant weed infestations throughout Dunngir National Park and preparation of a Weed and Vertebrate Pest management plan for the entire Park.

Lismore Mullumbimby 132kv Line Upgrade, NSW -
Client: Transgrid
Principal Botanist for this project. Responsible for targeted flora survey along the 45 km corridor. Locate, identify and map the location of listed threatened species within the corridor. Identify measures for management of impacts associated with construction and operational phases of the project. Provide input to amelioration and rehabilitation plans.

Flora Survey Mt Kaputar National Park Central Section
Client : New South Wales National Parks & Wildlife Service, Narrabri District
In collaboration with J.T.Hunter. Full floristic survey of Mt Kaputar National Park Central Section. Installation of 70 full floristic sites. Mapping of vegetation communities throughout the area and preparation of a detailed Report regarding the flora of the Park.

Flora Survey of Myall Lakes National Park
Client: New South Wales National Parks & Wildlife Service, Central Coast
In collaboration with J.T.Hunter. Conducted a full Floristic survey of Myall Lakes National Park including installation of 100 full floristic sites. Prepared detailed mapping of vegetation communities throughout the area and prepared a detailed Report regarding the flora of the Park.

Flora Survey of sections of the Pilliga Nature Reserve
Client : New South Wales National Parks & Wildlife Service, Western Zone Dubbo
In collaboration with J.T.Hunter. As part of a much larger exercise being run by the NSW NPWS conducted a floristic survey of parts of the Pilliga Nature Reserve. This included installation of 54 full floristic sites and preparation of raw data for incorporation into overarching reporting.

Flora Survey of additions to Guy Fawkes National Park.
Client : New South Wales National Parks & Wildlife Service, Glen Innes District
100 sites full floristic survey of additions to Guy Fawkes National Park. Other works included air photo interpretation. vegetation community mapping, preparation of a detailed report on the flora of the park addition.

EIS Flora Survey, Woodburn - Ballina Highway Diversion, NSW
Client: NSW RMS
Principal Botanist. This project was conducted as part of the route selection studies for the EIS of the Woodburn – Ballina Highway diversion and upgrade. The survey was conducted over the 5 proposed alternate routes and was used to help in the corridor selection process. Major tasks were field investigation and identification of significant flora and flora communities, detailed vegetation mapping, involvement in community consultation processes and provision of recommendations for corridor selection and supply of advice on rehabilitation of impacted areas

Clarence River (Kangaroo Creek Dam) Riparian and Instream Flora Survey, NSW
Client: NSW Public Works
Principal Botanist. This survey was conducted as part of the location selection planning studies prepared for the proposed Kangaroo Creek Dam. Principal tasks involved full floristic survey, vegetation mapping, and preparation of GIS coverages and air photo interpretation of approximately 30 sites across the lower Clarence catchment.

Shannon Creek Dam Flora Survey
Client: NSW Public Works
Principal Botanist. This survey was conducted as part of the planning studies prepared for the proposed Shannon Creek Dam. Major tasks involved a full floristic survey of the dam inundation area, vegetation mapping and air photo interpretation.

NCA Protected Plant Flora Trigger Surveys
Client: Various clients (Brisbane CC, GC Water, DTMR and Private Developers)
Completed 30 surveys of this nature since the Flora trigger Protected Plant requirement was introduced. All Surveys have been conducted in accordance with the relevant guidelines and all reporting has been accepted with no requests for additional information from State agencies.

Moreton Bay Rail Link – Saltmarsh Rehabilitation Plan
Client – Qld TMR Role: Technical reviewer
Technical review of a multi-site Saltmarsh Management and rehabilitation plan, as part of the offsetting requirements associated with the Moreton Bay Rail Link project.

Ipswich Motorway Upgrade (Dinmore to Goodna)
Client: Qld DTMR
Principal Botanist. Conducted detailed surveys for EVR species and communities and provided reports to inform the road design/ statutory approvals process. Also conducted detailed investigations and provide mapping of declared and environmental weeds.

Ipswich Motorway Upgrade (Rocklea to Darra)
Client: Qld DTMR
Principal Botanist. Conducted detailed surveys for EVR species and communities and provided reports to inform the road planning and preliminary design process. Also conducted detailed investigations and provide mapping of declared and environmental weeds.

Ecological (Flora and Fauna) Assessment
Client: Tiger International
Yeeda Station (WA) as lead ecologist completed detailed flora and fauna surveys and associated feasibility analysis for the establishment of a large scale aquaculture facility (1000 ha).

Daru Island (PNG) – Deep Water Port – EIS
Client: PNG Sustainable Development
Principal botanist/ team leader for flora assessment's required to support the preparation of the Environmental Impact Statement for the proposed deep water port at Daru Island, PNG.

Provision of Expert Witness Services
Client: Dept of Environment (Commonwealth)
Provision of expert witness advice to assist the Dept of Environment in the prosecution of landholders, under the EPBC Act for the alleged deliberate destruction of an area of endangered plant community. This involved flora survey of remaining vegetation community, provision of a detailed assessment of floristic structure and provision of expert opinion regarding the likelihood of regeneration.

New Oakleigh and Akland Mines Rehabilitation Monitoring
Client: New Hope Coal
Design and implementation of a mine vegetation rehabilitation monitoring program. This involved flora baseline survey, design of rehabilitation acceptance criteria in accordance with existing mine approvals and ongoing six monthly monitoring (Flora survey) of rehabilitation areas. Survey and rehabilitation planning advice for

Mangrove Health Monitoring
Client: Pacific Reef Fisheries (Bowen)
Annual monitoring (flora survey and floristic structure assessment) of Mangrove communities in accordance with the GBRMPA approval conditions for Pacific Reef Fisheries Aquaculture facility

Mangrove Health Monitoring
Client: Australian Prawn Farms Pty Ltd (Sarina)
Annual monitoring (flora survey and floristic structure assessment) of Mangrove communities in accordance with the GBRMPA approval conditions for Australian Prawn Farms Aquaculture facility.

Mangrove Health Monitoring
Client: Harbor Light Prawns Pty Ltd
Annual monitoring (flora survey and floristic structure assessment) of Mangrove communities in accordance with the GBRMPA approval conditions for Harbor Light Prawns Aquaculture facility.

North Curtis Island Ecotourism Facility
Client: Universal Partners
Survey, delineate and mapping of vegetation communities across the 2500ha North Curtis Island site to allow preparation of a Property Map of Assessable Vegetation (PMAV)

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