Old Bar Precinct 2A

Stormwater Quality Management Strategy

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Synopsis : This report outlines the results of stormwater quality and quantity modelling undertaken utilising the MUSIC and XP-RAFTS software to evaluate the performance of stormwater treatment measures proposed to be incorporated into the Old Bar Precinct 2A development.

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1 INTRODUCTION

Precinct 2A in Greater Taree City Council's *Old Bar Wallabi Point Development Strategy* incorporates provision for a residential subdivision consisting of approximately 200 lots. Precinct 2A lies within the Coastal Zone of NSW and is to be determined under Part 3A of the EP&A Act 1979 by the Minister.

Director General Environmental Assessment Requirements (DGEAR's) have been issued for the site. The key objective of this report is to address the DGEAR's that relate to the potential impacts of stormwater discharge from the development site on the local watercourses, adjacent SEPP14 wetlands and adjoining Crown Reserves. This report also includes consideration of Integrated Water Cycle Management (IWCM) for the site.

The stormwater management strategy for the site was developed incorporating a series of treatment measures to reduce the quantity of stormwater draining to the receiving waters and filter the runoff to improve the stormwater quality. The performance of the strategy was simulated within the Model for Urban Stormwater Improvement Conceptualisation (MUSIC).

The strategy includes source and sub-catchment scale stormwater treatment measures. The source control measures comprise rainwater tanks within individual lots to harvest roof runoff for appropriate internal and external uses. Rainwater tanks will assist with reducing the hydraulic loading on other measures and provide a water conservation benefit by reducing potable demand. The sub-catchment scale measures comprise grassed swales, bioretention swales and constructed wetlands in series. The swales will be positioned adjacent to a perimeter road intercepting the majority of runoff from the development site. These swales will direct runoff to three constructed wetlands provided for final polishing of stormwater runoff prior to discharge to the estuarine receiving waters.

The stormwater management strategy was developed considering the following guiding principles:

- The development should not exceed the capacity of the environment to receive surface water and associated wastes;
- The existing structure of, and ecosystems within, the receiving watercourses, coastal wetland and saltmarsh shall not be adversely impacted by the development;
- Existing riparian vegetation shall be preserved and degraded riparian buffers/zones rehabilitated where appropriate;
- The environmental management systems shall be efficient, adaptable and maintainable;
- The environmental management systems shall incorporate consideration for staging of the development;
- Ecologically sustainable development is required (precautionary approach, inter-generational equity, biodiversity and improved valuation, pricing and incentives);
- Source management shall be applied where feasible;
- The mitigation measures shall be cost effective to ensure that objectives are achievable without reducing the viability of the proposal; and

- Sufficient resources shall be available to effectively maintain the measures throughout their lifecycle.

2 STORMWATER MANAGEMENT OBJECTIVES AND TARGETS

Stormwater quality objectives are typically adopted for new development sites from existing planning policies and guidelines prepared to ensure that the receiving water quality would not be adversely impacted by development within the catchment. The receiving water objectives are typically established from a regional perspective considering inputs from a number of sources that discharge into the receiving waters. The objectives are typically not established based on individual developments.

Receiving water quality objectives and targets are often developed considering the ANZECC guidelines and these primarily align with ambient conditions within a receiving water body. The guidelines are not directly applied to assessing short term water quality impacts resulting from pulse stormwater loads. The guidelines are consequently not applied directly to establish stormwater quality objectives.

The Australian Runoff Quality (ARQ) guidelines include methods to estimate “sustainable” catchment loads for a range of receiving waters based upon the trigger values presented in the ANZECC guidelines. Although the approach outlined within ARQ can be applied to estimate sustainable catchment load targets for specific water bodies, the approach requires an understanding of the existing water quality conditions, flushing time, bathymetric data and contributing loads from adjacent catchments. Often this data is unavailable (as is the case for this site) or insufficient to estimate reasonable targets.

Since no specific “sustainable load” objectives have been established for the receiving waters for this site, best practice stormwater management objectives have been adopted for managing catchment runoff prior to discharge into the receiving waters. Best practice stormwater management objectives essentially reflect the limitations of current stormwater quality management technology, and therefore do not necessarily ensure that a receiving water body would not be impacted by development in a particular catchment.

The targets specified to achieve the stormwater quality objectives were adopted from the Greater Taree Urban Stormwater Management Plan (GTCC). The targets are:

- Total Suspended Solids (TSS) – 80% reduction in the mean annual load.
- Total Phosphorus (TP) – 45% reduction in the mean annual load.
- Total Nitrogen (TN) – 45% reduction in the mean annual load.
- Gross Pollutants (GP) – Retention of gross pollutants greater than 50mm for flows up to 50% of the 1 year ARI peak flow.

The ARQ guidelines also outline best practice load based objectives for NSW/Victoria. These are consistent with Council’s stormwater quality objectives for new developments outlined within the SMP. In the absence of sufficient data on the existing receiving water quality, these objectives have been adopted for the proposed development site. Since water quality data for the receiving waters at this site was unavailable, sampling was initiated by the development proponent during the course of the preparation of this report to provide a broad indication of the existing water quality. The sampling undertaken and testing results are described in **Section 3**.

3 RECEIVING WATER QUALITY

3.1 Water quality sampling

There is currently limited water quality data available for the Oyster Creek and Banyula Creek tributaries that form the receiving waters for runoff from the proposed development site. To quantify the existing water quality, sampling was undertaken by McGlashan & Crisp within the waterways adjacent to the site on 18 October 2006. The sampling was undertaken following rainfall of 19.6mm (recorded at Taree Airport) that occurred over 16-17 October, 2006. Sampling was undertaken at five locations and samples sent to the MidCoast Water Laboratory for testing. The sampling locations are shown in **Figure 3-1** and the results of the subsequent testing are provided in **APPENDIX A:**.

Figure 3-1 Water quality sampling locations 18/10/06 (source: McGlashan & Crisp)

3.2 Testing results

3.2.1 Nitrogen

Nitrogen is a nutrient that is commonly tested for as a component of water quality monitoring studies undertaken to assess aquatic ecosystems. Total nitrogen (TN) in surface waters comprises nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3, NH_4^+) and organic nitrogen. For analysis, nitrate and nitrite nitrogen are often reported together as oxidised nitrogen (NOx), and total ammonia (NH_4^+, NH_3) and organic nitrogen are grouped as total kjeldahl nitrogen (TKN).

Nitrate is the dominant form of oxidised nitrogen in most surface waters. The ammonium ion exists in equilibrium with un-ionised free ammonia, and the balance of the equilibrium is controlled by pH. Above pH of 8 the equilibrium increasingly moves towards free ammonia, which is toxic to aquatic organisms.

Nitrogen is a main nutrient for plant growth and is often the limiting nutrient in marine systems. Increased availability of biologically available nitrogen, can lead to excessive growth of algae or eutrophication of waterways, leading to choking of estuaries. Elevated levels of nitrogen can also cause changes to marine ecosystem structure.

The testing results for nitrogen for the sampled event are shown in **Figure 3-2**.

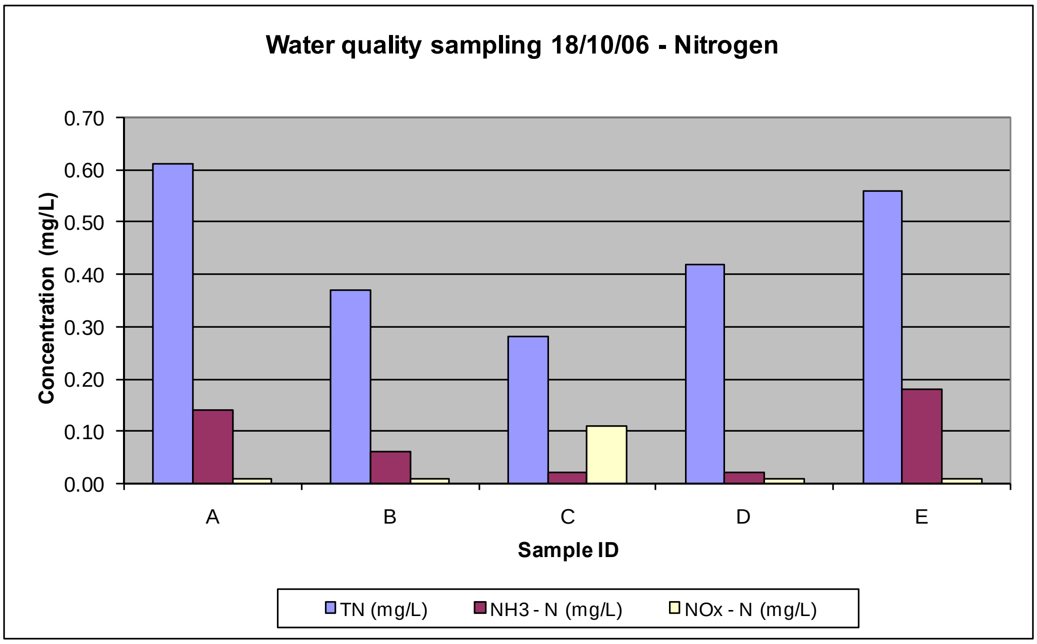


Figure 3-2 Nitrogen concentrations - 18/10/06

Default trigger values for slightly disturbed NSW estuary ecosystems presented in ANZECC guidelines are 0.30mg/L, 0.015mg/L and 0.015mg/L for TN, NH_4 and NO_x respectively. The water quality samples tested indicate that 4 of the 5 sites exceeded the TN trigger value, 3 of the 5 sites exceeded the ammonia trigger value and 1 of the 5 sites exceeded the NO_x trigger concentration. The concentrations tended to increase for upstream sections of the sampled waterways, although the higher concentrations observed at the confluence (Site D) tend to suggest that the loads from Oyster Creek may have dominated the water quality conditions for this event at this location.

The trigger values are for slightly disturbed catchments. Significant modification of this catchment has occurred due to land clearing and urban development and this may be the reason for the slightly elevated levels observed. The sampling was also undertaken following a period of wet weather, which would suggest the concentrations observed may be more representative of event conditions rather than ambient conditions that the trigger values are more applicable to.

3.2.2 Phosphorus

Phosphorus is a nutrient typically consisting of dissolved orthophosphates and polyphosphates, and organically bound phosphates. Total Phosphorus (TP) has soluble and particulate fractions in surface water. Filterable (soluble) fractions consist of orthophosphate (PO_4^{-3}-P), filterable condensed phosphates (FCP), filterable organic phosphorus (FOP) and filterable colloidal phosphorus (Fcol.P). Particulate phosphorus consists of particulate organic phosphorus (POP), which includes both live (plankton) and dead fine particulate organic matter, and particulate inorganic phosphorus (PIP), which includes mineral and occluded phosphates and organic and inorganic phosphates adsorbed to suspended particulate matter (SPM).

In many surface waters total particulate phosphorus (TPP) is the major fraction of TP and the orthophosphate ion is the major fraction of FRP. Bioavailable phosphorus (BAP) is the fraction of phosphorus that is readily available to organisms (such as algae) for growth. Bioavailable phosphorus is commonly some fraction greater than orthophosphate and less than TP. The balance between all these forms is highly site specific and not easily predicted from other environmental data.

The testing results for phosphorus for the sampled event are shown in **Figure 3-3**. It appears that results for Site C may be in error, as the orthophosphate concentration has been reported as being higher than the TP concentration.

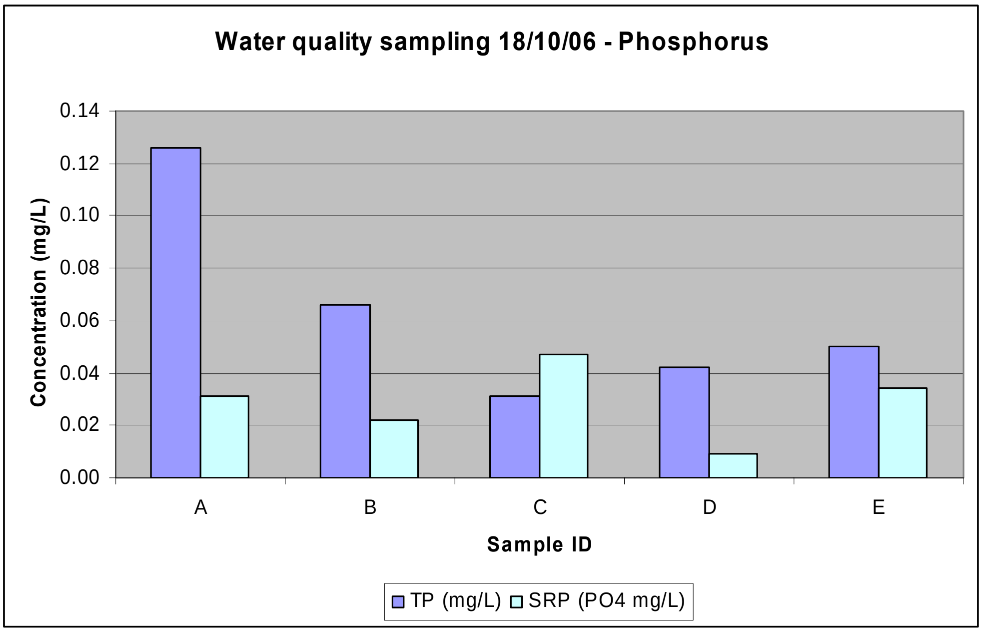


Figure 3-3 Phosphorus concentrations - 18/10/06

Default trigger values for slightly disturbed NSW estuary ecosystems presented in ANZECC guidelines are 0.030mg/L and 0.005mg/L for TP and FRP (SRP) respectively. The water quality samples tested indicate that 4 of the 5 sites had a TP concentration exceeding the trigger value, and 4 of the 5 sites exceeded the FRP trigger value. The concentrations tended to be higher for upstream sections of the sampled waterways. Similarly to the nitrogen species, elevated phosphorus concentrations are likely to be a result of existing catchment development and the input of catchment loads during wet weather. Also, similarly to nitrogen, input loads from the Oyster Creek tributary appear to have dominated the observed conditions at the confluence of Banyula and Oyster Creeks. Phosphorus is also commonly attached to suspended sediments conveyed within runoff, and therefore concentrations may be elevated in the receiving waters immediately after runoff events.

3.2.3 Indicator bacteria

Indicator bacteria are used to detect the potential for recent contamination of a waterway by faecal matter. Indicator bacteria concentrations are typically monitored for sites where primary and secondary contact recreation are key values. Faecal coliforms have traditionally been measured as the key indicator of faecal contamination, although, not all “faecal” coliforms originate from the gut of warm blooded mammals. Enterococci are another type of bacteria commonly found in the intestines of humans and tend to survive longer in water.

Faecal coliforms are relatively easy to measure and traditionally have been used as an ‘indicator’ micro-organism for other disease causing micro-organisms (pathogens). Within human faeces, faecal coliforms typically comprise *Escherichia coli* (E.coli) (97%), *Klebsella* (2%) and *Enterobacter/Citrobacter* (2%) bacteria (ANZECC, 2000). Faecal coliforms typically will die off faster than pathogens and therefore sampling may detect low levels of faecal coliforms when high concentrations of pathogens may be present. *Enterococci* are a type of faecal streptococci also found in human faeces which will typically survive longer than faecal coliforms in water and are therefore a better indicator of both recent and longer term contamination.

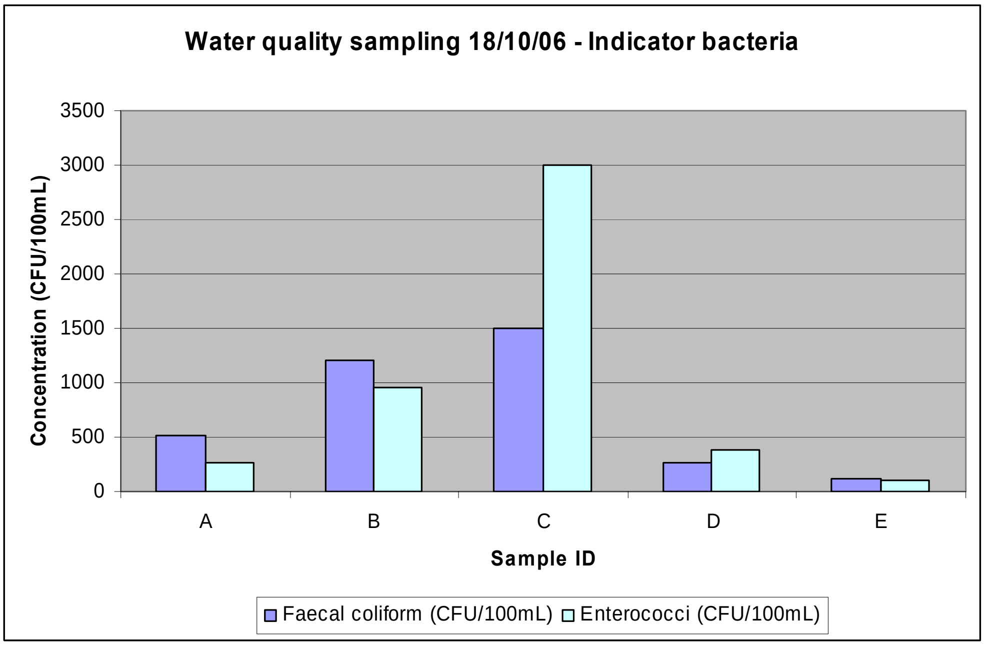


Figure 3-4 Indicator bacteria concentrations - 18/10/06

The ANZECC guidelines indicate that the median bacterial content in marine waters measured over the swimming season should not exceed 150 CFU/100mL for faecal coliforms and 35 CFU/100mL for enterococci bacteria for primary contact recreation. For secondary contact recreation, the median bacterial content in marine waters measured over the entire year should not exceed 1000 CFU/100mL for faecal coliforms and 230 CFU/100mL for enterococci.

The one sampling run undertaken (which may or may not be representative of median conditions) indicates that the faecal coliform primary contact guideline value is exceeded at 4 of 5 sites and the secondary contact guideline value is exceeded at 2 of 5 sites. The enterococci primary contact guideline value is exceeded at 5 of 5 sites and the secondary contact guideline value is exceeded at 4 of 5 sites. The results for Site D (which represents the most likely site for primary or secondary contact recreation) exceeded all the guideline trigger values with the exception of faecal coliform secondary contact criteria. It is important to note that the sampling run coincided with a period of wet weather and it is considered likely that concentrations of indicator bacteria would be elevated above long term median conditions at this time.

The results suggest that the indicator bacteria concentrations in the more urbanised Banyula Creek reach are higher than the more rural Oyster Creek reach. Although the measured concentrations in the Banyula Creek reach are higher, the concentrations observed at the confluence of the two creeks are significantly lower. Similarly to nutrients, it is likely that this is due to the dominance of lower concentration runoff (for this event) from the Oyster Creek catchment.

3.2.4 Total Suspended Solids

Total suspended solids (non-filterable residue) impact on the turbidity of water. The turbidity of water is affected by the concentration of silt, clay, fine organic and inorganic particles, soluble organic matter, plankton and other organisms in the water. Turbidity is caused by the scattering and adsorption of light by the suspended particles in the water. For a particular site, field turbidity measurements can often be compared with corresponding TSS samples tested in the laboratory to enable calibration of the turbidity readings to indirectly estimate TSS concentrations.

The ANZECC guidelines indicate that a turbidity range of 0.5-10 NTU is typical for estuarine waters, although it is noted that higher values are often attained in estuaries due to wind-induced re-suspension or the input of turbid water from the catchment. Turbidity and suspended solids are therefore not considered to be useful water quality indicators for estuarine waters.

Research by the former Co-operative Research Centre for Catchment Hydrology (CRCCH) has reported a typical range for total suspended solids in urban catchment base flow runoff as varying between 10.7 – 23.4mg/L with a mean value of 16mg/L (CRCCH, 2004). The values measured in the receiving waters potentially would be lower due to mixing and dilution of the incoming flows. The sampled results shown in **Figure 3-5** indicate that concentrations are up to approximately 10mg/L for the Banyula Creek sites and the confluence. TSS concentrations for this sampling period are higher for the Oyster Creek site (Site E).

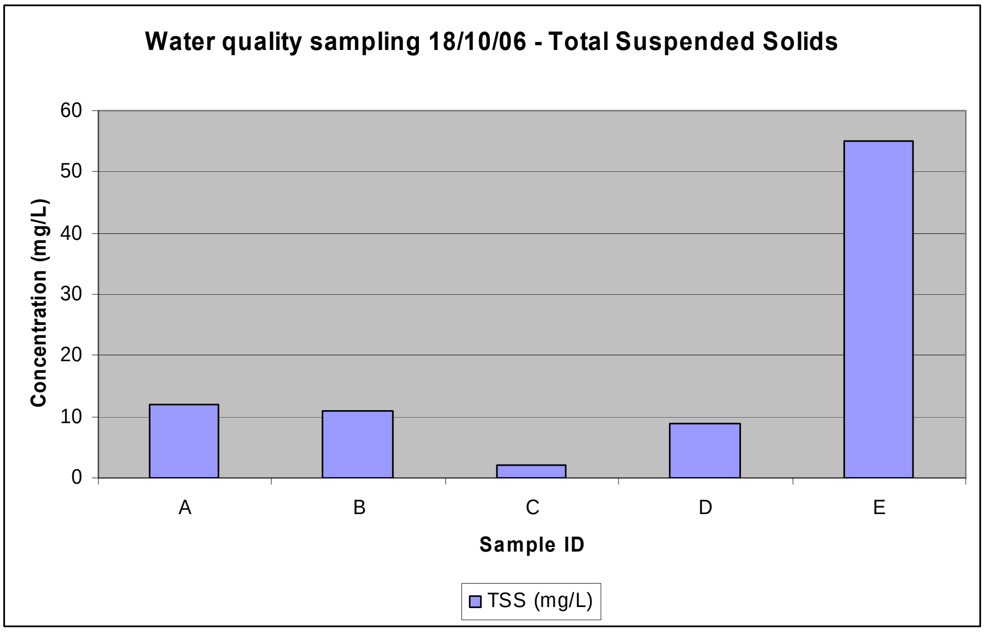


Figure 3-5 Total suspended solids concentrations - 18/10/06

4 STORMWATER QUALITY AND QUANTITY MODELLING

4.1 Introduction

Stormwater quality and quantity modelling was undertaken utilising the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). MUSIC includes algorithms to evaluate continuous hydrology and concentrations/loads of common stormwater pollutants (TSS, TP and TN) from urban catchments, and estimate the performance of stormwater treatment measures at capturing these pollutants.

MUSIC is a software tool designed to continuously simulate urban stormwater systems over a range of temporal and spatial scales utilising actual rainfall records. MUSIC is an appropriate conceptual design tool for assessment and sizing of stormwater treatment measures. Additional detailed calculations are required to size inlets and outlets to these storages.

The hydrologic algorithm in MUSIC is based on the model developed by Chiew & McMahon (1997). The model simplifies the rainfall-runoff processes and requires input of the following variables to perform the hydrological assessment:

- Rainfall data (time steps varying from 6 minutes to 1 days);
- Potential evapotranspiration rates;
- Catchment characteristics (area, % effective impervious area, % pervious area);
- Pervious area parameters (infiltration rates, rainfall losses, soil store depths, groundwater conditions); and
- Impervious area parameters (rainfall threshold).

MUSIC is a model primarily applied to compare runoff quality scenarios within developed urban catchments where impervious surface runoff dominates over pervious surface runoff. Within natural catchments the hydrology is more complex due to the high variation in soil types, field capacities and infiltration rates, which typically require calibration data (e.g. rainfall and corresponding stream flow records) for accurate representation of the hydrology. In most circumstances this data is not available in urban catchments requiring the adoption of typical values. Typically MUSIC is utilised to evaluate the performance of a particular WSUD strategy against load-based objectives, and this is the approach followed for this site.

4.2 Meteorological data

4.2.1 Rainfall

Local rainfall data was sourced for Station 60030 situated at Taree (Radio Station 2RE) over the period 1965-2001 for input to the MUSIC model. The rainfall station is located approximately 11km north west of the study site and the long term mean annual rainfall for Taree is 1175mm. The rainfall record from this site was adopted as being representative of conditions at Old Bar.

The rainfall data file was reviewed to determine a suitable length continuous period that reflected the mean annual rainfall and incorporated both dry and wet representative years. The period 1966-1975 has a mean annual rainfall of 1167mm (within 1% of the long term average at Taree). This 10-year period of the record was utilised as an input to MUSIC.

4.2.2 Potential evapotranspiration

The average monthly areal potential evapotranspiration (PET) rates for the site were estimated within GIS from evapotranspiration map grids prepared by the Bureau of Meteorology. The annual areal PET for the site is estimated to be 1325mm. The PET values adopted within the model are summarised in **Table 4-1**.

Table 4-1 Monthly average areal potential evapotranspiration rates

Month	Monthly average areal PET (mm/month)
January	180
February	135
March	135
April	90
May	65
June	50
July	50
August	70
September	100
October	135
November	150
December	165

4.2.3 Model time step

The selection of an appropriate time step for modelling in MUSIC often requires a compromise between accuracy and model run time. An appropriate time step is typically determined by estimating the time of concentration of the smallest sub-catchment within the model and the shortest expected detention time of the proposed treatment measures. An appropriate time step is then adopted considering the results of these preliminary estimates.

For this site, a time step of 6 minutes was adopted and this is the smallest time step currently able to be simulated within MUSIC.

4.3 Source node parameters

4.3.1 Sub-catchments

The MUSIC model was prepared dividing the site into three sub-catchments (AB, C and D) represented areas that drain to separate proposed dual purpose constructed wetlands/detention basins. The area modelled included both the developed area (roads and lots) and the open space area (treatment measure footprint).

Key assumptions adopted for each sub-catchment were-:

- The number of dwellings was estimated adopting a 10 dwellings/ha ratio;
- The residential lots and road reserve will take 75% and 25% of the developable area (total area excluding footprint area for stormwater management measures) respectively;
- The average roof area for each dwelling is 300m^2;
- The road reserve is 50% pavement and 50% footpath;
- 100% of roof and road areas are directly connected to either a rainwater tank, street drainage system or interallotment drainage line;
- 25% of landscaped areas (non-roof lot area and footpaths) are directly connected impervious areas; and
- 5% of the stormwater management measures footprint area is directly connected impervious area.

Based on these assumptions, the total estimated directly connected impervious area (DCIA) is 54% of the total site area. The adopted development surface characteristics adopted for the MUSIC modelling are summarised within **Table 4-2**.

Table 4-2 Development surface characteristics adopted for MUSIC modelling

Catchment ID	Total area (ha)	No. lots	Surface type	Area	DCIA (%)	DCIA (ha)
AB	11.57	116	roof	3.47	100%	3.47
			landscaped	5.69	25%	1.42
			road pavement	1.31	100%	1.31
			open space	1.10	5%	0.06
C	6.06	61	roof	1.82	100%	1.82
			landscaped	3.10	25%	0.78
			road pavement	0.70	100%	0.70
			open space	0.44	5%	0.02
D	4.86	49	roof	1.46	100%	1.46
			landscaped	2.25	25%	0.56
			road pavement	0.53	100%	0.53
			open space	0.62	5%	0.03
			∑ Total A =	**22.49**	**∑ DCIA =**	**12.16**
					DCIA (%)	**54%**

4.3.2 Rainfall-runoff parameters

The only impervious area parameter utilised by MUSIC is the rainfall threshold parameter which represents an initial daily rainfall loss from impervious surfaces. A rainfall threshold of 1.4mm/day was adopted for all impervious surfaces with the exception of roofs where a value of 0.2mm/hr was adopted as representative of a zinc-alum roof. The pervious area parameters were estimated from the results of a recent MUSIC calibration project undertaken by WBM for 7 urban catchments within

NSW (WBM, 2005). The adopted MUSIC model parameters for the development are outlined in **Table 4-3**.

Table 4-3 Adopted MUSIC rainfall-runoff model parameters

Parameter	Value
Impervious Area Parameters	
Rainfall threshold (mm/day)	1.4
Pervious Area Parameters	
Soil Storage capacity (mm)	170
Initial Storage (% of capacity)	30
Field Capacity (mm)	70
Infiltration Capacity Coefficient – a	210
Infiltration Capacity Exponent - b	4.7
Groundwater Properties	
Initial depth (mm)	10
Daily Recharge Rate (%)	50
Daily Baseflow Rate (%)	4
Daily Deep Seepage Rate (%)	0

4.3.3 Stormwater constituent concentrations

The adopted dry and wet weather concentrations ($\log_{10}$ transformed) for the site are outlined in **Table 4-4** and **Table 4-5** respectively. The mean values adopted are those derived by the Co-operative Research Centre for Catchment Hydrology for NSW (CRCCH, 2004). In the absence of additional local data, MUSIC defaults were adopted for the standard deviations for the stormwater constituent concentrations. A stochastic modelling approach was adopted within MUSIC for assessing the performance of the stormwater management measures.

Table 4-4 Adopted MUSIC dry weather (base flow) concentrations ($\log_{10}$ mg/L)

	TSS		TP		TN	
	mean	std. dev	mean	std. dev	Mean	std. dev
Roads	1.20	0.17	-0.85	0.19	0.11	0.12
Roofs	1.20	0.17	-0.85	0.19	0.11	0.12
Residential	1.20	0.17	-0.85	0.19	0.11	0.12

Table 4-5 Adopted MUSIC wet weather (event flow) concentrations ($\log_{10}$ mg/L)

	TSS		TP		TN	
	mean	std. dev	mean	std. dev	Mean	std. dev
Roads	2.43	0.32	-0.30	0.25	0.34	0.19
Roofs	1.30	0.32	-0.89	0.25	0.30	0.19
Residential	2.15	0.32	-0.60	0.25	0.30	0.19

4.4 Treatment measures

4.4.1 Rainwater tanks

Rainwater tanks were adopted in the model to represent the capture of runoff from all dwelling roofs. A tank size of 2.75kL/dwelling was estimated based on the water conservation criteria adopted within the BASIX tool. To allow for extended detention, trickle top up storage and sediment storage a minimum tank size of 3.5kL is proposed. It was assumed that approximately 10% of the total volume in each tank would be extended detention above an overflow. It has also been assumed that 0.5kL would be available for trickle top up storage from mains and 0.25kL would be available for sediment storage. Therefore, a maximum rainwater storage of 2.5kL/dwelling was adopted for modelling the tanks.

It was assumed that rainwater tanks would be constructed aboveground and that a maximum percentage of 50% of the roof area for each dwelling can feasibly be drained to the tank via roof gutters and downpipes (i.e. 50% of the roof area from each dwelling will bypass the tank). In addition it was assumed that roof runoff flows exceeding 15L/s per dwelling would exceed the capacity of the roof gutters, overflowing from the gutters and therefore bypassing the tank.

It was assumed that roof runoff captured within the tanks would be utilised for toilet flushing and external private irrigation only. An average occupancy of 2.3 persons per dwelling was assumed. The estimated demand for toilet flushing was 34kL/dwelling/yr and 57kL/dwelling/yr for external private irrigation (i.e. total of 91kL/dwelling/yr) and these figures are based upon estimates by Coombes (2000) for Coffs Harbour. The demand for toilet flushing was assumed to be constant throughout the year, whilst the private irrigation demand was modelled as varying with the areal PET rates (i.e. higher demands for irrigation water were modelled during the summer months).

4.4.2 Grassed swales

Grassed swales are proposed for this development as a pre-treatment coarse sediment filtering measure for flows directed to bioretention swales that lead into constructed wetlands. These measures function by impeding flow by filtration through relatively long grass which slows the flow velocity and assists with sedimentation.

For the MUSIC modelling it was assumed that the swales are trapezoidal shaped with an average 2m base width, 8m top width and 0.5m depth. Therefore, the assumed swale batters/side slopes are 1(v):6(h). It was assumed that the grass in the swale would be maintained at minimum height of 0.15m.

The grassed swales were modelled with an assumed longitudinal gradient of 0.5% and therefore may also infiltrate or increase evapotranspiration loss of water due to the slight gradient. A seepage loss of 0.10mm/hr was adopted to account for increased vegetation uptake of water and evaporation loss from the soil within the swale.

The assumed grassed swale lengths in Sub-catchment AB were 210m (northern swale) and 65m (southern swale). The assumed grassed swale length in Sub-catchment D was 130m. The locations of these swales are shown on drawings prepared by McGlashan & Crisp.

4.4.3 Bioretention swales

Bioretention swales for this development are proposed as an intermediate stormwater treatment measure between the grassed swales and constructed wetlands.

Bioretention measures consist of an aboveground storage and below ground filter. The above-ground storage retains runoff volume for settling of medium to fine particles and includes vegetation for the uptake of nutrients. The below-ground filter acts to detain filtered runoff for additional treatment and interception of fine particles and nutrients prior to infiltration to the insitu soils or discharge to the downstream drainage system.

Similarly to the grassed swales, it was assumed for modelling that the swales are trapezoidal shaped with an average base width of 2m and batters/side slopes of 1(v):6(h). It was assumed that the extended detention depth within the bioretention swales would be an average of 0.25m with an underlying filter that is 0.3m deep. It was assumed that the filter would be 2m wide for the full length of each bioretention swale (i.e. the entire base width). It was assumed that the filter media would consist of a loamy sand soil mix with a median particle diameter of 2mm. A saturated hydraulic conductivity of 150mm/hr has been assumed for this media. It was assumed that the bioretention swale base would have a slight gradient. A seepage loss of 0.10mm/hr was adopted to account for increased vegetation uptake of water and evaporation loss from the soil within the swale.

The total length of the modelled bioretention swales was 70m for each swale in Sub-catchments AB, C and D. The locations of these swales are shown on drawings prepared by McGlashan & Crisp.

4.4.4 Constructed wetlands

Constructed wetlands perform as tertiary stormwater treatment measures, providing habitat and final polishing of runoff prior to discharge to the receiving waters. Constructed wetlands may consist of deep open water zones with submergent aquatic vegetation and shallower zones that contain emergent aquatic vegetation. The key processes within the measures are sedimentation, adsorption of finer particles to vegetation and biological uptake of bioavailable nutrients.

For this development, an extended detention depth of 0.7m was adopted above the permanent pool water level for each of the constructed wetlands. A permanent pool / depression storage of 0.2m was adopted and it was assumed that the permanent pool storage would cover 75% of the base surface area. An average surface evaporation rate equivalent to 125% of the areal PET rate was adopted for the permanent pool. It was also assumed that emergent macrophytes would cover 50% of the base surface area of the wetland. The adopted wetland surfaces areas utilised within the MUSIC modelling are shown in **Table 4-6**.

Table 4-6 Adopted constructed wetland surface areas

Surface area	Wetland AB	Wetland C	Wetland D
Surface area at 1.00m depth (weir)	7775m^2	4390m^2	4630m^2
Surface area at 0.70m depth	6260m^2	3480m^2	3440m^2
Surface area at 0.35m depth[1]	3750m^2	2430m^2	2315m^2
Surface area at base	2400m^2	1405m^2	1470m^2

1. Surface area adopted in the model as representative of average conditions for storage volume calculations (MUSIC assumes vertical sides in storages).

4.5 Model results

The MUSIC modelling load and concentration results are summarised in **Table 4-7** and **Table 4-8** respectively. The load results in **Table 4-7** indicate that a strategy incorporating the treatment measures outlined in **Section 4.4** would achieve the load targets summarised in **Section 2**.

Table 4-7 MUSIC results - loads

Stormwater constituent	Source load	Outlet load	Reduction (%)
Flow (ML/yr)	172	142	17
Total Suspended Solids (kg/yr)	20300	2970	85
Total Phosphorus (kg/yr)	44.4	12.9	71
Total Nitrogen (kg/yr)	364	200	45
Gross Pollutants (kg/yr)	4000	0	100

Table 4-8 MUSIC results - concentrations

Stormwater constituent	50%ile	90%ile
Flow (m^3/s)	0.005	0.030
Total Suspended Solids (mg/L)	6.0	6.2
Total Phosphorus (mg/L)	0.060	0.062
Total Nitrogen (mg/L)	1.03	1.31

The stormwater concentration results outlined in **Table 4-8** adopt a minimum flow-based sub-sample of 1L/s (i.e. all zero flow periods in the continuous simulation have conservatively been excluded from the statistical analysis). The concentration results indicate that the median TSS concentration in the modelled site discharge (6mg/L) would be lower than the sampled concentrations in the receiving waters (approximately 10mg/L). The modelled median TP concentration (0.060mg/L) in the site discharge exceeds both the measured concentration in the receiving waters (0.042mg/L) and the ANZECC guideline trigger level (0.030mg/L). The modelled median TN concentration (1.03mg/L) in the site discharge also exceeds the measured concentration in the receiving waters (0.42mg/L) and the ANZECC guideline trigger level (0.30mg/L).

It is important to note that the ANZECC trigger values are for the receiving waters and include consideration of the biological consumption of catchment nutrient loads and other dynamic dilution and flushing processes that do not occur within the confines of an urban stormwater system. MUSIC currently only models catchment runoff quality and treatment processes within relatively small confined measures. Simulation of how stormwater impacts on receiving water quality would require development of an additional model. Currently there is limited data available on the existing receiving water quality, geometry and tidal behaviour and therefore any receiving water model developed would be indicative only. In addition, the default concentration parameters adopted in MUSIC are likely to be different (as reflected in the sampling results) to actual concentrations specific to this catchment.

The measured concentrations in the receiving waters were sampled immediately following a runoff event which is likely to have resulted in atypical water quality conditions in the estuary that may not be reflective of longer-term median ambient conditions that objectives are typically based upon. Although, the measured water quality conditions could also be endemic and reflective of the existing catchment conditions. Without longer term monitoring across a number of seasons incorporating both wet and dry periods it is not possible to confirm specific objectives for this location.

For these reasons it is considered that comparisons (other than broad comparisons) of the MUSIC model results with ANZECC trigger values or measured water quality are not valid, and therefore it is considered that comparison of the MUSIC model results with catchment load-based objectives would be most appropriate for this site.

The basin results for the complete 10 year continuous simulation period were reviewed to estimate the average period of time that particular storage depths in each basin would be exceeded. The derived storage depth exceedence curves for each basin are shown in **Figure 4-1**. These curves have been utilised to estimate the average annual number of days that particular storage depths would be exceeded in the wetlands/basins and these are summarised in **Table 4-9**. The derived curves adopt the key assumption that the outlets from the basin would remain operational for all events. It is considered likely that some outlet blockage would occur throughout the lifecycle of the measures, although these blockage periods could be minimised with close attention to inspection and maintenance of the wetland/basin outlets.

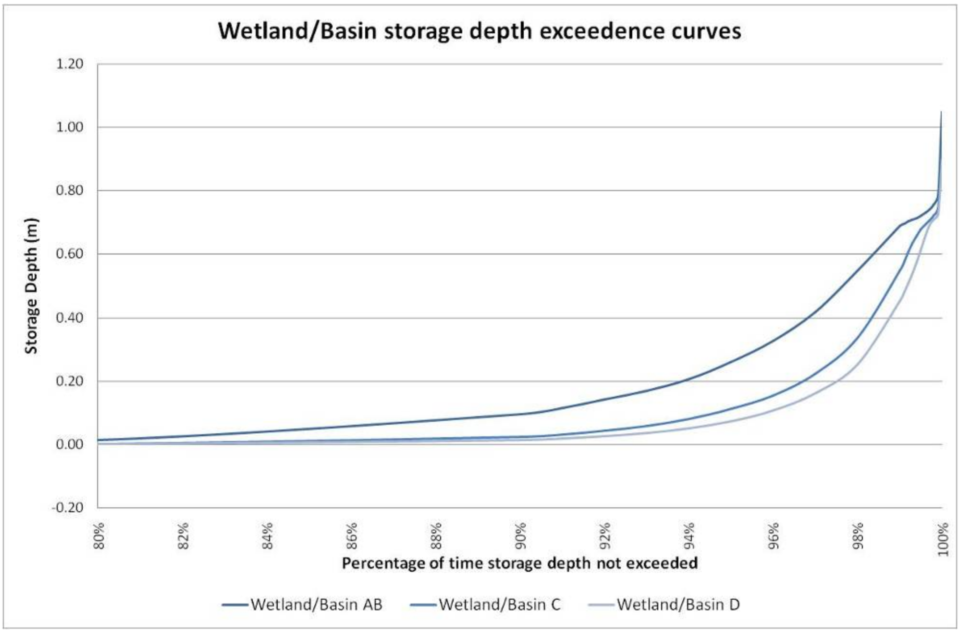


Figure 4-1 Estimated storage depth exceedence curves

Table 4-9 Estimated average annual days that particular storage depths are exceeded

Basin ID	Storage depth (m)		
	0m	0.7m	1.0m
Basin AB	110	3	<0.5
Basin C	75	1.5	<0.5
Basin D	75	1	<0.5

Table 4-10 WSUD strategy summary

Sub-catchment	WSUD elements	Preliminary configuration
AB	Rainwater tanks Grassed swales Bioretention swales Constructed wetland	➢ Rainwater tanks within all residential lots ➢ Rainwater tanks will have a minimum total storage capacity of 3.5kL/dwelling. Of the total storage, 0.25kL will be extended detention storage above the outlet pipe, 0.5kL would be allocated to trickle top up storage and 0.25kL would be provided for sediment storage. The minimum volume available for rainwater storage is therefore 2.5kL. ➢ Grassed swales would be located adjacent to the perimeter road. The total length of the northern swale in AB will be 210m and the total length of the southern swale in AB would be 65m. These swales would grade to a constructed wetland formed at the outlet to AB. ➢ Grassed swale specification (Total length = 275m; Top width = 8m (typical); Base width = 2m; Depth = 0.5m (minimum); Side slopes = 1(v):6(h); Grass maintenance height = 150mm (minimum)). ➢ Bioretention swales would be formed in alternate segments along the northern and southern grassed swales in AB. Each segment would be 35m long and positioned upstream of drainage outlets discharging into the grassed swale. ➢ Bioretention swale specification (Total length = 105m; Top width = 8m (typical); Base width = 2m; Depth = 0.5m (minimum); Side slopes = 1(v):6(h); Filter width = 2m; Filter media depth = 0.3m; Filter media = predominantly fine-medium sand soil with some organic content; Saturated filter media conductivity = 150mm/hr). ➢ Constructed wetland will be positioned at the discharge point of Sub-catchment AB on the eastern side of the site. ➢ Constructed wetland specification (Base surface area = 2400m^2, Top surface area = 7775m^2, Permanent storage depth = 0.2m, Low level outlet height = 0.7m, High level outlet height = 1.0m, Permanent pool volume=480m^3, Low level outlet storage volume = 2965m^3, Maximum (weir level) storage volume = 5020m^3, Vegetation coverage = 50% of base area)
C	Rainwater tanks Bioretention swales Constructed wetland	➢ Rainwater tanks – same specification as AB ➢ Bioretention swale will be positioned adjacent to the constructed wetland in C ➢ Bioretention swale specification (Total length = 70m; Top width =5m; Base width = 2m; Depth = 0.25m; Side slopes = 1(v):6(h); Filter width = 2m; Filter media depth = 0.3m; Filter media = predominantly fine-medium sand soil with some organic content; Saturated filter media conductivity = 150mm/hr). ➢ Constructed wetland will be positioned at the discharge point from Sub-catchment C into Oyster Creek.

Sub-catchment	WSUD elements	Preliminary configuration
		➢ Constructed wetland specification (Base surface area = 1405m^2, Top surface area = 4390m^2, Permanent storage depth = 0.2m, Low level outlet height = 0.7m, High level outlet height = 1.0m, Permanent pool volume=280m^3, Low level outlet storage volume = 1710m^3, Maximum (weir level) storage volume = 2870m^3, Vegetation coverage = 50% of base area)
D	Rainwater tanks Grassed swales Bioretention swales Constructed wetland	➢ Rainwater tanks – same specification as AB ➢ A grassed swale would be located adjacent to the perimeter road in D. The swale will grade to a constructed wetland formed at the outlet to D ➢ Grassed swale specification (Total length = 130m; Top width = 8m (typical); Base width = 2m; Depth = 0.5m (minimum); Side slopes = 1(v):6(h); Grass maintenance height = 150mm (minimum)). ➢ Bioretention swales would be formed in alternate segments along the grassed swales in D. Each segment would be 35m long and positioned upstream of drainage outlets discharging into the grassed swale. ➢ Bioretention swale specification (Total length = 70m; Top width = 8m (typical); Base width = 2m; Depth = 0.5m (minimum); Side slopes = 1(v):6(h); Filter width = 2m; Filter media depth = 0.3m; Filter media = predominantly fine-medium sand soil with some organic content; Saturated filter media conductivity = 150mm/hr). ➢ Constructed wetland will be positioned at the discharge point from Sub-catchment D into Oyster Creek. ➢ Constructed wetland specification (Base surface area = 1470m^2, Top surface area = 4630m^2, Permanent storage depth = 0.2m, Low level outlet height = 0.7m, High level outlet height = 1.0m, Permanent pool volume=295m^3, Low level outlet storage volume = 1665m^3, Maximum (weir level) storage volume = 2860m^3, Vegetation coverage = 50% of base area)

5 EVENT BASED RAINFALL-RUNOFF MODELLING

5.1 Overview

Event rainfall-runoff modelling was undertaken utilising the XP-RAFTS model to assess the impact of the proposed dual purpose constructed wetlands/detention basins on peak discharges from the site during infrequent probabilistic storm events.

Models were prepared for three scenarios including-:

- Existing scenario;
- Developed scenario (without basins); and
- Developed scenario (with basins).

A range of storm durations were simulated for each scenario utilising design temporal patterns outlined in Australian Rainfall and Runoff (ARR) Vol. 2, 1987. The design rainfall intensity for each storm was determined using the methods outlined in ARR, 1998.

5.2 Model parameters

5.2.1 Design events

The XP-RAFTS models were simulated for 11 design storms ranging in duration from 20 minutes to 48 hours. The design events were simulated for each of the three scenarios.

5.2.2 Catchment imperviousness

The site hydrology was assessed for design storm events utilising the split sub-catchment routine within XP-RAFTS (impervious and pervious proportions modelled separately for each sub-catchment). The site was divided into three sub-catchments each representing a part of the site draining to a proposed basin/constructed wetland.

The estimated total imperviousness of each sub-catchment for the developed scenario was estimated by McGlashan and Crisp for the purposes of completing their stormwater drainage analysis for the site. These values were reviewed for developing the event-based hydrologic models and subsequently adopted as a reasonable estimate of the total imperviousness. It has conservatively been assumed that the entire site is pervious for the existing scenario model. The adopted sub-catchment imperviousness percentages for the existing and developed conditions are summarised in **Table 5-1.**

Table 5-1 Sub-catchment imperviousness

Sub-catchment	Area (ha)	% impervious	
		Existing*	Developed
AB	11.57	0	46%
C	6.06	0	47%
D	4.86	0	44%

5.2.3 Rainfall loss parameters

The XP-RAFTS model requires the input of initial and continuing rainfall loss parameters to estimate the rainfall excess. An initial loss of 20mm was adopted for pervious surfaces for the existing and developed scenarios. The continuing loss rates were adjusted from 3.2mm/hr (existing scenario) to 2.5mm/hr (developed scenario) to reflect the decreased infiltration capacity as a result of soil compaction following development. The continuing loss rate for the existing scenario was adopted from published values for the Manning River catchment (ARR, 1998). An initial loss of 1.5 mm and continuing loss of 0 mm/hr were adopted for impervious surfaces for the developed scenario. The adopted loss parameters are summarised in **Table 5-2**.

Table 5-2 Adopted loss parameters

	Initial Loss (mm)		**Continuing Loss (mm/hr)**	
	Pervious	Impervious	Pervious	Impervious
Existing scenario	20	-	3.2	-
Developed scenario	20	1.5	2.5	0.0

5.2.4 Flow routing and storage parameters

Parameters required to simulate the routing of flows through the catchment (including sub-catchment slopes, surface roughness and hydrograph lagging) were estimated from the site inspections, available contour data, existing reports, hydraulic model results and professional judgement. The adopted surface roughness parameters are shown in **Table 5-3.**

Table 5-3 Adopted surface roughness values

	Surface roughness	
	Pervious	Impervious
Existing scenario	0.050	-
Developed scenario	0.025	0.015

The catchment storage co-efficient (B) utilised to estimate the storage delay was estimated utilising the standard approach for XP-RAFTS. As the catchment is ungauged and calibration was not undertaken, the estimated B co-efficient was not modified by applying a Bx factor.

5.2.5 Basin dimensions and characteristics

The dimensions of Basins AB, C and D were provided by McGlashan & Crisp and these were adopted for the XP-RAFTS simulations. Stage/storage and stage/discharge relationships for each basin were also provided by McGlashan & Crisp and these were adopted for the simulations.

The basins have each been modelled with a low level 100mm diameter outlet that forms the only outlet up to an extended detention depth of 0.7m. Due to the size of the outlet, discharge from the basin will be minor up to a depth of 0.7m. Protection of this low level outlet would be provided to minimise the potential for blockage and provide easy access if manual drainage was required. Above an extended detention depth of 0.7m, discharge from the basin would be controlled by a combination of weir and orifice flow through a discharge control pit. Discharge from the basin for extended detention depths exceeding 1.0m will be controlled primarily through the discharge control pit and a broad crested weir formed in the adjacent footpath. The adopted basin stage/storage and stage/discharge relationships are outlined within **Table 5-4**.

Table 5-4 Modelled detention basin characteristics

	BASIN AB		BASIN C		BASIN D	
Stage (m)	**Storage (m^3)**	**Discharge (m^3/s)**	**Storage (m^3)**	**Discharge (m^3/s)**	**Storage (m^3)**	**Discharge (m^3/s)**
0.00[1]	0	0	0	0	0	0
0.20	537	0.04	339	0.03	333	0.03
0.40	1311	0.05	795	0.03	763	0.03
0.60	2352	0.06	1366	0.04	1318	0.04
0.70[2]	2965	0.06	1711	0.04	1665	0.04
0.80	3578	0.22	2056	0.15	2013	0.15
1.00[3]	5018	0.90	2870	0.60	2860	0.60
1.05	5413	4.31	3094	5.05	3096	4.66
1.10	5821	10.52	3324	13.16	3341	12.63

1. Base of extended detention storage. Permanent wetland storage depth of 0.2m is provided in the base of each basin.
2. Basin discharge control pit inlet level.
3. Footpath broad crested weir level.

5.3 Model results

The XP-RAFTS estimated 100 yr ARI peak site discharges are summarised in **Table 5-5**, **Table 5-6** and **Table 5-7** for Basins AB, C and D respectively. Estimated inflow and outflow design hydrographs for the critical duration local event (2hr event) are summarised in **Figure 5-2**, **Figure 5-3** and **Figure 5-4** for Basins AB, C and D respectively.

Table 5-5 Basin AB – Peak discharge

Event Duration	Rainfall intensity (mm/hr)	Existing	Developed	Developed with basins
20min	138	1.41	3.78	0.22
30min	113	2.06	4.18	0.69
45min	91	2.35	3.46	1.23
60min	77	2.62	4.85	1.73
90min	62	2.77	5.72	1.87
2hr	52	2.95	4.85	1.95
3hr	41.2	2.34	3.59	1.77
6hr	28.1	2.28	2.50	2.31
12hr	19.1	2.12	2.30	2.29
24hr	12.8	1.46	1.54	1.61
48hr	8.4	1.16	1.23	1.35

Table 5-6 Basin C – Peak discharge

Event Duration	Rainfall intensity (mm/hr)	Existing	Developed	Developed with basins
20min	138	0.75	2.01	0.10
30min	113	1.09	2.22	0.33
45min	91	1.25	1.83	0.53
60min	77	1.0	2.56	0.58
90min	62	1.47	3.02	0.81
2hr	52	1.58	2.58	0.85
3hr	41.2	1.23	1.89	0.93
6hr	28.1	1.20	1.31	1.25
12hr	19.1	1.12	1.21	1.29
24hr	12.8	0.76	0.81	0.91
48hr	8.4	0.61	0.64	0.64

Table 5-7 Basin D – Peak discharge

Event Duration	Rainfall intensity (mm/hr)	Existing	Developed	Developed with basins
20min	138	0.43	1.42	0.04
30min	113	0.71	1.58	0.11
45min	91	0.88	1.28	0.30
60min	77	0.96	1.83	0.41
90min	62	1.01	2.21	0.47
2hr	52	1.03	1.88	0.49
3hr	41.2	0.84	1.44	0.50
6hr	28.1	0.92	1.05	0.57
12hr	19.1	0.85	0.97	1.04
24hr	12.8	0.61	0.65	0.56
48hr	8.4	0.48	0.51	0.50

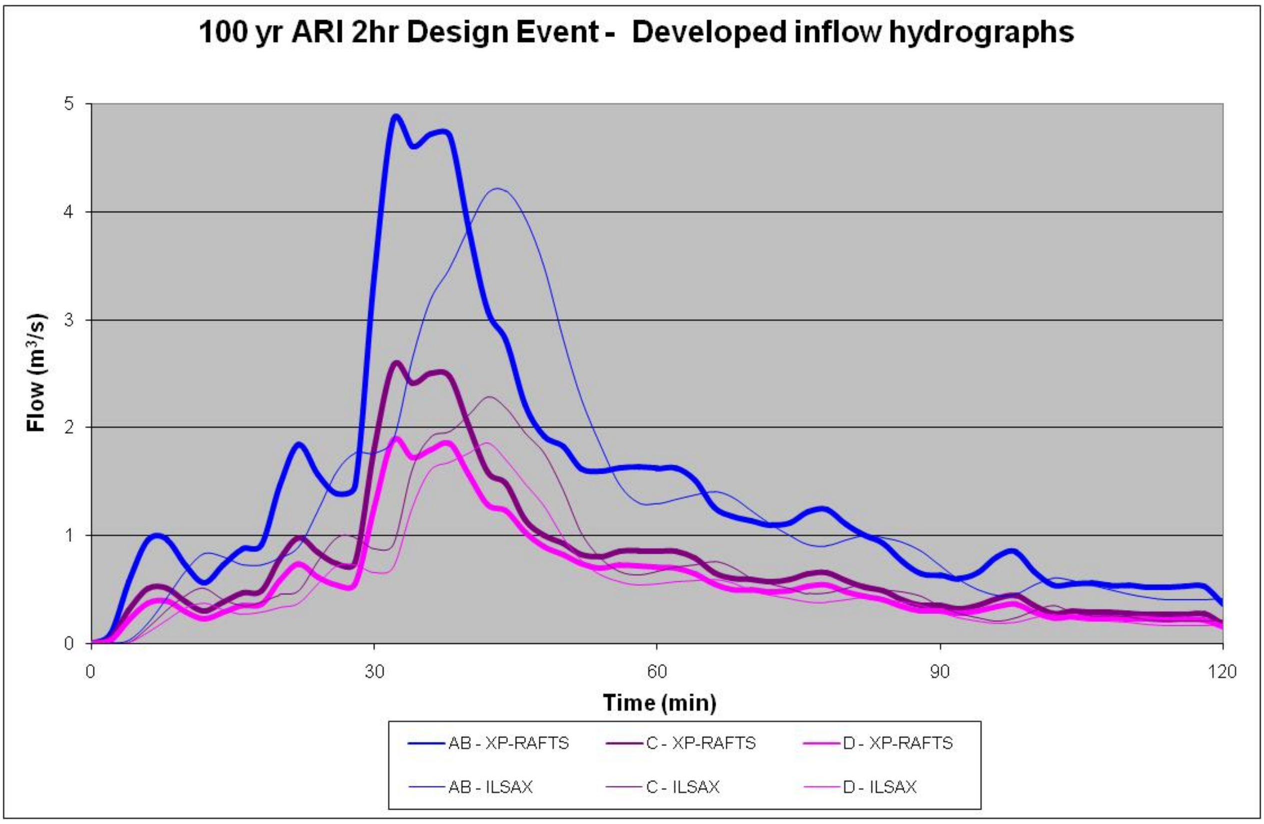


Figure 5-1 XP-RAFTS and ILSAX inflow hydrographs

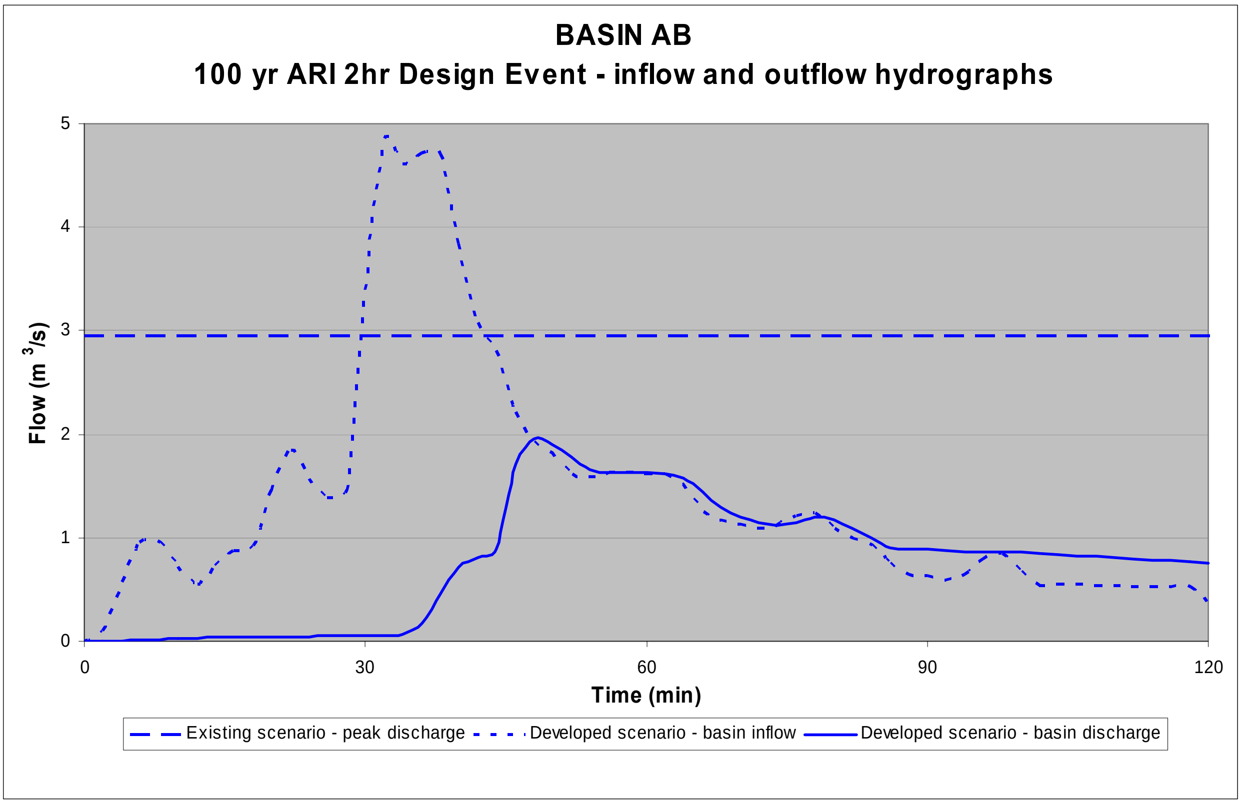


Figure 5-2 Estimated 100 yr ARI - 2hr design event hydrograph for Basin AB

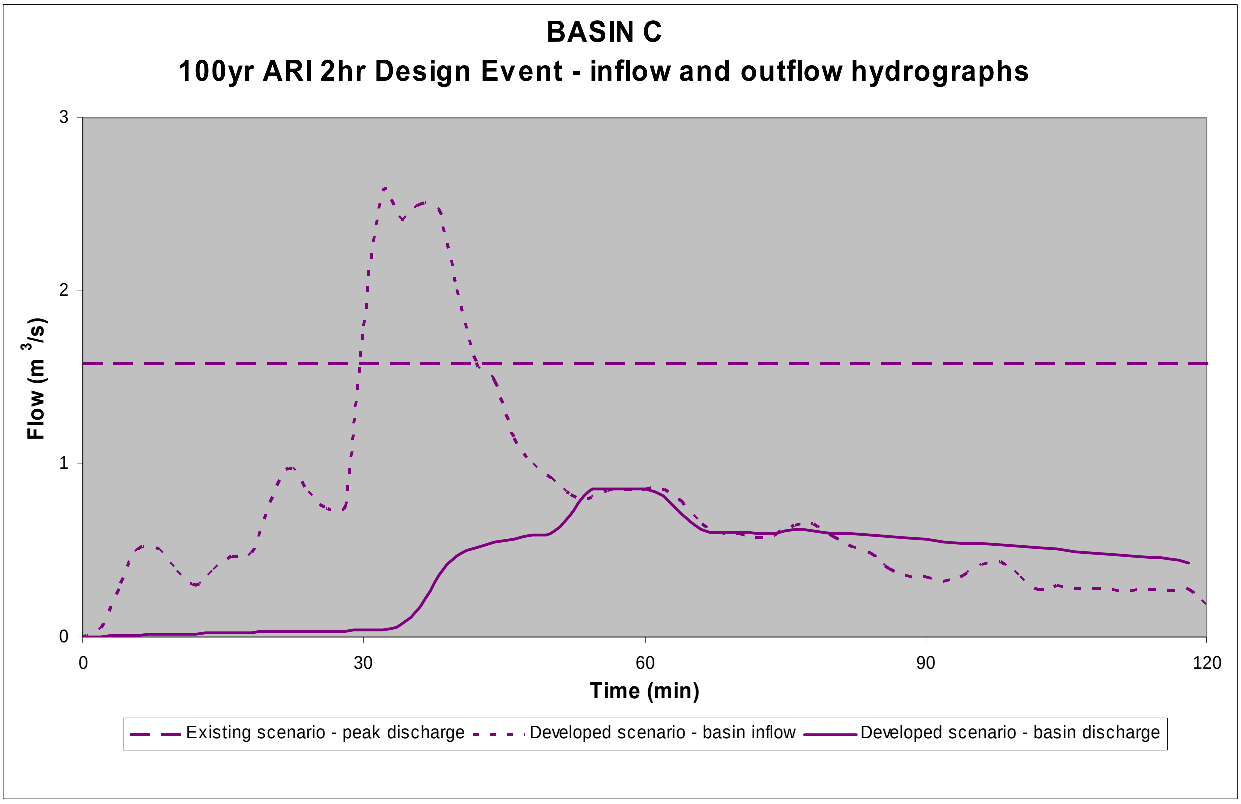


Figure 5-3 Estimated 100 yr ARI - 2hr design event hydrograph for Basin C

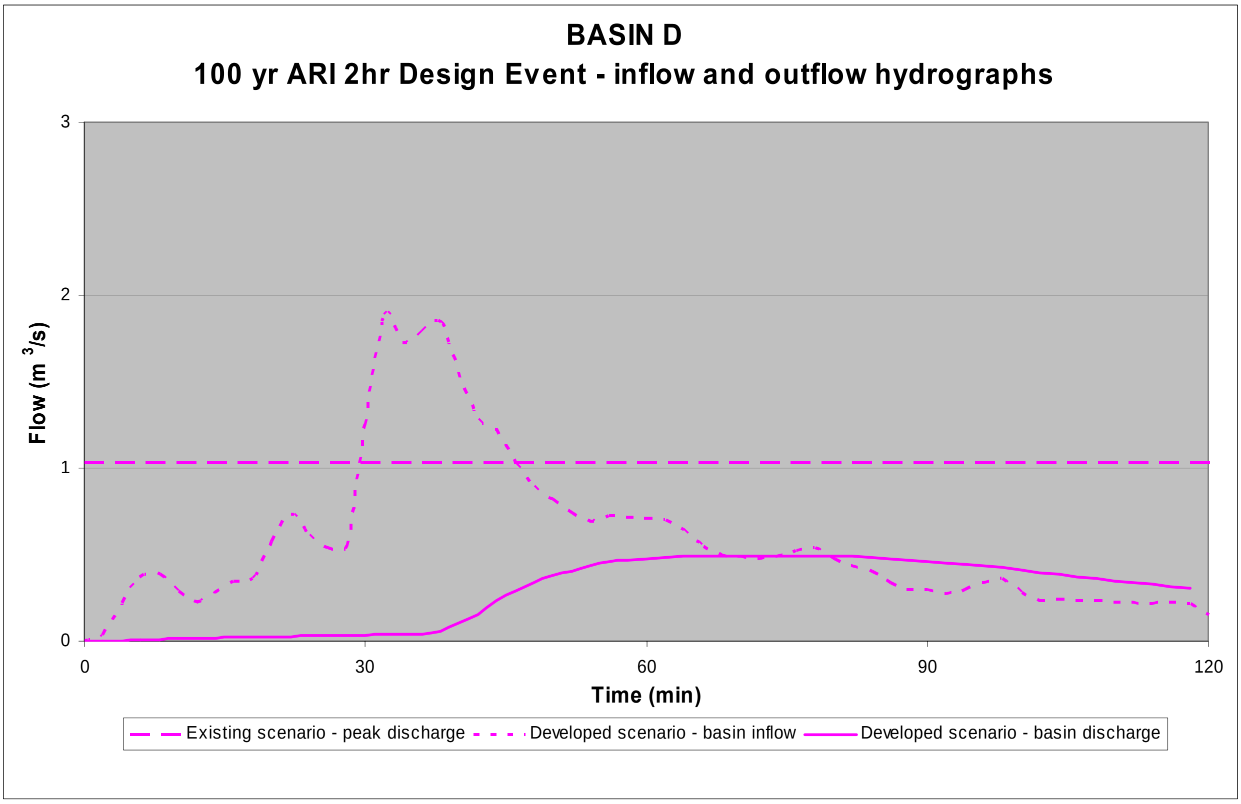


Figure 5-4 Estimated 100 yr ARI - 2hr design event hydrograph for Basin D

6 DISCUSSION AND CONCLUSIONS

The key objective of the stormwater management strategy for Old Bar Precinct 2A is to minimise the potential impacts of stormwater runoff from the proposed 130 lot residential subdivision on the existing estuarine receiving waters incorporating SEPP14 wetlands. The stormwater management strategy was prepared considering the management of runoff quality and quantity.

MUSIC modelling of the proposed stormwater treatment strategy indicates that the proposed system would achieve the load-based stormwater quality objectives adopted for the site (80/45/45% reductions in TSS, TP and TN respectively). The MUSIC modelling results also indicate that the proposed constructed wetlands/basins have appropriate extended detention storages that would minimise the potential for frequent breaching of the weir outlet. The continuous simulation results for the basins over the 10 year model period indicate that the storage depth would on average exceed the weir level for less than 0.5 days in a typical year for each basin. It is considered important to note that the modelling has assumed that the basin outlets would remain operational during the continuous modelling period. Potential for blockage of the outlets can be minimised through appropriate attention to detailed design, construction, inspections and maintenance.

The constructed wetlands/basins were also simulated in XP-RAFTS for 100 year ARI design storm event conditions. The results of this modelling indicate that the basins would provide sufficient storage and flow control to mitigate increased local catchment peak flow rates for design events up to the local critical duration design event. For some events with durations exceeding the critical duration, the magnitude of the total runoff volume would result in peak runoff rates for some events exceeding the existing conditions. Although this may occur, achieving a reduction in the peak flow rate for these events would require some compromise on the water quality function of the basins (i.e. reduced extended detention times for lower stages). Due to the site being positioned adjacent to the Manning River estuary it is considered that mitigation of peak flow discharges for this range of events is not be warranted when compared with the potential for compromising the water quality function during more frequent events.

During the preparation of this report, water quality sampling was undertaken for two events at five locations adjacent to the site. Testing results for each sampling run are presented in **APPENDIX A:** and the sampled concentration ranges for TSS, TP and TN are summarised in **Table 6-1** along with the adopted concentrations in MUSIC.

Table 6-1 Stormwater constituent concentrations (modelled and observed)

	MUSIC input concentrations (mg/L)				**Sampled concentrations (mg/L)**	
	Storm flow		**Base flow**		**18/10/06 & 28/02/07**	
Parameter	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean (median)**
TSS	67.6 – 295	141	10.7 – 23.4	15.8	2 - 91	24 (13)
TP	0.14 – 0.45	0.25	0.09 – 0.22	0.14	0.03 – 0.13	0.08 (0.07)
TN	1.29 – 3.09	2.0	0.98 – 1.7	1.29	0.28 – 1.74	0.60 (0.47)

The testing results for the two sampling runs (18/10/06 & 28/02/07) show that 8 of the 10 samples were either within or below the range of TSS base flow concentrations adopted in MUSIC. The remaining 2 samples (55 and 91mg/L) were below the mean storm flow concentration adopted in MUSIC. For TP, all samples were below the mean base flow concentration adopted within MUSIC. For TN, 9 of the 10 samples were below the mean base flow concentration adopted within MUSIC. Only 1 sample of 1.74mg/L exceeded the base flow concentration range which is close to the mean storm flow concentration adopted in MUSIC.

The testing results indicate that the sampled concentrations for TSS, TP and TN are generally within or below the range of base flow concentrations adopted in MUSIC. Most samples were taken adjacent to stormwater outlets from the existing urban areas and all were taken within approximately 12 hours of the conclusion of each rainfall period. Typically stormwater flows were reduced to low flow conditions when sampling occurred. It is considered likely that flushing of the impervious surfaces in the earlier stages of the 2 day rainfall period preceding each sampling run resulted in ‘cleaner’ runoff in the concluding stages of the event when sampling occurred. It is considered that this is a key reason why the sampled concentrations are typically lower than the range of event concentrations adopted in MUSIC. It is considered important to note that the default concentration ranges adopted in MUSIC were derived by scaling (reducing) those determined from the reviewed world-wide data to account for spatial/temporal variations (CRCCH, 2005) and possibly the observed concentrations at Old Bar may fall within the lower end of the unscaled range. Another possibility is that runoff from the existing Old Bar urban catchment may demonstrate lower stormwater pollutant concentrations than typical urban catchments. Although, to justify lowering the concentration parameters input to MUSIC, additional inter-event sampling during a number of storm events would be necessary. In particular, sampling would need to capture the early stages of each event where flushing of the catchment may result in concentrations significantly elevated above that observed near the end of an event.

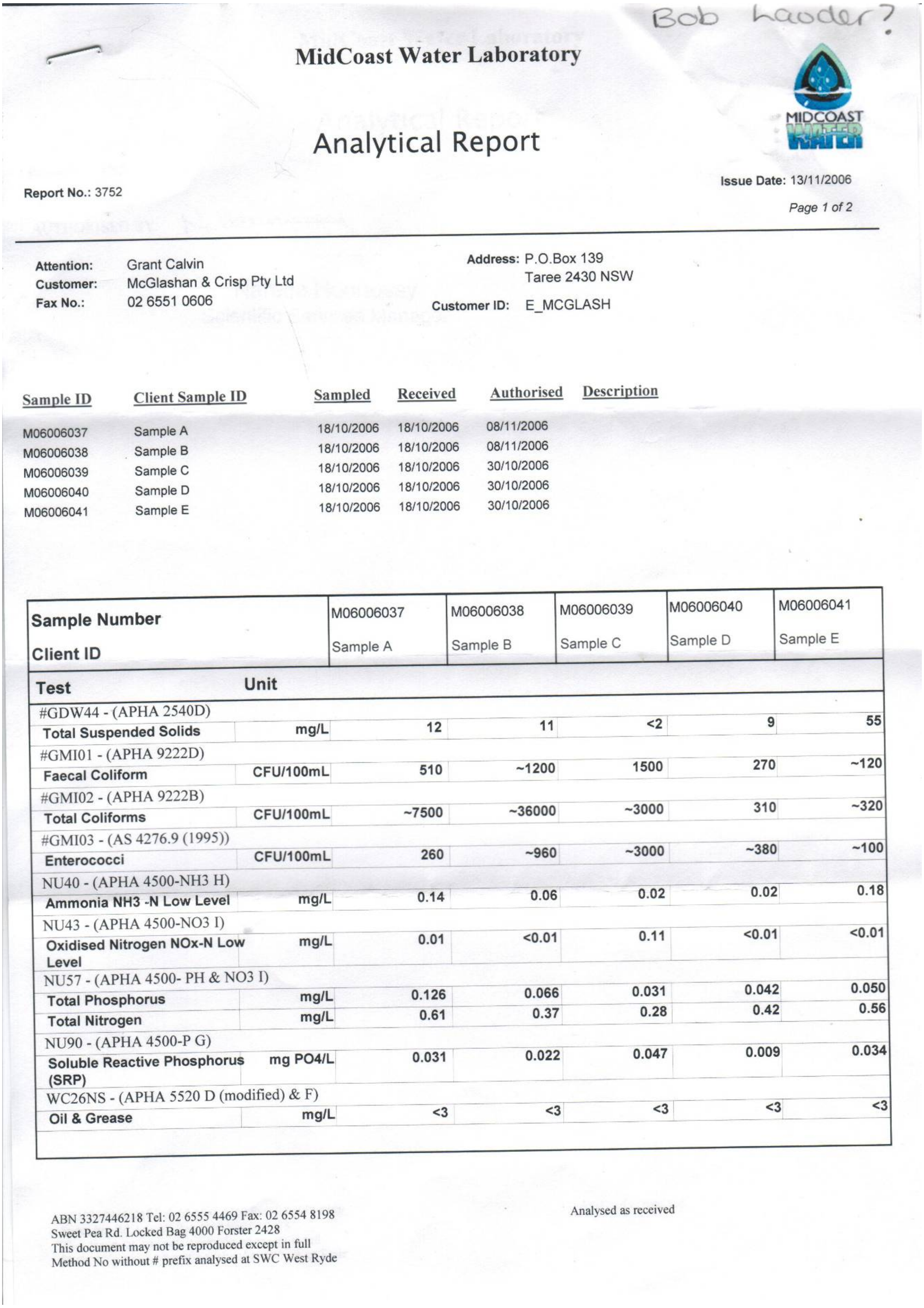
Limited water quality data were available for the estuarine receiving waters to enable specific water quality objectives to be established for the estuary. One water quality sampling run was undertaken during the preparation of the strategy (an additional run was undertaken after completion of the strategy) following a short period of catchment runoff and associated catchment loads being discharged to the estuary via Oyster Creek and Banyula Creek. The testing results from this sampling run identified that default ANZECC guideline trigger values for TN, NO_x, NH_4^+, TP, FRP, faecal coliforms and enterococci were exceeded for most parameters at most of the sampling sites. Due to the limited availability of data, it is not possible to confirm if the exceedence of these guideline levels is due to the sampling occurring soon after a runoff event that resulted in atypical water quality conditions in the estuary, and/or if the observed water quality conditions are more endemic and reflective of the existing catchment conditions. Consequently, these water quality results were only applied for broad comparative purposes and not for setting objectives.

In the absence of long-term monitoring data for the receiving waters, the stormwater management objectives for this development were adopted considering existing local planning documents (Greater Taree City Council’s SMP) and best practice guidelines for stormwater management (ARQ). For this reason load based objectives of 80/45/45% reductions in TSS, TP and TN were adopted for the site.

To address the uncertainty associated with the existing receiving water quality, a series approach to management of stormwater within the site is proposed to ensure that the management system is not reliant on any one specific measure to improve runoff quality. The proposed system incorporates rainwater tanks, grassed swales, bioretention swales and constructed wetlands in series. Rainwater tanks would harvest rainwater close to a significant source of runoff (roofs) for internal and external non-potable residential uses. Rainwater tanks also provide the related benefit of reducing potable water demand for the site. Grassed swales would provide the first vegetated treatment measure in series and these would be connected to the street drainage system outlets for initial filtering of runoff to remove coarse matter that is readily settleable. The grassed swales would connect to bioretention swales that provide additional filtering through both vegetation and an underlying media filter. Filtered runoff from the bioretention swales would be drained to constructed wetlands for final treatment prior to discharge to the receiving waters.

In conclusion, it is considered that the stormwater management strategy as proposed will achieve best practice management of stormwater runoff from the development site. The provision of treatment measures in series from the site sources to the site outlet affords the best possible protection for the receiving waters by providing a system that provides a level of redundancy.

APPENDIX A: WATER SAMPLING RESULTS – 18/10/07 & 28/02/07



Bob Laoder?

MidCoast Water Laboratory

Analytical Report

Report No.: 3752

Issue Date: 13/11/2006

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Address: P.O.Box 139
Taree 2430 NSW

Customer ID: E_MCGLASH

Sample ID	Client Sample ID	Sampled	Received	Authorised	Description
M06006037	Sample A	18/10/2006	18/10/2006	08/11/2006	
M06006038	Sample B	18/10/2006	18/10/2006	08/11/2006	
M06006039	Sample C	18/10/2006	18/10/2006	30/10/2006	
M06006040	Sample D	18/10/2006	18/10/2006	30/10/2006	
M06006041	Sample E	18/10/2006	18/10/2006	30/10/2006	

Sample Number		M06006037	M06006038	M06006039	M06006040	M06006041
Client ID		Sample A	Sample B	Sample C	Sample D	Sample E
Test	**Unit**					
#GDW44 - (APHA 2540D)						
Total Suspended Solids	**mg/L**	**12**	**11**	**<2**	**9**	**55**
#GMI01 - (APHA 9222D)						
Faecal Coliform	**CFU/100mL**	**510**	**~1200**	**1500**	**270**	**~120**
#GMI02 - (APHA 9222B)						
Total Coliforms	**CFU/100mL**	**~7500**	**~36000**	**~3000**	**310**	**~320**
#GMI03 - (AS 4276.9 (1995))						
Enterococci	**CFU/100mL**	**260**	**~960**	**~3000**	**~380**	**~100**
NU40 - (APHA 4500-NH3 H)						
Ammonia NH3 -N Low Level	**mg/L**	**0.14**	**0.06**	**0.02**	**0.02**	**0.18**
NU43 - (APHA 4500-NO3 I)						
Oxidised Nitrogen NOx-N Low Level	**mg/L**	**0.01**	**<0.01**	**0.11**	**<0.01**	**<0.01**
NU57 - (APHA 4500- PH & NO3 I)						
Total Phosphorus	**mg/L**	**0.126**	**0.066**	**0.031**	**0.042**	**0.050**
Total Nitrogen	**mg/L**	**0.61**	**0.37**	**0.28**	**0.42**	**0.56**
NU90 - (APHA 4500-P G)						
Soluble Reactive Phosphorus (SRP)	**mg PO4/L**	**0.031**	**0.022**	**0.047**	**0.009**	**0.034**
WC26NS - (APHA 5520 D (modified) & F)						
Oil & Grease	**mg/L**	**<3**	**<3**	**<3**	**<3**	**<3**

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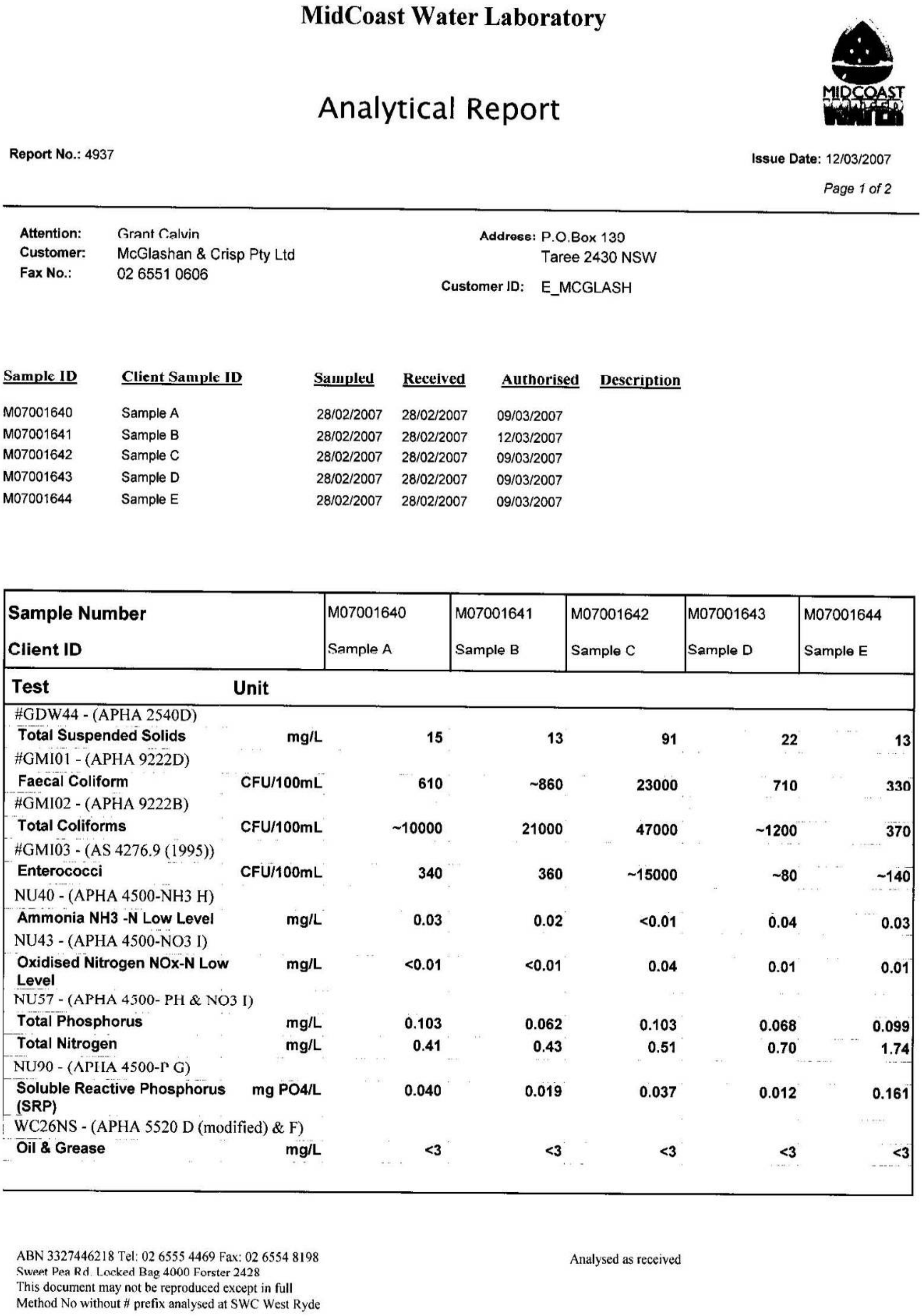

MidCoast Water Laboratory

Analytical Report

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Customer: McGlashan & Crisp Pty Ltd
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Address: P.O.Box 130
Taree 2430 NSW

Customer ID: E_MCGLASH

Sample ID	Client Sample ID	Sampled	Received	Authorised	Description
M07001640	Sample A	28/02/2007	28/02/2007	09/03/2007	
M07001641	Sample B	28/02/2007	28/02/2007	12/03/2007	
M07001642	Sample C	28/02/2007	28/02/2007	09/03/2007	
M07001643	Sample D	28/02/2007	28/02/2007	09/03/2007	
M07001644	Sample E	28/02/2007	28/02/2007	09/03/2007	

Sample Number		M07001640	M07001641	M07001642	M07001643	M07001644
Client ID		Sample A	Sample B	Sample C	Sample D	Sample E
Test	**Unit**					
#GDW44 - (APHA 2540D)						
Total Suspended Solids	**mg/L**	**15**	**13**	**91**	**22**	**13**
#GM101 - (APHA 9222D)						
Faecal Coliform	**CFU/100mL**	**610**	**~860**	**23000**	**710**	**330**
#GM102 - (APHA 9222B)						
Total Coliforms	**CFU/100mL**	**~10000**	**21000**	**47000**	**~1200**	**370**
#GM103 - (AS 4276.9 (1995))						
Enterococci	**CFU/100mL**	**340**	**360**	**~15000**	**~80**	**~140**
NU40 - (APHA 4500-NH3 H)						
Ammonia NH3 -N Low Level	**mg/L**	**0.03**	**0.02**	**<0.01**	**0.04**	**0.03**
NU43 - (APHA 4500-NO3 I)						
Oxidised Nitrogen NOx-N Low Level	**mg/L**	**<0.01**	**<0.01**	**0.04**	**0.01**	**0.01**
NU57 - (APHA 4500- PH & NO3 I)						
Total Phosphorus	**mg/L**	**0.103**	**0.062**	**0.103**	**0.068**	**0.099**
Total Nitrogen	**mg/L**	**0.41**	**0.43**	**0.51**	**0.70**	**1.74**
NU90 - (APHA 4500-P G)						
Soluble Reactive Phosphorus (SRP)	**mg PO4/L**	**0.040**	**0.019**	**0.037**	**0.012**	**0.161**
WC26NS - (APHA 5520 D (modified) & F)						
Oil & Grease	**mg/L**	**<3**	**<3**	**<3**	**<3**	**<3**

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Method No without # prefix analysed at SWC West Ryde

Analysed as received