# Background Information Document for Joes, Wimbie, Short Beach and Surfside Creeks
## *FINAL REPORT*

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| Prepared For: | Eurobodalla Shire Council |
| Prepared By: | WBM Oceanics Australia |

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| | ***Synopsis:*** | Background Information Document for four ICOLLs around Batemans Bay. The document provides relevant background information for use in the preparation of the Creek Management Policy and REF. |

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# 1 INTRODUCTION

The Background Information Document provides relevant technical information pertaining to Joes Creek, Wimbie Creek, Short Beach Creek and Surfside Creek. This technical information will be used in the development of the Creek Management Policies and the associated Review of Environmental Factors for these waterways.

## 1.1 Current Situation

Breaching of the entrance barriers to Joes Creek, Wimbie Creek, Short Beach Creek and Surfside Beach Creek is periodically undertaken by Eurobodalla Shire Council (ESC) to alleviate odour problems and as a flood prevention strategy for nearby homes and other assets. Figure 1-1 shows the location of the subject creeks.

The ESC is informed of the odour problems by complaints from residents living nearby. The levels of odour vary throughout the year.

The broader environmental implications of current approaches to opening the creeks has not to date been considered.

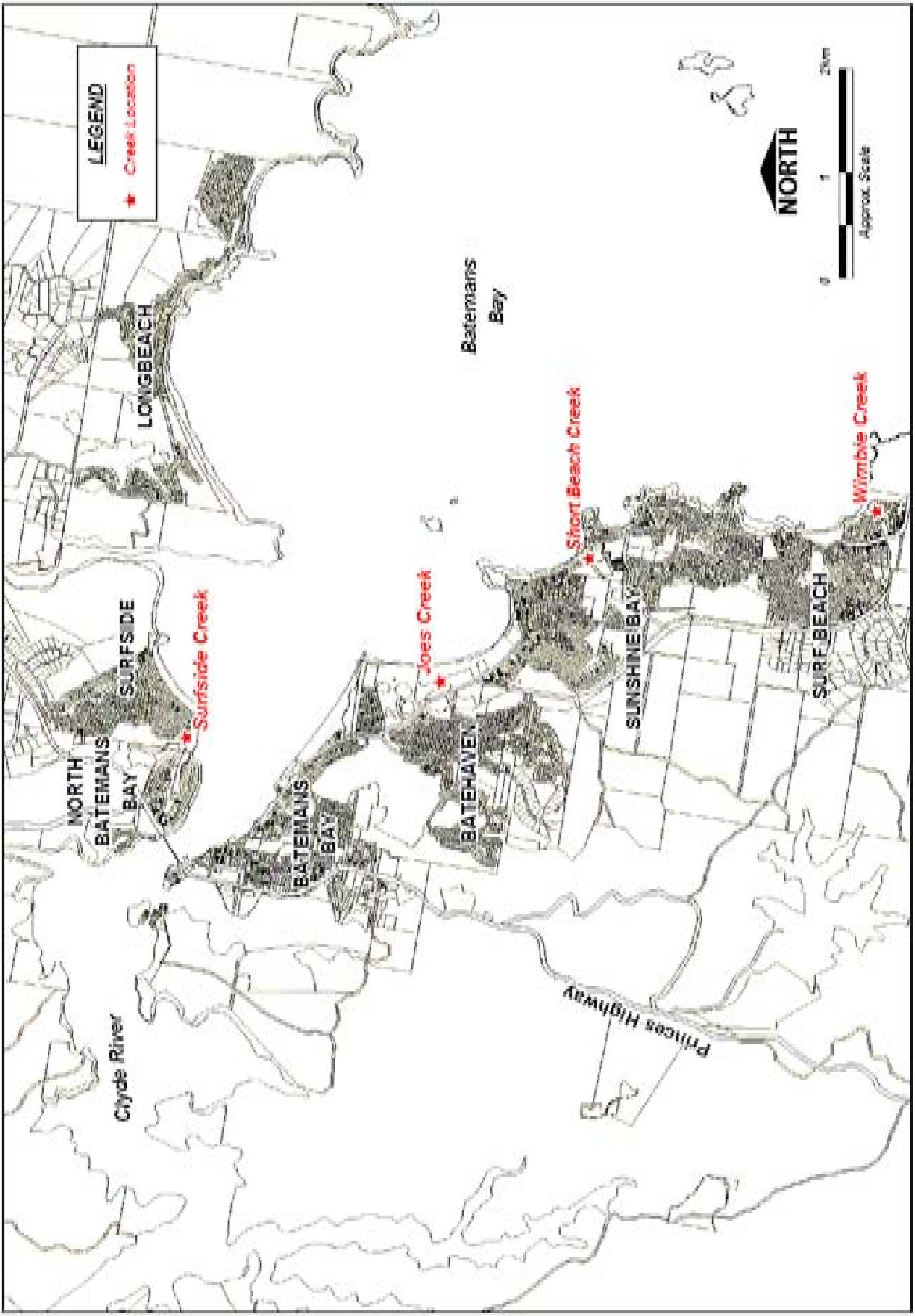
## 1.2 Relationship with Other Documents

Formal Creek Management Policies (taking into consideration creek opening) are being prepared. This document provides the relevant background technical information from which the Creek Management Policies have been derived.

The Review of Environmental Factors considers the broader social and environmental implications of the Creek Management Policies.

## 1.3 Report Format

Section 1 of the report provides some background information on the study, while Sections 2 to 10 provide both general and detailed descriptions of the existing environment. Aspects of the existing environment considered include Acid Sulfate Soils, Water Quality, Hydrology, Odour, Flora, Fauna, Cultural Heritage, Landscape Qualities and Recreational Qualities.




**Locality Map** **Figure 1-1**

## 1.4 Data sources

The following is a list of data sources used in the preparation of this background document:

- Management Plan to Mitigate the Impact of Urban Development on Wetlands Lot 7, D.P. 701830 Princes Highway, Surfside, Batemans Bay, July 1989;
- Plan of Management Batemans Bay Wetland No. 214, September 1993;
- Review of Environmental Factors for the Artificial Opening of Coila Lake, June 2001;
- Review of Environmental Factors for the Artificial Opening of Intermittently Closed/Open Lakes and Lagoons in Eurobodalla National Park, March 2001;
- Coila Lake Entrance Management Policy, June 2001;
- Joes Creek Flood Study, July 1989;
- Wimbie Creek Catchment and Estuary Management Program, June 1995;
- Batemans Bay Primary School Relocation Surfside, Stormwater Drainage Study, November 2000;
- Hydrological Analysis North Batemans Bay, June 1986;
- Short Beach Creek Flood Study, July 1989;
- Creek Water Level Monitoring in the North Eurobodalla;
- Monitoring of the effects of urbanisation and natural breaching on the health of small south coast estuaries, December 2002.
- Macroinvertebrates in Small Intermittently Closed Open Lake Lagoons (ICOLLs), 2002.
- Opening Regimes in Five Small, Contrasting ICOLLs of the Batemans Bay (NSW) Area.
- Wimbie Creek Odour Problem, February 2003.

Refer to the References section for full details of all publications used.

# 2 GENERAL CHARACTERISTICS

## 2.1 Small ICOLLs in the Eurobodalla Shire

The "creeks" under consideration in this study are all small Intermittently Closed and Open Lakes and Lagoons (ICOLLs). Along the Eurobodalla Coast, there are approximately 30 small ICOLLs, of between 200 metres and 1 km in length and less than 20-40 m in width, which have lagoons located behind a beach berm. The ecology of these ICOLLs, and hence the biota contained within them, is largely unknown. Many of these estuaries have urbanised and agricultural catchments and the effects of land use changes on these systems are also unknown (University of Canberra, 2002).

The ICOLLs considered in this document have small catchment areas (i.e. less than $5km^2$) when compared to a number of the larger ICOLLS along the Eurobodalla Coast, such as Coila Lake. This means that these ICOLLs have a relatively high ratio of catchment runoff to estuary volume, due to the large catchment area compared to the small creek/lagoon volumes. This high ratio results in these systems having a very small dilution capacity, meaning that the effect of changes in the water quality (as a result of changes in catchment runoff quality) could be expected to be far greater in these systems than in many other creeks/lagoons with larger dilution capacities.

The capacity of the creek/lagoons to assimilate pollutants, such as nutrients or organic material from rainfall events, may not be sufficient to protect periodic water quality deteriation. Analysis of water quality data supports this conclusion. For this reason, a number of the smaller ICOLLs are highly vulnerable to changed land use practises within their respective catchments, such as urban development. Some of the ICOLLs studied in this document are showing signs of being unable to assimilate the pollutant loads they currently receive.

This is of concern as collectively, the small coastal creeks may be essential for maintaining biodiversity on a local and regional scale (University of Canberra, 2002). The presence of malodour, stagnation, degraded riparian zones, increased instances of eutrophication and associated algal blooms commonly seen in these small ICOLLs are symptomatic of catchment degradation and environmental stress (University of Canberra, 2002). It has been acknowledged by resource managers that additional scientific information is required of the functioning, value etc of these ICOLLs that places the correct degree of emphasis on their preservation and to also allow for the development of sustainable, scientifically derived, management strategies for their preservation.

## 2.2 Wimbie Creek

Wimbie Creek is situated approximately 7km southeast of the Batemans Bay Town Centre. The catchment of Wimbie Creek extends approximately 1.5 km to the west of the creek outlet, to Ridge Road which forms the western boundary of the catchment. Figure 1-1 shows the location of Wimbie Creek and Figure 2-2 shows the approximate extent of the Wimbie Creek catchment.

The southern catchment boundary is formed by Old Grandfathers Pit Rd and the Ridge Road. The northern boundary is formed partly by the western portion of Surf Beach Avenue (to Timber Way) from where it weaves its way down to a junction between Surf Beach and Wimbie Beach. The total catchment area of Wimbie Creek is approximately 1.9 $km^2$. The catchment is approximately 76% forested and 13% cleared with the remaining 11% under urban development (Mackenzie et al, 2002).

The surface area of the creek is approximately 2000 $m^2$ and it has a total length of 294m and mean depth of 1.2m. The estimated volume of the creek is 2.4 ML (Uni. of Canberra, 2002).

From the hinterland area where the creek originates, it passes by a quarry, a refuse tip and wastewater treatment plant prior to crossing under George Bass Drive between Jerupa Close and Newth Place and entering an area of urban development known as Denhams Beach. Wimbie Creek ultimately leads to Wimbie Beach from where it enters Batemans Bay. The movement of the mouth of Wimbie Creek along this beach is constrained to the south by the presence of a rocky outcrop. The entrance area itself is characterised by an expanse of unvegetated sand.

The substrate in the entrance area is dominated by unconsolidated and unsorted sand with varying amounts of broken shell and at times significant amounts of drying algae, such as kelp, which has been washed ashore from nearby rocky reefs. The entrance of Wimbie Creek is highly dynamic with several openings possible in any given year. Figure 2-1 shows Wimbie Creek and the beach entrance/exit zone on 7 April 2003.

**Figure 2-1 Entrance/exit zone of Wimbie Creek to Wimbie Beach**


**Wimbie Creek Catchment** **Figure 2-2**

## 2.3 Short Beach Creek

Short Beach Creek is situated approximately 4.4 km southeast from the Batemans Bay Town Centre in the district of Batehaven. The largest portion of the Short Beach Creek extends approximately 3 km to the south-west from Caseys's Beach to the Ridge Road. Figure 1-1 shows the location of Short Beach Creek and Figure 2-4 shows the approximate extent of the Short Beach Creek catchment.

A tributary of Short Beach Creek exists to the south of the main creek catchment. The tributary's catchment extends down into suburban areas of Denham Beach and flows past the Pleasurelea Caravan Park to its junction with the main branch at the rear of the Kooringa Coastal Retreat Camp/Conference Centre. The total catchment area of Short Beach Creek is approximately 3.1 $km^2$. The catchment is a mixture of urban development and forested areas. Significant urban subdivision/development is presently underway within the mid to lower portions of the catchment (along Sunshine Bay Road).

The surface area of the creek is approximately 6000 $m^2$ and it has a total length of 370 m and mean depth of 0.95 m. The estimated volume of the creek is 0.6 ML (University of Canberra, 2002), however this is believed to be a typographical error and it should be around 6 ML (based on its mean depth and surface area).

The creek exits to Batemans Bay at the southern end of Caseys Beach. The movement of the entrance to Short Beach Creek along this beach is constrained by the Beach Road bridge abutments. On the beach, the creek entrance is constrained to the south by the presence of a rocky outcrop. The entrance area itself is characterised by an expanse of unvegetated sand. At the time of inspection, the creek mouth was shoaled to the bridge (Beach Road).

The substrate in the entrance area is dominated by unconsolidated and unsorted sand with varying amounts of broken shell. Small pieces of drying algae and kelp had been washed ashore. The entrance behaviour of Short Beach Creek is dynamic with a number of openings possible in any given year. Figure 2-3 shows the entrance/exit zone of Short Beach Creek.

**Figure 2-3 Entrance/exit zone of Short Beach Creek**


**Short Beach Creek Catchment** **Figure 2-4**

## 2.4 Joes Creek

Joes Creek is situated approximately 2.4 km southeast of the Batemans Bay Town Centre in the district of Catalina. Figure 1-1 shows the location of Joes Creek and Figure 2-6 shows the approximate extent of the Joes Creek catchment.

The catchment of Joes Creek extends approximately 3.5 km to the southwest from Corrigans Beach to The Ridge Road. The southern boundary meets the catchment of Short Beach Creek, while the northern boundary runs predominantly along Vista Avenue and Ridge St in Catalina. The total catchment area of Joes Creek is approximately 5.2 $km^2$. The catchment is approximately 70% forested and 5% cleared with the remaining 25% under urban development (Mackenzie et al, 2002).

The surface area of the creek is approximately 30,000 $m^2$, it has a total length of 800 m and mean depth of 1.4 m. The estimated volume of the creek is 42 ML (University of Canberra, 2002). It is the largest water body of the creeks under investigation.

The creek discharges to Batemans Bay via Corrigans Beach. The exit location of the Creek is on the northern end of the beach and is situated between Birdland Animal Park and the Glenhaven Caravan Park. The entrance area itself is characterised by an expanse of unvegetated sand. At the time of inspection (7 April 2003) the creek entrance was shoaled as shown in Figure 2-5.

The substrate in the entrance area is dominated by unconsolidated and unsorted sand with varying amounts of broken shell. The entrance behaviour of Short Beach Creek is dynamic with a number of openings possible in any given year.

**Figure 2-5 Entrance/exit zone of Joes Creek**


**Joes Creek Catchment** **Figure 2-6**

## 2.5 Surfside Creek

Surfside Creek is situated approximately 1 km northeast of the Batemans Bay Town Centre in the district of Surfside. The catchment of Surfside Creek extends approximately 3 km to the north from Surfside Beach and is bounded by the Kings Highway to the west and Clyde Road to the east. Figure 1-1 shows the location of Surfside Creek and Figure 2-8 shows the approximate extent of the Surfside Creek catchment.

The total catchment area of Surfside Creek is approximately 2.1 $km^2$. The catchment is predominantly forested with urban development existing in the southern portions closest to Surfside Beach. A freshwater wetland (SEPP 14 No. 214) exists in the lower reaches of the catchment, the wetland is maintained in a predominantly freshwater state by the presence of a partial bund wall which has been built along the southern boundary of the wetland. The creek extends approximately 400 m from its opening to where it meets the southern extent of the wetland.

The creek exits to Batemans Bay via culverts under Wharf Road on the western end of Surfside Beach. The entrance area itself is characterised by an expanse of unvegetated sand. At the time of inspection, the creek entrance was shoaled at the culverts (7 April 2003) as shown in Figure 2-7.

The substrate in the entrance area is dominated by unconsolidated and unsorted sand with varying amounts of broken shell and minor amounts of dry algae, such as kelp, which has been washed ashore.

**Figure 2-7 Exit/entrance zone of Surfside Creek**


**Surfside Creek Catchment** **Figure 2-8**

# 3 ACID SULFATE SOILS

In NSW, potential acid sulfate soils have been mapped in every estuary and embayment along the coastline. The impacts of acid drainage can be substantial and may include fish kills, oyster damage and mortality, release of heavy metals from contaminated sediment, human and animal health impacts, adverse impacts on soil structure and damage to built structures such as bridges.

Acid sulfate soils are those that have been formed in low energy, depositional environments over the last 6000 years. The entrances to all creeks considered in this document are, in geological terms, highly dynamic areas and consist predominantly of marine sands. Acid sulfate soils are unlikely to occur in the areas where the creeks open to the ocean.

# 4 HYDROLOGY

The frequency and duration of an ICOLL's entrance opening is an important determinant of its hydraulic character (i.e. the frequency and magnitude of water level fluctuations). When the entrance is open, water levels are relatively stable, varying across the tidal range (usually attenuated) on an approximately twelve-hour cycle. When the entrance is closed, water levels tend to be stable on a daily basis (unless there is major rainfall inflow taking place, in which case water levels will be rising). Water levels vary to a much greater extent over a time scale of months in response to the combined impacts of rainfall, catchment runoff and evaporation. The water level could potentially rise up to three metres above mean sea level during floods, or fall below sea level during drought conditions as a result of evaporation exceeding inflow (Mackenzie *et al*, 2002).

A recent cooperative project between Eurobodalla Shire Council, South East Water Quality Monitoring Project, Eurobodalla Landcare, the Shire's Creekcare program, David McKenzie and the community has been undertaken to investigate the hydraulic characters of five brackish creeks around Batemans Bay since December 2000. The project has brought about the installation of water level data loggers in Quierga, Joes, Wimbie, Reedy and Saltwater Creeks. Quierga Creek is located in the Murramarang National Park (as it is subject to limited anthropogenic influence). Quierga Creek has a 2 $km^2$ totally forested catchment, which is 7km due east of the Batemans Bay town centre.

Table 4-1 includes summary data for berm openings for Joes, Quierga and Wimbie Creeks. Both natural and artificial openings have been recorded.

**Table 4-1 Summary data for berm openings for Joes, Quierga and Wimbie Creeks for 600 days from Dec. 2000 (Mackenzie *et al*, 2002)**

| | Joes Creek | Quierga Creek | Wimbie Creek |
|---|---|---|---|
| Total number of openings | 7 | 3 | 14 |
| Total time open (%) | 9 | 2 | 42 |
| Total time closed (%) | 91 | 98 | 58 |
| Shortest opening (d) | 3 | 2 | 1 |
| Longest opening (d) | 13 | 7 | 68 |
| Shortest closure (d) | 3 | 11 | 2 |
| Longest closure (d) | 156 | 258 | 148 |
| Lowest berm height (m AHD) | 1.09 | 0.975 | 0.551 |
| Highest berm height (m AHD) | 1.38 | 1.793 | 0.958 |

Some of the relevant conclusions of the study in relation to creek hydrology are (Mackenzie *et al*, 2002):

- Sites vary widely in both the frequency and duration of openings;
- Simple landuse statistics are insufficient to explain the opening variability of the creeks; and
- The scope of information recorded to date needs to be expanded in order to allow for the future possible development of an accurate berm opening model.

Appendix A includes graphs of creek water levels since December 2000 til the most current records in mid 2002.

## 4.1 Flooding

The frequency and duration of creek closure/opening is influenced primarily by prevailing climatic conditions and as such cannot be predicted. With a closed entrance, and freshwater inflows from the catchment, water levels in the creeks can rise to a height considerably above peak tidal levels. Water levels sometimes rise rapidly (that is, within a day) following heavy rainfall. Frequently however, levels rise slowly over a period of months.

High water levels can affect the urban developments which have taken place along the fringes of parts of the creeks. Flooding waters can cause disruption to activities and/or damage to assets and property by inundating the stormwater system, residences, and other infrastructure. To eliminate this disruption, ESC has on occasions opened the creeks when high water levels have established (for smaller flooding events) to avoid any problems with additional runoff entering the creeks and increasing water levels.

### 4.1.1 Joes Creek

A flood study of Joes Creek was undertaken on behalf of the Eurobodalla Shire Council by Willing and Partners in July 1989. The study was undertaken to obtain information on present and future flooding as a result of planned urban development and construction of the proposed George Bass Drive extension. The study has provided estimates of 1:5, 1:20, 1:50 and 1:100 Annual Exceedence Probability flood levels along Joes Creek from upstream of the proposed George Bass Drive extension to Beach Road in conjunction with both high tide and storm surge sea levels.

The extent of planned urban and rural development in the Joes Creek catchment is essentially consistent between the 1989 study and those currently mapped by Council. The proposed extension to George Bass Drive to meet up with Glenella Road has since been constructed. The RAFTS model (also developed by Willing and Partners) was used in their study to derive peak flow rates for the catchment at the current level of development (i.e. at 1989) and with the ultimate extent of urban and rural development allowable within the catchment.

HEC-2 was used to analyse the hydraulic performance and flood levels at several cross sections along Joes Creek. A backwater analysis was also performed for Joes Creek from a section 200m upstream of Beach Road to a section upstream of the proposed George Bass Drive. The backwater analysis used for each of the design flood events under tidal influence was carried out for an adopted highwater summer solstice tide level of 0.94 m AHD. From Table 4-1 it can be seen that the berm height at the outlet of Joes Creek can vary between a minimum of 1.09 m AHD and a maximum of 1.38 m AHD (from late 2000 to late 2002). Hence, the adopted highwater summer solstice tide level for the HEC-2 modelling is lower than observed berm heights and the berm height will have an effect on flood levels for smaller events.

However, the findings of the flood study are of limited use in determining opening levels for the creek, as it does not include inundation maps or existing asset levels (e.g. floor levels of buildings etc). The following is a list of locations along Joes Creek for which asset height information has been estimated for this investigation. It would improve this study if accurate survey levels could be obtained for the lowest critical areas below.

- Glenhaven Caravan Park, 1.14 m AHD top of bank;
- Glenhaven Caravan Park, 1.5 m AHD maximum tolerable;
- Birdland Animal Park, 1.3m AHD, lower ground level;
- Batemans Bay High School, approximately 2.0 m AHD for school grounds;
- BMX park, 1.7m AHD;
- Matthew Parade, 1.7m AHD rear of lowest lots; and
- Edward Road, 1.5 m AHD rear of lowest lots.

These heights have been derived from:

1. ESC sewer base plans (1:1000 with 1 metre contour interval) for spot heights; and
2. ESC survey for Corrigans Beach Plan of Management.

Creekcare and Eurobodalla Shire Council staff have maintained records of creek openings since March 2000. Data indicates that the creek has been opened artificially seven times. Of the times that the upstream water level has been recorded at the time of opening, the water levels were 1.35, 1.3 and 1.2 m AHD, respectively. The openings were performed to alleviate any potential for flooding of the Glenhaven Caravan Village and/or Birdland.

From discussions with the operators of the Glenhaven Caravan Village there was one resident at the caravan village who was relocated approximately 18 months ago, as their low-lying site was particularly at risk from flooding.

The critical level for opening of Joes Creek to avoid flooding of residential lots at Edward Road is estimated at 1.4m AHD when measured at the gauge on the downstream side of the Beach Road Bridge. This critical level should be checked by ground survey at Birdland and the Glenhaven Caravan Village.

Recorded water levels in Joes Creek from January 2001 to August 2002 are shown in Appendix A.

### 4.1.2 Short Beach Creek

A flood study of Short Beach Creek was undertaken on behalf of ESC by Willing and Partners in July 1989. The study was undertaken to investigate flooding that occurred in the lower portions of the catchment including the Pleasurelea Caravan Park.

The report specifically investigated the adequacy of existing flood control structures within the catchment. The study provided estimates of 1:5, 1:20, 1:50 and 1:100 Annual Exceedence Probability flood levels along Short Beach Creek from Beach Road Bridge to the proposed George Bass Drive (including the main tributary) in conjunction with both high tide and storm surge sea levels.

The extent of planned urban and rural development in the Short Beach Creek catchment is essentially consistent between the 1989 study and that currently mapped by Council. The (then) proposed extension to George Bass Drive to meet up with Glenella Road has been constructed as far as Sunshine Bay Road.

The RAFTS model (also developed by Willing and Partners) was used in their study to derive peak flow rates for the catchment at the current level of development (i.e. at 1989) and with the ultimate extent of urban and rural development allowable within the catchment.

HEC-2 was used to analyse the hydraulic performance and hence flood levels at several cross sections along Short Beach Creek. A backwater analysis was also performed for Short Beach Creek from the Beach Road Bridge to the proposed Batehaven bypass (i.e. extension of George Bass Drive). The backwater analysis of the tributary extended from the Short Beach Creek confluence to just south of the Pleasurelea Caravan Park.

The backwater analysis used for each of the design flood events under tidal influence was carried out for an adopted highwater summer solstice ocean water level of 0.94m AHD. It is not known what range of berm heights exist at the outlet of Short Beach Creek, however, they are expected to vary somewhere between 0.5 and 2m AHD. The Willing and Partners report identified that the berm at the outlet of Short Beach Creek may reach R.L. 1.5 m AHD during dry periods, however, the berm is likely to be scoured out during minor floods. It is considered likely that at times the adopted highwater summer solstice tide level for the HEC-2 modelling would be lower than the observed berm height, which may therefore affect modelled flood levels.

The findings of the flood study are only of limited use in determining opening levels for the creek as it did not include inundation maps or existing asset levels (e.g. floor levels of buildings etc). The following is a list of locations along Short Beach Creek for which asset level information has been estimated for this investigation. It would improve this study if accurate survey levels could be obtained for the lowest critical areas below.

- Beach Road, 1.3 m AHD at rear of lowest lots;
- Beach Road, 1.33 m AHD at lowest garage;
- St Bernards Primary School, 1.3 m AHD at edge of school grounds;
- St Bernards Primary School, 4.06 m AHD floor level of school building;
- Sunshine Bay Primary School, 1.4 m AHD at playground;
- Sunshine Bay Primary School, 2.47 m AHD at floor level school building;
- Education Centre, 1.8 m AHD at ground level;
- Pleasurelea Caravan Park, **no survey detail available**;
- End of Lisa Place, 3.0 m AHD;
- Sunshine Bay Rd, 3.0 m AHD at low lots filled to 1% level; and
- Peter Crescent flats, 2.07 m AHD at lowest floor level.

These heights have been derived from:

- ESC sewer base plans (1:1000 with 1 metre contour interval) for spot heights; and
- Floor level survey for Short Beach Creek Flood Study (1989) by ESC.

The critical height for opening of Short Beach Creek to avoid flooding of the Pleasurelea Caravan Park is yet to be determined. Flood heights should be measured at a gauge to be installed upstream of the Beach Road Bridge. It should be noted that Short Beach Creek normally opens naturally and that flooding is an issue during extremely heavy rain when the flood gradient elevates creek levels at Pleasurelea Caravan Park.

### 4.1.3 Surfside Creek

The Technical Services Division of ESC undertook a flood study of Surfside Creek. A Public Draft of the study was released in November 2000 and is summarised below. The study was undertaken to determine the stormwater drainage impact of the proposed Batemans Bay Primary School relocation site at Surfside. The report supersedes a flood study of the area performed in 1986 by Willing and Partners.

The study provided estimates of 1:1, 1:20 and 1:100 Annual Exceedence Probability flood levels along Surfside Creek upstream from the McLeod Street culverts in conjunction with both high tide and storm surge sea levels.

The extent of planned urban and rural development in the Surfside Creek catchment is consistent between the 2000 study and those areas currently mapped by Council.

RAFTS-XP was used in their study to derive peak flow rates for 'existing' (i.e. with the current level of development) and 'developed' catchments (i.e. with the Batemans Bay Primary School built conditions), but with all other development levels in the catchment remaining the same.

HEC-RAS was used to analyse the hydraulic performance and flood levels at several cross sections along both tributaries of Surfside Creek.

A backwater analysis was performed for Surfside Creek from the culverts under Wharf Road and continued upstream. The backwater analysis for each of the design flood events under tidal/ocean inundation influences used tailwater levels of 0.6m AHD, 1.1m AHD, 1.5m AHD and 2.3m AHD.

It is not known what range of berm heights exist at the outlet of Surfside Creek, however, the existing formation of Wharf Road has an overflow level of 1.61 m AHD (the proposed road formation has an overflow level of 1.62 m AHD). It is considered unlikely that the berm height would exceed the road formation overflow height. Also the Primary School has now been developed and only post development flood levels are reported. It has also been assumed that the northern access road culvert has been replaced by a 3300 by 900mm box culvert.

The findings of the flood study are of limited use in determining opening levels for the creek, as it does not include inundation maps or asset heights (e.g. floor levels of buildings etc). The following is a list of locations along Surfside Creek for which asset height information has been estimated for this investigation. It would improve this study if accurate survey levels could be obtained for the lowest critical areas below.

- Lincoln Crescent, 2.8 m AHD at rear of lots;
- Palana St, 2.3 m AHD at rear of lots;
- Timbara Crescent, 1.9 m AHD near pump station;

- Timbara Crescent, 2.6 m AHD at rear of lots opposite public toilets;
- Timbara Crescent, 1.7 m AHD at reserve on corner of Myamba Parade;
- Hockey Fields, 2.7 m AHD, typical surface level;
- McLeod Street, 1.62 m AHD, low point near culverts; and
- Reserve, 1.5 m AHD, near corner Timbara Crescent & McLeod Street.

These heights have been derived from spot heights on ESC sewer base plans (1:1000 with 1 metre contour interval) and the McLeod Street Reconstruction Plans developed by the Eurobodalla Shire Council. The data indicates that the critical level for opening of Surfside Creek to avoid flooding of residential lots along Timbara Crescent is 1.62m AHD.

From discussions with local residents, water can pond in the park near the pump station before entering the stormwater drainage system. This is consistent with spot height data which indicates a low point of 1.5m in the reserve near Timbara Crescent and McLeod Street.

Several repeated openings of the creek over the course of a week have on occasions been required to sufficiently flush the creek, as the entrance has repeated closes due to sand build-up. Repeated openings are typically not required if there is sufficient water flow through the creek which tends to keep the entrance scoured (T. Brooks, pers. comm., 2003).

The creek opening also removes sand materials from the beach when it opens. The degree of scour is dependent upon the beach condition at that time (i.e. quantity of sand present) and the force of water resulting from the creek opening (dependent on water levels in the creek prior to opening). Beach scour is an existing issue on Surfside Creek and is primarily influenced by broader coastal processes which occur in Batemans Bay.

The opening of the creek tends to only flush the creek and does not have a significant effect on the upstream wetland. The wetland upstream of the creek is protected against tidal flushing by the presence of a partial bund wall.

### 4.1.4 Wimbie Creek

No flood studies have been performed for Wimbie Creek.

A spot level of approximately 2.0m AHD was identified at the rear of the lowest lots on Newth Place. This level was determined from ESC sewer base plans (1:1000 with 1 metre contour interval). Creek levels could be measured by the use of a flood gauge to be installed on Wimbie Creek at the footbridge.

Wimbie Creek normally opens naturally at a level controlled by the beach berm level. As reported in Table 4-1, the berm level at the Wimbie Creek opening location has been recorded at heights between 0.55m and 0.96m AHD. These levels are well below the critical infrastructure level of 2.0m AHD, and it is unlikely that Council would need to open Wimbie Creek to relieve a flood threat.

Recorded water levels in Wimbie Creek from December 2000 to August 2002 are shown in Appendix A.

# 5 WATER QUALITY

The water quality processes of the subject creeks are of prime interest to this study as poor water quality has in the past been blamed for the periodic generation of odours, particularly by local residents. To gain a full appreciation of the water quality dynamics in the subject creeks, their interaction and interrelationship with biological and hydraulic processes must be considered.

In the past, the poor water quality in the creeks has been attributed to urban development and other forms of anthropogenic interference within the catchments. Joes, Wimbie, Surfside and Short Beach Creeks all have urban development within their catchments. The ultimate levels of urban development within these catchments is defined by Council's Urban Local Environment Plan 1999.

Since the early 1990's, Eurobodalla Shire Council, SEWQMP and Creekcare have undertaken a program of regular water quality monitoring in Joes and Wimbie Creeks. The program extends to several other creeks within the shire, some of which are located in areas away from significant human influence such as in National Parks. In particular Quierga Creek will, where required, be used for comparative purposes to highlight differences between a creek in an 'undisturbed' and a 'disturbed' catchment.

The creeks are considered individually in the following sections, taking into account differences between the catchments, e.g. catchment size, level of human disturbance, creek opening behaviour etc.

## 5.1 Wimbie Creek

### 5.1.1 Previous Studies

Hydrogen sulfide odours (i.e. 'rotten egg gas') from Wimbie Creek have led to several studies being performed on the creek to try and determine the reasons for the odour generation. Other studies have been performed more recently in relation to the ecological functioning of the creeks. These studies include (along with a brief description of what they investigated) the following:

- **Wimbie Creek Odour Problem**, conducted by CSIRO Centre for Environmental Mechanics in 1993. This study covered three ICOLLs including Wimbie, Lilli Pilli and Joes Creeks. The study involved site inspections and limited water quality sampling and analysis.
- **Wimbie Creek Catchment and Estuary Management Program – Problem Definition and Management Strategies**, conducted by Environmental Management Services in 1995. This study used a systematic sediment sampling program to determine the sources of nutrient input to Wimbie Creek.
- **Monitoring of the effects of urbanisation and natural breaching on the health of small south coast estuaries**, study by University of Canberra in 2002. This project aimed to identify changes in sediment composition, water quality and biotic communities as the result of urbanisation of catchments and opening and closing of estuaries.
- **Macroinvertebrates in Small Intermittently Closed Open Lake Lagoons**, Dalton *et al*, 2002. This study investigated the populations of macroinvertebrates in Wimbie Creek, Joes Creek, Saltwater Creek and Quierga Creek. The aim of the study was to determine whether urban

development was increasing the frequency and severity of anoxic conditions within these ICOLLs. The ICOLLs chosen vary in their percentages of urban development. The study monitored benthic macroinvertebrates, sediment nutrients and grain size, water quality and their relationships to breaching of the berms of the ICOLLs. The study was undertaken over a 15-month period.

The major findings of these and other related studies, combined with observations made during site inspections, discussions with ESC Officers and Creekcare Coordinators (and review of community data) are that:

- Wimbie Creek is relatively well sheltered by surrounding topography and adjacent trees. This reduces the ability of winds to mix the creek. Non-uniform salt concentrations within the creek are consistent with non-uniform mixing (CSIRO, 1993);
- Wimbie Creek lagoon is a substantial embayment relative to the size of the inflowing creek and will hence tend to act as a settling basin for at least part of the sediment load of any inflowing streams. The presence of saline waters will, when present, assist in flocculating (and precipitating) suspended particulate matter (CSIRO, 1993);
- The catchment of Wimbie Creek is mixed urban-rural with considerable (in parts) disturbance of surface soils yielding a significant clay fraction able to impound nutrients from urban derived runoff/stormwater (CSIRO, 1993);
- Water quality pollutants within the Wimbie Creek catchment appear to originate from a number of diffuse sources such as sediments from cleared areas, leaf litter, animal faeces, diffuse detergents from such activities as car washing and loss of nutrient applied as fertilisers. Additionally there is the potential for the quarry, the tip and water treatment area and the sewage treatment works to be point sources of contaminants (Environmental Management Services, 1995);
- It was not possible to quantify clearly the contributions of point and diffuse sources of pollution to Wimbie Creek, although it is considered that diffuse sources of pollution were likely to outweigh the point sources. (Environmental Management Services, 1995);
- Nutrients bound to clay particles entrained in stormwater and subsequently precipitated on the creek bed are being released into the water column when anoxic conditions establish (Environmental Management Services, 1995);
- Observed drops in Oxygen Reducing Potential in the water column (often associated with large algal biomass) allows phosphate and ammonia to be released from the sediment and thus be available for further growth of algae (University of Canberra, 2002);
- Nutrient levels within Wimbie Creek are (at times) very high and comparable with those normally associated with highly eutrophic freshwater bodies or highly eutrophic estuarine environments/salt marshes (CSIRO, 1993);
- The cumulative effects of inputs of nutrients from a range of sources exceed the ability of Wimbie Creek estuarine system to remain in balance (Environmental Management Services, 1995);
- Wimbie Creek is well illuminated for at least part of the day (CSIRO, 1993);

- Considerable growth of algae, floating as rafts or around the shoreline of Wimbie Creek is often observed (Environmental Management Services, 1995). Dead algae will subsequently fall to the bottom of the creek as organic detritus and in the absence of adequate flushing/mixing from the creek, ocean or by wind, the detritus will accumulate;
- Filamentous algae in the water column can cause large diurnal fluctuations in dissolved oxygen levels, oxygen reduction potential (ORP) and also pH (University of Canberra, 2002);
- There is at times poor tidal flushing of Wimbie Creek, depending on the state of the entrance berm (CSIRO, 1993);
- Due to the presence of oceanic water, Wimbie Creek will contain significant quantities of sulfate (CSIRO, 1993; Environmental Management Services, 1995; Dalton *et al*, 2002);
- Hydrogen sulfide odour is relatively common in the vicinity of Wimbie Creek and major odour incidents occur about two days after heavy rain. The odour builds up over two to three days and then declines over the next two to three days (CSIRO, 1993);
- The base of the creek can at times be covered almost entirely with black sulphidic deposits (Environmental Management Services, 1995);
- The dominant processes controlling the establishment of the intermittent anoxic waters in Wimbie Creek are <u>not</u> from nutrient enrichment and autotrophic production, although there is considerable benthic algae, but large inputs of organic matter either from the land or the sea (Dalton et al, 2002);
- Macroinvertebrate data considered in conjunction with water quality data and field notes indicate that salinity changes, variable seaweed inputs, frequency of opening and closing, and periods of anoxic water are stronger influences ("on macroinvertebrate assemblages") than urbanisation per se, although the frequency of opening is increased through urbanisation (Dalton et al, 2002);
- There are obvious differences in water quality between creeks (Wimbie, Joes, Saltwater, Surf Beach and Short Beach Creeks), and clearly differences before and after flushing (University of Canberra, 2002);
- Water quality parameters must be interpreted with time of day, amount of sunlight and algal biomass present (University of Canberra, 2002);
- Wimbie Creek had frequent large loads of sea wrack (i.e. seaweed) being dumped into the creek after storms. On one instance, it was estimated that 8000 tonnes of sea wrack was deposited onto the adjacent beach after a storm and much of this was driven into Wimbie Creek. The decomposition of this material caused the whole creek to go anoxic and produce hydrogen sulfide gas. During this period of extreme anoxia, no macroinvertebrates were found in the sediment and there was a large fish kill. At other times more moderate quantities of sea wrack have been deposited, providing a rich source of nutrients for the algal mats and associated biota (University of Canberra, 2002);
- Reducing the quantities of seaweed washed into the Wimbie creek via the creek mouth would probably reduce odour (Dalton et al, 2002) and
- Wimbie Creek has a medium to high catchment runoff volume to creek volume ratio, indicative of a relatively low dilution capacity (Mackenzie, D. pers. comm. 2003).

In Wimbie Creek, it is considered likely that sulfate reducing bacteria (SRB) exist naturally in the sediments. SRB release hydrogen sulfide gas as they breakdown organic material in anoxic (low or zero oxygen) conditions. Lake Wollumboola near Nowra is well known for its production of hydrogen sulfide gas and SRB are known to exist in the sediments of the lake.

### 5.1.2 Water Quality Data

Water quality monitoring has been undertaken intermittently in Wimbie Creek since March 1992 (a gap in the data exists between August 1996 to December 2001) to the present day (last water quality data available is February 2003). A one to three monthly data collection program is continued through Creekcare coordinated by the Eurobodalla Shire Council. Data has generally been collected at several locations in the creek since 1992. In recent years, data has been collected from two main sites located above the road bridge at Jerupa Close (WC400) and under the footbridge at the end of Bayview St (WC401). Water quality samples have been obtained at a range of depths to assist in the determination of changes throughout the water profile. The locations of water quality sampling are shown in Figure 5-1.

Data collected for Wimbie Creek includes Thermotolerant coliforms, Nutrients (Ammonia, Nitrate, Nitrate, Total Oxidised Nitrogen, Total Nitrogen, Orthophosphate and Total Phosphorus), pH, Biochemical Oxygen Demand, Temperature, Dissolved Oxygen, Salinity/Conductivity and a range of observations of creek condition, such as water level, water colour, floating substances, presence of algae, bar condition etc.

However, not every observation/test has been collected at every sampling event. No nutrient data was collected for Wimbie Creek before December 2001.

Table 5-1 presents a summary of water quality data for Wimbie Creek from 1992 to 2003. Data has been included for several sampling locations, WC401, WC405, WJC406, WC407, WC408 and WJC409. The majority of the water quality data has been collected at these monitoring sites. WC401 has been sampled at several depths, i.e., 40cm, 60, 80 cm below the water surface as denoted by JC401 – 40 etc. The number of samples taken at a particular location is denoted in the "number" row. In viewing the results, it is important to keep in mind that samples have been taken over a long period of time and through a range of climatic and environmental conditions and can at best be interpreted as a series of snapshots of water quality in Wimbie Creek. Also for a number of the sites, the number of samples taken is very low, i.e. only 1 or 2 samples taken over the past ten years. Low sampling numbers do not allow a high degree of statistical certainty to be drawn from the results.


**Wimbie Creek Water Quality Monitoring Locations**

**Figure 5-1**

### Table 5-1 Wimbie Creek Summary Water Quality Data

| | | FC | $NH_3$-N | TN | TNOx | $PO_4$ | TP | pH | $BOD_5$ | Temp. | DO | % Sal | Turb. | Cond. | TDS | Chl-a |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site Code** | **Unit** | **(cfu / 100mL)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **-** | **(mg/L)** | **($^o$C)** | **(mg/L)** | **-** | **(NTU)** | **(mS/cm)** | **(ppm or mg/L)** | **(µg/L)** |
| WC400 | **median** | 22 | 0.12 | 0.545 | 0.055 | 0.006 | 0.06 | 6.71 | - | 16.9 | 2.1 | 0.05 | 40 | 1.2 | 54 | 5.8 |
| | **number** | 21 | 8 | 10 | 2 | 4 | 8 | 14 | 0 | 10 | 10 | 8 | 9 | 8 | 1 | 8 |
| WC401 | **median** | 185 | 0.06 | 0.59 | 0.04 | 0.021 | 0.03 | 8.11 | - | 19.3 | 4.7 | 2.72 | 10 | 43.3 | - | 4.4 |
| | **number** | 16 | 7 | 13 | 5 | 4 | 13 | 20 | 0 | 20 | 20 | 19 | 15 | 18 | 0 | 13 |
| WC401-40 | **median** | - | - | - | - | - | - | 8.2 | - | 19.5 | 2 | 2.95 | 8 | 45 | - | - |
| | **number** | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 17 | 17 | 17 | 15 | 17 | 0 | 0 |
| WC401-60 | **median** | - | - | - | - | - | - | 7.66 | - | 20 | 2.3 | 3.26 | 7.5 | 49.1 | - | - |
| | **number** | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 12 | 12 | 12 | 12 | 12 | 0 | 0 |
| WC401-80 | **median** | - | - | - | - | - | - | 7.62 | - | 20.1 | 0.2 | 3.28 | 7 | 49.9 | - | - |
| | **number** | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 0 |
| WC405 | **median** | 885 | - | - | - | - | - | 6.3 | 5 | - | - | - | - | - | - | - |
| | **number** | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC406 | **median** | 315 | - | - | - | - | - | 6.5 | - | - | - | - | - | - | - | - |
| | **number** | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC407 | **median** | 24 | - | - | - | - | - | 7.5 | 0 | - | - | - | - | - | - | - |
| | **number** | 57 | 0 | 0 | 0 | 0 | 0 | 41 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC408 | **median** | 170 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **number** | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC409 | **median** | 10 | - | - | - | - | - | 6.4 | 13.75 | - | - | - | - | - | - | - |
| | **number** | 9 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **EPA*** | **median** | <150 | | 0.1-0.75 | | | 0.01-0.1 | 6.5-9 | | | >6 | | <6 | | | 1-10 |
| **ANZECC#** | **median** | | 0.015 | 0.3 | 0.015 | 0.005 | 0.03 | 7-8.5 | | | | | 0.5-10 | | | 4 |

FC = Faecal Coliforms, $NH_3$-N = Total Ammonia Nitrogen, TN = Total Nitrogen, TNOx = Total Oxidised Nitrogen, $PO_4$ = Orthophosphate, TP = Total Phosphorus, $BOD_5$ = 5 Day Biochemical Oxygen Demand, Temp. = Temperature, DO = Dissolved Oxygen, %Sal = Percentage Salinity, Turb. = Turbidity, Cond. = Conductivity, TDS = Total Dissolved Solids, Chl-a = Chlorophyll a. * = NSW Environmental Protection Authority interim water quality objectives for Clyde River for Primary Contact Recreation and Protection of Aquatic Ecosystems. # = ANZECC 2000 Default trigger values for physical and chemical stressors in southeast Australia for slightly disturbed open estuarine systems.

However, from a comparison of the water quality results obtained for Joes Creek, in relation to the Interim Water Quality Objectives for Clyde River (as determined by the NSW EPA) and the ANZECC 2000 Guidelines, the following is noted:

- Wimbie Creek generally exists in a nutrient enriched state with concentrations above guideline values. The presence of orthophosphate and ammonia indicate conditions suitable for algal growth;
- Low chlorophyll-a readings are representative of low phytoplankton concentrations. Filamentous algal species are believed to out-compete phytoplankton for available nutrients (Dalton, R., pers. comm., 2003). The stringy nature of the filamentous algae may prevent them from being collected during routine water quality sampling and hence not appear in the chlorophyll-a readings;
- pH values are generally within an acceptable range;
- $BOD_5$ values indicating a very high demand for oxygen at WC409, however this is based on only two samples, while $BOD_5$ values at WC407 are zero;
- DO levels are below the acceptable limit and appear to decrease with increasing depth indicating that anoxic conditions have existed at the bed of the creek; and
- The waters of Wimbie Creek are at times highly turbid (where 5-25 NTU = medium turbidity and 25-50 NTU = high turbidity).

Overall, the water quality in Wimbie Creek appears to be outside guideline values for water quality in the region and is generally unlikely to support robust aquatic ecosystems for any length of time. Odours, high turbidity, presence of algae and small channel size/length make Wimbie Creek an unlikely candidate for primary or secondary contact recreation, even though the water quality in Wimbie Creek would generally support such activities.

### 5.1.3 Conceptual Model of Creek Processes

When the findings of the previous studies, observations of the community and collated water quality data are combined, conceptual models of water quality processes in the creek can be developed, as follows.

**Model 1 – Creek remains closed and receives stormwater input from catchment**

- Day 0 – Rain event and stormwater is generated. Stormwater collects diffuse particulate and dissolved pollutants and enters Wimbie Creek. Due to physical settlement, some particulate nutrients are precipitated onto the creek bed (possibly aided by flocculation if oceanic water is present in creek water). Creek remains closed to ocean. Algae start to consume dissolved nutrients in stormwater.
- Day 1 to 2– Particulate organic (e.g. leaf litter) matter that has settled on the creek bed decomposes, releases nutrients to the water column and consumes available oxygen. Extensive anoxic conditions establish when available oxygen is consumed. The anoxic conditions promote the liberation of phosphorus into the water column that was previously chemically bound to particles (e.g. clay) residing on the creek bed. In conjunction with this process, sulfate reducing bacteria (SRB) breakdown organic material in the anoxic conditions by reducing sulfate (from

sea water). This process generates hydrogen sulfide gas, carbon dioxide and water. Algae continue to consume the high quantities of available nutrients.

- Day 3 onwards - The processes for generating hydrogen sulfide gas continues as long as there exists a source of organic material and anoxic conditions. The high supply of algal nutrients leads to the establishment of eutrophic conditions, which in combination with other environmental factors, such as abundant sunlight and still water conditions leads to excessive algal growth, i.e. an algal bloom and rafts form in the creek. The algae later die and settle to the creek bed adding to the existing organic load (such as leaf litter) on the bed of the creek.

**Model 2 – Creek receives seaweed input from ocean and closes**

- Day 0 – Seaweed washed into creek. Seaweed settles to the bottom of the creek bed.
- Day 1 onwards – Seaweed starts to decompose and consumes available oxygen. Inadequate oxygen prevents oxygen-consuming bacteria from breaking down all the organic materials and anoxic conditions establish. Due to the very large seaweed inputs that occur from time to time, quite severe anoxic conditions can establish within the creek. Sulfate Reducing Bacteria (SRB) then start to break down the remaining organic material in the anoxic conditions by reducing sulfate (from sea water). This process generates hydrogen sulfide gas, carbon dioxide and water. The process will continue as long as there exists a source of organic material and anoxic conditions. Plant decomposition also releases nutrients back into the water column which can be consumed by algae. Plant decomposition in anoxic conditions can generate nitrogen in the form of ammonia which is readily consumed by algae. Excessive levels of plant decomposition (in anoxic conditions) can lead to the formation of algal rafts.

**Model 3 – Creek opens to the ocean (naturally or artificially)**

- Creek opening results in oxygenated water entering the creek, thereby re-establishing oxygen-rich conditions and preventing the generation of hydrogen sulfide gas. Tidal flushing also reduces residual nutrient and/or algal concentrations. In some instance, the flushing of water and low water levels may disturb and/or expose sulfidic muds on the lake bottom, which can also generate odours for a period of time.

It should be noted that the major assumption in these conceptual models is that the quantity of organic material that enters the creek in Models 1 and 2 is unsustainable for Wimbie Creek.

### 5.1.4 Summary

Water quality in Wimbie Creek can at times be very poor. Wimbie Creek regularly experiences excessive organic loadings from the catchment (via stormwater) and from the ocean (i.e. sea wrack). The subsequent decomposition of organic material can cause anoxia and thereby present ideal conditions for the generation of hydrogen sulfide gas. The relatively small volume of Wimbie Creek make it highly susceptible to the organic inputs as it has little buffering capacity (as opposed to Joes Creek for instance). Anoxic conditions result in the release/formation of excessive available plant nutrients which is responsible for the algal rafts often noted in the creek.

## 5.2 Joes Creek

### 5.2.1 Water Quality Data

Water quality monitoring has been undertaken intermittently in Joes Creek since June 1992 (a gap in the data exists between August 1996 to February 2001). A one to three monthly data collection program is presently continued through Creekcare coordinated by the Eurobodalla Shire Council. Water quality data has been collected from three locations on Joes Creek. The site most commonly used is located on the Beach Road Bridge over Joes Creek between Glenhaven Caravan Park and Birdland (JC401). Two other sites used less commonly are located upstream from this location (JC402 and JC403). Water quality samples have been obtained at a range of depths to assist in determination of changes throughout the water profile. The location of the monitoring site JC401 is shown in Figure 5-2.

Water quality data has not been collected at every sampling event and in particular no nutrient data are available for Joes Creek. Data collected for Joes Creek includes thermotolerant coliforms, pH, biochemical oxygen demand, temperature, dissolved oxygen, salinity/conductivity, turbidity and a range of observations of creek condition, such as water level, water colour, floating substances, presence of algae, bar condition etc.

The information that has been collected is insufficient in the types of parameters monitored (i.e. lack of nutrient data) and the intensity of sampling events to draw any firm conclusions on water quality processes that may have established in Joes Creek. However, there are reports of hydrogen sulfide gas being generated from the creek. This would suggest that anoxic conditions have existed at some stage.

Observations from Creekcare staff responsible for monitoring the water have on occasions noted the presence of floating macroalgae blooms. This indicates a high level of available nutrients in the water column as a result of dissolved nutrients entering the creek from the surrounding catchment, breakdown of organic materials on the creek bed and/or release of nutrients from sediments under anoxic conditions.

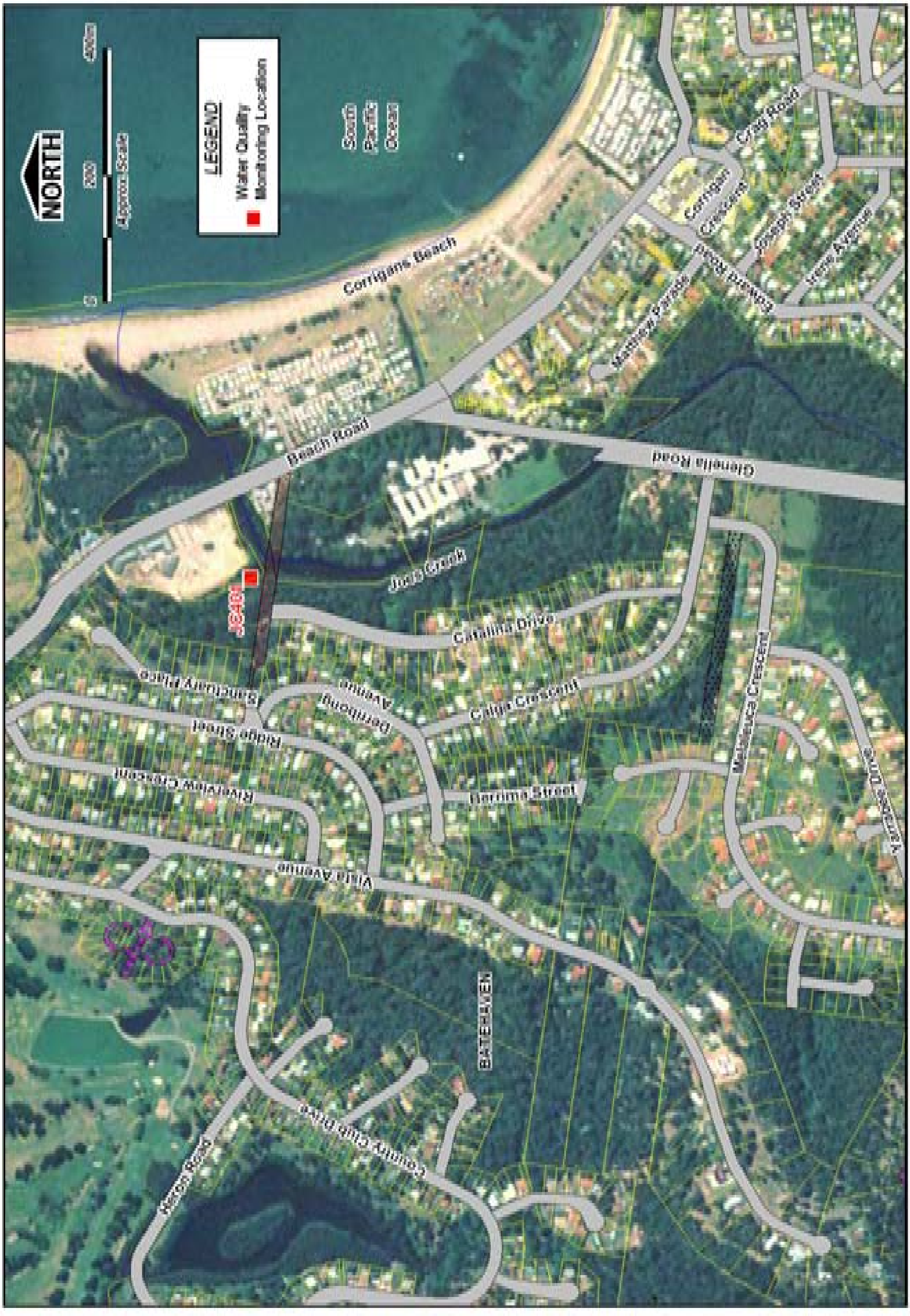
Table 5-2 presents a summary of water quality data from Joes Creek from 1992 to 2003. Data has been included for the three sampling locations, JC401, JC402 and JC403. JC401 has been sampled at several depths, i.e., 40cm, 60, 80, 100, 120 and 140 cm below the water surface as denoted by JC401 – 40 etc. The number of samples taken at a particular location is denoted in the "number" row. In viewing the results it is important to keep in mind that samples have been taken over a long period of time over a range of climatic and environmental conditions and can at best be interpreted as snapshots of water quality in Joes Creek. Also for a number of the sites, the number of samples taken is very low, i.e. only 1 or 2 samples taken over the past ten years. Low sampling numbers do not allow for a high degree of statistical certainty to be drawn from the results.

**Table 5-2 Joes Creek Summary Water Quality Data**

| Site | Unit | FC (cfu / 100mL) | pH - | $BOD_5$ (mg/L) | Temp. (°C) | DO (mg/L) | % OS - | Sal. (g/L) | Turb. (NTU) | Cond. x1000 (mS/cm) | TDS (ppm or mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| JC401 | median | 31.5 | 8.00 | 0.0 | 18.25 | 8.36 | 101 | 13.85 | 10.0 | 41.20 | 85.0 |
| | number | 40 | 53 | 24 | 14 | 13 | 4 | 6 | 12 | 8 | 4 |
| JC401-40 | median | - | 8.32 | - | 23.70 | 8.35 | - | - | 8.0 | 43.50 | 40.0 |
| | number | 0 | 9 | 0 | 9 | 9 | 0 | 0 | 8 | 8 | 1 |
| JC401-60 | median | - | 8.28 | - | 23.25 | 6.16 | - | - | 8.0 | 41.70 | 40.0 |
| | number | 0 | 8 | 0 | 8 | 8 | 0 | 0 | 8 | 7 | 1 |
| JC401-80 | median | - | 9.18 | - | 23.40 | 8.89 | - | - | 5.0 | 39.10 | - |
| | number | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 |
| JC401-100 | median | - | 9.17 | - | 23.15 | 8.67 | - | - | 4.5 | 39.10 | - |
| | number | 0 | 2 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 0 |
| JC401-120 | median | - | 9.91 | - | 18.90 | 13.65 | - | - | 0.0 | 41.60 | - |
| | number | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| JC401-140 | median | - | 8.49 | - | 26.60 | 2.68 | - | - | 20.0 | 36.90 | - |
| | number | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| JC402 | median | - | 6.00 | - | 14.00 | 9.20 | 91 | - | 10.0 | 0.26 | 70.0 |
| | number | 0 | 3 | 0 | 4 | 4 | 4 | 0 | 2 | 2 | 4 |
| JC403 | median | - | 6.00 | - | 12.00 | - | - | - | 10.0 | 0.15 | - |
| | number | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| EPA* | median | <150 | 6.5-9 | | | >6 | 80-90 | | <6 | | |
| ANZECC# | median | | 7-8.5 | | | | 80-110 | | 0.5-10 | | |

Note: FC = Faecal Coliforms, BOD = Biochemical Oxygen Demand, Temp. = Temperature, DO = Dissolved Oxygen, % OS = Percentage Oxygen Saturation, Sal. = Salinity, Turb. = Turbidity, Cond. = Conductivity, TDS = Total Dissolved Solids, * = NSW Environmental Protection Authority interim water quality objectives for Clyde River for Primary Contact Recreation and Protection of Aquatic Ecosystems. # = ANZECC 2000 Default trigger values for physical and chemical stressors in southeast Australia for slightly disturbed open estuarine systems.

However, from a comparison of the water quality results obtained for Joes Creek in relation to the Interim Water Quality Objectives for Clyde River (as determined by the NSW EPA), the water quality in Joes Creek is generally in compliance with these objectives. This is a good result as the Clyde River is an open system with substantial oceanic exchange. Joes Creek by comparison is only intermittently open to the ocean. The favourable result is likely to be due to the large physical size of the creek, which will tend to buffer Joes Creek against minor catchment inputs. Joes Creek would appear to generally support primary recreation contact and the maintenance of aquatic ecosystems. However, there have been instances where poor water quality has been observed, such as a dissolved oxygen reading of 2.68 mg/L at JC401-40. Also abundant quantities of filamentous algae have been observed in the creek (Dalton R., pers. comm., 2003).




Joes Creek Water Quality
Monitoring Locations

Figure 5-2

### 5.2.2 Previous Related Studies

Some recent water quality related studies encompassing Joes Creek include:

- **Monitoring of the effects of urbanisation and natural breaching on the health of small south coast estuaries**, 2002. This project aimed to identify changes in sediment composition, water quality and biotic communities as the result of urbanisation of catchments and opening and closing of estuaries.
- **Macroinvertebrates in Small Intermittently Closed Open Lake Lagoons**, Dalton *et al*, 2002. This study investigated the populations of macroinvertebrates in Wimbie Creek, Joes Creek, Saltwater Creek and Quierga Creek. The aim of the study was to determine whether urban development was increasing the frequency and severity of anoxic conditions within these ICOLLs. The ICOLLs chosen vary in their percentages of urban development. The study monitored benthic macroinvertebrates, sediment nutrients and grain size, water quality and their relationships to breaching of the berms of the ICOLLs. The study was undertaken over a 15-month period.

The major observations and findings of these and other related studies combined with observations made during site inspections, discussions with ESC Officers and Creekcare Coordinators (and review of community data) were that:

- Macroinvertebrate data considered in conjunction with water quality data and field notes indicate that salinity changes, variable seaweed inputs, frequency of opening and closing, and periods of anoxic water are stronger influences than urbanisation per se, although frequency of opening is increased through urbanisation (Dalton et al, 2002);
- There are obvious differences in water quality between creeks (Wimbie, Joes, Saltwater, Surf Beach and Short Beach Creeks), and clearly differences before and after flushing (University of Canberra, 2002);
- Water quality parameters must be interpreted with time of day, amount of sunlight and algal biomass present (University of Canberra, 2002);
- Joes Creek had less stratification and fewer periods of anoxia when compared to other creeks (i.e. Wimbie and Queriga Creeks) which seemed to be due to better wind mixing (University of Canberra, 2002); and
- In Joes Creek, there may be positive interactions with large bivalves which filter the water thus improving water quality. It should be noted that the generally higher quality of water in Joes Creek allows the bivalves to exist (University of Canberra, 2002).

### 5.2.3 Conceptual Model of Creek Processes

From the available data the following conceptual model of creek processes for Joes Creek has been developed. The main observations and data available are that:

- Joes Creek had less stratification and fewer periods of anoxia when compared to other creeks (i.e. Wimbie and Queriga Creeks) possibly as a result of better wind mixing;

- The larger physical size of the Joes Creek makes it more resilient to small changes in water quality parameters as a result of catchment or oceanic inputs;
- Hydrogen sulfide smells are present on occasions around the creek, but odour issues are not as severe as for some of the other creeks;
- Certain species of macrofauna that exist in Joes Creek require higher water quality;
- Algal rafts have been noted floating on the surface of the creek;
- The creek opens infrequently (approximately 10% of the time);
- Berm heights are typically quite high, thereby limiting the opportunity for input of seaweed (and there are no adjacent offshore reefs to provide a source of seaweed (kelp); and
- Lower catchment runoff volume to creek volume ratio, indicative of a higher dilution capacity.

Based on these observations the following conceptual model has been developed for Joes Creek.

**Model 1 – Creek remains closed and receives stormwater input from catchment**

- Day 0 – Rain event and stormwater is generated. Stormwater collects diffuse particulate and dissolved pollutants and enters the creek. Due to physical settlement, some particulate nutrients are precipitated onto the bottom of the creek bed (possibly aided by flocculation if oceanic water is present in creek water). Creek remains closed to ocean. Algae start to consume dissolved nutrients in stormwater.
- Day 1 to 2 onwards – Particulate organic (e.g. grass & leaf litter) matter that has settled on the creek bed decomposes, releases nutrients to the water column and starts to consume the available oxygen supply. Due to the larger assimilative capacity and strong wind exposure of Joes Creek, anoxic conditions rarely establish as a direct result of catchment inputs.

  Excessive quantities of filamentous algae have been observed to establish in the creek (Dalton R., pers. comm., 2003) in spring and summer if the creek remains closed. The exact processes for the excessive growth are unknown, but are likely to be a function of excessive available nutrient in the water column.

**Model 2 – Creek opens to the ocean (naturally or artificially)**

- Creek opening results in ocean water entering the creek and water quality in the creek tends towards that of oceanic water. At times the opening of Joes Creek may disturb sediments, promoting the release of hydrogen sulfide gas, which may be generated in anoxic creek sediments. In the past this has caused odours and occasional fish kills.

### 5.2.4 Summary

The reasons why the odour problems are less significant for Joes Creek than the other creeks considered in the document, may be attributed to lower quantities of organic inputs from the surrounding catchment relative to the creek's larger physical surface area and volume, i.e. Joes Creek has a relatively high assimilative capacity.

Lower quantities of sea wrack also appear to naturally enter the creek of Joes Creek and this assists in maintaining high water quality and causing less odour instances.

## 5.3 Short Beach Creek

### 5.3.1 Water Quality Data

Very little water quality monitoring has been undertaken in Short Beach Creek. Consequently there is insufficient information available other than observations to draw any firm conclusions on water quality processes that may have established in the creek.

### 5.3.2 Previous Related Studies

Recent water quality related studies encompassing Short Beach Creek include:

- **Monitoring of the effects of urbanisation and natural breaching on the health of small south coast estuaries**, 2002. This project aims to identify changes in sediment composition, water quality and biotic communities as the result of urbanisation of catchments and opening and closing of estuaries.

### 5.3.3 Conceptual Model of Creek Processes

There is little data available from which to develop a conceptual model for Short Beach Creek. The main observations are:

- Occasional rotten egg gas smells from the creek have been observed, suggesting that anoxic conditions exist at times. Council has indicated that most odour complaints are received on the southern branch of Short Beach Creek. The southern branch extends down into suburban areas of Denhams Beach and it flows past the Pleasurelea Caravan Park. Water in the southern branch appears to receive less tidal flushing and more readily appears "stagnant" (K. Tarbuck, pers. Comm. 2003);
- Occasional black sulphidic deposits on creek bed near the creek mouth, but the creek typically maintains a sandy bottom at this location;
- Occasional presence of floating macroalgae rafts in the creek;
- The creek is open to the ocean for a fair percentage of time. Data from ESC and Creekcare indicate that between April 2001 and March 2003 the creek was open to the ocean for approximately 27% of the time. The accuracy of the data is not known, however, it does suggest that at times tidal flushing of the creek occurs and this will affect water quality in the creek;
- Oceanic flora and fauna has been observed near the creek entrance such as crabs, barnacles, ulva etc, indicative of predominantly oceanic conditions (R. Dalton, pers. comm. 2003);
- The disturbance of sediments causes odour to be generated (K. Tarbuck, pers. comm. 2003);
- Visitors to the Kooringa Coastal Retreat Camp/Conference Centre often use the creek for primary and secondary contact recreation, e.g. swimming and canoeing when the ocean is flushing the creek (K. Tarbuck, pers. Comm. 2003);
- There are often fish in the creek (i.e. mullet and bream) and other wildlife such as birds, which hunts these fish. Occasional fish kills have been observed as a result of poor water quality believed to be a result of water quality pollutants entering the creek from urban areas (K. Tarbuck, pers. Comm. 2003);

- The creek has been opened artificially by Council in the past due to sewer pump station failure. A pump station is located adjacent to the outlet of the creek on the Batemans Bay foreshore. However, odours from the creek do not appear related to the operating of the pump station (K. Tarbuck, pers. Comm. 2003);
- The high percentage of time that the creek is open presents significant opportunities for seaweed to be washed into the creek. Odours from the creek generally result from the decomposition of trapped seaweed (K. Tarbuck, pers. comm. 2003); and
- High catchment runoff volume to creek volume ratio, indicative of a low dilution capacity.

Based on these observations the following conceptual model has been developed for Short Beach Creek.

**Model 1 – Creek remains closed and receives stormwater input from catchment**

- Day 0 – Rain event and stormwater is generated. Stormwater collects diffuse particulate and dissolved pollutants and enters Short Beach Creek. Due to physical settlement some particulate nutrients are precipitated onto the bottom of the creek bed (possibly aided by flocculation if oceanic water is present in creek water). Creek remains closed to ocean. Algae start to consume dissolved nutrients in stormwater.
- Day 1 to 2– Particulate organic (e.g. leaf litter) matter that has settled on the creek bed decomposes, releasing nutrients to the water column and consuming the available oxygen. Extensive anoxic conditions establish when available oxygen is consumed. The anoxic conditions promote the liberation of phosphorus into the water column that was previously chemically bound to particles (e.g. clay) residing on the creek bed. In conjunction with this process, sulfate reducing bacteria (SRB) breakdown organic material in the anoxic conditions by reducing sulfate (from sea water). This process generates hydrogen sulfide gas, carbon dioxide and water. Algae continue to consume the high quantities of available nutrients.
- Day 3 onwards - The processes for generating hydrogen sulfide gas continue as long as there exists a source of organic material and anoxic conditions. The high supply of algal nutrients leads to the establishment of eutrophic conditions, which in combination with other environmental factors, such as abundant sunlight and still conditions leads to excessive algal growth, i.e. an algal bloom and rafts form in the creek. The algae later die and settle to the creek bed adding to the existing organic load (such as leaf litter) on the bed of the creek.

**Model 2 – Creek opens to the ocean (naturally or artificially)**

- Creek opening results in oxygenated water entering the creek, thereby re-establishing healthy oxygen concentrations and preventing the generation of hydrogen sulfide gas. Tidal flushing also reduces residual dissolved nutrient and/or algal concentrations.

### 5.3.4 Summary

The southern branch of Short Beach Creek is likely to have more severe odour problems as it receives less tidal flushing than the main branch and hence it appears to “stagnate”, also the catchment is predominantly urban and therefore it is more likely to receive increased pollutant loadings. Given the still water conditions it is likely that most pollutants settle out and reside on the creek bed. Various biological and water quality processes occur which generate odour.

The northern (main) branch of the creek has a predominantly forested catchment, this is likely to result in the creek receiving lower pollutant loadings. This branch of the creek appears to receive better tidal flushing and this is likely to be the primary reason for the lower occurrences of severe odour events.

The water quality at the mouth of the creek appears to be affected primarily by the entrapment and decomposition of sea wrack. This can also result in the generation of odour.

## 5.4 Surfside Creek

### 5.4.1 Water Quality Data

No water quality monitoring has been undertaken in Surfside Creek. Consequently there is insufficient information available to draw any firm conclusions on water quality processes that may have established in the creek.

### 5.4.2 Previous Related Studies

There are no previous water quality related studies of Surfside Creek.

### 5.4.3 Conceptual Model of Creek Processes

There is limited data available from which to develop a conceptual model for Surfside Creek. The main observations are:

- Occasional rotten egg gas smells from creek, suggesting that anoxic conditions exist at times;
- Creek becomes smelly when shut (i.e. no tidal flushing) for long periods. The creek is often shut for periods of three to six months (T. Brooks, pers. comm., 2003);
- Odour from the creek worsens when it is opened (T. Brooks, pers. comm., 2003), this is most likely due to the disturbance of sediments in the creek which then releases large quantities of hydrogen sulfide gas. During an opening event, a percentage of the black sulphidic sediments discharged from the creek washes onto nearby beaches causing that area to smell for a period of time;
- History of algae problems in Lincoln Downs lagoon. The catchment of Lincoln Downs lagoon consists of a high percentage of urban development and the Princes Highway. The potentially high levels of nutrients from these sources is likely to be the cause of algal problems in the lagoon. The lagoon will overflow past Batemans Bay Primary School towards Surfside Creek;
- The creek outlet (culverts under McLeod Street) is typically blocked by sand buildup for a large percentage of the time, thereby preventing tidal flushing;
- A significant wetland exists upstream of the outlet. The wetland provides habitat for a range of avifauna and possibly fish. However, the wetland is predominantly fresh due to the presence of a partial berm at the southern end of the wetland which limits the opportunity for any tidal exchange;
- There is limited opportunity for the input of seaweed due to the predominantly closed entrance.

Based on these observations the following conceptual model has been developed for Surfside Creek.

**Model 1 – Creek remains closed and receives stormwater input from catchment**

- Day 0 – Rain event and stormwater is generated. Stormwater collects diffuse particulate and dissolved pollutants and enters Surfside Creek. Due to physical settlement some particulate nutrients are precipitated onto the bottom of the creek bed (possibly aided by flocculation if oceanic water is present in creek water). Creek remains closed to ocean. Algae start to consume dissolved nutrients in stormwater.
- Day 1 to 2– Particulate organic (e.g. leaf litter) matter that has settled on the creek bed decomposes, releasing nutrients to the water column and consuming the available oxygen supply. Extensive anoxic conditions establish when available oxygen is consumed. The anoxic conditions promote the liberation of phosphorus into the water column that was previously chemically bound to particles (e.g. clay) residing on the creek bed. In conjunction with this process, sulfate reducing bacteria (SRB) breakdown organic material in the anoxic conditions by reducing sulfate (from sea water). This process generates hydrogen sulfide gas, carbon dioxide and water. Algae continue to consume the high quantities of available nutrients.
- Day 3 onwards - The processes for generating hydrogen sulfide gas continue as long as there exists a source of organic material and anoxic conditions. The high supply of algal nutrients leads to the establishment of eutrophic conditions, which in combination with other environmental factors, such as abundant sunlight and still conditions leads to excessive algal growth, i.e. an algal bloom and rafts form in the creek. The algae later die and settle to the creek bed adding to the existing organic load (such as leaf litter) on the bed of the creek.

**Model 2 – Creek opens to the ocean (naturally or artificially)**

- Creek opening results in disturbance and or exposure of sulphidic sediments and associated release of hydrogen sulfide gas worsening odours after opening;
- Oxygenated oceanic waters enter the creek as a result of tidal forcing, thereby re-establishing healthy conditions and preventing the generation of hydrogen sulfide gas. Tidal flushing also reduces residual nutrient and/or algal concentrations; and
- Creek closes due to sand buildup and process recommences.

### 5.4.4 Summary

Surfside Creek experiences odour problems during periods of long closure when the levels of organic input and associated decomposition exceed the ability of the creek to process it aerobically. When anoxic conditions establish, odours can be generated. The presence of anoxia can promote the release of nutrients from sediments leading to excessive algal growth as evidenced by the presence of algal rafts on occasions. The creek appears to be in a relatively sheltered location which may limit opportunities for wind mixing. The creek is opened infrequently, limiting opportunities for tidal flushing.

# 6 ODOUR

All creeks considered as part of this study have at times been the source of odour in the form of rotten egg gas (i.e. hydrogen sulfide gas). This gas is generated as a result of biochemical processes occurring in the creek which are highly inter-related with the hydrological functioning of the creek.

These odours have been the source of complaints for ESC. ESC has responded to these complaints up to 2002 by opening the creek to the ocean and allowing ocean waters to mix with the waters contained in the creek. On occasions this has “flushed” out the cause of the odour and stopped the generation of odours and hence, further odour related complaints. Observations from nearby residents at Surfside, Joes and Wimbie Creeks indicate that creek openings can occasionally result in a temporary worsening of odours.

From 2003, ESC no longer carries out the opening of coastal creeks in response to odour complaints.

From site inspections and discussions held with Council and Creekcare staff, the following list ranks the creeks for which ESC most commonly receives odour complaints:

1 Wimbie Creek;

2 Short Beach Creek;

3 Surfside Creek; and

4 Joes Creek.

This ranking is subjective and is based upon the opinion of staff from ESC.

## 6.1 Wimbie Creek

The odours in Wimbie Creek are primarily due to the excessive organic loading that the creek receives either from the catchment (via stormwater) or from the ocean (in the form of seaweed) as described in Section 5.1. Biological processes decompose the organic material firstly in an aerobic state until such time as the available oxygen is consumed and the process then continues in an anaerobic state. The lack of oxygen in the water column (particularly near the bottom) allows for Sulfate Reducing Bacteria (SRB) that live in the sediments to breakdown organics (via the reduction of sulfate) to produce hydrogen sulfide gas (rotten egg gas).

In the past this odour has been relieved by opening Wimbie Creek to the ocean to allow fresh oxygenated ocean water in, which returns the water column to an oxic state and ends the processes of hydrogen sulfide gas production.

## 6.2 Joes Creek

Joes Creek appears to have generally high water quality and does not appear to suffer widespread anoxic conditions. However, there have been reports of the die-off of filamentous algae in the creek which enables anoxic conditions to establish as the algae settles to the creek bottom and decomposes.

Due to the higher average berm height it is considered unlikely that significant quantities of seaweed material enter the creek.

There have also been reports of severe odours resulting from opening the berm as this exposes significant amount of bed sediment. The sediment when exposed continues to release hydrogen sulfide gas for several days. So, based on local observations, the opening of Joes Creek to the ocean may worsen odours. This is more likely if an artificial opening is conducted when water levels are of an insufficient elevation to scour out an entrance that will sustain tidal exchange. The creek entrance will then close at a low level and expose sediments until the next rain tops the level up. Opening at a higher level will scour out a more stable entrance, permitting tidal inflows to sustain higher creek levels.

## 6.3 Short Beach Creek

The southern branch of Short Beach Creek has a greater number of odour instances. It is uncertain if this is because the southern branch is closer to residential areas and hence noticed more than the main branch, or if it is due to other factors. The other factors, which may contribute to its odour problems, include reduced tidal flushing (when compared to the main branch) and the higher likelihood of it receiving pollutant loadings as a result of its predominantly urbanised catchment. The conceptual processes for odour generation are described in Section 5.3.

The entrapment and decomposition of sea wrack in the creek mouth appears to be a primary cause of odour in this reach.

## 6.4 Surfside Creek

Based on observations of the local Landcare and other local residents, odours from Surfside Creek can occur at different times. Odours have been noted to occur at various times when the entrance has been closed for up to several months. In instances, the odour levels can be quite high and cause annoyance for a number of local residents near the creek. The processes for odour generation are described in Section 5.4.

The odour levels can be worsened in the short term by the opening of the entrance (either naturally or artificially) due to the disturbance/exposure of sulphidic sediments in the creek. Often these sediments are redistributed onto the adjacent beach during openings of the creek. These sediments have been noted to have a strong sulfide smell.

# 7 FLORA AND FAUNA

## 7.1 Flora

The Wimbie, Short Beach, Joes and Surfside Creek catchments are primarily comprised of vegetative communities described as 27 and 25, 15 and 9 as determined through vegetation mapping undertaken by NPWS in 2001. These communities consist mainly of *Corymbia maculata* (Spotted Gum), *E. paniculata*, *E. botryoides* and/or E. *saligna* which are coastal species, common across the shire in the coastal zone.

Information pertaining to vulnerable vegetation ecosystems in the Eurobodalla Shire was obtained for the various creek catchments by accessing Eurobodalla Shire Council's Geographical Information Database. Searches conducted in the respective catchments indicated that the following vulnerable ecosystems exist in the catchments:

- Short Beach Creek – Vulnerable Vegetation Ecosystem No. 24. This ecosystem is called Coastal Swamp Oak- Swamp Melaleuca Wet Heath Swamp Forest and is dominated by *Casuarina glauca* (Swamp Oak) and *Melalueca ericifolia* (Swamp Paperbark). The vegetation is located along the downstream branches of Short Beach Creek and is approximately 7.5ha in size. Although already relatively dysfunctional, this highly vulnerable vegetation ecosystem is under threat from clearing and urban development in the catchment.
- Joes Creek - Vulnerable Vegetation Ecosystems No. 24, 25 and 28. Ecosystem No. 25 is called South Coast Swamp Oak Forest Complex and is dominated by *Casuarina glauca* (Swamp Oak), *Acacia sophorae* (Coastal Wattle), *Avicennia marina* (River Mangrove). System No. 28 is called Coastal Sands Bangalay-Old Man Banksia Grassy Bracken Shrub Forest and is dominated by *Eucalyptus botryoides* (Bangalay) and *Banksia serrata* (Old-man Banksia). Vegetation system 28 is located in the lower reaches of the creek (24 ha). Although already relatively dysfunctional, this highly vulnerable vegetation ecosystem is under threat from land-clearing and weed competition in the catchment. Vegetation system 25 is located in the mid to upper reaches of the creek (6.2 ha) and near the mouth of the creek (3 ha). This relatively functional yet highly vulnerable vegetation ecosystem is under threat from land-clearing and the effects of recreation within the catchment. Vegetation system 24 is located in the mid reaches of the creek (9.5 ha) and near the mouth of the creek (1.5ha). Although already relatively dysfunctional, this highly vulnerable vegetation ecosystem is under threat from land-clearing and weed competition in the catchment.
- Surfside Creek - Vulnerable Vegetation System No. 24. This ecosystem is located along the downstream branches of Surfside Creek and is approximately 24 ha in size. Although already relatively dysfunctional, this highly vulnerable vegetation ecosystem is under threat from clearing and urban development in the catchment.

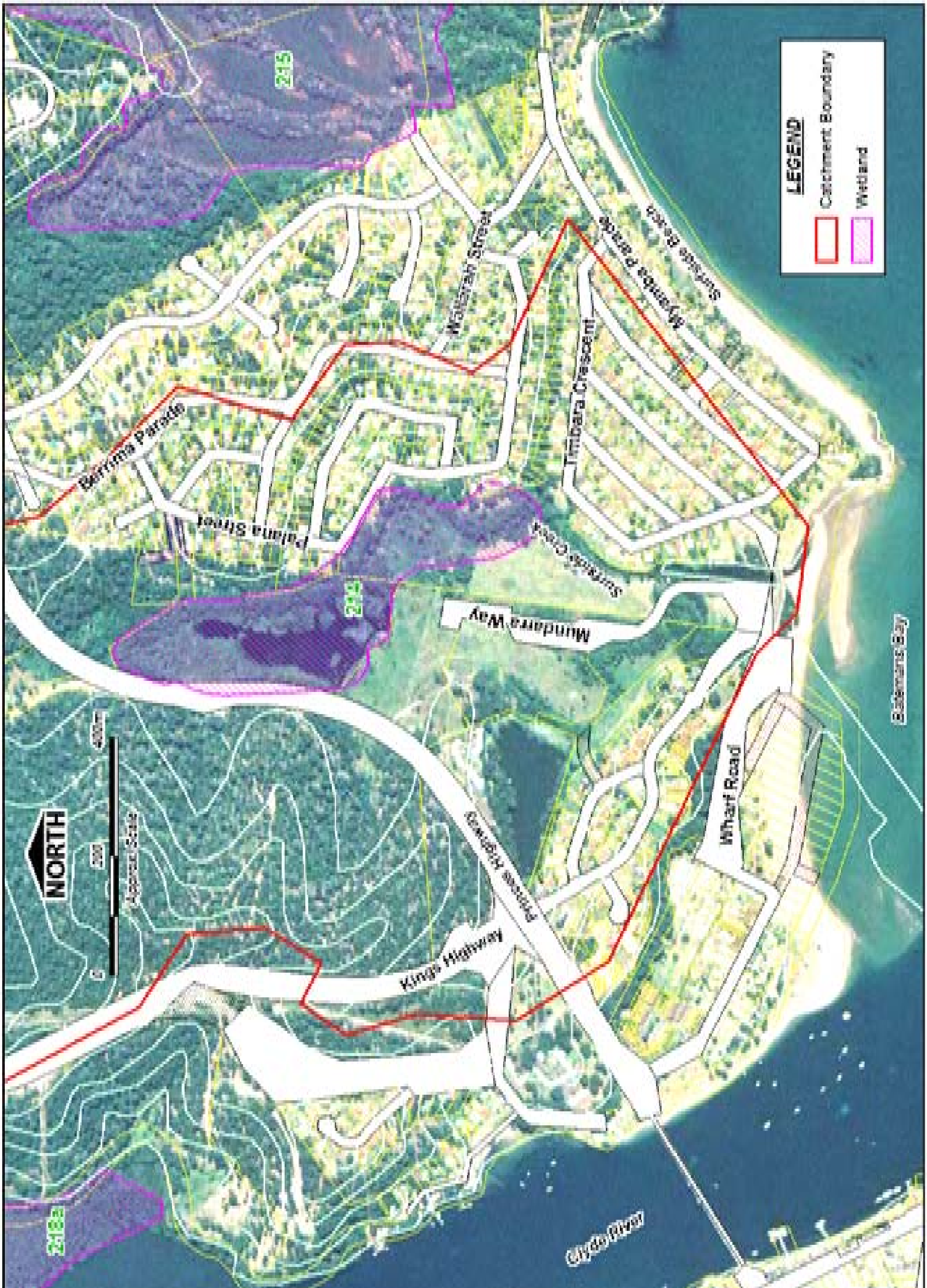
A SEPP 14 wetland is located within the Surfside Creek catchment as shown in Figure 7-1. This wetland has had a Plan of Management prepared for it. The Plan of Management was prepared by Resource, Design and Management Pty Ltd in September 1993 and is based upon an ecological assessment performed by Travers Morgan Pty Ltd, and a hydrological analysis prepared by Willing and Partners in June, 1986 (refer also to Section 4.1.3).

The ecological assessment was performed to identify the various plant communities and ecologies existing within the wetland environment. In terms of vegetation, the study identified the following major vegetative species:

- Extensive areas of reeds on the higher ground of the margins of the wetlands. The reeds were both native i.e. *Juncus articulatus* and introduced i.e. *Juncus acutus*;
- A large stand of *Phragmites australis*;
- A large stand of Cumbungi (*Tyhpa orientalis*);
- The dominant species throughout the main waterbody however was the spike rush *Eleocharis sphacelata*. This species, along with *Triglochin procera* and *Ludwigia peploides* ssp *montevidensis,* were found in large stands in the central area of the wetland; and
- Terrestrial fringing vegetation consisting of *Casuarina glauca – Melaleuca ericifolia* woodland, grading back to *Eucalyptus spp* woodland on higher ground on the northern and eastern sides.

The vegetation assessment identified that the wetlands main value was for the provision of habitat for wildlife. The report states that "….none of the known flora and fauna is rare or restricted, the numbers are not high, the area does not form an integral link in the system of waterways. The area is not of regional significance, but is an important local wetland which provides a variety of habitat types for a moderate diversity of wetland species."

It is important to keep in mind that the assessment was performed in 1986, some 17 years ago, which is a considerable period of time and some of its findings may not reflect the current situation.




**Wetland No. 214**

**Figure 7-1**

## 7.2 Fauna

No specific studies have been performed of faunal species within the various creek catchments. However, some information is available from other studies performed in the region. Generally the various catchments are expected to provide habitat to a range of birds, mammals and reptiles commonly found in coastal areas within the Shire. The various representations of different species in the various catchments would vary according to the variety of water-based and terrestrial habitats available.

A range of fish and crustaceans have been observed to occur within the creeks (presence depends on season) including mullet, bream, flathead, whiting, garfish, tailor, mulloway, gobi, prawns, eels, trevally, luderick and toad fish. The populations of fish within the creeks are determined by the ability of fish to gain access and find habitat within the creek. Creeks that only open occasionally have little if any fish within them, whereas creeks that have good exchange with the ocean have populations of fish that can survive within the creeks (University of Canberra, 2002).

A SEPP 14 wetland is located within the Surfside Creek catchment as shown in Figure 7-1. This wetland has had a Plan of Management prepared for it. The Plan of Management was prepared by Resource, Design and Management Pty Ltd in September 1993 and is based upon an ecological assessment performed by Travers Morgan Pty Ltd, and a hydrological analysis prepared by Willing and Partners in June, 1986 (refer also to Section 4.1.3).

The ecological assessment identified from site inspections and other published data some of the major fauna utilising the wetland. The study identified that the wetland is well used by particular waterbirds including:

- Rallidae family - Species using the wetland include the Purple Swamphen and Coot. Other possible users are the Dusky Moorhen and Banded Landrail, both common in the area;
- Anatidae family - Species using the wetland include the Black Swan, Black Duck, Grey Teal, Chestnut Teal and White-eyed Duck;
- Plataleidae family - Species using the wetland include the Ibis and Spoonbills. The Sacred Ibis and Royal Spoonbill have been recorded using the wetland. The Yellow-billed Spoonbill has also been recorded in the area;
- Ardeidae family - Species using the wetland include the White-faced Heron and Large Egret. Other species recorded in the area include the Little Egret, Plumed Egret, Pacific or White-necked Heron, Nankeen Night-Heron and the Brown Bittern;
- Podicipedidae family - The Australasian Grebe has been recorded as breeding in the area with the wetland providing a suitable habitat; and
- Phalacrocoracidae family – Cormorants including the Little Pied Cormorant have been recorded in the wetland.

Other species using the wetland or the surrounding terrestrial vegetation are likely to include the Japanese Snipe, Little Grassbird and Reed Warbler, along with many other terrestrial bird species which would use the reed system from time to time e.g. wrens, thornbills etc.

While no other information was recorded on other types of fauna using the wetland, there is likely to be a range of mammals such as the Water Rat and Swamp Rat, reptiles such as the Eastern Long-necked Tortoise and Red-bellied Black Snake and frogs such as the Spotted Marsh Frog and Dwarf Green Tree Frog.

### 7.2.1 Macrofauna

Studies of the creeks have identified the presence of a range of macrofaunal species. While humans do not typically use these species, they form an important part in ecological functioning of creek systems by utilising available nutrients and in turn becoming a food source for higher order species such as fish.

A study recently conducted by the University of Canberra aimed to determine the effects of opening and closing small coastal creeks on macrofaunal abundance and diversity. This was done by assessing populations before and after closing and at subsequent times after closure, for four contrasting creeks namely Wimbie Creek, Joes Creek, Quierga Creek and Saltwater Creek. The results of this study were:

- Strong groupings of macroinvertebrate assemblages in different creeks suggests a strong resilience of the systems;
- Macrofauna were found to have greater differences between creeks than differences between times at the same creek;
- There was a large variation in assemblage numbers before and after flushing of creeks, primarily as a result of sediment scour and associated removal of macrofauna;
- During flushing, large quantities of sediment may be removed and the sediment inhabitants with it, though there always seemed to be some areas relatively undisturbed which may act as seeding for the rest of the creek. Results indicated that the sites towards the rear of the creek retained macroinvertebrates, while the sites near the front of the creek (where the scour would be greatest) recorded no invertebrates for weeks after flushing until the freshly deposited sediment was stabilised and recolonised; and
- Large quantities (of the order of tonnes) of macroinvertebrates can exist in the sediments of an ICOLL and a percentage of these would be washed out into the ocean during an opening event. This represents a rich source of food for fish within Batemans Bay.

A subpart of this study, which took a snapshot of around seventeen ICOLLS along the Eurobodalla Coast, identified that macrofauna populations were highly geographically influenced, with populations grouping into the relative geographic locations. Creeks with the largest surface area and volume contained the greatest species richness (such as Joes Creek). This is possibly due to the relative stability of these systems in respect to their ability to buffer changes such as inputs of nutrients and water from the catchment.

# 8 LANDSCAPE QUALITIES

The entrance area itself, being simply a large expanse of bare sand, does not in general have strongly attractive landscape qualities when the entrance channel is closed. The adjoining ocean beach and the lake's waters tend to provide a more notable visual feature under these circumstances. When the entrance is open, visual qualities tend to be higher being characterised by a tidal channel passing between the ocean and creek.

The visual qualities are unlikely to be altered to any great extent by the construction of a channel. There may be some temporary creation of an unnatural appearance due to excavated sand being piled alongside the channel, but this is also likely to be short-lived as wind and water action will erode it away and reduce it to the general level of the surrounding sand spit.

# 9 RECREATIONAL ACTIVITIES

The creeks are used for a range of recreational activities as detailed below:

- Wimbie Creek is used for a range of passive recreational activities, such as walking and birdwatching;
- Joes Creek is used for a range of passive recreational activities, such as walking and birdwatching. When water and odour conditions are good, it is likely that the creek would be used for a range of primary and secondary contact recreational activities such as canoeing (particularly given its long channel length and location near the caravan park). It may also be used for primary contact recreation (i.e. swimming) at times when the mouth is open and it is being tidally flushed;
- Short Beach Creek is used for a range of passive recreational activities, such as walking and birdwatching. When water and odour conditions are good, it is known that the creek is used for a range of secondary contact recreational activities such as canoeing (particularly given location near Kooringa Coastal Retreat). It is also used for primary contact recreation when the mouth is open and it is being tidally flushed; and
- Surfside Creek is used for a range of passive recreational activities, such as walking and birdwatching.

# 10 CULTURAL HERITAGE

Records of Aboriginal occupation identify numerous sites around the estuary that are considered culturally significant by the indigenous community. Few middens have been recorded around coastal lakes and creeks, with the majority of these sites found on rocky headlands, cliff tops and dunes behind sandy embayments or on the shores of larger estuaries (Mills, 1994). However, the extremely dynamic nature of the entrance area means that no Aboriginal sites exist directly within the beach berm areas where these creeks open.

# 11 REFERENCES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# APPENDIX A: RECORDED CREEK WATER LEVELS