# NOTICE OF MEETING


## COASTAL ESTUARY CATCHMENT PANEL MEETING

A Coastal Estuary Catchment Panel Meeting of Byron Shire Council will be held as follows:

| | |
|---|---|
| **Venue** | **Council Chamber, Station Street, Mullumbimby** |
| **Date** | **Thursday, 15 March 2018** |
| **Time** | **2.00pm** |

Phil Holloway
Director Infrastructure Services

*I2018/420*
*Distributed 09/03/18*

## CONFLICT OF INTERESTS

**What is a "Conflict of Interests" -** A conflict of interests can be of two types:

**Pecuniary** - an interest that a person has in a matter because of a reasonable likelihood or expectation of appreciable financial gain or loss to the person or another person with whom the person is associated.

**Non-pecuniary** – a private or personal interest that a Council official has that does not amount to a pecuniary interest as defined in the Local Government Act (eg. A friendship, membership of an association, society or trade union or involvement or interest in an activity and may include an interest of a financial nature).

**Remoteness –** a person does not have a pecuniary interest in a matter if the interest is so remote or insignificant that it could not reasonably be regarded as likely to influence any decision the person might make in relation to a matter or if the interest is of a kind specified in Section 448 of the Local Government Act.

**Who has a Pecuniary Interest?** - a person has a pecuniary interest in a matter if the pecuniary interest is the interest of the person, or another person with whom the person is associated (see below).

**Relatives, Partners -** a person is taken to have a pecuniary interest in a matter if:

- The person's spouse or de facto partner or a relative of the person has a pecuniary interest in the matter, or
- The person, or a nominee, partners or employer of the person, is a member of a company or other body that has a pecuniary interest in the matter.

N.B. "Relative", in relation to a person means any of the following:

(a) the parent, grandparent, brother, sister, uncle, aunt, nephew, niece, lineal descends or adopted child of the person or of the person's spouse;

(b) the spouse or de facto partners of the person or of a person referred to in paragraph (a)

**No Interest in the Matter -** however, a person is not taken to have a pecuniary interest in a matter:

- If the person is unaware of the relevant pecuniary interest of the spouse, de facto partner, relative or company or other body, or
- Just because the person is a member of, or is employed by, the Council.
- Just because the person is a member of, or a delegate of the Council to, a company or other body that has a pecuniary interest in the matter provided that the person has no beneficial interest in any shares of the company or body.

**Disclosure and participation in meetings**

- A Councillor or a member of a Council Committee who has a pecuniary interest in any matter with which the Council is concerned and who is present at a meeting of the Council or Committee at which the matter is being considered must disclose the nature of the interest to the meeting as soon as practicable.
- The Councillor or member must not be present at, or in sight of, the meeting of the Council or Committee:
  (a) at any time during which the matter is being considered or discussed by the Council or Committee, or
  (b) at any time during which the Council or Committee is voting on any question in relation to the matter.

**No Knowledge -** a person does not breach this Clause if the person did not know and could not reasonably be expected to have known that the matter under consideration at the meeting was a matter in which he or she had a pecuniary interest.

**Participation in Meetings Despite Pecuniary Interest (S 452 Act)**

A Councillor is not prevented from taking part in the consideration or discussion of, or from voting on, any of the matters/questions detailed in Section 452 of the Local Government Act.

**Non-pecuniary Interests -** Must be disclosed in meetings.

There are a broad range of options available for managing conflicts & the option chosen will depend on an assessment of the circumstances of the matter, the nature of the interest and the significance of the issue being dealt with. Non-pecuniary conflicts of interests must be dealt with in at least one of the following ways:

- It may be appropriate that no action be taken where the potential for conflict is minimal. However, Councillors should consider providing an explanation of why they consider a conflict does not exist.
- Limit involvement if practical (eg. Participate in discussion but not in decision making or vice-versa). Care needs to be taken when exercising this option.
- Remove the source of the conflict (eg. Relinquishing or divesting the personal interest that creates the conflict)
- Have no involvement by absenting yourself from and not taking part in any debate or voting on the issue as if the provisions in S451 of the Local Government Act apply (particularly if you have a significant non-pecuniary interest)

## RECORDING OF VOTING ON PLANNING MATTERS

**Clause 375A of the Local Government Act 1993 – Recording of voting on planning matters**

(1) In this section, **planning decision** means a decision made in the exercise of a function of a council under the Environmental Planning and Assessment Act 1979:
  (a) including a decision relating to a development application, an environmental planning instrument, a development control plan or a development contribution plan under that Act, but
  (b) not including the making of an order under Division 2A of Part 6 of that Act.

(2) The general manager is required to keep a register containing, for each planning decision made at a meeting of the council or a council committee, the names of the councillors who supported the decision and the names of any councillors who opposed (or are taken to have opposed) the decision.

(3) For the purpose of maintaining the register, a division is required to be called whenever a motion for a planning decision is put at a meeting of the council or a council committee.

(4) Each decision recorded in the register is to be described in the register or identified in a manner that enables the description to be obtained from another publicly available document, and is to include the information required by the regulations.

(5) This section extends to a meeting that is closed to the public.

## BUSINESS OF MEETING

**1. APOLOGIES**

**2. DECLARATIONS OF INTEREST – PECUNIARY AND NON-PECUNIARY**

**3. ADOPTION OF MINUTES FROM PREVIOUS MEETINGS**

3.1 Coastal Estuary Catchment Panel Meeting held on 30 November 2017

**4. STAFF REPORTS**

**Infrastructure Services**

## STAFF REPORTS - INFRASTRUCTURE SERVICES

**Report No. 4.1** **Management and Reporting for the 24 Hectare Melaeuca Plantation at the Byron Bay STP**
**Directorate:** Infrastructure Services
**Report Author:** Peter Rees, Manager Utilities
**File No:** I2018/413
**Theme:** Community Infrastructure
Sewerage Services

**Summary:**

At the last panel meeting it was requested the panel receive the Management Plan for the Byron Bay 24 Hectare Melaleuca Regeneration site. The plan is attached.

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**RECOMMENDATION:**

**That the panel note the report.**

**Attachments:**

1 Final (2007) 24ha Operations & Management Document PDF version Word version for edits is 666967, DM666975 , page 6⇩

**Report**

At the last panel meeting it was requested the panel receive the Management Plan for the Byron Bay 24 Hectare Melaleuca Regeneration site. The plan is attached

**Financial Implications**

The costs of implementing the plan are included in the Sewer operational budget.

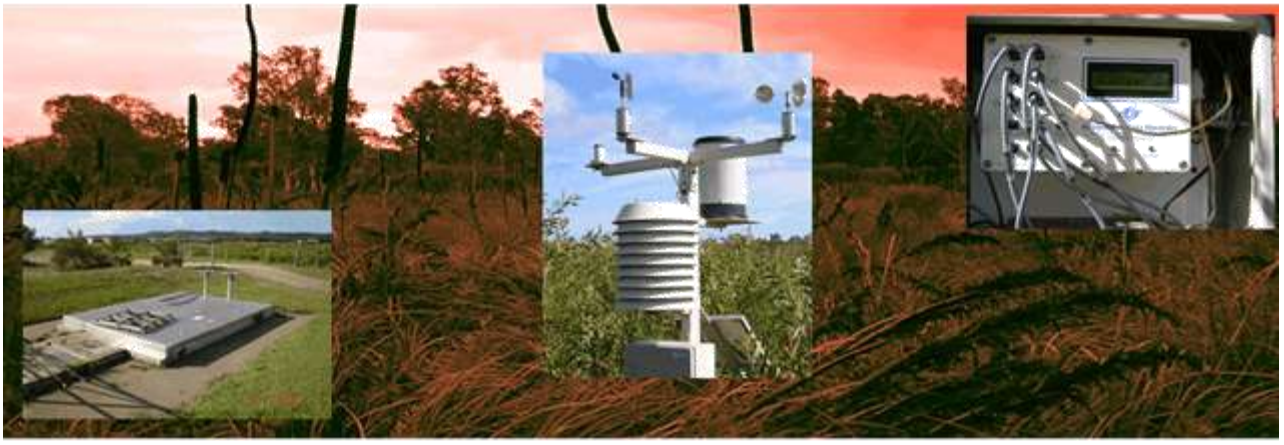
**Statutory and Policy Compliance Implications**

This project and ongoing operation is in accordance with the current 2006 adopted Byron Bay Effluent management Strategy.

# Byron Shire Council

## Effluent Reuse & Wetland Regeneration [24ha site]: Operational & Management Guidelines

March 2007



A Byron Shire Council & Southern Cross University
Collaborative Research Project

| Version | Document Number | Date | Name | Purpose of revision |
|---|---|---|---|---|
| A (Draft) | #522108 | May 2005 | D Bonner | Re-draft of preliminary (Feb 2005) management document. |
| B (Final) | #666967 | March 2007 | D Bonner | Update to include operation of new irrigation system and consideration of the advisory notes of Dr K Bolton (ref: #639754). |

**Byron Shire Council**

# Effluent Reuse & Wetland Regeneration [24ha site]:

# Operational & Management Guidelines

**Report Updated - March 2007**

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**SCU Project Team [2001-2005]**:

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**Report compiled by DA Bonner**

## Purpose and Structure of the Guidelines

This document, 'Effluent Reuse & Wetland Regeneration [24ha site]: Operational & Management Guidelines', provides recommendations for the ongoing management of the site, as well as details of day-to-day operational requirements. Prior to January 2005, management, research, and field tasks, including the day-to-day maintenance & monitoring of the irrigation system, were carried out by the staff and post-graduate students of Southern Cross University (SCU). Since January 2005 the site has been managed and maintained by Byron Shire Council (BSC), following completion of a 'transition phase' in which the management and day-to-day operational activities were passed over from the SCU team. This management document was compiled as part of the hand-over process, and in order to facilitate an improved understanding of the operation and management of the site.

This document aims to:

- Provide details of management and operational tasks that have been, or are likely to be, undertaken as part of an effective management and maintenance programme for the *Melaleuca* regeneration site;
- Present background information where plain explanation of management or operational tasks would have been insufficient;
- Present scientific information in support of management recommendations; and
- Define roles, tasks and level of skills required;

### Document Structure

The document is divided into Thirteen Chapters or Sections as follows:

***Chapters 1 & 2*** - Provides a background to the project, describes the adaptive management approach, and includes a general task overview (Management 'Quick View');

***Chapters 3 & 4*** - Describes the management requirements for the developing Melaleuca vegetation, and provides both background information and management recommendations for dealing with acid sulfate soils;

***Chapters 5 & 6*** - Explains the earlier (2003/ 2004) water-balance modelling process for the site, and includes information on daily & annual irrigation volumes. A brief description of existing irrigation infrastructure is given (Ch. 6).

***Chapters 7 & 8*** - Provides details for ongoing ground-water and weather station monitoring, including the use of field data-loggers.

***Chapters 9, 10 & 11*** - Offer edited extracts and management recommendations from several third party documents: Biodiversity Management Plan, Weed Management Plan, and the Feral Animal Management Plan.

***Chapters 12 & 13*** - Briefly outlines anticipated human resource requirements, and provides details of SCU OH&S risk assessment.

**Main Recommendations**

Each chapter of this document contains a summary of management recommendations. The main recommendations are listed below.

- Due to the broad scope of the project, some management & operational tasks requirements will continue to evolve. An adaptive management approach is proposed.
- An ongoing commitment to soil and water quality monitoring is recommended as part of the adaptive management process. Monitoring will provide the trigger for both day-to-day operational tasks, as well as management review points.
- The 'new' irrigation infrastructure, which was installed in 2005/ 2006, should be further improved to include the installation (re-installation) of drain blockers and V-notch Weirs. This will provide improved control of water-table depth in the paddocks - important for acid sulphate soil management (and run-off control). As well this will provide important data which can be used in future analysis of water requirements for the site.
- A programme of water-table depth fluctuation has been recommended as a key management control to prevent the build-up of sulfides at the soil surface.

- Hazard mitigation measures are proposed (and detailed in the ASS management section), which can be used to deal with the actual or potential release of acid and acid by-products from the site.
- Juvenile *Melaleuca* trees should continue to be protected from frost, using waterlogging during the Winter period, until at least age 2 years.
- Juvenile *Melaleuca* trees should continue to be protected from wallaby predation, by maintaining existing fences, until at least age 2 years.
- An annual review of crop water demand and water balance modelling is recommended.

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# 1 Background To The Project

The Byron Bay Sewerage Augmentation Project includes an on-site effluent re-use component within the boundary of the West Byron STP land. This entails the gradual replacement of an existing 24ha *Ghania* sedge-land, with a densely planted *Melaleuca quinquenervia* wetland (also referred to as the '24ha *Melaleuca* regeneration area' or 'the 24ha site'). The 24ha site is located in the South-Western area of the West Byron STP land. Immediately to the East is the constructed wetland 'Cell 1', to the North lies the SEPP 14 wetland (No. 75), the areas to the West and South are a mix of private and Council owned property currently used for cattle grazing. The 24 ha site is further bounded by drains to the north, south and west. A central drain bisects the 24ha site along an East/ West corridor.

Pre-existing vegetation included Ghania (*Ghania sieberana)*, Typha (*Typha orientalis*), the native fern *Blechnum indicum*, and Tassel-rush *Restio tetraphyllus*. *Melaleuca* planting was completed in early 2004, and some replacement planting was carried out in January 2005 and November 2005. Some of the trees are reaching six years at the time of writing. *Melaleucas* were planted intensively (>600,000 seedlings at 2/$m^2$ have been planted to date), to achieve a high level of effluent re-use and a consequent reduction in waste-water discharge to the Belongil catchment.

Management techniques that will reduce the impact of acid sulphate soils (ASS) are also being developed at the 24ha site, and the impact of effluent on ASS has been part of previous research, and should continue to be monitored. In this context, waste-water is being used to maintain water tables at levels sufficient to reduce the likelihood of rapid oxidation of ASS, which in turn will help prevent the export of potentially harmful levels of acid and acid by-products to the broader environment. The overall objectives of the project are:

- Successfully convert the existing *Ghania* sedge-land to a *Melaleuca* wetland,
- Utilise effluent to maintain the wetland,
- Reduce hydraulic & nutrient discharge to the Belongil catchment,

- Manage & stabilise acid sulphate soils, (and neutralise acid/ acid by-products),
- Eliminate or reduce the incidence of acid/ acid by-products leaving the wetland,
- Protect the biodiversity of the site.

***Note:***

Since the early planning stages of the 24 ha re-use project there has been increasing interest in waste-water re-use. The construction of a pipeline to supply recycled wastewater to a number of users along an urban corridor at Byron Bay is one of several re-use projects underway. As the number of 'off-site' recycled water users increases, there is the potential to impact on the future allocation and availability of waste-water for the 24 ha site. This could lead to the possibility of a reduction in both the frequency and quantity of waste-water delivery to the site. In the case that waste-water availability for the site be subject to future constraints, irrigation modelling has been provided to indicate the minimum water requirements to achieve *Melaleuca* health and acid sulphate soil protection. However, ongoing field monitoring will provide a better guide to the water requirements for the site.

## 2 Management Approach

Due to the scope of the operational & management requirements of the 24ha site, and the recognition that although many of the management needs have been identified, some of the management requirements remain only partially understood. Uncertainties associated with the disturbance of natural ecosystems (even already highly modified ecosystems) will potentially lead to surprising or unpredicted outcomes. Consequently, management of this site will continue be an adaptive process, with ongoing trials to help define better management options over time. This approach is particularly useful in settings where there is little historical management experience (Walters 1997), and an adaptive approach can serve a number of functions:

1. Problem identification & communication among stakeholders (managers, field-operators, researchers, community);
2. Review processes to improve management objectives (by screening in/ out options that are most likely to work/ fail); and
3. Identification of key knowledge/ operational gaps that make management less effective.

In practise this means that adaptive management techniques will, over time, lead to a better understanding of how management inputs do or don't affect the functioning of the (now modified) ecosystem, and an example of this approach can be found in the management of acid sulphate soils.

Current knowledge suggests that maintaining high water tables will provide protection against rapid oxidation of the deep sulfide layer. However, during three years of soil and water monitoring at the site, it has been shown that prolonged waterlogging is related to the formation of 'new' sulphidic material at the peat surface – which complicates water management at the site.

As yet, neither the consequences nor the causative processes of sulphidic material reforming at this site are fully understood. Accordingly, management techniques which help to avoid or mitigate the affects of sulfide reforming, and at the same time prevent the oxidation of the deeper sulfide layer, will be developed as a result of ongoing trials. Specifically, more information is required in order to assess the effect that varying irrigation rates, and/ or fluctuating water table height, has on the long term build-up of sulfide at the soil surface.

For an adaptive management approach to work, a commitment to the long-term monitoring of a number of 'environmental effectors' for each management area will be required (e.g. ASS, Weed management etc.).


**Adaptive Management Cycle**

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## 2.1 Management 'Quick View' (Data Interpretation)

***Melaleuca* Plantation: Management & Maintenance**

| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Replanting** | | | | **3/17** |
| Site preparation | Planting date | Slashing two weeks prior to planting, followed by flood irrigation & maintain water level throughout planting + 3 months | Reduce flora competition with *Melaleucas* and to ensure adequate soil moisture for new plants | |
| Re-planting | Replacement | Plant as per previous layout i.e. trees in rows, 2 trees / $m^2$ | Density determined for predicted evapotranspiration | |
| Fencing | Tree age | Maintain until trees are at least two years. | Prevent wallaby grazing | |
| **Irrigation** | | | | **3/17** |
| Irrigation demand | 1st 3 mths | High water table during initial (*Melaleuca*) 3 months | To ensure adequate water soil moisture for new plants | |
| | Winter | Waterlogging required, June to August, until trees have weathered three winters | Frost protection measure | |
| | Established (full canopy) | None required for survival; default to effluent re-use requirement or ASS management. | Mature trees more tolerant of water stress | |
| **Wallaby Predation** | | | | **3/17** |
| Fencing | Tree age | Saplings (up to two years age) require fencing. | To prevent wallaby grazing | |
| Fencing removal | Tree age | Gradual removal of fencing as plots mature (> 2 yrs). | Mature trees less vulnerable to wallaby predation | |
| **Monitoring** | | | | **3/18** |
| Growth & health survey | Biennial<br>Or<br>As required | Survival / mortality, height, damage [frost, insect, other] | To assess factors affecting *Melaleuca* survival at this site | |

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**ASS: Management**

| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Groundwater & Drain-water** | | | | **4/38** |
| Monitoring | Water-table depth | Record depth weekly at all five piezometer locations, and central weir. | Irrigation triggered by water-table depth | |
| | Physico-chemical. | Download from data-loggers weekly. | Provides data for trend analysis of geochemical processes (e.g. acid pulses) | |
| | Soluble metals. | Sample bores/ drain and return to laboratory (YTBD) | Provide information on geochemical process (e.g. metal toxicity) | |
| Data-management | Ongoing | Transfer/ maintain data in MSExcel (or other) at each data download. Report as required. | To provide information, where and when required (e.g. committees other agencies) | |
| **Drain Control** | | | | **4/39** |
| Infrastructure | Irrigation Upgrade | Reconstruct V-notch weirs, install drop boards for flow control. Re-commission Greenspan flow loggers or other as suitable. | To control water-table and provide data on site drainage losses | |
| Water depth | 60 - 30 cm | Maintain water-table depth above 60 cm below natural elevation. | Maintains adequate water depth to prevent oxidation of pyrite layer below | |
| Weir Flow | pH < 4.0 | Minimise flow across weir.<br>- Re-commence irrigation if paused (add effluent direct to drain if possible) | To prevent acid discharge into Union drain | |

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| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Sulphide: Formation & Oxidation** | | | | **4/38** |
| Water-table | Depth<br><br>3 monthly<br><br><br><br>pH | Maintain water-table above 60 cm<br><br>Lower to 30 cm and maintain at that level for 1 month.<br><br>Raise to surface and maintain at that level for 3 months.<br><br>If pH falls < pH 3.5 apply effluent. | As above<br><br>Potentially oxidises reformed sulphidic material<br><br>Return to normal irrigation setting<br><br>Effluent will raise pH | |
| **Soil sampling** | | | | **4/39** |
| Sulfides | Annual | Soil sampling at previously established sampling points and depths for CRS analysis. | Monitoring sulphide levels provides warning of sulphide build-up | |

**Irrigation: Water Demand**

| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Irrigation** | | | | **5/51** |
| Even water distribution | Water table | Check irrigation scheduling; check riser pipe flows; measure water-table depth. | Even distribution gives better crop utilisation | |
| Seasonal flow variation | Season | Adjust daily flow according to seasonal demand. | Crop demand is seasonal | |
| Flooding | Rainfall | Reduce or cease irrigation. | Irrigation not required | |
| Flow volumes | Irrigation on | Record. | Maintain data-base | |
| Crop water demand | Data-base records | Annual review of water balance model predictions vs. actual field conditions. | To test Model predictions against 'real' data | |

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**Irrigation: Operation & Maintenance**

| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Irrigation Network** | | | | **6/55** |
| Distribution valve | Water demand | Change water flow to appropriate site | Water demand | |
| Coarse & fine screens | Daily | Clean | Maintain water flow | |
| Pump | Daily | Test for running | Maintain water flow | |
| Flow data | Daily | Record pump flow volume | Site water usage required | |
| Pressure release valve | Weekly | Visual inspection only (when running): check pressure on vacuum gauge, check vacuum pipes and other cables connected. | System checks | |
| Paddock valve(s)(SV) | As required | Select valve on/ off | Irrigation requirements for paddocks | |
| High risers | Weekly | Check flow (visual) for approximate 'balance' along the laterals. | Uniform irrigation rate | |
| General | | Visual inspection of:<br>- Pipe-work for damage e.g. root or plant debris intrusion.<br>- Risers for balance, damage, blockage. | System checks | |

**Monitoring [groundwater, soil, weather]**

| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Groundwater & Drain-water** | | | | **7/64** |
| 90-FLMV calibration | Weekly | Calibrate sensor probes | Calibration check | |
| Data download | Weekly | Download data to laptop computer | Maintain data for reporting purposes | |
| Phosphorous (P) | 3 monthly | Sample and analyse for 'P' from Central v-notch weir | Check for excess P leaching from site | |
| Phosphorous (P) | Increasing P concentrations recorded at v-notch weir | Sample and analyse for 'P' from 'fixed' piezo logger sites. | To locate source of high P | |
| DIPNR | Request | As requested | Refer DIPNR | |
| **Soil** | | **REFER TO ASS MANAGEMENT** | | **Ch. 7** |
| | | | | |
| **Weather** | | | | **8/69** |
| Data download | Monthly | Download Weather Station data. | Limited 'on-board' data storage | |
| Maintenance | Monthly | Sensors to be cleaned and checked. | Maintain system serviceability | |
| Data management | Ongoing | Maintain data record | For distribution as required | |

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**Biodiversity Management**

| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Biodiversity Conservation** | | | | **Ch. 9** |
| Weed control | Proposed activity | Refer to BMP, WMP, FAMP<br>Contact Environmental Officer | | |
| Filling/ draining | Proposed activity | | | |
| Work/ infrastructure | Proposed activity | | | |
| Environmental Survey | Proposed activity | | | |

**Weed Management & Maintenance**

| Management Issue | Trigger | Action Required | Reason | Ch. / Page |
|---|---|---|---|---|
| **Weed Control** | | | | **Ch. 10** |
| Target Weed Control | Presence | Refer WMP + this document | | |
| Veg. Restoration | Ongoing | Refer WMP + this document | | |
| Fencing | *Melaleuca* age | Decommission at 3yrs | Mature trees | |
| Monitoring | Ongoing | Refer WMP + this document | | |

**Feral Animal Management**

| Management Issue | Trigger | Action Required | | Ch. / Page |
|---|---|---|---|---|
| **Pest Control** | | | | **Ch. 11** |
| Red Fox<br>Feral Cat<br>Wild Dog<br>Cane Toad | Presence<br>"<br>"<br>" | Poisoning, Trapping, Fencing, Muster. [Refer FAMP] | | main doc. |

YTBD Yet to be determined
BMP 'Biodiversity Management Plan'
WMP 'Weed management Plan'
FAMP 'Feral Animal Management Plan'
EO 'Environmental Officer'

# 3 Melaleuca Management

The conversion of the 24 ha site, from the existing Ghania sedgeland to a *Melaleuca* wetland, commenced in December 2001 with an initial planting of 100,000 trees in the NW paddock. At the time of writing, a total of 600,000 trees had been planted, in three separate planting phases, to achieve the multiple aims of effluent re-use, acid sulphate soil management, and wetland regeneration. A wealth of experience, knowledge and understanding has been gained during the three years since initial planting was carried out, and this will contribute to the better management of the *Melaleuca* plantation.

## 3.1 Planting: History & Survival

### *3.1.1 Seed propagation*

In order to maintain genetic integrity, seeds were selected from approximately 200 *Melaleuca quinquenervia* trees located within 1 km of the site. Mature seedpods were cut from parent trees, and dried in paper bags either in the sun, or in a drying oven set to 35$^{O}$ C during humid weather. Seeds were then collected and delivered to contractors for propagation and subsequent planting of saplings. It takes approximately 6 months to produce viable saplings, so seeds should be collected and delivered to a nursery well in advance of the proposed planting date.

### *3.1.2 Planting History*

*Melaleuca* planting occurred in three main phases, within which there were two non-scheduled re-plantings due to high mortality (Table 1).

**Table 1** ***Melaleuca*** **planting history**

| Date | Paddock (s) | Number of trees |
|---|---|---|
| Dec 2001 – Jan 2002 | NW | 100,000 |
| Dec 2002 – Jan 2003 | NC, NE, SE | 200,000 |
| Dec 2003 – Jan 2004 | SC, SW<br>NW<br>N'NC | 190, 000<br>100, 000 (replanting)<br>10,000 (replanting) |
| Nov 2005 | NW | 80,000 (replanting) |

### *3.1.3 Survival & Mortality: factors affecting*

The canopy establishment phase – the first three years of growth - is the period of highest risk to *Melaleuca* saplings. A survey (August – October, 2004) was conducted to assess the health of the overall *Melaleuca* plantation, and to record survival/ mortality data. The survey results indicate that 50.6% of the trees have survived, and that a number of factors were found to influence the health of the trees including frost, insects, wallabies, and other vegetation present. It is hypothesised that the absence of a high water-table, particularly where it coincides with young *Melaleucas* and 'frost', increases the level of damage/ mortality. A third attempt to establish *Melaleucas* in the NW paddock was carried out in November 2005 with the planting of 80,000 seedlings. An assessment of survival/ mortality is recommended for this most recent planting.

#### *3.1.3.1 Frost*

The initial planting of 100,000 trees in the NW paddock was lost due to frost. Following this 'winter water-logging' was adopted, during the coldest periods of Winter, to reduce the incidence of frost damage at the root zone (and subsequent stress or death). The survey data, along with field observations, suggests that the 'water-logging technique' is a useful preventative measure and should be continued – particularly in the case of young *Melaleuca*. However, a number of trees in the following Winters (2003, 2004) were severely affected by frost when a low water table, caused through insufficient irrigation water, coincided with frost.

During spring, severely frost damaged trees coppice vigorously at the base. However the more frost-tolerant companion species – particularly Ghania and Restio – establish more rapidly during the subsequent spring and out compete the establishing saplings, which are unlikely to persist if they are severely frost damaged.

#### *3.1.3.2 Wallabies*

Wallaby disturbance was evident throughout the site. As the *Melaleuca* matures the wallabies are less inclined to use them as a food source. The swamp wallabies graze young *Melaleuca* leaf tips, can uproot newly planted saplings, and can seriously defoliate establishing saplings. Furthermore, wallabies appear to physically trample and chew trees in discrete areas up to 20 $m^2$, possibly as a means of preventing tree growth in these areas to maintain habitat and grazing advantages. Mature trees with a height exceeding 1.5 m are not generally affected by grazing and trampling.

#### *3.1.3.3 Unidentified (animal) predation*

A number of *Melaleuca* in the 24ha site have been damaged by a small mammal, sometimes causing complete severance of the tree stem. This affects both small and large diameter stems, and could be an ongoing problem. Scats collected from near the base of the trees were identified to be from *Rattus lutreolus*, and there is also evidence showing the presence of the long-nosed Potoroo (*Potorous tridactylus*). These animals may have chewed the trees either as a source of water during the prevailing drought conditions, or to maintain cleared areas for habitat. Although coppicing has occurred at the base of toppled trees, it is unlikely that toppled trees will survive due to competition effects from companion species.

#### *3.1.3.4 Insect damage*

*Melaleuca quinquenervia* are affected by a wide range of insects that chew leaves, suck sap and lay eggs in *Melaleuca* leaf tissues. In natural conditions, *Melaleuca* are tolerant of insect damage, however in disturbed and high nutrient conditions, insect damage can be significant. While insect damage itself rarely kills saplings, it can reduce their vigour, and therefore makes them more prone to competition effects from the companion vegetation.

## 3.2 Management Recommendations

### *3.2.1 Replanting*

Areas where *Melaleuca* trees have not survived could be replanted if a decision is taken to increase *Melaleuca* cover in the future. Further planting in the NW paddock may not be advisable if the November 2005 planting fails. In that instance, replanting with *Melaleucas* should not be reconsidered without evidence to support the likely survival of *Melaleucas* in this paddock.

#### *3.2.1.1 Site preparation for planting*

Any site preparation must be carried out in accordance with the BMP and care must be taken to avoid slashing during the Eastern Grass Owl breeding season Feb - Aug. During previous site preparation Ghania stems were removed from the site to reduce their density in some areas, and groundsel and other weeds were also removed. During the third and fourth planting phases, the paddocks were ripped to a depth of 150 mm. This improved survival during the early establishment phase (first 6 months) by allowing saplings to be planted deeper, and by reducing root competition with other plants, particularly Restio, which forms a dense surface root mat. However this is not essential.

#### *3.2.1.2 Planting*

Saplings are planted using "Potiputki" hand planters, and a good planter can plant 2,500 trees per day. Plants are nominally spaced at 2 trees per square meter, however micro-topographical, and planter variability, cause a planting density range between around 1 – 3 trees per square meter. It is expected that planting density will be reduced by establishment mortality and natural self-thinning to an average of around 1 tree per square meter after 8 years of establishment.

### 3.2.2 *Irrigation: Early establishment phase*

Irrigation is essential during planting to ensure that the saplings have direct contact with water when they are planted. If this is not the case, saplings can rapidly wilt and die during hot days. Paddocks should be well soaked, with high water tables maintained for several days prior to planting. After planting, a high water table should be maintained for at least three months to ensure optimal conditions for establishment. It is recommended that trees are exposed to 'soaking conditions' at least once every two months during the first two years to promote healthy growth.

### 3.2.3 *Irrigation: Post-canopy establishment phase*

Once the canopy is established, the irrigation requirement for survival will be low, and although irrigation during hot, dry weather will benefit the growth of the trees, it is not necessary for tree survival. These trees will survive and grow without supplementary irrigation and the presence of non-irrigated *Melaleuca* trees, in similar areas surrounding the wetland provides testament to this. In contrast, the *Melaleuca* trees are also able to survive waterlogged conditions for prolonged periods. However, it is worthwhile noting that while the *Melaleuca* trees will not require irrigation to survive, irrigation will be required for acid sulfate soil management (See section 4).

### 3.2.4 *Frost: Winter water-logging*

Frost is a major factor in the survival of the planted *Melaleuca* trees. It is important to keep the newly planted seedlings inundated with water during winter to prevent the frost entering the root zone and killing the tree. Once a *Melaleuca* tree reaches a certain maturity it can tolerate higher degrees of frost, and the winter water-logging period will no longer be required. Sub-zero temperatures have been recorded on the site between late May to mid August, and it is therefore recommended that waterlogged conditions (with surface ponding water) be maintained during the period May 15 to August 31 for the first three winters following planting.

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### 3.2.5 *Wallaby predation: Fencing*

Fences are essential to reduce wallaby damage. It is recommended that saplings remain enclosed by wallaby-proof fencing for a period of two years after planting. All paddocks had fencing in place at the time of writing. The fences have been constructed from star pickets and 100 mm box wire to a height of at least 1.2 m. Wallabies can get under, and in some cases, through fences, and the fence perimeter should be monitored regularly and repaired when necessary. Fences can be removed after two years if no further trees are to be planted in the fenced area. Currently only the North West paddock remains with protective fencing.

### 3.2.6 *Fire Management.*

Drainage and drought are the two main factors which expose peat to excessive drying conditions, and lead to a build-up of combustible fuel. Peat fires can start naturally, as with forest fires, but are more likely to start as a result of human activity (deliberate or accidental). Once burning, peat fires can be extremely difficult to extinguish, and can smoulder for weeks causing extensive damage to the ecosystem. Once the peat layer has burnt it loses important functions including flood buffering, water storage, habitat loss and pollutant filtering. Fire has damaged the SEPP 14 wetland directly adjacent to the effluent reuse wetland, resulting in a peat fire, and causing mortality of mature trees.

It is essential to prevent peat fires from establishing on the 24 ha site and the best fire protection is the maintenance of high water-tables. If a fire does occur in the 24 ha area, the peat should be irrigated to maintain waterlogged conditions to prevent the possibility of a peat fire. Mature trees will survive a fire without significant stress if the peat layer is not burnt. All fire management activities should be consistent with the FMP.

### 3.2.7 *Monitoring*

Annual monitoring is recommended and should be carried out until the trees are 8 years old. The monitoring would preferably be based on the previous SCU Melaleuca study (Ryffel, 2004). Monitoring should include survival/ mortality rates, growth rates, evidence of

predation, insect damage, and frost damage. For simplicity a photographic record would suffice for verification of growth rates, but the survival/ mortality monitoring, if based on the previous study, would require an intensive site assessment and vegetation count. Predation and other crop damage would be noted during this assessment.

### *3.2.8 Summarised Actions*

**Table 2** ***Melaleuca*** **Management: Task Summary**

| Maintenance Issue | Action Required |
|---|---|
| **Replanting** | **(assuming seed has been collected & propagated)** |
| - Site preparation | - slashing two weeks prior to planting (not Feb – Aug)<br>- flood irrigate after slashing & maintain throughout planting + 3 mths |
| - Planting | - Using 'Potiputki' hand planters<br>- Plant in rows 2 trees per $m^2$ |
| - Fencing | - Saplings require Wallaby proof fencing for at least 2 yrs |
| **Irrigation** | |
| - Establishment phase ( 2 years) | - High water-table for the first three months<br>- 'Flood Irrigation' at least two monthly until 2 years |
| - Established Trees (Full canopy) | - None required for survival |
| - Winter Water-Logging | - Required annually until trees have weathered 3 winters.<br>- Water-log during months May to August. |
| **Wallaby Predation (Prevention)** | |
| - Fencing | - Establishment phase ( 2 years) Saplings require Wallaby proof fencing for at least 2 yrs. |
| - Fencing Removal | - Fencing can be progressively removed as individual paddocks come to the end of their establishment phase. |

| Maintenance Issue | Action Required |
|---|---|
| **Monitoring** | |
| - Growth & health monitoring | - Survival (annual)<br>- Growth rates (annual)<br>- Predation, frost, insect damage (annual) |

**Table 3** ***Melaleuca*** **Management: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Replanting | ➢ Site preparation<br>➢ Planting | - Tractor & operator<br>- Bush regeneration/ Nursery | |
| | ➢ Fencing | - Field assistant | |
| Irrigation | ➢ Manage & monitor | - Field assistant | - See Ch.5 |
| Predation | ➢ Fencing | - Field assistant | |
| Monitoring | ➢ Tree health & survival | - Field assistant/ Bush regeneration/ Ecologist | |

# 4 Acid Sulphate Soils

The occurrence of acid sulfate soils (ASS), at the 24 ha site, is one of the factors driving the need to develop broad-ranging management techniques that will promote both a healthy wetland, and at the same time reduce the potential export of harmful levels of acid and acid by-products to the broader environment. This section of the document provides a higher level of background information than is given in other sections, but is presented here so that future managers of the site can gain an overview of the prevailing soil conditions, the risk associated with ASS, and the likely affects of management actions.

## 4.1 Acid Sulfate Soils

Acid sulfate soils (ASS) is the name given to soils that contain iron sulfides (usually pyrite) and/or pyrite oxidation products. The requirements for sulfide formation are soluble sulfate and iron, sufficient organic matter, and waterlogged conditions. These conditions were common in recent (Holocene age) estuarine sediments worldwide (Dent and Pons 1995). In NSW, every major coastal catchment is underlain by these sediments (Bush and Sullivan 2002). Low-lying areas in the Byron area also contain ASS (e.g. the 168ha Belongil Swamp). Environmental degradation, caused by severe acidity and toxic amounts of soluble metals (particularly iron (Fe) and aluminium (Al)), can result when these soils are exposed to the air (e.g. through drainage or excavation).

For plants, acidity causes impaired nutrient adsorption by roots, nutrient deficiencies, increased attack by soil pathogens and accumulation of other toxic products (including soluble Al and Fe) in the soil (Rorison 1973). Acidity also causes corrosion of concrete and metal structures. Soluble Al causes stunted roots by interfering with cell division in root tips and laterals, and interferes with the uptake, transport, and use of essential nutrients (Wolt 1994). In fish, soluble Al causes skin damage, contributes to skin disease and can block gills (Sammut et al. 1995). It is toxic in small amounts to other aquatic organisms (Hyne and Wilson 1997). Soluble Fe is also toxic to plants, and can cause flocs which deoxygenate

water, smother aquatic plants and animals, and clog fish gills and drains (Van Breeman 1993).

The NSW Government has nominated several ASS Management Priority Areas. These are identified areas where land management actions have contributed to past and present soil acidification, poor water quality, and diminished environmental values. They require land management changes to improve environmental conditions (Tulau 1999). The Belongil Swamp is one of these ASS Management Priority Areas, and the subject of this chapter (the 24 ha revegetation site) lies within the Belongil Swamp.

## 4.2 ASS Risk Assessment

Within the 24 ha site, the toxicity of acids and metals in solution can adversely impact on vegetation growth. This is typical of drained ASS landscapes that have been modified to support introduced crops and pastures. Natural wetlands often ameliorate these effects and produce plants with specialised adaptations for coping with the waterlogging and consequent build-up of toxic substances (Kadlec and Knight 1996).

The risk associated with ASS, at this site, ultimately relates to the amount of acid that can be produced, and then exported via the drainage network. In acidic conditions, metals remain in solution and can be exported as runoff or lateral groundwater flow into the drainage network. Off-site impacts include: detrimental impacts on receiving waters (e.g. Belongil Creek); aquatic ecosystem decline; fish disease and mortality; corrosion of human-built infrastructure; and reduction in recreational, scenic and tourism values.

### *4.2.1 Acid Production & Action Criteria*

The critical question facing managers of ASS affected sites is whether the acidity is of sufficient concentration to be environmentally damaging. For this reason, the NSW Government has developed various **action criteria** for the disturbance[1] of ASS (Ahern et al. 1998a). Action criteria are trigger points, which indicate the need for a management plan (preventative action) to avert the adverse environmental impacts of severe acidity.

For the purposes of risk assessment, two main categories of action criteria are referred to in the following sections:

1. The reduced inorganic sulfur (%S) content of the soil (usually present as pyrite).
2. Quantities of acidity in the soil (expressed as mol $H^+$/tonne).

### *4.2.2 Soil Sulfide Assessment*

Action criteria for soil sulfide content are:

I. 0.03% S for sand,
II. 0.06% S for loam, and
III. 0.1% S for clay (of oven dry soil weight).
IV. For amounts of disturbed soil material > 1000 tonnes, the action criterion is 0.03% S for all soil types (Ahern et al. 1998a).

Soil sulfide content from the site was measured using the Chromium Reducible Sulfur method of Sullivan et al. (1998) and will henceforth be expressed as % $S_{CR}$. Soil has been sampled and analysed at approximately 6 month intervals since project inception (2002). Soil sampling was from three distinct areas (Figure 1):

- Non-irrigated,
- Effluent irrigated, and
- Long-term waterlogged due to proximity to STP discharge point.

[1] Disturbance refers to exposing the soils to air, usually through excavation or dredging. However, drainage is also disturbance if it allows air into the soil profile.

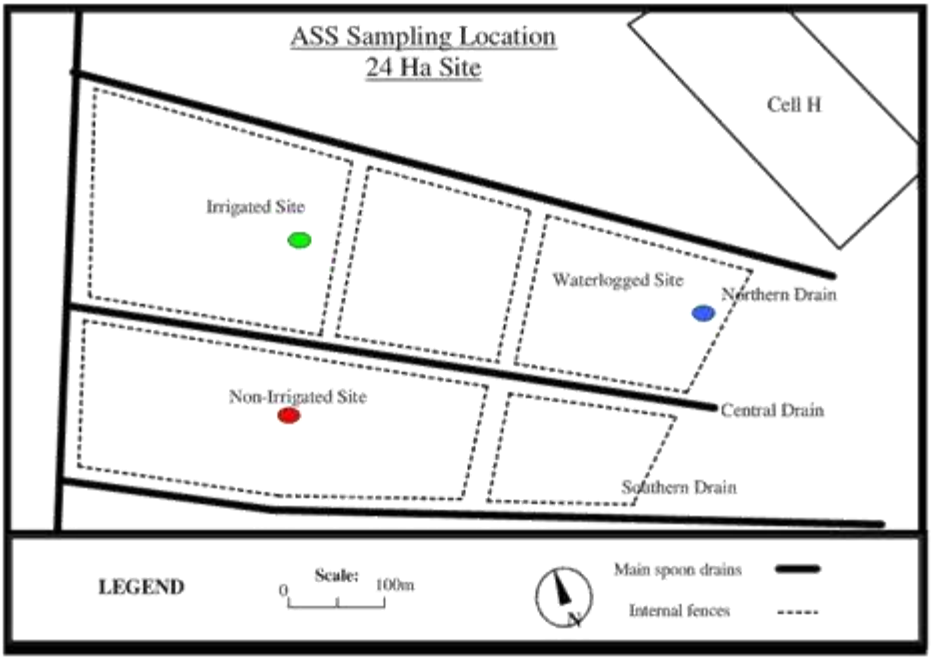


**Figure 1** **ASS Sampling sites showing location of the Waterlogged, Irrigated and Non Irrigated sampling sites.**

Extensive soil sampling shows a peat layer extending down to 120 – 140 cm (average depth) across the site. The peat is underlain by clay-rich material. At the extreme eastern side of the site, sand occurs below the clay material below ~1 m depth.

#### *4.2.2.1 Presence of Sulfides*

No official action criteria exist for peat materials. However, because drainage affects the entire 24 ha site, which contains almost 200,000 tonnes of material in the top 2 m, the action criterion of 0.03% applies in this case (criteria IV). Sulfides were found to occur throughout the site, and a concentrated sulfide zone (in places 1.5% $S_{CR}$, or ~ 50 times greater than the action criteria) was found in a sub-surface layer ~ 60 cm thick, starting ~ 100 cm below the surface (Figure 2). This concentrated sulfide layer encompasses the top of the clay (estuarine deposits) and the bottom of the peat (swamp deposits).

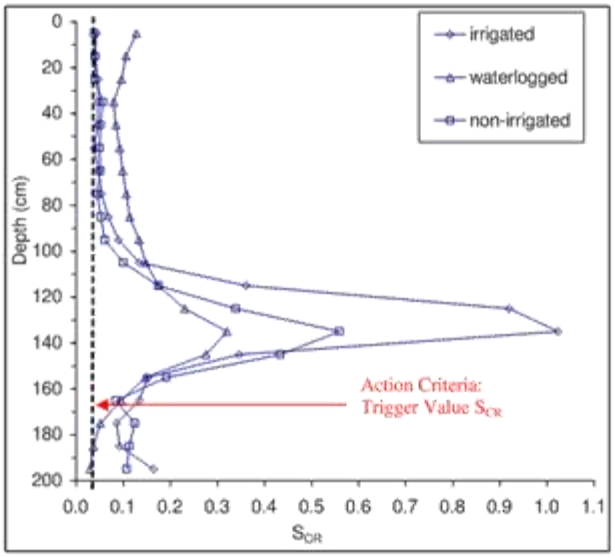


**Figure 2** **Average $S_{CR}$ values in the top 2 m at the 24 ha site. Samples from 5 sample rounds, collected over 2 years: non-irrigated, irrigated, waterlogged areas.**

The concentrated sulfide layer is surrounded by lower, but still environmentally significant, sulfide concentrations (≥ 0.03% $S_{CR}$). These lower sulfide concentrations occur as far up as the soil surface throughout the site, with highest concentrations measured at the waterlogged site (0.5% $S_{CR}$).

Surface sulfide concentrations, at the waterlogged site, declined over an 18 month monitoring period (to ~ 0.1% $S_{CR}$), following construction & drainage works that gradually changed the previous waterlogged condition. Conversely, sulfide at the irrigated site increased over time from ~ 0.05% $S_{CR}$ to ~ 0.1% $S_{CR}$ during the monitoring period. The non-irrigated site remained at ~ 0.05% $S_{CR}$ over the monitoring period.

*Risk Summary: Presence of Sulfides*

- The top 2 m of the 24 ha site contains actionable levels of sulfides (≥ 0.03% $S_{CR}$).
- There is a concentrated sulfide zone between ~ 100 – 160 cm below the soil surface. This zone is up to 50 times greater than the action criteria (0.03% $S_{CR}$).
- There is a surface-zone concentration of sulfides associated with increased waterlogging. Concentrations up to 0.5% $S_{CR}$ were recorded at the waterlogged site, up to 5 times higher than at the irrigated site and 10 times higher than at the non-irrigated site.
- Sulfide oxidation and acid production can be expected when water tables fall below the surface.
- Treated effluent may be a factor in increased sulfide formation, possibly due to the presence of sulfate in wastewater.

### *4.2.3 Acidity Assessment*

The acidity risk relates to the oxidation of sulfides, and the consequent acid and soluble metal production. These toxic products could be transported into the wider environment through the drainage network. Acidity is usually calculated and expressed as moles of $H^+$ per tonne of soil material. The action criteria (above which the amounts of acidity can cause environmental damage, and a management plan should be produced) are:

I. 18 mol $H^+$/tonne for sand,
II. 32, mol $H^+$/tonne for loam, and
III. 64 mol $H^+$/tonne for clay material
IV. When amounts of disturbed soil exceeds 1000 tonnes, the action criteria of 18 mol $H^+$/tonne should be used (Ahern et al. 1998a).

The total risk from acid production can be calculated by adding the actual acidity to the potential acidity and then subtracting the buffering capacity of the soil.

- **Total actual acidity** is that which is readily exported from the site with groundwater outflow. This is made up of soluble acid in the soil water, and exchangeable acid attached to soil and organic matter particles in readily-available forms.

- **Total potential acidity** is that which could be formed if all sulfide materials were allowed to oxidise (that is, if water tables were permanently dropped to 2 m).

- **Soil buffering capacity** is the soil's capacity to neutralise acid produced in the soil.

*Total Acidity at the 24 ha site*

**The total actual acidity** was estimated for this report and values are indicative only. Average actual acidity was 403 mol $H^+$/t in the top 1 m of the soil profile, and 259 mol $H^+$/t in the 1-2 m depth. These are 22 and 14 times, respectively, the action criteria (18 mol $H^+$/t) discussed above.

**The average total potential acidity** at the 24 ha site was 45 mol $H^+$/t in the top 1 m of the soil profile, and 143 mol $H^+$/t in the 1-2 m depth. These are 2.5 and 8 times, respectively, above the action criteria (18 mol $H^+$/t) discussed above.

**Soil buffering capacity** is likely to be very low, due to the prevailing acidic peat environment, and is expected to do little to buffer against a build-up of acid conditions.

However, only extreme conditions such as prolonged drought, coupled with no irrigation, could cause oxidation of the entire soil profile (years would be required), and this is highly unlikely. The majority of the acidity is readily-available actual acidity, and this can easily be transported into drains and to downstream aquatic ecosystems when heavy rain causes runoff from the site. Acid export will be a problem in the period after rain events, when overland flow diminishes, drain or creek flows subside, but drains will still be fed by acidic groundwater flows.

The effluent contains some buffering capacity (alkalinity) which can consume acidity. Amounts of alkalinity are expressed as moles of calcium carbonate ($CaCO_3$) per litre of water. Using an average effluent alkalinity (0.002168 mol/L $CaCO_3$) and an average irrigation rate (1,000,000 L/day), the buffering capacity of effluent would be around 2,168 mol $CaCO_3$/day (BSC Environmental Laboratory) 1 mol $CaCO_3$ (alkaline) will neutralise 2

mol $H^+$ (acid) (Ahern and Blunden 1998). So the effluent could neutralise 4,336 mol $H^+$ (acid) per day on the 24 ha site. However, the amount of acidity (actual plus potential) in the top 1 m of soil over the 24 ha site is estimated at over 23,000,000 mol $H^+$, and around 58,000,000 mol $H^+$ in the 1 – 2 m layer. Total acid neutralisation via irrigation is obviously not feasible, however, the alkaline content of the irrigation water does provide some buffering against small volumes of acid constantly 'leaching' from the site.

[*Care must be taken when considering the* ***actual acidity*** *results. Peat soils are naturally acidic and it is likely that not all the actual acidity found at the 24 ha site is due to sulfide oxidation. The test used to obtain the results is subject to interference from organic acids in the peat (Ahern et al. 1998b). Positive results have been reported where further analyses found no mineral sulfides present. However, at the 24 ha site, significant mineral sulfides have been found, and acidity produced by their oxidation would be adding to the already acidic environment. The pH results reflect an extremely acidic environment and such large amounts of actual acidity are still an environmental problem, mainly due to the potential for metal mobilisation*].

*Risk summary: Presence of Acidity*

- The 24 ha site has the potential acidity of 2.5 and 8 times the action criteria (18 mol H+/t) at 0-1 m and 1-2 m depth (respectively) below the soil surface.
- The 24 ha site has the actual acidity of 22 and 14 times the action criteria (18 mol H+/t) at 0-1 and 1-2 m depth (respectively) below the soil surface.
- Neutralisation capacity of the soil is low, and alkalinity of the effluent is minimal when compared to the amount of acid in the top 2 m of the 24 ha site.
- Acid outflows can be expected with sufficiently large rainfall events.

### *4.2.4 Soluble Metals Assessment*

Peat swamps are naturally acidic and this enhances the mobility of metals. Soluble iron (Fe) is produced from sulfide oxidation, and soluble aluminium (Al) is produced by dissolution of clay minerals (mainly present in the 1 – 2 m depth zone, below the peat). Concentrations of these soluble metals at the site are well above levels set for protection of aquatic ecosystems (Ahern et al. 1998a). Recommended levels are:

- 0.5 mg/L for Fe, and
- 0.005 mg/L for Al (at pH < 6.5).

Soil and water pH have been routinely measured throughout the first three years of the project, and these measurements provide both a snap-shot of available acidity at any point in time, and management trigger points. Low pH (acidity) is a problem for several reasons:

1. The critical pH value at which soluble iron (Fe) and aluminium (Al) start to increase in peat ASS materials is reported to be pH 3.5 (Allery 2003).
2. Below pH 3.5, soluble Fe can continue to oxidise sulfides, even with a return to waterlogged conditions.
3. At pH < 3.5 Fe and $H^+$ (acidity) is likely to be highly inhibitory to plant growth (at pH < 5, Al and ammonia are the major plant inhibitors) (Rorison 1973).

Soil monitoring over the first 3 years of the project consistently found pH < 3.5, especially in the top 1 m of the soil profile. Figure 3 shows soil solution pH values taken as part of a detailed soil analysis conducted in February 2002.

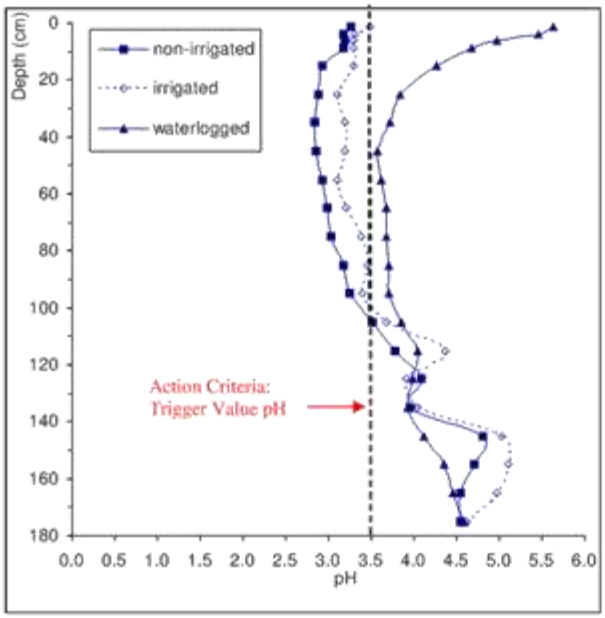


**Figure 3** **Average soil-water acidity (pH) values in the top 2 m at the 24 ha site. Samples from cores taken in February 2002: non-irrigated, irrigated, waterlogged areas.**

These conditions are sufficiently acidic to cause high concentrations of soluble Fe and Al throughout the soil profile. Concentrations of Fe in the lower soil profile are > 200 mg/L and > 300 mg/L, for the non-irrigated and irrigated areas respectively (this is 400 and 600 times the recommended water quality criteria). Surface soil contains a concentrated zone of soluble Fe (≤ 15 times the water quality criteria).

High concentrations of soluble Al also occurs in the lower half of the soil profile (> 10 and >35 mg/L) for the non-irrigated and irrigated monitoring areas respectively (this is 2,000 and 7,500 times the recommended water quality criteria). The highest concentrations of both Fe and Al appear to be in the irrigated areas. Of particular interest was a dramatic decline in soluble metals in the top 10 cm of the soil profile at the waterlogged sites. This is associated with a pH increase (> 5 pH) (see Fig. 3) caused by soil saturation and exclusion of air, triggering soil biochemical processes (e.g. sulfide formation) which consume acidity.

*Risk Summary: Soluble Metals*

- Extremely high concentrations of soluble Fe and Al are present in the top 2 m of the soil at the site.
- These soluble metals can be transported to the surface (through evapotranspiration, water-table rise) and/or carried off-site in the drainage system through ground and surface water flows.
- Mitigating factor: the high concentrations of soluble metals were not found in the groundwater on-site, but during soil analysis i.e. the metals first have to come into solution before they can be exported from the site via the drainage system.

## 4.3 ASS Management: Hazard Mitigation

ASS management at the 24 ha site must pursue the conflicting goals of,

a) preventing sulfide formation and,

b) preventing sulfide oxidation .

Both formation and oxidation can occur simultaneously at various locations and depths across the site. If the conditions are suitable, sulfide formation can occur below the water-table, and oxidation above - regardless of water-table depth. The only sure way to prevent sulfide oxidation is to ensure that the site is kept waterlogged (Van Breeman 1993). However, surface waterlogging produces high concentrations of sulfides in the surface soil zone.

Management of ASS on the 24 ha site should aim to:

- prevent oxidation of the main sub-surface sulfide zone
- minimise surface sulfide formation
- minimise export of toxic oxidation products.

### *4.3.1 Mitigating Factors*

A number of factors have been identified that reduce the likelihood of, or lessen the severity of, export of acid or acid by-products from the 24 ha site. These are:

- Soil chemical and biological processes would take months, years or decades to release all acid and soluble metals. Appropriate management techniques will prevent the complete release of these components.
- Belongil Swamp is 168 ha in size, of which 14% is occupied by the 24 ha revegetation site. Other areas within the Belongil swamp are extensively drained for agriculture and industry. In this context, the 24 ha site is unlikely to be the main contributor of acid and soluble metals to the estuary.
- Peat is known to adsorb acidity and soluble metals. High organic matter content (as found at the 24 ha site) can form stable complexes with metals (Wang et al. 1999), reducing their toxicity.

- Effluent irrigation will neutralise some of the acidity present, and raise the pH. Surface irrigation will neutralise some acid and immobilise metals in surface soil, which is the most biologically active zone of the soil profile.

### *4.3.2 Preventing ASS Formation & ASS Oxidation: Water-table Control*

#### *4.3.2.1 Sulfide Formation*

Sulfide formation will inevitably occur, but should be prevented at the surface. Surface sulfide formation is a problem because it can readily oxidise and produce acidity even after short dry periods (or periods without added effluent). The result is a flush of soluble acid and other toxins in the biologically-sensitive surface soil zone. The toxins can damage plant roots, and are more likely to be exported with runoff in surface water flow. Surface sulfide increase is not unusual, and it has been found at various ASS sites along the NSW coast (Rossicky et al. 2004).

The recommended management practise will be to avoid large increases in sulfide concentration in the top 1 m of the soil profile (where it will be most susceptible to re-oxidation during periods of low water tables, and consequent release of damaging flushes of acidity with the next water-table rise): instead, sulfide formation should be kept at depth i.e. closer to the main sulfide layer or below the lowest recommended water-table depth - to be set at 60 cm depth (discussed below).

#### *4.3.2.2 Sulfide Oxidation*

As with sulfide re-formation, it would be unrealistic to expect that all ASS oxidation could be prevented. However, water-table management would minimise the amount and frequency of oxidation events, and in order to achieve this water tables should be kept above the main sulfide zone. This zone, which begins at a depth of ~ 100 cm, should be permanently waterlogged. If the minimum water table depth is set at 60 cm, then this will provide a 40 cm buffer which will take into account any depth variability of the main sulfide zone.

Smaller, but significant, sulfide concentrations occur above and below the main layer of sulfidic material. To completely avoid oxidation of sulfidic materials in the top 1 m, permanent waterlogging would be required. This is unrealistic for two reasons. Firstly, variation in irrigation flow causes fluctuation in water-table depth. Secondly, environmentally significant concentrations of sulfides are known to form near the soil surface at this site, even when waterlogged for a relatively short period (6-12 months). Ideally, a period of near-surface sulfide formation (waterlogging), would be followed by a period of sulfide oxidation (draining).

Fluctuating the water-table between the surface and 60 cm depth would allow cycles of sulfide formation and oxidation to occur. Ideally, the water table should be raised or lowered by 30 cm increments at 3 monthly intervals (0 cm, 30, 60, 30, 0 cm depth). This should prevent excessive concentrations of near-surface sulfides forming as a consequence of extended waterlogged periods. Realistically, this water-table management regime may be difficult to achieve for a number of reasons:

1. The site is an effluent re-use area and there is an expectation of high volume effluent re-use; the preferred water-table management regime may fall short of effluent re-use requirements i.e. cycling the water-table as described above, will require progressively less effluent for up to six months of the year.
2. The existing irrigation technology may be insufficient to achieve the refined level of water-table management proposed i.e. it is much easier to keep the water-table at the surface (because excessive water will simply run off), than it is to maintain the water-table at depth (because excessive water will lift the water-table, whilst insufficient water will lower it).
3. Water-table management will be affected by rainfall/drought, which could cause excessive periods of waterlogging/desiccation. Low water tables should be particularly avoided due to the likelihood of oxidation of the main sulfide layer.
4. Water-table depth may vary across the 24 ha site at any given time. Trigger points may be reached in some areas but not in others (a flexible irrigation system may be able to cope with this situation).

5. Prolonged rainfall, resulting in surface waterlogging, will re-set the water-table management point to the beginning of the drying cycle i.e. following prolonged rainfall leading to prolonged waterlogging, irrigation should be stopped.

**Sulfide: Management Recommendations**

- Ideally, water tables should be raised or lowered by 30 cm increments every 3 months (0 cm, 30, 60, 30, 0 cm depth). Realistically, water tables should at least be cycled between the soil surface and a minimum depth of 30 cm every 3-6 months: this will allow controlled, regular oxidation of sulfides in the upper soil profile, and will decrease the build-up of re-formed sulfides.
- To prevent oxidation of the main sub-surface sulfide zone (100 cm and below): water tables should be maintained above 60 cm.
- If water tables fall below 60 cm (because of drought or lack of effluent) for extended periods, they should be raised as soon as possible.
- Water tables should not remain at the soil surface for extended periods (i.e. > 3 months).
- If the soil is waterlogged to the surface for extended periods (> 3 months), the water table must be lowered as soon as possible.
- The management plan must be flexible and adaptive. Emphasis needs to be placed on monitoring so that management actions can be fine tuned (monitoring Section 4.4).

### *4.3.3 Reducing Export of Acid and Acid Products*

Export of acid and acid products can never be totally avoided, although introducing the water-table management regime, described in the previous section, will at least minimise the quantities of oxidation products (acid and metals in solution) in the surface soil. These toxic oxidation products could leave the 24 ha site via the drainage network. A sure way to prevent export would be to impede drainage (particularly the central and southern drains) to the point where only waters from major flooding would overtop the barriers. This will reduce the incidence of poor quality water leaving the site to times of high rainfall. During high rainfall large volumes of water, draining from the surrounding landscape, will help dilute the run-off from the 24 ha site.

Impeding drain-flow could be achieved by installing weirs in existing drains, or filling in drains and constructing berms. High drain-water levels will also impede groundwater flow into the drains (which carry soluble acids and metals). Removable drop-boards would provide water-level control: drain levels could be raised or lowered as needed. During wet weather and high outflow, the drop-boards could be lowered to allow escape of surface waters if required. During dry weather, drop-boards could be raised to maintain higher drain-water/ groundwater levels (which will also prevent out-flow from the drains). Existing drains should be managed so that water levels are maintained above 30 cm below surrounding ground level (and definitely above 60 cm depth).

**Drainage Control (To Reduce Acid Export): Management Recommendations**

- Reconstruct the V-notch weirs on the central and southern drains (or fill drains) to impede outflow and assist in maintaining higher water tables.
- Drain water height should be maintained above 30 cm depth (measured from surrounding ground surface), to minimise water losses from the site. During hot dry weather, and/or when effluent is not available, this may not be possible. However, during such periods excess water (and export of acid) will not be an issue.
- Monitor drain water at the V-notch weirs: physico-chemical parameters – continuously; soluble metals during low pH conditions (see Section 4.4).

## 4.4 ASS Soil, Groundwater & Drain-water Monitoring

Soil, groundwater, and drain-water monitoring programmes have been conducted throughout the *Melaleuca* establishment period, with weekly measuring of groundwater and drain water quality (see Section 7), and annual soil analysis. It is recommended that the monitoring programme be continued and, particularly in the case of soil monitoring, this will provide important feedback on the status of ASS re-formation, and confirmation of whether or not the management techniques are succeeding.

### *4.4.1 Soil monitoring*

Testing near-surface soils (top 40 cm) for sulfide content following prolonged dry periods and prolonged waterlogging (≥ 3 months) will measure changes in sulfides in the surface zone over time. This sampling should be undertaken at least once in a 12 month period. Annual soil sampling is also recommended to 2 m depth – this will reveal any changes in the status of sulfide below the permanently waterlogged layer (above, within, and below the main sulfide layer). Where practical, soil sampling should continue in close proximity to areas that have been tested previously (Figure 1). This will enable a comparison to be made with existing data. Sampling should also be close to groundwater monitoring sites to test for any relationship between soil conditions and groundwater quality.

It is assumed that the soil sampling will be carried out annually by an experienced field technician, and returned to a laboratory for analysis. Consequently the method for sampling will not be described here in detail.

Soil should be extracted as a complete core, using a plunge auger, and discrete samples removed from the core at the following intervals:
Near surface sampling: 0 - 40cm Cores: (0-5, 5-10, 10-15, 15-20, 20-30, 30-40 cm)
Full profile sampling: 0 - 200cm Cores: (0-5, 5-10, 10-15, 15-20, then 10 cm intervals)

Multiple samples can be taken from the same location and 'bulked' (thoroughly mixed together), to reduce analysis costs, and improve sample coverage. [Multiple samples may

only be mixed where they represent soils from the same location and depth i.e. multiple samples taken from the old waterlogged site, could be mixed for their respective depth intervals e.g. 0-5 cm with other samples at 0-5 cm].

### *4.4.2 Groundwater & Drain-water Monitoring*

The main focus of groundwater and drain water monitoring will be the continuous monitoring of water-table height and water physico-chemical parameters (DO, pH, EC, Eh, Temp - see Section 7). This will show the effects of recent sulfide dynamics, and will provide information on the effectiveness of groundwater management on sulfide status, and also the influence of sulfide status on pH.

Coordinated monitoring of groundwater and drain-water will identify their relationship over time. It is likely that a lag period will exist between sulfide oxidation, groundwater acidification, and changes in drain water quality. In the case that drain-water pH drops below pH 4, water leaving the site should be minimised, and irrigation should be re-commenced if paused.

Groundwater pH fluctuations will occur both naturally, and as a consequence of the 'managed' sulfur oxidation-reduction cycle. Groundwater pH could drop to very low levels during the oxidation process (soil drying period). However, pH levels should be maintained above pH 3.5 if possible. Applying effluent will raise the pH, and in circumstances where the pH falls below pH 3.5, irrigation should be resumed; this will help to prevent the release of acid and acid by-products (soluble metals).

**Soil & Water Monitoring: Management Recommendation**

- Test soil for sulfide content in the surface horizon annually (top 40 cm) after both prolonged (≥ 3 months) waterlogging and dry periods.
- Test for sulfide content in top 2 m of soil profile annually.
- Multiple surface and deep samples can be 'bulked', at one sample round, to save costs.
- Monitor drain-water height (weekly).

- Monitor drain-water for physico-chemical parameters: pH, DO, EC, Eh, Temp (continuous with data-logger in-situ).
- Restrict drain outflow if pH drops < pH 4.0, and resume irrigation.
- Monitor groundwater depth (weekly).
- Monitor ground-water for physico-chemical parameters: pH, DO, EC, Eh, Temp (continuous with data-logger in-situ). Resume irrigation if groundwater pH < 3.5.

**ASS: Adaptive Management**

On-going monitoring over the short to medium term will allow management actions to be refined. However, it may become clear over a longer period of time that management aims should change. This could occur as a consequence of on-site or off-site factors. Two examples are given:

1. It may become evident that irrigation volumes will need to be reduced in response to a continued and unacceptable build up of sulfides in the surface zone.
2. Preferential distribution of effluent, to other parties, may require that volumes available for the 24 ha site be reduced.

In the second example, the 24 ha site could be returned to a more natural hydrological regime, with drains filled in and the site allowed to function more as a natural wetland. Export would occur only in high rainfall periods, and berms could be constructed to stop the tail waters leaving the site. It is these tail waters that usually contain large amounts of toxic products that enter natural systems whose dilution capacity is already reduced. However, effluent should still be made available to ameliorate groundwater conditions if the water-table drops to the main sulfide layer.

### *4.4.3 Summarised Management Actions*

**Table 4 ASS Management: Task Summary**

| Management Issue | Action Required |
|---|---|
| **Groundwater: Monitoring** | |
| - Water-table height | - Measure and record weekly at each of the five piezometer locations, plus boundary piezometers. |
| - Physico-chemical | - Download data weekly, at each of the five piezometer locations, from the 90- FLMV data-logger to laptop computer. |
| - Soluble metals analysis | - Annual for Fe & Al [sample from the five piezometer sites] |
| - Data management | - Maintain MS Excel database (or other as required): report as required |
| **Groundwater: Depth Variation** | |
| - Depth | - Maintain water-table above 60cm<br>- Raise water-table at earliest opportunity if it drops below 60cm |
| - 3 monthly | - Lower water-table to 30 cm and maintain for one month, then<br>- Raise water-table to surface and maintain for three months.<br>- Avoid prolonged (> 3mths) surface waterlogging; lower water-table at earliest opportunity if this occurs.<br>[This is the minimum water-table cycling required to allow controlled, regular oxidation of sulfides in the upper soil profile; and to decrease the build-up of re-formed sulfides]. |
| - pH < 3.5 | - Apply effluent if possible |

| **Drain Monitoring & Management (ASS export prevention)** | |
|---|---|
| - Water monitoring | - Depth below surrounding soil surface (weekly).<br>- Fe & Al (as for routine STP/ off-site drain monitoring)<br>- DO, pH, EC, Eh, Temp (ongoing using 90-FLMV data-logger) |
| - Infrastructure | - Reconstruct V-notch weirs on Central and Southern drains (or fill drains in) to impede outflow and assist in maintaining higher water tables. |
| - Water Depth | - Maintain water level above 30cm depth (i.e. 30 cm below embankment) where possible. To assist in maintaining water-table height on-site. |
| - pH < 4.0 | - Minimise flow across weir.<br>- Re-commence irrigation if paused (add effluent directly to drain if possible). |
| **Soil Sampling & Analysis** | |
| - Annual | - Test for sulfide content<br>a) 0 – 40 cm [0-5, 5-10, 10-15, 15-20, 20-30, 30-40 cm]<br>b) 0 – 200cm [0-5, 5-10, 10-15, 15-20, then 10 cm intervals] |

**Table 5 ASS Management: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Groundwater & Drain-water | ➢ Water table height | - Field assistant/ STP | All to be carried out on an 'as required basis' |
| | ➢ Physico-chemical | - Field assistant/ STP | |
| | ➢ Water sampling | - EO, EHO, Lab.Tech/ STP | |
| | ➢ Data management, reporting & trigger actions. | - EO, EHO, Lab.Tech | |
| | ➢ Weir Re-construction | - Engineering & Construction | |
| Soil | ➢ Sampling & analysis | - EO, EHO, Lab.Tech | |

# 5 Irrigation: Water Demand

The key factor to achieving the management objectives of the 24ha site is water: particularly the volume, distribution and scheduling of irrigation water. The operation and maintenance of the irrigation system will be a critical management tool in achieving these objectives. A spreadsheet model was used to estimate the water requirement of the 24ha *Melaleuca* regeneration site.

## 5.1 Modelling Process

The model solves the daily water balance by treating the 24 ha soil column as a 'leaky bucket', accounting for both losses via evapotranspiration, percolation and interflow, and gains from rainfall and irrigation water. When the soil column is saturated to the surface, the model stops irrigation; when the water table drops below the surface, irrigation is resumed. With the exception of surface run-off, all inputs and outputs (gains & losses) to the model are instantaneous; run-off is dealt with much like a drum of water draining out through a hole near its base i.e. the higher the water level the greater the drainage rate, and vice versa. This produces a longer (than instantaneous) post rainfall run-off period (and therefore more days without irrigation), but mimics observed run-off characteristics of the 24 ha site.

The model was used to predict water demand for: 95$^{th}$, 80$^{th}$, median, 20$^{th}$, and 5$^{th}$ percentile rainfall years i.e. very wet through to very dry years. In addition, the modelling included the likely growth in evapotranspiration during the next 8 years of *Melaleuca* development. The modelling also restricts crop water-demand by adding a default factor for ASS management which triggers an annual non-irrigation period of 60 days and this had a considerable impact on the predicted water requirement for the site. There is also some uncertainty in regard to *Melaleuca* evapotranspiration potential, and further assessment of actual evapotranspiration rates for the site is recommended.

### 5.1.1 Model Data

***Rainfall & potential evapotranspiration***

Meteorological data for the model includes rainfall & Class 'A' Pan evaporation from the Alstonville Agricultural Research Centre - used as a surrogate data-set for the 24ha site. Class 'A' Pan evaporation was converted to Byron potential evapotranspiration using a coefficient of (1.2344 x Class 'A' Pan).

*Potential evapotranspiration is usually less than Class 'A' Pan evaporation (Meyer et al., 1999), and in this case a factor of (0.8) was used. Potential evapotranspiration at the 24 ha site was calibrated to the Alstonville Class 'A' Pan data, by comparing overlapping data-sets from the 24 ha weather station and the new Alstonville weather station. Regression analysis gives: Byron = 1.534 x Alstonville. Thus, our coefficient for Alstonville Class 'A' Pan to Byron potential evapotranspiration (0.8 x 1.534 = 1.2344).*

***Percolation & interflow losses***

A small field study was conducted in order to differentiate between evapotranspiration, deep percolation, and interflow losses. Regression analysis, based on data collected during a non-irrigation and low rainfall period - from 28 piezometers at the North Central paddock, indicates that:

1. Evapotranspiration ($Et_c$), for current vegetation, is related to the 24 ha weather station Et.

   $Et_c = 0.737$ x weather station Et (mm/day)

2. Percolation was found to be a function of the difference between water table height and drain-water height.

   *Percolation = -0.269 + (0.00348 x difference in water table ht) (mm/day)*

3. Interflow was found to be a function of the piezometer distance from the central drain: the closer to the drain the greater the lateral flow toward the drain.

   *Interflow (mean) = -0.0057 x (distance from drain) + 0.0506 (mm/day)*

   *Interflow (max) = -0.012 x (distance from drain) + 1.0027 (mm/day)*

Due to the relative flatness of the 24 ha site, drain effect was considered equal for all drains i.e. Northern, Western & Southern drains were assumed to have the same effect on interflow as the subject Central drain. Consequently, the site was divided into zones at 20 m intervals from, and parallel to, all drains (0-20 m, 20-40 m, etc.). Interflow values for each zone were calculated, and area values for each zone were used to calculate a total interflow value for the 24 ha site, based on a proportional factor for each zone.

- *Total max interflow = 0.5 mm/day*
- *Total mean interflow = 0.24 mm/day*

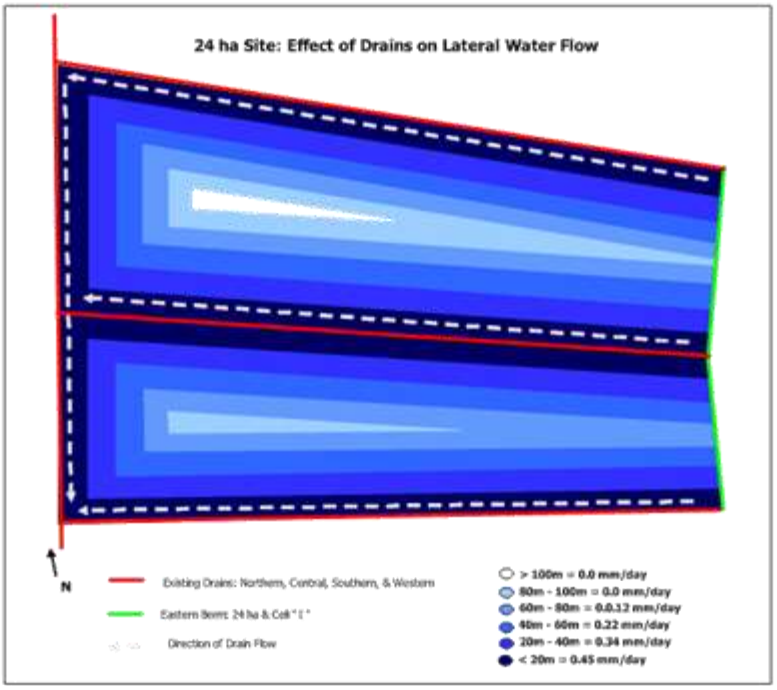


**Figure 4** **Drain 'Buffer zones' in 20 m intervals, with drain effect shown as mean interflow (mm/day).**

### 5.1.2 *Local Rainfall Patterns*

Local rainfall and Class 'A' Pan evaporation data was analysed for monthly distribution. The results, presented in Tables 6 & 7, show average monthly rainfall and Class 'A' Pan evaporation, as well as monthly percentile information that demonstrates the high level of variability, particularly rainfall, that occurs in this area. By comparing the data in Tables 6 & 7, it indicates that during any very wet month (see 95th percentile rows for rainfall and Class 'A' Pan evaporation), there will be little or no opportunity for irrigation because in every month rainfall is higher than Class 'A' Pan evaporation. The converse comparison, any very dry month (see 5th percentile rows for rainfall and Class 'A' Pan evaporation), irrigation could occur for every month because rainfall is less than Class 'A' Pan evaporation.

**Table 6 Rainfall: Monthly Percentiles & Mean (monthly values are independent).**

| Percentile | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| | | | | | | | | | | | | |
| 95th v. wet | 420 | 534 | 607 | 477 | 541 | 312 | 248 | 137 | 175 | 244 | 249 | 368 |
| 80th wet | 315 | 342 | 441 | 306 | 265 | 213 | 173 | 97 | 116 | 154 | 198 | 210 |
| 50th | 147 | 172 | 235 | 166 | 155 | 120 | 83 | 44 | 38 | 84 | 105 | 127 |
| 20th dry | 79 | 137 | 102 | 101 | 82 | 88 | 31 | 28 | 12 | 34 | 63 | 72 |
| 5th v. dry | 45 | 78 | 55 | 48 | 52 | 38 | 6 | 7 | 2 | 16 | 37 | 45 |
| Mean | 186 | 243 | 277 | 208 | 197 | 152 | 105 | 61 | 61 | 108 | 129 | 159 |

**Table 7 Class 'A' Pan evaporation: (monthly values are independent).**

| Percentile | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| | | | | | | | | | | | | |
| 95th v. wet | 147 | 109 | 112 | 78 | 57 | 62 | 61 | 88 | 109 | 138 | 134 | 154 |
| 80th wet | 156 | 124 | 115 | 94 | 66 | 66 | 73 | 94 | 114 | 145 | 142 | 169 |
| 50th | 173 | 139 | 134 | 103 | 84 | 73 | 82 | 108 | 135 | 153 | 162 | 187 |
| 20th dry | 194 | 151 | 142 | 117 | 90 | 83 | 90 | 119 | 147 | 164 | 182 | 201 |
| 5th v. dry | 206 | 157 | 161 | 131 | 104 | 96 | 106 | 132 | 165 | 175 | 196 | 216 |
| Mean | 175 | 138 | 131 | 105 | 80 | 75 | 82 | 108 | 134 | 155 | 163 | 186 |

However, statistical analysis of the Alstonville meteorological data does not reflect the actual distribution of rainfall or evapotranspiration. Furthermore, when considering monthly percentile data, values are independent between months and cannot be summed to give annual totals. Dry years will have a mixture of wet and dry months, and wet years will also have a mixture of wet and dry months. This has a considerable effect on the irrigation potential for the 24 ha site. Table 8 shows how ambiguous total annual rainfall is, as an indicator of a 'wet' or 'dry' year in terms of actual rainfall distribution.

The examples in Table 8 show that despite the 'wet' years (1974 & 1976) having more than double the combined annual rainfall of the 'dry' years (1986 & 1997), the number of days with or without rain is identical (± 1 yr) for all years in the table. In fact, most rainfall occurring during either of the wet years fell on days of > 30 mm rainfall, 19 days and 23 days for 1974 and 1976 respectively.

**Table 8 Variation in rainfall distribution for selected wet and dry years**

| Year | Annual Rainfall (mm) | Days Without Rain | Days With Rain | Days >30mm Rain | Rainfall Total for Days > 30mm | % of Annual Rain Falling On Days With > 30 mm | Categorised By Total Annual Rainfall |
|---|---|---|---|---|---|---|---|
| 1974 | 2687 | 199 | 166 | 19 | 1878 | 70 % | wet |
| 1976 | 2532 | 201 | 164 | 23 | 1624 | 64 % | wet |
| 1986 | 1122 | 201 | 164 | 9 | 391 | 35 % | dry |
| 1997 | 1440 | 199 | 166 | 7 | 334 | 23 % | dry |

### *5.1.3 Irrigation Demand*

Percentile monthly water demand, for existing vegetation (September 2004), for both wet and dry times, is presented in Figures 5 & 6. Monthly irrigation rates are clearly related to the trend in Class 'A' Pan evaporation (Table 7).

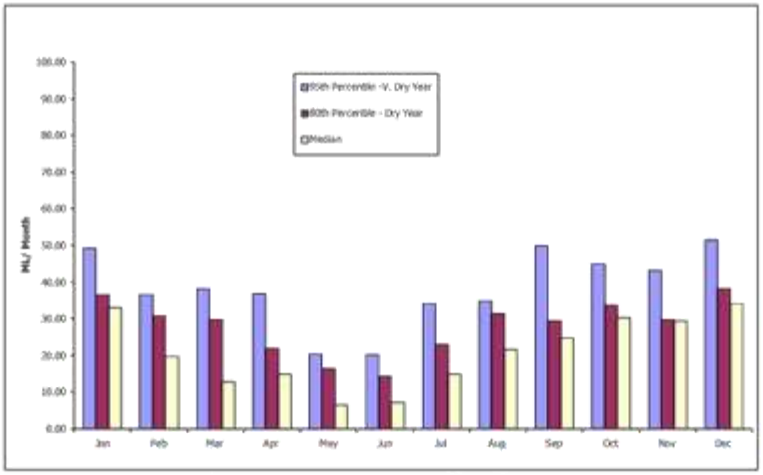


**Figure 5 Irrigation demand for median, 80th, 95th percentile rainfall - dry years.**

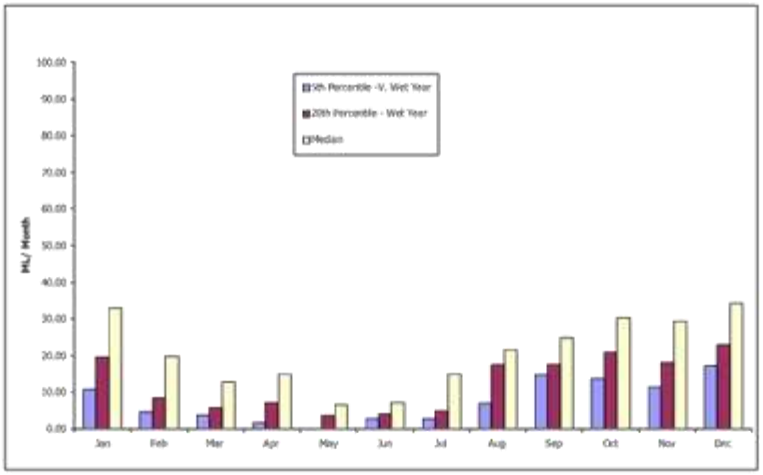


**Figure 6 Irrigation demand for median, 80th, 95th, percentile rainfall - wet years.**

*5.1.3.1 Irrigation: predicted annual volumes*

Predicted annual irrigation demand includes the bi-annual non-irrigation periods of thirty days each, for ASS management. Irrigation volumes were calculated for both low *Melaleuca* evapotranspiration at maturity, and high evapotranspiration at maturity. Irrigation volumes are presented in Tables 9 & 10.

Note: ASS management has a considerable impact on annual water demand. [e.g. mean annual demand, for 2005, dropped from 292 ML to 217 ML].

**Table 9 Annual Irrigation Demand: Low Transpiration Rate At Maturity (1.4x ET)**

| Annual Irrigation in ML (assuming 1.5 mm/day GW loss) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Percentile** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
| **95th dry** | 244 | 254 | 272 | 292 | 334 | 362 | 367 | 374 |
| **80th dry** | 240 | 250 | 277 | 292 | 331 | 354 | 364 | 371 |
| **50th** | 212 | 218 | 236 | 251 | 291 | 319 | 322 | 330 |
| **20th wet** | 202 | 209 | 224 | 237 | 268 | 292 | 297 | 299 |
| **5th wet** | 182 | 196 | 212 | 223 | 253 | 270 | 277 | 284 |
| **Mean** | 217 | 226 | 245 | 260 | 297 | 319 | 326 | 332 |

**Table 10 Annual Irrigation Demand: High Transpiration Rate At Maturity (1.8x ET)**

| Annual Irrigation in ML (assuming 1.5 mm/day GW loss) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Percentile** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
| **95th dry** | 244 | 260 | 291 | 341 | 426 | 492 | 499 | 518 |
| **80th dry** | 240 | 256 | 290 | 337 | 426 | 473 | 478 | 503 |
| **50th** | 212 | 221 | 250 | 297 | 373 | 428 | 436 | 450 |
| **20th wet** | 202 | 212 | 236 | 274 | 339 | 384 | 390 | 404 |
| **5th wet** | 182 | 195 | 223 | 258 | 328 | 370 | 368 | 393 |
| **Mean** | 217 | 229 | 259 | 303 | 379 | 432 | 438 | 457 |

*5.1.3.2 Irrigation: predicted seasonal variation*

The effect of seasonal variation, on irrigation demand, is shown in Figures 7 & 8. Crop coefficients used to calculate the seasonal variation are listed in Table 11. The Winter coefficient value, (0.74), was applied directly from results of the study referred to in Section 5.1.1. Spring and Summer coefficients, (1.05), were sourced from Allen *et al.* (2000). The Autumn value, (0.85), is an estimate.

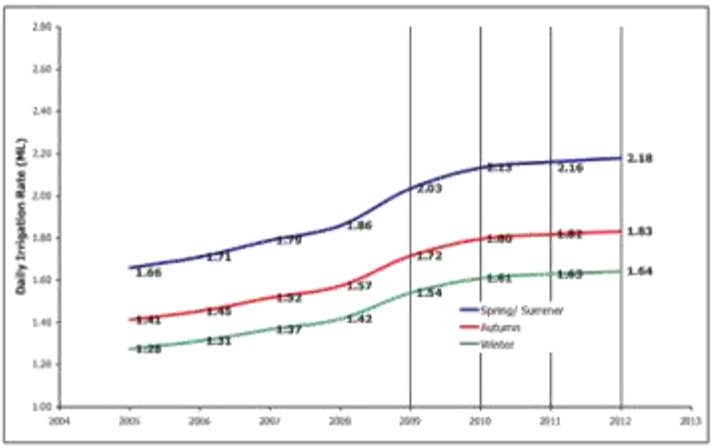


**Figure 7** **Seasonal variation in irrigation demand for low mature Melaleuca evapotranspiration.**

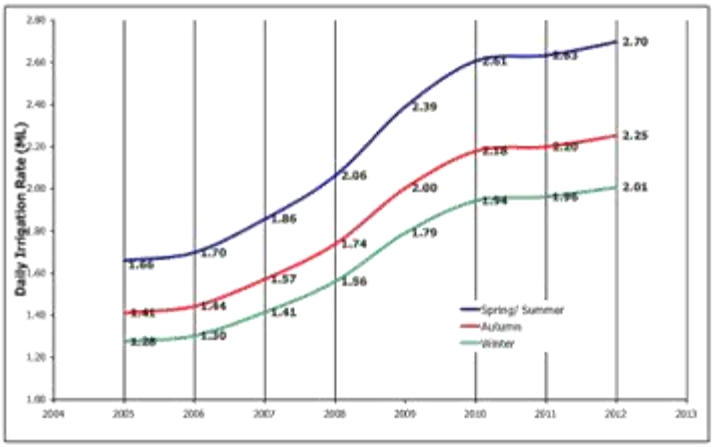


**Figure 8** **Seasonal variation in irrigation demand for high mature *Melaleuca* evapotranspiration.**

**Table 11 Evapotranspiration and seasonal crop coefficients used in the model.**

| Melaleuca Age | Low Transpiration Coefficients | High Transpiration Coefficients | Season | Seasonal Crop Coefficient |
|---|---|---|---|---|
| **2005** | 1 | 1 | Summer | 1.05 |
| **2006** | 1.03 | 1.04 | | |
| **2007** | 1.1 | 1.41 | Autumn | 0.85 |
| **2008** | 1.154 | 1.436 | | |
| **2009** | 1.289 | 1.561 | Winter | 0.74 |
| **2010** | 1.365 | 1.702 | | |
| **2011** | 1.386 | 1.763 | Spring | 1.05 |
| **2012** | 1.4 | 1.8 | | |

## 5.2 Model Assumptions & Controls

Water demand modelling for the 24 ha site is based on a number of assumptions or considerations. Including:

- Alstonville meteorological data is representative of rainfall and evaporation rates likely to occur at the West Byron site.
- Existing vegetation will continue to thrive in a now much wetter environment i.e. current evapotranspiration rates will, as a minimum, be maintained.
- *Melaleuca* forest will potentially come to dominate all or part of the 24 ha site.
- Mature *Melaleuca* forest will have a higher water demand than existing vegetation (two figures have been used for mature *Melaleuca* ET demand: 1.4x and 1.8x reference potential ET values) (Bolton 2001).
- Percolation has been set at a maximum for high paddock water table: drain water difference (1 mm/day).
- Interflow (to the drains) has been set at the calculated maximum value of 0.5 mm/day.
- Acid sulphate soil management requires periods of drainage. This has been incorporated into the water balance by factoring in two annual drainage periods of

30 days each (total 60 days of non-irrigation [and without rainfall] for ASS management). The modelling also accounts for the 'top up' required at the end of the drainage period.

- Planned or proposed modifications to the existing irrigation system, including bunding the site, may reduce the loss to drains, and consequently reduce irrigation demand.
- Irrigation water will be available on demand.
- Daily irrigation rate is fixed by season and mean evaporation rate, rather than fluctuating daily to 'catch up' with water-table fluctuations.
- The coarse, undulating peat surface, combined with very low relief, will inhibit run-off and will instead, promote water storage.
- There remain unknowns regarding both the hydraulic performance of the site, and the future water requirements of the developing *Melaleuca* forest. Consequently, the long-term irrigation predictions presented here should be used as an interim guide to the potential irrigation requirements for this site.

### *5.2.4 Irrigation Scheduling: management recommendations*

Replicating 'modelled conditions' in the field is unlikely to be achieved i.e. the model 'assumed' that water delivery was available on demand, at a constant rate, that the site would experience homogeneity in water table variation, and that some engineered system would ensure that irrigation could stop & start based on daily demand variation. None of the above is true for existing field conditions and, any irrigation infrastructure upgrade may or may not include sophisticated irrigation control. As a minimum it is recommended that the following actions be implemented as part of the water management of the site:

- Ensure even distribution of irrigation water across the site (dependent on infrastructure improvements but required immediately);
- Set daily delivery volumes to seasonal volumes given in Figure 7 or Figure 8;
- Adjust (stop or start) irrigation by observing water table height: surface ponding will require cessation of irrigation (this is unlikely to occur across the whole site at any one time, but will require variable control between paddocks);

- Adjust (stop or start) irrigation by rainfall: during wet weather the combination of irrigation water and rainfall will cause excessive ponding at the surface. Irrigation should be stopped during these periods.
- Record irrigation flow volumes and maintain record.
- An annual review of crop water demand and the water-balance model must occur in order to ground-truth the water-demand values proposed in this report.

Effective water management at the 24 ha site also requires consideration of *Melaleuca* and ASS water demand. For further details regarding those two management demands refer to Sections 3 & 4.

### *5.2.5 Summarised Actions*

**Table 12 Irrigation: Task Summary**

| Maintenance Issue | Action Required |
|---|---|
| **Irrigation** | |
| - Even water distribution | - Check irrigation scheduling; clear infrastructure blockages; measure water-table depth. |
| - Seasonal flow variation | - Adjust daily flow according to seasonal demand (see Figure 7 or 8). |
| - Rainfall & flooding | - Reduce or cease irrigation. |
| - Flow volumes | - Record and maintain data-base. |
| - Crop water demand | - Annual review of water balance model predictions vs. actual field conditions. |

**Table 13 Irrigation: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Irrigation Scheduling | - All irrigation management & maintenance tasks listed in Table 12. | - Field assistant/ STP | 6 |
| | - Annual review of crop demand | - Hydrologist/ Enviro. Sci. | As required |

## 6 Irrigation: Infrastructure & Maintenance

The current irrigation infrastructure, installed during 2005-2006, replaced the temporary SCU/ BSC 'poly-pipe' irrigation system. The new infrastructure provides a robust, and low maintenance irrigation system which can supply wastewater to each, or all of, the six paddocks at any one time. The site is fed by one main 150mm UPVC delivery line, which then splits to six, one for each paddock, 100mm UPVC pipe-lines, with between three and six lateral off-takes depending on paddock size. The laterals feed into open ended 100mm vertical 'high risers' (approximately 1.6m height) which then 'spill' water into the paddocks (Figures 9a and 9b). Each of the high-risers' has an adjustable collar, which can be raised or lowered, effectively reducing or increasing the flow of water. The new infrastructure was completed in 2006 and has been operating satisfactorily since that time. Only minor maintenance is required.

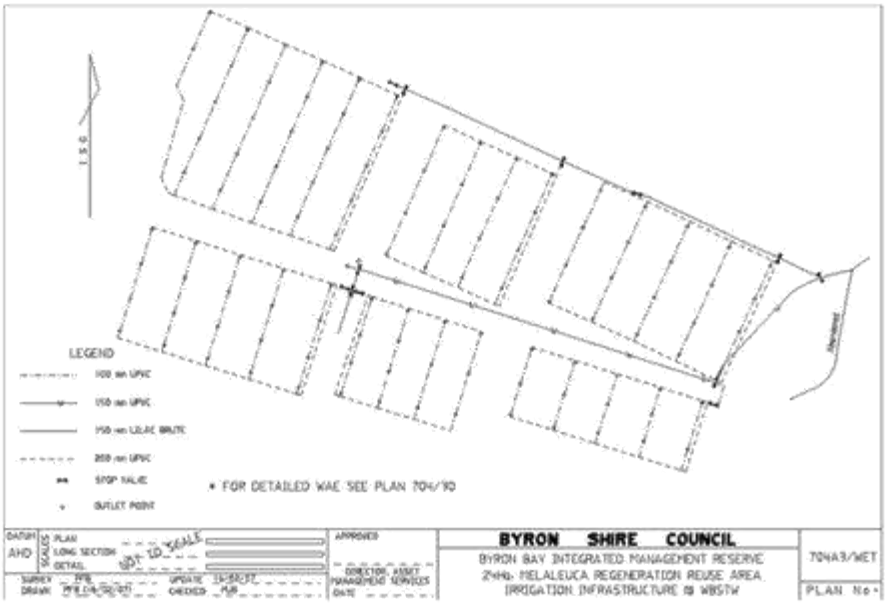


**Figure 9a Irrigation infrastructure plan: 24 ha February 2007.**

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**Fig 9a (a) Control unit for duty pump; (b) Mag flow records irrigation volume; (c) Distribution 'chamber' to wetland cells 'I' 'J' & 'H' plus 24ha site; (d) Pressure reduction valve (PRV) adjacent NE paddock; (e) Pressure meter for PRV; (f) 150mm:100mm reducer; (g) Paddock valve box (SV); (h) 'High riser' irrigation pipe (with adjustable collar).**

## 6.1 System Maintenance: summary

Due to the large outlet pipe sizes used in the irrigation infrastructure, the amount of maintenance has been considerably reduced, and there is no longer a requirement for flushing and unblocking of the lines. However, ongoing maintenance and monitoring is required in order to ensure that there is satisfactory volume and distribution of water to the site. Minimum human resource input for the key maintenance & monitoring tasks is given in Tables 14 & 15.

**Table 14 Irrigation network: routine maintenance and monitoring**

| Maintenance Issue | Action Required |
|---|---|
| **Irrigation Network** | |
| - Distribution chamber:<br>- Distribution valve<br>- Coarse screen<br>- Fine screen | <br>- Select distribution as required (cells I, J or H, or 24ha site)<br>- Clean daily<br>- Clean daily |
| - Pump | - Test for running: visual in-field check of pipes or at main pump control station adjacent the Interpretive Centre. |
| - Flow Data | - Flow to be recorded in daily log sheet. Cumulative flow to be noted, from the MagFlow, and forwarded to Dean Baulch. |
| - Pressure release valve | - Visual inspection only (when running): check pressure on vacuum gauge, check vacuum pipes and other cables connected. |
| - Paddock valve(s)(SV) | - Select valve on/ off depending on irrigation requirements for individual paddocks. |
| - High risers | - Check flow (visual) for approximate 'balance' along the laterals. |
| - General | - Visual inspection of:<br>- Pipe-work for damage e.g. root or plant debris intrusion.<br>- Risers for balance, damage, blockage. |

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**Table 15 Irrigation network: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Irrigation | ➢ Distribution chamber cleaning | - Field assistant/ STP | 3.5 |
| | ➢ Flow recording, data management | - Field assistant/ STP | 1.0 |
| | ➢ Irrigation schedule (manual valve adjustment) | - Field assistant/ STP | 1.0 |
| | ➢ Inspection (infrastructure - visual) | - Field assistant/ STP | 1.5 |

# 7 Monitoring: Ground Water & Drain Water

An intensive groundwater monitoring programme was established in early 2002, and was maintained throughout the period 2002 - 2005, by the team at Southern Cross University. The purpose of the programme was to measure groundwater physical & chemical characteristics, and to develop a data-base as a means of tracking long-term trends and changes. Groundwater information provides an opportunity to 'review management inputs', and in that context has been (and will continue to be) used to assess the effects of wastewater on a number of parameters e.g. groundwater depth, the stability of ASS, salinity levels, pH fluctuations, and the effect of these factors on *Melaleuca* survival.

At the time of writing, the monitoring programme, which was partly associated with ongoing research at SCU, has been completed. However, as part of the management process it is recommended that groundwater monitoring should continue, and that monitoring for Phosphorous in ground and drain waters also be included (see section 7.3)

## 7.1 Monitoring: parameters & locations

Routine monitoring was previously conducted on a weekly basis at forty one piezometer locations across the site (Figure 10). Data has been collected and stored in a central data-base for the following parameters:

- Water table height (WT) [collected by hand - all sites],
- Dissolved oxygen (DO),
- Electrical conductivity (EC),
- pH (pH),
- Redox potential (Eh), and
- Temperature (T °C).

### *7.1.1 Ongoing monitoring*

A total of four automated data-loggers (TPS 90-FLMV), based at four of the forty one piezometer locations listed in Figure 10, are currently used to record 'continuous' groundwater information. Data was collected manually from the remaining thirty seven piezometers, using a hand held data-logger (TPS 90-FLMV).

A minimum of five locations has been recommended for ongoing groundwater monitoring (Figure 10). It is further recommended that the full range of parameters is measured, a relatively simple procedure using the automated 90-FLMV data-logger.

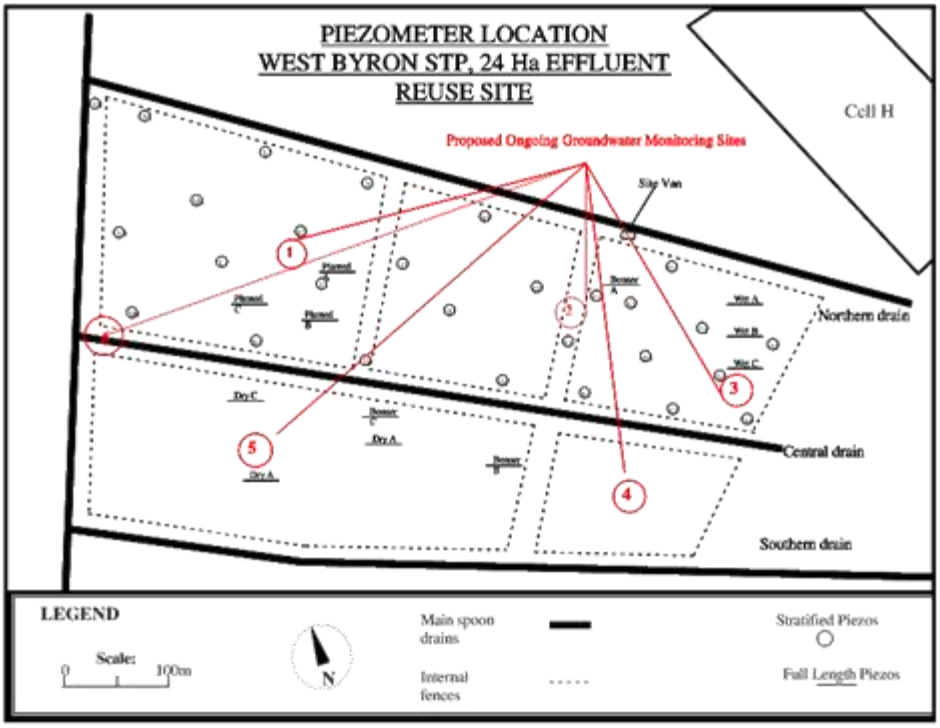


**Figure 10 Existing piezometer locations *Note:* In addition to the recommended monitoring programme, it is possible that further monitoring may be requested by the Department of Infrastructure & Natural Resources (DIPNR). At the time of writing no formal request or arrangement had been made.**

## 7.2 Equipment: 90-FLMV data-logger

Throughout the life of the groundwater monitoring programme, the TPS 90-FLMV has been the equipment in use: all units have performed well considering their location and high level of use. Four of the units are solar powered, the fifth requires occasional battery charging. We recommend continuing with the 90-FLMV whilst the units remain serviceable.

**Figure 11** **Data-logger 'in-situ' central weir; 2. probe location central weir; 90-FLMV 'key-pad and LCD display'.**

### *7.2.1 Operating the 90-FLMV*

The intention is that five data-loggers be placed in the locations described in Figure 10, where they will be set to automatically log data at a pre-set time interval (probably once each day). This will deliver background data from the selected areas, and will provide a general representation of conditions across the 24ha site. Each of the five data-loggers can also be used as a portable instrument - easily taken to areas of particular interest for 'one off' readings (e.g. pooling surface water) (Figure 12).

**Figure 12** **1. Piezometer 'head' in-ground; 2. One-off reading using 90-FLMV;**

*7.2.1.1 One-off reading*

The data-loggers are straightforward to operate and each unit comes with four attached sensors for measuring DO, pH, EC, Eh & temperature (the EC probe is a dual function sensor measuring both EC & temperature). A limited description of the operation of this unit is given here and the operator is assumed to have laboratory or field sampling training and experience. Taking a 'one off' reading requires the following steps:

1. remove storage caps and rinse sensor probes with distilled water,
2. insert all sensor probes into the water sample,
3. switch the unit to 'on' (there is a 30 second 'warm-up'),
4. the sensors need a gentle 'stirring' if the sample is still water,
5. allow the LCD display to stabilise (Figure 11) (this is important for DO & pH),
6. read from left to right on the LCD display for: DO (% saturation or mg/L), EC (uS/cm), pH (pH units), Eh (milli-volts), Temperature ($^{0}$C),
7. remove sensors from sample, rinse and re-cap for storage/ transportation,
8. switch off unit.

#### 7.2.1.2 *Water depth*

To gauge water table height, the piezometer cap is removed and water depth is measured from the 'lip' of the piezometer to the water surface. Each piezometer is calibrated so that the height above soil surface is known: data is then entered into MS Excel and corrected to indicate water table depth below soil surface. Water table height is measured weekly.

### 7.2.2 *Data: downloads & management (90-FLMV)*

Data downloading is required for all field data-loggers set for 'continuous logging'. Continuous logging is assumed to be the 'default' setting for this equipment, and a description of how to set the 90-FLMV to automatic data-logging modes will not be given.

Starting the automatic logger, if it has been disabled, requires four steps:

1. Switch unit on,
2. Press the menu button,
3. Select: Logger (F3),
4. Select: Start (F4).

The unit will now log data in a pre-set logging mode. Viewing the data 'log' is equally straightforward requiring four steps:

1. Switch unit on,
2. Press the menu button,
3. Select: Logger (F3),
4. Select: Recall (F1),
5. Use F2 & F4 keys to scroll through log record.

#### 7.2.2.1 *Download data to a Computer*

Data is recorded as periodic information and, depending on the time interval between logged records, the data-base can rapidly accumulate thousands of data points. Downloading large data-sets is done on a weekly basis using a laptop computer. The following is a brief description of the steps involved. Prior to attempting downloads, TPS software 'WinTPS: communication software for TPS Instruments' must be installed on the computer.

Steps 1 -7

1. Connect the 90-FLMV unit to the com port of the computer,
2. Switch on 90-FLMV,
3. Switch on computer,
4. Select from "Start" menu: "Programs": "WinTPS"
5. WinTPS download screen will appear; when TPS unit has been detected;
6. Select "Logged Data" from the menu, and wait for data transfer to complete;
7. Select "Save" from the menu, and save file to appropriate location.

* Note: The data will be saved as .prn or .txt or .csv file. To convert to MS Excel the data must be exported and saved as an .xls file. To do this:

1. Open MS Excel,
2. Select: File - Open,
3. Choose 'text files' from Files of Type pull-down menu,
4. Navigate to the stored data folder,
5. Select: 'fixed width' in the text import wizard,
6. Select: next, and check selected columns for correct values,
7. Follow prompts to finish.

The completed import to MS Excel will look like the example in Table 16 below. [water table height is generally added as an extra column to this data-set].

**Table 16 Example of MS Excel data table**

| Date | Time | DO (% sat) | EC (uS/cm) | pH | Eh (mV) | Temp (°C) |
|---|---|---|---|---|---|---|
| 19/12/04 | 06:00:00 | 1.5 | 1501 | 5.84 | -222 | 19.0 |
| 19/12/04 | 12:00:00 | 0 | 2444 | 4.27 | -184 | 17.2 |
| 19/12/04 | 18:00:00 | 10.1 | 925 | 4.95 | -167 | 17.4 |
| 19/12/04 | 00:00:00 | 14.7 | 924 | 4.21 | -106 | 17.4 |

### *7.2.3 Maintenance: 90-FLMV Data-logger*

Currently the project (SCU & BSC) has six TPS 90-FLMV data-loggers, four of which are permanently located on-site, and two extra units are available as a 'back up'. Although simple to operate, the units require regular calibration and occasional return-to-base servicing. Due to the technical nature of the calibration process it is recommended that only laboratory staff or staff trained in this procedure should carry out the calibration. Similarly, assessing the service requirements of the unit should be left to a trained technician.

### *7.2.4 TPS 90-FLMV: Manufacturer Contact Details*

Routine maintenance, beyond sensor calibration, should not be required. If the unit is faulty and servicing is required, this should be carried out by the manufacturer.
TPS contact details:

TPS Pty Ltd.,
4 Jamberoo Street,
Brisbane, 4127.
Phone (07)3290 0400
e-mail: tps@.tps.com.au

## 7.3 Monitoring Nutrients

Wetlands are good removers of nitrogen, and the nitrogen balance (input/ output) has not been found to be an issue at the 24ha site. However, phosphorous stability and the potential for stored phosphorous to leach from the 24 ha site has been raised by Bolton (2001) and Bonner (2003). The peat appears to have little phosphorus adsorption capacity and it is likely that future phosphorus storage in the wetland will take place as bio-accumulation of refractory organic material, rather than formation of metal-phosphate complexes.
Nevertheless, small quantities of phosphorous have accumulated, at the 24 ha site, as metal-phosphate complexes (iron and aluminium phosphates), and the stability of this phosphorous is unknown (Bonner 2003). Ongoing phosphorous monitoring is recommended, and water flowing through the Central drain should be routinely sampled and the results used as an 'early indicator' of phosphorous discharge from the site.

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### 7.3.5 *Summarised Actions*

**Table 17 Groundwater Management: Task Summary**

| Maintenance Issue | Action Required |
|---|---|
| **Groundwater & Drainwater** | |
| - Water table height | - Measure and record weekly at each of the five piezometer locations, plus boundary piezometers. |
| - Physico-chemical | - Download data weekly, at each of the five piezometer locations, from the 90- FLMV data-logger to laptop computer. |
| - Calibration | - Calibrate the sensor probes on the 90-FLMV weekly. |
| - Data management | - Maintain MS Excel database (or other as required): report as required* |
| - Phosphorous (P) | - Sample and analyse for total 'P' from Central V-notch weir: quarterly interval. |
| - Phosphorous (P) | - Sample and analyse for total 'P' from fixed piezo sites: Sample if trend shows 'P' increase over time. |
| | * pH is an ASS management (and possibly frog habitat) 'trigger'. Refer section 4. |

**Table 18 Groundwater monitoring: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Groundwater & Drainwater | ➢ Water table height | - Field assistant/ STP | 2:00 |
| | ➢ Physico-chemical | - Field assistant/ STP | 1:30 |
| | ➢ 90-FLMV Calibration | - Lab. Tech./ STP | 1:30 |
| | ➢ Repair | - Return to factory | as req'd |
| | ➢ Data management, reporting & trigger actions. | - EO, EHO, Lab.Tech | as req'd |
| | ➢ Water quality 'phosphorous' (sampling) | - Lab. Tech./ STP | |

## 8 Monitoring: Weather

An 'E Tech' general purpose, solar-powered, weather station was purchased from Environmental Instrument Technology (EIT) and installed at the 24ha site 31st July 2002 (Figure 13). The weather station was installed to provide a long-term data-base, and to supply detailed information that can be used for hydrological modelling. A wide range of environmental parameters are recorded by the weather station, and this data can be viewed using EIT computer software. Data is recorded as 'both periodic daily information', and 'summarised daily information', either of which can be viewed graphically using the supplied software or, alternatively, exported to a spreadsheet for further analysis.

The weather station has been operational at the 24ha site for 2½ years providing accurate on-site meteorological information: only a minimum of maintenance has been required since installation. It is recommended that the weather station data-base be maintained as part of the future assessment of water demand at the 24 ha site.

**Figure 13** **Weather Station 'in-situ' 24ha site.**

## 8.1 Data: downloads & management

A weather station data-base has been maintained by SCU staff. Weather station meteorological data is produced in two formats: either as daily composite (24 hr time interval) or periodic (15 minute time interval). An example of the parameters recorded as daily composite information is shown in Table 19.

**Table 19 Weather Station: Data Format 'Daily' Imported to MS Excel**

| Temp Min (°C) | Temp Max (°C) | Wind Speed (m/s) | Wind Direction (°) | Rainfall (mm) | Evapotranspiration (mm) | Solar Radiation (kJ/m2) |
|---|---|---|---|---|---|---|
| 10 | 19 | 48 | 330 | 0 | 6.6 | 150 |
| 8 | 18 | 11 | 310 | 0 | 4.0 | 140 |

Downloading data, from the weather station data-logger (Figure 14), is a relatively simple process which entails direct transfer to a lap-top computer. The download process requires that the appropriate software, supplied by Environmental Instruments Technology, be installed on the lap-top computer (see attached CD). A maximum 1 month download interval is recommended.

The data-logger is mounted inside a waterproof enclosure, and access is via the front panel which opens to reveal the data-logger, weather station sensor connectors, and a 12v DC battery (Figure 14). The following steps should be followed for monthly data-downloads:

1. Connect data-logger cable to laptop via computer com-port.
2. Turn on computer.
3. Open 'Etech' programme.
4. Either select 'green phone icon' (top right hand screen), or 'Communications' – connect.
5. Select: Online – Retrieve 'daily data', follow prompts to save in desired location.
6. Select: Online – Retrieve 'periodic data', follow prompts to save in desired location.
7. On completion of download, select either, 'red phone icon' (top right hand side screen) or 'Communication' – disconnect.

* Note: The data is saved as a .dbf or db file. To convert to MS Excel the data must be exported and saved as an .xls file. To do this:

8. Select: File – Export Data.
9. Follow prompts and select the .dbf file for export.
10. Follow prompts to name and specify file location: Remember to change file format to .xls.

**Figure 14** **Weather Station: Control Panel & Data-Logger – access point for data download.**

## 8.2 Routine Maintenance

The 'E Tech' station requires little in the way of maintenance, nevertheless some 'house keeping' is recommended by the manufacturer. This can usually be included as an adjunct to the data-download schedule, and includes the following tasks (refer Figure 15):

1. Check solar panel for visible damage (e.g. cracks) – clean if dirty.
2. Check wind-sensor movement and spray with WD 40 (3 monthly).
3. Rain gauge can be tested by pouring a known quantity of water through the funnel.
4. Solar radiation sensor – requires factory/ specialist calibration (bi-annual or if damaged / malfunctioning).
5. Temperature and relative humidity sensor – requires factory/ specialist calibration (bi-annual or if damaged / malfunctioning).


**Figure 15** **'Business End' of the 24ha Weather Station, showing the five sensors.**

### *8.2.1 Weather Station: Manufacturer Contact Details*

Beyond the requirement for routine maintenance, EIT recommend that the unit is inspected and serviced at two yearly intervals.

EIT contact details:

Col Peak (Manager)

Phone 6628 3400;

e-mail: peak@eitechnology.com.au

### *8.2.2 Summarised Actions*

**Table 20 Weather Station Task Summary**

| Maintenance Issue | Action Required |
|---|---|
| **Weather** | |
| - Data collection | - download monthly to laptop computer. |
| - Data management | - maintain record in MS Excel data-base (or other as required) |
| - maintenance | - monthly: check solar panel for dirt & cracks; check wind-sensor & spray WD40; test rain gauge by pouring water into rain funnel.<br>- factory service every two years |

**Table 21 Weather Station Maintenance: Skills Required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Weather | ➢ Data download | - Lab.Tech./ EHO/ EO/ Field Tech./ STP Staff | 0.15m |
| | ➢ Data management | - Tech. staff/ EO / EHO | 0.15 m |
| | ➢ Maintenance | - monthly: Lab.Tech/ Field Tech./ STP Staff | 0.15 m |
| | | - bi-annual: Factory Tech. | n/a |

# 9 Biodiversity Management Plan

[Reference: *Biodiversity Management Plan for the Byron Bay Sewerage Augmentation Scheme*, ERM, 2004]

***Biodiversity: a definition***

Biodiversity refers to the variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form. Human beings are dependent for their sustenance, health, well-being and enjoyment of life on fundamental biological systems and processes. Humanity derives all of its food and many medicines and industrial products from the wild and domesticated components of biological diversity. (DEST, 1993).

## 9.1 Biodiversity Management Plan: Scope

Environmental Resources Management Australia (ERM) have prepared a flora and fauna Biodiversity Management Plan (BMP) for the land within, and surrounding, the West Byron STP. The BMP applies to a total land area of 102.8 ha, and goes beyond the scope and purpose of this document. The purpose here is to provide an overview of the recommended management actions and guidelines as they apply to the 24ha *Melaleuca* wetland. Detailed descriptions of management guidelines, background studies, flora & fauna, and NPWS concurrence conditions, particularly where they apply to construction activities and/ or areas beyond the boundaries of the 24ha site, will not be discussed in this document. The reader is directed to the main BMP document for a more detailed analysis.

Several points should be noted in regard to biodiversity management on the site:

1. While several species may lose habitat as a result of Paperbark planting in the Ghania sedge land, others are likely to benefit from this activity. Species that could experience a positive impact as a result of changes to the 24 ha *Ghania* sedge land

include: Queensland Blossom Bat; Grey-headed Flying fox; Black Flying Fox; Other insectivorous bats; Long-nosed Potoroo; and Common Planigale.

2. Base-line assessment for flora and fauna for the proposed BMP (ERM, 2004), appears to be that of the original species impact statement (ERM, 2001). The 24ha site has changed considerably since that survey, and at least some of the species recorded would have been affected by the slashing, ripping and *Melaleuca* planting that has occurred throughout the site during that period.

3. It is recommended that a current flora & fauna assessment* of the 24ha site be conducted in order to establish base-line data from which species-specific management decisions can be made with more confidence i.e. when accurate base-line data becomes available, we can better determine how to manage it. [This assessment* is likely to occur as part of the Management Impact Verification Plan (MIVP)]

### *9.1.1 Strategic Context of Biodiversity Management*

Strategic biodiversity planning objectives for the site to which the ERM BMP applies are as follows:

- to protect the remnant native vegetation within natural areas as self-sustaining ecological systems, retaining as far as possible locally indigenous plants and animals;
- to maintain the scenic, scientific, educational, aesthetic, and heritage values of natural areas;
- to provide Council, contractors and community groups with detailed management guidelines to reduce potential impacts on communities present within the site;
- to prevent disturbance to native flora and fauna communities with particular regard to threatened species;
- to prevent the occurrence of key threatening processes on the property;
- to prevent degradation of natural areas, minimise physical disturbance to land, and restore degraded land;

- to promote, foster awareness of and support for the management of natural areas, and to encourage community involvement;
- to maintain important visual and habitat corridors; and
- to promote research and monitoring of natural areas to document their significance and improve management practices.

### *9.1.2 Biodiversity Management: Main Objectives*

The primary objective of the BMP is to develop and manage the site in a way that protects and where possible enhances its natural values. The dominant purpose of biodiversity management is therefore to protect and maintain the natural ecosystems that are present on the land.

#### *9.1.2.1 Subsidiary objectives of the BMP are:*

- to inform Council staff and the community of the way in which the site is to be managed with respect to the protection of flora and fauna communities;
- to achieve the specific objectives and works identified in the plan;
- to maintain, and where appropriate, improve the values of the land, and to minimise the long-term maintenance costs;
- to provide a data bank for information relevant to present and future management of the land;
- to establish an administrative structure that ensures achievement of the objectives of this plan;
- to identify the major management issues applying to the land;
- to provide for the plan's periodic review; and
- to simplify the process of management as far as possible.

## 9.2 Biodiversity at the site

The site currently affords important habitat for native flora and fauna including a range of threatened species. The site supports natural and semi-natural habitats of conservation value and is discussed in Chapters 5 and 6 of the Species Impact Statement (SIS) (ERM 2001). The BBSAS will entail clearing and modification of some habitats on the site and compensatory habitat has been provided on the site for particularly vulnerable species*. Mitigation measures outlined in the main BMP aim to offset any potential impacts that may occur during the construction and operational stages so that the health, diversity and productivity of the communities present on the site are maintained and preserved.

***Note: compensatory habitat***

In compliance with NPWS concurrence condition #12 for the *Melaleuca* Regeneration Project, Byron Shire Council (BSC) has assigned 8.1 ha of the site in the north west corner to be habitat for the Eastern Grass Owl, Wallum Froglet and the Wallum Sedge Frog. This area, once defined, will be rezoned as an appropriate environmental protection zone in accordance with Council zoning plans.

### *9.2.1 Fauna*

For the purposes of this document, threatened species are those listed in the schedules of the *Threatened Species Conservation Act 1995,* and/or the *Environment Protection and Biodiversity Conservation Act 1999.*

ERM (2001) identified fourteen endangered and/or vulnerable fauna species within the greater West Byron site, five of which occur at the 24ha site and are likely to be impacted by the BBSAS. A list of these species and habitats in which they were encountered is given in Table 22., and targeted mitigation measures have been designed for these species (see section??).

**Table 22 Endangered species: 24 ha Site (Fauna)**

| COMMON NAME | SCIENTIFIC NAME | STATUS | Location/Habitat Type |
|---|---|---|---|
| **Frogs:** | | | |
| Wallum Froglet | *Crinia tinnula* | V (TSC) | 24ha Ghania sedge lands, Grassland/Sedge lands (north-west and east) |
| Wallum Sedge Frog | *Litoria olongburensis* | V (TSC)<br>V (EPBC) | Grassland/Sedge lands (north-west and east) |
| **Birds:** | | | |
| Grass Owl | *Tyto capensis* | V (TSC) | Overhead in SW sedge land (24ha) |
| **Insectivorous Bats:** | | | |
| Large-footed Myotis | *Myotis macropus* | V (TSC) | 24ha Ghania sedge land, Open Ponds, Paperbark Ponds, Typha |
| Little Bentwing Bat | *Miniopteris australis* | V (TSC) | 24ha Ghania sedge land Open Ponds, Paperbark Ponds, |

E - Endangered species listed under Schedule 1 of the TSC Act 1995.
V - Vulnerable species listed under Schedule 2 of the TSC Act 1995
V - Vulnerable species listed under the EPBC Act 1999

### *9.2.2 Flora*

Despite a history of disturbance at the site, the area supports a large number of native plant species. There are six major vegetation types found on the West Byron site. Table 23 describes the features of the five of vegetation types within or adjacent to the 24ha regeneration site. A vegetation map is shown in Figure 16.

**Table 23 Vegetation Communities within/ adjacent the 24ha Site**

| Vegetation Community / Habitat Type | Description |
|---|---|
| 24ha *Melaleuca* regeneration area. | Prior to planting with *Melaleuca* this area was dominated by Saw Sedge (*Ghania sieberana*) and was cleared for agriculture during the 1970s. Historically this area would likely have formed part of the Swamp paperbark forest, found in the adjacent SEPP 14 (No. 75)<br>The 24ha *Ghania* sedge land community has formed partly as a result of natural succession and partly due to the effluent water from West Byron STP. |
| Paperbark Forest SEPP14 Wetlands No. 75 [Northern Boundary to 24ha] | Paperbark Forest is present within SEPP 14 area (75) and along the margins of some of the constructed wetland within the West Byron STP.<br>Within the SEPP 14 (75) the understorey is dominated by Saw Sedge (*Ghania sieberana* ) and ferns including Swamp Water Fern (*Blechnum indicum*) and Batswing Fern (*Histiopterus incisa*). |
| Regenerating Shrubland/ Fernland [Northern Boundary to 24ha] | An area of regenerating Shrubland/ Fernland exists between Cell H, the 24ha area and the SEPP 14 (75). This area has a dense covering of shrubs and ferns with some scattered Paperbarks. The regenerating Shrubland/ Fernland is dominated in parts by species such as Batswing Fern (*Histiopterus insisor*), *Aotus ericoides*, and *Ochrosperma lineare*. Scattered Paperbarks *Restio tetraphyllus* and *Ghania sieberana* are also present within this community. |
| Cumbungi (*Typha orientalis*) Wetland [Eastern boundary to 24ha] | This community dominates approximately 6 ha of the Wetlands adjacent to the Saw Sedge Community, and is in close proximity to the V-notch outlet where the effluent is released. Clearing and alteration to the drainage patterns have created the existing *Typha* wetlands.<br>Species diversity within the *Typha* is lower than that within the Saw sedge Sedge-land and is dominated by a few species including the native Swamp Water Fern (*Blechnum indicum*) and the significant weeds Groundsel (*Baccharis halimifolia*) and *Azolla filiculoides* |

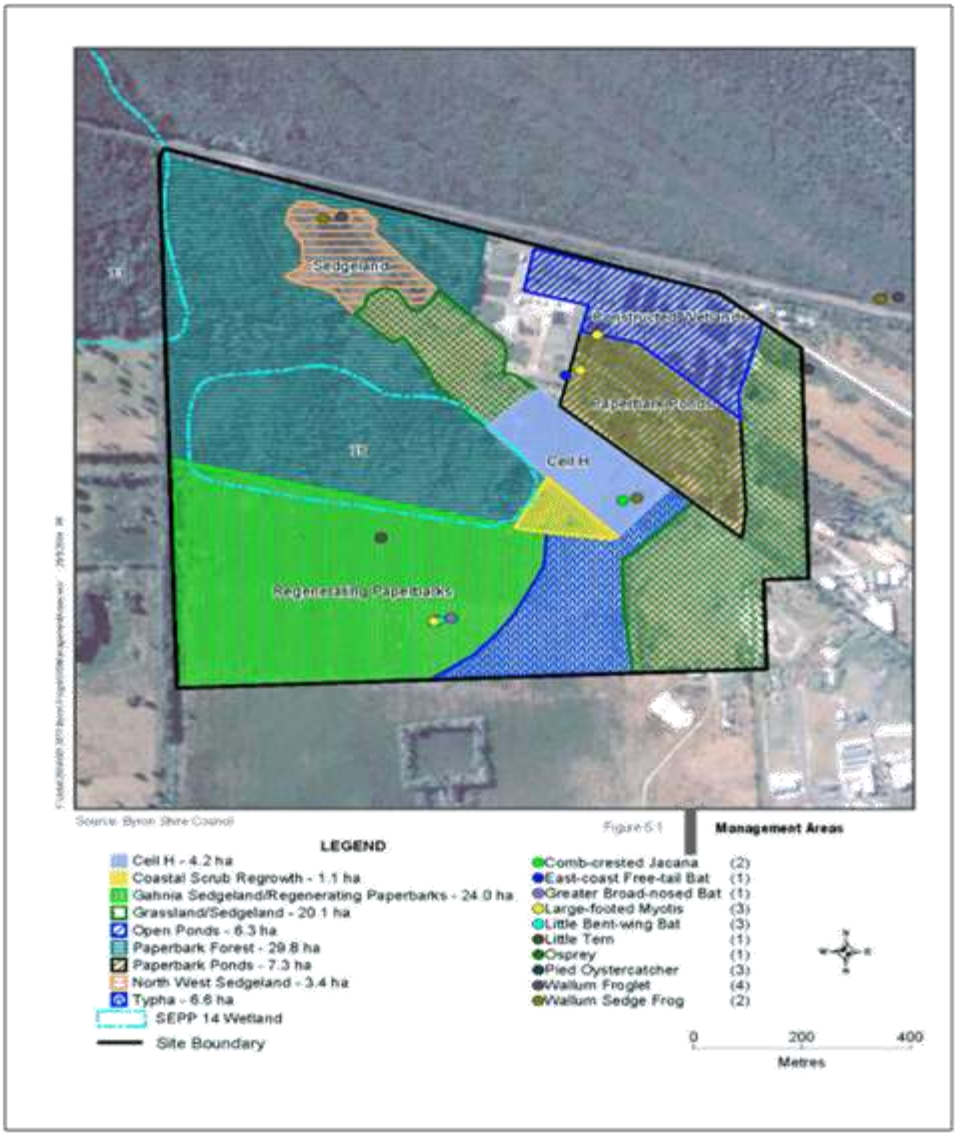


**Figure 16** **24 ha Vegetation Map**

## 9.3 Specific Issues, Impacts & Management

### *9.3.1 Melaleuca regeneration & changes to hydrology*

Within the 24ha sedge land area, the Ghania and associated plants have been altered both by irrigation and by planting of Swamp Paperbark (*Melaleuca*). This change in habitat will impact on the Wallum Froglet and Eastern Grass Owl. *Melaleuca* regeneration will reduce the area of sedge lands, reducing foraging and possible nesting sites for the Eastern Grass Owl. Further to this there is also likely to be habitat reduction for both the Wallum Froglet and Wallum Sedge Frog, and to a lesser extent the Long-nosed potoroo and Common planigale (ERM, 2001). Slashing within the sedge land, and installation of the irrigation pipe network have a direct and immediate effect on this habitat.

Whilst changes in management of the hydrology in the area are occurring, the impacts on the Grass Owl and Wallum Froglet habitat are likely to occur indirectly as a result of the changes in vegetation in the area, rather than changes in the hydrology as such.

*Management*

- Compensatory habitat has been provided for the Eastern Grass Owl, Wallum Froglet and the Wallum Sedge Frog (8.1 ha of the site in the north west corner of the 108 ha STP site). Provision will be made to manage habitat areas in the North-West sector for the Eastern Grass Owl, Wallum Froglet and Wallum Sedge Frog to compensate for habitat lost by planting and irrigating *Melaleuca*.

- The indirect impacts of clearing for *Melaleuca* planting have been minimised, as far as practicable, by slashing only part of the 24ha area on any given day. Slashing is not permitted during the breeding season of the Eastern Grass Owl (Feb –Aug).

- Upgrading the existing irrigation infrastructure is likely to temporarily impact on the existing vegetation, the *Melaleuca*, and threatened species habitat. Care should be taken to prevent damage and disturbance to existing vegetation. Further clearing/ slashing of the site must not be carried out except where approvals have been sought.

Fill material obtained from other sites shall be avoided where possible. Off-site soil material may only be used where it has a minimal weed content, and measures are to be taken to minimise the compaction of soil by heavy machinery.

## 9.4 Management Guidelines

Management guidelines take into account the BMP's primary objective, that is, to manage the site in a way that protects its natural values. This requires consideration of the following specific issues:

1. biodiversity conservation;
2. vegetation management & weeds
3. fauna;
4. bushfire;
5. streams, wetlands & stormwater management;
6. works & infrastructure;
7. activities & maintenance;
8. pollution control;
9. access & occupation; and
10. administration.

In order to determine whether an action is likely to have a significant impact, it is necessary to take into account the nature and magnitude of potential impacts. A limited 'issue and action/ avoidance' table has been prepared for items 1 - 6, and 8 - 10, above (Table 24).

### *9.4.1 Summarised Actions*

**Table 24 Conservation: Task Summary**

| Issue | Action/ Avoidance Measures |
|---|---|
| **1. Biodiversity Conservation** | Proposed activities should be compliant with: CC & EMS |
| Fragmentation of natural areas | Measures are to be taken to avoid fragmentation of vegetation in natural areas by roads, tracks, services, etc. Natural areas should be retained in contiguous areas as large as possible, with the minimum length of perimeters. |
| Vulnerable species | At all times staff will avoid actions that will:<br>– lead to a decrease in the size of an important population of a species, or<br>– reduce the area of occupancy of an important population, or<br>– fragment an existing important population into two or more populations, or<br>– adversely affect habitat critical to the survival of a species, or<br>– disrupt the breeding cycle of an important population, or<br>– modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline, or<br>– result in invasive species that are harmful a vulnerable species becoming established in the vulnerable species habitat, or<br>– interferes substantially with the recovery of the species. |
| **2. Weeds** | Proposed activities should be compliant with: CC, EMS & WMP |
| Weed management | See Chapter 8 (this document) or refer Bower (2004) |
| **3. Fauna** | Proposed activities should be compliant with: CC & EMS |
| Threatened or native fauna | – Activities undertaken on the site shall be carried out in a manner that ensures that such animals are not adversely affected by the activity. |
| **4. Bushfire** | |
| Bushfire management plans | Where appropriate, specific parcels of Council land are to have a fire management plan (FMP) prepared and adopted.<br>Proposed activities should be compliant with: CC, EMS & BMP |

| Issue | Action/ Avoidance Measures |
|---|---|
| Bushfire hazard reduction | – To be undertaken where there is an identified high hazard to buildings or other improvements on the site or on surrounding land.<br>– Hazard reduction programs are to include an adequate environmental assessment, and are to be implemented in a manner that protects the biodiversity |
| **5. Wetland management** | Proposed activities should be compliant with: CC & EMS |
| Filling and draining | – Reclamation, filling, slashing, draining or other works that results in any loss of, fragmentation of, or disturbance to wetlands or other associated natural habitat can only be carried out with approval.<br>– The fauna habitat value of wetlands and associated surrounding natural areas is to be maintained, and where possible, enhanced. |
| **6. Works & infrastructure** | Proposed activities should be compliant with: CC, EMS, BMP, WMP, MIVP, FMP, FAMP. |
| Protection of trees | Measures are to be taken to prevent damage and disturbance to tree roots by cutting of roots, loss of water, soil compaction or build up of soil. |
| Clearing | Further clearing of bushland on the site must not be carried out except where approvals have been sought. |
| Filling | Fill material obtain from other sites shall be avoided where possible. Off-site soil material may only be used where it has a minimal weed content. |
| Soil compaction | Measures are to be taken to minimise the compaction of soil by heavy machinery, such as by fencing off undisturbed vegetation |
| **9. Access & occupation** | Proposed activities should be compliant with: CC, EMS, BMP, WMP, MIVP, FMP, FAMP. |
| New roads | The BMP does not authorise the construction of new roads, or the substantial realignment of existing roads. |
| Four wheel drive access | Only where there has been historical use, and such access is specifically permitted. |
| Track construction | Walking tracks are to be constructed and located so as to ensure minimal erosion and soil loss and reduce maintenance requirements. |
| Track closure | Non-essential tracks, or other roads and tracks that are poorly located and those that represent an erosion hazard may be closed. |
| Fencing | May be constructed to restrict access or to protect sensitive areas. Fences are to be constructed in accordance with any adopted standards or guidelines and as provided for in the *Dividing Fences Act 1991*. |
| Illegal access | Measures are to be taken to cease or prevent any unauthorised access across the |

| Issue | Action/ Avoidance Measures |
|---|---|
| | land. |
| **10. Administration** | Proposed activities should be compliant with: MIVP |
| Environmental information | A database of environmental information of relevance for management should be established and maintained. Key components would include information on the presence of plant and fauna species, plant communities, bushfire history and weeds. |
| Environmental monitoring | Periodic environmental monitoring of important environmental indicators is desirable to establish changes or trends, and should be undertaken, especially in relation to water quality. |

**Table 25 Conservation: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Conservation | - Weeds | Bush Regeneration; Weed Control. | As Required |
| | - Flora & Fauna | - Ecology; Bush Regeneration; Environmental Management. | |
| | - Wetland Management | - Ecology; Environmental Management. | |

## 10 Weed Control

[Reference: *West Byron Sewerage treatment Plant Weed Management Strategy*, Bower Bush Works, 2004]

Comprehensive vegetation survey and mapping was undertaken by Bower Bush Works, during 2004, to determine the status of native plant communities and the extent of weed species throughout the West Byron STP site. As a consequence of that study, a weed management strategy has been proposed that will help to control the occurrence of environmental weeds at the site. The management strategy, in the main document, covers both natural ecosystems and operational areas; the scope of this current document is limited to the 24ha *Melaleuca* wetland, referred to as 'Zone 4' in the main weed management document.

**Weed Management Aim:**

- The aim of this Strategy is to identify and control weeds, to control serious weed threats and to promote the restoration of the native vegetation and habitats present on site.

**Weed Management Objectives:**

- To control noxious weeds and prevent their spread.
- To control isolated infestations of major environmental weeds.
- To carefully control weeds through each weed management zone utilising an ecological restoration approach.
- To control weed invasions before they become a problem, and to reduce future weed invasions by promoting and maintaining healthy vegetation condition.
- To eradicate weeds from native plant communities.
- To rehabilitate degraded plant communities by promoting natural regeneration or in areas with low recovery potential assisting site recovery through planting.

- To utilise weed control measures that are appropriate in proximity to threatened species and their habitats.
- To protect and enhance the viability of fauna habitats.
- To prevent the colonisation and spread of problem weeds that may affect operational areas and associated infrastructure or native ecosystems.

## 10.1 Weed Description & Categorisation

A weed was defined, in the main report, as an introduced or exotic plant that is not endemic or naturally occurring at the site, and includes native plants that occur beyond their natural range or habitat. The level of threat or problem caused by weeds is determined by a species growth characteristics and habitat requirements, dispersal mechanisms and ability to invade native habitats or impact on agricultural activities. Weed infestations if left unchecked will spread and further compromise the values of the site, and may require greater control effort in the future. Targeted control of noxious and major environmental weeds and strategic weed control incorporating the regeneration of disturbed vegetation and weed prone areas are proven strategies to control weed infestations and reduce future invasions.

Weeds occurring at the site are recognised under the following categories:

- Noxious weeds
- Weeds of regional significance
- Environmental weeds
- Wet area/ aquatic weeds
- Weedy native species

### *10.1.1 Noxious Weeds*

Two 'declared' noxious weeds were recorded from the 24ha site. A declared noxious weed is a species that is listed under the *Noxious Weed Act* 1993 (Main Report - Section 5/ Appendix 6) and is required to be controlled (Main Report - Section 4/ Appendix 3). Species

listed in the Far North Coast Weeds Authority control area for Byron Shire that are located the site include Groundsel Bush *Baccharis halimifolia*, and Crofton Weed *Ageratina adenophora*.

Groundsel Bush is listed as a noxious weed, but is also recognised a weed of regional significance, and a major environmental weed. The North Coast Weeds Advisory Committee: Regional Weed Management Plan, for this species, recognises that untreated Groundsel Bush is expected to dominate the understorey of most coastal forests and SEPP14 wetlands (NCWAC 2004).

### *10.1.2 Environmental weeds*

At least eight species of weeds recorded at the 24ha site are considered as environmental weeds (see Table 26). An environmental weed is recognised as a plant that has the capacity to invade native ecosystems, out compete and displace native plant species, modify plant community structure and habitat viability. The main occurrences of environmental weeds have been mapped as woody weeds and non-woody weeds (Main Report - Section 2). Groundsel Bush *Baccharis halimifolia*, Camphor Laurel *Cinnamomum camphora*, Slash Pine *Pinus eliottii*, and Setaria *Setaria sphecelata,* will be a problem on site due to their presence as reproductively mature plants or are established on adjacent tenure.

### *10.1.3 Weeds of regional significance*

Weeds of regional significance are those that are either noxious or environmental weeds and require coordinated control (NSW NCWA 2003). Two species of regionally significant weeds are recorded on site including: Camphor Laurel, Groundsel Bush, (NSW NCWA 2003). Additional species such as Broad-leaved Pepper Tree *Schinus terebinthifolia* and Glory Lily *Gloriosa superba*, which are proliferating in Byron Bay, are over time likely to be dispersed on the site. Early intervention of newly emerging weeds on site is advised.

### *10.1.4 Aquatic weeds*

Aquatic weeds occur as either emergent or submerged plants, which can invade the beds and banks of drains, wetlands and waterways. Many terrestrial weed species are also able to invade semi-aquatic habitats colonising areas of slight 'micro' elevation above the water level, or poorly drained sites.

Weed species of concern to aquatic habitats of the 24ha site include Setaria Grass *Setaria sphecelata*, Paspalum *Paspalum urvillei*, Cuphea *Cuphea carthaginensis*, and Parrots Feather *Myriophyllum aquaticum*. Cuphea is a species that colonises poorly drained flats and ditches and has the potential to out compete native herbs and sedges and may potentially modify feeding stratum for wading birds. Wet areas should be periodically checked for aggressive exotic aquatic weeds as they can be introduced to the site by birds and machinery.

### *10.1.5 Native species as weeds*

There are a number of native terrestrial and aquatic plants that colonise various wetland habitats, which may be problematic to the maintenance of constructed wetlands, drains and fauna habitat. Such species may require strategic control in some instances. For example the *Ghania* spp. has been found to compete with planted *Melaleuca* in the 24ha site however, a dense cover of Ghania provides important habitat and will minimise the establishment of other weeds such as Groundsel Bush. Native species that have the potential to exhibit weed characteristics in certain conditions pose management issues that must be carefully considered.

## 10.2 Weed Infestation

Of the 76 species of weeds, from 30 families, recorded across the STP site, eleven species were recorded on the 24ha *Melaleuca* Wetland. These are listed below in Table 26 (see photographs Figure 17). Most weeds in this zone are associated with soil disturbance and deep ripping for *Melaleuca* planting.

**Table 26 Common and/or environmental weed species**

| Botanical Name | Common Name | *Category* |
|---|---|---|
| Ageratina adenophora | Crofton Weed | N(W3), WA |
| *Axonopus compressus* | Carpet Grass | E |
| *Baccharis halimifolia* | Groundsel Bush | N(W2), WA |
| *Cinnamomum camphora* | Camphor Laurel | E |
| *Cirsium vulgare* | Spear Thistle | E |
| *Cuphea carthagenensis* | Cuphea | E, A |
| *Drymaria Cordata, subsp. diandra* | Tropical Chickweed | |
| *Erechtites valerianifolia* | Brazilian Fireweed | D,WA |
| *Paspalum urvillei* | Vasey Grass/ Paspalum | E,WA |
| *Pinus eliottii* | Slash Pine | E |
| *Setaria sphacelata* | Setaria/ Sth. African Pigeon Grass | E, WA |

Weed Codes: E-Environmental, N-noxious (W - category), D- weed of disturbed open areas, WA- wet area coloniser (inc. edges), for noxious weed categories see Section 4.

- Annual weeds favouring moist habitats are prevalent throughout site (e.g. Brazilian Fireweed, Thistle), however these will decline with the establishment of a *Melaleuca* canopy. Dense ground weeds in this zone are associated to soil disturbance from deep ripping for tree planting.
- Woody weeds such as Slash Pine and Camphor Laurel occur sporadically along fence lines.
- Groundsel Bush tends to be widely scattered occurring as seedlings to shrubs. It is more common however towards the central southern section of the 24ha site but is also scattered throughout the eastern section.

- Setaria is common along tracks through the zone and on drains to the north and south of the 24ha site.
- Crofton Weed occurs sporadically – more common near drains and in association with high water tables, mainly on the eastern portion of the site.
- Cuphea is scattered through the area but is likely to be shaded out by native vegetation.

### *10.2.1 Weed Management: main issues*

- LEP zoning - legislative requirements (Appendix 5, main document).
- Spread of Groundsel Bush.
- Spread of Slash Pine throughout site from plants on site and infestations on neighbouring land.
- Spread of Setaria and Crofton Weed.
- Weed establishment on tracks and fence lines, and spread of weeds from drain edges.
- Acid sulphate soils.
- Typha and Common Reed were considered as unfavourable competition to recently planted *Melaleuca*.
- Target control of these species had been undertaken to assist the establishment of *Melaleuca*.
- However, with prevailing site conditions and their potential benefits in the uptake of treated effluent these species are not considered as an issue.

### *10.2.2 Required Actions*

Management zones have been 'generally' prioritised, based on weed species issues, habitat vulnerability and general condition of vegetation - the 24ha regeneration area has been categorised as high priority. Weed management issues and personnel responsibilities are listed (see summary of actions 3.3.2. main document).

The systematic control of weeds within native vegetation areas is required utilising a bush regeneration approach involving both primary and follow-up weed control, planting (where required), until native vegetation recovers to a degree that deflects weed invasions. Areas

that have received initial weed treatment should be provided with ongoing follow-up to prevent the re-infestation of weeds. Higher priority weed issues have been noted in the summarised actions - Table 27. Details of weed control techniques are listed in Appendix 3 – Section 4, of the main document.

**Table 27 Weed Management: Summarised Actions**

| 1.Target weed control | Priority | Timeframe |
|---|---|---|
| ➢ Ensure control of Groundsel Bush before seeding (before February) and spot control Crofton Weed (before July) prior to seed set. Control weeds simultaneously. | Very high | Ongoing |
| ➢ Control Groundsel Bush infestation on eastern edge of council's 40 ha south of the site, in drainage lines and vegetation edges. | Very high | Ongoing |
| **2. Weed control/vegetation restoration** | | |
| ➢ Systematically control environmental weeds through the zone. | High | Medium |
| ➢ Follow-up control weeds as required. | High | Medium |
| 1. Establish plantings on edges of fence lines and drains to reduce weed invasions and to shade out Setaria, over the long term. | Moderate | Short |
| 2. Regularly slash tracks supporting Setaria Grass. Spot spray re-growth shortly after slashing or trial use of slasher with wick-wiper attachment. | Very High | Ongoing |
| 3. Promote the development of native ground covers and less invasive grasses on tracks. | Very High | Ongoing |
| **3. Fencing** | | |
| 4. Decommission wallaby fences after *Melaleuca* are adequately established to improve access for weed management and wildlife movement. | Medium | Short |
| **4. Monitoring** | | |
| 5. Routine monitoring is required to determine the success, and need for follow up management, of the weed management programme (refer pages 16-17 main doc.) | | Ongoing |

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**Table 28 Weed Management: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Weed Control | - Monitoring<br>- Weed control<br>- Native plant restoration | - Ecologist<br>- Bush regenerator<br>- Bush regenerator | refer main doc. |

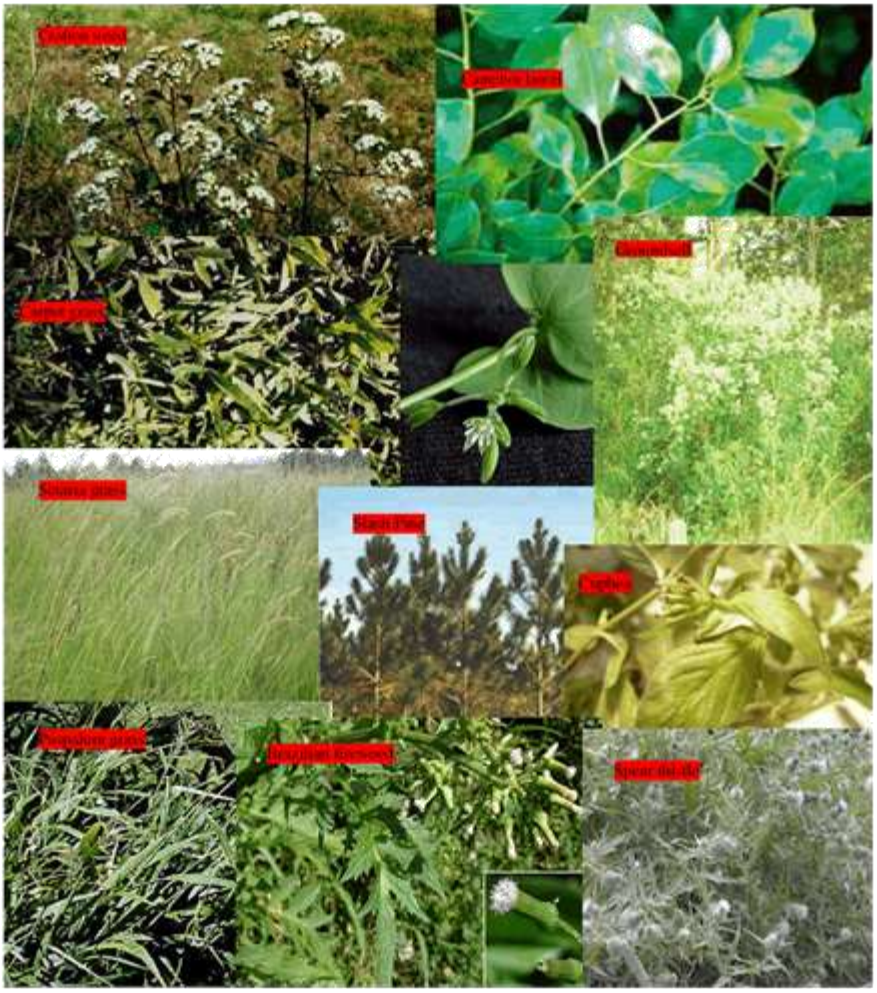

**Figure 17** **Weed species found at 24ha site. [Photo source: various]**

## 11 Feral Animal Control

[Reference: *Feral Animal Management Plan: West Byron Sewerage Treatment Plant*, Aspect North, 2004]

A comprehensive fauna survey was undertaken by ERM as part of the Environmental Impact Assessment for the Byron Bay Sewerage Augmentation Scheme, during 2001. That study identified that a number of feral animals are either known to occur, or are likely to occur, on the site of the West Byron STP. Feral species identified as occurring at the site and/or in the vicinity of the site include the Fox (*Vulpes vulpes*), Dog (*Canis lupus familiaris*), Feral Cat (*Felis catus*) and Cane Toad (*Bufo marinus*).

The impacts of feral animals that are of primary concern within the area of the WBSTP are related to their predation of, and competition with, native species - particularly threatened species. Feral pest species prey on native wildlife including mammals, avifauna, reptiles and amphibians and/or compete with native wildlife for food (RPLB, 2001). It is likely that feral animals on the 24 ha site will:

- Compete with native animals for food and shelter;
- Prey upon native animals;
- Degrade natural environments, damaging vegetation which is the habitat and food source of native animals.

A diversity of strategies exists for the control of the various pests, occurring at the site, and these strategies have been reviewed, with recommendations, in the main document. The scope of this document has been limited to provide an overview of the problem, and some description of control strategies.

## 11.1 Feral Animals: Legislation, Potential Impacts, Control Options

The management of feral pests in NSW requires the consideration of relevant legislation and associated strategies, and those considered relevant to the site are listed below.

**State Legislation and Associated Planning Instruments:**

- Threatened Species Conservation Act 1995 (TSC Act);
- NSW Fox Threat Abatement Plan;
- National Parks and Wildlife Act (1974) NPW Act;
- Environmental Planning and Assessment Act 1979 (EP&A Act);
- Local Government Act 1993 (LG Act);
- Pesticides Act 1999;
- Rural Lands Protection Act 1998 (RLP Act); and

**National Legislation and Associated Planning Instruments:**

- Environmental Protection and Biodiversity Conservation Act (EPBC Act)
- Commonwealth Fox Threat Abatement Plan.

The main objective of the TSC Act is to conserve biological diversity by encouraging the recovery of threatened species, populations and ecological communities so that their long-term conservation can be assured. One of the key methods provided in the TSC Act, to achieve the goal of species conservation, is the listing of 'key threatening processes'. A given process is eligible to be listed as 'key threatening' if it is considered by the NSW Scientific Committee that it:

a) Adversely affects two or more threatened species, populations or ecological communities; or
b) Could cause species, populations or ecological communities that are not threatened to become threatened.

Predation by the European Red Fox and the Feral Cat are listed as a 'key threatening process' under the TSC Act (NPWS, 2001). The Red Fox is the only animal for which the NPWS has created a threat abatement plan and, although the NPWS has not developed a threat abatement plan for the feral cat, a national plan does exits.

### *11.1.1 Impacts & Control Options*

#### *11.1.1.1 Red Fox Impacts*

As foxes are know to occur in urban, agricultural, natural and semi natural areas it is likely in the case of the West Byron STP that individual animals would roam between the neighbouring Tyagarah Nature Reserve and private land into the area of the subject site.

The fox is an opportunistic predator and scavenger with no prescribed diet or specialised food requirements, and is known to prey upon a diversity of native fauna species. Evidence of impacts is greatest for medium sized ground dwelling and semi-arboreal mammals, ground-nesting birds and chelid tortoises. These impacts are potentially intensified in areas of minimal understorey. Threatened species known to occur at the 24 ha site that represent potential prey for the Red Fox, are:

- Grass Owl
- Long-nosed Poteroo
- Wallum Froglet
- Wallum Sedge Frog

#### *11.1.1.2 Red Fox Control*

The options currently available for the control of foxes are as follows:

- Trapping;
- Poisoning;
- Shooting;
- Control of food supply; and
- Exclusion fencing.

The preferred methods of control for foxes occurring at the WBSTP are **poisoning**, **trapping** and/or **exclusion fencing**. However, these methods themselves have limitations in the context of the STP and these limitations are described in the main document.

*11.1.1.3 Feral Cat Impacts*

It is likely that most cats occurring on the site are domestic animals originating from the surrounding urban and agricultural areas. Additionally, there is a Council animal pound neighbouring the subject site and there is potential for unwanted animals to be dumped in the vicinity of this facility thus potentially increasing the occurrence of cats in the area of the STP.

Feral cats are carnivorous and known to prey on a diversity of small animals including native fauna. Although the feral cat is capable of killing vertebrates up to 3 kilograms in weight, they show a preference for animals weighing less than 220 grams and prey upon reptiles, amphibians and invertebrates. Ground dwelling mammals and ground-nesting birds are at particular risk. Threatened species occurring at the 24 ha site that are considered to be potential prey of the feral cat are:

- Grass Owl
- Long-nosed Poteroo
- Wallum Froglet
- Wallum Sedge Frog

*11.1.1.4 Feral Cat Control*

The management of cats is difficult because feral cats are shy of traps, do not readily take baits and are generally shy of human contact making them difficult to shoot. The options currently available for the control of Feral Cats are as follows:

- Trapping;
- Poisoning (including lures); and
- Islands or Barriers (including fencing).

The preferred methods of control for feral cats occurring at the site are **poisoning**, and **exclusion fencing** (for small areas only). However, limitations with these controls, including type of lure and type of fencing, are described in the main document.

*11.1.1.5 Wild Dog Impacts*

The wild dog population comprises two sub-species of canid, dingoes (*Canis lupusdingo*) and feral dogs (*Canis lupus familiaris*) and hybrids of the two (Fleming *et al*, 2001). it is likely that most dogs occurring on the site are domestic dogs originating from the surrounding urban areas. Additionally, there is a Council animal pound neighbouring the subject site and there is potential for unwanted animals to be dumped in the vicinity of this facility thus increasing the occurrence of dogs in the area of the STP.

The diet of wild dogs has been studied comprehensively and they mostly prey on mammals, although other prey includes avifauna, vegetation, reptiles, and an assortment of insects, fish, crabs and frogs. There are numerous fauna species, including threatened species, occurring at the site, which are potential prey for wild dogs. The threatened species are:

- Grass Owl
- Long-nosed Poteroo
- Wallum Froglet
- Wallum Sedge Frog

*11.1.1.6 Wild Dog Control*

As with foxes there are a number of control techniques available to manage the impact of wild dogs including the following:

- Trapping;
- Poisoning;
- Shooting; and
- Exclusion fencing.

The preferred methods of control for wild dogs occurring at the site are **poisoning** (1080 is the most lethal and cost effective method), **exclusion fencing,** and **trapping**.

#### *11.1.1.7 Cane Toad Impacts*

The cane toad is an extremely tough and adaptable species that seems to quickly outnumber native frogs when it colonises an area. It is possible that it competes with some native species for resources and it is poisonous at all stages of its development (Robinson, 1998). This species is common at the STP and it is likely that the relatively large population is a result of the fact that the effluent treatment ponds provide the habitat required for the production of abundant toadlets.

In Australia the cane toad has no natural enemies, an insatiable appetite and secretes a toxin that can kill most native animals that normally eat frogs. These traits give cane toads a competitive edge over native species. Cane toad tadpoles have been seen to prey upon the eggs of some native frog species and the toad themselves are known to eat mainly insects but will consume almost any small creature that fits in their mouth. They also eat honey bees and are likely to compete with native species for food resources, and are also suspected of carrying diseases that may be transmitted to native frogs and fishes. Threatened species known to occur at the site that represent potential prey/competition for the Cane Toad are:

- Wallum Froglet
- Wallum Sedge Frog

#### *11.1.1.8 Cane Toad Control*

Aside from habitat management (refer Section 5.1 main document), there is little that can be done to permanently reduce cane toad levels in a given area. Despite limitations associated with musters and the misidentification of Cane Toads and native frogs, it is recommended that periodic musters be undertaken for the control of cane toads at the subject site. However, such musters must be undertaken by STP staff that are trained in the identification of cane toads and native frogs of similar appearance.

### *11.1.2 Feral Animal Control Methods: Constraints*

Legislative restrictions on the use of poisoned baits in semi-urban areas and various limitations to the use of exclusion fencing at the site are outlined in Section 5.6 of the main document. A brief description is listed below.

- Poison: 1080 baits must not be laid within close proximity to urban areas unless the baiting program is planned in conjunction with, and has been agreed to, by an Authorised Control Officer. Such programs must include strategies for minimising risk to non-target animals. Proposals for poisoning programs must include strategies for minimising risk to non-target animals. Proposals for baiting in closely settled farming areas or areas within four kilometres of a village or any street with a speed restriction of 70 kilometres per hour or less fall within this requirement. The West Byron STP clearly falls within a 4km radius of a speed restriction of 70km per hour or less and is obviously in close proximity to urban areas where domestic pets are kept.
- Fencing: The use of fencing is commonly recognised as an expensive control measure. Additionally, native fauna can be injured or killed by exclusion fencing as they collide, are electrocuted or become trapped or entangled.
- Trapping: relatively high costs associated employing the specialist labour required and the fact that it may be considered some to be inhumane and have potential to harm non-target animals.

**Table 29 Pest Management: Task Summary**

| Issue | Action Required |
|---|---|
| **Pest Management** | |
| – Red Fox<br>– Feral Cat<br>– Wild Dog<br>– Cane Toad | Poisoning, Trapping, Fencing, Muster.<br><br>Refer FAMP |

**Table 30 Pest Management: level of skill required**

| Operational Area | Task description | Skill Level Required | Hours/ week |
|---|---|---|---|
| Pest Control | ➢ Poisoning<br>➢ Trapping<br>➢ Fencing<br>➢ Muster | Specialist Pest Management<br><br>Refer FAMP | |

## 12 OH&S

All work activities conducted at the 24 ha Wetland Regeneration Site must be carried on in accordance with the *NSW Occupational Health and Safety Act 2000*, and its supporting regulatory and advisory framework.

The objectives of the act are:

a) To secure and promote the health, safety and welfare of people at work,
b) To protect people at a place of work against risks to health or safety arising out of the activities of persons at work,
c) To promote a safe and healthy work environment for people at work that protects them form injury and illness and that is adapted to their physiological and psychological needs,
d) To provide for consultation and co-operation between employers and employees in achieving the objects of this act,
e) To ensure that risks to health and safety at a place of work are identified, assessed, and eliminated or controlled,
f) To develop and promote community awareness of occupational health and safety issues,
g) To provide a legislative framework that allows for progressively higher standards of occupational health and safety to take account of changes in technology and work practises,
h) To protect people (whether or not at a place of work) against risks to health and safety arising from the use of plant that affects public safety.

The 24 ha site has previously, 2001 - 2004, been supervised by trained OH&S staff from SCU. It is assumed that an appropriate Council OH&S employee will take over this role and ensure that appropriate OH&S awareness, implementation & staff training is continued.

## 12.1 Risk Assessment & Safe Working Methods

A general risk assessment, for the 24 ha working environment, was carried out in early 2004, and this is attached below in Table 31. Staff working at the 24 ha site should be familiar with this risk assessment and, in addition should be familiar with the Safe Working Methods Statements for the tasks listed in Table 31.

A total of eleven work tasks were assessed for this site, all of which will continue to be carried out in the short term.

**Table 31 Identified 'Risk Assessed' work tasks**

| | Work Task/ Activity |
|---|---|
| 1. | Site preparation (for planting - using tractor for slashing) |
| 2. | Tree planting |
| 3. | Tree transplanting |
| 4. | Vegetation survey |
| 5. | Groundwater monitoring |
| 6. | Soil sampling |
| 7. | Instrument calibration |
| 8. | Equipment maintenance |
| 9. | Irrigation infrastructure (maintenance) |
| 10. | Drain maintenance |
| 11. | Fence installation/ removal |

**Table 32 Risk Assessment: Hazard Risk Rating**

| Hazard | Cause | Risk Rating | Safety Controls/Comments | Residual Risk Rating |
|---|---|---|---|---|
| Traffic | Heavy Plant while accessing and leaving site | 1 | ▪ Always check into site office for an update on vehicle movements when arriving on site<br>▪ Stay clear of plant – postpone working in construction area if possible<br>▪ Close work area using barriers and marking tape if necessary to work in their working zone<br>▪ Always give plant right of way<br>▪ Always wear appropriate PPE – hard hats, high vis vests, flashing light on vehicles | 3 |
| Biological hazard | Effluent | 2 | ▪ Inform employees working on site about risk of effluent-borne pathogens and availability of immunisation and rebates. Particularly recommend hepatitis immunisation.<br>▪ When practical, close valves when working close to effluent outlets<br>▪ Avoid direct contact with pooling effluent and effluent coming out of pipes<br>▪ Avoid hand-face contact whilst working on site<br>▪ Wear appropriate PPE ie. Gloves to prevent direct contact with effluents when handling soil and vegetation and when sampling effluent, gum boots or waders, eye protection.<br>▪ When it is not possible to avoid contact with effluent, wash yourself thoroughly with an antiseptic wash after work is complete | 4 |

| Hazard | Cause | Risk Rating | Safety Controls/Comments | Residual Risk Rating |
|---|---|---|---|---|
| Fauna | Snakes | 2 | ▪ Avoid overgrown areas whenever possible<br>▪ Maintain slashed tracks<br>▪ Be cautious at all times on site – snakes may be present in overgrown areas, on tracks and around infrastructure – make noisy progress and ensure you wear PPE – safety boots and long pants<br>▪ If dangerous snake is encountered stay clear and inform others working in vicinity. Do not attempt to move or approach snake.<br>▪ Carry immobilisation bandage and mobile phone / UHF radio on person at all times whilst on site<br>▪ Work with a companion who is trained in first aid<br>▪ Wear appropriate PPE ie. Long pants, long sleeved collared shirt, hat, safety boots, repellent. | 4 |
| | Mosquitoes, ticks | 2 | ▪ Check body thoroughly after working on site<br>▪ Wear appropriate PPE – long pants, long sleeved collared shirt, hat, safety boots, repellent<br>▪ Avoid working around dusk | 6 |
| | Leeches, wasps | 4 | ▪ Check body and clothing thoroughly after working on site<br>▪ Wear appropriate PPE – long pants, long sleeved collared shirt, hat, safety boots, repellent | 6 |
| | Wallabies, birds, marsupials, frogs | 5 | ▪ Drive slowly on site<br>▪ Never swerve or brake in a dangerous manner to avoid fauna on roads | 6 |
| Excavator | Earth works | 2 | ▪ Maintain safe distance from excavator's working area, stay clear of excavator arm's work zone<br>▪ Only enter excavations if safe<br>▪ Make excavator operators aware of your location and intentions<br>▪ Wear correct PPE ie hardhat, high visibility vest, safety boots | 5 |
| Slasher | Slashing | 2 | ▪ Stay well clear of working area<br>▪ Wear PPE ie hardhat, high visibility vest, safety boots | 6 |

| Hazard | Cause | Risk Rating | Safety Controls/Comments | Residual Risk Rating |
|---|---|---|---|---|
| Manual handling | Lifting and moving equipment | 2 | ▪ When appropriate, mechanical lifting devices should be used if possible. When lifting, use correct lifting methods, do not bend your back, keep back straight, etc.<br>▪ When possible reduce weight of load (for example – lift esky on to truck before loading samples into esky).<br>▪ Ask for assistance when lifting heavy items | 6 |
| Sun exposure | Sun, outdoor work | 3 | ▪ Minimise sun exposure during critical hours – do not work in exposed areas when temperature exceeds 37°C<br>▪ Drink lots of water<br>▪ Selection of appropriate staff in hot weather<br>▪ PPE- wear protective clothing ie. Long shirt and hat and sunscreen | 6 |
| Struck by object | Close proximity to other workers | 3 | ▪ Communicate! Make other workers aware of your activities<br>▪ Be aware of location of other workers when using hand tools<br>▪ Wear PPE ie hardhat, high vis vest<br>▪ Carry UHF radio<br>▪ Keep safe distance from other workers using tools which may harm | 5 |
| Vehicle overturn | Unstable ground | 3 | ▪ All people working on site to check in at site office on arrival – make intentions known<br>▪ Heavy plant should not be allowed onto areas of ground known to be unstable<br>▪ If the stability is not known care should be taken and all personnel should stay clear of vehicle until stability is known<br>▪ Mark dangerous areas off limits to vehicles<br>▪ Drive slowly and cautiously<br>▪ Wear seatbelts on site | 6 |

| Hazard | Cause | Risk Rating | Safety Controls/Comments | Residual Risk Rating |
|---|---|---|---|---|
| Working in location with limited access | Wetland environment | 3 | ▪ Work with companion<br>▪ Ensure that site managers know that you are working on site<br>▪ Carry mobile phone / UHF radio on person at all times whilst on site<br>▪ All workers to have basic first aid training and equipment available | 6 |
| Brush cutter | Usage | 3 | ▪ Care in use – follow guidelines<br>▪ Be aware of people working in vicinity and maintain a safe distance<br>▪ Wearing appropriate PPE ie. Chaps, eye protection, foot protection, long sleeves, ear protection | 6 |
| Contact with chemicals | Herbicide | 3 | ▪ Care in use<br>▪ Be aware of chemical in use<br>▪ Have access to material safety data sheets | 6 |
| Hand tools | Manual work | 3 | ▪ Caution when using hand tools<br>▪ Use appropriate tool for job<br>▪ Maintain safe distance from other workers<br>▪ Wear appropriate PPE – safety boots, gloves, safety glasses | 6 |
| Gas | Naturally occurring hydrogen sulfide gas | 3 | ▪ Work with companion<br>▪ Only trained and equipped persons to enter excavations/confined spaces | 6 |
| Deep water | Working in vicinity of wetland cells or drains | 3 | ▪ Stay away from edge of cells containing deep water where possible<br>▪ Correct PPE to be worn when it is necessary to work in or around deep water ie. Waders, gum boots, eye protection<br>▪ Work with companion | 6 |

| Hazard | Cause | Risk Rating | Safety Controls/Comments | Residual Risk Rating |
|---|---|---|---|---|
| Vegetation | Working environment | 3 | ▪ Move in vegetation carefully to avoid cuts on exposed skin and vegetation around eyes and face<br>▪ Wear PPE ie. Long sleeves, gloves when appropriate, eye protection<br>▪ Clean any cuts with antiseptic | 5 |
| Slips and falls | Uneven ground, water-logged soil, dense vegetation | 4 | ▪ Examine ground condition<br>▪ Be cautious while working in soft, wet areas<br>▪ Be cautious in areas of unstable or uneven ground and areas of low visibility<br>▪ Carry a mobile phone or UHF radio<br>▪ When carrying large loads, use a backpack to maintain forward vision<br>▪ PPE - Wear safety boots | 6 |
| Contact with high pressure | Pipe work, irrigation maintenance | 6 | ▪ Ensure pressure has been released before opening valves and pumps are switched off when possible | 6 |
| Under-ground services | Sub surface irrigation supply | 6 | ▪ Personnel working on site to be aware of location of underground services and avoid digging in vicinity<br>▪ When it is necessary to work around underground services or to maintain underground services, pump is to be turned off | 6 |

## 13 Human Resources

Considerable human, financial, and material resources, have been consigned to develop the 24ha site to its current level. During the period 2001 - 2005, human resourcing has drawn heavily on inputs from SCU, and BSC. Further to this, specialist advice and technical support, was sourced to a range of private sector providers. Since early 2005 BSC has had sole responsibility for the management and maintenance of the 24 ha site.

Many of the activities that were carried out during the 2001 - 2005 period, were related to research/ monitoring programmes, and would only be considered as part of a future management programme on an 'as needs' basis i.e. where BSC determines a need to conduct management specific research, monitoring, and/ or survey. Similarly, initial tasks & activities associated with the establishment of the *Melaleuca* plantation do not need to be repeated or form part of ongoing maintenance e.g. tree planting and the construction of the irrigation infrastructure.

Activities considered to be a part of ongoing operational requirements for 2007 and beyond, have been summarised and are listed below in. For a more detailed description refer to Tables located at the end of Chapters 3 – 12, or the Management Overview Table in Chapter 2.

**Table 33 Task Description**

| Operational Area | Task description | Skill Level Required |
|---|---|---|
| Irrigation | ➢ Irrigation scheduling. | - Field assistant/ STP |
| | ➢ Infrastructure maintenance | - Field assistant/ STP |
| | ➢ Flow recording, data management. | - Field assistant/ STP |
| | ➢ Annual review (crop demand) | - Enviro. Scientist |
| Groundwater | ➢ Water-table depth. | - Field assistant/ STP |
| | ➢ Monitoring & recording physico-chemical parameters. | - Field assistant/ STP |

| Operational Area | Task description | Skill Level Required |
|---|---|---|
| | ➢ Water sampling/ return for lab. Analysis | - Lab. Technician/ STP |
| | ➢ Instrument calibration (data-logger) | - Lab. Technician |
| | ➢ Instrument maintenance | - Lab. Technician |
| | ➢ Data management & reporting | - Enviro. Health Officer/ Scientist |
| Soil (ASS) | ➢ Sampling & return to lab. | - Lab. Technician/ Field assistant |
| | ➢ Data management & reporting | - Enviro. Health Officer/ Scientist |
| *Melaleuca* | ➢ Frost mitigation (re-schedule irrigation - during Winter) | - Field assistant |
| | ➢ Weed assessment/ reporting to weed maint. Team | - Field assistant |
| Weather Station | ➢ Data download | - Field assistant |
| | ➢ Maintenance | - Field assistant |
| | ➢ Data management | - Field assistant |
| Drain | ➢ Water sampling/ return to lab. | - Lab. Technician/ STP |
| | ➢ Data download - Flow | - Field assistant |
| Fences | ➢ To be removed when trees are 3 yrs of age. | - Maintenance Crew |

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## 15 Appendix 1

**NPWS Concurrence Conditions**

[Reasons for the Director-General's Decision]

The Byron Shire Council has requested that the Director-General of National Parks and Wildlife provide concurrence under Section 112C of the EP & A Act to the proposed establishment of a 24ha *Melaleuca* regeneration area at the West Byron STP. The Establishment of the 24ha *Melaleuca* regeneration area will be determined by Council as a stand-alone project and separately to the determination of the overall Byron Bay Sewerage Augmentation Scheme. The Determination Report considers that there is no statutory impediment to this approach.

After considering the SIS, SIS Supplement, EIS, Representations Report and Determination Report, as well as relevant recovery and threat abatement plans and other matters provided for in Section 112D of the EP & A Act, I have decided to grant concurrence to the proposed amended activity (the establishment of a 24ha *Melaleuca* regeneration area) as described in these documents, subject to the conditions detailed in Section 11 of this report. The reasons for this decision are:

1. The relevant requirements of Section 112D of the EP & A Act have been considered, these being:
    a. Any species impact statement prepared in relation to the activity;
    b. Any assessment report prepared by or on behalf of the proponent;
    c. Any representations made under section 113 concerning the species impact statement;
    d. Any relevant recovery plan or threat abatement plan;
    e. Whether the activity is likely to reduce the long-term viability of these species, population or ecological community in the region;
    f. Whether the activity is likely to accelerate the extinction of the species, population or ecological community or place it at risk of extinction;
    g. The principles of ecologically sustainable development (as described by section 6 (2) of the *Protection of the Environment Administration Act 1991);* and
    h. The likely social and economic consequences of granting or of not granting concurrence.

2. On available evidence, the proposed amended activity, as ameliorated by the conditions of concurrence, is unlikely, in the opinion of the NPWS, sot significantly compromise the local or regional viability of any threatened species known to occur on the subject site.

3. Generally, the impacts of the proposal on threatened species as considered in the EIS, SIS and SIS Supplement will be ameliorated by the effective implementation of the measure outlined in the EIS, SIS, SIS Supplement and Determination Report, and the conditions of concurrence detailed in Section 11 of this report.

Concurrence Conditions:

1. Byron Shire Council and contractors must implement the ameliorative measure documented in the EIS (Section 11.10), SIS, SIS Supplement and Determination Report, including all the measures referred to in section 2.3 of this concurrence report, unless modified by the following conditions.

*Reason:* To ensure compliance with the conditions proposed in the EIS (Section 11.10), SIS, SIS Supplement and Determination Report.

2. Byron Shire Council and contractors must not commence any clearing or construction activities (that may impact upon threatened species or their habitats) that result form variation of activities without the prior written approval of the NPWS. The term "variation of activity" referred to above is defined as any changes in location, design, or construction of the proposed activity which are not contained within the EIS, SIS, SIS Supplement or Determination Report.

*Reason: To ensure that variations to the proposed activity do not increase adverse impacts on threatened species, or lessen protection provided to threatened species by the conditions contained in the EIS (Section 11.10), SIS, SIS Supplement and Determination Report.*

3. Byron Shire Council must, when developing measures impacting or ameliorating impacts on the following threatened species (Grass Owl, Australasian Bittern, Black Bittern, Comb-crested Jacana, Black-necked Stork, Wallum Froglet and Wallum Sedge Frog) and their habitats, request appropriately experienced specialists to provide advice and information on these measures.

*Reason: To ensure that the design and implementation of measures impacting or ameliorating impacts on the specified threatened species and their habitats are soundly based, efficient and cost-effective.*

4. Byron Shire Council must prepare a Biodiversity Management Plan (BMP) to address the impacts of the activity on threatened species and their habitats. The BMP's scope and framework must address the requirements outlined in the NPWS's Director-General's Requirement 7.1. The BMP must, unless modified by the conditions outlined below, incorporate the actions outlined in Chapter 7 and Appendix 1 of the SIS. The BMP must be submitted to the NPWS for review and written approval before implementation. The BMP must be implemented once approved by the NPWS. A report must be prepared annually for a minimum of five years which outlines the management actions undertaken during the previous year, the results of the monitoring programs and actions proposed for the forthcoming year.

*Reason: To ensure that the impacts of the proposed activity on threatened species and their habitats are addressed in the context of an overall management plan. To ensure that the impacts of the activity and the BMP actions upon threatened species and their habitats are documented and made available to interested parties.*

5. Byron Shire Council must review the practice of an rationale for slashing grassland, sedgeland and heath land, cease or reduce the frequency of slashing in areas where no justification for (regular) slashing can be determined, and where practicable, identify and implement more environmentally acceptable alternatives in areas where control of native vegetation can be justified.

*Reason: To permit regeneration and the development of natural growth and succession of native vegetation where management controls are inappropriate, and to improve habitat for threatened species.*

6. *Ghania* Sedgeland Management

Byron Shire Council must minimise the impacts of the installation of irrigation piping and the proposed ground preparation, planting and maintenance of Swamp Paperbark *Melaleuca*

*quinquenervia* plants in the *Ghania* sedgeland on threatened species. Measures to achieve this outcome must include:

- Ensuring the process of determining the nature, location, extent, season and approximate time frames of implementation of slashing programs includes identifying how these program components may impact on threatened species known or likely to inhabit the area, and adjusting them where practicable to minimise these impacts;
- Maximising the use of existing vehicular and foot tracks, and only implementing new tracks if there are no practicable alternatives;

*Reason: To minimise the impacts of the installation of irrigation piping and the proposed ground preparation, planting and maintenance of Swamp Paperbark Melaleuca quinquenervia plants on threatened species, particularly the Grass Owl Tyto capensis and the Wallum Froglet Crinia tinnula.*

7. Grass Owl Management

Slashing of native vegetations is prohibited between February and August inclusive within areas likely to be utilised by the Grass Owl, unless the slashing is part of an activity authorised to be done by or under the *Rural Fires Act 1997* or the *State Emergency and Rescue Management Amendment Act 2000.*

*Reason: To maximise the likelihood that Grass Owl occurrences will be noted and actions taken.*

8. Byron Shire Council must ensure that Council staff and contractors undertaking activities that may impact upon the Grass owl are appropriately trained in the identification of the Grass owl and signs of their presence (eg pellets, roost and nest sites and calls).

*Reason: To maximise the likelihood that Grass Owl occurrences will be noted and appropriate actions taken.*

9. If a Grass Owl is detected prior to or during undertaking any action likely to affect breeding, feeding or roosting activities or habitat by that individual bird, Byron Shire Council must:
   - Cease or not commence that action within 200m of the location of the observed Grass Owl;

- Have a person experienced in Grass Owl ecology inspect the area to be affected by the action and assess, in a written report to Council, the likely impact of the action on the observed Grass Owl;
- Not (re-) commence that action unless the assessment has determined that the proposed action will not significantly adversely impact upon the observed Grass Owl;
- If the proposed action has been determined to be likely to have a significant adverse impact upon the Grass Owl, not (re-) commence the action until a person experienced in Grass Owl ecology has inspected the site again and determined, in a written report to Council, that:
    - The proposed action is not likely to now have a significant impact upon the observed Grass Owl;
    - Or that the observed Grass owl has of its own accord left the area to be affected by the proposed action.

*Reason: To ensure that Grass Owls are not adversely impacted upon by management actions.*

10. Constructed Wetlands (including Cell H, Open Ponds and Paperbark Ponds) Management

Byron Shire Council must provide a diverse and enhanced habitat for the threatened and protected waterbird, bat and frog species recorded and likely to occur in the constructed wetlands. Measure to achieve this outcome must include:

- Managing water quality, depth and volume to ensure, within the constraints of managing the input of sewage for treatment, that adverse impacts on threatened species, particularly waterbird breeding events, are minimised and where practicable, impacts are beneficial;
- Appropriately landscaping the sides and bottom of the wetlands when dry to provide a range of appropriate profiles and depths for waterbird and frog species;
- Planting or maintaining or encouraging (or any combination of these) the natural establishment of appropriate wetland plants, particularly species known to be food and shelter plants for waterbird and frog species;
- Removing weeds from within and surrounding the wetlands;

- Assessing the practicality of establishing and appropriately vegetating islands to provide potential breeding or roosting habitat for threatened waterbird species and refuge from predators, if considered practical, establish and maintain islands for these purposes;
- Periodically drying wetlands where practicable to control and if possible eliminate the introduced Mosquito Fish *Gambusia holbrooki;*
- Undertaking a study to assess the practicality and economics of re-introducing the endangered Green and Golden Bell Frog *Litoria aurea;* if considered practical and economically reasonable, undertaking a re-introduction project for the species; and
- Monitoring threatened waterbird species (and Green and Golden Bell Frog, if re-introduced) population distributions and abundances, particularly during breeding events.

*Reason: To maximise opportunities for conservation for waterbird and native frog species, in particular the threatened species Comb-crested Jacana Irediparra gallinacean, Australasian Bittern Botaurus poiciloptilus, Black-necked Stork Ephippiorhynchus asiaticus, Black Bittern Ixobrychus flavicollis AND Green and Golden Bell Frog Litoria aurea.*

11. Feral Animal and Weed Management

Byron Shire Council must minimise the impacts of feral animals and weeds on threatened and protected native species likely or known to occur on the subject site. Measures to achieve this outcome must include:

I. Developing and implementing a process to:
   - Identify the likely impacts on threatened species of proposed feral animal and weed control measures prior to their first application;
   - Determine whether these control measures may have a significant impact upon threatened species; and
   - If they may have a significant impact, refer the proposed application to the NPWS for review and written approval or rejection.

II. Prohibiting the use of herbicides in wetland or moist habitats unless the proposed use has been referred to the NPWS for review and written approval or rejection;

III. Minimising the clearing of passage ways through vegetation to provide vehicular or foot access;

IV. Reviewing all existing vehicular and foot tracks through native vegetation to determine their current and proposed future usage; close and revegetate tracks for which no needs can be identified;

V. Ensuring that proposals to construct new vehicular or foot tracks through native vegetation, prior to construction, undergo assessment to determine whether there are any practicable existing alternatives and identify impacts on threatened species. The proposed track can only be constructed if no practicable alternatives can be identified, and the impact on threatened species can be shown not to be significant;

VI. Minimising opportunities for the spread of weeds and movement of feral animals, in particular into areas of native vegetation where weeds and feral animals are currently absent or present only in low densities;

VII. Reducing, and where practicable, eliminating existing weed and feral animal occurrences, particularly aquatic weeds and those feral animals known or likely to adversely impact on threatened species such as foxes, wild dogs and feral cats; and

VIII. Maintaining dense native vegetation adjacent to the edges of constructed water-bodies to reduce their attraction as breeding habitat for the introduced Can Toad *Bufo marinus.*

*Reason: To minimise the impacts of feral animals and weeds on threatened and protected native species.*

12. Sedgeland Compensatory Habitat – Conservation and Management

Byron Shire Council must, with respect o the proposed compensatory habitat area (identified as "Conservation Area" in Figure 2.4 of the SIS Supplement), rezone the land as an appropriate environmental protection zone. Additionally, an instrument must be prepared pursuant to Section 88 of the *Conveyancing Act 1919* to require the land to be managed and accordance with the management plan referred to in condition 15. This instrument must preclude the land being utilised for other purposes or its sale without the prior written approval of the NPWS.

*Reason: To ensure that the zoning of this land reflects its primary use as compensatory habitat for the loss of habitat for the Grass Owl, Wallum Froglet and potentially Wallum Sedge Frog Litoria olongburensis through the conversion of Ghania sedgeland to Melaleuca*

*swamp forest. To ensure that any changes to this primary usage require the concurrence of the NPWS.*

13. Byron Shire Council must undertake a (single) survey to identify the flora and fauna species currently present in the compensatory habitat area, and their approximate distributions and abundance. In particular, the survey must attempt to determine the current relative suitability (eg, availability, quality, distribution and abundance of habitat and likely food sources) of the area for the Grass Owl, Wallum Froglet and Wallum Tree Frog.

*Reason: To provide baseline data to be utilised in the preparation of a plan to conserve and manage*

14. Byron Shire Council must prepare and implement a plan (within the BMP if considered appropriate) to conserve and manage threatened species and their habitat in the compensatory habitat area. The plans major objectives must include the development, enhancement, restoration or rehabilitation, as appropriate, of habitat for the Grass Owl, Wallum Froglet and Wallum Sedge Frog. The plan must include:
    - Monitoring of Grass Owl, Wallum Froglet and Wallum Sedge Frog population abundances and distributions, including information on Grass Owl (attempted) breeding events;
    - A program to review the results of management actions and identify and instigate alternative actions where appropriate;
    - Feral animal and weed control measures;

Reason: *To ensure that the compensatory habitat area is appropriately managed for threatened species, particularly the Grass Owl, Wallum Froglet and Wallum Sedge Frog.*

15. Belongil Estuary

Byron Shire Council must prepare and implement a strategy (if considered appropriate within the context of the Belongil Estuary Management Plan) to:

- Identify and monitor any impacts on threatened fauna and their habitats, in particular the Pied Oystercatcher *Haematopus longirostris,* Beach Stone Curlew *Esacus neglectus* and

Little Tern *Sterna albifrons,* in the Belongil Estuary and adjacent coast waters, resulting from the implementation of the activity, in particular;

- The nutrient levels in the treated effluent discharge, and the projected substantial increase in volume of effluent discharge, to the Belongil Estuary and adjacent coast waters; and
- Changes in the frequency of opening of the mouth of the Belongil Estuary;

- Develop and implement measures to rectify any identified adverse impacts on the breeding, roosting and feeding habitats of threatened fauna, particularly the Pied Oystercatcher, Beach Stone Curlew and Little Tern, in the Belongil Estuary and adjacent coastal waters, resulting from the implementation of the activity, in particular:
  - The nutrient levels in the treated effluent discharge, and the projected substantial increase in volume of effluent discharge, to the Belongil Estuary and adjacent coast waters; and
  - Changes in the frequency of opening of the mouth of the Belongil Estuary;
- Assess the practicality and economics of establishing one or more islands in the Belongil Estuary as roosting and/or breeding sites for migratory waders and threatened fauna, particularly the Pied Oystercatcher, Beach Stone Curlew and Little Tern. If considered practical and economically reasonable, establish and maintain one or more islands as roosting and breeding habitat for these species.

*Reason: To ensure that any adverse impacts on threatened fauna and their habitats in the Belongil Estuary are identified and ameliorated.*

16. In the event that Byron Shire Council and the NPWS cannot reach agreement on an issue subject to the above conditions that requires approval from the NPWS after granting of this concurrence, the matter shall be referred to the Director-General of Planning NSW for arbitration between the parties.

*Reason: To provide a mechanism for the resolution of differences between Byron Shire Council and the NPWS should there be irreconcilable differences regarding the implementation of the above conditions.*

**Report No. 4.2** **Environmental Management Plan for the opening of the Tallow Creek**
**Directorate:** Infrastructure Services
**Report Author:** James Flockton, Drain and Flood Engineer
**File No:** I2018/415
**Theme:** Community Infrastructure
Waste and Recycling Services

**Summary:**

As requested there is no formal report for this meeting. The following point is for discussion.

The Attachment is the Final Tallow Creek Mouth Opening Environmental Management Plan as requested to be provided in the previous minutes for discussion purposes.

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**RECOMMENDATION:**

**That the Panel note the report.**

**Attachments:**

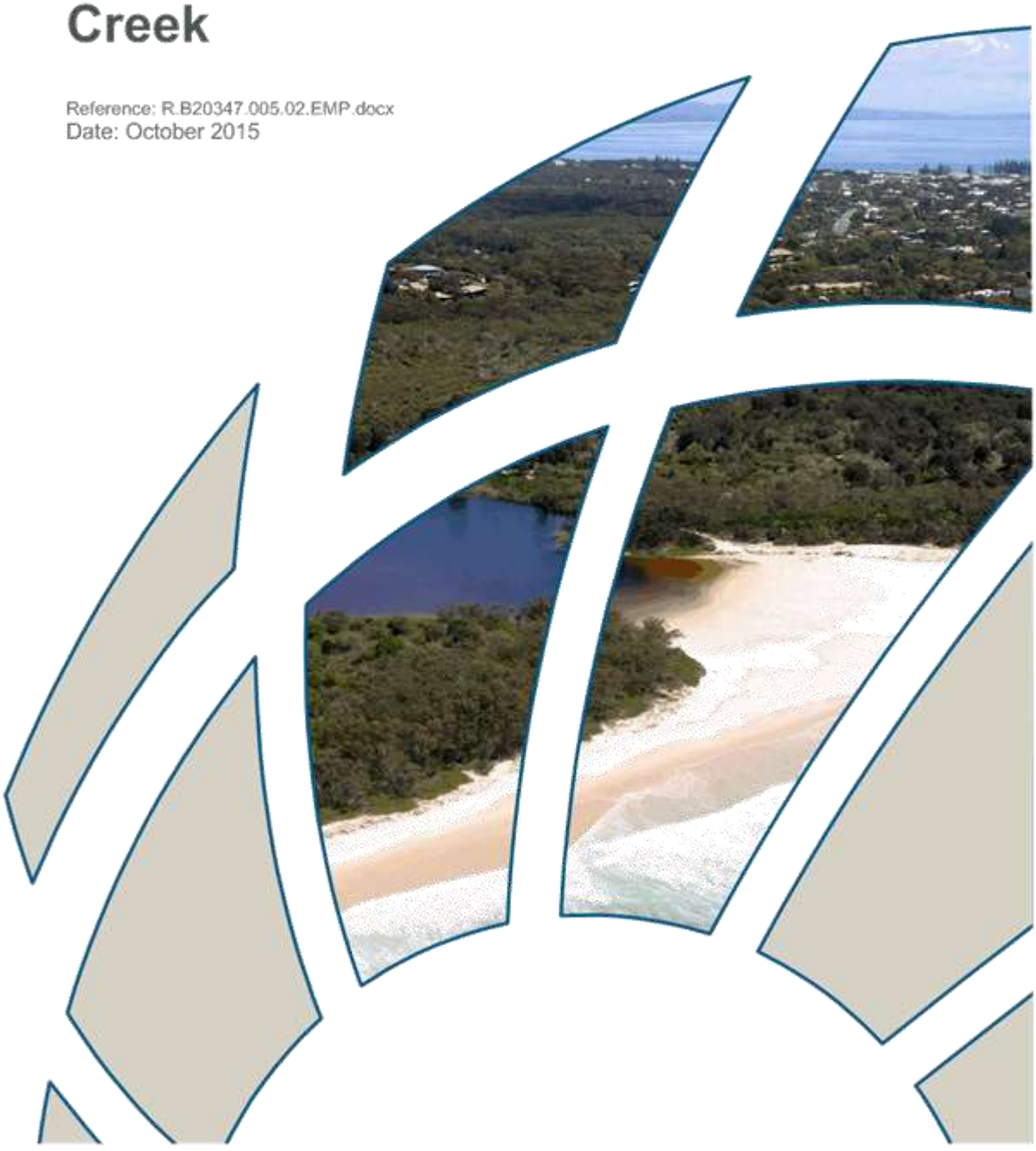
1 24.2013.20.1 Final Tallow Creek Mouth Opening Environmental Management Plan (EMP) - Rev 2 - for NPWS permit application, E2015/82792 , page 140⇩

A part of BMT in Energy and Environment

BMT WBM

# Environmental Management Plan and Opening Strategy for Tallow Creek

Reference: R.B20347.005.02.EMP.docx
Date: October 2015



# Environmental Management Plan and Opening Strategy for Tallow Creek

| | |
|---|---|
| Prepared for: | Byron Shire Council |
| Prepared by: | BMT WBM Pty Ltd (Member of the BMT group of companies) |

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|---|---|
| **Document:** | R.B20347.005.02.EMP.docx |
| **Title:** | Environmental Management Plan and Opening Strategy for Tallow Creek |
| **Project Manager:** | Damion Cavanagh |
| **Author:** | Damion Cavanagh |
| **Client:** | Byron Shire Council |
| **Client Contact:** | James Flockton |
| **Client Reference:** | |

**Synopsis:** **This EMP and Opening Strategy has been developed to provide environmental management guidance to Council staff in the conduct of an artificial opening or pre-emptive scraping event at the Tallow Creek mouth. It accords with and reflects key elements of the Review of Environmental Factors completed for this activity.**

**REVISION/CHECKING HISTORY**

| Revision Number | Date | Checked by | | Issued by | |
|---|---|---|---|---|---|
| 0 | 2 June 2015 | J. Visser | | D. Cavanagh | |
| 1 | 3 June 2015 | J. Visser | | D. Cavanagh | |
| 2 | 9 October 2015 | J. Visser |  | D. Cavanagh |  |

**DISTRIBUTION**

| Destination | Revision | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
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## Contents



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# 1 Introduction

This Environmental Management Plan (EMP) and Opening Strategy have been prepared to provide construction related environmental management guidance to Council staff in the conduct of an opening event (and also pre-emptive beach scraping) at the Tallow Creek mouth. It also provides operational environmental management guidance for ongoing or regular activities associated with entrance management.

It accords with and reflects key elements of the Review of Environmental Factors (and the National Parks and Wildlife Service permit application) completed for this activity.

## 1.1 Coverage and Audience

The EMP and Opening Strategy have been developed for internal Council use. It is to be used by managers and works staff alike. It is intended to describe aspects of the activity (need, location, outcomes, potential effects, management requirements) alongside communication protocols such that during the process of undertaking an opening or scraping, appropriate liaison and activities are implemented to open the creek.

## 1.2 Need for the Activity

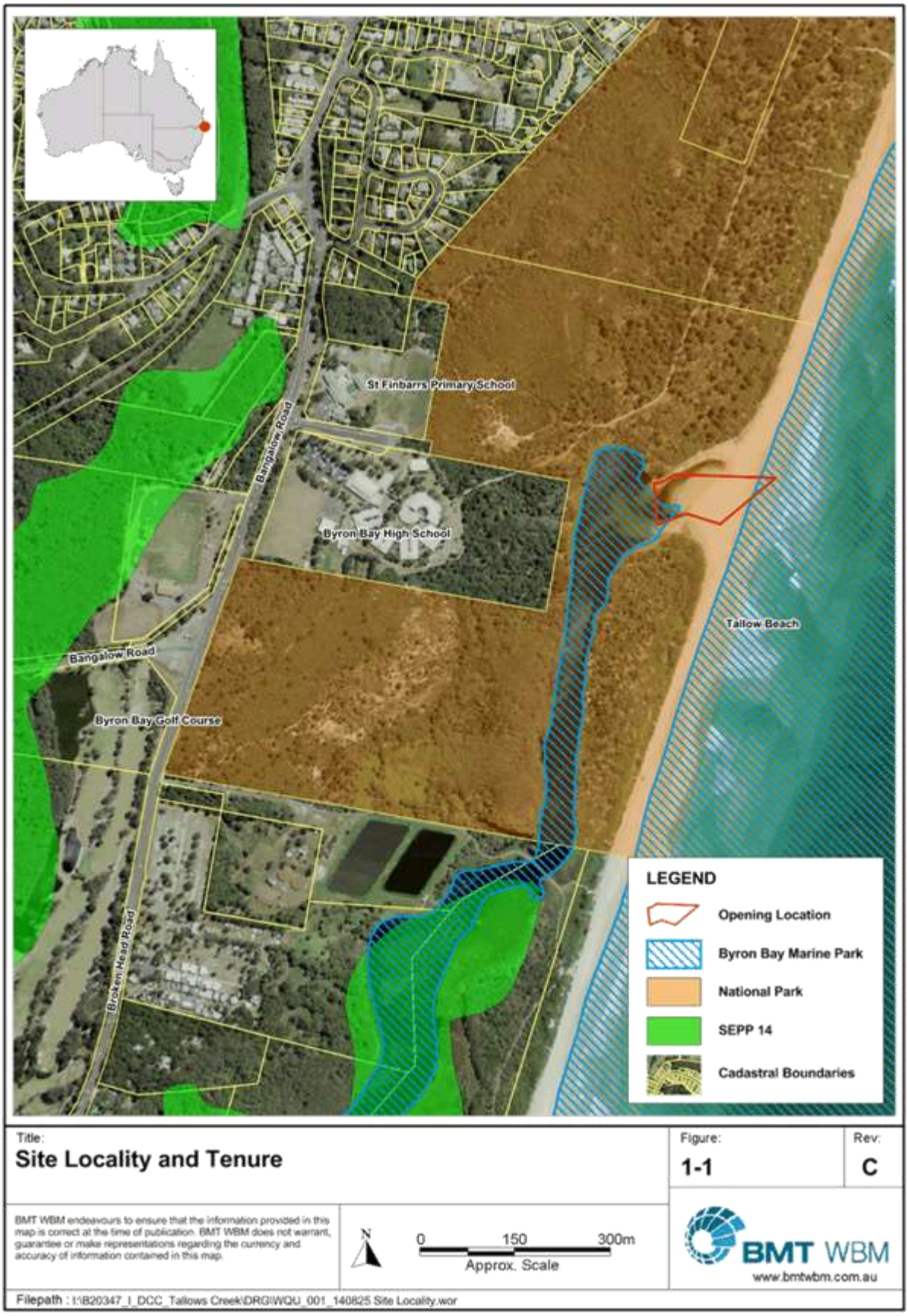
The proposed activity involves limited and infrequent sand relocation at the beach berm of Tallow Creek to allow waters within Tallow Creek to drain to the ocean to limit flood risks to properties within the catchment. Certain berm height triggers exist to maintain a balance between natural processes and requirements of flood mitigation in the catchment.

## 1.3 Location of the Activity

The activity will occur at the ocean entrance of Tallow Creek as it adjoins Tallow Beach as shown in Figure 1-1. It is approximately 700m east of the road entrance to St Finbarrs Primary School and Byron Bay High School (at intersection with Bangalow Road). The site is to the south of Byron Bay and to the north of Suffolk Park and is located within the Arakwal National Park.

**Table 1-1 Activity Location Description**

| | | |
|---|---|---|
| Suburb | Suffolk Park | |
| State | NSW | Postcode: 2481 |
| Title reference | LOT 437 DP 729107 | |
| Site reference | Easting: 560,691 | Northing: 6,828,767 |
| | MGA zone: 56 | Reference system: GDA94 |
| Local Government Area | Byron Shire | |
| National Park | Arakwal | |


St Finbarrs Primary School
Bangalow Road
Byron Bay High School
Tallow Beach
Bangalow Road
Byron Bay Golf Course
Broken Head Road
LEGEND
Opening Location
Byron Bay Marine Park
National Park
SEPP 14
Cadastral Boundaries
Title:
Site Locality and Tenure
Figure:
1-1
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C
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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150
300m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
Filepath : I:\B20347_I_DCC_Tallows Creek\DRG\WQU_001_140825 Site Locality.wor

# 2 Entrance Management Processes

Table 2-1 and Table 2-2 provide a condensed version of monitoring, communications and other actions which occur associated with an entrance opening or scraping event. As conditions on-site at the time of entrance management may be very different, an adaptive management approach is to be applied. Key parts of the adaptive management process discussed with stakeholders include:

- NPWS periodically monitoring the creek entrance for nesting bird activity, commencing when Council notifies NPWS that Tallow Creek water levels have reached 1.8 metres AHD;
- Council's engagement of an ecological specialist to provide Council with further advice if NPWS observes threatened and/or migratory birds nesting adjacent the entrance. Council to liaise with NPWS regarding specialist management approaches for nesting species if identified to be subject to impact; and
- Liaison with NPWS regarding need for artificial opening based on poor water quality data. Water quality parameters and details of monitoring are included in Table 5-2.

The processes in Table 2-1 and Table 2-2 account for both low level (normal) activities and communications, as well higher order activities being initiated based on water or berm levels within Tallow Creek and at its entrance.

**Table 2-1 Triggers and Actions for Artificial Entrance Opening**

| | Normal | Moderate Alert | High Alert | Initiate Opening |
|---|---|---|---|---|
| **Water Level*** | <1.8 m | 1.8 to 2.0 m AHD | >2.0m | >2.2m |
| **Monitoring** | Periodic water level checks | • Weekly water level checks (Dec. to June), or monthly water level checks (July to Nov.) and periodic water quality checks<br>• Level checks after rainfall events<br>• Daily observation of rainfall predictions<br>• Berm height check | • Weekly water levels checks and daily observation of rainfall predictions<br>• Additional water quality testing (as required)<br>• Monitor complaints<br>• Berm height check | Opening required unless sandbar is likely to breach naturally (based on berm height) |
| **Communications** | None | Liaise with NPWS regarding need for NPWS observation of presence of nesting species at Tallow Creek entrance and to advise them of elevated water levels or depressed water quality conditions | | • Liaise with NPWS regarding opening level and planned timing of opening<br>• Advise Byron Bird Buddies of a planned opening event |
| **Other Actions** | None | Ecologist advising Council on mgt. options (if nesting species | • Council Works Depot on standby<br>• Ecologist advising | • Complete pre-start surveys and activities (as required) |

| | Normal | Moderate Alert | High Alert | Initiate Opening |
|---|---|---|---|---|
| | | present) | Council on mgt. options (if nesting species present)<br>• Aboriginal cultural heritage spotter on standby | • Complete opening of system (at or within 2 hours of a daytime low tide), with required persons present. |
| **Responsibility** | Overseer Road Maintenance | Overseer Road Maintenance | Overseer Road Maintenance and Council Engineer | Overseer Road Maintenance and Council Engineer |

* In the absence of an automated water level sensor manual monitoring of water levels is completed at the calibrated gauge attached to the public walkway bridge over Tallow Lake.

**Table 2-2 Triggers and Actions for Entrance Scraping**

| | Observation | Entrance Scraping |
|---|---|---|
| **Berm Level** | <2.2m | >2.2m |
| **Monitoring** | • Berm level observed at a minimum monthly frequency (this will typically occur associated with activities outlined in Table 2-1) | • Berm level observed at a minimum monthly frequency |
| **Communications** | | • Liaise with NPWS regarding:<br>◦ Need for NPWS observation of presence of nesting species at Tallow Creek entrance<br>◦ Actual presence of species at entrance and specialised management approaches<br>◦ Timing of pre-emptive scraping works<br>◦ Advise Byron Bird Buddies of a planned opening event |
| **Actions** | | • Ecologist advising Council on management strategies (if nesting species present)<br>• Complete entrance scraping with required personnel present applying agreed (with NPWS) management strategies for nesting species. |
| **Responsibility** | • Overseer Road Maintenance | • Overseer Road Maintenance and Council Engineer |

## 2.1 Description of the Activity

### Artificial Opening

The proposed activity will comprise the mechanical opening of the mouth of Tallow Creek at the sandbar. The excavation will create a "pilot" channel that is both narrow and shallow and allows for

elevated waters in Tallow Creek to drain to the ocean. Once drainage commences, the escaping waters will erode the pilot channel to form a larger drainage channel.

A 5 tonne excavator will be used to construct the pilot channel. The excavator will operate from the shoreline toward Tallow Creek and then the last section of sand at the sandbar will be taken from the water in the estuary. The excavator will operate from either side of the channel, while operating to protect existing banks. All excavated material will be placed on the northern side of the work area to minimise erosion risks to existing dunes.

The proposed location of artificial opening works is shown in Figure 2-1. This location is preferred on the basis that it promotes drainage channel formation away from the northern and southern vegetated foreshores and may avoid erosion of dunes and loss of vegetation. There are other on-site environmental constraints which may exist including the presence of nesting fauna. The presence of these fauna will be advised prior to access being granted to construct the pilot channel. A consulting ecologist will be on-site to observe local site conditions and determine a suitable location for the pilot channel to be excavated. There may also be other restrictions imposed by the ecologist which would need to be observed, depending on site conditions at the time.

The channel will be excavated to between 0.5 and 1.0 m depth below the ground surface of the beach berm (depending on berm height and water level at the time). The channel is to be constructed nominally two (2) metres wide. The length of the channel will vary as it will depend on the configuration of entrance and beach profile at the time of opening. It is expected that the length could vary between 50 and 80m although it will be as long as it needs to be to affect an adequate entrance opening. Figure 2-2 provides a scale image of an indicative entrance channel.

**Pre-emptive Beach Scraping**

The proposed activity will comprise the mechanical scraping of the Tallow Creek ocean berm to facilitate a breakout in the event of future catchment rainfall events. Anecdotal information indicates that the beach berm at Tallow Creek can exceed 2.2m AHD. Such elevated beach berm levels can assist flood levels to elevate to high levels.

The scraping will form of a broad swale which has an invert (bottom) elevation at 2.2m AHD. Sands removed to form the swale will be dispersed on the northern side of the swale. The proposed location of scraping is shown in Figure 2-1 (although it is for a swale not a channel in this instance) and has been selected to minimise risks of impacts to vegetation and dunes.

The location of the swale is also subject to the outcomes of any pre-scraping ecological surveys (if required based on advice from NPWS). These surveys may identify the presence of certain species which may influence the location and approach to scraping activities. The intended outcome of the opening will be to avoid nesting species; this includes the sand scraping and dispersant activities.

In terms of dimensions, the swale is to be constructed nominally five (5) metres wide along the base with batter slopes of up to a couple of metres width. It is expected that the entire swale would around 10 to 15 metres in width. The length of the swale will vary depending on the configuration of entrance and beach profile at the time of opening. It is expected that the length could vary between 50 and 80m, although it will extend as far as required to provide a suitable escape path for

In summary, the location of the swale will aim to avoid locations near to the existing north and south dunes, as well as any nesting species identified from pre-works surveys.

Figure 2-3 provides a scale image of an indicative scraped beach swale and sand dispersal area.

**Access**

The excavator will access the site via three potential access routes (refer Figure 2-4), in order of priority these are outlined below:

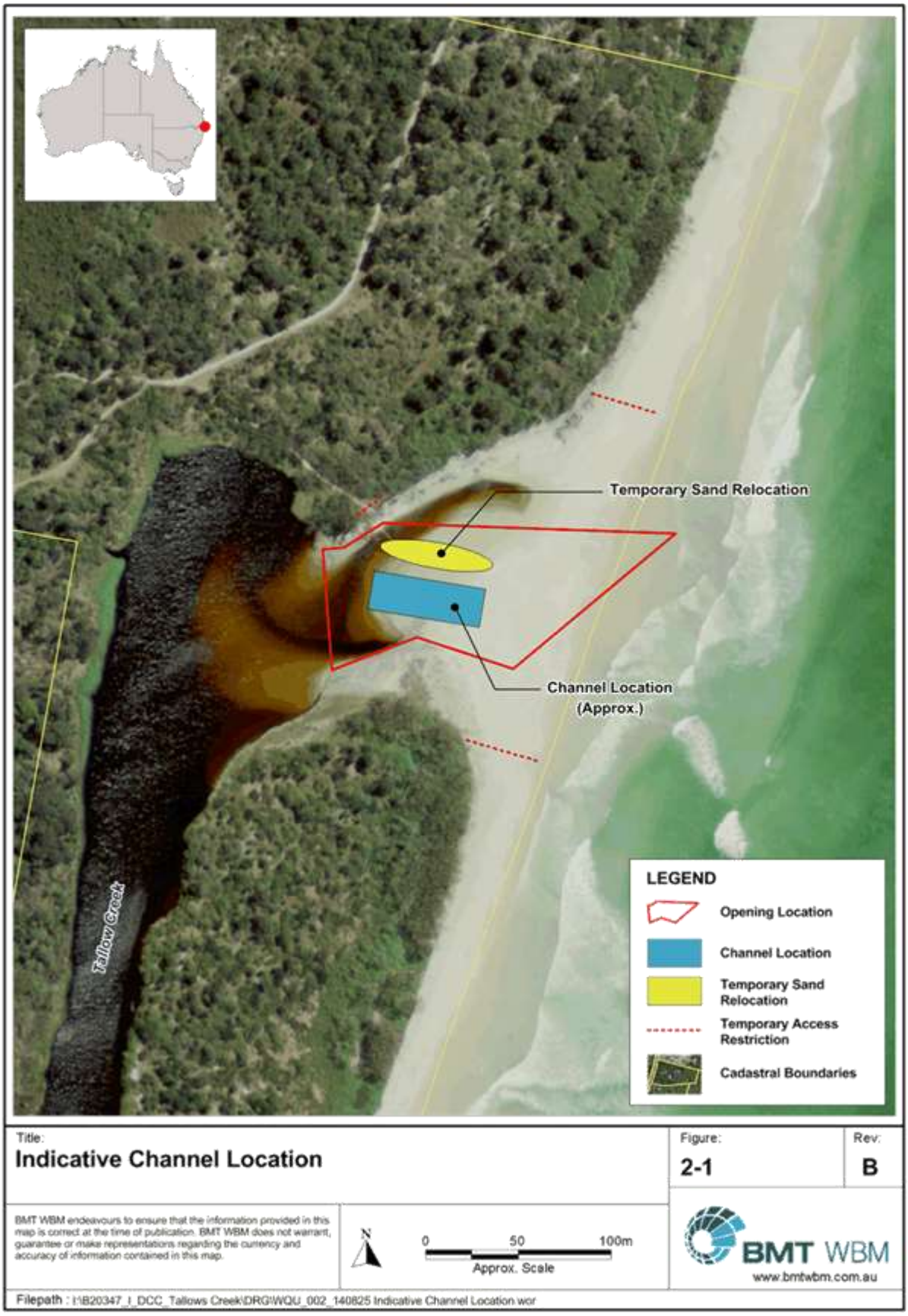
(1) Clifford Street – Suffolk Park (travel distance – 3 km);

(2) Beach Road/Broken Head Reserve Road – Broken Head (travel distance – 4.6km); and

(3) Tallow Beach car park in Cape Byron State Conservation Area – Byron Bay (travel distance – 2.6 km).

An emergency access is also available via Ocean Street Byron Bay, however, this access has narrow clearances to vegetation and may have a sizeable beach dune to navigate to then access the beach.

The selection of a beach access point would depend on suitability at the time works are proposed.


Temporary Sand Relocation
Channel Location
(Approx.)
Tallow Creek
LEGEND
Opening Location
Channel Location
Temporary Sand Relocation
Temporary Access Restriction
Cadastral Boundaries
Title:
Indicative Channel Location
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2-1
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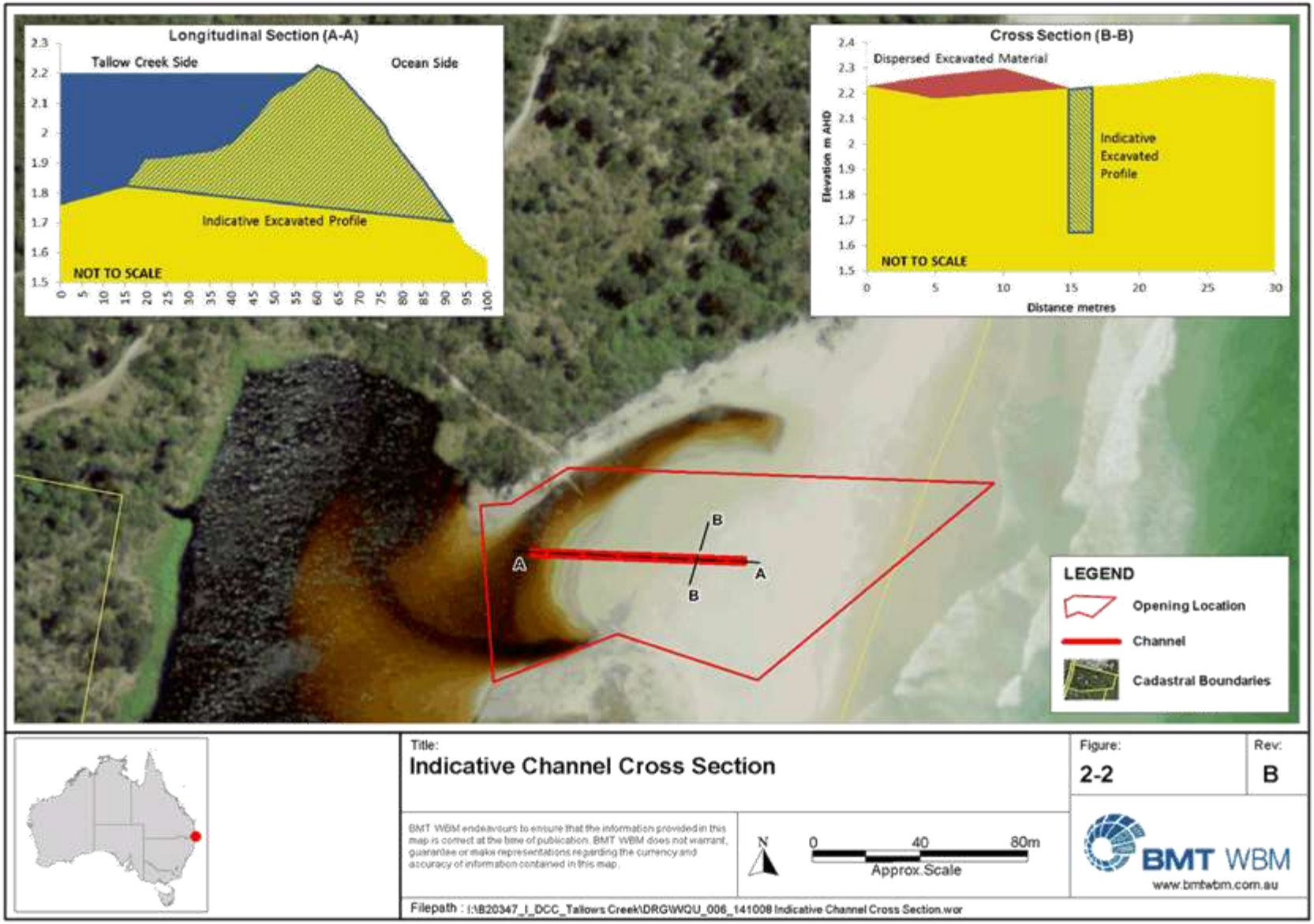
Longitudinal Section (A-A)
Tallow Creek Side
Ocean Side
Indicative Excavated Profile
NOT TO SCALE
Cross Section (B-B)
Dispersed Excavated Material
Indicative Excavated Profile
NOT TO SCALE
Elevation m AHD
Distance metres
A
A
B
B
LEGEND
Opening Location
Channel
Cadastral Boundaries
Title:
Indicative Channel Cross Section
Figure:
2-2
Rev:
B
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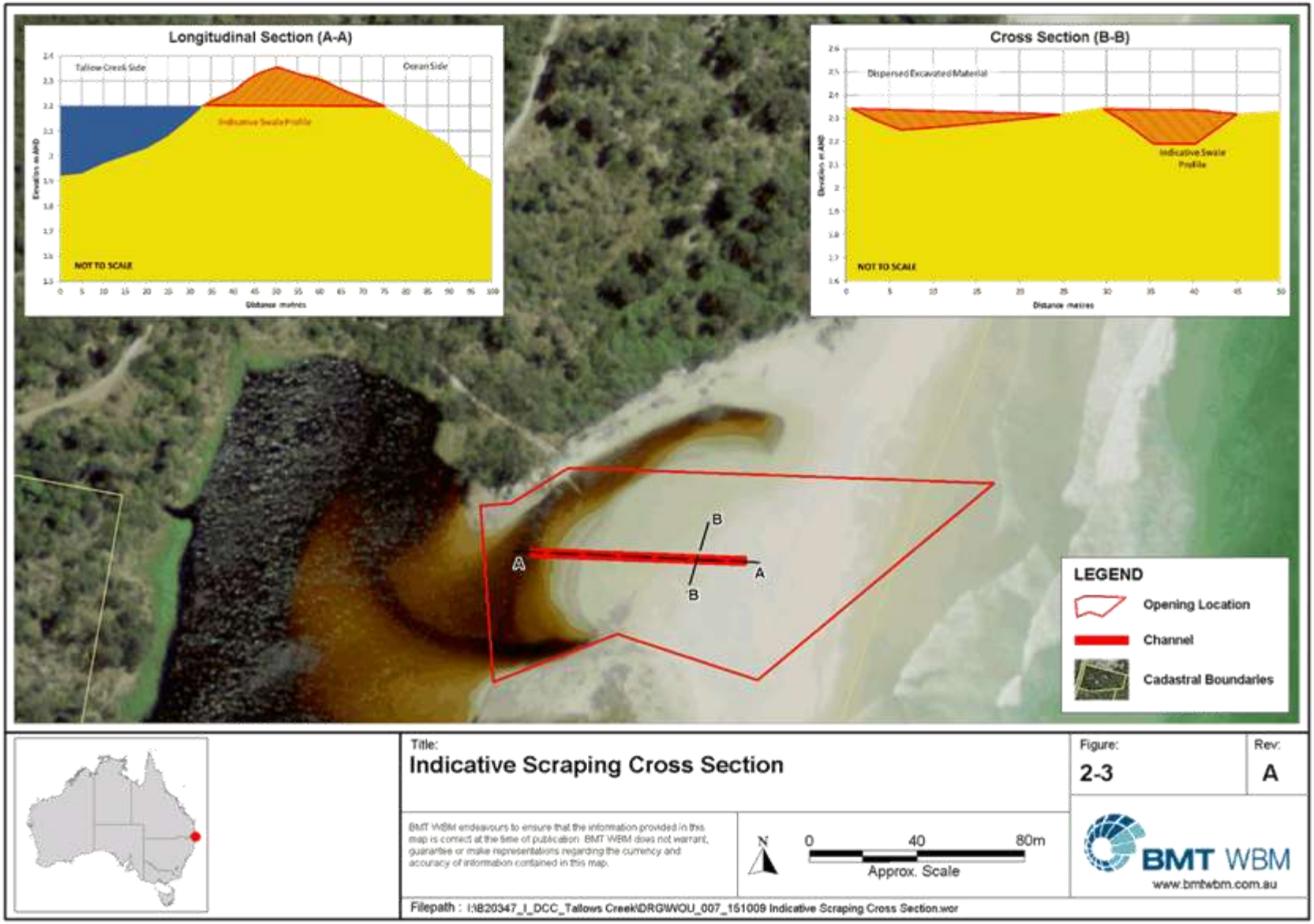
Longitudinal Section (A-A)
Tallow Creek Side
Ocean Side
Indicative Swale Profile
NOT TO SCALE
Distance metres
Cross Section (B-B)
Dispersed Excavated Material
Indicative Swale Profile
NOT TO SCALE
Distance metres
A
A
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B
LEGEND
Opening Location
Channel
Cadastral Boundaries
Title:
Indicative Scraping Cross Section
Figure:
2-3
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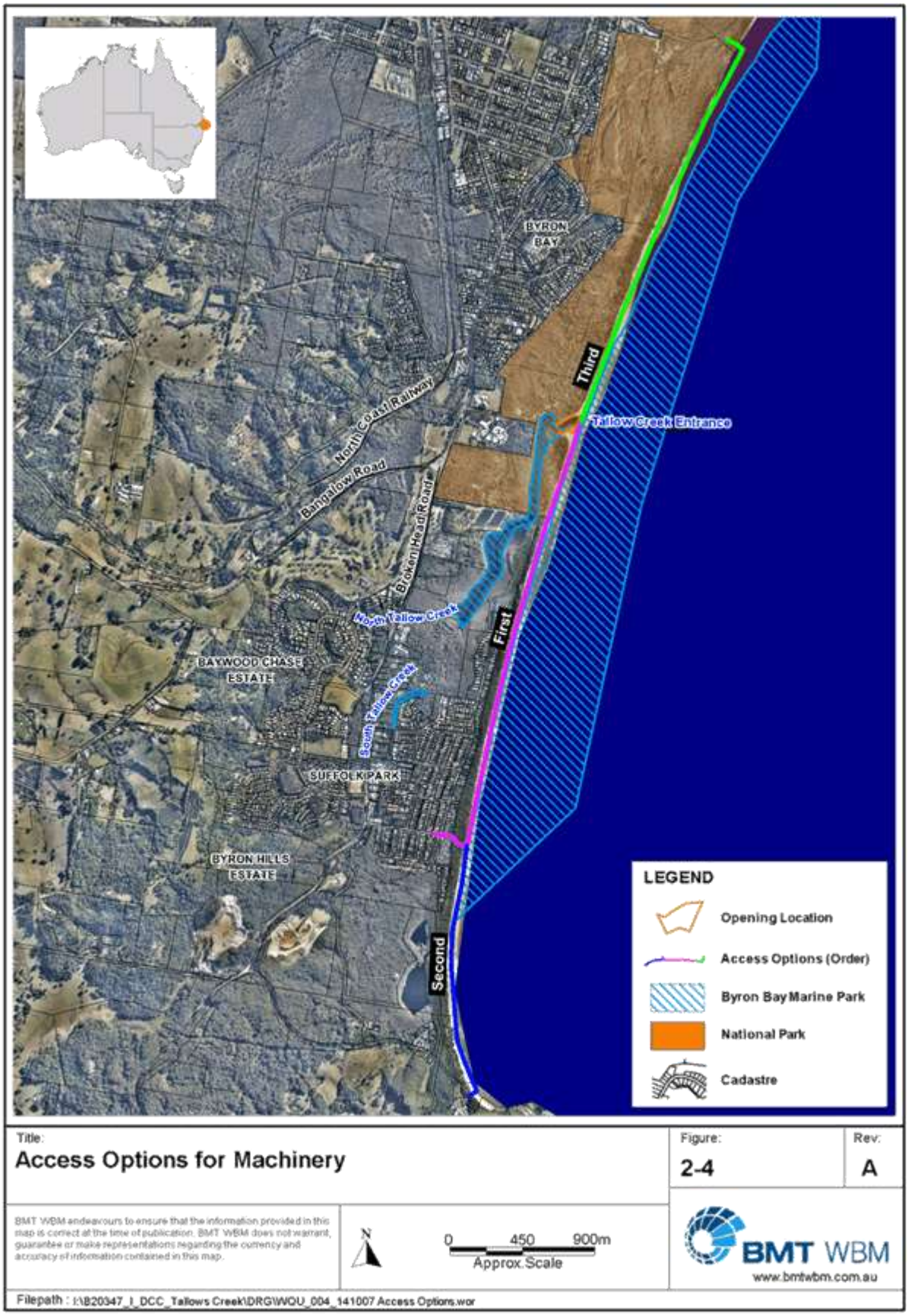
BYRON BAY
Third
Tallow Creek Entrance
North Coast Railway
Bangalow Road
Broken Head Road
North Tallow Creek
First
BAYWOOD CHASE ESTATE
South Tallow Creek
SUFFOLK PARK
BYRON HILLS ESTATE
Second
LEGEND
Opening Location
Access Options (Order)
Byron Bay Marine Park
National Park
Cadastre
Title:
Access Options for Machinery
Figure:
2-4
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## 2.2 Approvals

No additional approvals will be required to undertake the entrance opening activity, as it is conducted under a Licence (under s151, NPW Act) granted by the NSW Office of Environment and Heritage (NPWS).

## 2.3 Relevant Policies and Acts

The Review of Environmental Factors has considered the permissibility of the activity against the following legalisation.

- *National Parks and Wildlife Act 1974* (NPW Act);
- *Marine Parks Act 1997* (MP Act);
- *Environmental Planning and Assessment Act 1979* (EP&A Act), including environmental planning instruments (EPIs);
- *Threatened Species Conservation Act 1995* (TSC Act);
- *Fisheries Management Act 1994;*
- *Water Management Act 2000;* and
- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The activity is permissible under these relevant Acts, and a licence has been granted by OEH for the activity. The licence does not cover activities outside of the scope of the REF.

All work crews are to ensure they abide by Work Health and Safety Act and Regulations. All necessary paperwork for the tasks required of this EMP will be prepared prior to undertaking the activity and approved by the relevant manager for the activity.

# 3 Description of the Environment and Potential Effects

Without providing a detailed description of coastal and fluvial processes, it can simply be stated that the Tallow Creek entrance exists in a dynamic environment which is regularly modified by the actions of coastal sand movement (by winds and waves) and catchment processes (i.e. rainfall and runoff).

The entrance (beach berm) of Tallow Creek is typically closed, but does periodically open to allow water to drain to the ocean. Typically these openings occur naturally at heights below 2.2 m AHD. If the beach berm is allowed to increase above 2.2m AHD, it has the potential to worsen flood impacts in the catchment, particular for a number of low-lying properties.

The subsoil conditions of the Tallow Creek sand berm are likely to include a mixture of predominantly marine sands interspersed with terrestrially derived and reworked marine sands from the catchment and inside Tallow Creek. Acid Sulfate Soils are not expected to be encountered at the site.

The site has been assessed for its potential European and Aboriginal cultural heritage value and Tallow Creek (as well as its beach and dune systems) are an important Aboriginal cultural heritage landscape for the Arakwal people. However, the activity proposed is unlikely to unearth items of cultural heritage significance. An Aboriginal cultural spotter will be on-site to observe for the potential unearthing of significant artefacts.

In terms of human use, Tallow Beach is regularly used by beachgoers for swimming, fishing, walking and various forms of nature appreciation. The proposed activity will bring relatively heavy and uncommon machinery along the beach to the entrance to excavate a channel. This activity may cause temporary inconvenience to beach users. The activity may also pose small risk to beach users unfamiliar with an eroding channel, potentially with small shallow drop offs on the edge of the channel.

At the entrance of Tallow Creek (in the vicinity of the activity), the following species of conservation significance have been identified as potentially being affected, beach stone curlew, pied oyster catcher, little tern, loggerhead turtle and green turtle. Other species, particularly a range of migratory species, may also be potentially affected as well and impacts to these species should be minimised.

As indicated earlier, the presence of these species will be advised prior to issuing orders for entrance management activities. An ecologist will be on-site to assist in locating the pilot channel to manage potential impacts to nesting species.

Entrance opening activities have the ability to influence water quality in Tallow Creek after opening events and has been implicated in past fish kills. The exact mechanism leading to fish kills has not been investigated in detail, but is understood to relate to de-oxygenation of residual waters within Tallow Creek after the opening event. As a result, it is recommended to complete the system opening coincident with a daytime low tide or up to two hours after the low tide. This timing from experience serves to limit the extent of scouring and lake emptying and reduces the potential for impacts.

# 4 Communications

The key party with which Council will liaise with is NPWS. Council will liaise with NPWS regarding need for observation of the presence of nesting species at the Tallow Creek entrance when Council themselves become aware that water levels in Tallow Creek have exceeded 1.8m AHD. Similarly, Council will liaise with NPWS if beach berm levels at the entrance exceed 2.2 m AHD and beach scraping may be a future requirement.

NPWS will then communicate back to Council regarding the presence of nesting species in the entrance area that may be affected. Council will be required to initiate further monitoring to ascertain if identified species are actually nesting in the entrance area.

When an artificial opening or pre-emptive scraping event is imminent, Council will advise and liaise with NPWS about the timing and procedures for the artificial opening, along with advising other relevant parties.

Council will liaise with support staff as required to assist in entrance management at Tallows Creek. It is anticipated that this will include an ecologist to advise regarding potential adaptive measures to minimise impacts to species that may be present, and an Arakwal representative to spot for any potential Aboriginal cultural heritage items. An Aboriginal spotter is not required for pre-emptive scraping activities.

## 4.1 Communication Associated with Artificial Opening

**Water Levels up to 2.0m AHD**

Council's Overseer Road Maintenance will be responsible for monitoring lake water levels on a weekly basis. The location to measure the water level is at the footbridge of Tallow Lake. The water level that is recorded dictates the action that is carried out (refer Table 2-1).

The overseer is responsible for initiating processes once the 1.8m AHD trigger level has been reached.

The Overseer Road Maintenance will consult and update NPWS on a weekly basis, once the 1.8m trigger level has been reached. The Overseer Road Maintenance is responsible for all communication internally, and with NPWS between the water levels 1.8 to 2.0 m AHD.

**Water Levels above 2.0m AHD**

When the 2.0m water level is imminent or reached the Overseer Road Maintenance is to consult with Council's Flood and Drainage Engineer regarding ongoing management and any approval to initiate an opening event. In the absence of the Flood and Drainage Engineer Council's Team Leader Infrastructure Planning will stand in. The Overseer Road Maintenance will arrange for suitable site operators and equipment to be made available to complete the opening. Typically the opening will occur within one to three days of the upper trigger level being reach (or likely to be being reached).

Councils Engineer will advise and liaise with NPWS (and Byron Bird Buddies) about the timing and procedures for the artificial opening. Council's engineers will also advise other persons to attend the opening, including a cultural heritage spotter who will be invited to attend and

observe the opening activities, and ecologist who may be required to guide entrance opening locations and activities to manage impact to nesting species that may be present.

During the opening event, the Site operators will be required to communicate with Council's Engineer and others nominated by the Engineer, such as the cultural spotter and ecologist. Site activities may need to be modified on-site prior to or during the opening based on conditions and events at the time. Site operators will also be required to inform beach users of the activities being performed (if asked).

For all written (email) correspondence, the following are to be copied into all communication regarding management of Tallow Creeks Entrance (see Table 4-1).

**Table 4-1 Written Communications Table**

| Name | Responsibility | Agency | Number | Email |
|---|---|---|---|---|
| Patrick Dwyer | Conservation Manager | NSW Fisheries | 6626 1397 0407 264 391 | Patrick.dwyer@dpi.nsw.gov.au |
| Sue Walker | Area Manager | National Parks and Wildlife | 6620 9300 0401 832 843 | Sue.walker@environment.nsw.gov.au |
| Andrew Page | Manager | Marine Parks Authority | 6639 6200 0439 485 266 | Andrew.page@environment.nsw.gov.au |
| Ben Fitzgibbon | Coastal Officer | Office of Environment and Heritage | 6620 9310 0428 303 733 | Ben.fitzbibbon@environment.com.au |
| James Flockton | Council Flood and Drainage Engineer | Byron Shire Council | 6626 7158 0408 187 375 | James.flockton@byron.nsw.gov.au |
| TBC (Tony Nash in absence) | Team Leader – Infrastructure Planning | Byron Shire Council | TBC 6685 9303 | TBC Tony.nash@byron.nsw.gov.au |
| Rob King | Overseer Road Maintenance | Byron Shire Council | 6685 9313 0418 484 359 | Rob.king@byron.nsw.gov.au |
| Sandy Pimm | Consulting Ecologist | Private | 6626 7104 | Sandra.pimm@byron.nsw.gov.au |
| Jan Olly | | Bird Buddies | 0428 864 378 | jeanatteolley@gmail.com |

## 4.2 Communication Associated with Beach Scraping

Communications commence once berm levels exceed 2.2 m AHD. Berm levels typically change relatively slowly unlike water levels which can vary rapidly, hence there is likely to be ample time to respond to increasing berm heights.

Council's Overseer Road Maintenance will be responsible for monitoring berm levels on a regular basis and will consult with Council's Flood and Drainage Engineer regarding pre-emptive scraping once the trigger height has been reached. In the absence of the Flood and Drainage Engineer, Council's Team Leader Infrastructure Planning will stand in.

Council's Engineer (or stand in) will inform NPWS that the entrance berm has exceeded 2.2 m AHD and seek feedback on the presence of nesting species. The Engineer will arrange for further specific ecological monitoring work to be completed if required.

Councils Engineer will advise and liaise with NPWS (and Byron Bird Buddies) about the timing and procedures for the pre-emptive scraping. Council's Engineer will arrange for other necessary personnel to attend the opening. The Overseer Road Maintenance will arrange for suitable site operators and equipment to be made available to complete the scraping. Typically the scraping will occur within a month of the upper trigger level being reached

During the scraping, the Site operators will be required to communicate with Council's Engineer and others nominated by the Engineer, such as ecologist. Site activities may need to be modified on-site prior to or during the opening based on conditions and events at the time. Site operators will also be required to inform beach users of the activities being performed (if asked).

For all written (email) correspondence, those listed in Table 4-1 are to be copied into all communication regarding management activities at the Tallow Creeks Entrance.

# 5 Management Plan Elements

Once an action has been chosen, Table 5-1 provides the relevant Construction Environmental Management Plan (CEMP) elements for the proposed activities. These should be used to guide the management of site works from an environmental perspective.

An Operational Environmental Management Plan (OEMP) is included in Table 5-2 to capture normal operational management activities and particular monitoring activities that are triggered or relate to entrance management activities.

Appendix A includes a 2-page Opening Strategy document which has been prepared as a Quick Read document for field staff to familiarise themselves with the activities that are required to be undertaken.

**Table 5-1 Construction Environmental Management Plan for Key Elements**

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| Flora and Fauna | Traversing to the site and excavation / scraping of the entrance channel has the potential to impact on species, including threatened species (birds and turtles). | Conduct work practices to avoid impacts to resident species through appropriate route selection for access to the site, excavation of the pilot channel, beach scraping and dispersal of removed materials. | If species are known or thought to be present, an ecologist will be on-site for the entrance management works and will guide certain activities, particularly locating the pilot channel and sand dispersal areas. Ongoing liaison with NPWS will be required, particularly if any actively nesting species are present.<br>Threatened (T) or migratory (M) species to observe for during pre-opening inspections include:<br>• Beach Stone Curlew (T)<br>• Pied Oyster Catcher (T)<br>• Little Tern (T)<br>• Loggerhead Turtle (T)<br>• Green Turtle (T)<br>• Sand Spurge (T)<br>• Cattle Egret (M)<br>• Ruddy Turnstone (M)<br>• Short-tailed Shearwater (M)<br>• Wedge-tailed Shearwater (M)<br>• Sharp-tailed Sandpiper (M)<br>• Eastern Reef Egret (M)<br>• Bar-tailed Godwit (M) | Photograph works at commencement, half way and at completion.<br>Report any harm to species to the Council Engineer who will liaise immediately with the OEH (NPWS) Ranger.<br>Report presence of any unknown bird nests/eggs and subsurface turtle egg nests immediately to the Council Engineer who will liaise immediately with the OEH (NPWS) Ranger<br>Relevant information will be recorded in Council's REFLECT system in the field. | Cease or modify works as advised by ecologist, and Council Engineer (after consulting with OEH (NPWS) |

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| | | | • Pacific Golden Plover (M)<br>• Common Tern (M)<br>• Grey-tailed Tattler (M)<br>• Common Greenshank (M)<br>• March Sandpiper (M)<br>• Rainbow Bee-eater (M)<br>• Little Tern (T, M)<br><br>*Access*<br>Inspect access route prior to traversing for presence of species and suitability.<br>Access site via preferred access ways in order of priority, unless access route will lead to excessive impact.<br>Traverse to the site on hard packed intertidal sands (if possible).<br><br>*Pilot Channel / Berm Lowering Swale*<br>Locate channel / swale to avoid nesting species (consult with ecologist if required). Move sand to the dispersal area and spread out (again the ecologist may advise on where this area is located to avoid impacts to species). | | |

**Management Plan Elements**

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| | | | Use small machinery appropriate for task (i.e. 5 tonne excavator).<br>Wash vehicles prior to entry to site. | | |
| Water Quality | Over-draining of Tallow Creek estuary leading to a situation which might contribute to poor water quality and ultimately fish kills<br>Chemical spill to the waters or substrate surrounding Tallow Creek | Remove final portion of pilot channel and commence draining of Tallow Creek at the correct time.<br>Avoid contamination of waters with chemicals | Complete opening of system coincident with a daytime low tide or up to two hours after the low tide.<br>In the event of a fluid spill from machinery, the spill will be managed to mitigate and reduce potential impacts to the environment and nearby humans. Equipment operators are trained to respond to fluid spills.<br>An Artificial Opening event will trigger the completion of water quality monitoring. The necessary parameters are included in '**Physical**' monitoring as outlined in Table 5-3, at the locations nominated. | Record time that the pilot channel has been connected fully to Tallow Creek and waters commence to drain.<br>Record with GPS the location of the material spill to allow later identification.<br>Relevant information will be recorded in Council's REFLECT system in the field. | It may be possible to block the initial drainage by blocking it with sand, but this likelihood will decrease with time as the outflow rate increases. |
| Coastal and Dunal Processes | Activities which remove sand from the coastal environment, affect coastal processes<br>The pilot channel location will influence where the drainage channel forms, if it is | Ensure all materials excavated from the beach remain on the beach.<br>Locate the pilot channel away from existing dunes to limit risk of them eroding as the drainage channel | All sand materials excavated for the purposes of constructing the pilot channel are to remain on the beach, typically dispersed on the northern side of the pilot channel<br>Complete the pilot channel or scraping activities away from the existing northern and southern banks | Photograph works at commencement, half way and at completion.<br>Record with GPS the location of the entrance channel.<br>Relevant information will be recorded in Council's | None. |

**Management Plan Elements**

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| | close to banks this may result in bank/dune erosion | forms. | | REFLECT system in the field. | |
| Cultural Heritage | Exposure of items of Aboriginal or European Cultural Heritage significance | Work activities will cease if potential artefacts in substrates are located during the progress of excavating the pilot channel<br>A cultural spotter may be on-site at the time of the opening. | Adopt a 'Proceed with Caution' approach to the excavation activities as there may be items of cultural significance in the subsoils.<br>Cease work activities if an item of potential cultural significance has been found (this may be advised by the cultural spotter if present), inform Council's Flooding and Drainage Engineer immediately. Await advice from the Council Engineer on what further activities may need to occur on-site prior to leaving, such recovering the items to limit vandalism. | Report a potential find immediately to Council's Engineer who will consult with relevant parties (OEH and/or Aboriginal groups) in respect of the potential find.<br>Take photographs of the item(s) in-situ after advising the Engineer.<br>Provide photographic evidence to the Council Engineer for broader distribution.<br>Relevant information will be recorded in Council's REFLECT system in the field. | Cease works as advised by the cultural spotter.<br>Await advice on further actions on site once the initial suspected find has been reported to Council's Engineer. |
| Beach Amenity and Use | Disruption of typical beach usage patterns and beach access | Mark out construction site for duration of works using high visibility marker | Limit access to the site of planned works, including beach access (north and south) and pathway access on the north side of Tallow Creek. Note that it may be possible to provide | Take photographs of barriers once installed.<br>Relevant information will be recorded in Council's | Modify or move barriers as required to ensure they remain |

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| | | materials | safe beach access from the pedestrian pathway, this will need to be determined on site.<br>Utilise a suitable barrier material which can be quickly erected with limited staff and equipment, and will be suitable for the duration of works in an exposed coastal location. Remove barriers at completion of works. | REFLECT system in the field. | effective for the duration of works. |

**Table 5-2 Operational Environmental Management Plan for Key Elements**

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| Flora and Fauna | It is anticipated that vegetation communities at the upper extent of the floodzone will be most sensitive to a potential decrease in flooding extent and residency as a result of more frequent | Assess and document changes in the floristic composition, particularly threatened communities within the estuary in in response to artificial entrance opening of Tallow | Figure 5-1 indicates the location of two monitoring transects within the predicted impact zone. Thesetransects sample ecotones between saltmarsh and freshwater wetlands for the purpose of detecting changes in vegetation composition and condition.<br>Indicators of condition to be measured will include species composition and cover, occurrence of dieback, disease and other | Vegetation transects shall be monitored twice per year in Autumn and Spring.<br>Permanent monitoring transects will be established across each ecotone to track vegetation composition and condition. The length of each transect will be determined based on site condition with both ends to be permanently marked with a wooden stake, star picket and/or PVC pipe and georeferenced.<br>Photographs will be taken along and perpendicular to the transect line at the start, middle and end points to document landscape features within and adjacent to the monitoring sites. | TBC |

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| | opening of the estuary mouth. | Creek. | stresses and observations of substrate and profile characteristics.<br><br>Monitoring will be undertaken once a year following the wet season (April). Baseline monitoring will be undertaken a year before artificial opening commences. Monitoring will be carried out for a minimum of three years following artificial opening of the mouth.<br><br>Data collected from the permanent transect and survey plots is primarily intended to track vegetation changes over time and will be used to analyse mean cover by species, change in community structure over time, water soil salinity and species richness. | Starting at the 0m point, 1m x 1m squares will be located every 5m along the transect line until the end point. Care must be taken during transect establishment not to remove or damage vegetation and substrate within the plots. The percentage cover of groundcover species will be assessed within each of the quadrats. Observations of vegetation condition including dieback and disease will be recorded and observations of substrate condition (such as cracking soils, siltation) will be noted. Spot photos will be taken of each quadrat to document groundcover condition over time.<br><br>Walking along the transect line looking upwards, the start and finish distance of the woody canopy will be recorded to determine the percentage canopy cover over the transect line per height class. Multiple overlapping canopies will be identified as continuous unbroken cover. Shrub canopy cover will be measured using the same line intercept method and can be assessed from above the canopy if below eye level. Observations of woody vegetation condition such as dieback and disease will be recorded.<br><br>Data collected shall be compiled by Byron Shire Council and provided to third parties as required. | |
| Water Quality | Elevated water levels in Tallow Creek increase likelihood of human | Collect water quality data as part of operational monitoring of the estuary. | **Water levels > 1.8m**<br><br>Completion of a water quality test for '**Health**' parameters outlined in Table 5-3. Testing may be repeated as required if water levels | Complete water quality testing as outlined in 'Management Actions' and by reference to Table 5-3.<br><br>Data shall be collated by Council in a single secure location for ongoing records and reference. | TBC |

| Aspect | Potential Impacts | Management Objectives | Management Actions | Monitoring and Reporting | Corrective Actions |
|---|---|---|---|---|---|
| | interaction with it. Providing increased health risks.<br><br>Additionally the effects of entrance management and catchment inputs on water quality are not fully understood and further data is required to improve understanding. | Use data in special circumstances to justify an artificial opening when it is likely that the water in the estuary is presenting a sufficiently high health risk.<br><br>Use data to better understand and manage catchment inputs to the estuary over time. | are sustained for extended periods above 1.8m AHD.<br><br>**Permanent Logger**<br><br>If a logger is installed, it should be telemetered to provide real-time data on-line as well as SMS alerts. The logger should as a minimum record water level and water salinity/conductivity.<br><br>**Artificial Opening Event**<br><br>Included in Table 5-1.<br><br>**No Opening Event**<br><br>If no artificial openings occurs, '**Physical**' monitoring as outlined in Table 5-3 will be completed in Autumn and Spring of every year.<br><br>'**Nutrient**' sampling to completed at the rate of twice per year if funded. | | |

Table 5-3 Water Quality Monitoring – Tallow Creek

| Parameter | Unit | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |
|---|---|---|---|---|---|---|
| **Health*** | | | | | | |
| Enterococci (any one sample) | EC/100mL | N/A | N/A | >700 | >700 | >700 |
| Enterococci (median across 4 out of 6 samples) | EC/100mL | N/A | N/A | >230 | >230 | >230 |
| Faecal coliforms (median in 4 out of 6 samples) | FC/100mL | N/A | N/A | >1000 | >1000 | >1000 |
| Cyanobacteria (toxic species) | cells / mL | N/A | N/A | >15000 | >15000 | >15000 |
| Mosquito larvae | Lv/100mL | N/A | N/A | >100 | >100 | >100 |
| **Physical (Permanent Logger)**** | | | | | | |
| Water Level | Metres AHD | N/A | N/A | N/A | N/A | 0-2.2 |
| Conductivity (Salinity) | µS/cm | N/A | N/A | N/A | N/A | 7-50,000 |
| **Physical (on mechanical opening or skimming)***** | | | | | | |
| Conductivity (Salinity) | µS/cm | 125-2200 | 125-2200 | 0 – 10,000 | 0 – 10,000 | 0 - 10,000 |
| Temperature | Degree C | 8-25 | 8-25 | 8-25 | 8-25 | 8-25 |
| Dissolved oxygen | % Saturation | 85-110 | 85-110 | 80-110 | 80-110 | 80-110 |
| pH (outside range) | no units | 6.5 to 8.5 | 6.5 to 8.5 | 7 to 8.5 | 7 to 8.5 | 7 to 8.5 |
| Turbidity | NTU | 6-50 | 6-50 | 0.5-10 | 0.5-10 | 0.5-10 |
| **Physical (twice a year)****** | | | | | | |
| Conductivity (Salinity) | µS/cm | 125-2200 | 125-2200 | 0 – 10,000 | 0 – 10,000 | 0 – 10,000 |
| Temperature | Degree C | 8-25 | 8-25 | 8-25 | 8-25 | 8-25 |
| Dissolved oxygen | % Saturation | 85-110 | 85-110 | 80-110 | 80-110 | 80-110 |
| pH (outside range) | no units | 6.5 to 8.5 | 6.5 to 8.5 | 7 to 8.5 | 7 to 8.5 | 7 to 8.5 |
| Turbidity | NTU | 6-50 | 6-50 | 0.5-10 | 0.5-10 | 0.5-10 |
| **Nutrient (desirable program and range)******* | | | | | | |
| Total phosphorus | mg/L | <0.025 | <0.025 | <0.03 | <0.03 | <0.03 |
| Chlorophyll a | µg/L | <5 | <5 | <4 | <4 | <4 |
| Total nitrogen | mg/L | <0.35 | <0.35 | <0.3 | <0.3 | <0.3 |

**Key:**

Site 1 Entry point from Byron Hills drainage system – Broken Head Road near BP station

Site 2 Stormwater drain into Tallow Creek on boundary of Byron @Byron, near the weir

Site 3 End of Marattia Place

Site 4 Behind 34-38 Acorn St
Site 5 Footbridge over Tallow Lake

*Samples to be taken fortnightly when lake water level is above 1.8m AHD. If results above these figures are found, a discussion with NPWS will be held. Council will advise if they believe the results warrant an opening and request concurrence from NPWS, in accordance with licence conditions.

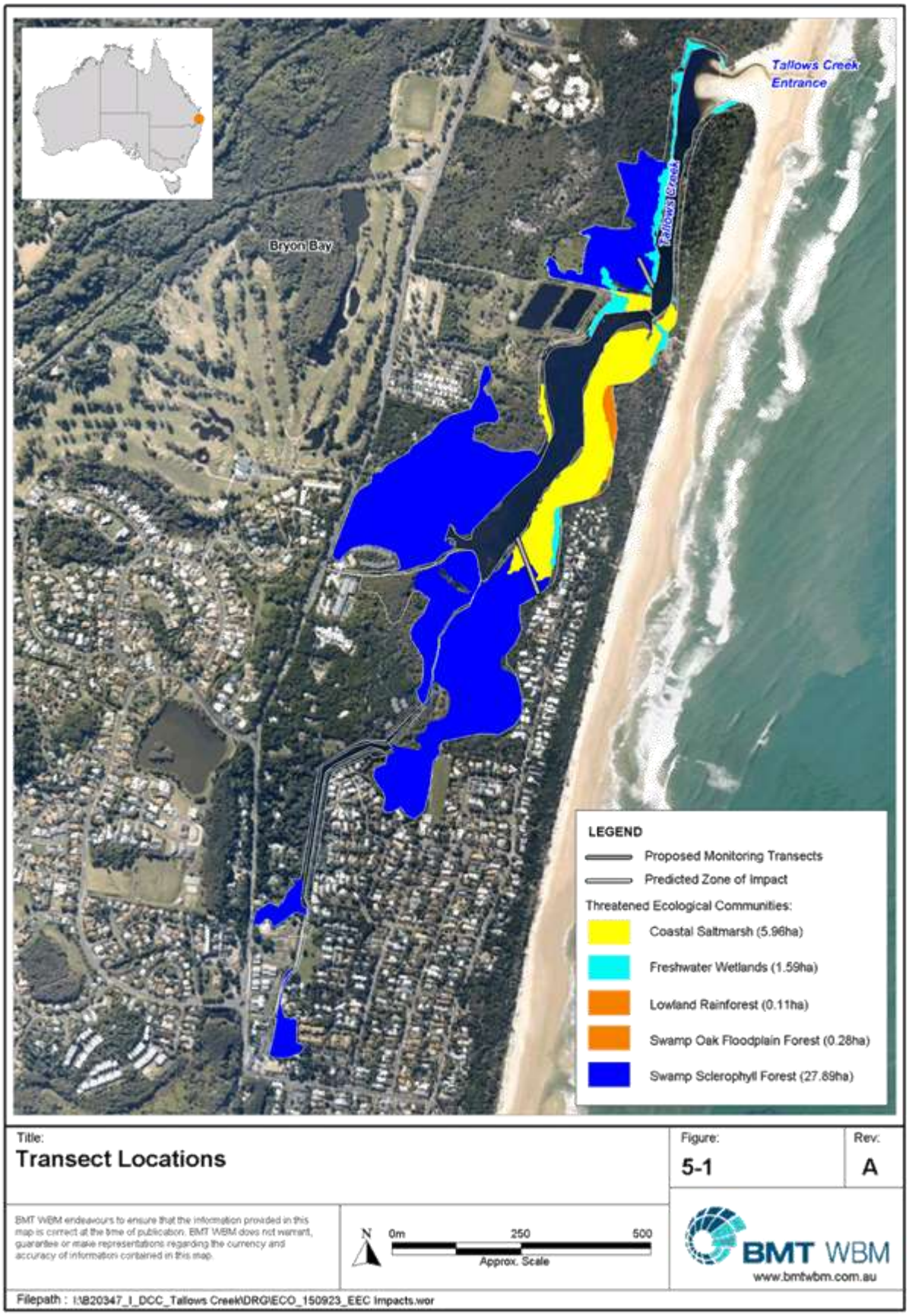
**A single logger constantly monitoring water level and salinity to provide long term data on the water quality, and the effects and timing of openings. The numbers provided indicate the range of values that need to be recorded by the logger.

***Sampling regime to occur 1 day before and 6 days post a mechanical opening or an opening due to mechanical skimming. Figures for Site 1 and 2 show desirable catchment runoff targets, Sites 3, 4 and 5 show the estimated ranges for Tallow Creek. ICOLLS such as Tallow Creek tend to display a wide range of water quality data and further data is required to derive typical "healthy" values for this estuary.

****Twice yearly sampling program. If a mechanical opening does not occur. Figures show the typical ranges for catchment runoff and estuaries.

*****A desirable sampling program should funding become available through Council, NPWS or grants. Values reflect WQO for Lowland Rivers as per ANZECC guidelines.

Note: Health parameters taken from ANZECC Guidelines, Paper 4, Vol 1, Section 5 for secondary contact. i.e boating, walking or riding through water, fishing, water in private back yards.


Tallows Creek Entrance
Tallows Creek
Bryon Bay
LEGEND
Proposed Monitoring Transects
Predicted Zone of Impact
Threatened Ecological Communities:
Coastal Saltmarsh (5.96ha)
Freshwater Wetlands (1.59ha)
Lowland Rainforest (0.11ha)
Swamp Oak Floodplain Forest (0.28ha)
Swamp Sclerophyll Forest (27.89ha)
Title:
Transect Locations
Figure:
5-1
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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# Appendix A Opening Strategy

**Introduction**

This Opening Strategy applies to activities associated with entrance management at Tallow Creek, this includes artificial openings to release waters from Tallow Creek or pre-emptive scraping activities to reduce the height of the berm to alleviate potential flood effects.

**When should Entrance Management Activities Occur?**

An artificial opening will normally be undertaken once water levels in Tallow Creek (when measured at the permanent gauge on the walk bridge) exceed 2.2m AHD. An entrance scraping event will only occur when berm levels exceed 2.2 m AHD (with or without elevated water levels). In special circumstances associated with continued poor water quality in Tallow Creek (and water levels exceed 1.8m AHD) an artificial opening may also be affected.

**Where**

The location of artificial openings and pre-emptive scrapings can only occur within a polygon shown within the EMP (refer Figure 2-1). This location is preferred to promote drainage channel formation away from the northern and southern vegetated foreshores to avoid erosion of dunes and loss of vegetation.

**Responsibilities for Entrance Management**

There is a variety of monitoring, communication and decision making which occurs prior to a decision to manage the entrance at Tallow Creek.

The entrance management activities can only be undertaken with approval of Council's Flood and Drainage Engineer. In the absence of the Flood and Drainage Engineer, Council's Team Leader Infrastructure Planning will make these decisions. Council's 'Engineer' will advise and liaise with NPWS (and Byron Bird Buddies) about the timing and procedures for the artificial opening or scraping.

Council's Engineer will also advise other persons to attend the entrance management activities, including a cultural heritage spotter who will be invited to attend and observe artificial openings, and an ecologist who may be required to guide entrance management activates to minimise impacts to nesting species.

The Overseer Road Maintenance will arrange for suitable site operators and equipment to be made available to complete the opening. Typically the opening will occur within one to three days of the upper trigger level being reached (or likely to be being reached).

During the opening event, the Site operators will be required to communicate with Council's Engineer and others nominated by the Engineer, such as the cultural spotter and ecologist. Site activities may need to be modified on-site prior to or during the opening based on conditions and events at the time. Site operators will also be required to inform beach users of the activities being performed (if asked).

An Environmental Management Plan has been prepared for the entrance management activities to avoid and/or manage impacts to:

- Flora and Fauna
- Water
- Coastal and Dunal Processes

- Cultural Heritage
- Beach Amenity and Use

This plan needs to be applied during entrance management activities. Also, an Artificial Opening event will trigger the need for water quality monitoring for a period of time after the opening. This is done to build knowledge of estuarine response after openings occur.

**Description of the Activity**

Artificial openings involve the excavation of a "pilot" channel that is both narrow and shallow and allows for elevated waters in Tallow Creek to drain to the ocean. Once drainage commences, the escaping waters will erode the pilot channel to form a larger drainage channel.

A 5 tonne excavator will be used to construct the pilot channel. The excavator will operate from the shoreline toward Tallow Creek and then the last section of sand at the sandbar will be taken from the water in the estuary. The excavator will operate from either side of the channel, while operating to protect existing banks. All excavated material will be placed on the northern side of the work area to minimise erosion risks to existing dunes.

The proposed location of artificial opening works is discussed above, other on-site environmental constraints such as nesting fauna and these will be advised by Council's engineer or advised on site by a consulting ecologist.

The channel will be excavated to between 0.5 and 1.0 m depth below the ground surface of the beach berm (depending on berm height and water level at the time). The channel is to be constructed nominally two (2) metres wide. The length of the channel will vary as it will depend on the configuration of entrance and beach profile at the time of opening.

The main difference with pre-emptive scraping is that the excavator will be used to form of a broad swale which has an invert (bottom) elevation at 2.2m AHD. Sands removed to form the swale will be dispersed on the northern side of the swale.

In terms of dimensions, the swale is to be constructed nominally five (5) metres wide along the base with batter slopes of up to a couple of metres width. It is expected that the entire swale (top width) would be less than 10 metres.

The excavator will access the site via three potential access routes in order of priority:

(1) Clifford Street – Suffolk Park (travel distance – 3 km);

(2) Beach Road/Broken Head Reserve Road – Broken Head (travel distance – 4.6km); and

(3) Tallow Beach car park in Cape Byron State Conservation Area – Byron Bay (travel distance – 2.6 km).

An emergency access is also available via Ocean Street Byron Bay, however, this access has narrow clearances to vegetation and may have a sizeable beach dune to navigate to then access the beach.

The selection of a beach access point would depend on suitability at the time works are proposed.

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**Report No. 4.3** **Alternative / Additional Flowpath BBSTP**
**Directorate:** Infrastructure Services
**Report Author:** Peter Rees, Manager Utilities
**File No:** I2018/417
**Theme:** Community Infrastructure
Sewerage Services

**Summary:**

There are no constraints to utilising the identified alternative flowpath through the West Byron Arts and Industry Estate and an assimilation pathway for the excess recycled water from the Byron Bay Sewage Treatment plant.

Council should now proceed with formal applications and detailed engineering for the alternative flowpath.

---

**RECOMMENDATION:**

**That Council allocate $250,000 for detailed design and formal application for the Byron Bay Sewage Treatment Plant Alternative Flowpath project.**

**Attachments:**

1 Alternative Additional Flowpath BBSTP, E2018/18165 , page 175⇩

**Report**

At the Council meeting 26/10/2017 Council resolved:-

> *that Council consider the "Bayley Report" as amended after the Panel meeting 28 September complete, and use it as the basis for application for permissions from various authorities (including BSD Union) to introduce a second drainage path as described by Option 2 of the Report. (Lyon/Ndiaye)*

The attached Investigation report has been prepared in response to this resolution. It has been given to the Belongil Swamp Drainage Union for comment. Essentially is has confirmed there are no impediments to pursuing the identified alternative flowpath through the West Byron Arts and Industry drainage system.

Council should now proceed to full engineering design and formal application to the relevant authorities to utilise this alternative flow path for recycled water.

**Financial Implications**

A budget of $250,000 will need to be allocated from the Sewer reserves to undertake this phase of the project. This sum does not include construction.

**Statutory and Policy Compliance Implications**

Environment Protection licence 3404 and Local Government Act Section 60 and Water Management Act 2000.

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(02) 6687 4666
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Planit Reference: J234-LT01

22 November 2017

Dean Baulch
Principal Engineer, Systems Planning
Byron Shire Council
PO Box 219
Mullumbimby NSW 2482
Email: dean.baulch@byron.nsw.gov.au

Dear Dean,

**RE: PRELIMINARY INVESTIGATION FOR THE PROPOSED BYRON BAY STP ADDITIONAL FLOW PATH VIA INDUSTRIAL ESTATE AND CENTRAL UNION DRAIN**



## 1. INTRODUCTION

Byron Shire Council wish to investigate the use of the Industrial Drain (additional flow path) to discharge flow from the Byron STP to Belongil Creek during dry conditions. Currently, the Union Drain is used to discharge polished water from the Byron STP wetlands to Belongil Creek, see Figure 1 below. Currently up to 3ML/day is discharged to Belongil Creek via the Union Drain causing some concerns from local landholders. To address these concerns, the Industrial Estate additional flow path is being investigated as a discharge option. During wet conditions, flow would be diverted back to the Union Drain as per existing conditions.

Figure 1 | **Existing (blue) and proposed (red) Byron Bay STP excess recycled water discharge drains**

By discharging into the Industrial Drain during dry periods, it will take pressure off the Union Drain and will allow for additional water quality treatment within the Industrial Drain through enhanced Water Sensitive Urban Design (WSUD) before travelling through the West Byron development into Belongil Creek. Planit has been engaged to investigate the necessary approvals required for the additional flow path and to complete a preliminary engineering investigation for the works. This letter details the work completed including desktop review of existing information, site visit, approvals and planning investigations and preliminary engineering assessment of the proposed additional flow path.

## 2. DESKTOP REVIEW

A desktop review of BMTWBM report on the Capacity Assessment of the Belongil Creek Drainage System (December 2016) was completed as part of the works. The report investigates the impact of the increased discharge expected in the next 5-10-year period due to the increase in development within Byron Bay. The report looks at three options for discharging to Belongil Creek including:

- Utilising the existing discharge location and flow path;
- Option 1 – Tributary of Union Drain South of Ewingsdale Road; and
- Option 2 – Industrial Estate Drain.

The key finding of the report recommends utilising the Industrial Drain (Option 2) as the additional flow path for discharging treated effluent to Belongil Creek. The Industrial Drain flow path has minimal flooding impacts on the Belongil Creek drainage system. The hydraulic modelling simulated three flowrates for discharging through the Industrial Drain including 2ML/day, 4ML/day and 7ML/day while discharging a constant 1ML/day through the current Union Drain flow path for the regeneration of the wetlands. The modelling demonstrated that the predicted increased flood durations were significantly less for all flow rates for Option 2 – Industrial Drain flow path, compared to the other two flow path options.

It is Planit's understanding that no engineering investigations have been completed on the Industrial Drain between the proposed discharge point and Ewingsdale Road. Section 4 of this letter details the findings of the Industrial Drain engineering investigation.

## 3. ASSOCIATED APPROVALS

Byron Shire Council's Environmental Protection License No. 3404 has the following discharge and monitoring points as detailed in Table 1.

**Table 1 | Byron Bay STP EPA Discharge Points**

| EPA Identification No. | Type of Monitoring Point | Type of Discharge Point | Location Description |
|---|---|---|---|
| 1 | Discharge to wetland Effluent Quality Monitoring | Discharge to wetland Effluent Quality Monitoring | outlet of STP as marked on map #598568 attached to Council's letter dated 2 June 2006 |
| 2 | Total volume monitoring | | Magnetic flow meters on the rising mains at the entrance to the plant as marked on map #598570 attached to Council's letter dated 2 June 2006 |
| 3 | Effluent Reuse - Volume and Quality Monitoring | Effluent Reuse - Volume and Quality Monitoring | Wetland pump station SPS 3028 - as shown on map #598567 attached to Council's letter dated 2 June 2006 |
| 4 | Discharge from wetland | Discharge from wetland | Outlet of the constructed wetland as marked on map #598567 attached to Council's letter dated 2 June 2006 |
| 5 | Discharge to urban re-use pipeline - Volume and Quality Monitoring | Discharge to urban re-use pipeline - Volume and Quality Monitoring | Outlet to urban re-use pipeline as marked on map #598570 attached to Council's letter dated 2 June 2006 |

Discussions have been undertaken with Environment Protection Authority Officer Peter Lynch regarding Environment Protection Licence No.3404 and the proposed use of the Industrial Drain which runs through the Byron Bay Arts and Industry Estate as another discharge point. The concept presented to the officer was as follows:

- Up to 3ML/day of Sewage Treatment Plant recycled effluent would be discharged through the Industrial Drain during dry weather. During wet weather, to ensure the Industrial Drain can accommodate stormwater runoff, council would switch the effluent discharge back to the existing Union Drain;

- Discharging the recycled effluent through the Industrial Drain is preferred to be done by a new pump station and new discharge point. The location of this would be confirmed following initial due diligence investigations; and
- Discharge would occur 24hrs/day as per the current operations.

The outcome of the discussion with Peter Lynch and the approval process to progress the additional flow path discharge point includes the following actions:

- Complete an application for an Environmental Protection License (EPL) amendment which will need to include the following information:
  a) Justification relating to the proposal providing a better environmental outcome;
  b) Justification relating to the proposal helping to address 'public perception issues' and not 'flooding issues' with existing Sewerage Treatment Plant operations
  c) Consistency with any development consent (if applicable) or any other approvals to operate the Sewage Treatment Plant;
  d) A risk assessment of the additional discharge location including but not limited to increased potential for persons to come into contact with discharged recycled effluent;
  e) Information to address any pollution load impact on the ultimate receiving environment in Belongil Creek due to the change in the inflow location into Belongil Creek;
  f) All relevant mapping identifying the new discharge location points to Environment Protection Authority requirements.
  g) Consultation with New South Wales Department of Primary Industries was recommended given the intermittent tidal nature of Belongil Creek.

## 4. PRELIMINARY ENGINEERING ASSESSMENT

### a. Site Inspection

A site inspection of the Industrial Drain that passes through the Byron Bay Arts and Industry Estate was undertaken on 20 October 2017. During this inspection, general conditions were noted and photographed, with pipe diameters and pipe cover in the culverts recorded. Due to the overgrown nature of the culverts, some pipes were unable to be accessed and estimates have been made based on the adjacent pipes and Council GIS data. No infrastructure upstream of the Banksia Drive culvert was obtained during the site inspection and is indicative based on Council GIS data.

The Industrial Drain consists of vegetated drainage channels and culverts that convey the Arts and Industry Estate stormwater runoff discharge through the Industrial Drain, to Belongil Creek via the Central Union Drain (see Attachment 1). There are three (3) culverts along the length of the Industrial Drain up to Ewingsdale Road, and these culverts were considered to be the hydraulic controls for the drain (i.e. limiting flows). The culvert under Banksia Drive at the intersection of Bayshore Drive and Banksia Drive contains three (3) 375mm concrete pipes, the culvert under Grevillia Street contains four (4) 600mm concrete pipes. The culvert under Ewingsdale Road contains three (3) 900mm concrete pipes and two (2) 600mm concrete pipes.

It was noted in the site inspection that each of the drainage channels and culverts still had standing water from a rainfall event three (3) days prior (Figure 3). Upon close inspection of each culvert, there was debris and reeds/sediment that occupied approximately the bottom one-third of each pipe (Figure 2). All preliminary calculations in this letter have been undertaken assuming that the Industrial Drain will be cleared and will be working optimally.

Figure 2 | Upstream Grevillea Street Culvert

Figure 3 | Vegetated drainage channel behind council depot



**b. Drain Capacity**

It is proposed by Council that the discharge from Byron STP is conveyed to the Industrial Drain in dry conditions via a new line that connects to the existing infrastructure on the northern intersection of Bayshore Drive and Centennial Circuit (see Attachment 1). The treated effluent is discharged from the Byron STP at a rate of up to approximately 35L/s (3ML/day). Based on reference material for concrete culverts provided by Humes, a 375mm diameter concrete pipe at a 0.5% grade can convey up to 150L/s of discharge. It is proposed that a single 375mm diameter concrete line is installed to convey flows from the proposed additional discharge location form the Byron STP to the Industrial Drain. An exact route shall be confirmed during the detailed design stage, pending quality results from the proposed additional discharge point from the Byron STP.

A preliminary investigation of the current flow capacity of the Industrial Drain has been undertaken in dry weather. It has been assumed that the three (3) culvert crossings will act as the hydraulic controls in the Industrial Drain as the vegetated drainage channel has a significant capacity based on site inspections undertaken. The maximum flows

that can be achieved in the culverts have been based on the reference material provided by Humes for their "off the shelf" concrete pipes, assuming that the culverts are cleared and free of dense vegetation. Based on the pipe measurements recorded during the site inspection, the Banksia Drive culverts have a capacity of 450L/s, the Grevillia Street culverts have a capacity of 2400L/s, and the Ewingsdale Road culverts have a capacity of 4800L/s.

**c. Water Sensitive Urban Design (WSUD)**

There is opportunity to utilise Water Sensitive Urban Design (WSUD) features along the Industrial Drain to improve water quality. Based on inspections of the site, there is no opportunity to utilise any infiltration methods for WSUD as standing water remains throughout the drainage channel, showing that soil infiltration rates are minimal. Healthy Waterways states that dense vegetated swales can offer improved sediment retention by slowing flows more and providing vegetation enhanced sedimentation for deeper flows. Utilising WSUD vegetation such as reed beds will assist with water quality treatment and water polishing prior to discharging into Belongil Creek. Densely vegetated swales can become features of the urban landscape and once established, require minimal maintenance and are hardy enough to withstand large flows. The existing drainage channel is heavily vegetated; however, a landscape architect shall confirm the vegetation type is suitable for treatment during the detailed design stage if Council wish to promote WSUD in the drainage channel.

It is understood that Council are considering installing shared paths and public spaces throughout the Byron Bay Industrial Estate. If WSUD is incorporated further into the drainage channels and culverts are cleared and maintained, the drain will act as an aesthetic landscape feature and could serve as a potential recreational area. There is opportunity to install a shared path parallel to the drainage channels throughout the Banksia Drive block. To ensure that the paths connect, some minor crossings will need to be installed across the drainage channels. If Council wish to pursue this, dimensions and clearances shall be provided in the detailed design stage of the project.

## 5. RECOMMENDATIONS

Based on the preliminary investigation undertaken, utilising the Industrial Drain as an additional flow path for the Byron Bay STP treated effluent discharge is achievable during dry conditions. The investigation has resulted in the following recommendations:

- In principle and still subject to detailed assessment, the Environment Protection Authority officer raised no issue with an additional discharge location via the Industrial Drain for dry weather operations and they confirmed the proposal would require an amendment of the Environment Protection Licence.
- Based on this preliminary assessment there is sufficient capacity in the Industrial Drain to convey STP treated effluent discharge from Byron STP during dry conditions.
- Based on visual inspection during the site visit, the culvert crossings will need significant clearing prior to the Byron STP discharge being directed to the Industrial Drain. It is recommended that the vegetation within 5m of the culvert on both the upstream and downstream ends is completely cleared to ensure that the maximum capacity in the respective culverts can be achieved. A formal maintenance plan should be put in place to ensure that regular clearing of the culverts occurs over time.
- Dense vegetation planting should be avoided within close proximity of culverts to ensure that flow isn't restricted through the culverts.

The next stage of works to implement the additional flow path includes:

- Detailed survey of drainage network and connection route (by subcontractor, unless provided by Council)
- Geotechnical assessment (if required)
- Underground and overhead services locations
- Consultation and liaison with stakeholders, including Drainage Union, Council, EPA, DPI Water, AWC, Crown Land, West Byron developers and other relevant stakeholders as required
- DPI and EPA licence amendment applications
- Development of concept design for Council and stakeholder consultation and agreement
- Review and update of flood model by BMTWBM to ensure no impact on flooding
- WSUD development and vegetated drains
- Detailed engineering design
- Detailed Risk Assessment
- Implementation of approvals and licensing pathway

- Liaison with Council about integration of the additional flow path into the overall stormwater management strategy for the Industrial Estate and West Byron
- Input into Council's recycled water discharge strategy in regard to rainfall events and the switching protocols between the existing and additional flow paths.

If you have any questions regarding the information provided in this letter, please do not hesitate to contact the undersigned on 0419 202 587 or alternatively via email at MattP@planitengineering.com.au.

Yours sincerely

**Matt Plain**
**Senior Civil Engineer / Project Manager**

## ATTACHMENT 1 – INDUSTRIAL DRAIN PROPOSED ROUTE

## ATTACHMENT 2 – SITE INSPECTION PHOTOS

1. Upstream Banksia Drive culvert

2. Downstream Banksia Drive culvert

3. Downstream Grevillea Street culvert

4. Downstream Ewingsdale Road culvert

5. Downstream of Banksia Drive culvert – Potential shared path location

6. View from upstream of Grevillea Street culvert Looking downstream