6.4 c WSUD Stormwater Objectives DesignFlow

Ella Bay
Stormwater Management Objectives

DesignFlow
Prepared for Satori Developments
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Document Control Sheet

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Disclaimer

Potential implications of climate change

Unless expressly stated otherwise, historical climate data has been used in, or underpins, the analyses that are presented in this report. The historical climate is not necessarily a valid indicator of future climate, which may contain prolonged periods that are wetter or drier than the historical record used for this analysis. There is significant uncertainly surrounding how climate, and in particular, rainfall, will be impacted by various levels of greenhouse gas accumulation in the atmosphere. Rainfall has a much greater spatial variability than temperature and some areas are likely to become wetter whilst other areas become drier. Further to this there may be changes in the seasonality and intensity of rainfall. Such changes in climate could affect the conclusions and recommendations of this report.

Inherent natural variability in soils and plants

Where particular types of soils are recommended, such recommendations are based on information provided by soils suppliers, laboratories and published industry guidelines. There can be inconsistencies in the behaviour of soils under field conditions compared to laboratory conditions, and, for both natural and blended soils, many soils are non-homogenous and properties and behaviour can be variable. Where particular plant species have been recommended, such recommendations are based on botanical knowledge and observations of similar species growing in similar, but not identical conditions. Plants can be sensitive to subtle changes in climate, hydrology, soil and surrounding ecological conditions. Further to this, plant health is often closely linked to the level of maintenance provided. No warranty or guarantee, whether explicit or implied is made with respect to the suitability or performance of soils or plant species recommended in this report

Acknowledgement

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1 INTRODUCTION

The proximity of Ella Bay to sensitive aquatic ecosystems within and adjacent to the site means analysis of any changes to the water cycle as a results of development must be undertaken to ensure protection of these systems. In this regard, the planning and design of the Ella Bay development will be guided by the principles of Water Sensitive Urban Design (WSUD). It is envisaged that WSUD will be used extensively to create a development zone that promotes sustainable and integrated management of land and water resources, which incorporates best practice stormwater management, water conservation/reuse and environmental protection.

Experience throughout Australia has identified that successful implementation of WSUD and requires the adoption of clear and quantitative design objectives and targets. Objectives must respond to the protection requirements of local aquatic ecosystems and be applicable in a practical sense. The lack of appropriate quantitative objectives in Queensland has resulted in some confusion about when WSUD should apply and what objectives should be adopted.

This discussion paper has been prepared for Satori Resorts Ella Bay Pty Ltd in response to an information request from the Department of the Environment, Water, Heritage and the Arts (DEWHA) relating to stormwater management of the proposed Ella Bay development. The queries relate specifically to storm water quality and quantity management and associated protection of existing ecosystems. Correspondence from the DEWHA dated the 1st August 2008 includes:

- "The quality of water discharges into the GBRWHA and into creek systems to ensure habitat for listed frog species and for the protection of the water quality in the GBRWHA" (1st August 2008)
- "As you are aware, the Australian and Queensland governments have developed a Reef Water Quality Protection Plan for the long term protection of the water quality in the Great Barrier Reef area. Any discharges into the Great Barrier Reef marine area should meet the objectives of this plan. " (22nd May 2008)
- "some reference is made to the adherence to water quality criteria (EPA 2006). Can you please send a copy of the water quality criteria that you expect to implement ?" (13th December 2007)
- "Water balance for the site, in particular to ensure that the water regime of the Northern Wetland area and coastal swales that support habitat for listed species would not be affected by the development" (1st August 2008)
- "The report by EnSight on water balance for the project does not provide quantitative data. If all rainwater is to be collected in rainwater tanks, what are the downstream hydrological impacts? How are the environmental water flows to the streams, wetland and beach swale areas be maintained?" (22nd May 2008)

The correspondence is clearly asking for stormwater quality and hydrologic management of stormwater leaving the Ella Bay site in order to protect adjacent ecosystems. The paper provides commentary on the potential WSUD objectives in response to the issues raise above by DEWHA and recommends quantitative objectives to guide the WSUD and water management strategy.

2 WATER SENSITIVE URBAN DESIGN (WSUD)

WSUD is a new theory in the planning and design of urban development that aims to minimise impacts on the natural water cycle and protect aquatic ecosystem health. WSUD supports the integration of the urban water streams, specifically stormwater, potable water supply, sewerage management and groundwater, and is focused on delivering sustainable water cycle solutions.

WSUD integrates these urban water cycle solutions into the urban plan, architecture and landscape of urban development, towards an overall goal of ecologically sustainable development (ESD), as illustrated in Figure 1. Further description of the philosophy and implementation of WSUD is provided in Australian Runoff Quality (Engineers Australia, 2005).

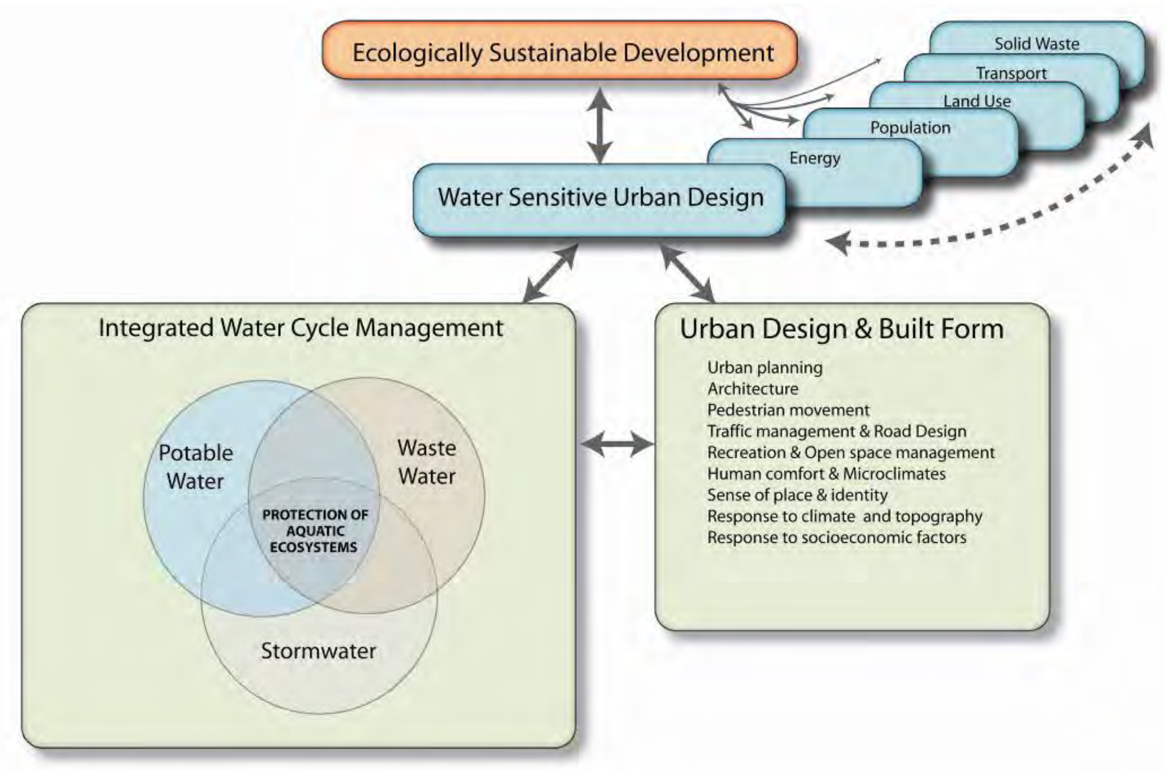


Figure 1 Relationship between water sensitive urban design, ecologically sustainable development and integrated water cycle management [1]

[1] Draft Water Sensitive Urban Design – Design Objectives for the Dry Tropics – Discussion Paper (March 2008)(co-authored by DesignFlow)

2.1 WSUD PRINCIPLES

The guiding principles of WSUD are to:

- Protect existing natural features and ecological processes.
- Protect water quality of surface and ground waters.
- Maintain natural hydrologic behaviour of catchments.
- Minimise demand for potable water.
- Minimise wastewater generation and discharge to the natural environment.
- Integrate water into the landscape to enhance urban design, visual, social, cultural and ecological values.

These guiding principles are adopted to reduce the impacts of urban development on receiving aquatic ecosystems. The principles are consistent with the goals of the Ella Bay development.

2.2 THE NEED FOR QUANTITATIVE WSUD OBJECTIVES

In order to realise the WSUD principles listed above it is critical they are quantified. Stakeholder consultation throughout Australia has consistently identified the requirement for quantitative design objectives (i.e. measurable targets) to guide the conceptualisation and assessment of WSUD within urban development. The lack of quantitative objectives has been identified as a significant barrier to the effective implementation of WSUD (MBWCP, 2005).

The WSUD objectives must be clear and consistent and relate to ecosystem protection outcomes. Quantitative WSUD objectives are a key component and precursor to the development WSUD policy and framework and are an essential element of the development assessment process.

In response, the Queensland Environmental Protection Agency (now Department of Environment and Resource Management) has developed quantitative WSUD objectives for the state and created new state policy (State Planning Policy for Healthy Waters) which enforces the adoption of WSUD on new development. DesignFlow has been involved in the creation of these objectives and associated implementation of the policy.

Details of the objectives that apply to Satori are provided in this discussion paper. This discussion paper focuses on the stormwater management aspect of WSUD.

3 SITE OBSERVATIONS

A site inspection of the wetlands and waterways at the proposed Ella Bay development was undertaken by DesignFlow on the 15th and 16th of April, 2009.

Figure 2 Photos of the Ella Bay site

3.1 GENERAL

The site is characterised by a large wetland mosaic complex to the north (Northern Wetland) and a series of wetlands (Wetland Swale) that run in a northerly direction in a swale behind the beach to the east of the site. There are also several smaller wetlands present in shallow alluvial depressions located throughout the site. Refer to Figure 3 for a diagram of wetland extent in the property boundary.

A diagram of the catchment split across the site in the context of the broader topography in the region is provided in Figure 4The majority of the surface runoff from the site discharges via well defined drainage lines into Farm Creek, which flows through the site in an easterly direction and discharges directly to Ella Bay. A tributary flowing in a northerly direction dissects the site and conveys runoff from the south of the site into Farm Creek. Surface water runoff from the northern section of the site flows into the Northern Wetland system (refer Section 3.3) via two well defined shallow depressions.

The wetland and waterway plant communities at the site have been severely degraded by the invasion of Pond Apple (*Annona glabra*). The presence of Pond Apple in the Northern Wetland and Wetland Swale areas is of particular concern, as several pure stands of the Pond Apple have now developed, and further incursion of this weed into these wetland areas will continue to threaten the remaining wetland communities. Pond Apple and Lantana (*Lantana camara*) are also present along Farm Creek, and constitute a threat to the condition of the riparian communities in these sections.

Mapping of the Pond Apple is currently occurring. The figures will be updated once this mapping is available.

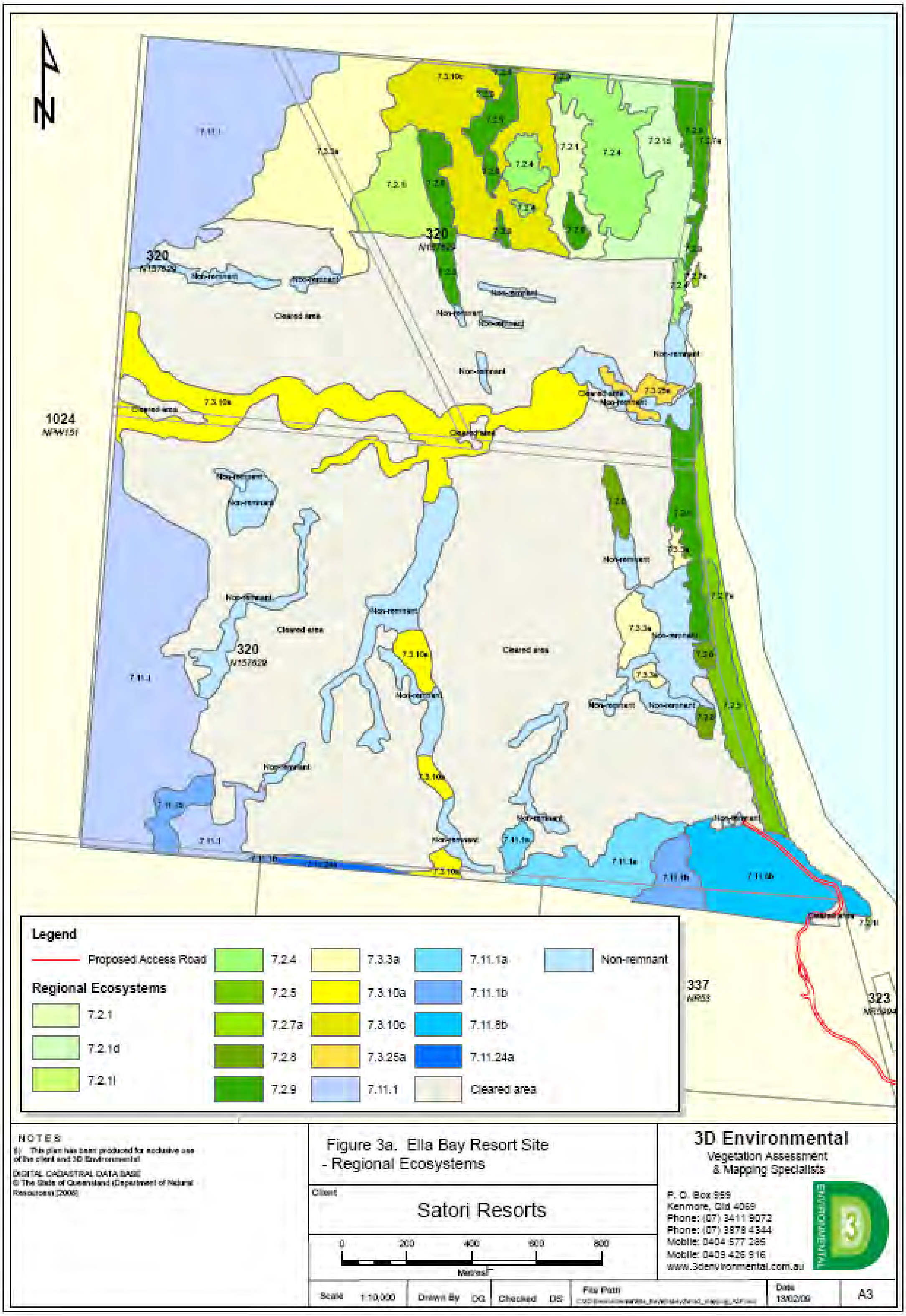


Figure 3 Extent of wetland areas (taken from 3D Environmental, Vegetation Survey Report 2009) (areas in dark and light green correlate with wetland extents)

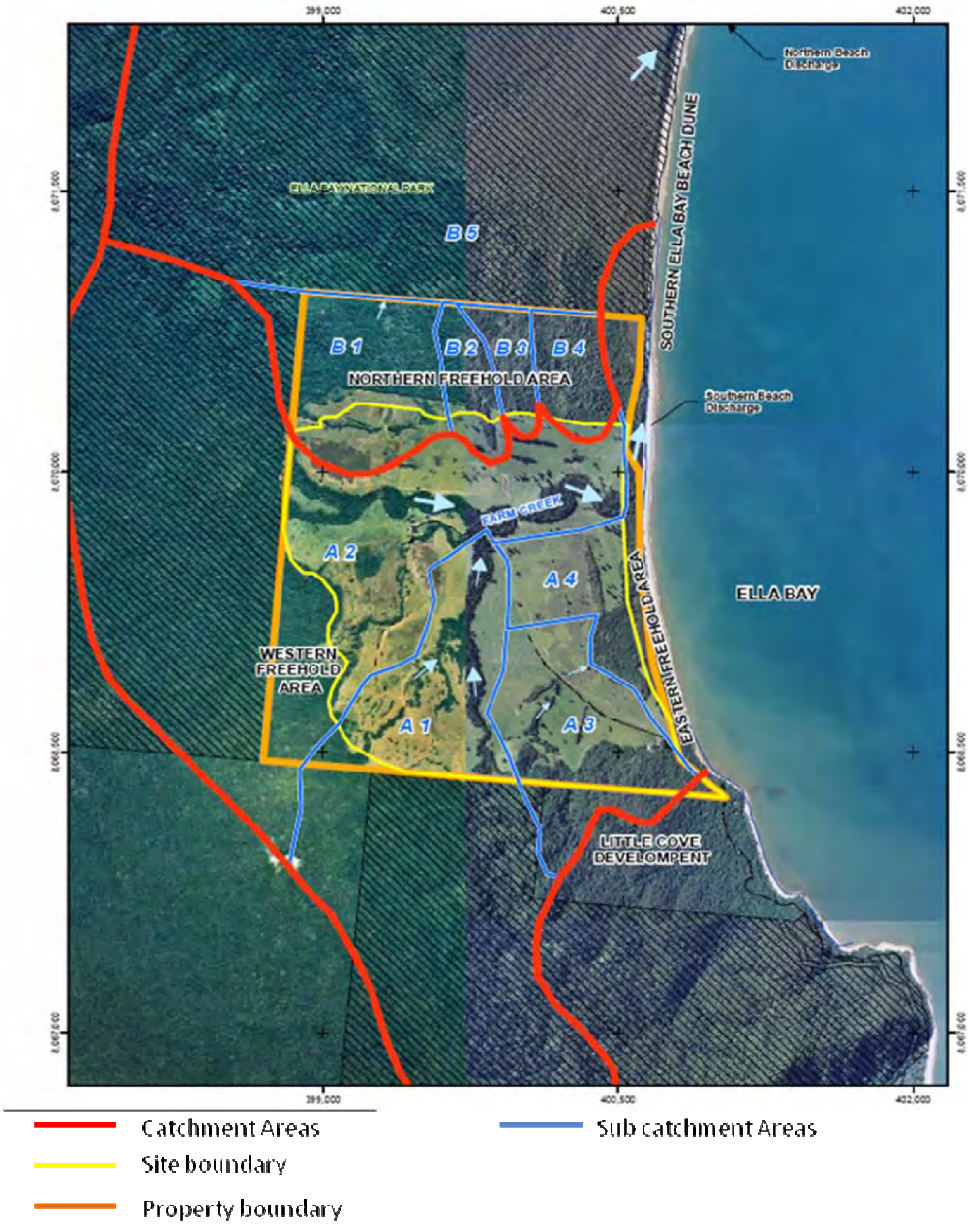


Figure 4 Ella Bay Site (taken from Golder Associates Pty Ltd, Conceptual Surface Water and Groundwater Hydrology Report 2007)

Figure 5 Pond apple presence on the Ella Bay site

3.2 FARM CREEK

Farm Creek and the tributary are densely vegetated with diverse riparian communities that extend between 5-15 m from the edges of the waterways. The Farm Creek channel is highly stable due to the presence of the riparian vegetation. Minor erosion has occurred along a short reach (50m) in the lower section of Farm Creek. It would appear that the removal of the riparian vegetation in this section has destabilised the stream embankments causing active bank erosion and subsequent mass slumping.

The floodplain levels adjacent to Farm Creek and the tributary are extremely flat. There appears to have been no formal drainage implemented at the site. However, minor modifications have been made to a small drainage line in the northern section of the site, where runoff from the floodplain appears to have been diverted away from Farm Creek towards the Northern Wetland.

Figure 6 Farm Creek: bank erosion

3.3 NORTHERN WETLAND

The Northern Wetland is comprised of a wetland mosaic of patches of Open forest (dominated by *Melaleuca quinquenervia*) interspersed with Mesophyll vine forest (dominated by *Archontophoenix alexandre*) in the drainage depressions, and Sclerophyll vine forest (dominated by *Lophostemon suaveolen*) in the higher sections.

The Melaleuca dominated Open forest and the Mesophyll vine forest are characterised by moist depressions interspersed with shallow bodies of surface water (generally less than 100 mm depth) during the wet season. The wetland areas are frequently inundated during the wet season (0-200 mm depth). The presence of surface water within the Open forest and Mesophyll vine forest wetland areas is maintained throughout the year by a combination of surface water runoff from the northern section of the site, catchment areas to the west of the wetland areas and groundwater discharges.

3.4 WETLAND SWALE

The Wetland Swale complex comprises of Melaleuca dominated Open forest in the wetter alluvial depressions, Tall open forest (dominated by *Melaleuca leucandra*) and Mesophyll forest (dominated by *Syzygium forte*) on the coastal dunes to the south, and a coastal Foredune complex (dominated by shrubland and *Casuarina equisetifolia*) on the dunes between the swale depression and Ella beach.

Runoff from the south-eastern area of the site enters the Wetland Swale complex via a large shallow alluvial depression that extends onto the floodplain above the swale complex. The depression is characterised by a mosaic of vegetation communities consisting of dense shrubland (*Hibiscus tiliaceus* and *Archontophoenix alexandrae*), Mesophyll vine forest (*Archontophoenix alexandrae*) and Open forest (*Melaleuca leucadendra*). The plant communities throughout the depression are dominated by dense infestations of Pond Apple.

The Wetland Swale is characterised by widespread interspersed areas of shallow surface water (0-150 mm depth). Surface water enters the swale diffusely from the shallow alluvial depression and from the adjoining floodplain, and drains freely through the swale in a northerly direction towards the mangrove dominated intertidal area at the mouth of Farm Creek. Water levels in the Wetland Swale are maintained by a combination of surface runoff, groundwater discharges and infiltration back to the beach dune system.

Groundwater discharges to the Wetland Swale result in a permanent low flow within the Wetland Swale and the adjoining alluvial depression area, and the maintenance of permanent pools within these areas.

Flooding occurs in the Wetland Swale when there is surface runoff. The zonation of the vegetation along the margins of the swale depression indicates that water levels temporarily rise by up to 300 mm during the wet season; however residence times for flooding will be low due to the direct connection of the swale complex to lower section of Farm Creek. Flooding may persist in the swale complex following rain due to higher water levels in the lower sections of Farm Creek and also from higher groundwater infiltration rates. It is expected that the coastal dunes are also occasionally over topped by king tides, leading to temporary inundation of the Wetland Swale with saline water.

Figure 7 Areas within the Wetland Swale

3.5 HYDROLOGY OF NORTHERN WETLAND & WETLAND SWALE

Water levels within both the Northern Wetland and Wetland Swale complex are expected to persist as shallow permanent pools during the wet season, but significantly lower during the dry season due to evapotranspiration or infiltration via the sand dunes to Ella Bay.

The upper substratum in the Northern Wetland and Wetland Swale complexes comprise of a thick layer (up to 50 mm depth) of organic material (decomposing leaves and litter). This suggests that decomposition of organic material occurs slowly and that the surface soils in these areas remain relatively moist throughout the dry season.

There is currently no hydrologic data available for Farm Creek, although anecdotal evidence indicates that there is no outflow connection to Ella Bay during the dry season.

3.6 WETLAND CLASSIFICATION

Based upon the Queensland Wetlands Programme classification system, the dominant wetland types at the proposed Ella Bay development site in both the Northern Wetland and the Wetland Swale areas are commensurate with the Coastal Melaleuca Swamp Wetlands wetland management profile (Queensland Wetlands Programme, 2009).

Wetland management profiles developed under the auspices of the Queensland Natural Heritage Trust Wetlands Programme are designed to provide general information and management recommendations for individual species, ecosystems and cultural heritage in Queensland.

Coastal melaleuca swamp wetlands

Melaleuca swamps are non-tidal, wooded wetlands that occur in or near coastal areas of Queensland. They can be temporarily inundated with water for three to six months of the year, as they occupy the depressions, drainage lines and dune swales within the landscape (Queensland Wetlands Programme, 2009b).

Coastal melaleuca swamp wetlands are characterised by vegetation communities that are able to tolerate a high frequency of inundation during the wet season, such as many *Melaleuca* species. Melaleuca swamp wetlands have a relatively high tolerance to increased nutrient loads, provide an effective buffer against erosion, are efficient sinks of nutrients and act to retain flood waters (Queensland Wetlands Programme, 2009b).

The management of wetland hydrology is a critical element in preserving wetland function and structure. Limited information is available on the hydrological characteristics of Coastal Melaleuca Swamp wetlands. It is generally recognised that Coastal Melaleuca Swamp wetlands are sensitive to hydrological changes; whereby decreases or increases to natural water flow can cause the coastal melaleuca swamp wetlands to deteriorate, dry out and disappear or become larger and wetter changes (Queensland Wetlands Programme, 2009b).

As part of the *Water Sensitive Urban Design Solutions for Catchments above Wetlands (May 2007)* published by the Hunter and Central Coast Regional Environmental Management Strategy, Ecological Engineering (2007a) derived a wetland classification system that enables different wetland types to be distinguished, and the appropriate supporting hydrology and water quality parameters to be determined for each wetland type. This is particularly important where remnant wetlands exist below existing or proposed urban developments, and where catchment urbanisation can lead to alteration of the water regime. Members of the DesignFlow team were employed at Ecological Engineering when this classification scheme was established and are well versed in its application.

The wetland classification system proposed by Ecological Engineering (2007a) is based upon the; dominant vegetation, dominant substratum, water chemistry and typical life forms. All wetland types present within Australia were integrated into the classification system, and the classification system compared to other classification schemes.

Based upon the proposed classification system, the dominant wetland types present at the proposed Ella Bay site (**Coastal Melaleuca Swamp wetlands**) were judged to be commensurate with the **Wet Forest Swamp** classification (Ecological Engineering, 2007a). Wet forest swamps are flooded on a regular or seasonal basis, and are generally dominated by Melaleuca species (Ecological Engineering, 2007a). The typical frequency of drying/exposure of the wetland substrata in wet forest swamps ranges between once every 1-3+ years (Ecological Engineering, 2007a). The average duration of drying in wet forest swamps varies between 2-6 months per year, however this is expected to be significantly lower in areas with high rainfall occur during the dry season. Wet forest swamps are adapted to regular inundation, and are able to cope with inundation depths ranging between 0-2 m (Ecological Engineering, 2007a).

This classification has been used to establish hydrologic objectives (Section 7.2) that should be achieved on the Ella Bay site to ensure the wetland systems are protected.

4 CURRENT STORMWATER MANAGEMENT POLICY AND OBJECTIVES

4.1 STORMWATER QUALITY

The following documents are relevant to stormwater quality management at Ella Bay:

- *Water Quality Guideline for the Great Barrier Reef Marine Park 2008 (DRAFT*).
- *Queensland Water Quality Guidelines 2006*
- The Australian and Queensland Government's *Reef Water Quality Protection Plan 2003* (Reef Plan)
- *The Australian Government's Coastal Catchments Initiative* (CCI)
- The Australian Government's *National Water Quality Management Strategy* (NWQMS)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)
- *State Coastal Management Plan — Queensland's coastal policy* (2008)
- Johnstone Shire Planning Scheme (2005)
- *Water Quality Management Guidelines (Supplement to Council's Subdivison and Development Guidelines), Version 1, Waterways Program, Urban Management Division, Brisbane City Council 2000*[2]

The *Water Quality Guideline for the Great Barrier Reef Marine Park* is the most recent guideline for receiving water quality objectives for the Ella Bay region. It compiles the currently available scientific information to provide environmentally based values for water quality contaminants that, if reached, will trigger management solutions. It is noted within the Guideline that the levels of contaminants identified are not targets, instead are guideline trigger values for ambient concentrations in the receiving ecosystem (i.e. they are not discharge criteria). These guidelines recommend a trigger value for Suspended Solids, Particulate Nitrogen and Particulate Phosphorus. For enclosed coastal waterbodies, the Guideline trigger values have been taken directly from the Queensland Water Quality Guideline (2006)

The table below identifies the water quality objectives for the Wet Tropics as outlined in the Queensland Water Quality Guidelines (2006). As discussed further in Section 6, The guideline uses scheduled water quality objectives (WQOs) as the reference for defining the health of aquatic ecosystems and for assessing the potential water quality impact as a result of an activity in the catchment. The scheduled WQOs represent target pollutant concentrations in receiving waterways necessary to achieve Environmental Values under ambient (dry-weather or baseflow) conditions. The Ella Bay site does not sit within the areas marked as being of High Ecological Value in the Guidelines,

[2] Referenced by FNQROC Development Manual – Design Guidelines for Stormwater Quality Management (FNQROC 2004)

therefore the values that are representative of a slightly disturbed ecosystem have been referenced.

Table 1 Water Quality Objectives from the Queensland Water Quality Guidelines (2006) for the Wet Tropics

	Indicator	Objective
Freshwater Wetlands	Total Suspended Solids	50th percentile TSS < 15 mg/L
	Total Phosphorus	50th percentile TP < 10 – 50 µg/L
	Total Nitrogen	50th percentile TN < 350 – 1200 µg/L
Freshwater Lowland Stream	Total Suspended Solids	50th percentile TSS < 15 mg/L
	Total Phosphorus	50th percentile TP < 10 µg/L
	Total Nitrogen	50th percentile TN < 240 µg/L

The ANZECC 2000 Guidelines refer to lowland freshwater streams are defined as all freshwater streams or stream sections below 150m. The freshwater lowland stream has been included to represent discharge to Farm Creek.

There is no formal definition of wetlands in the ANZECC 2000 Guidelines. However, the ANZECC Guideline "wetlands" essentially refers to Palustrine wetlands. definition of Palustrine wetland adopted by the EPA and the Queensland Wetlands Programme is: The palustrine system includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ‰.The wetland WQOs have been assumed to represent the northern wetland and the wetland swale.

4.2 HYDROLOGY (STORMWATER QUANTITY)

There is no current policy or guidance material in Queensland that outlines hydrologic or stormwater quantity objectives that would apply to Ella Bay. Therefore, hydrologic objectives need to be specifically established for Ella Bay based on the protection requirements for Northern Wetland and the Wetland Swale.

5 NEW STORMWATER MANAGEMENT POLICY AND OBJECTIVES (NEW STATE PLANNING POLICY)

The Queensland Department of Environment and Resource Management (formerly the Environmental Protection Agency) has recently prepared the draft *State Planning Policy for Healthy Waters* (DERM, 2009) which incorporates a *Urban Stormwater Code*. This code provides direction on urban storm water management for new development in Queensland and requires local authorities implement the code provisions directly in development assessment or through compatible planning scheme provisions. Both the SPP and code refer to the *Best Practice Environmental Management Guidelines – Urban Stormwater* (DERM, 2009) for design objectives, planning guidance, development assessment and compliance details.It is anticipated that the State Planning Policy will be released in the second half of 2009. Once these guidelines are enforced the objectives stated within the *Best Practice Environmental Management Guidelines – Urban Stormwater* will represent the minimum that must be met in terms of storm water management. Quantitative objectives for stormwater quality and quantity as dictated by the *Best Practice Environmental Management Guidelines – Urban Stormwater* are summarised in the table below.

Table 2 New State Planning Policy WSUD Objectives for Queensland

Type of objective	Intent	Design objective
Stormwater quality management	To minimise the impacts of urban development on waterway health by reducing the pollutant loads discharged to receiving waters in the post-construction period.	Achieve best practice stormwater treatment of runoff leave the development site. Achieve the following minimum reductions in total pollutant loads , compared with that in untreated stormwater runoff from the developed part of the site (for the Wet Tropics): • 80% reduction in total suspended solids; • 65% reduction in total phosphorus; • 40% reduction in total nitrogen; and • 90% reduction in gross pollutants.
Waterway stability management	To minimise the impacts of urban development on channel-bed and bank erosion by limiting changes in flow rate and flow duration within the receiving waterway.	Limit the post-development peak one-year average recurrence interval (ARI) event discharge within the receiving waterway to the equivalent pre-development peak discharge.
Frequent flow management	To reduce the frequency of disturbance to aquatic ecosystems by managing the volume and frequency of surface runoff during small rainfall events.	For the proposed development, capture and manage: • the first 10 mm of runoff from surfaces that are 0% to 40% impervious; and • the first 15 mm of runoff from surfaces that are >40% impervious. Note: The capacity to capture runoff must be restored within 24 hours of the runoff event.

The following sections describe the application of the objectives to Ella Bay given the characteristics of the site and suggest a preferred set of objectives to guide WSUD on the site.

6 STORMWATER QUALITY OBJECTIVES

6.1 NEW STATE PLANNING POLICY

The philosophy that underpins the stormwater quality objectives included in the future *State Planning Policy for Healthy Waters* (DERM, 2009) and *Best Practice Environmental Management Guidelines – Urban Stormwater* (DERM, 2009) is that stormwater discharge from development is to be treated in accordance with best practice.

DesignFlow were involved in the derivation of the objectives and much of the following text is taken from this document and reproduced for this response to illustrate the modelling and assessment process.

The approach to developing load based objectives for the Wet Tropics is summarized in detail in *Best Practice Environmental Management Guidelines – Urban Stormwater* (DERM, 2009) and *Technical Note: Derivation of Design Objectives* (DERM and EDAW, 2009). The derivation of the objectives used predictive modelling techniques employing continuous simulation based on a continuous period of typical climatic conditions for different regions in Queensland (Healthy Waterways, 2006). The computer model MUSIC (Model for Urban Stormwater Improvement Conceptualisation) developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH) was used to undertake this. MUSIC is a conceptual stormwater model that represents our current best understanding of the transformation of rainfall to runoff (surface and baseflow) in urban environments, the generation of key stormwater pollutants (stressors) in surface flows and base flows from various land surfaces, and the removal of key pollutants (stressors) from urban stormwater runoff by contemporary best practice stormwater treatment technologies.

The derivation of the objectives adhered to three underpinning principles which called for the objectives to be (Healthy Waterways, 2006):

- Locally relevant - The design objectives must, to the extent possible, be derived using locally relevant information on urban stormwater pollution generation rates and stormwater quality treatment measure performance,

- Practical - The design objectives must be achievable with more than one design solution, and

- Best Practice - The design objectives must result in the adoption of the most effective and efficient forms of contemporary 'best practice' designed stormwater quality treatment infrastructure sized to operate at their respective limit of economic performance (i.e. beyond which any further increase in treatment size will not result in any appreciable increase in treatment performance).

Ella Bay is located in the Wet Tropics region of the state and the following load based objectives will represent best practice stormwater quality management in the Wet Tropics:

- Reduction in post development total suspended solids loads of > 80%
- Reduction in post development total phosphorus loads of > 65%
- Reduction in post development total nitrogen loads of > 40%
- Reduction in post development gross pollutants loads of > 90%

6.2 RELATIONSHIP WITH CONCENTRATION OBJECTIVES

As highlighted in the DEWHA information request, the basis for the assessment is the *Water Quality Guideline for the Great Barrier Reef Marine Park* (DRAFT). This Guideline also refers to the *Reef Water Quality Protection Plan 2003* (Reef Plan), the *Coastal Catchments Initiative* (CCI) and the *National Water Quality Management Strategy* (NWQMS).

The guideline uses scheduled water quality objectives (WQOs) as the reference for defining the health of aquatic ecosystems and for assessing the potential water quality impact as a result of an activity in the catchment. The scheduled WQOs represent target pollutant concentrations in receiving waterways necessary to achieve Environmental Values under ambient (dry-weather or baseflow) conditions.

As highlighted in the Guideline, the concentration levels of contaminants identified are not targets, instead they are guideline trigger values based on ambient concentrations. Adding to this, experience within Australia and overseas has identified difficulties with the application of concentration-based ambient receiving water targets as discharge criteria for urban stormwater. This is well articulated in the *Queensland Water Quality Guidelines* (2006_, Section 4.2.1 Application of guidelines to flood events and ANZECC (2000) Page 2-17. For the reasons listed in these documents, concentration based WQOs that have been derived from ambient (dry weather) flow conditions in undisturbed receiving streams do not directly apply to stormwater discharges (ANZECC 2000, p. 2-17).

This is recognised by the Queensland DERM and the response has been the development of the load based design objectives to be included in the *Best Practice Environmental Management Guidelines – Urban Stormwater* (DERM, 2009).

Pollutant concentrations in receiving waterways are influenced by a wide range of factors, including the quality of stormwater from urban and other land uses within the catchment, point source discharges, in-stream pollutant assimilation processes and tidal influences. Developing and testing load based objectives for stormwater management requires the creation of catchment and receiving ecosystem water quality models to simulate the processes within the catchment and receiving system that influence water quality concentrations. It is our understanding that this has not yet occurred within the Cassowary Coast Regional Council. In the interim, it is suggested that the stormwater system is designed to achieve the best practice objectives for the wet tropics region as outlined in the *Best Practice Environmental Management Guidelines – Urban Stormwater* (DERM, 2009). Additionally, it is suggested further information is provided to DEHWA which quantifies the performance of the stormwater strategy in relation to the WQOs. Refer Section 6.4 for details on how this can be achieved.

6.3 RELATIONSHIP WITH NON-WORSENING CRITERIA

Our experience on other projects in Queensland have found that DEWHA have applied a non-worsening criteria which requires a stormwater management plan that "ensures that the water quality of discharge from the site is the same as, or better then, the discharge from the site relevant to baseline levels recorded prior to development" (i.e. non-worsening criteria).

Experience across Queensland indicates that the application of non-worsening criteria can be difficult to administer and achieve. In some cases, the pre-development situation may represent a disturbed catchment already having a substantial impact on the receiving waterway. The objective in this case should be to improve the quality of water discharging from the site rather than apply non-worsening. In situations where the pre-development condition is forest, the non-worsening criteria are very difficult to achieve, even when applying current best practice stormwater techniques.

Given the above, it is recommended the stormwater system for Ella Bay is designed to achieve the best practice objectives load based objectives outlined in the *Best Practice Environmental Management Guidelines – Urban Stormwater* (DERM, 2009) and additional information is provided which quantifies pollutant loads pre-development, post development without treatment and post development with treatment.

6.4 SUGGESTED STORMWATER QUALITY OBJECTIVES FOR ELLA BAY

6.4.1 MANDATORY OBJECTIVES

Stormwater discharge from development is to be treated in accordance with best practice:

- Reduction in post development total suspended solids loads of > 80%
- Reduction in post development total phosphorus loads of > 65%
- Reduction in post development total nitrogen loads of > 40%
- Reduction in post development gross pollutant loads of > 90%

6.4.2 COMPARISON OBJECTIVES

As discussed in Section 6.2, concentration objectives and non-worsening objectives do not directly apply to stormwater discharges. Nevertheless, the performance of the proposed treatment strategy should be compared with the concentration based objectives and non-worsening objectives. This comparison can be achieved by providing the following:

Concentration Based Objectives

- Pre-development TSS, TP and TN 50%ile and 90%ile concentrations in stormwater discharge

- Post development without treatment TSS, TP and TN 50%ile and 90%ile concentrations in stormwater discharge

- Post development with treatment TSS, TP and TN 50%ile and 90%ile concentrations in stormwater discharge

- WQOs for the wet tropics as outlined in the Queensland Water Quality Guidelines (in the absence of more locally specific WQOs

Non-worsening objectives

- Pre-development TSS, TP and TN loads (it is suggested that loads for both Forest and Agricultural landuse are provided for comparison)

- Post development without treatment TSS, TP and TN loads

- Post development with treatment TSS, TP and TN loads

6.5 STORMWATER QUALITY MANAGEMENT OPTIONS AT ELLA BAY

MUSIC models were established for a typical residential catchment in Ella Bay and two contemporary stormwater treatment systems (bioretention and wetland) were applied to the model. The purpose of this exercise was to determine the size and type of treatment that would meet the objectives, and be appropriate at Ella Bay. The MUSIC modelling process used landuse and rainwater tank assumptions that are consistent with the current development proposal.

- 10 ha urban source node with the landuse assumed to be typical urban residential at 10 dwellings per hectare:

  - 25% roof (100% impervious and draining to tanks)

  - 45% ground level (15% impervious)

  - 30% road reserve (60% impervious)

- Default soil parameters (based on Brisbane defaults)

- Pollutant generation rates as recommended in Gold Coast City Council MUSIC Modelling Guideline for residential

- Rainfall data was sourced from the Bureau of Meteorology gauging station at South Johnston (station 32037). The average annual rainfall there is 3301 mm. 6 minute rainfall data for a period of ten years, 1996-2005, was used for all model runs. Over this period the rainfall was typical of the long-term average, at 3167 mm/year.

- Rainwater tanks at 10kL plumbed to all demands in the property including 130L/p/day indoor and approximately 65L/p/d outdoor (seasonally adjusted). Household population assumed to be 2.5 people per household.
- The bioretention and construction wetland systems were implemented to treat all ground surface runoff plus overflow from rainwater tanks. They were modelled using the default MUSIC parameters as there is insufficient local data available to justify changes in the default parameters.
  - Bioretention basins were assumed to have 0.3m extended detention depth, 0.6m filter media depth and extended detention area the same as filter media area.
  - Constructed wetlands were assumed to have 0.5 m extended depth, 0.3 m average permanent pool depth and an average detention time of 48 hours.

The figures below illustrate the load reduction results predicted by MUSIC compared to the proposed stormwater quality management objectives.

The point of diminishing return (i.e. limit of economic performance) for bioretention basins is at 1.5% of the catchment area which represents TSS reduction of 80%, TP reduction of 65% and TN reduction 40%.

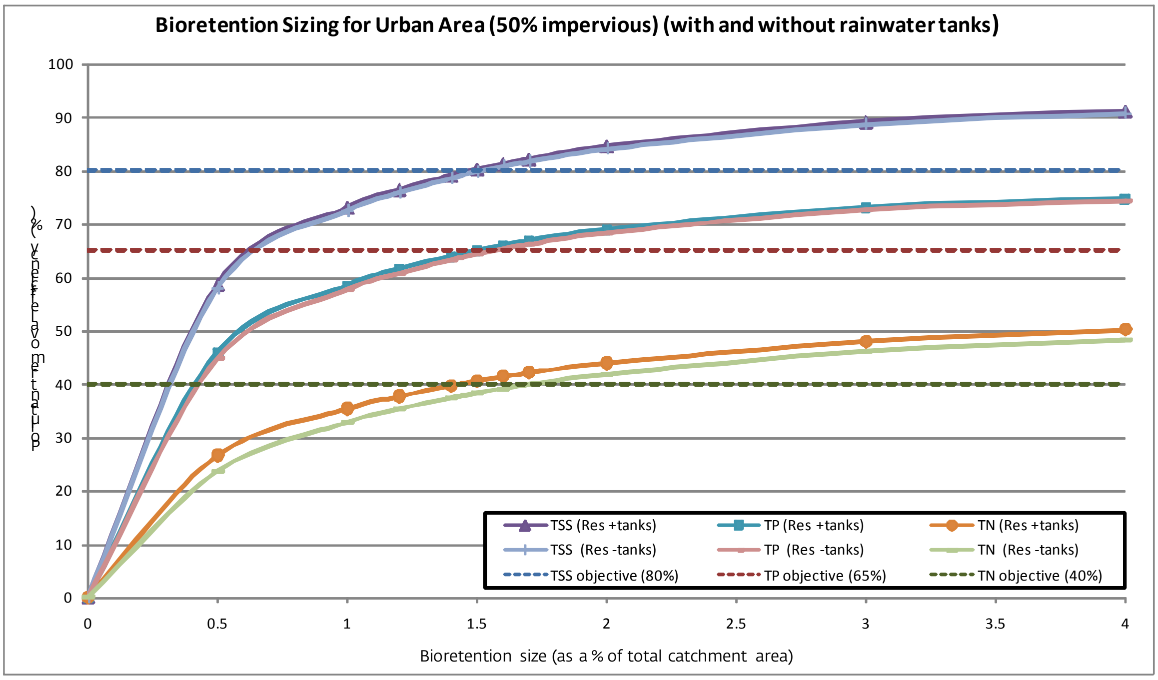


Figure 8 Bioretention Treatment Performance Curve (Ella Bay)

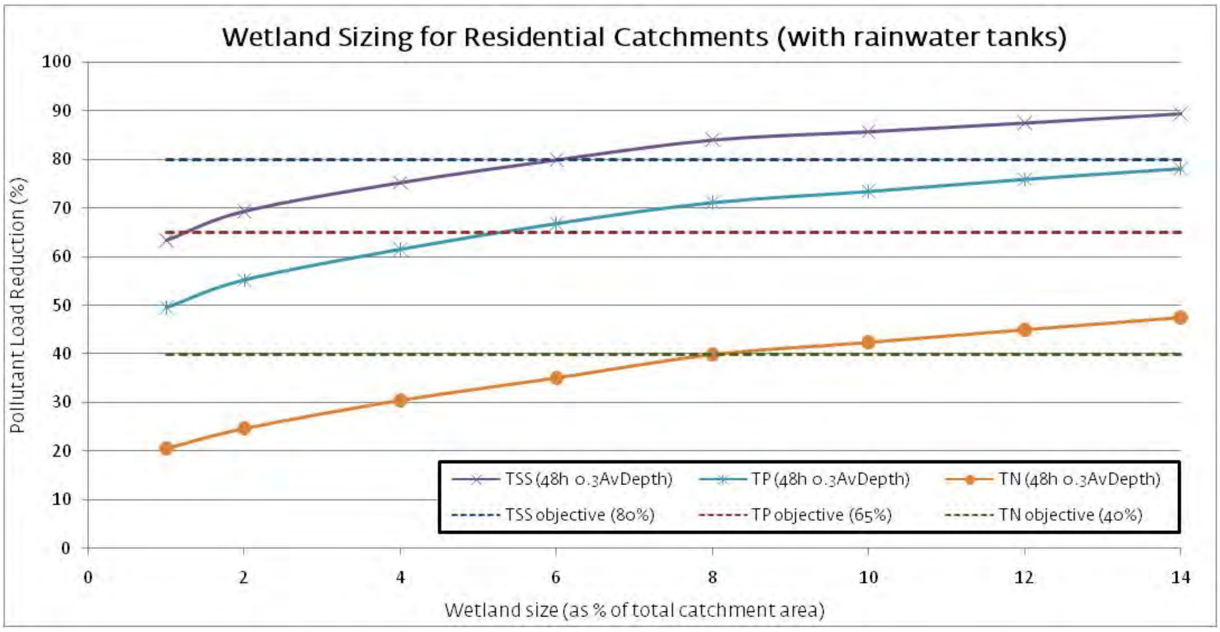


Figure 9 Constructed Wetland Treatment Performance Curve (Ella Bay)

6.6 EXAMPLE APPLICATION OF COMPLIANCE APPROACH AT ELLA BAY

To demonstrate compliance with the proposed storm water quality management objectives, two typical catchments at Ella Bay were assessed:

- 10 ha residential catchment (as per assumptions provided in Section 6.5)
- 10 ha golf course catchment

The following scenarios were assessed in the MUSIC model using the parameters and assumptions listed earlier in this letter:

- Pre development – The previous land use at the site was cattle grazing, however this has been discontinued. The site is currently occupied by a large number of wallabies and pigs and as such the current condition of the Ella Bay site is considered to be agricultural.
- Post developed without treatment
  - Residential area is 50 % impervious (as per assumptions provided in Section 6.5)
  - Golf course is 5% impervious (allowing for access tracks)
- Post development with treatment:
  - Residential catchment with both bioretention and wetland ((as per assumptions provided in Section 6.5)

- Golf course runoff being treated with a wetland

6.6.1 *WATER QUALITY LOAD BASED OBJECTIVES*

Residential

Figures 7 and 8 provided the performance curves for construction wetland and bioretention basins. To achieve the mandatory objectives, either of the following is required:

- Bioretention basin sized at 1.5% of the catchment or 1500m^2 of the 10ha catchment

- Constructed wetland sized at 8% of the catchment or 8,000m^2 of the 10ha catchment (note that this size relates to the macrophyte zone of the wetland. The actual footprint of the entire wetland would be at least 25% larger than this).

The results of the performance assessment for the residential catchments with 50% imperviousness and either wetland or bioretention treatment are presented in Table 3 below. The bioretention basin performance curve provided in Figures 7 illustrates the basin has been sized to achieve “optimal” performance.

Table 3: Residential catchment load based results

Parameter	Rainwater tanks and wetland (8,000 m^2)	Rainwater tanks and bioretention (1500m^2)	Objectives
TSS	84.6%	81.8%	80%
TP	71.9%	67.3%	65%
TN	40.0%	40.1%	40%

Golf Course

To achieve the stormwater quality design objectives on the golf course, a wetland of 8% of the catchment area is required. The results of the performance assessment for the golf course and constructed wetland are presented in Table 4 below.

Placing vegetated swales upstream of the wetland will reduce this wetland size.

Table 4: Golf Course wetland load based results

Parameter	Wetland (8,000 m^2)	Objectives
TSS	80%	80%
TP	65.8%	65%
TN	42%	40%

6.6.2 COMPARISON OBJECTIVES (CONCENTRATION AND NON-WORSENING)

To assess the proposed stormwater treatment for the comparison objectives of receiving water quality concentration and non-worsening, a pre- and post-development assessment has been undertaken. The existing site conditions at the proposed Ella Bay development site are assumed to be representative of a typical agricultural site. The site was previously used for cattle farming and has been cleared and is currently heavily populated with wallabies and wild pigs. Typically the quality of the storm water runoff from an agricultural site can be worse than from an urbanised catchment.

For comparison purposes, the catchment was modeled as agriculture, which is considered to be the current landuse, and as forested (pristine). The following tables present 50%ile and 90%ile concentrations in relation to the water quality objectives and also the annual average loads for each of the scenarios.

Residential Catchment

Table 5 Comparison of 50%ile concentrations (50% of the daily flow weight mean)

Parameter	Forest	Agriculture	Post development without treatment	Post development with rainwater tanks and wetland	Post development with tanks and bioretention	Water Quality Objectives (for wetlands)	Water Quality Objectives (for freshwater lowland streams)
TSS (mg/L)	8.32	26.3	13.9	6	1.3	15	15
TP (mg/L)	0.03	0.138	0.17	0.06	0.047	0.01 – 0.05	0.01
TN (mg/L)	0.76	1.24	2.2	1.00	0.96	0.35 – 1.20	0.24

Table 6 Comparison of 90%ile concentrations (90% of the daily flow weight mean)

Parameter	Forest	Agriculture	Post Development without treatment	Post development with wetland	Post development with tanks and bioretention	Water Quality Objectives (for wetlands)	Water Quality Objectives (for freshwater lowland streams)
TSS (mg/L)	12.1	38.2	202	6	17.6	15	15
TP (mg/L)	0.05	0.2	0.42	0.06	0.11	0.01 – 0.05	0.01
TN (mg/L)	1.07	1.79	2.93	1.13	1.09	0.35 – 1.20	0.24

Table 7 Comparison of annual average loads

Parameter	Forest	Agriculture	Post Development (residential) without treatment	Post development with tanks and wetland	Post development with tanks and bioretention
TSS (kg/yr)	12,000	35,500	46,200	77,00	8460
TP (kg/yr)	13.8	98.8	91.5	30.3	30.2
TN (kg/yr)	173	691	505	300	300

Golf Course Catchment

Table 8 Comparison of 50%ile concentrations (50% of the daily flow weight mean)

Parameter	Forest	Agriculture	Golf course without treatment	Golf course with wetland	Water Quality Objectives (for wetlands)	Water Quality Objectives (for freshwater lowland streams)
TSS (mg/L)	8.32	26.3	13.9	6	15	15
TP (mg/L)	0.03	0.138	0.17	0.06	0.01 – 0.05	0.01
TN (mg/L)	0.76	1.24	2.19	1.00	0.35 – 1.20	0.24

Table 9 Comparison of 90%ile concentrations (90% of the daily flow weight mean)

Parameter	Forest	Agriculture	Golf course without treatment	Golf course with wetland	Water Quality Objectives (for wetlands)	Water Quality Objectives (for freshwater lowland streams)
TSS (mg/L)	12.1	38.2	150	6	15	15
TP (mg/L)	0.05	0.2	0.346	0.06	0.01 – 0.05	0.01
TN (mg/L)	1.07	1.79	2.66	1.13	0.35 – 1.20	0.24

Table 10 Comparison of annual average loads

Parameter	Forest	Agriculture	Golf course without treatment	Golf course with wetland
TSS (kg/yr)	12,000	35,500	30,100	6060
TP (kg/yr)	13.8	98.8	68.3	23.2
TN (kg/yr)	173	691	530	306

6.7 RESULTS

The results presented in the tables above for the typical golf course and residential catchments indicate the following:

Wetland WQOs

- The post development with bioretention treatment with meets the 50%ile and 90%ile TSS , TP and TN concentrations
- When a wetland is employed as a treatment measure the TSS and TN 50%ile and 90%ile results are being met. The TP results are only marginally over the required WQOs wetlands and are producing better results than the existing agricultural catchment runoff. These results essentially replicate the forested (pristine) conditions. This is representative of the best TP output that a wetland can produce in the MUSIC model.

Freshwater lowland stream WQOs

- For freshwater lowland stream catchments, the WQOs are more difficult to achieve. It is important to note that though the WQOs are not being met for the developed catchments scenarios, neither does the modelled runoff from a pristine catchment meet the WQOs. It is important to remember that direct comparison of WQOs with stormwater flow concentrations in this manner is not supported by ANZECC and the *Queensland Water Quality Guidelines*.
- Though the results are only being met for TSS, the results are still providing a large improvement on the existing agricultural catchment runoff and are closely representative of a pristine catchment. This represents a significant outcome and provides further justification for proposed load based stormwater management outcomes as it is clear that when stormwater treatment is applied in accordance with the mandatory objectives (i.e. best practice) that the water quality in the receiving ecosystem will be protected.

7 STORMWATER QUANTITY OBJECTIVES

7.1 NEW STATE PLANNING POLICY

As outlined in Section 5, the future *State Planning Policy for Healthy Waters* (2009) and *Best Practice Environmental Management Guidelines: Urban Stormwater* (DERM, 2009) provides stormwater quantity objectives, namely:

- waterway stability
- frequent flow

The following sub-sections discuss the application of these objectives to Ella Bay.

7.1.1 WATERWAY STABILITY

Urban development typically increases the duration of sediment-transporting flow in urban streams, often leading to increased rates of bed and bank erosion and damage to key benthic habitat (i.e. scouring of sand/gravel beds and displacement of larger structural habitats such as pool riffle sequences). The purpose of this design objective is therefore to limit changes in downstream sediment transport potential by attenuating flows of intermediate magnitude (i.e. up to 1 yr ARI). These events are responsible for a large proportion of total sediment movement in streams (EDAW, 2009).

The waterway stability objective requires that the post development 1 year Average recurrence Interval (ARI) flow <u>within</u> the receiving waterway is limited to the pre-development peak 1 year Average Recurrence Interval (ARI) event discharge.

Considering the nature of Farm Creek, the sandy non-cohesive soils and the erosion risk that exists if significant changes in bank full flow occur, it is recommended the waterway stability objective is applied to Farm Creek and the major tributaries. Additionally, discharge of stormwater to Farm Creek needs to be closely considered to avoid local erosion at discharge points.

7.1.2 FREQUENT FLOW

The frequent flow management objective is designed to protect in-stream ecosystems from the effects of an increased frequency in run-off. This is achieved by capturing the initial portion of runoff from impervious areas in order to maintain a similar frequency of hydraulic disturbance in the pre and post development conditions.

For a site that is more than 40% impervious, the first 15 mm of daily runoff from impervious surfaces would need to be captured and the storage emptied again within 24 hours.

As outlined in the guidelines, these objectives can be achieved through capture and reuse, infiltration, evaporation or discharge through a bioretention basin. This objective is applicable to sites where the discharge from the site passes through or drains to unlined channels or non-tidal waterways or wetlands.

In the context of the Ella Bay site and adjacent wetlands, the frequent flow management objective does not fully consider the hydrologic management required for protection of the ecosystems, in particular Northern Wetland. Capturing and "managing" the post development flows may not preserve the key hydrology of the wetland. Depending of the management approach the frequent flow management objective may result in localised drying out (if the full 15mm is reused) or increased wetting (if simply treated and discharged through a bioretention).

It is suggested the modelling approach and associated hydrologic objectives outlined in *Water Sensitive Urban Design Solutions for Catchments Above Wetlands (Ecological Engineering 2007)* provide a more rigorous management approach of the frequent flows from the Ella Bay site. The primary reason for this conclusion is that the management objectives suggested in *Water Sensitive Urban Design Solutions for Catchments Above Wetlands (Ecological Engineering 2007)* specifically respond to the protection requirements for the wetlands (i.e. aimed at preserving the key hydrologic objectives).

7.2 HYDROLOGIC OBJECTIVES FOR WETLANDS

7.2.1 WETLAND CLASSIFICATION

As outlined in Section 3.6, the North Wetland and Wetland Swale have been classified as **Coastal Melaleuca Swamp Wetlands** wetland management profile in accordance with the *Queensland Wetlands Programme*. This classification has been related to the *Water Sensitive Urban Design Solutions for Catchments above Wetlands (May 2007)* wetland classification system that enables different wetland types to be distinguished, and the appropriate supporting hydrology and water quality parameters to be determined for each wetland type. Based upon the proposed classification system, the dominant wetland types present at the proposed Ella Bay site (Coastal Melaleuca Swamp wetlands) were judged to be commensurate with the **Wet Forest Swamp** classification (Ecological Engineering, 2007a).

7.2.2 HYDROLIGIC CHARACTERISITICS

It is considered that the drying out of the Coastal Melaleuca Swamp wetlands due to potential interception of natural runoff and infiltration at the site, represents a risk to wetland structure and function. Alternatively, given the high rainfall experienced at the site during the wet season (over 2000 mm), the additional stormwater runoff created by increased impervious areas is not expected to represent a significant risk to the wetlands' hydrological characteristics.

Considering the high annual rainfall experienced at the site, it is proposed that the following hydrological characteristics of the North Wetland and Swale Wetland are achieved:

Dry season hydrology	1. Drying duration is preserved. If any change in dry season hydrology is to occur as a result of the development, it is preferred that wetter conditions result rather than dryer conditions.
Wet season hydrology	2. Existing frequency and duration of flood inundation is maintained.
	3. Runoff from the proposed urban development does not increase average inundation depths within the wetland systems.

7.2.3 HYDROLIGIC OBJECTIVES (QUANTITATIVE)

In order to assess the potential impact of the development on the wetland hydrology it was considered critical to quantify the wetland hydrologic objectives listed in Section 7.2.2. The *Water Sensitive Urban Design Solutions for Catchments above Wetlands (May 2007)* recommends three key hydrologic indices should be considered when determining the drying and flooding hydrology for wetland systems:

Drying hydrology	1. Dry season flow duration frequency curves 2. Low flow spell frequency curves
Flooding hydrology	3. Annual high flow duration frequency curves

Further explanation on low /high flow duration curves and low flow spell frequency curves can be found in Error! Reference source not found..

The process outlined in *Water Sensitive Urban Design Solutions for Catchments above Wetlands (May 2007)* was used to define specific flow duration and low flow spells targets for protection of the Ella Bay Wetlands:

Preserve the dry duration during dry season (avoid drying out):

- Preserve the pre-development 30-day low flow duration frequency curve for the dry season (July to November).
- Preserve the low flow spells frequency curve for the dry season.

Preserve the wet duration during year (avoid over wetting):

- Preserve the pre-development 30-day high flow duration frequency curve for entire year (all months).

Achieving compliance of the hydrologic management objectives should be demonstrated by the post-development flow duration curves and spell frequency curves achieving similar shapes and slopes. For the "drying duration" curves, if the curves indicate slightly wetter conditions then this can be considered as compliance as the critical requirement is not to dry out the wetland.

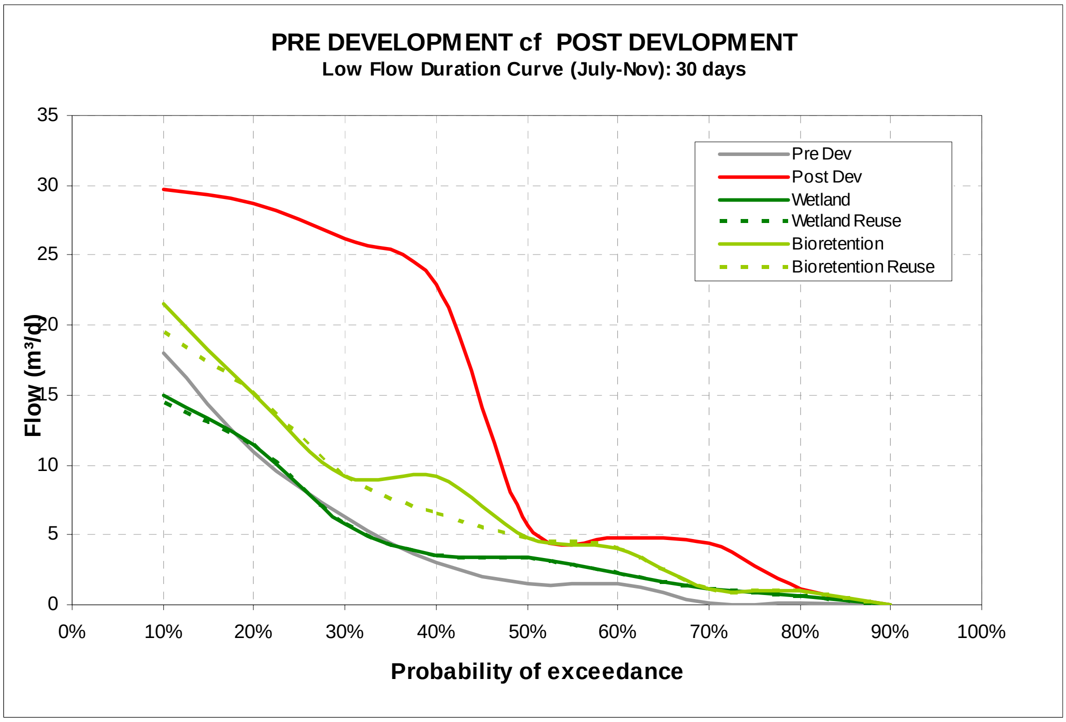
7.3 EXAMPLE APPLICATION OF HYDROLOGIC OBJECTIVES FOR WETLANDS

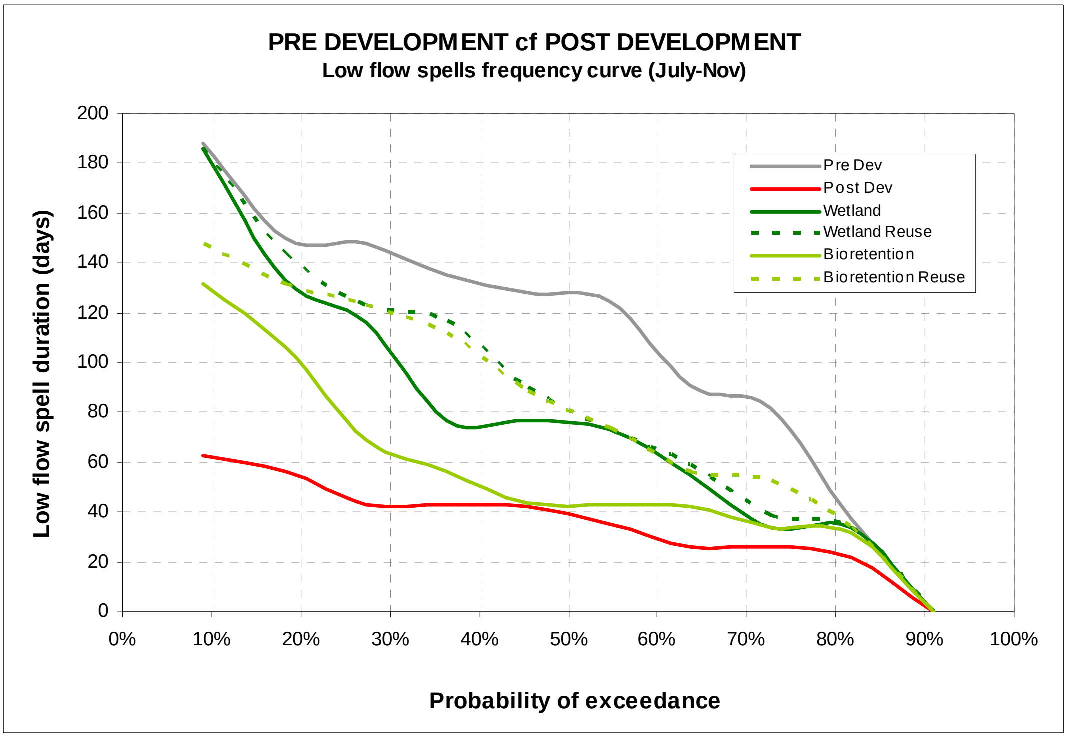
To demonstrate compliance with the proposed wetland hydrologic objectives, three scenarios were simulated:

- Local Wetland - 10 ha residential catchment draining to a local wetland
- Local Northern Wetland – 3ha of development in Ella Bay draining to a small portion of the North Wetland which receives runoff from another 20ha which is not being developed
- Large North Wetland – 3ha of development in Ella Bay draining to the North Wetland which received runoff from a total of 811ha which is not being developed

The following scenarios were assessed in the MUSIC model using the parameters and assumptions listed earlier in this letter:

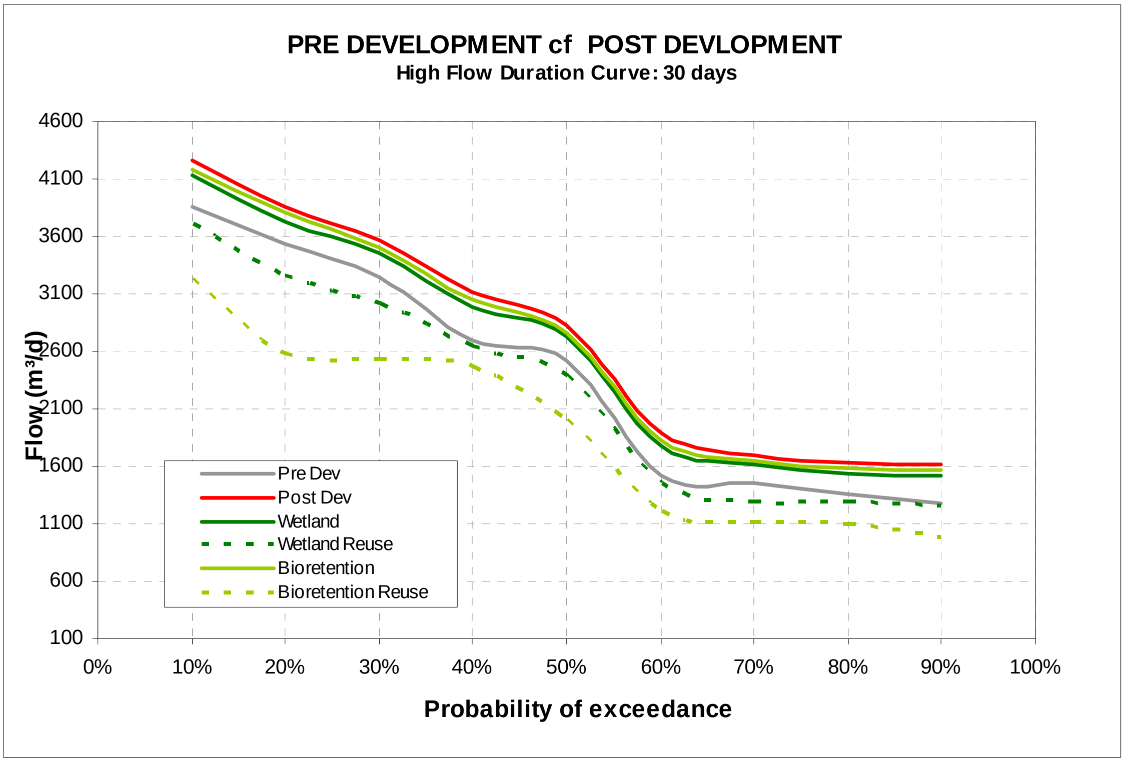
- Pre development – Mix of forest and grazing land. The same soil parameters were used to represent forest and grazing.
- Post developed without treatment - residential area is 50 % impervious
- Post development with treatment – wetland and bioretention
- Post development with treatment and reuse/diversion





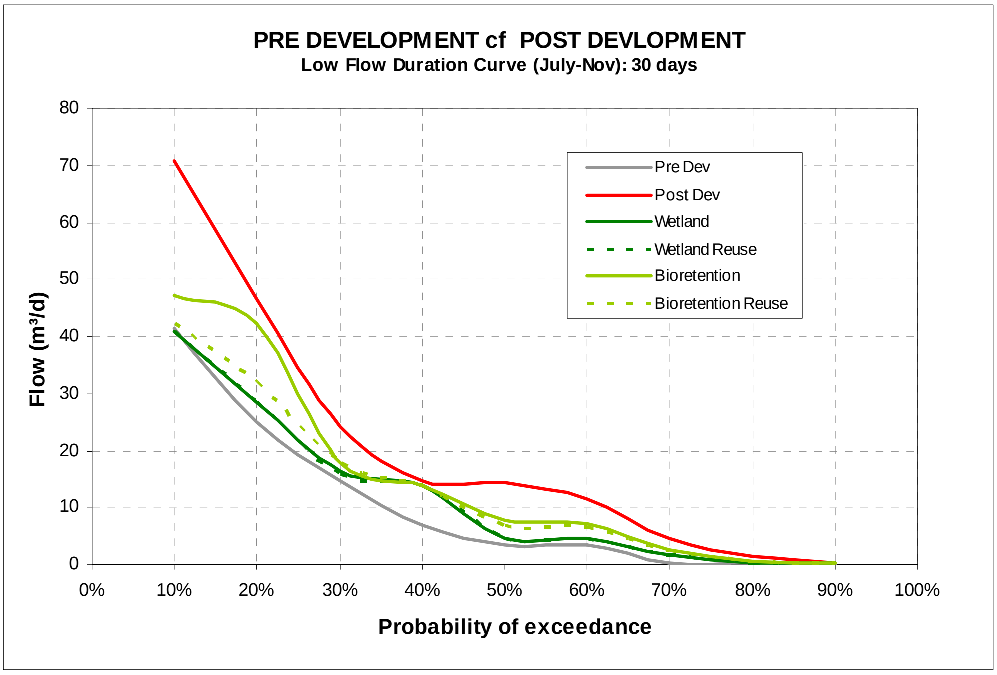
Local Wetland – Preserve the dry duration during dry season

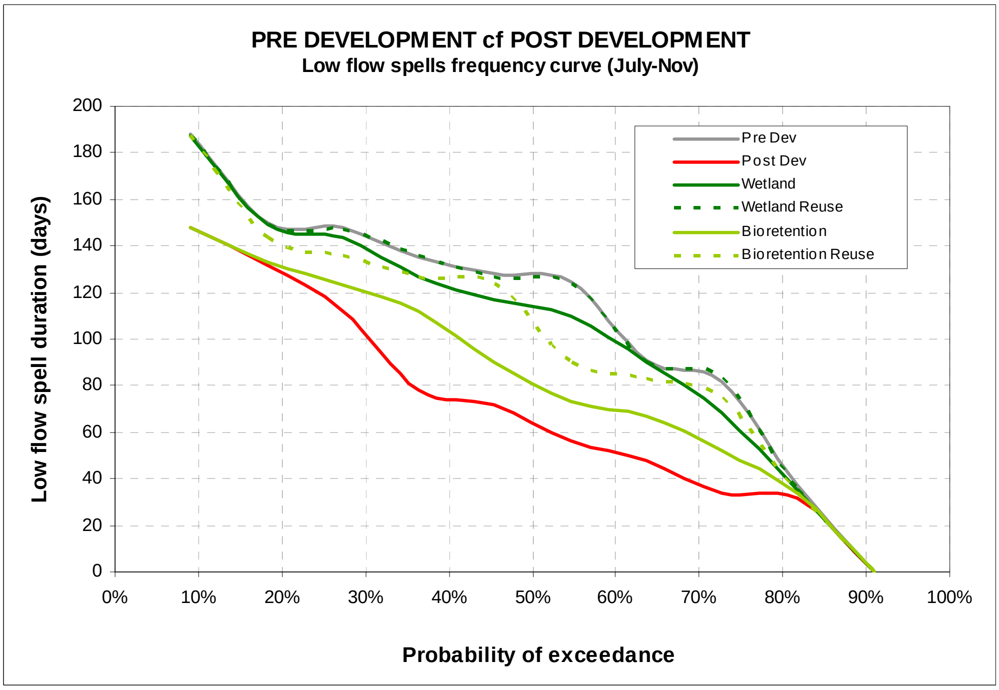
Results indicate that if left un-mitigated runoff will result in wetter conditions following development. This can be readily managed through incorporation of rainwater tanks combined with wetland with the potential for reuse of a small portion of this water during the dry season (reuse details to be provided).



Local Wetland – Preserve the wet duration during year

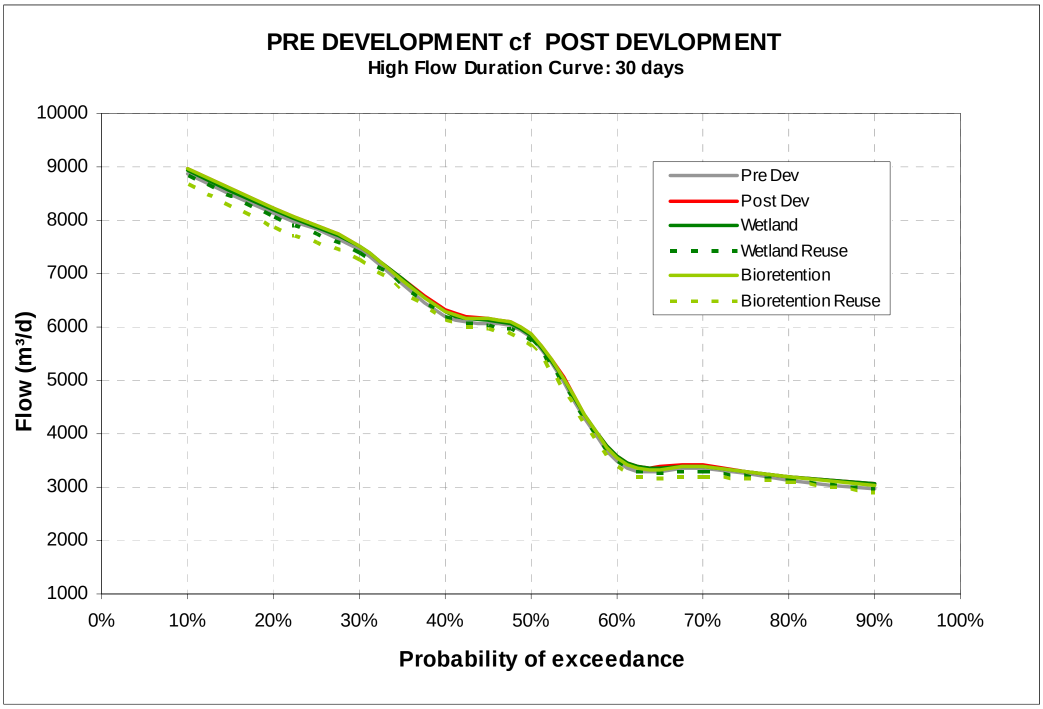
Results indicate that if left un-mitigated runoff will result in very minor increase in wet durations during the wetland season (i.e. slightly wetter conditions following development). Introducing tanks and wetland (or bioretention treatment) will reduce to close pre-development conditions. It is suggested that reuse of treated stormwater during the wet season managed carefully (suitably smaller) as over-reuse of stormwater may reduce wetland season flows to wetlands (see dashed light green lines in graph above).





Local Northern Wetland – Preserve the dry duration during dry season

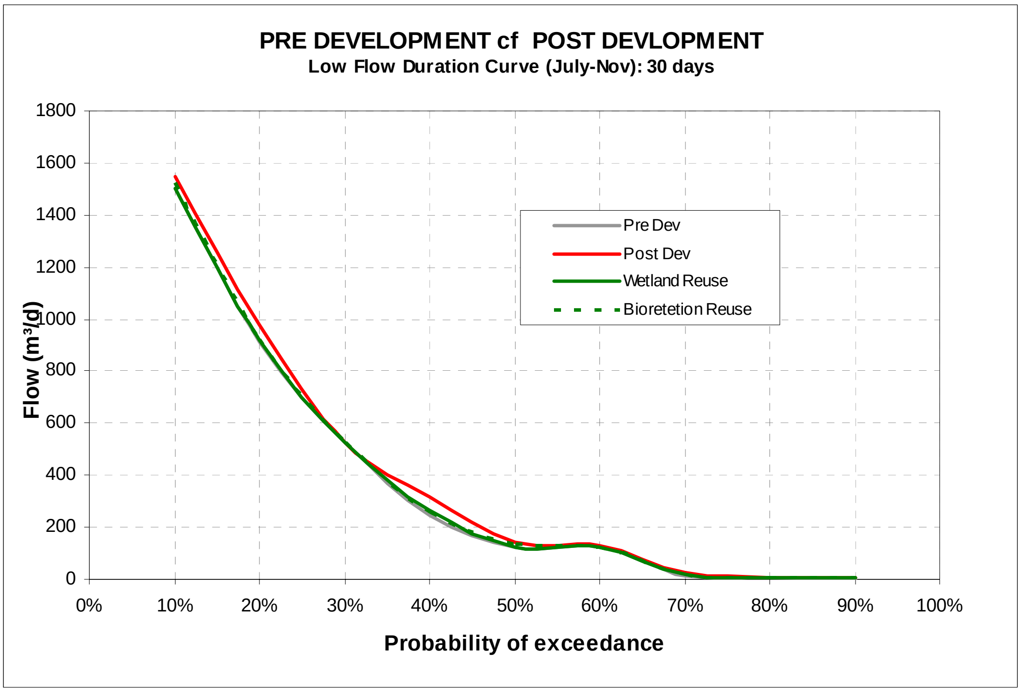
Results indicate that if left un-mitigated runoff will result in wetter conditions following development. This can be readily managed through incorporation of rainwater tanks combined with wetland or bioretention treatment with the potential for reuse of a small portion of this water during the dry season (reuse details to be provided).

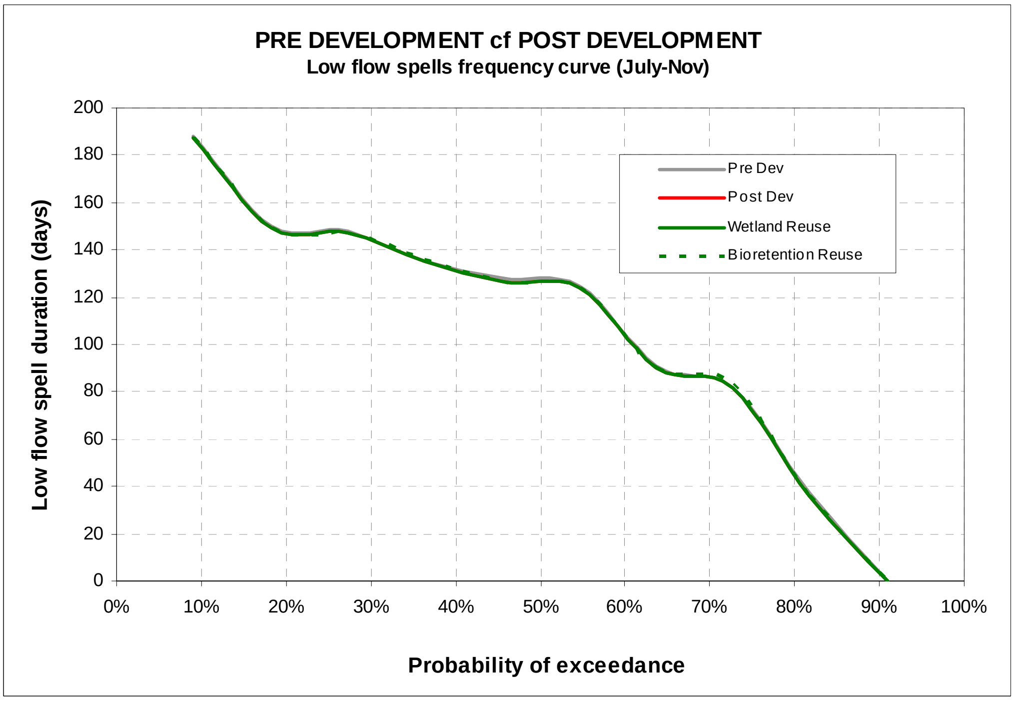


Local Northern Wetland – Preserve the wet duration during year

Results indicate that if left un-mitigated runoff will result in very minor increase in wet durations during the wetland season (i.e. slightly wetter conditions following development). Introducing tanks and wetland or bioretention treatment will reduce to pre-development conditions. It is suggested that reuse of treated water during the wetland season is avoided as this may reduce wetland season flows to wetlands (see green lines in graph above). This is not a major concern given the quantum of the flows but should be avoided if possible.

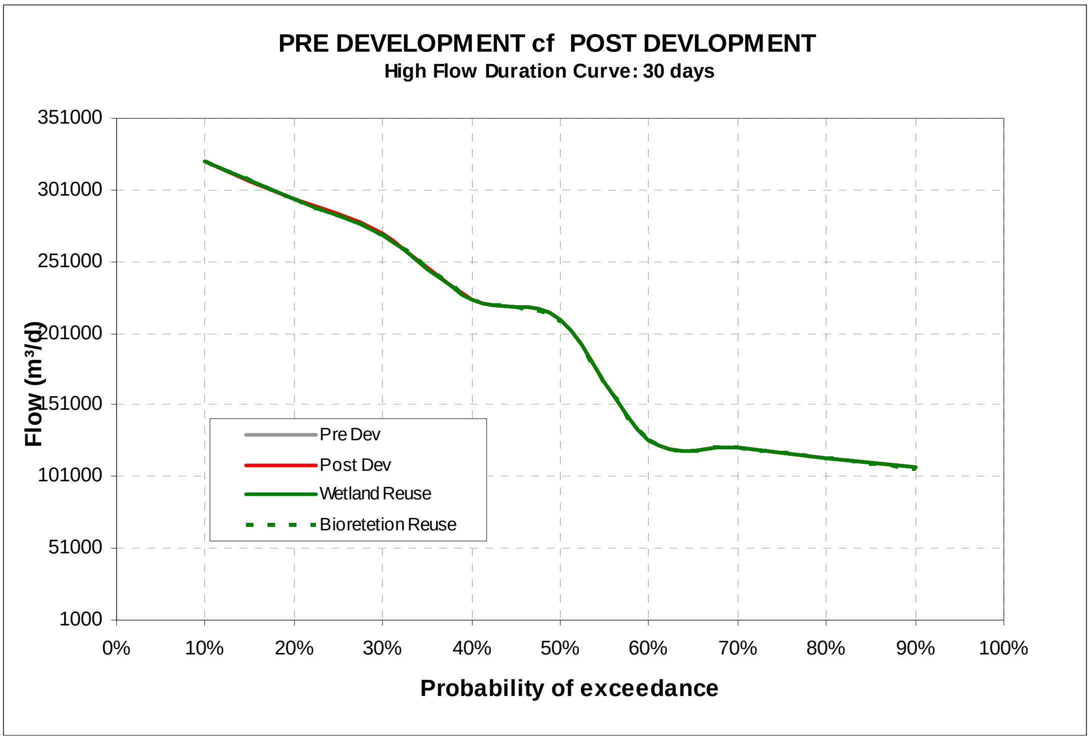
These plots show that in the context of the total flows entering the local North Wetland, the change in hydrology as a result of the development is minor and can be managed through reuse in dry season or diversion but low flow pipes to the tidal section of the Wetland Swale.





Large Northern Wetland – Preserve the dry duration during dry season

Results indicate there is very little change in the overall North Wetland hydrology as a result of the Ella Bay development. Therefore management should focus on local impacts to wetland only. These can be readily managed through incorporation of rainwater tanks combined with wetland or bioretention treatment with the potential for reuse of a small portion of this water during the dry season (reuse details to be provided). As illustrated in the figures above these initiatives have very little influence on the overall hydrology of the regional wetland.



Large Northern Wetland – Preserve the wet duration during year

Results indicate that if left un-mitigated runoff will result in very little change in wet durations during the wetland season through the regional wetland (i.e. slightly wetter conditions following development). Introducing tanks and wetland or bioretention treatment will reduce to pre-development conditions.

These plots show that in the context of the total flows entering the regional North Wetland, the change in hydrology as a result of the development is minor. Any management of flows should focus on local impacts to wetland only.

8 SUMMARY

The WSUD Strategy for the Ella Bay will be developed with the aim of achieving the objectives summarised in the table below.

WSUD Objectives	Performance Measure and Target			
Stormwater Quality/Pollution Control	Best practice stormwater quality management in the Wet Tropics: - Reduction in post development total suspended solids loads of > 80% - Reduction in post development total phosphorus loads of > 65% - Reduction in post development total nitrogen loads of > 40% - Reduction in post development gross pollutants loads of > 90%			
Waterway Stability	Post development 1 year Average recurrence Interval (ARI) flow within the receiving waterway is limited to the pre-development peak 1 year Average Recurrence Interval (ARI) event discharge.			
Wetland Hydrology	Preserve 30day low flow duration curve for dry season*	Preserve the low flow spells frequency curve for the dry season*	Preserve 30day high flow duration curve (annual)	Flow delivery management
North Wetland	✓	✓	✓	✓
Wetland Swale (freshwater section)	✓	✓	✓	✓

* For the "dry season" curves, if the curves indicate slightly wetter conditions then this can be considered as compliance as the critical requirement is not to dry out the wetland.

9 REFERENCES

DERM (2009), *Best Practice Environmental Management Guidelines – Urban Stormwater*, Department of Environment and Resource Management

DERM (2009), *State Planning Policy for Healthy Waters*, Department of Environment and Resource Management

DERM & EDAW (2009) *Technical Note: Derivation of Design Objectives*

Ecological Engineering (2007a) Water Sensitive Urban Design Solutions for Catchments above Wetlands: Appendix A: Wetlands Classification Scheme. Prepared for the Hunter Central Coast Regional Environmental Management Strategy.

Ecological Engineering (2007b) Water Sensitive Urban Design Solutions for Catchments above Wetlands: Appendix B: Catchment Hydrologic Indices and Urban Water Management Performance Objectives. Prepared for the Hunter Central Coast Regional Environmental Management Strategy.

Environmental Protection Agency (2008-2009) *Draft State Planning Policy for Healthy Waters*

Queensland Wetlands Programme (2009a) Wetland Management Profiles – An overview. Report prepared for the Queensland Environmental Protection Agency.

South East Queensland Healthy Waterways Partnership (SEQ HWP 2007), *WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland – Version 2, 8th November 2007*

Townsville City Council (2008) *Draft Dry Tropics WSUD Guideline*

APPENDIX A: FLOW DURATION CURVES EXPLAINED

The following information can be referenced to the Hunter and Regional Coast Council's document, WSUD Solutions for Catchments above Wetlands (2007).

Flow duration frequency curves

A flow duration frequency curve is one of the simplest and most informative means of showing flow characteristics of a stream (McMahon and Mein, 1986). It describes the relationship between the average flow of a given number of consecutive days (usually 1, 7, 14, 30 and 60 days) and its annual probability of exceedence.

Flow duration frequency curves are derived by examining recorded or synthesized streamflow data and defining either the maximum (flooding hydrology) or minimum (drying hydrology) average flow over 1, 7,14, 30 or 60 consecutive days for each year or selected critical period within each year (eg. the wet or dry season of the year). The average flow is computed as the moving average over the selected duration and the maximum or minimum value for each year (or selected critical period) selected for statistical analysis.

The selection of the critical periods within a given year for flow duration analysis of stream flow data depends on whether wetland flooding or drying hydrology is to be defined. For instance, wetland drying is influenced by both catchment hydrology (base flow magnitude, flow duration etc.) and meteorological (rainfall and evapotranspiration) patterns.

Drying Hydrology

The difference between potential evapo-transpiration and rainfall will define the critical months for low flow duration analysis i.e. where the difference between monthly mean potential evapo-transpiration and rainfall are highest.

Flooding Hydrology

In defining the flooding hydrology, analysis will need to be undertaken to define the average maximum flow-duration curves. The influence of evapotranspiration on flooding in wetland is less significant and the deposition of organic matter and increasing wetness in substratum are the important occurrences associated with wetland flooding. Given this, there is no critical period for derivation of the high flow duration frequency curve and that it is less important when flooding occurs as long as it does at the appropriate frequency and duration. Analysis of maximum flow duration characteristic to define the flood hydrology characteristics of natural wetland should be undertaken for all months in a calendar year (January to December).

Low flow spell frequency

Low flow spell frequency curves describe the cumulative probability distribution of the annual maximum consecutive period (days) in which streamflow is less than a given threshold discharge. It is generally recommended that a threshold discharge corresponding to the mean base flow (50%probability of exceedence) of the critical drying period be selected as the threshold discharge for computing low flow spell frequency curves for wetlands that are subjected t flooding by overland flow pathways.

Demonstrating Compliance

In demonstrating compliance to the hydrologic management objectives with the adoption of WSUD in catchments upstream of natural wetlands it is necessary to compare the post development hydrologic indices with pre-development hydrologic indices. It is often unrealistic to expect the post development flow duration frequency curves and spell frequency curves to match the corresponding pre-development curves in its entirety and mis-match will be most common at either ends of the probability distribution curve. An inability to match flow characteristics at these ends are not considered critical in the overall scheme of preserving the hydrologic characteristics of natural wetlands as it is often the more frequently recurring conditions that are critical. Furthermore, flow magnitudes corresponding to the two ends of the probability distribution are the least reliable and thus some level of pragmatism in assessing compliance is reasonable.

It is recommended that the critical region of the flow duration and spell frequency curves that need to be preserved should be limited to between 10% and 90% AEP to avoid the extremities of the pre-development hydrologic characteristics. There are no known theoretical probability distributions for the flow duration curves and thus it is not possible to reliably define their confidence limits. Achieving compliance of the hydrologic management objectives should be demonstrated by the post-development flow duration curves and spell frequency curves attaining similar shapes and slopes