**Final Report**

# CATCHMENT STUDY – GUSTAV CREEK, MAGNETIC ISLAND

**ACTFR Report 00/05**

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## RECOMMENDATIONS

- To maintain the integrity of Gustav Creek, a Catchment Management Plan that follows best practice should be developed, taking into consideration weed control, flood and erosion mitigation, biodiversity, and water quality. A major contribution to this would be the establishment of a community landcare program to address the issue of sustaining vegetation communities, hydrological, and ecological functioning of Gustav Creek.

- It is recommended that a coordinated approach to bank stabilisation be adopted, and as a priority, a geomorphologist with local knowledge assess bank stability through out the Gustav Creek catchment. It is expected that within the urban area, bank protection and stabilisation strategies will need to be employed to protect the surface of stream banks from fluvial erosion, and to protect properties from flooding.

- It is recommended that riparian buffer zones of at least 20m be retained in any further land sub-divisions, and that all smaller tributaries linked to Gustav Creek be maintained as watercourses.

- Vegetation communities within the Gustav Creek catchment, particularly the vine forest and mangrove woodland areas, should be managed to retain suitable habitats for resident and nomadic birds, and continue to attract migratory species.

- Control of Singapore daisy is strongly recommended, with the goal of eradication from the catchment. Equally, regular monitoring and control of stinging tree populations is required, with a view to eradicate the species at least from the riparian zone.

- Plans to minimise any impacts on Gustav Creek and its habitats must be included as part of the Environmental Management Plan for the proposed harbour development.

- As part of the land-based infrastructure associated with the harbour development permission has been sought to clear an area of mangroves. The value of the remaining mangrove community should be specifically recognised in the Environmental Management Plan.

- In Gustav Creek it is recommended that primary contact water quality guidelines be maintained for the protection of children.

- The TCC should revise the existing water quality monitoring and reporting methodology and develop a proforma to record additional environmental information. Additionally, an expanded parameter list should be included for contaminants relating taste, odour and colour.

- To establish connections between activities in the catchment and the quality of water being discharged into Nelly Bay it is recommended that significant rainfall events and creek discharge be monitored.

- Given the nature of the alluvium in Gustav Creek catchment, the predominance of septic tank systems and the high summer rainfall, a thorough groundwater investigation is recommended.

- Studies on effluent irrigation at the Nelly Bay site have not been reported; and site-specific studies are required to clarify the impact of existing and any future effluent irrigation areas planned for the Island.

- It is recommended that gross pollutant traps be installed at all drainage points to reduce the input of litter into the creek and consequently into the bay.

- It is recommended that any oil spills be prevented from moving upstream from the harbour and due consideration given to the continuing health of the mangrove ecosystem at this site.

- TCC should consider using smoke tests with paraffin oil to identify cracks in pipes that mat result in contamination of Gustav Creek.

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# 1 INTRODUCTION

The Australian Centre for Tropical Freshwater Research (ACTFR) was commissioned by the Environmental Planning Services of the Townsville City Council (TCC) to undertake a catchment management study for Gustav Creek, Nelly Bay, Magnetic Island. The catchment management study is one of 27 recommendations listed in the 1999 Assessment Report on the 1999 Final Environmental Impact Survey for the Nelly Bay Harbour development, and endorsed by the Co-ordinator General of the Department of State Development.

The 1999 Assessment Report concluded that the proposed Nelly Bay harbour development could be managed so that environmental impacts are acceptable, subject to the completion of additional studies and surveys. Recommendation 25 relates to management of the harbour during operation:

> **"A catchment management study for Gustav Creek should be initiated by Townsville City Council to identify and address sources of contamination (to the) creek."**

The scope of the catchment management study was defined by the TCC in a letter dated 18th November 1999. This included:

- Collate, assess and analyse all environmental, Towns planning (including land use) and engineering data for the Gustav Creek catchment.
- Assess if and how Gustav Creek and land use in its catchment will/may affect and interact with the environment of the proposed Nelly Bay Harbour development or vice versa.

In accepting the commission, the ACTFR agreed, in addition to the abovementioned objectives, to:

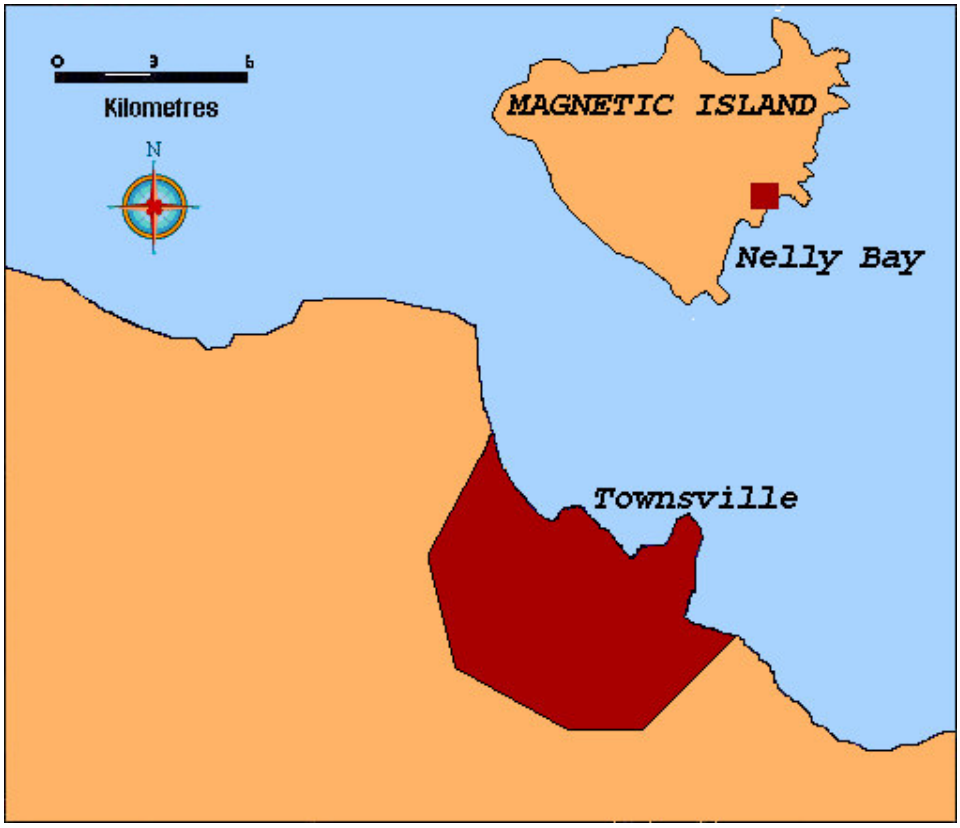
- describe the Gustav Creek catchment (including its biota, geomorphology, hydrology and water quality, land uses and management instruments),
- assess possible management/ mitigation strategies for catchment land uses, and
- produce a written report and mapping (GIS based).

# 2 THE STUDY SITE

## 2.1 Location

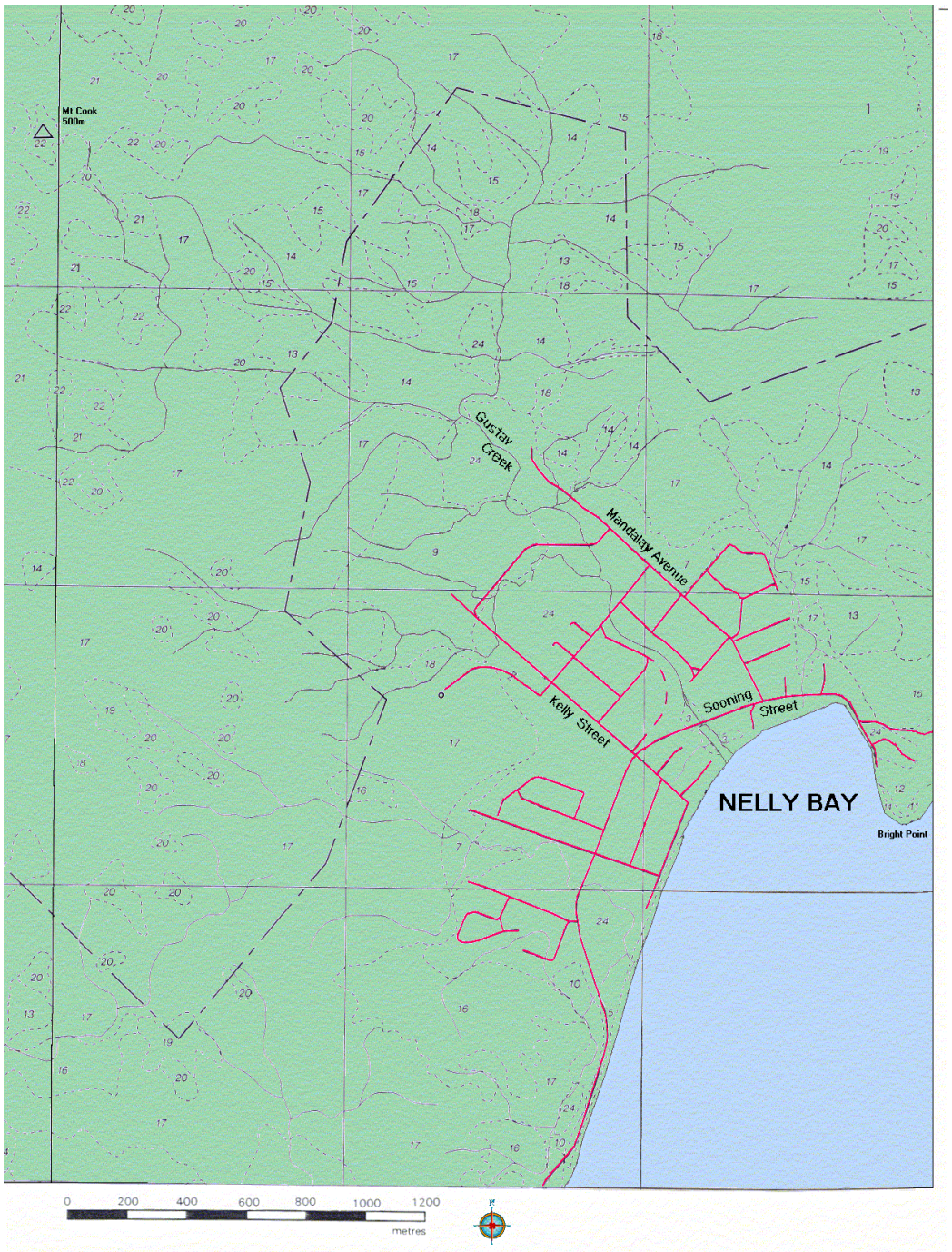
Magnetic Island is situated 10km northeast of Townsville (147°E, 19°S) and due to its close proximity to the mainland, has developed as a suburb of Townsville. The majority of the island is dedicated to National Park (56%), with only a small portion being freehold or leasehold land (EA/QEPA, 1999). The Island is also a popular tourist destination for locals from the mainland as well as visitors. Nelly Bay is located on the southeastern side facing Cleveland Bay and is the major settlement of Magnetic Island. Figure 2.1 illustrates the location of Magnetic Island and Nelly Bay.

**FIGURE 2.1:** Location of Nelly Bay




Nelly Bay is the second largest embayment on the Island and measures some 2.3km between headlands. Gustav Creek is the main watercourse flowing through Nelly Bay discharging into the harbour area (see Figure 2.2). As it is one of the largest catchments on the island, its size and importance is demonstrated by the fact that it is the only creek on the island which retains water throughout the year (SKM, 1998).

**FIGURE 2.2:** Nelly Bay and the Gustav Creek Catchment




## 2.2 Population

Recent figures from the 1996 Census show that the population of Magnetic Island is 3,027, with 1,236 in Nelly Bay. This is a significant increase from the previous census in 1991 (Table 2.1). In 1996, the planned maximum residential capacity for Nelly Bay was 5,300, with 12,025 for the Island (TCC, 1996). These figures were based on 1991 Census data. However, the TCC is currently reviewing the Development Control Plan (No. 6) for Magnetic Island and recent research indicates that planning for the previous DCP (1994) may have been based on an unsustainable population threshold. The population capacity for Nelly Bay has now been revised at 2,500 (pers. comm. P. Lindwall, 2000).

**TABLE 2.1:** Comparison between 1991 and 1996 Population Data on Magnetic Island

| Population Centre | Permanent Population incl. Visitors from 1991 Census | Permanent Population incl. Visitors from 1996 Census |
|---|---|---|
| Nelly Bay | 1,048 | 1,236 |
| Picnic Bay | 536 | 575 |
| Arcadia | 629 | 638 |
| Horseshoe Bay | 436 | 528 |
| Balance of Is. | 22 | 50 |
| **TOTAL** | **2,671** | **3,027** |

Source: GHD, 1995; Commonwealth of Australia, 1999a

It should be noted that the Nelly Bay Harbour proposal would result in a resident population increase of up to 307 over time (EA/QEPA, 1999). This development represents some 6% of the 5300 maximum residential capacity. Any increase is likely to place extra pressure on existing facilities and infrastructure including schools, health care and community services; however, Townsville City Council supported the proposal in its submissions during the EIS process, and consider infrastructure requirements to be manageable.

## 2.3 History

Magnetic Island was named by Captain Cook in 1770 (Cupitt, 1996). The local surveyor, Mr. J. O'Connell, surveyed the Island Bays in 1886 and the bays were named after the Pearce family, then living in Townsville (Hayles Magnetic Island Pty. Ltd., Undated). Family names that were used included Nellie, Geoffrey, Alma, Arthur and Florence. Nelly Bay was first identified on maps as Nellys Bay in 1886. This was changed in 1892 to Nellie Bay, and then around 1920 it was changed to Nelly Bay (Barnes, 1997). The first permanent settlers at Nelly Bay were William and Mrs. Bright and daughter, farming pineapples, pawpaws and mangoes (Hayles Magnetic Island Pty. Ltd., Undated). European historical sites of Nelly Bay include the cemetery, school, magnetic island memorial gardens, plus a number of unmarked gravesites. Part of the 'Presto' shipwreck can also be located in the bay, reported to have been brought there to form a breakwater by William Bright (Barnes, 1997).

# 3 CLIMATE

## 3.1 Introduction

There is no official weather station on Magnetic Island. The official Bureau of Meteorology weather information has been gathered from a major weather station (site number 32040) at the Townsville airport (suburb of Garbutt) since 1940. The site's official location is Lat S 19.25, Long E 146.77. However, there is an unofficial rainfall data site at Nelly Bay and comparisons between the two sources of information have been included. The Townsville area is considered to have a tropical climate with hot wet summers and warm dry winters (GHD, 1990).

## 3.2 Temperature

The mean annual temperature for Townsville is about 24.2$^0$C with a mean daily maximum temperature of 28.7$^0$C and a mean daily minimum temperature of 19.7$^0$C (Bureau of Meteorology, 1999). Over a 57-year period (1940-1996), the highest recorded maximum temperature was 44.3$^0$C in January and the lowest 0.1$^0$C in July (Bureau of Meteorology, 1999). Table 3.1 provides a month by month temperature range for Townsville. Figures 3.1 & 3.2 show average annual maximum and minimum temperatures for the north Queensland coast, indicating where Townsville is placed in respect to temperature.

**TABLE 3.1:** Mean Daily Maximum and Minimum Temperatures (deg C)

| | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Max** | 31.3 | 31.0 | 30.6 | 29.5 | 27.5 | 25.5 | 24.9 | 25.9 | 27.6 | 29.3 | 30.7 | 31.3 |
| **Min** | 24.2 | 23.9 | 22.8 | 20.5 | 17.6 | 14.4 | 13.6 | 14.7 | 17.2 | 20.6 | 22.8 | 23.9 |

Source: Bureau of Meteorology, 1999 (average of years 1940 – 1996)

**FIGURE 3.1:** Average Annual Maximum Temperature for Townsville

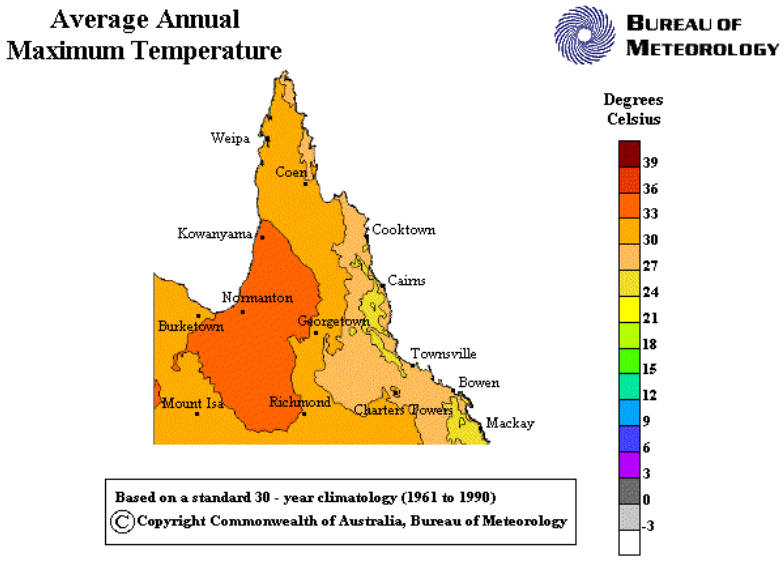
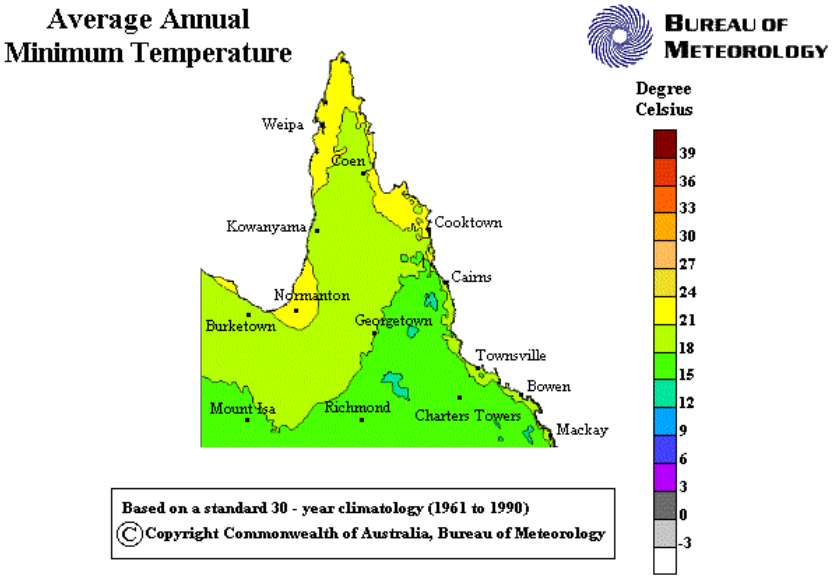


**FIGURE 3.2:** Average Annual Minimum Temperature for Townsville




The Townsville region is seasonally dry (Oliver, 1978), with most of the rainfall falling during the summer months. SKM (1995b) states that 76% of the average annual rainfall is precipitated between January and April, during which time the area is also exposed to tropical cyclones. The highest monthly rainfall recorded for January in Townsville was 1141.7mm and the lowest was 8.8mm. Townsville's median annual rainfall is approximately 1070mm, while the rainfall on Magnetic Island can be anywhere between 18-50% greater than on the mainland (Bureau of Meteorology, 1999; SKM, 1995b). Table 3.2 shows the average mean and median rainfall figures and Figures 3.3 & 3.4 present monthly rainfall data and average annual rainfall, respectively.

**TABLE 3.2:** Mean Rainfall (mm) and Median (Decile 5) Rainfall (mm) for Townsville

| | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 269 | 283 | 195 | 63 | 36 | 21 | 14 | 13 | 11 | 24 | 54 | 126 |
| **Median** | 216 | 217 | 155 | 32 | 20 | 10 | 3 | 5 | 3 | 13 | 33 | 76 |

Source: Bureau of Meteorology, 1999 (average of years 1940 – 1996)

The SKM report (1995b) showed several differences in rainfall between Nelly Bay and the mainland. First, there may be a slight rain shadow effect from Mount Cook since it is on the sheltered lee of the island. The mean annual rainfall for Nelly Bay was 1361mm for the period 1972 to 1994 and ranged from 642 to 2557 mm, suggesting a highly variable pattern of rainfall. Unofficial figures for the period 1995 to 1999 show a similar range (794 to 2605 mm). There is also a distinct wet and dry season. For example, in 1999 a total of 1291 mm was recorded with only 67 mm falling during the dry season (May to October) (Bureau of Meteorology, 1999a). There can also be prolonged periods of minimum rainfall (ie. during a drought). For example, between 1992 and 1994, Nelly Bay barely received the mean annual rainfall.

**FIGURE 3.3:** Average Monthly Rainfall Pattern for Townsville

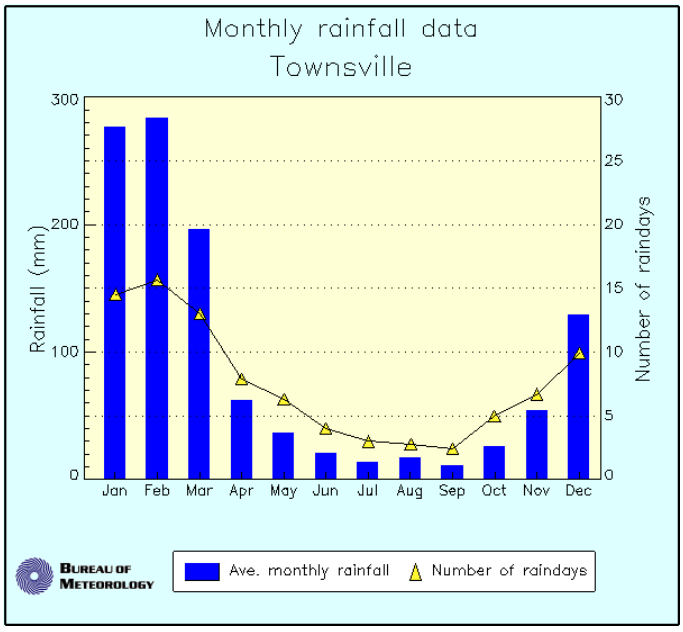
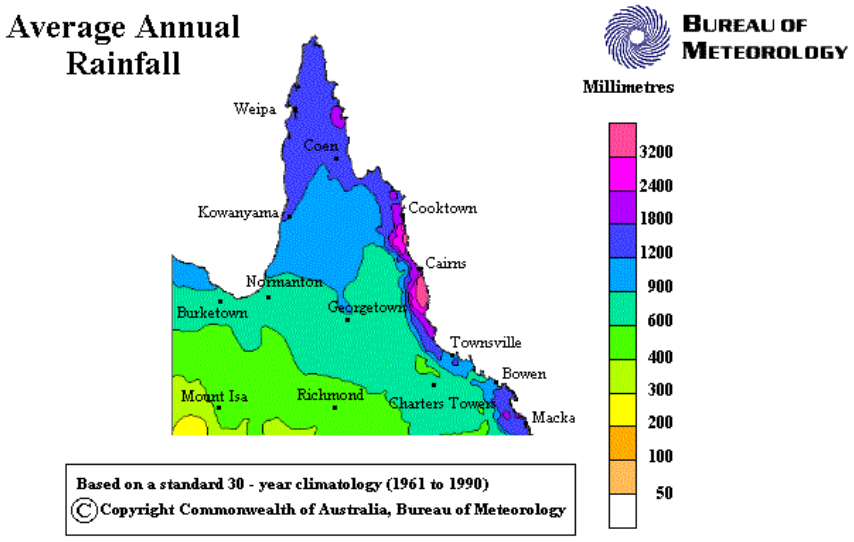



**FIGURE 3.4:** Average Annual Rainfall for Townsville



As rainfall is variable and seasonal, the discharge of Gustav Creek is also highly variable seasonally and from year to year. During the drier years very little surface runoff is generated and during the winter months, stream flows may be reduced to a trickle (maintained by limited groundwater seepage), or cease altogether (SKM, 1995b). In the wetter years, substantial surface runoff and associated flooding may occur in the lower reaches of the catchment. Such conditions often occur when cyclonic storms are present (SKM, 1995b).

### 3.3 Wind

The dominant winds in the area are from the south east, with north east afternoon breezes common (GHD, 1990). Average wind speeds throughout the year are about 6-8 knots in the morning and 10-12 knots in the afternoon and are generally highest during September through to November. Cyclonic winds have been known to gust at over 100 knots.

### 3.4 Cyclones

The entire Queensland coastline is open to tropical cyclones. Generally the stronger destructive cyclones cross the Queensland coast between Cooktown and Rockhampton (see Figure 3.5). The coast between Townsville and Mackay is particularly at risk from cyclonic storms because of its more NW - SE direction, and these storms appear to have a frequency of about one in three years along this portion of the Queensland coast (GHD, 1990).

**FIGURE 3.5:** Tropical Cyclone Risk Areas

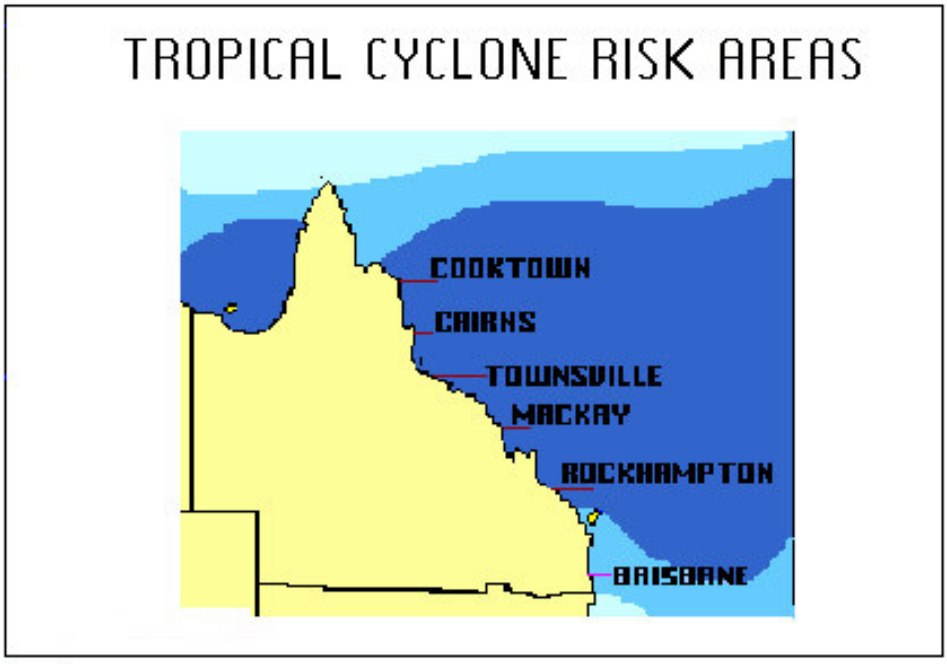



Table 3.3 presents recent cyclonic storms for the Townsville area. Cyclone Althea which struck Townsville in December 1971 contained winds of approximately 200 km/h (125mph) (SKM, 1995b). This particular cyclone created a 3m (10ft) storm surge, and caused $50 million worth of damage (GHD,

1990). In early 1991 following Cyclone Joy nearly 1500 mm of rainfall was recorded in January and February. This resulted in flooding along the lower reaches of Gustav Creek, with water ponding up against the main culvert along Sooning Road, before the creek drains into the bay (SKM, 1995b). Recently (1998), ex-cyclone Sid also left its impression on the Island, where in addition to flooding, the prolonged periods of rain produced saturated soils and this resulted in large scale landslips on steeper slopes (see aerial photo 1999 and Geology Section).

**TABLE 3.3:** Historical Cyclonic Events

| CYCLONIC STORM | YEAR AND MONTH OF OCCURRENCE |
|---|---|
| **3.1 Althea** | 1971 – December |
| **Una** | 1973 – December |
| **Vera** | 1974 – January |
| **Pam** | 1974 – February |
| **Keith** | 1977 – February |
| **Otto** | 1977 – March |
| **Kerry** | 1979 – March |
| **Winifred** | 1986 – January |
| **Aivu** | 1989 - April |
| **Joy** | 1990 - December |
| **Justin** | 1997 – March |
| **Ex-cyclone Sid** | 1997 - December |

Source: SKM, 1995b; BOM, 1999

# 4 OVERVIEW OF GUSTAV CREEK

## 4.1 Description and Condition Overview

The Gustav Creek catchment covers an area of 516ha and is one of the largest catchments on Magnetic Island. The stream length of the creek is 3550m and there is a $15\text{-}20^0$ slope over 80% of the basin. The valley of Gustav Creek forms a relatively flat area behind Nelly Bay and Gustav Creek is the main watercourse flowing into the bay. The catchment is characterised by four main geological units. They include granite boulders in the upper catchment with colluvium on the lower slopes of the valley underlying the alluvium deposits, adjacent to Gustav Creek. Beach deposits characterise the coastal fringe. Groundwater levels in the catchment are dependent on seasonal inputs.

There are a number of key reports and publications relating to the flora on Magnetic Island and numerous studies have been undertaken at Nelly Bay in relation to the marina proposal. There are ten identified vegetation types associated with the catchment of Gustav Creek, the most important being the Vine forest in the upper catchment. There are also a large number (49) of introduced plant species present in the catchment. The Queensland National Parks & Wildlife Service have listed the fauna of Magnetic Island; however, there have only been limited surveys on Gustav Creek.

Historically, the creek has had various water quality problems and it has been suggested that this may be from a number of different sources (such as the sewage treatment plant and residential septic systems) (Heideker, 1979; SKM 1995). Stormwater can also exacerbate problem.

## 4.2 Existing Land Uses

Nelly Bay is an urbanised area with the majority of this area zoned residential. The Gustav Creek catchment is therefore influenced by this urban impact. Impacts on the catchment can include invasion of weed species, as well as point source and diffuse pollution problems (eg. stormwater drains and seepage from septic tanks). Nelly Bay also has a large resident population, which can increase considerably, particularly during the tourist season and school holidays. The proposed Nelly Bay Harbour development is also expected to increase the population.

Nelly Bay comprises the only industrial sector on Magnetic Island, and also contains various commercial and tourist facility zonings. There is limited acreage allocated for future urban development.

The majority of residences in Nelly Bay, particularly in the older precincts, use septic systems for their wastewater treatment. Recently developed residential subdivisions and some tourist/commercial areas are connected to a wastewater reticulation system (see Map A that also illustrates locations of stormwater drains and water mains). A sewage treatment plant (STP) is located within the township of Nelly Bay to service both the septic systems and the reticulated areas. The total connected to the STP is approximately 750 EP (Equivalent Persons) – almost two thirds of the population.

## 4.3 Future Development Issues

The Nelly Bay Harbour proposal is currently the major development issue associated with Gustav Creek. Concerns include the proposed sedimentation basin in the harbour development, and water quality. The sedimentation basin (to be constructed at the outlet of Gustav Creek) will be designed to reduce the amount of sediment deposited in the harbour, catch sand for beach nourishment, and assist in the control of gross pollutants (EA/QEPA, 1999). If not properly managed, the Nelly Bay Harbour and basin could add to present water quality problems in Gustav Creek.

# 5 TENURE AND CONTROLS

## 5.1 Marine & Tidal Jurisdiction

All marine waters and tidal lands surrounding Magnetic Island have been designated as Marine Parks. EA/QEPA (1999) state that all waters seaward of Mean Low Water Mark are within the Great Barrier Reef Marine Park, established under the *Great Barrier Reef Marine Park Act 1975*. All of the Island's tidal lands and tidal waters between high water mark and low water mark, but excluding any alienated areas, are part of the Townsville –Whitsunday (State) Marine Park, proclaimed in 1987 under the *Marine Parks Act 1982*. The Queensland Parks & Wildlife Service in accordance with the Townsville - Whitsunday Marine Park Zoning Plan, manage the State Marine Park. The zoning provisions and objectives of both the GBRMP and (State) Marine Park are complimentary.

The marine waters of Nelly Bay are within the General Use 'A' Zone of both Marine Parks. Permissible uses in the General Use 'A' Zone include the navigation and operation of vessels, operation of tourist facilities, port developments and construction of moorings.

## 5.2 Harbour Proposal

The Nelly Bay Harbour development covers a number of jurisdictions. In the event the proposal is accepted, a number of Commonwealth and State planning and permit approvals will need to be granted. The proposal is therefore subject to the conditions of the Great Barrier Reef Marine Park (GBRMP) and the Townsville - Whitsunday (State) Marine Park. Magnetic Island is also within the Great Barrier Reef World Heritage Area (WHA). Permits for construction and operation will be required from the Great Barrier Reef Marine Park Authority (GBRMPA) and the Queensland Parks and Wildlife Service for the proposal to proceed. State agencies will need to provide approvals for works, and the Townsville City Council will be required to supply planning approvals. This is summarised by EA/QEPA (1999) below:

> "Any proposed works within the GBRMP will require permit approval under the Great Barrier Reef Marine Park Act 1975. Proposed works in the Townsville - Whitsunday (State) Marine Park will also require permits under the Marine Parks Act 1982, administered by the Queensland PWS. Approvals will be needed under legislation administered by the Queensland EPA (Environmental Protection Act 1994, Harbours Act 1955, Canals Act 1958, Beach Protection Act 1968, Queensland Heritage Act 1992 and Cultural Record (Landscapes Queensland and Queensland Estate) Act 1987). The Queensland Department of Primary Industries will assess any applications to remove or destroy marine plants pursuant to Section 51 of the Fisheries Act 1974. The Queensland Department of Natural Resources will assess any application for a Permit to Occupy the development lease pursuant to the Land Act 1994. Planning approvals are also needed from the Townsville City Council pursuant to Council by-laws, the Townsville Planning Scheme and the Integrated Planning Act 1997."

Table 5.1 provides an overview of the approvals and permits required for the development.

**TABLE 5.1**: Permits and Approvals Required for Nelly Bay Harbour Development

| Permits/Approval required | Permitting/approval authority | Regulatory Basis |
|---|---|---|
| Construction | | |
| Development Lease | State Government | Land Act 1962-1988 |
| Traffic Management Plan | Townsville City Council (TCC) | TC Planning Scheme |
| Plan of Subdivision | TCC | TC Planning Scheme |
| Drainage Management Plan | TCC | TC Planning Scheme |
| Stormwater Management Plan | TCC | TC Planning Scheme |
| Landscape Master Plan | TCC | TC Planning Scheme |
| Detailed Site Services Plan | TCC | TC Planning Scheme |
| Building approvals | TCC | TC Planning Scheme |
| Wharf structures | EPA | Harbours Act 1955 |
| Removal of sea bed material | EPA | Harbours Act 1955 |
| Permit to conduct works (State) | Parks & Wildlife Services (PWS) | Marine Parks Act 1982 |
| Permit to conduct works (Cwlth) | GBRMPA | GBRMP Act 1975 |
| Monitoring/investigative | GBRMPA & PWS | Marine Parks Act 1982<br>GBRMP Act 1975 |
| Permit to remove or destroy marine plants | Department of Primary Industries | Fisheries Act 1994 |
| 'Environmentally Relevant Activities' (includes dredging, earthworks, construction, waste disposal) | EPA | Environment Protection Act 1994 |
| Operation | | |
| Maintenance dredging | TCC<br>PWS | Canals/Harbour Act<br>Marine Parks Act 1982 |
| 'Environmentally Relevant Activities' (dredging, storage oils and fuels, port and marina operations) | EPA | Environment Protection Act 1994 |
| Other | | |
| Native Title Work Procedures | Premier and Cabinet | Native Title Act 1993 |
| Cultural Heritage | EPA | Cultural Record Act |

Source: EA/QEPA, 1999

## 5.3 Planning Considerations

Local government can only zone all land precincts within the harbour proposal area when they are raised above MHW. Once this takes place, the land precincts will come under Townsville City Council (TCC) jurisdiction. It is proposed that a 'Plan of Development' be incorporated in the Townsville City Planning Scheme and Magnetic Island Development Control Plan No.6 as the planning mechanism.

In respect of planning processes for precincts other than the harbour proposal, the Town Planning Scheme is presently being revised and a draft should be available in the near future. For the purpose of this report, all information has been derived from the current planning scheme.

# 6 LAND USE

## 6.1 Introduction

Nelly Bay is one of the most established and popular settlements on Magnetic Island. The bay has a large number of residents and has the largest visitor accommodation capacity. Nelly Bay also provides residents and tourists alike with the use of a number of community facilities (including shops, a school and a health care centre) and is the only bay which has land allocated for an industrial district (GHD, 1990).

Provided the Nelly Bay Harbour development is completed, SKM (1998) anticipate that Nelly Bay will provide a focus for tourism, commercial activities and industry. Nelly Bay is also expected to have one of the highest populations with an anticipated ultimate future population of 5300 persons (based on the Townsville City Council's Development Control Plan).

## 6.2 Land Tenure

Land tenure on Magnetic Island comprises National Park, Freehold Land, Leasehold Land and Vacant Crown Land (unallocated state land).

### *6.2.1 National Park*

The Department of Environment and Heritage administer the National Park under the provisions of the National Parks and Wildlife Conservation Act 1975. It is also governed by the Nature Conservation Act 1992 and the Environmental Protection Act 1994.

The use of National Park land is limited to conservation, recreation and educational purposes. There is a small amount of infrastructure within the National Park at Nelly Bay (e.g. trails) which is aimed at day use (GHD, 1990). Camping is not permitted. The walking trail within Nelly Bay starts at the end of Mandalay Avenue and climbs to a saddle between Nelly and Horseshoe Bay. Part of the track to this area runs parallel with Gustav Creek for approximately ½km.

### *6.2.2 Freehold and Leasehold Land*

The area of land designated as leasehold or freehold is situated on the relatively flat, low-lying coastal areas of Nelly Bay. GHD (1990) noted that Nelly Bay has a considerable amount of vacant land with these tenures and stated there were over 200 vacant allotments plus some large rural parcels. From BLINMAPs (Maps B and C) supplied by the Department of Natural Resources, most of the residential allotments are classified as freehold land.

### *6.2.3 Vacant Crown Land*

Vacant Crown land in Nelly Bay exists on the steep slopes of the surrounding hills and at the top end of the Gustav Creek catchment. This area is currently zoned as 'Non Urban' and was originally left out of the National Park to be assessed for appropriate land uses in the future (GHD, 1990). The area of particular interest lies at the head of Gustav Creek and has been recommended on numerous occasions to be included in the National Park because of the rare vine thicket community (see Vegetation Section 8). Within the Townsville-Thuringowa Draft Strategy Plan (1998) this area has been identified as being of 'Very High Conservation Value'. It is a regionally significant area of high priority protected area status. This area is also under Native Title consideration.

**Map B**: DNR BLINMAP of Nelly Bay – lower Mandalay Avenue subdivisions (Note: Gustav Creek is not included as integral part of DNR BLINMAP)

**Map C:** DNR BLINMAP of Nelly Bay – upper Mandalay Avenue subdivisions (Note: Gustav Creek is not included as integral part of DNR BLINMAP)

## 6.3 Zoning

### *6.3.1 Planning Schedule*

The current Townsville City Planning Scheme was prepared pursuant to the former Local Government (Planning and Environment) Act 1990. This scheme includes current zonings, strategic plans, development control plans and maps. The Planning Scheme sets out guidelines for present and future development for the City of Townsville. Magnetic Island is seen as having the following planning attributes:

- functioning suburb of Townsville;
- an area for retirement;
- tourist area providing low cost accommodation;
- recreational area for Townsville; and
- potential for high quality accommodation suited to international tourists (TCC, 1996).

Land above high water mark is under the jurisdiction of the TCC, (including Gustav Creek), and use of this land is subject to the provisions of the Town Planning Schedule for the City of Townsville (GHD, 1990; SKM, 1995; TCC, 1996). There is currently a Magnetic Island Development Control Plan (DCP) No.6 (TCC, 1997). The DCP explains the *preferred* land uses for the island.

Any amendments to this scheme would occur under transition provisions of the Integrated Planning Act 1997. Assessment of any development proposals would be undertaken in accordance with the Integrated Development Assessment System (IDAS). As previously mentioned, the Planning Scheme is currently being reviewed.

There is also the Townsville-Thuringowa Draft Strategy Plan (1998) which 'aims to achieve the optimum balance between economic, social and environmental objectives by identifying the preferred long-term structure of the region'. This plan has also adopted the principles of the National Strategy for Ecologically Sustainable Development (1992) which are to 'recognise, protect and enhance the region's important nature conservation values and biological diversity'.

### *6.3.2 Current Zoning*

Map D illustrates the existing town planning zones for the whole of Nelly Bay. The major zones relevant to Nelly Bay are residential and future urban, industrial, commercial, tourist facilities and special purpose. Land in Nelly Bay is zoned predominantly residential; however, there is a considerable amount of tourist facility zoning. There is also a significant area at the top of the catchment zoned 'Future Urban'.

### *6.3.3 Future Zoning*

As mentioned previously (Section 2.2), the TCC is reviewing the Town Planning Scheme including a review of the Development Control Plan (No.6) for Magnetic Island. In addition, the TCC is undertaking a Landslip Hazard Study and a Bush Fire Hazard Study for the region (pers. comm. P. Lindwall, 2000). It is anticipated that the outcomes of these studies will have an impact on future residential and business zones for Nelly Bay. Appropriate buffer zones may be required to protect residential development from the impact of landslips and bushfires and it is expected that these recommendations will be incorporated into the new Planning Scheme. In addition, it is anticipated that the revised scheme will take the opportunity where possible to create buffer zones along Gustav Creek to facilitate its effective management (pers. comm. P. Lindwall, 2000).

The Magnetic Island DCP (1997) (Figure 6.1) includes the Nelly Bay Harbour development proposal. At this stage, zoning cannot take place for this proposal and the EA/QEPA (1999) states why:

*"The majority of the site is below the mean low water mark and is not currently subject to 'land use' planning provisions. Once reclamation has occurred, these areas will fall within the jurisdiction of the TCC and its planning controls. The SEIS included an indicative Plan of Development to guide development within the various precincts*

*of the Nelly Bay Harbour development. A final plan would need to be approved in conjunction with, and to the satisfaction of, State agencies and the TCC. The approved plan would be incorporated into the DCP for Magnetic Island as an amendment to the Planning Scheme."*

**Map D:** Land zoning map

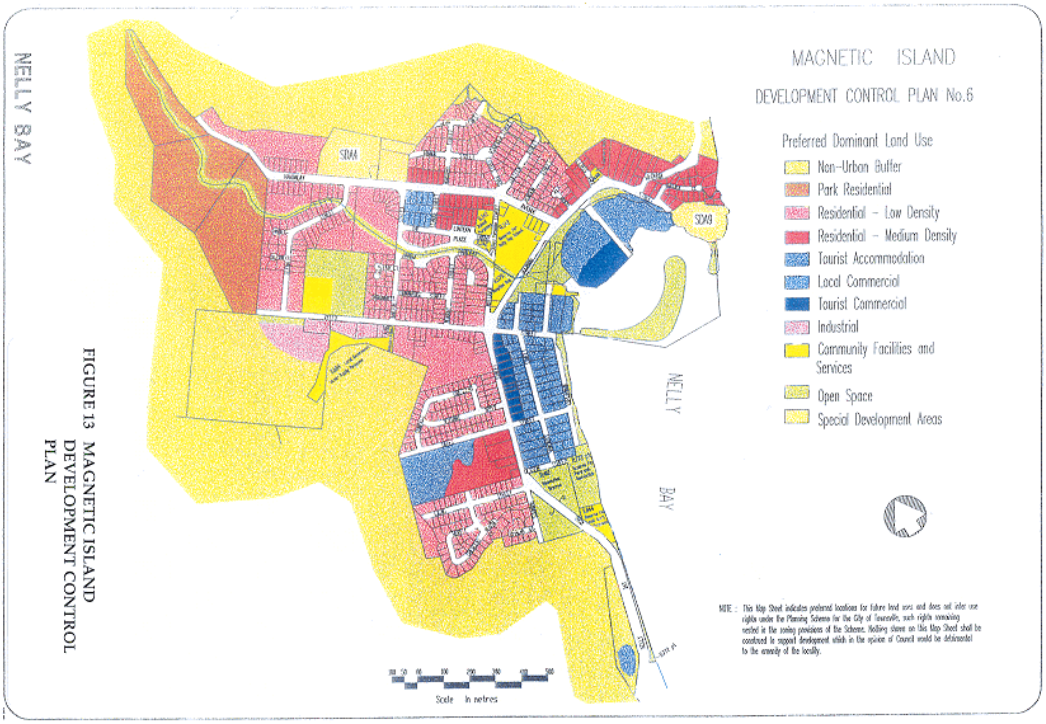



**FIGURE 6.1:** Magnetic Island Development Control Plan No.6

## 6.4 Zoning types

### *6.4.1 Residential*

Urban development of Nelly Bay has been taking place since the late 1800's, but has significantly increased since the 1960's (SKM, 1995). While the majority of land within Nelly Bay is zoned residential development, there is also evidence many blocks and areas are still vacant (SKM, 1995). This was also visible during the field trip for this report; for example the area behind the sewerage treatment plant was vacant and is presently being used to store extracted sand.

There are four separate residential zoning categories – Residential 1, 2, 3 and Park Residential. Park Residential is defined as a minimum allotment size of 4000m2 and the total size density does not exceed 2.5 lots per hectare. This land is considered unsuitable for any higher density developments due to site characteristics. The Magnetic Island Development Control Plan (TCC, 1997) states that the council is required to retain the stands of Vine Forest and Alexandra Palms in these areas. There is one area at the top of the catchment presently zoned as Future Urban, but which is defined as Park Residential on the DCP. This area will need to be rezoned prior to any development. It is intended that Park Residential areas will retain their natural values and aesthetic appeal.

'Residential - Low Density', as noted in the DCP (1997), are expected to be zoned Residential 1 and Residential 2. Development types will include dwelling houses and dual occupancy. The preferred density of development is equivalent to Residential 1 with maximum heights of buildings or structures to be no more than 2 storeys. There is only one parcel of land that is indicated on the DCP as Residential – Low Density but presently zoned 'Future Urban' (next to the Magnetic Island International Hotel on Mandalay Street). This area is close to steep slopes and has already been exposed to landslips. Buffer zones between housing and the slopes are currently being considered to reduce damage to buildings and to help reduce sediment flow into the creek.

There is also a parcel of land currently owned by PA & H Watson (mentioned above and used to store extracted sand) that is presently zoned as Residential 1 but is undeveloped (see Map E). It is situated on

Barton Street and behind the Sewage Treatment Plant. According to the Development Control Plan (DCP), 'it is intended that subdivision of land reflect the Aims and Objectives of this Plan with respect to appropriate buffer widths to creeks and to other areas of environmental significance'. As Gustav Creek runs through the centre of this parcel of land, we would strongly recommend that buffer strips along this section of the creek be included into any subdivision. This will enable access to the creek. In the past, Gustav Creek has been included in freehold titles, which only allows access to the creek with the owners' consent. The Townsville City Council has indicated access difficulties to carry out their responsibilities along the creek (such as weed and sediment maintenance). The DCP does include a buffer strip along the entire section of Gustav Creek within the urbanised area of Nelly Bay. This represents a preferred land use. However, unless the TCC purchases the creek areas from freehold owners, or comes to an arrangement with owners, the preferred land use along the length of Gustav Creek cannot occur. It would be recommended that these boundary issues be resolved.

The DCP also designated parcels of land as 'Residential – Medium Density'. This refers to a range of housing types and densities, including predominantly multiple dwellings and accommodation unit development. These areas provide for higher density residential development. The appropriate zoning for these land parcels is Residential 3 which has a maximum allowable height of 3 storeys, however 2 storeys are the preferred height. Areas currently zoned Residential 3 and which may impact Gustav Creek through stormwater pollution include an area on Mandalay Street. The area is also not connected to the wastewater and stormwater reticulation system. Table 6.1 provides an overview of specific requirements for the various residential zonings.

**TABLE 6.1:** Zoning Requirements for Residential Categories

| **ZONING REQUIREMENTS** | | |
|---|---|---|
| Zoning Category | Persons per Hectare | Maximum Building Height (Storeys) |
| Park Residential | 7 | 2 |
| Residential 1 | 30 | 2 |
| Residential 2 | 75 | 2 |
| Residential 3 | 100 | 3 |

Source: TCC, 1996; TCC, 1997

According to the GHD (1990) report, the majority of the development of Nelly Bay is to be residential development and the opportunity exists for a variety of residential densities in new subdivisions and in the redevelopment of existing residential land (as mentioned above). However, TCC (1996) noted a number of constraints to development on Magnetic Island. They include:

- The extent of common ownership of freehold land (This land may be amalgamated in the future in expectation of future integrated development)
- The extent of vacant crown land
- The adopted population densities in each zone
- Community profile and attitudes
- Historical and environmental constraints or opportunities
- Infrastructure constraints or opportunities
- Existing land zoning's and "as of right" uses
- Compensation if land is "down zoned"

### *6.4.2 Industrial*

There are two zonings for industrial – light industrial and general industrial. According to the Development Control Plan, there will be no further expansion of the industrial area for Nelly Bay. Nevertheless, it also states that the old quarry reserve (next to the concrete company) will provide an area for further industrial activity (presently under District Land Office jurisdiction); however, this type of activity will 'generally not be encouraged by the Council'. The industrial sectors are located on Kelly Street opposite the Townsville City Council's sewerage treatment plant and residential areas. The

industrial companies are also not connected to the stormwater and wastewater reticulation systems and it is recommended that this be rectified.

The industries include welding, a moke hire service centre, and a concreting company. A tributary linked to Gustav Creek goes through the land of the concrete company and has been extensively scoured from the recent 1997 and 1998 wet seasons. According to the DCP, industrial land which abuts land uses may require landscaped buffer strips and screen fences. It would be recommended that as a tributary runs through the property, buffer strips be included to slow runoff and discharges. Table 6.2 shows the company names and addresses operating on Kelly Street.

**TABLE 6.2:** Companies operating within the Industrial Zone

| **INDUSTRIAL COMPANIES** | |
|---|---|
| Magnetic Mix Concrete | 64a Kelly St |
| Cossey Welding | 64 Kelly |
| Island Engineering & Welding | 56 Kelly St |
| Patons Motor Repairs | 56 Kelly St |
| Holiday Moke Service Centre | Kelly St |

### *6.4.3 Commercial and Community*

The DCP has areas designated as Local Commercial and Community Facilities and Services. Local Commercial designates areas which commercial retail activities and services for local residents can predominate. Facilities can include business for weekly shopping needs, professional and business services and health services. Areas presently zoned as 'Local Shopping' include an area at the corner of Mandalay Avenue and Sooning Street and another located at the corner of Mandalay Avenue and Barton Street. The second area comprises numerous companies operating within this precinct and is shown in Table 6.3. 'Local Shopping is located on Mandalay Street. There are also two main shopping centres located on Sooning Street (zoned 'Tourist Facility' which should be zoned 'Local Shopping') and Mandalay Avenue (zoned 'Local Shopping').

**TABLE 6.3:** Companies operating within the area zoned 'Local Shopping'

| **COMPANY** | **ADDRESS** |
|---|---|
| Townsville City Council depot | Barton St |
| Magnetic Island Bus Service | 44 Mandalay Ave |
| Magnetic Island Hardware | 38 Mandalay Ave |
| Seafood Factory | 38 Mandalay Ave |
| Petrol/Auto Parts | 38 Mandalay Ave |
| Greencross Veterinarians | 38 Mandalay Ave |
| Magnetic Island Electrical, Appliances, Refrigeration & Airconditioning | 18 The Grove |
| Magnetic Island Auto & Marine Electrical | 29 Grove St |

The DCP lists various community facilities (see Figure 6.1, Map D and Table 6.4). They include the Nelly Bay State School (zoned Special Purpose 2 and located on the northern side of the creek) and the medical centre (zoned Special Purpose 3 and located on the southern side of the creek) on Sooning Street. It also identifies the reservoir (zoned Special Purpose 4), the ambulance centre (zoned Special Purpose 11) and the sewage treatment plant (zoned as Special Purpose 12) on Kelly Street. The DCP explains that Community Facilities and Services are intended to accommodate community welfare facilities, infrastructure services and active recreational areas that benefit the community. The maximum height of buildings/structures within this zoning shall not exceed 3 storeys and low-density developments are encouraged by TCC. Other companies operating within Nelly Bay are shown in Table 6.5.

**TABLE 6.4:** Majority of community facilities operating in Nelly Bay

| COMPANY | ADDRESS |
|---|---|
| Magnetic Community News | 5 Trana Ct |
| Magnetic Island Afterschool Care | 5 Grove St |
| Magnetic Island Childcare & Kindergarten | 25 Nelly Bay Rd |
| Magnetic Island Health Care | 74 Sooning St |
| Magnetic Island Medical Centre | 68 Sooning St |
| Magnetic Island State School & Community Swimming Pool | Mandalay Ave |
| Magnetic Island Transport & Crane Hire | 6 Bottiger St |
| Magnetic Times | Barton St |
| Magnetic Island Ambulance Station | Kelly St |

**TABLE 6.5:** Other companies operating within Nelly Bay.

| COMPANY | ADDRESS |
|---|---|
| Magnetic Community News | 5 Trana Ct |
| Magnetic Island Transport & Crane Hire | 6 Bottiger St |
| Magnetic Times | Barton St |

*6.4.4 Tourist Facilities*

The Development Control Plan identifies areas of Tourist Accommodation and Tourist Commercial. These areas are presently zoned 'Tourist Facilities'. Table 6.6 lists the companies within the precinct identified as Tourist Commercial (along Sooning Street) by the DCP and zoned as Tourist Facilities.

**TABLE 6.6:** Tourist Facilities located along Sooning Street

| COMPANY | ADDRESS |
|---|---|
| Magnetic Island Hairport | 10 Sooning St |
| Magnetic Island Mini Golf | 27 Sooning St |
| Magnetic Island Pharmacy | 5/55 Sooning St |
| Magnetic Island Real Estate | 2/68 Sooning St |
| Magnetic Island Supermarket | 55 Sooning St |
| Magnetic Island Travel & Accommodation | 55 Sooning St |
| Magnetic Travel | 55 Sooning St |

The major areas zoned as 'Tourist Facilities' and listed as Tourist Accommodation in the DCP include the foreshore of The Esplanade, Mandalay Street (Magnetic Island International Hotel) and Yates Street. Proposed tourist facilities include the Nelly Bay Harbour development. Tourist Facilities are able to have densities of between 100-200 persons per hectare (GHD, 1990). TCC (1997) point out that 'major tourist accommodation and commercial activity is preferred on land identified east of Sooning Street to the foreshore and including the Nelly Bay reclamation area'. Additional zoning specifications are required for tourist facilities outside this area to prevent residential disruption.

An example of this is the Magnetic Island International Hotel (formerly Latitude 19 Resort) which is a special development area zoned 'Tourist Facilities'. Special site requirements apply to this area due to its proximity to residential development and the potential loss of amenity to residents (SKM, 1998). Limited expansion and upgrading will be considered by council and a maximum height of 3 storeys apply to the

site (SKM, 1998). The majority of the tourist facilities are not connected to the stormwater/wastewater system. Table 6.7 shows tourist facilities presently operating in Nelly Bay.

**TABLE 6.7:** Majority of Current Tourist Facilities operating in Nelly Bay

| TOURIST FACILITY | ADDRESS |
|---|---|
| Anchorage Apartments | 110 Sooning St |
| Baringa Holiday Units | 15 Warboys St |
| Camlachie Holiday Units | 122 Sooning St |
| Camp Irwin | 63 Sooning St |
| Coconuts on Magnetic Beach | 1 Nelly Bay Road |
| Island Leisure Resort | 4 Kelly St |
| Island Palms | 13 The Esplanade |
| Magnetic Island International Hotel | Mandalay Ave |
| Magnetic Island Tropical Resort | 56 Yates St |
| Palm View Chalets | 114 Sooning St |
| Surfside Palms Holiday Units | 15 The Esplanade |
| Travellers Backpackers Resort | 1 The Esplanade |

Source: Telephone directory

### *6.4.5 Non Urban*

As seen in Figure 6.2 there is a considerable amount of land zoned 'Non Urban' (vacant Crown land) which is generally located on the steeper slopes. According to the Development Control Plan, 'it is intended that urban development will generally be discouraged by the Council' in these precincts and these areas will be retained 'as an open space buffer between the Island settlements and National Park lands. This land is noted on BLINMAPs supplied by DNR as unallocated state land. As previously mentioned, the vine thicket community is of particular importance within this zoning. This area is also under a Native Title application (see Heritage Issues Section 7).

### *6.4.6 Special Purpose*

There are a number of Special Purpose zoning's relevant to Nelly Bay and the Gustav Creek catchment and are listed in Table 6.8 (also see Figure 6.1). These areas require special development guidelines and land included in this category may be subject to drainage problems or site constraints due to adjacent land uses. In the current zoning map there are two areas listed as Special Purpose 3 and noted in the Table below. It is recommended that the numbering of one of these listings be changed.

**TABLE 6.8:** Special Purpose Facilities

| FACILITY | SPECIAL PURPOSE ZONING |
|---|---|
| Education Queensland (Nelly Bay State School) | SP2 |
| Northern Regional Health Authority (Nelly Bay Medical Centre) | SP3 |
| District Land Office Land (vacant) | SP3 |
| Townsville City Council Sewerage Treatment Plant | SP4 |
| | SP7 |
| Reservoir | SP12 |

## 6.5 Contaminated Land

A Contaminated Sites Register was provided by the TCC on sites that were considered contaminated lands under the act. The sites for Nelly Bay are summarised below (Table 6.9).

**TABLE 6.9**: Contaminated Sites Listed by Townsville City Council for Nelly Bay

| SITE | ADDRESS |
|---|---|
| Fuel Depot – Magnetic Keys | 146 Sooning Street |
| Fuel Storage | 44 Mandalay Avenue |
| Service Station – BP Nelly Bay | 36 Mandalay Avenue |

All licences and approvals for an activity that may cause contaminated land comes under the Environmental Protection Act 1994. The Integrated Planning Act 1997 only comes into effect if the existing use of land is changed under a planning scheme or the land is listed on the contaminated land register.

# 7 HERITAGE ISSUES

## 7.1 Aboriginal Heritage

### *7.1.1 Artefacts*

A number of artefacts have been located near Gustav Creek. EA/QEPA (1999) describe these artefacts as follows:

> "Artefact scatters and two middens were located on opposite sides of the mouth of Gustav Greek. The midden on the eastern side of Gustav Creek (NB#1) was carbon dated and revealed a maximum date of 650±70 years Before Present. The second midden, on the western side of Gustav Greek (NB#2), has since been excavated as part of the works undertaken in the early 1990s and is unrecognisable. The remaining midden on the western side of Gustav Creek has also been described as extremely disturbed by development work, although scatters of pumice, coral fragments and juvenile shellfish were observed. The Wulgurukaba Corporation was concerned over the midden located on the western side of Gustav Creek, and the possibility of uncovering human remains during further excavation."

None of the remaining sites are listed on the State Register under Section 44 of the *Cultural Records (Landscapes Queensland and Queensland Estate) Act 1987* (CR(LQQE) Act) (EA/QEPA, 1999). However, if an artefact is found, it is an offence under Section 56 of the CR(LQQE) Act to 'take, destroy, damage, deface, excavate, expose, conceal or interfere with an item of the Queensland Estate', unless covered by a permit (EA/QEPA, 1999).

It is generally accepted that the Wulgurukaba people are the traditional owners on Magnetic Island and we have been advised that the Bindal people would not be involved in any site locations (pers. comm. M. Bird). We have also been advised that no archaeological work has been carried out further up the catchment (pers. comm. M. Bird; L. Hatte). Therefore, no current information is available on archaeological sites within or near the Gustav Creek catchment.

### *7.1.2 Native Title*

In 1998, the Gabulbarra Reference Group lodged two native title claims over areas of Magnetic Island. The reference group acts for the Wulgurukaba people of Townsville and the Manbarra people of Palm Island. The first claim (NNTT Ref#QC98/30) covers the National Park and the Horseshoe Lagoon Environmental Park (AIATSIS, 1998). The second claim (NNTT Ref#QC98/31) refers to the area of state land (unallocated state land) between the towns and the National Park (AIATSIS, 1998). Freehold, leasehold and government land is excluded from the claims. In September 1999, the applications were accepted by the Federal Court (AIATSIS, 1999; NNTT, 1999).

## 7.2 Non Aboriginal Heritage

### *7.2.1 National Estate*

The Register of the National Estate lists areas for their natural, historic or cultural value. The whole of Magnetic Island and its surrounding waters are included in the category 'natural'. (Australian Heritage Commission, 1999). A full explanation of the listing is in Appendix A.

# 8 FLORA AND FAUNA

## 8.1 Vegetation of the Gustav Creek catchment

### *8.1.1 General description*

This section describes the vegetation of Gustav Creek catchment based on published and unpublished information and a specially conducted survey on the lowland riparian vegetation of Gustav Creek.

There have been few published descriptions of the vegetation of Magnetic Island prior to the 1980's. Maitland (1892) mentions 'bloodwood, Moreton Bay ash, and occasional ti-tree swamps and mangrove flats' fringing the south-west coast, and indicated 'bloodwood and Moreton Bay ash' in 'Nelly's Bay'. A reference in Specht *et al*. (1974) was limited to a brief description of the vegetation communities of Magnetic Island National Park. The vegetation of the Gustav Creek estuary and adjacent Bright Point was described by Jackes in the initial Impact Assessment Study (McIntyre and Assocs.,1986b) for the (then named) Magnetic Keys development. Mangrove species were not separately listed but mangroves were described as 'a rich collection of easily accessible species'. The flora survey was restricted to the boundaries of the development and recorded 71 species, focussing on Bright Point. Jackes (1987) later published a guide to the plants of Magnetic Island; however, this key included no distribution data.

A floristic survey of Magnetic Island vegetation was later undertaken by Queensland National Parks and Wildlife Service (QNPWS) (Sandercoe, 1990) based on plant collections from 1979, 1981 and 1982, and Queensland Herbarium records to 1984. Vegetation distribution and conservation significance was described for the entire island, and a map was produced at a scale of 1:15000, delineating vegetation communities. A total of 513 taxa were recorded including 46 introduced weed species. This study has formed the basis for most subsequent vegetation assessments of the Nelly Bay area. Twenty-three vegetation types were recognised on the island, ten of which were associated with the catchment of Gustav Creek (Table 8.1). The Gustav Creek catchment vegetation map (Sandercoe, 1990) is shown in Map F. (Note that some plant species names have since undergone taxonomic revision.)

Revised and updated species lists for vegetation types 9, 13/14,15, 17, and 18 (based on the QNPWS report of Sandercoe, 1990) are included in Appendix B1. Types 20/21/22 are chiefly restricted to inaccessible areas at the headwaters of Gustav Creek above 200m and within the National Park, and have not been listed.

A subsequent report on vegetation communities and conservation priorities in the Townsville region commissioned by the Townsville City Council (Skull, 1996) validated the vegetation boundaries identified on Magnetic Island by QNPWS. Digitised data based on this study facilitated the production of the map (Map F) detailing vegetation communities of the Gustav Creek catchment. Some vegetation types have been amalgamated to facilitate mapping. Vegetation communities described by Skull (1996) and their equivalent QNPWS types are listed with associated map codes in Table 8.2.

### *8.1.2 Vulnerable and Endangered species*

The *Queensland Nature Conservation Act 1992* defines the status of vascular plant taxa in Queensland. Plants may be classified as Common, Vulnerable, Endangered or Presumed Extinct. Plants recorded by Sandercoe (1990) include several species listed as vulnerable.

Four species listed as vulnerable have been reported as occurring within vegetation types found in the Gustav Creek catchment (Table 8.3). Two of these (*Livistona drudei* and *Croton magneticus*) have been recorded from vine forest (vegetation type 13/14), and two (*Leucopogon cuspidatus* and *Marsdenia brevifolia*) from the mixed eucalypt woodland community (type 17). *C. magneticus* has also been recorded from mixed deciduous woodland (type 15).

**Table 8.1: Vegetation types associated with the Gustav Creek catchment (Sandercoe, 1990)**

| Type | Vegetation | Description |
|---|---|---|
| 3 | Mixed mangrove shrubland | Mixed tall to very tall closed shrubland/shrubland |
| 9 | Poplar gum and bloodwood woodland | *Eucalyptus platyphylla* and *Corymbia intermedia* tall woodland with layered shrub and grass understorey |
| 13 | Low vine forest amongst boulders | Simple-complex notophyll mixed vine mid-high closed forest sometimes with *Corymbia tessellaris* and/or *Araucaria cunninghamii* emergents. |
| 14 | Vine forest | Simple-complex notophyll mixed vine tall closed forest with *Corymbia tessellaris* emergents and *Acacia solandri*. |
| 15 | Mixed semi-deciduous woodland | Mixed *Lophostemon grandiflorus* mid-high to tall woodland/open woodland with a diverse layered shrubby understorey. |
| 17 | Mixed eucalypt woodland | Mixed *Eucalyptus* sp.mid-high to tall woodland/open woodland with a shrubby and/or grassy understorey. |
| 18 | Acacia shrubland | *Acacia leptostachya* low to mid-high closed forest/open forest with sparse shrubby understorey. |
| 20 | Mallee brush box forest | *Lophostemon confertus* very tall open mallee forest (at altitude amongst huge granite boulders) |
| 21 | Cabbage tree palm and forest she-oak forest | *Livistona drudei* and *Allocasuarina torulosa* mid-high to tall open forest/woodland with grassy *Xanthorrhoea* understorey. |
| 22 | Forest sheoak and grass tree shrubland (on exposed ridges) | *Allocasuarina torulosa* very tall open shrubland, with *Xanthorrhoea* understorey. |
| 24 | Disturbed areas – cleared or urban | |

**Table 8.2: Vegetation communities of the Gustav Creek catchment described by Skull (1996) and equivalent descriptions from the QNPWS report (Sandercoe, 1990).**

| Map code | Skull (1996) description | Equivalent QNPWS (Sandercoe, 1990) description |
|---|---|---|
| AS | Acacia scrub | 18 Acacia shrubland |
| C | Cleared land | 24 Disturbed areas – cleared or urban |
| CM | Casuarina/melaleuca riparian woodland | Not described |
| EP | *Eucalyptus platyphylla* open woodland | 9 Poplar gum and bloodwood woodland |
| EW | Eucalyptus woodland on shallow soils | 17 Mixed eucalypt woodland |
| FLW | Footslope *Lophostemon* woodland | 15 Mixed semi-deciduous woodland |
| M | Mangroves | 3 Mixed mangrove shrubland |
| MEW | Mixed Eucalypt open woodland | 17 Mixed eucalypt woodland |
| V | Vine thicket | 13 Low vine forest amongst boulders<br>14 Vine forest |

These plants are listed as vulnerable within Queensland. Three of these taxa – *C. magneticus*, *L. cuspidatus* and *M. brevifolia* are also considered to be vulnerable throughout Australia and are listed by the ANZECC List of Threatened Australian Flora (1997). *L. drudei* is not considered vulnerable nationwide.

**Table 8.3: The status of threatened taxa listed by the Queensland Herbarium, and associated vegetation communities in the Gustav Creek catchment.**

| Species | Family | Form | Status | Vegetation Community |
|---|---|---|---|---|
| *Croton magneticus* | Euphorbiaceae | Shrub | Vulnerable | Types 13 and 15 |
| *Leucopogon cuspidatus* | Epacridaceae | Shrub | Vulnerable | Type 17 |
| *Livistona drudei* | Arecaceae | Tree | Vulnerable | Type 14 |
| *Marsdenia brevifolia* (formerly *Gynema brevifolia*) | Asclepiadaceae | Vine | Vulnerable | Type 17 |

*8.1.3 Conservation status of vegetation communities*

Within Queensland, 19 bioregions have been recognised, based on broad landscape patterns that reflect differences in geology, topography, climate, and vegetation (Sattler and Williams, 1999). Bioregions have been further divided into a number of provinces, each having distinctive geologies, landform, and associated soils and vegetation. At a finer scale, vegetation communities that are associated with specific combinations of geology, landform, and soil have been classified into regional ecosystems. In order to facilitate biodiversity planning across the state, each regional ecosystem has been assigned a three-part number and has been assessed in terms of its conservation status. Assessments are based on current regional ecosystem distribution compared with pre-European extent. The assessment classes are defined as follows:

- *Endangered*: less than 10% of pre-European extent remains in an intact condition, or distribution has contracted to <10% of its former range. This category includes regions in which severe degradation has occurred and the area is not expected to recover in the medium to long term.
- *Of concern*: 10-30% pre-European extent remains in an intact condition. This category includes regions where moderate degradation has occurred. Floristic diversity in these regions is greatly reduced but may be expected to recover if threats are removed. A management response is warranted to ensure that the ecosystem does not become endangered.
- *No concern at present*: over 30% of pre-European extent remains, and little or no degradation has occurred. The ecosystem is relatively widespread.

Magnetic Island is included in Province 1, Townsville Plains, within the Brigalow Belt (Young *et al*., 1999). The conservation status of vegetation communities of the Gustav Creek catchment is correlated with those described in the QNPWS report (Sandercoe, 1990) and listed in Table 8.4.

Vegetation communities associated with Gustav Creek are well represented within the Brigalow Belt bioregion and there is no concern as to their continued conservation status (Young *et al*., 1999). However, vegetation type 14 (Vine forest), which is reported to contain two species listed as vulnerable (*C. magneticus,* and *L. drudei* – see section 8.1.2) is not represented in the Magnetic Island National Park. In her technical report to QNPWS, Sandercoe (1990) highlighted the importance of vegetation type 14, termed the 'Nelly Bay scrub', as one of the closest rainforests to Townsville. She suggested that the inclusion of this vegetation type to the National Park would 'enhance significantly the conservation value of Magnetic Island National Park and secure most of the features of the island that attract so may visitors'. The value of this vegetation type was also noted in the Magnetic Island Management Plan (GHD, 1990). The Townsville and Thuringowa Councils Draft Strategy Plan (TTDSP) (1998) acknowledged that significant areas with important conservation values exist outside the present conservation reserves within the region, and planned to incorporate 'representative samples of all land systems, fauna and vegetation communities… within nature conservation reserves by the year 2011'. Unallocated State Land (USL) between Arcadia and West Point (including the Gustav Creek catchment) was listed as a priority area. This land is currently the subject of native title claims by the Wulgurukaba and Manbarra Aboriginal peoples. The Queensland Environmental Protection Agency also recognises the ecological significance of the area but has no immediate plans to incorporate it into the Magnetic Island National Park (pers.comm.G. Morgan).

**Table 8.4: Conservation status of vegetation communities in the Gustav Creek catchment.**

| Regional ecosystem | Vegetation type (Sandercoe, 1990) | Extent reserved | Estimated extent | Conservation status |
|---|---|---|---|---|
| 11.12.4 | 13, 14 | Medium | >30% remains of a naturally restricted type | No concern at present |
| 11.12.9 | 9 | Low | >30% remains | No concern at present |
| 11.12.13 | 17 | High | >30% remains | No concern at present |
| 11.12.14 | 20 | High | >30% remains | No concern at present |
| 11.12.15 | 22 | High | >30% remains | No concern at present |
| 11.12.16 | 15 | High | >30% remains | No concern at present |

The Townsville Development Control Plan No.6: Nelly Bay (TCC, 1997) mentions 'a sole area of Alexandra Palm Rain Forest' occurring in the Gustav Creek Basin. This forest community was not designated as a distinct vegetation type in the QNPWS report (Sandercoe 1990) and was there described as 'a clump of *Archontophoenix alexandrae* [Alexandra palm]… clearly visible where the spring emerges on the hillside behind Nelly Bay'. This vegetation assemblage appears to have affinities with vine forests in the Wet Tropics bioregion and may be considered as a depauperate variation of these communities (pers.comm. G. Morgan). The extent of this vegetation unit could be ascertained by ground-truthing.

### *8.1.4 Gustav Creek riparian vegetation*

Species lists produced by QNPWS (Sandercoe, 1990) are considered generally representative of the vegetation communities of the Gustav Creek catchment with the exception of the casuarina/melaleuca riparian woodland (CM) mapped by Skull (1996). Sandercoe (1990) did not separately survey this community; however, a brief description of the riparian and instream vegetation within the Nelly Bay township was included in an assessment of the stream channel in the Draft Environmental Impact Survey (1995). This report also stated that the mangroves upstream of Sooning Street are isolated from regular tidal patterns by the road bridge. This upstream mangrove community has not been described. In order to address this deficiency, a brief field survey of the Gustav Creek riparian and mangrove communities was undertaken as part of this study on December 15th, 1999. During this survey, the structure and floristic composition of the vegetation was assessed.

### *8.1.5 Survey*

This survey should not be considered comprehensive; it gives an indication of those taxa present on the date of survey only. Vegetation surveys conducted during the dry season may reveal additional species. The lowland vegetation surrounding Nelly Bay township is described as eucalyptus woodland (see Map F). A mangrove community has been recorded at the mouth of Gustav Creek.
Gustav Creek was divided into four sections within the Nelly Bay urban area. The four sections were:

1. the riparian community within the most recent subdivision at the inland end of Mandalay Avenue, on the lower slopes of the foothills; altitude 10-15 m;
2. Gustav Creek downstream from the private road bridge (Site 1) to upstream from the Barton Street Bridge, altitude approximately 5-10 m;
3. downstream from the Barton Street bridge (<5 m altitude) to the Sooning Street bridge;
4. mangroves below Sooning Street bridge.

Sections 1-4 are indicated on the vegetation map (Map F). Where accessible, the Gustav Creek streambed was traversed from Section 1 to Section 4. Plants were identified to species wherever possible; those that

could not be identified in the field were individually labelled and returned to James Cook University for later identification.

*8.1.6 Section descriptions*

Section 1 The stream was not flowing when the vegetation survey was conducted although large granite boulders within the streambed showed indications of higher water levels. Where the gradient was steep, large boulders dominated the bed, grading to gravel and coarse sand as the gradient reduced. The riparian vegetation matched with the description of QNPWS (Sandercoe, 1990) vegetation type 14 – simple-complex notophyll mixed vine tall closed forest with *Corymbia tessellaris* emergents, and mature *Melaleuca leucadendra* close to the creek. Common trees included *Schefflera actinophylla, Canarium australianum, Terminalia muelleri, Macaranga tanarius, Mallotus philippensis, Omolanthus populifolius, Cryptocarya triplinervis*, *Nauclea orientalis*, and various *Ficus* species, with occasional *Araucaria cunninghamii.* The shrub *Croton magneticus* was also present. Stinging trees *Dendrocnide moroides* were common where native vegetation had been cleared. On stream banks the presence of fruit trees – mango *Mangifera indica*, and pawpaw *Carica papaya*, coconut *Cocos nucifera*, and macadamia *Macadamia integrifolia* – and exotic palms *Caryota mitis*, and the traveller's palm *Ravenala madagascariensis,* suggested that attempts had been made to integrate food trees and garden specimens with rainforest species in a rural residential setting. One specimen of the palm *Livistona decipiens* was recorded. On sandy stream banks and where the canopy was less dense, introduced species included Singapore daisy *Wedelia trilobata,* quisqualis *Quisqualis indica*, and mother-in-law's tongue *Sansevieria trisfasciata*. The introduced guinea grass *Panicum maximum* was common. Lantana *Lantana camara* was also present.

Section 2 This section of the stream passes through the suburban area of the Nelly Bay township. Banks show evidence of erosion. The stream bed sediments are predominantly sand with occasional concretions. Some stream banks have been completely cleared of native vegetation and replanted with exotic garden species. Nevertheless, native vegetation persists in some stream reaches. Melaleuca *Melaleuca leucadendra* was the dominant species, but tree species typical of adjacent eucalypt woodland were also common, including Burdekin plum *Pleiogynium timorense, Terminalia muelleri, Terminalia melanocarpa, Cochlospermum gillivraei, Canarium australianum, Acacia leptostachya, Alphitonia excelsa, Corymbia tessellaris, Eucalyptus platyphylla* and *Ficus* species. Weedy herb and grass species had invaded the streambed in many areas, particularly where sandbanks had developed. Singapore daisy *Wedelia trilobata* and guinea grass *Panicum maximum* were abundant on stream banks and on bed sediments. Lantana was also present. The stream in this section flows through private land, either along the boundary between adjacent blocks, or across residential property sites.

Section 3 Below Barton Street bridge the stream channel widens to form the mouth of Gustav Creek. Large melaleucas *M. leucadendra* are common close to the water's edge, with smaller tree species including *Macaranga tanarius, Omolanthus populifolius, Millettia pinnata, Neolitsea australiensis, Cupaniopsis anacardioides* and *Lophostemon grandiflorus* on the banks. Mature tamarind *Tamarindus indica*, and mango *Mangifera indica* form extensive canopies. Downstream, the grass *Panicum maximum* and sedges *Cyperus eragrostis* and *Cyperus involucratus* have grown across the stream bed, forming dense clumps. Weedy herb species and garden escapes were also common. Numerous *M. leucadendra* seedlings had developed on the exposed stream sediments near Barton street bridge. Seedlings of the exotic palms *Carpentaria acuminata* and *Caryota mitis* had also developed in the streambed, presumably germinated from seeds washed downstream by overland flow from adjacent gardens. Singapore daisy was also common in this section. This area includes the maximum extent of high tides before the construction of the Sooning Street bridge and culvert. The mangrove fern *Acrostichum speciosum* and a poor specimen of the blind-your-eye mangrove *Excoecaria agallocha* were growing near the

main stream channel at a point level with Murray Street on the right bank, and the northwest end of Lintern Place on the left bank. On the banks, away from saline conditions, tree species were typical of those found in at higher elevations and included *Melaleuca leucadendra, Omolanthus populifolius, Planchonia careya, Ficus congesta, F. racemosa*, and *Corymbia maritima*.

The Sooning Street bridge foundations incorporate a culvert for Gustav Creek water. Sediments have built up on the landward side of the foundations, obstructing tidal movement. A dense stand of the tropical reed *Phragmites karka* has developed on this material. A deep pool of standing water was present on the landward side of the reed community, edged with *Avicennia marina*. Close to the water's edge, mangrove tree species dominated the vegetation with *Lumnitzera* sp. common, with occasional *Rhizophora stylosa*, and vines *Entada phaseoloides* and *Mucuna gigantea*. Ground cover beneath mangrove species was sparse, with occasional patches of the stinging tree *Dendrocnide moroides.* On sediment banks tree species including *Corymbia tessellaris, Cupaniopsis anacardioides, Ficus hispida, Pandanus* sp. and *Macaranga tanarius* formed sparse woodland, with the scrambler *Clerodenron inerme* common. Ground cover was almost exclusively guinea grass *Panicum maximum,* with opportunistic weed species *Wedelia trilobata, Macropterilium atropurpureum, Sida rhombifolia* and *Lantana camara* along mangrove edges.

Section 4 Mangroves here are a depauperate community although a variety of tree species remain, including *Xylocarpus* sp., *Rhizophora stylosa*, *Excoecaria agallocha*, *Lumnitzera* sp. and *Avicennia marina.* On higher dunes tree species include *Hibiscus tiliaceus*, *Meleleuca leucadendra* and *Casuarina equisitifolia* with an understorey of the grass *Sporobolus virginicus* and the scrambler *Ipomoea pes-caprae*. The parasitic creeper *Cassytha filiformis* and the vine *Dioscorea transversa* were also recorded. This section is greatly disturbed as a result of marina developments and has been colonised by weed species including *Macropterilium atropurpureum, Lantana camara, Wedelia trilobata,* and the grass *Melinus repens.*

A total of 167 plant species were identified, including 40 introduced species. Of these, 21 were likely to have been garden escapes. This number does not include native plants that are not known from the area and were probably planted by residents e.g. black bean *Castanospermum australe* and macadamia *Macadamia integrifolia*. The survey identified 74 species not previously recorded in vegetation communities of the Gustav Creek catchment by Sandercoe (1990). Combined species lists for the urban survey and the QNPWS (Sandercoe, 1990) data are presented in Appendix B1. A total of 359 plant species are listed for the Gustav Creek catchment.

### *8.1.7 Conservation status of vegetation communities*

*Croton magneticus* (Family Euphorbiaceae), listed as Vulnerable under the *Queensland Nature Conservation Act 1992* was recorded during the survey on land zoned 'Park Residential'. *Macadamia integrifolia* is also listed as Vulnerable; however, the specimen encountered was probably planted as no *Macadamia* species are recorded by the Queensland Herbarium as occurring in the district (Henderson, 1997). No other vulnerable species were recorded.

The presence of the palm *Livistona decipiens* was of interest. This palm is similar in appearance to the vulnerable species *L. drudei* and it is very difficult to distinguish between them from vegetative material. An unpublished survey of the Gustav Creek vine forest recorded no *L. drudei*, although *L. decipiens* was present (pers. comm. John Dowe). The species identification of the *Livistona* within the cabbage tree palm forest (vegetation type 21) has yet to be confirmed; further surveys of the *Livistona* communities on the foothills behind Nelly Bay would clarify their distributions.

The occurrence of vulnerable species on land zoned for future development within the Nelly Bay township is of concern. Urban expansion has occurred close to the stream and in some allotments Gustav Creek has been included within property boundaries. In the *Townsville City Council Region: Vegetation*

*Communities and Conservation Priorities* (Skull, 1996) Skull reiterated concerns expressed by Sandercoe (1990) (see section 8.1.3 above). He recommended that options for restricting further sub-division into sensitive habitats on Magnetic Island should be investigated. In the Gustav Creek catchment steep gradients on the foothills behind Nelly Bay preclude extensive development. However, vegetation surveys of land zoned for future development, particularly where the dominant vegetation is vine forest, are warranted. ***It is also suggested that riparian buffer zones of at least 20m width, as recommended by the Department of Natural Resources (1998) for the wet tropical coast, and as suggested in the Magnetic Island Management Plan (GHD, 1990), should be retained in any further sub-divisions.***

### *8.1.8 Introduced species*

A large number (49) of introduced species were present (many of which are considered weeds), both in Sandercoe's original survey (1990) and in this survey of Gustav Creek township riparian vegetation. A list of introduced specie is provided in Appendix B2. It is not surprising that more introduced species were recorded from within the township (40 = 24%) compared with those (19 = 7%) found in vegetation communities on undeveloped areas of the catchment. Half the number of introduced species in the urban setting was garden plants.

### *8.1.9 Declared plants*

The Rural Lands Protection Act (1985) lists declared plants under five different categories:

| | |
|---|---|
| P1 | Plants whose introduction to the State is prohibited |
| P2 | Plants that are to be destroyed |
| P3 | Plants whose numbers and/or distribution are to be reduced |
| P4 | Plants that are to be prevented from spreading |
| P5 | Plants that are to be controlled on land under Government authority. |

However, only one species of declared plant – Rubber vine *Cryptostegia grandiflora* – was recorded by Sandercoe (1990). This was listed under vegetation type 17. Rubber vine is classified as category P3. No rubber vine was found during the recent survey although Sandercoe (1990) noted a significant increase in rubber vine infestation in the years 1979-1985. Lantana *Lantana camara* was recorded in vegetation types 9, 14, 15 and 17, and in all sections during the recent vegetation survey although it was not abundant. While recognised as a weed species, lantana is not yet a declared plant. However, the Rural Lands Protection Act (1985) is currently under revision and under the new proposal, *Lantana camara* is listed as a declared plant. Sandercoe (1990) suggested that lantana is unlikely to become a problem because of poor soils and relatively low rainfall.

The almost ubiquitous presence of Singapore daisy *Wedelia trilobata* in all sections attests to the species' tolerance to a wide range of environmental variables. This 'vigorous and competitive weed' (Lazarides *et al*., 1997), once established, is difficult to eradicate. It is able to rapidly regenerate from broken rhizome fragments and often forms dense tangled mats. It is likely that further proliferation of this weed within the streambed will impede stream flow and cause debris to build up. It is interesting to note that QNPWS (Sandercoe, 1990) did not list the plant and its occurrence in Gustav Creek may thus be a recent invasion as a garden escape. Singapore daisy is not listed as a declared plant but may be considered under the revised schedule (pers. comm. Peter James, DNR). The Townsville City Council Pest Management Planning Group lists the plant as a pest. ***Control and eradication of this species is strongly recommended.***

Stinging trees are not commonly found in mangrove areas and their presence there suggests that seeds may have been transported to the area during floods. The native stinging tree *Dendrocnide moroides* is a common regrowth in recently cleared forest, and has been described by Williams (1979) as 'the most virulent stinging plant in the Australian bush'. It is highly recommended that stinging trees be removed from areas where the public is likely to encounter them. Extreme care is advised when cutting the plants. Nevertheless, the stinging tree is not a declared plant; the Rural Lands Protection Act (1985) lists only introduced species and the Department of Natural Resources has no policy on problem native plants (pers. comm. Peter James, DNR).

### *8.1.10 Weed control*

Clearing of native riparian vegetation was a common practice in the past along urban watercourses, and the lack of riparian vegetation in some areas can result in increased erosion and sediment load, and weed invasion.

Anecdotal evidence suggests that Gustav Creek was heavily scoured during the floods of January 1998 and vegetation in the streambed was washed downstream. Weedy grasses and herbs proliferate rapidly following floods, often blocking access to the creek and impeding passage along it. Heavy rains during successive wet seasons may wash away much of the regrowth vegetation, resulting in rotting plant material reaching the proposed marina.

Revegetation of degraded creek banks with native grasses may trap sediment and topsoil from adjacent land before it is washed into the creek, and significantly reduce bank erosion. The introduction of native shade trees and shrubs is also an effective measure to reduce weed growth. However, some form of weed and erosion control may be required whilst trees and shrubs become established. An opportunity exists for a revegetation program to be established that could involve students from the nearby Magnetic Island Primary School. The Principal has indicated her support for such a program provided weed species and problem plants such as stinging trees are first removed (pers.comm. R.Browne,Principal).

State legislation provides protection for all vegetation and other resources along a watercourse (defined as including the bed and banks and any other element of a river, creek or stream that confines or contains water). Under the Queensland Water Resources Act 1989 and the Water Resources Amendment Act 1993, approval is required for any works to be undertaken adjacent to or in a watercourse; a person must not destroy vegetation in a watercourse, excavate or place fill within the watercourse without a permit. This requirement does not apply to the destruction of vegetation that is necessary to prevent property damage – for example, the removal of weed species to prevent flooding. Under the Water Resources Amendment Act 1993 'fill' is defined as any material in solid form capable of being deposited in a place and could be interpreted as plant material.

### *8.1.11 Mangroves*

All mangrove communities in Queensland are protected under the Fisheries Act 1994. Mangrove species are resistant to or tolerant of saline conditions and their upstream presence (Section 3) may indicate the point reached by the highest tides or the extent of salt intrusion. However, the construction of the Sooning Street culvert would have affected the inland extension of high tides. The reed *Phragmites karka* is known to tolerate brackish water but prefers fresh water (Aston, 1973); the presence of the reed bed suggests that sea water rarely reaches beyond the culvert. Mangroves in this inland area may thus represent the remnants of a past vegetation community, although mangrove distribution in eastern Australia indicates that some mangrove trees are surrounded by seawater only once or twice a year (Macnae, 1966). Marina construction may further reduce upstream tidal incursion and the future health of mangrove species in this area may be compromised. Propagules may not be carried into or out of the area and recruitment may be reduced.

Mangrove vegetation shows distinct zonation (Macnae, 1967). *Lumnitzera racemosa* is relatively tolerant of high salinity (Clough, 1992) and is typical of the landward mangrove zone in the region (Macnae, 1967). Other species – *Xylocarpus* sp., *Excoecaria agallocha* and the mangrove fern *Acrostichum speciosum* – are also typical of plants that occur on the landward edge of mangroves. Studies on litter fall in mangroves in the region (Duke *et al*., 1981; Williams *et al*., 1981), and elsewhere (Mall *et al*., 1991; Bunt, 1995) have not included *Lumnitzera racemosa*, the most abundant species in this particular community. It is therefore difficult to assess the amount of litter that could be expected to contribute to debris washing into the proposed sedimentation basin.

As part of the land-based infrastructure associated with the harbour development permission has been sought to clear an area of these mangroves (pers.comm. A. Hesse). ***The value of this mangrove community should be recognised, and weed growth should be controlled.***

### *8.1.12 Remedial work and future management*

To maintain the integrity of Gustav Creek, a management plan to follow current best practice should be developed, taking into consideration weed control, flood and erosion mitigation, biodiversity, and water quality. A major contribution to this could be a community landcare program to address the issue of sustaining vegetation communities, hydrological, and ecological functioning of Gustav Creek. Community groups may apply for funding from the National Heritage Trust (NHT) to assist in creek rehabilitation (pers. comm. Michele Wallace, Regional NHT Coordinator). Local government also often supports this type of initiative.

## 8.2 The fauna of the Gustav Creek catchment.

### *8.2.1 Birds*

A list of birds recorded for the island has been produced by the Queensland National Parks and Wildlife Service (QNPWS undated) and similar lists have been compiled by members of the Zoology and Tropical Ecology Department of James Cook University for student use. In the Magnetic Keys Impact Assessment Study (1986) Professor Rhonnda Jones of JCU described the bird species of the island arranged by habitat preference, based on various sources. Habitats included woodland, thickets and rainforest, mangroves, and 'ubiquitous', and were not restricted to the Gustav Creek catchment; however, rainforest (vine forest – vegetation type 14) is confined mainly to the Gustav Creek basin and foothills behind Nelly Bay township (Sandercoe 1990). The 1986 study also included a record of birds of Bright Point. Eighteen species were listed as occurring specifically in thickets and rainforest, 9 in mangroves, and 115 in woodlands.

Wieneke (1988) published observations on Magnetic Island birds. She recorded 188 species over the island, with notes and distributions. References to birds of the Nelly Bay area included the Bush-hen *Gallinula olivacea*, which had not been seen since 1982 when areas where it was recorded had subsequently been cleared for subdivision.

The appended list of bird species (Appendix C) has been assembled following discussions with Professor Richard Pearson, Zoology and Tropical Ecology, JCU. It is representative of those species that could be expected to inhabit vine forest and woodland vegetation communities. Specific references to Nelly Bay, Gustav Creek and closed forest recorded by Wieneke (1988) are also listed. Of the one hundred and nine bird species recorded, 64 are associated with the vine forest community, and 32 with other terrestrial habitats. Wieneke (1988) noted an additional 13 species. Birds are not exclusive to any particular vegetation type and may be recorded from other communities.

The birds of Magnetic Island reflect the island's diverse range of natural habitats. Wieneke (1988) commented that the numbers of species were declining, and that the Magnetic Island National Park 'does not include all the habitat types necessary to ensure a secure future for all of the island's resident and migratory bird species'. Andrews (1998) also observed that the rapid rate of residential development has reduced the native habitat of the Bush stone-curlew *Burhinus grallarius*. Once common on Magnetic Island, the birds are also at risk from predation by cats and dogs. Stone-curlews require nesting sites with little ground cover (grasses less than 25cm tall) and fallen tree debris. Andrews (1998) found a reduction in the numbers of breeding birds, which may be attributed to the lack of suitable nesting habitat.

***Vegetation communities within the Gustav Creek catchment, particularly the vine forest and mangrove woodland areas, should be managed to retain suitable habitats for resident and nomadic birds, and continue to attract migratory species.*** The maintenance of riparian vegetation is particularly important for maintaining connectivity between habitats. Riparian plants provide food for native birds – nectar, fruits, and insects – and creek-side vegetation communities are often an important refuge for birds that use surrounding areas for feeding. The integrity of riparian zones is vital to particular groups of animals.

### *8.2.2 Mammals*

No fauna survey was carried out during this study. The Queensland National Parks and Wildlife Service compiled a species list (QNPWS undated) of mammals of Magnetic Island (Appendix D). There are no published records of mammals specific to the Gustav Creek catchment but the diversity of habitats outside the urban zone suggests that most of the mammal species listed for the Island as a whole may be found in the area. The koala *Phascolarctos cinereus* was probably introduced to the Island and has a scattered distribution in lowland eucalypt woodland around the bays. The Brush-tailed possum *Trichosurus vulpecula* is very common, particularly around human habitation. The allied rock-wallaby, *Petrogale assimilas*, and the unadorned rock-wallaby, *Petrogale penicillata assimilis* are also widespread. Several species of bats frequent the island, and the black flying fox *Pteropus alecto,* and the little red flying fox *Pteropus scalpulatus* have been recorded. Feral pigs and feral goats were once widespread on the Island but were controlled by an effective eradication program. There have been no reports of goats for many years but there has been a recent unsubstantiated sighting of a feral pig in Nelly Bay (pers. comm. Shane Hunter, Ranger-in-Charge, Magnetic Island QPWS).

### *8.2.3 Reptiles*

A list of reptiles of Magnetic Island has also been compiled by QNPWS (undated) and is appended (Appendix E). Reptiles and frogs in Gustav creek were also surveyed by students from James Cook University during field trips in June-July and September. Seventeen species of lizard were recorded, including *Lampropholis mirabilis*, listed under the Queensland Nature Conservation Act. The Gustav Creek catchment is a particularly good habitat for lizards (pers.comm. Dr. R. Alford, JCU).

### *8.2.4 Invertebrates*

Pools and riffles associated with higher elevations in the Gustav Creek catchment would provide habitat for a diversity of macroinvertebrates including worms, leeches, molluscs, crustacea, aquatic beetles and mites, and the aquatic larvae and nymphs of terrestrial insects. A reduced diversity of aquatic invertebrates could also be expected to inhabit waters and sediments of the degraded section of Gustav Creek within the Nelly Bay township.

The many vegetation communities of Gustav Creek catchment also offer diverse habitat for terrestrial insects. Butterflies – in particular, the common crow *Euploea core,* and *Tirumala hamatas* – have been observed overwintering in the vine forest (M. Overton, pers comm. 1999). The common butterflies of the area are listed in Appendix F.

# 9 GEOLOGY, SEDIMENTS AND SOILS

## 9.1 Geology

### *9.1.1 General description of Magnetic Island*

Maitland (1892), Stephenson (1962), and Wyatt et al (1970) described the geology of Magnetic Island. Most the island is underlain by granite comprising medium to coarse-grained adamellite containing a few phenocrysts of feldspar, with small amounts of biotite, iron oxides and zircon – termed Magnetic Island Granite. The island has a distinctive granitic tor landscape with tower-like rock formations rooted in bedrock standing conspicuously above their surroundings. The chemical weathering of granitic rocks along joints and fractures forms Tors, resulting in the isolation of corestones of coherent rock within a finer matrix of composed granite or saprolite. Further removal of finer material by weathering processes results in the exposure of the corestones, producing the typical tor landscape. Weathering has progressed to a depth of 20m in places.

### *9.1.2 Gustav Creek catchment geology*

Gustav Creek is the main watercourse flowing into Nelly Bay, with two smaller (unnamed) intermittent watercourses to the east and west. The valley of Gustav Creek forms a relatively flat area behind the bay, between the headlands of Bright Point to the east, and Hawkins Point to the west. (See Map G).

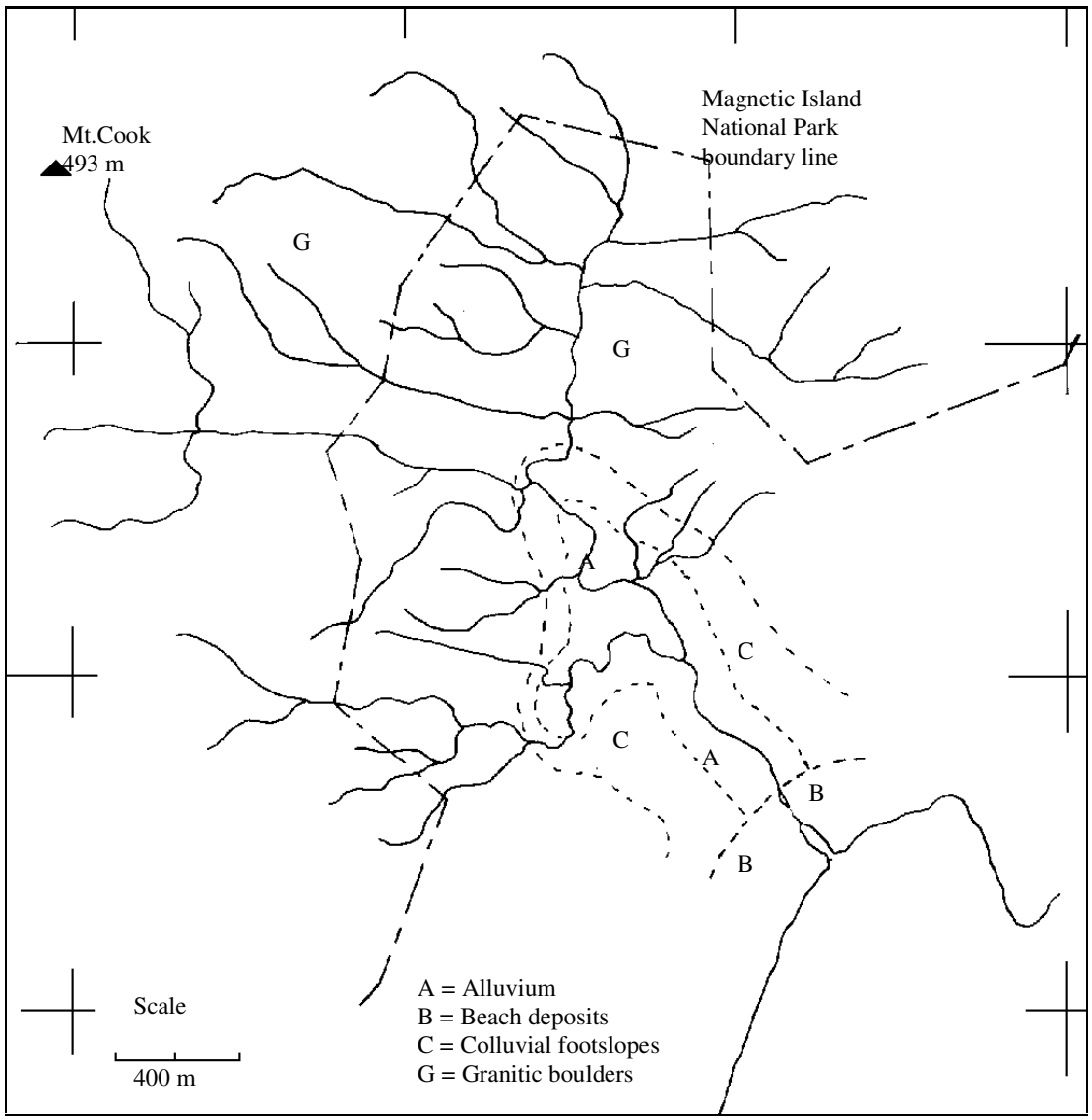
The Gustav Creek catchment is characterised by four main geological units. Boulders and underlying granitic rock are of Magnetic Island Granite, and grade to coarse, unconsolidated material or colluvium on foothill slopes. These sediments are reported to have been laid down by fluvial activity as fan or wash deposits during the Pleistocene (Wyatt, 1968); however, this process continues as further landslides result in the deposition of weathered material on the lower footslopes behind Nelly Bay. The colluvium has built up over time and reaches depths of several metres, grading down into the underlying saprolite. The lower Gustav Creek channel cuts into this material. Coastal features of the island are typical of a 'drowned' landscape. Alluvial plains have built up inland from the present shoreline as a result of the elevated stream base level following the post-glacial marine transgression approximately 6000 years ago. The alluvium deposits extend almost 200m in width along the creek, and approximately 1500 m inland, and underlay dune and beach deposits at the seaward edge for approximately 225 m from the present shoreline.

### *9.1.3 Drainage pattern*

Moisture collecting in fractures in granite accelerates weathering, causing faults and joints to erode faster than surrounding bedrock. Gullies and valleys so formed in the Magnetic Island Granite of the Gustav Creek catchment have resulted in a drainage network with a distinctive trellis formation, reflecting the strong structural control of the associated lithology. The catchment drainage pattern is illustrated in Figure 9.1.

Water is channelled into two main tributaries, which intersect at the base of the foothills behind Nelly Bay. The northeast branch was identified as Gustav Creek on the map drawn by Maitland (1892); the steeper northwestern branches drain the Narrung Plateau around Mt. Cook. Gustav Creek is said to be the only permanent/semi-permanent watercourse on Magnetic Island.

**Figure 9.1:** Drainage lines and geological units associated with the Gustav Creek catchment, Magnetic Island.




### *9.1.4 Catchment characteristics*

The influence of Gustav Creek on Nelly Bay was assessed in a survey of runoff and sedimentation (WBM Oceanics 1995). Catchment characteristics were described in detail with accompanying maps. Detailed descriptions of the Gustav Creek catchment, characteristics of the drainage system, and estimations of sedimentation and runoff yields were included. Catchment details are summarised in Table 9.1.

**Table 9.1:** Catchment details for Gustav Creek (WBM195):

| Description | Details |
|---|---|
| Catchment area | 516ha |
| Maximum elevation | 493m (Mt. Cook) |
| Slope | 15-20degrees over 80% basin |
| Drainage network | 30,127m |
| Main stream length | 3550m |
| Av. Density | 58.4m/ha (up to 88m/ha on footslopes) |
| Gradient – upper channel | 0:230m/m |
| Gradient – lower channel | 0:006m/m |
| Sediment yield to river mouth | 326 to 829 $m^3$/yr |

## 9.2 Sediments

Groundwater investigations of alluvial deposits (Wyatt, 1959) revealed granitic sand and fine gravel, with angular quartz and feldspar fragments in a loose clayey matrix. Mica and ferric material is also present in small amounts. Closer to the foothills the gravel component is coarser (Stephenson, 1962). Deposits of alluvium are thick and depths of 16m have been recorded from well records without striking the granite base. In some places along the stream channel the alluvium has been cemented by iron oxides into hard arenaceous rock. Heideker (1979) also described 'native cement' that formed an impermeable creek bed at a level of 3.5m A.H.D. below which occurs a manganiferous 'ironstone' pan. Test drilling for well construction indicated that soil profiles in Gustav Creek region are extremely variable (GHD, 1981). Investigations by Heideker (1979) in an area at the intersection of two major tributaries draining highlands on both sides of the Gustav Creek valley identified layers of sediments built up over geological time. Table 9.2 lists the sediments of this region of Nelly Bay (Heideker, 1979).

There is some dispute as to the nature of the 'native cement' described by Heideker (1979) as Hopley in McIntyre & Assoc. (1986) referred to it as 'siliceous material…that may be the equivalent of the Pleistocene 'creek rock' which underlies Holocene alluvial deposits and parts of the Townsville coastal plain'.

**Table 9.2:** Nelly Bay sediments:

| Geological period | Description | Details |
|---|---|---|
| Recent | Products of present geomorphological regime | ◦ Boulder, colluvium<br>◦ Unconsolidated silty sand<br>◦ Unconsolidated coarse sand, felspathic. |
| Mid-Holocene | Early infillings of a dissected surface | ◦ Mottled clayey sand<br>◦ Blue clay and mottled blue-brown clay<br>◦ Sand with feldspar weathered to white grains |
| Pleistocene (?) | Sediments with differentiated soil profiles, subsequently dissected | ◦ Buff red semi-consolidated sand with scattered boulders occurring as older dissected terraces and fans<br>◦ Mottled clayey sand<br>◦ Blue clay mottled blue-brown clay which dries out as clay-pan, referred to as 'native cement'<br>◦ Manganiferous 'ironstone' (limonite) occurring as a concretionary pan |
| Palaeozoic | | ◦ Granite |

### *9.2.1 Slope stability*

Mass movement of material on the steeper slopes of the Gustav Creek catchment is limited to soil creep and occasional rock and debris falls. However, during high intensity rainfall the shallow soils saturate rapidly resulting in large-scale landslides that contribute to sediment load in the creek. The Environmental Assessment Report (EA/QEPA, 1999) accepted the estimated sediment loads from Gustav creek as between 500 and 1000 $m^3$/yr with 50% of this actually reaching the sedimentation basin; however, it was recognised that no reliable methods exist for accurately predicting sediment yields from small catchments in tropical Australia. It was suggested in the Draft Environmental Impact Statement (SKM, 1995b) the medium to fine sediment fraction easily mobilised during floods is likely to be deposited in pools and low level terraces upstream of the Sooning Street bridge, although much of the time infrequent high rainfall events preclude high sediment outputs. The Draft Environmental Impact Statement (SKM, 1995) reported little evidence of flood debris and sediment deposition within the lower reaches of the creek, whereas sediment banks deposited during the major floods of 1998 are currently a conspicuous feature of the channel. These sandbanks have been densely colonised by herbs, grasses and sedges, further stabilising the sediments during periods of low flow and limiting sediment supply to the mouth of the creek. Build-up of sediments behind the bridge is relatively small during low rainfall periods. Fluctuations in weather patterns (El Nino/La Nina) may result in intermittent high rainfall in the northern Tropics with the potential for increased mobilisation of sediments. Currently, a Landslip Hazard Study is being undertaken by the TCC which aims at protecting residential properties from the impacts of mass movement of soil and rock.

Hopley in McIntyre & Assoc. (1986b) reported that aerial photographs from 1941 onwards showed that the course of Gustav Creek has changed several times over the years and that its exact location was determined by a sand spit built from sediments transported down the creek during wet seasons. In 1941 and 1961, photographs showed the mouth of the creek completely closed off by the spit. The 1974 photograph, taken after a series of cyclones in preceding years (Cyclones Althea in 1971, Bronwyn in 1972, and Una in 1973) shows the spit disrupted and the creek flowing through the gap. The 1982 photograph shows the spit re-established and, in 1983, enclosing a small lagoon. The climate during subsequent years was strongly influenced by the El Nino effect and lower rainfalls were recorded (see Climate Section 3). Aerial photographs from 1999 show the landslides and erosion in Gustav Creek following severe storms in 1998. The harbour development has reduced build up of sand spits in the mouth of the creek (Figures 9.2 & 9.3).

### *9.2.2 Stream banks*

In some areas where Gustav Creek flows through private land property owners have constructed erosion control devices to protect stream banks. The design of these structures may vary between properties and it may be that flood mitigation at one site may exacerbate erosion further downstream. In the tributary near the Sewage Treatment Plant severe erosion following the January 1998 high rainfall washed away metres of soil and undermined the main residential sewage pipe, necessitating remedial bank stabilisation works by the Townsville City Council. Changes to the stream course are clearly visible on the aerial photograph taken in 1999 compared with that taken in 1995 (see Figures 9.2 & 9.3). On alluvial floodplains erosion must be considered as a natural process. Where watercourses pass through urban areas problems with bank erosion may be exacerbated. ***It is recommended that a coordinated approach to bank stabilisation be adopted, and geomorphologist with local knowledge be consulted to assess bank stability.***


**Figure 9.2:** Aerial photograph of Nelly Bay township and Gustav Creek 1995.

(White rectangle shows area subject to major erosion in 1998 – see Figure B)


**Figure 9.3:** Aerial photograph of Nelly Bay township and Gustav Creek 1999.
(White rectangle shows major erosion)

## 9.3 Acid sulphate soils

Soils under tidal swamps and coastal plains invariably generate sulphuric acid when exposed to air and oxidised. These acid sulphate soils may generate large volumes of acid, which lowers the pH of the water, releasing aluminium ions, which are toxic to vegetation and aquatic organisms. The acid may also corrode metal and concrete. Any disturbance e.g. dredging, vegetation clearing, or earth removal that results in the exposure of acid sulphate soils may thus have serious consequences.

The issue of acid sulphate soils (potential and actual) at the Nelly Bay harbour development site was investigated by The Land Resource and Assessment Pty. Ltd. for the Draft EIS (SKM, 1995a). Two sites were sampled: one under a closed mangrove community beside the creek channel and inundated by most high tides, and the other 50m inland from the creek under open mangroves where tidal inundation occurs only during extreme high tides. The study found that disturbance of soils at both sites had the potential to generate acid, and acid production would increase with depth. Soil under the inland site had the capability to produce more acid than the creek-side site. The EAR (EA/QEPA, 1999) recommended (recommendation 15) that an acid sulphate management plan for the proposed harbour site be prepared prior to excavation of identified potential acid sulphate soil (PASS) areas.

There are no records of acid sulphate soil tests on Gustav Creek stream sediments or riparian land upstream from the Sooning Street bridge. The presence of an established mangrove community and an adjacent area described as a melaleuca swamp prior to redevelopment (see Vegetation Section 8) suggests that acid sulphate soils may be present. Engineering works associated with the harbour redevelopment may impinge on this area and it is therefore strongly recommended that tests be conducted to determine the extent of acid sulphate soil development before any works are commenced.

## 9.4 Issues associated with the proposed sedimentation basin

It was reported in the SEIS (1998) that the design of the sedimentation basin associated with the proposed Nelly Bay Harbour development was influenced by:

- the need to minimise impacts on the environmentally sensitive mangrove forest upstream and downstream of Sooning Street;
- the influence of tidal flushing and sea water levels;
- impacts on flood levels upstream of the sedimentation weir on low level residences; and
- minimisation of scour in the vicinity of the basin weir.

There has been no discussion in previous publications and reports associated with the proposed Nelly Bay harbour development about changes to the present structure of the Sooning Street bridge and culvert immediately upstream from the proposed sedimentation basin; however, it cannot be assumed that the existing structure will be retained. No engineering information is available on headworks associated with the harbour development proposal, outside of the actual site boundary.

In addition, little consideration has been given to the continued maintenance of the Gustav Creek channel upstream from the Sooning Street bridge. As part of the TCC Drainage Waterway Management Plan, waterways in the Townsville region, including Gustav Creek, are cleared of vegetation and sediments to maintain drainage prior to the onset of the wet season. However, work has not been carried out in Gustav Creek since 1998, awaiting decisions on the Nelly Bay Harbour development proposal (pers. comm. A. Hesse). The stand of reeds *Phragmites karka* growing immediately upstream from the Sooning Street bridge has been cut back annually (prior to 1998). Reeds regenerate from rhizomes that are generally left undisturbed by the process. The continuing growth of the reed bed helps to stabilise the sediments and encourages build-up behind the bridge. An increase in sediments may result in greater flooding of school grounds and nearby properties, and damage to the inland mangrove community.

During the last major flood (1998) water flowed over Sooning Street and poured into the proposed site of the sedimentation basin associated with the harbour development. Sediments already in the sedimentation basin may be mobilised and be carried into the harbour by the in-pouring of water under these conditions.

It is not clear whether sediments will be allowed to continually build up in this site as well as in the proposed sedimentation basin, or whether the existing culvert will be replaced by a structure more suited to new conditions associated with the marina. The installation of water pipes, power lines, sewerage and other services will require changes to land adjacent to, and inland from the Nelly Bay Harbour development site. It is essential that engineering works associated with the development be assessed as to their likely impacts and that the environmental management plan protect the environmentally sensitive mangrove area inland from Sooning Street.

# 10. HYDROLOGY

## 10.1 Groundwater

### *10.1.1 Past Investigations*

Previous groundwater investigations (Wyatt, 1959; Stephenson, 1962; Heidecker, 1979 and 1981) conducted on Magnetic Island, although primarily aimed at identifying a supplementary water supply for the island, nonetheless provide limited data on groundwater in the Gustav Creek catchment.

### *10.1.2 Alluvial Groundwater*

The coastal alluvium comprises coarse sand and granitic debris with a clay matrix extending to an estimated average depth of 15 m, although it may extend as deep as 30 m in places (Stephenson, 1962). Upstream of Barton Street bridge, the alluvium comprises buff-reddish semi-consolidated permeable sand ranging from 2 to 8 m in depth. The permeable sand is mostly underlain by clay (blue clay, mottled blue-brown clay, and grey clay) and hard pans (calcareous cementations, and concretionary manganiferous limonite) (Heidecker, 1979). There is a limited amount of groundwater held in the alluvial aquifer. Groundwater levels are highly seasonal – for example, a 48ft (16m) well at 'Mandalay' guesthouse was reported to have a June water level of 10ft (3.3m) below the well collar, dropping to 36ft (12m) during dry weather (Wyatt 1959).

Several studies (Wyatt, 1959; Stephenson, 1962; Heideker, 1979) proposed that groundwater stored in fractured rock in Nelly Bay could be a viable alternative water supply. However, further investigation determined that groundwater supplies were insufficient to warrant harvesting (GHD1981). Fractures in underlying rock were likely to be infilled with clay as a result of weathering processes.

## 10.2 Discharge

Infiltration rates on exposed slopes in the catchment are low due to large areas of exposed bedrock, steep gradients and shallow soils. Runoff is high; thus discharge from Gustav Creek is highly variable, with limited flow during drier seasons. Indeed, many watercourses within the catchment remain dry for extended periods.

Discharge from Gustav Creek has not been monitored. Peak discharges during storm events have been estimated to be 31 $m^3$/sec for 24 hour rainfall of 140mm, and 140 $m^3$/sec for 24 hour rainfall of 470mm (the 1:50 year flood discharge) (WBM Oceanics 1995).

Few flow measurements are available for Gustav Creek. Heideker (1979) recorded 2.5 litres per sec or 200kl/day flow at a site 50m above Barton Street bridge, 1.5 l/sec (100kl/day) flow along Gustav Creek at the top end of Mandalay Avenue, and 0.5L/sec (30kl/day) at the lower end of the main north western branch of Gustav Creek. Flows are frequently reduced to a trickle although Heideker (1979) reported that flows of 200kl/day were maintained along Gustav Creek at the end of August 1979, after a prolonged dry period.

The highly seasonal and variable climate of the region (see Climate Section 3) often results in unpredictable flows. Major flooding of the lower reaches of the creek occurred in 1991, during Cyclone Justin in 1997, and in 1998. During the 1998 floods, water dammed up against the main culvert under the Sooning Street bridge and inundated the medical centre and playing fields of the adjacent primary school. Debris remains deposited 1.7m above ground level in mangroves inland from the Sooning Street bridge. The force of the water during these often-unforeseen events could result in significant damage to pontoons and small craft in the proposed harbour (as happened in the Ross River in 1998).

The high rainfall event that occurred on January 10th 1998 associated with Cyclone Sid resulted in the inundation and severe erosion of a creek bed that had been dry for a number of years. This apparently redundant drainage line had been marked as major watercourse on an older map (Maitland 1892). The significance of intermittent streams was highlighted in a report on the wetlands of the Townsville area

(Lukacs, 1996). The authors were concerned that although drainage lines and seasonal streams such as Gustav Creek may be significant conduits for stormwater, they are often disregarded by development proposals. ***It is strongly recommended that all smaller tributaries linked to Gustav Creek should be maintained as watercourses, in the event of future large wet seasons. Wide riparian buffer zones of at least 20m either side of the stream (Department of Natural Resources 1998) would allow for natural stream migration. Within the urban area, bank protection and stabilisation strategies – for example, the establishment of rock revetments or retaining walls, soil stabilisation, or stream bank revegetation (Kapitzke et al., 1998) – should be employed to protect the surface of stream banks from fluvial erosion, and to protect properties from flooding.***

# 11 WATER QUALITY ISSUES

## 11.1 Wastewater management

### *11.1.1 Existing situation*

The majority of older buildings in Nelly Bay have septic systems (including the primary school), although the more recently developed residential sites and some tourist/commercial areas have wastewater reticulation. The residential areas which are fully reticulated include all houses on Elena Street, the top end of Mandalay Street, a portion of Barton Street, and residents on Compass Crescent and Sextant Drive. Part of Sooning Street is also connected to the waste system. Some of the tourist facilities reticulated include the resort on Yates Street and one of the resorts on the corner of Sooning and Kelly Streets. The large resort on Mandalay Avenue (Magnetic International Resort) is not connected to the wastewater system.

### *11.1.2 Septic systems*

Septic systems have been used for wastewater treatment on Magnetic Island for many years. They receive and treat domestic sewage and produce effluent with a reduced level of suspended solids, which is then conveyed to subsurface soil absorption systems or trenches. Grey water (from washing machines, showers etc.) generally goes directly to the trench system, while toilet and kitchen wastes are carried to the septic tanks. The satisfactory operation of septic systems requires:

- sufficient space on each block for appropriately sized systems,
- good soil drainage
- minimal possibility of overflow
- low water table

The installation of septic systems is controlled by the Queensland Government Interim Code of Practice for On-site Sewerage Facilities (ICPOSF) (DNR, 1999). While on-site sewerage facilities are recognised as being under the control of the property owner, their 'long-term effective operation… requires the oversight of local government to ensure that effluent quality, operation and maintenance objectives are met and cumulative impacts do not compromise environmental values' (DNR, 1999).

### *11.1.3 Allotment size and site*

Under the ICPOSF (DNR, 1999), a minimum allotment size on an unsewered subdivision should be determined by a site evaluation and assessment of various parameters including soil type, surface water drainage channels, proximity of land to surface waters, groundwater, and land use (DNR, 1999 Section 3.3.3). The ICPOSF requires, as an example, an allotment size of 2000 $m^2$ to accommodate an on-site sewerage facility for a dwelling of 5 or less bedrooms under ideal site conditions with no area located below the 1:50 year probability flood level.

The effective functioning of on-site sewerage facilities such as septic systems is dependent on associated land application facilities. For septic systems in Nelly Bay these are generally absorption trenches. The ICPOSF prescribes vertical separation distances between land application facilities and the seasonal high water table (Section 5.7.2.) For example, the minimum unsaturated soil depth to a permanent water table is recommended to be 0.6 m for secondary effluent. Surface horizontal distances are also stipulated; for example, a separation distance of 30 m is recommended between a land application facility and the bank of a permanent or intermittent watercourse or drainage channel.

Existing allotments must comply with the provisions of the Environmental Protection Act 1994, Environmental Protection (Water) Policy 1997, and the Integrated Planning Act 1997. Effluent from on-site sewerage facilities should have no unsustainable impacts on land, groundwater and surface water (DNR, 1999).

### *11.1.4 Sewage treatment plant operation*

Figures from 1996 (TCC, 1996) indicated that the total population connected to the sewage main in Nelly Bay was 300 Equivalent Persons (EP), consisting of 180 allotments with sewerage, of which 86 were vacant. The sewage treatment plant also accepts effluent from commercial grease traps and septic tanks all over the island. In 1991, the TCC advised residents that the existing sewage treatment facility was intended as an "interim" plant only.

The description of the existing Nelly Bay Sewage Treatment Plant is reprinted here from the TCC Wastewater Strategy Volume 1 (Jackson, 1996), page 3-1:

> "The treatment plant facilities consist of an older and currently decommissioned package activated sludge plant (nominal capacity of 500EP) and a proprietary 1000 EP treatment plant, currently in use. The 1000 EP plant was constructed in 1991 and uses 3 circular concrete tanks with an intermittent aeration system in the second tank. All effluent is disinfected with U.V. light prior to storage on site in a lagoon. Under normal circumstances, 100% of the disinfected secondary treated wastewater is used for irrigation of the buffer strip surrounding the plant." *[Effluent also passes through a sand filter prior to UV treatment (pers. comm. K. MacIntyre)].*

The plant is surrounded on three sides by residential land. Separation distances to adjoining land vary from 70 metres to about 150 metres, including a drainage line that connects with Gustav Creek. These distances compare with typical guidelines for separation distances of 300 metres for a 1000 EP plant (Guidelines for Planning and Design of Sewerage Schemes, 1991).

Future plans

The Townsville City Council, under the Environmental Protection Act 1994, has statutory obligations to minimise environmental impact within its boundaries. The Council recognised the need for effective wastewater management on Magnetic Island, and planning options were reviewed with extensive public consultation and published in 1996 (Jackson, 1996). Further development has been constrained to a significant degree by TCC budget limitations.

The Council's management strategy is to divide the island into two zones – the northern zone to include Horseshoe Bay and Radical Bay, and the southern zone to include Nelly Bay, Picnic Bay and Arcadia. Recommendations for initial works in the southern zone included:

- Ultimately decommission the Nelly Bay Sewage Treatment Plant.
- Investigate seepage from the sludge lagoon
- Develop a 1000EP Plant for Picnic Bay with allowance for expansion
- Picnic Bay to serve all southern bays
- Interbay collection system

The TCC review (Jackson, 1996) also found that the existing Nelly Bay plant is undesirably close to existing residential land for adequate buffers. It was also recommended that the plant should be continued to be used to its capacity until other infrastructure (Picnic Bay) is developed but management issues at the plant should not be neglected.

### *11.1.5 Issues associated with the proposed Nelly Bay harbour development*

A fully reticulated sewerage system is proposed for the Nelly Bay project. The proposal includes a pump station to be located to the east of Gustav Creek. It was originally planned to pump sewage to the TCC's existing treatment plant in Kelly Street (SKM, 1995a). When the sewerage system was designed for the Nelly Bay harbour it was considered that the Nelly Bay STP had sufficient excess capacity to accommodate the proposed development's requirements.

The 1998 SEIS (SKM, 1998) indicated that effluent was still to be transferred to the current treatment plant; however, the study mentioned that TCC had plans to connect more residences to the mains sewerage system, but this was largely dependent upon upgrading the Nelly Bay treatment plant. This was dependent on partial funding by the developer if the project proceeded.

In a submission to the 1998 SEIS, Manager of TCC Town Planning services, Peter Gopal, stated that 'the Nelly Bay Sewage Treatment Plant is already overloaded during peak tourist times. Council's adopted strategy is not to increase the size of this plant, but to provide any additional treatment capacity at a new southern regional plant situated in Picnic Bay' (SKM 1999) (see Future Plans section 11.1.4 above). Thus, it appears that under the current TCC wastewater strategy, the existing Nelly Bay STP cannot process sewage from the proposed harbour development.

#### *11.1.6 Construction site effluent*

A pump-out system with effluent transferred to the Nelly Bay plant has been accepted as the preferred option for wastewater disposal at the construction site. The number of workers on site at any one time has been estimated at 45-50 (compared with the original estimate of 300 in the 1988 Magnetic Keys Public Environmental Report). Effluent disposal at the treatment plant should pose no problems (pers. comm. H. Fracchia).

### 11.2 Guidelines

The Australian and New Zealand Environment and Conservation Council (ANZECC) established guidelines for the water quality of fresh and marine waters in 1992 (ANZECC 1992). New guidelines are planned to be published this year; however, the Draft 1999 guidelines are now open for public consultation and have not yet been endorsed. It has been recognised that tropical aquatic environments have very different water quality issues compared with more temperate regions; thus, regional water quality guidelines need to be included in the national water quality management strategy. A meeting between water quality specialists from the Great Barrier Reef Marine Park Authority, the Australian Centre for Tropical Freshwater Research, the Australian Institute of Marine Science, the Queensland Environmental Protection Agency, together with State representatives, is planned in order to address these issues, and to draft water quality guidelines for tropical environments.

A fundamental step in the management of a watercourse and the definition of its environmental values requires the identification of community needs (ANZECC, 1992). Water quality required to achieve these aims may then be determined and compared with existing water quality. The ANZECC (1992) guidelines consider 5 environmental values: ecosystem protection, recreation and aesthetics, raw water for drinking, agricultural water, and industrial water.

The ANZECC (1992) water quality guidelines for recreational use cover primary and secondary contact. Primary contact includes swimming and bodily emersion where there is a high probability of drinking the water. It is assumed that children will drink water in small quantities. Median faecal coliform levels should not exceed 150/100ml with 4 out of 5 samples containing <600. Secondary contact includes wading, and it is assumed that water will wet the skin but is unlikely to be swallowed. Median faecal coliform levels for secondary contact should not exceed 1000/100ml with 4 out of 5 samples containing <4000. The EPA requires that primary contact guidelines should be maintained for the protection of children in public recreational areas.

The ANZECC (1992) guidelines also specify the monitoring of other parameters such as pH, temperature, visual clarity, colour, toxic chemicals and surface films. A summary of water quality guidelines for recreational waters is included in Appendix G.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Draft 1999) does not retain guidelines for recreational use of water. The National Health and Medical Research Council (NHMRC), ANZECC and the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) have recognised the need for a single document and have adopted the Draft World Health Organisation Guidelines for Safe Recreation – Water Environments: Coastal and Fresh-water (yet

to be finalised). The Queensland Environmental Protection Policy (1995) cites the 1992 ANZECC guidelines as a reference for use in Queensland. There may therefore be a period of confusion when the ANZECC 2000 guidelines and WHO recreational water guidelines are published. Reference to both guidelines is recommended.

## 11.3 Water quality in Gustav Creek

### *11.3.1 History*

The Draft EIS states:

> "The results of the sample analysis and previous studies show that Gustav Creek suffers from a number of chronic water quality problems including: it is not suitable for swimming because in has a high faecal coliform count, …and it may potentially suffer periodically from the effects of excessive algal growth and/or severe oxygen depletion. High faecal coliform concentrations of this kind can be attributable to various possible sources:
>
> - contamination from warm-blooded animals;
> - urban stormwater;
> - leachate from the sewage treatment system, or;
> - leachate from the septic tanks/trenches."
>
> (SKM 1995)

There is a long history of problems associated with water quality in Gustav Creek. There has been community concern that the water may have consistently high nutrient levels and/or bacteriological contamination, and that poor water quality may have significant effects on the ecology of a stream. However, ecosystem protection is not a primary issue for a small ephemeral urban watercourse. In a degraded system there is unlikely to be a significant aquatic community; nevertheless, some aspects of the ecosystem need to be maintained in order to preserve aesthetic and recreational values. Appropriate guidelines are essential, and protection of the downstream ecosystem is also an important consideration.

### *11.3.2 Water samples from Gustav Creek*

The Citiwater (Townsville) laboratory has carried out analyses of water from Gustav Creek and data have been made available for this survey. Samples were collected between 17/02/98 and 15/12/99 whenever Gustav Creek was flowing, from sites near the Barton Street (site M6) and Elena Street (site M5) bridges, and from a site in the 'Island Hideaway' subdivision (site M4). The raw data and summary statistics are tabulated in Appendices H1 and H2. Five sites on Gustav Creek were also sampled by the ACTFR during the current investigation:

- Site 1 Gustav Creek, upstream from Barton Street bridge (TCC site M6) (Plate).
- Site 2 Gustav Creek, upstream from Elena Street bridge (TCC site M5) (Plate).
- Site 3: Pooled water in sand extraction pit, Gustav Creek tributary, downslope from Sewage Treatment Plant (Plate).
- Site 4: Northwest branch of Gustav Creek, within forested area (TCC's 'Island Hideaway' Site M4) (Plate).
- Site 5: Gustav Creek, upstream from Sooning Street bridge (Plate).

Sites 1, 2 and 4 coincided with sites previously sampled by the TCC. Samples collected on 7/12/99 were analysed for pH, conductivity, turbidity, true and apparent colour, suspended solids, nutrients, chloride, sulphate, faecal coliforms and *E. coli*. A second set of samples collected on 15/12/99 was analysed for faecal coliforms and *E. coli* only. Results are tabulated in Appendix I.

### *11.3.3 pH*

The TCC data indicates that pH was clearly acceptable with values falling well within the ranges specified in ANZECC (1992) guidelines for recreation (5-9) and ecosystem protection (6.5-9). The ACTFR sampling sites reported higher values but results still complied with the guideline criteria.

### *11.3.4 Conductivity*

The TCC data indicate that there was water present at each monitoring site from February 1998 until August 1999 and during this time conductivity (i.e. salinity) concentrations remained relatively constant and were quite moderate (median conductivities 154, 158 and 192 µs/cm at sites M4, M5 and M6 respectively). By September sites M4 and 5 had run dry and the conductivity at M6 had risen significantly to 1603 µs/cm. The creek flowed again early in December and the samples collected by the ACTFR on 8/12/99 show that conductivity levels fell back to more moderate levels (238 µs/cm to 426 µs/cm). Site M4 had run dry by the 15/12/99 and water levels were very low at most other monitoring sites. At this time the conductivity values at M5 and M6 rose remarkably to levels 3280 and 3430 µs/cm respectively.

Conductivity changes do not directly affect the environmental values that would normally be ascribed to an urban stream and are of no consequence to the marine waters downstream. Nonetheless high conductivities can indirectly affect aesthetic values – for example, by killing freshwater aquatic plants. ANZECC (1992) guidelines suggest that conductivity values above 1500 µs/cm have the potential to harm steno-haline organisms; however, the results of numerous investigations conducted by the ACTFR in local lowland streams and wetlands suggest that acceptable plant and animal diversity is usually maintained unless dry season conductivity levels exceed 6000 to 9000 µs/cm. Hence the levels observed in Gustav Creek are unlikely to seriously effect aesthetic values.

Rising conductivity levels are commonly observed in streams late in the dry season when water levels and flows become minimal. This is due to the combined effects of decreased inputs from low salinity alluvial groundwater reserves (and a greater proportion of baseflow being derived from deeper, more saline, fractured rock aquifers), and evapo-concentration processes (due to the high surface to volume ratio of shallow streams daily evaporative water losses can constitute a very significant proportion of the total volume present).

### *11.3.5 Nutrient levels*

Nutrient-enriched waters – high in phosphorus (P) and nitrogen (N) – promote the growth of algae and aquatic plants. Excessive growth can lead to severe degradation of aesthetic qualities and ecosystem values, etc. ANZECC (1992) Guidelines do not propose values for nitrogen and phosphorus concentrations because natural levels and ecosystem responses vary tremendously between waterbodies and regions. ANZECC include indicative concentration ranges but recommend that site specific or regional investigations be undertaken to determine the nutrient status of individual waterbodies. The indicative values are based largely on data from large rivers in temperate Australia. They have little relevance to the current situation and therefore are not reproduced here. Monitoring conducted by the ACTFR in small ephemeral rivers and streams in the wet/dry tropics of North Queensland indicate that at low baseflows pristine and moderately disturbed systems of this kind commonly exhibit phosphorus levels less than 10 µg/l, but nitrogen concentration varies with reach and/or location from 80-800 µg/l. These levels are reflected in the TCC sampling data, although there are occasional occurrences of elevated P or N concentrations.

### *11.3.6 Nitrogen: phosphorus (N:P) ratios*

The N:P ratio is often an indicator of the source of water in a stream. For example, surface runoff generally gives a lower N:P ratio than groundwater-driven baseflows. This can vary somewhat according to the groundwater parent lithology but groundwater inputs rarely carry significant levels of P. The sensitivity of phosphorus analysis conducted by TCC does not allow a determination of the N:P ratio of water in Gustav Creek, but there is clear indication that, at times, the mass ratio exceeds 88:1, confirming that it is a groundwater-driven system. This suggests the sites monitored by the TCC are generally influenced more by subsurface inputs, than by surface drainage of water from domestic

irrigation, car washing, grey water etc. However, there is evidence of occasional surface inputs; for instance TCC data from water collected on 29/7/98, show a high P concentration but no attendant rise in faecal coliforms and/or N, thus implicating surface drainage of detergents in wash water as a probable source of phosphorus on that occasion.

Groundwater nitrogen is generally discharged to the surface stream in the form of highly bioavailable nitrate. In biologically active surface waters this is rapidly denitrified and/or assimilated and recycled into organic forms. Hence in slowly flowing systems high nitrate to total nitrogen ratios are often encountered in close proximity to groundwater discharge points and ratios generally decrease with increasing distance from the source. There are insufficient nitrate data available to evaluate the distribution along Gustav Creek but it is worth noting that ACTFR site 3 is the only sampling location that exhibited a high ratio.

Values reported fall within the range of natural processes. Occasional extreme values are of concern; however, there is insufficient information from monitoring to determine their cause. In order to interpret water quality data, information is required on antecedent rainfall, flow rate, water depth, and the presence of contaminants (foaming, bad odours, discolouration, surface films etc.). ***It is recommended that the TCC revises water quality monitoring and reporting methodology and develops proformas to record such environmental information. Water quality expectations may thus be assigned for each sample, and the cause for anomalous values more readily determined.***

### *11.3.7 Iron and manganese concentrations*

Heideker (1979) observed that the manganese content of the water in Gustav creek was high. He determined that areas of stagnant oxygen-poor water in contact with the manganiferous 'ironstone' pan resulted in manganese being taken into solution with iron, to be again deposited as a brown scum if water became oxygenated. Manganese and iron are essential elements in animals and humans. The ANZECC (1992) water quality guidelines suggest that high manganese concentrations in drinking water are not hazardous to health although the National Health and Medical Research Council (NHMRC) now consider concentrations above 0.5mg/l to be toxic (NHMRC, 1996). Drinking water is not an issue in Gustav Creek; however, both iron and manganese cause flocs and stains which may adversely affect the aesthetics of a stream and create poor community impressions of water quality, prompting complaints from the public. The ecological consequences of iron and manganese flocculation may be significant. Floc creates substrate for bacteria and tends to protect them from natural UV disinfection (sunlight), increasing survival rates. Flocs are also highly sorptive and can bind phosphate (but not usually nitrogen), leading to high N/P ratios. High iron and manganese concentrations are associated with groundwater and there is the potential for using iron or manganese as tracers for groundwater aquifers for future investigations.

### *11.3.8 Bacteriological contamination*

Water samples from Gustav Creek taken in 1979 at a site corresponding to site 4 of the present study, were reported to be 'chemically of high quality but showed persistent evidence of faecal pollution' (Heideker, 1979). At the same time, samples from higher in the catchment were not polluted. A report in the Draft EIS (Butler, 1995) which has been quoted in several subsequent publications, indicates that the bacteriological status of the creek had not improved in the interim. The sampling carried out by TCC during 1998 and 1999 indicates that median concentrations of 133, 115 and 125 organisms/100ml were maintained at sites M4, 5 and 6 respectively. These values are significant but comply with the primary body contact guideline (150 ORES/100ml) stipulated by ANZECC (1992). In contrast, all of the samples collected by the ACTFR late in December reported values above the guideline median value, with results ranging from 4600/100ml at site 2 to 210 at site 5 (8/12/99) and from 1200/100ml at site 4 to 190/100ml at site 2 (16/12/99). In fact, 4 of the 5 results obtained on 8/12/99 exceeded the secondary body contact guideline. It is clear from these results that bacteriological contamination is still an issue of concern for Gustav Creek. However, the data provide no evidence of obvious distribution patterns or attenuation gradients that might serve to indicate potential input areas. To the contrary, significant concentrations appear periodically and all monitoring sites suggesting either widespread diffuse inputs or at least multiple sources.

## 11.4 Water quality issues associated with the sewage treatment system

The Townsville City Council conducted investigations over the period 1990-1995 but failed to determine any relationship between elevated faecal coliform counts in Gustav Creek and operations at the Sewage Treatment Plant. This was attributed to the transient nature of pools of water in the creek (TCC, 1996). Studies did not include groundwater samples. The potential for contamination of the creek by overflow from the wet weather storage basin at the Sewage Treatment Plant during prolonged rainfall has been recognised (TCC, 1996), although it is considered that this would be a rare occurrence (pers.comm. K. MacIntyre).

### *11.4.1 Leakage from sewer pipes*

Leakage from sewer pipes – for example, due to damage from plant roots or corrosion – could contaminate groundwater. No matter how good a system is, some leakage is expected (pers. comm. H. Fracchia). Infiltration from rain or illegal stormwater connections could potentially overload pump stations if systems are not maintained. ***Smoke tests using paraffin oil are used to identify cracks in pipes, and the TCC should consider such a test to identify sources of any possible contamination.*** The size of pump stations for any given amount of effluent is controlled by the EPA, and the Council is issued with appropriate licences.

### *11.4.2 Irrigation leachate and aerosols*

The capacity of the irrigation area around the Sewage Treatment Plant is 700-1000 EP. Eight individual irrigation stations operate for 10 minutes at a time, allowing sufficient drainage of water into the soil. Under prolonged rainfall and with saturated soils, overland flow could certainly carry treated effluent downslope towards the creek. However, irrigation is generally discontinued during rainfall, and the disinfected secondary treated water is then stored in a holding tank or may be recirculated around the system. At present, irrigation is operator-controlled, and irrigation is maintained 'on demand' 24 hours a day. With the commissioning of a new holding tank, irrigation will be fully automated and will operate each night between 8pm and 4am, and operations will shut down during storm events (pers. comm. M. Langford).

Bio-Track assessed the potential for land-based disposal of treated wastewater for the TCC (Biotrack 1996). They stated that provided irrigation water has a long residence time in the soil prior to entry to a creek there would be no expectation of a health hazard. Problems could arise in sandy soils and in areas with high water tables, or where seepage water runs downslope. Bio-Track (1996) recommended a buffer of 400m to prevent aerosol particles reaching urban areas, considerably wider than the existing buffer zone of 70-150 m at the Nelly Bay STP.

Effluent from the Nelly Bay STP is disinfected with ultra violet (UV) light and has a limited bacteria count. Bacterial contamination of creek water by treated effluent could occur if the UV disinfection was ineffective; thus, monitoring of irrigation water is paramount. The quality of effluent generated from secondary treatment at the Nelly Bay Sewage Treatment Plant between January 1992 and January 2000 is summarised below (Table 11.1).

**Table 11.1: Summary of performance for Nelly Bay STP Jan 1992 –Jan 2000**

| Parameter | Median | $10^{th}$ % ile | $90^{th}$% ile |
|---|---|---|---|
| Total N mg/l | 21.1 | 5.8 | 30.9 |
| Total P mg/l | 6.7 | 94.6 | 9.3 |
| Suspended solids | 9 | 2 | 24 |
| BOD | 6 | 2 | 17 |
| Faecal coliforms | 4000 | 376 | 46000 |

The Draft 1999 ANZECC guidelines for irrigated water endorse the National Water Quality Management Strategy Draft Guidelines for Sewage Systems (1996) recommendation for use of reclaimed water, and

advise a bacterial level of <1000 thermotolerant coliforms per 100ml effluent. Release quality characteristic limits for sewage effluent under the terms of the licence for the sewage treatment plant are tabulated in Appendix J. The median level of faecal coliforms for data from October 6th 1999 to January 19th 2000 inclusive (Appendix H1) is 37,000 organisms per 100ml. This is far in excess of ANZECC/NWQMS guidelines and exceeds the levels for the licence. If results over this 3-month period are indicative of the performance of the UV system it is clear that a review of the disinfection process is warranted.

The Bio-Track (1996) study also identified potential nutrient hazards associated with effluent irrigation. De-nitrification rates of up to 500kg/ha/y can be expected where soils are finely textured with a high moisture content. However, sandy soils drain rapidly and significant amounts of nitrogen may be lost to groundwater before plants access it. Soils around the Sewage Treatment Plant are sandy, and irrigation water soaks in rapidly (pers.comm. K. MacIntyre). However, figures for effluent irrigation are not based on tropical situations where evaporation may be particularly high (pers. comm. H. Fracchia). Effective irrigation levels depend on soil properties, weather conditions, plant uptake, and effluent quality, and should be determined experimentally for each site (pers. comm. Dr. Xiandeng Hu). ***Studies on effluent irrigation at the Nelly Bay site have not been reported; site specific studies would clarify requirements at this site or future effluent irrigation areas planned for the Island.***

### *11.4.3 Sludge lagoon leachate*

It has been suggested that effluent leaches through the unlined base of the Sewage Treatment Plant sludge lagoon and contaminates groundwater (Draft EIS1995). In order to monitor the superficial groundwater, an observation bore was installed in February 1999 downslope from the Sewage Treatment Plant, on land adjacent to the effluent irrigation area. Installation details are appended (Appendix K). The bore was screened to 2.37m below ground level, with the top of the screen 1.77m below ground. The bore log describes the soils as 'fluvium' (alluvial), with a change at 2.4m below ground to mature clay with oxidised iron stringers and decomposed granite (limey). Pump tests yielded no water despite charging the bore on two occasions. The bore has been dry since its installation and no water samples have been taken for testing. It could be argued that the bore was not installed at sufficient depth to intercept the water table, although the presence of clay suggests that this should not be the case. Alternatively, it may be that the sediments underlying the irrigation area do not drain in the direction of the bore site. Kevin MacIntyre, a worker in the area for many years, disputes the allegation that the base of the sludge lagoon leaks. He argues that fine silt in the sludge seals pores in the earth base, making a hard impenetrable layer.

### *11.4.4 Leachate from septic systems*

In the early 1970's, tests were carried out by the Council which indicated a number of wells in Magnetic Island were polluted with *E. coli* or were classified as 'polluted underground water'. In Nelly Bay, maps from that time indicated 60 septic tanks, and 20 sites with polluted groundwater of which 2 had *E. coli* present. However, polluted wells do not necessarily imply polluted groundwater as contaminants may fall into wells from above.

The area between Barton and Sooning Streets was melaleuca swamp in the past. The ground was boggy and often flooded (pers. comm. K. MacIntyre). There is concern that older residences in this area have septic systems that are positioned too close to the creek. When the water table is high water can seep into septic tanks causing them to overflow. The primary school is also in this vicinity. In 1999, overflow from septics was considered to be a health hazard to students (pers.comm. S. Stronach, former Principal). A spokesman for the Education Department stated that school lands could no longer accommodate effective trenches. The installation of a pipe connection to the Nelly Bay sewage Treatment Plant is to alleviate this problem. Recommendations by Bio-Track (1996) (see section 11.4.3.) also apply to septic systems; in sandy soils and with high water tables pollution from septic systems may be significant.

The only real solution to pollution would be to remove existing septic tanks (pers.comm. H. Fracchia). Once the area is sewered, owners have an obligation by law to connect to the mains.

### *11.4.5 Groundwater issues*

The groundwater inputs that are likely to impact on the water quality of Gustav Creek will derive from shallow alluvial material. The presence of coarse sands in the Gustav Creek catchment area will permit the rapid movement of infiltrated rainfall and septic tank effluent through the alluvium, particularly during the wet season. Downward drainage may be retarded by the extensive presence of low permeability clay and hard pan layers (at fairly shallow depths), which may result in a lateral throughflow of groundwater to Gustav Creek. The potential thus exists for contaminants associated with suburban stormwater runoff and septic tank effluent to discharge into Gustav Creek in a diffuse manner, and further investigation into the quality and hydrodynamics of shallow groundwater in the Gustav Creek catchment is thus warranted. In addition, Jackson (1996) outlines the potential for contamination of water bodies by septic tank systems on Magnetic Island, and also emphasises the need for groundwater investigations.

### *11.4.6 Recommendations for further groundwater investigations*

While a number of reports and studies have focused on the Gustav Creek catchment and the possible impact of discharge from Gustav Creek into the Nelly Bay marine environment, a groundwater investigation has not been forthcoming despite it having been identified as an area requiring further investigation. It is understandable that such a study has been neglected to date, as groundwater investigations are time-consuming; furthermore, solutions to groundwater problems are generally complex and expensive to implement. ***Nonetheless, given the nature of the alluvium in Gustav Creek catchment, the predominance of septic tank systems and the high summer rainfall, any impact assessment would be incomplete without a thorough groundwater investigation.***

A groundwater investigation in the Gustav Creek catchment should include the following:

- An investigation into the groundwater hydrodynamics, including the determination of the direction of groundwater flow, and seasonal fluctuations in the depth of the water table.
- An analysis of groundwater quality, in particular a microbial and chemical analysis that focuses on contamination by human faecal matter (faecal microbes). Groundwater samples should be obtained by induced flow into the borehole. A number of the monitoring boreholes should be established at a fairly close proximity to, and down-gradient from, septic tank soak-away systems. Monitoring sites should also be established down-gradient from the TCC sewerage treatment plant.
- Groundwater monitoring during a wet season. Higher water tables are normally encountered during a wet season, and a greater potential may exist for the input of contaminants (via groundwater) into Gustav Creek.

Given the basically diffuse nature of groundwater inputs to a fluvial system, it is essential that a number of borehole monitoring sites are established throughout the catchment, with each site comprising a number (at least 3) of shallow boreholes (<10 m in depth).

## 11.5 Contamination from warm-blooded animals

Faecal contamination of creek water by warm-blooded animals is to be expected. Elevated levels during baseflow or lentic conditions are most likely due to the deposition of faecal matter in or very close to the water. Animals have easy access to Gustav Creek from residential properties and roadways, and dogs and cats are common in urban areas. Fruit bat colonies utilise riparian vegetation, and birds roost in riparian trees. The low volumes of water present in the stream at all time other than during brief periods of swiftflow during and immediately after storms means that the stream is vulnerable to contamination, and dilution is often severely limited.

## 11.6 Urban Stormwater

Urban stormwater drainage follows the land contours and is directed to Gustav Creek and associated tributaries. Stormwater outflows are illustrated on Map A. Drains empty into the creek at Barton and Elena Street bridges, on the high southern bank of the creek behind residential properties along Elena

Street, opposite Lintern Place towards the mouth of the creek, and via an open drainage line from the school area. Stormwater from the Magnetic International Resort is directed under Mandalay Avenue to a concreted drainage line that runs into Gustav Creek. The Kelly Street tributary, which runs through the sewage treatment plant, is shown on the map as an 'open drain'. The school also has an open drainage channel through the property emptying into the lower reaches of Gustav Creek. Kerbing and channelling have been constructed along roads in newer residential areas and underground pipes conduct stormwater. There are no gross pollutant traps or litter collection devices on stormwater drains. The majority of pollutants – litter, animal wastes, sediments, fuel, oils etc. – that have collected in the catchment during dry periods are removed by the first rains and flushed into the creek.

There is also expected to be an increase in stormwater runoff with the development of the proposed marina. A submission from the North Queensland Conservation Council noted that a large increase in concrete surface area would significantly increase stormwater discharges (EA/QEPA, 1999). The SEIS considered that the quality of stormwater runoff from the finished development would be relatively high. This was based on the assumption that these areas would be fully sewered. In addition, the stormwater management plan required that the TCC Development Control Plan (TCC, 1996) would include provisions to minimise risks to water quality such as the use of vegetated filter strips and grassed swales, use of native vegetation to minimise fertilising requirements and use of pollution traps.

### *11.6.1 Litter*

As this catchment is considerably urbanised, litter from residential and commercial areas and tourist facilities would be a constant impact to the creek. Much of this litter would reach the creek through stormwater and would be flushed into the bay. With the construction of the marina and sedimentation basin, litter build-up would be confined to the basin; however, it may be possible that litter could be washed back upstream by tidal movement. Marina activities could also increase litter quantity. Any litter deposited in the harbour may not be contained within the sedimentation basin and may be deposited on beaches within the harbour. ***It is recommended that appropriate litter containment and pollution control devices be identified through the Environmental Management Plan associated with the proposed harbour development. Gross pollutant traps be may be necessary at the mouth of Gustav Creek to reduce the amount of litter washing downstream into the marina, and of equal importance, measures to prevent litter washing upstream from the marina – for example, floating litter curtains – should be considered.***

### *11.6.2 Fuel*

Fuel spillage may come from a number of different sources. They presently include major sources such as the petrol station (which ahas an underground storage facility) and the Magnetic Island Bus Service on Mandalay Avenue, the Moke Hire Service Centre on Kelly Street, and the Townsville City Council depot on Barton street. Future sources are the new service station to be built for the proposed harbour development, and the marina area where fuel spillage may occur from boats and ferries.

## 11.7 Waterway Management

The Townsville City Council has recognised the potential impact of stormwater run-off and associated toxicant and contaminant loadings to waterways in the region and developed the Drainage Waterway Management Plan (1998). Regular maintenance of drainage channels is essential to maintain surface water flow and water quality. Under the DWMP (1998), the TCC aims to provide effective management of stormwater drains and drainage channels. Maintenance activities include: the removal of debris, sediment/litter build-up; vegetation control using chemical or physical methods, including pruning of marine plants; dredging existing flood mitigation channels; the upkeep of machinery access points; bank stabilisation and erosion control; and acid sulphate soil management. Permits and approvals from the EPA, GBRMPA, and DPI are required before maintenance can be carried out. The area covered by permits in Gustav Creek is illustrated on Figure 11.1.

Maintenance of the Gustav Creek waterway by the TCC may occasionally require sediment removal. Under the TCC DWMP mandatory sediment testing must be carried out before work may commence. If

acid sulphate soil exposure is found to be a serious risk, work may be re-evaluated and disturbance avoided where possible. Where works are unavoidable, sediments are removed to the ASS treatment site and neutralised in accordance with the TCC's Acid Sulphate Soils Environmental Management Plan.

### *11.7.1 Property boundaries along Gustav Creek*

Gustav Creek is a significant conduit for stormwater drainage in Nelly Bay township. Major sections of Gustav Creek are included within private property boundaries although boundaries are often unclear. The creek is not marked in the DNR BLINMAP for Nelly Bay (Maps B & C). Aerial photographs have indicated that the creek mouth has changed position and the creek course has altered a number of times over the last 50 years. Undoubtedly, the dynamic character of the Gustav Creek watercourse may result in inconsistencies with land tenure. Boundaries should be resolved, and ownerships should be clarified. Cooperation between property owners and the TCC is essential to maintain clear passage along the creek for stormwater drainage.

## 11.8 Marina Issues

### *11.8.1 Contaminants*

It is possible that water contamination in the marina may also be an issue for Gustav Creek. Flushing times for the sedimentation basin are estimated to be in the vicinity of 2.9 days. Tidal movement during this period, if tides were high, could move contaminated water upstream. The FEIA (1999) noted (pg.40) that 'surface pollutants could originate through accidental spillage [in the marina] from any point, at any time', and that 'sewage outflows, were they to occur (from the proposed sewage pump station) would largely remain in the area of the Gustav Creek sedimentation basin.'

Marinas are commonly contaminated by high levels of toxic anthropogenic chemicals, especially oil and gas, and various metals (Lenihan *et al*., 1990). In the event of a fuel spill in the marina basin it was envisaged that a flotation boom would be placed across the channel entrance to contain the fuel (McIntyre 1988). However, there was no mention of a similar boom across the mouth of Gustav Creek to prevent any fuel or surface pollutants from proceeding upstream.

### *11.8.2 Tributylin*

The most toxic compound that has been introduced into coastal water may be tributylin (TBT), an antifouling paint (Lenihan *et al*., 1990). TBT has been used on boat hulls and pilings since the early 1970's and is considered to be 100 to 1000 times more toxic to laboratory animals than zinc or copper compounds (other antifouling chemicals) (Lenihan *et al*., 1990). This chemical is best known for causing deformities in fauna such as oysters and mussels, and accumulates in the food chain. The EAR (1999) stated that ' the proponent advised that, while it was not possible to impose controls over the existing paint on boats which may enter the marina, facilities for boat maintenance would not be provided in the harbour'. The International Maritime Organisation agreed in November 1998 to ban the use of TBT in antifoulants by 2003, with a 5-year period of phasing out. The ANZECC Antifouling Code of Practice governs TBT usage in Australia. Use has been restricted to vessels greater than 25m; thus, it would be larger vessels or vessels from countries with less rigorous regulatory controls that could provide a potential source of TBT. Given the small size of the marina, ferries will probably be the largest vessels. Sunferries (Magnetic Island) advise they presently use a TBT-free antifoulant and plan to change to a Teflon-based product (with no leachate) in the future. Capricorn Barge Company uses Jotun antifouling paint (a chlorinated rubber compound). Thus, TBT is unlikely to be a major issue. However, levels of TBT will be monitored and GBRMPA and QEPA/QPWS will establish locations of monitoring sites, frequencies and parameters.

**Figure 11.1:** Area covered by permits for drainage maintenance on Gustav Creek (shaded )
(TCC, 1998)

### *11.8.3 Effects of oil spills on mangroves*

Oil spills are recognised as posing the greatest risk to the nearshore environments and tidal areas. Studies in Panama on the effects of oil spills on mangroves (Burns *et al*., 1993; Getter *et al*., 1985) found that crude oil residues had a detrimental effect on mangrove vegetation and intertidal invertebrates for at least 5 years after a major spill. The effects of localised oil spills on mangrove and *Melaleuca* communities have been assessed near Cairns (Burns and Codi, 1998). No large-scale biological damage was observed although hydrocarbon levels in mangrove sediments remained high for eighteen months, and in *Melaleuca* forest sediments for 2 years post spill. Burns and Codi (1998) concluded that once the oil-affected sediments are removed, natural processes associated with tidal flushing should be sufficient to reduce toxicity over time. Similar studies by Duke *et al*., (1999) found that the mortality of mangrove trees from commonly transported oils was not reduced by bioremediation. The following year, the effects of oil on mangrove vegetation and sediments appeared to have been reduced in sites where bioremediation had been used, but not in control sites.

In the absence of contingency plans, oil spills in the proposed Nelly Bay harbour could be washed up Gustav Creek by high tides. Without adequate flushing, hydrocarbon residues in the sediments could persist for longer periods, with subsequent detrimental effects on the biota. ***It is recommended that oil spills be prevented from moving upstream and due consideration is given to the continuing health of mangroves at this site.***

### *11.8.4 Other contaminants*

Boats can also contribute other contaminants to a marina through boating-related activities (such as washing-down, draining bilge water, and refuelling). The effects of increased contamination levels, as well as changes in water circulation patterns and suspended sediment, are likely to interact to adversely affect residential marine and intertidal organisms (Turner *et al*., 1997).

### *11.8.5 Recommendations*

The EAR (1999) recommended that all possible measures must be taken by the proponent to ensure maintenance of water quality during harbour operations. Measures to be implemented as part of the Environmental Management Plan for the harbour include the preparation of an oil spill contingency plan, provision of pump-out facilities for vessels/boats, prohibition of boat maintenance or other activities likely to generate pollutants, and contingency plans in the event of poor water quality events. Management of oil and surface pollutants in Nelly Bay harbour must include strategies that exclude contaminants from upstream areas of Gustav Creek. ***Plans to minimise any impacts must be included as part of the Environmental Management Plan.***

## 11.9 Monitoring

Other parameters listed by the ANZECC (1992) guidelines (Appendix G), such as the presence of surface films may be easily monitored but this has not been done to date. Visual clarity and colour may be recorded but it is often difficult to discriminate between natural and anthropogenic sources and, for example, iron or manganese staining (see section 11.3.7).

Given the absence of industrial activities in the Gustav Creek catchment, the potential for contamination by toxic substances is not high, so routine monitoring of toxic contaminants is probably not justified. However, imprudent handling and/or storage of domestic chemicals such as pesticides and hydrocarbons can result in episodic contamination problems. ***The presence of many such contaminants can be detected in the laboratory by conducting taste, odour or colour tests or in the field by visual observations of surface films, etc. Accordingly, it would be worthwhile to conduct such tests in future monitoring programs.*** The capacity of Gustav Creek to maintain aesthetic and recreational values can be properly evaluated by TCC monitoring, provided it is refined by the addition of information as described.

During storm events, concentrations change by orders of magnitude over short time scales. In small streams of this kind, at the rising stages of the hydrograph there is a close correlation between contaminant concentration and the discharge rate. During the falling stages of the hydrograph the relationship is less predictable. For example, the ACTFR have monitored flow rates and water quality over 2 years in 2 adjacent catchments on the Mutalunga Range near Townsville, on streams similar in size to Gustav Creek (ACTFR, 1997). Figure 11.2 illustrates the relationship between the contaminant concentration and discharge rate on these streams.

***To establish connections between activities in the catchment and the quality of water being discharged into Nelly Bay it is essential to monitor significant rainfall events.*** Surface discharges vary so quickly in small catchments of this kind that it is not feasible to entertain the possibility of taking manual samples; thus, in order to ascertain some indication of both water and contaminant discharge rates, event monitoring requires automated sampling equipment.

The TCC ambient monitoring program provides an adequate basis for evaluating longterm baseflow water quality but is not adequate to serve as an investigative tool for locating contaminant input sources. This would require a greater number of site locations, the inclusion of tracer parameters and possibly the establishment of groundwater monitoring points before such a program could be designed. A pilot scale investigation would need to be implemented in order to determine if potential groundwater tracers such as trace metals or nitrate could be employed successfully in the Gustav Creek catchment. Trace metals, even those which occur in quite low concentrations in groundwater, often the surface stream and this can result in mild enrichment of concentrations in close proximity to groundwater input points. It would therefor also be worthwhile checking the distribution of fine particulate metals in the bottom sediments along the creek. Monitoring of this kind is rarely capable of identifying precise input locations or providing quantitative measures of input rates but the techniques that are used can accurately determine if particular subcatchments contribute higher than normal inputs and/or can detect stream reaches that are subject to anomalous input levels. Hence ensuring that subsequent investigations, such as groundwater monitoring are focused in the correct locations.

**Figure 11.2:** Suspended sediment pollutograph for one storm event 30/01/97 (ACTFR, 1997).

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## APPENDIX A: REGISTER OF THE NATIONAL ESTATE DATABASE

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Magnetic Island (in part) , Magnetic Island QLD
Class: Natural
Legal Status: Registered
Database Number: 008986
File Number: 4/05/245/0026

Statement of Significance: Magnetic Island and its surrounding waters form a significant natural environment that maintains natural processes, is a habitat of rare and uncommon species, has high biological diversity and contains evidence of past geological events and present ecological processes. The Island also has considerable cultural and aesthetic significance. The area is important for maintaining natural processes and systems at the regional level, that includes breeding and feeding of fish, turtles, other marine life and birds. The area is also an important over wintering (non-breeding season) aggregation site for a number of butterfly species, predominantly from the family Nymphalidae, sub-family Daninae. Magnetic Island is a habitat of three nationally vulnerable plant species (LIVISTONA DRUDEI, CROTON MAGNETICUS and GYMNEMA BREVIFOLIA), three nationally rare plant species (BONAMIA DIETRICHIANA, CASSIA QUEENSLANDICA and ACACIA JACKESIANA) and of VITTADINIA SCABRA that is poorly known but is suspected to be either nationally endangered, vulnerable or rare. The Island is also a habitat of a further sixteen plant species which are considered to be regionally uncommon. Wet sclerophyll forest and open woodland in sites close to the shore of Magnetic Island are a habitat of the nationally vulnerable legless lizard, the striped tailed delma (DELMA LABIALIS). The internationally endangered green turtle (CHELONIA MYDAS) and the nationally vulnerable flat back turtle (CHELONIA DEPRESSA) nest on the beaches of the Island, while the green turtle the internationally endangered hawksbill turtle (ERETMOCHELYS IMBRICATA) and the internationally threatened dugong (DUGONG DUGON) feed in the seagrass meadows that adjoin the Island. Magnetic Island is one of a few known locations of a butterfly LIBYTHEA GEOFFROY sub spp NICEVILLEI. The Island, which has been separated from the mainland for at least 7,000 years, provides an opportunity to study isolated populations and their evolution towards new forms, sub species or species. The Island contains one endemic plant CROTON MAGNETICUS and ten undescribed plant species, some of which may prove to be endemic or regionally restricted species, subspecies or forms. The Island is the habitat of a distinct sub species of the butterfly HESPERILLA MALINDEVA. The fringing reefs of the place have a high species diversity, due in part to the large range of marine conditions around the Island. The Island itself supports a high diversity of vegetation types, as a result of the different conditions of slope, aspect, altitude and soil parent material, which can be found across a relatively small area. An unusual exposure of the contact between the Permian Magnetic Island granite and an older volcanic and dyke rock complex is exposed at Huntingfield Bay, which provides evidence that the region's Permian granites are intrusive. Due to its proximity to the James Cook university, Magnetic Island has been the focus of biological work on intertidal and fringing reefs for over twenty years. The reefs have been important to the development of knowledge of fringing reefs in tropical Australia and to the understanding of the timing and mechanisms of coral spawning. The Island also provides an important teaching resource for secondary and tertiary educational institutions in Townsville. The overall character of Magnetic Island is dictated by the granitic landforms (particularly the rugged topography and the dominate boulders and bare granite surfaces), the hoop pine dominated ridges near the coast and the numerous bays, beaches and reefs that define its shoreline. These features together with the islands position as a backdrop to Townsville, give the area aesthetic significance. The fringing reefs have coral formations that are spectacular in their diversity and colour. The forts and searchlight platforms on the island are an important component of the World War Two relics in the Townsville area and are a reminder of its role as a staging area for personnel and equipment.

The Commission has determined that this place has Indigenous values of National Estate significance. The Australian Heritage Commission is currently consulting with relevant Indigenous communities about the amount of information to be placed on public record.

Description : Magnetic Island is a large granite continental island about 8km north of Townsville. It is roughly triangular in shape, with a central high point of Mount Cook (493m). The Island has an area of

5184ha, of which nearly half is reserved as the Magnetic Island National Park. There is also a small (4ha) Environmental Park at Horseshoe Bay Lagoon. The main settlements occur on the eastern third of the Island and here generally occupy flat land behind bays. The core of the island is a granitic intrusion of Permian to Mesozoic Age (approximately 280 million years). In the west between Huntingfield Bay and West Point, there is an area of felsic to andesitic pyroclastic volcanic rocks, closely intruded by (felsic to basic) dyke swarms. Lowland areas consist largely of sands eroded off the granitic Hills. There are beach ridges and vegetated older rear dunes along most of the bays. Coastal she oak (CASUARINA EQUISETIFOLIA) and weeping melaleuca woodland occur here, while in swampy or seasonally inundated areas behind the dunes long eaved paperbark (MELALEUCA LEUCADENDRON) usually form tall stands, such as near the Horseshoe Bay Lagoon. Associated with this lagoon is a good development of bulkura (ELEOCHARIS DULCIS) and other sedges. The Lagoon at Horseshoe Bay is the only substantial body of freshwater on the Island though this dries up in very dry seasons. Gustav Creek in Nelly Bay is the nearest to a permanent watercourse, but this ceases to run after poor wet seasons. Steep Granite Hills, rising to the summit of Mount Cook, feature many spectacular outcrops of large boulders, bare granite surfaces and cliffs. Similarly the coast, except in the shelter of the bays, is typically a jumble of granite boulders rising to ridges with extensive granite outcrops. Most of the hilly country supports eucalypt woodlands. Common species include Queensland grey ironbark (EUCALYPTUS DREPANOPHYLLA), ghost gum (E PAPUANA) or white mahogany (E ACMENOIDES). Vine forests with hoop pine (ARAUCARIA CUNNINGHAMII) emergents occur on the massive boulders, talus slopes and rocky headlands. This community contains some of the rarer plants found on the island including the endemic species CROTON MAGNETICUS. The higher exposed areas near Mount Cook may support brush box forest (LOPHOSTEMON CONFERTUS) or cabbage tree palm (LIVISTONA DRUDEI) and forest she oak open forest/woodland (CASUARINA TORULOSA. The beaches along the northern and eastern sides of the Island are separated by rugged headlands. The west coast is characterised by mangrove and samphire communities, several sandy beaches and wide flats of mud, coral and gravel that dry on the lowest tides. Extensive fringing coral reefs are found off the south-west corner between Bolger Bay and Picnic Bay, in Picnic, Nelly and Geoffrey Bays on the south-eastern coast and along the eastern shore of Horseshoe Bay on the northern side of the Island. Large stands of hard corals are found on the floors of some of the smaller bays on the south-eastern coast. There are extensive seagrass beds off Young Bay on the south-west of the island. Various woodlands are found on the foothills of the Island including Moreton bay ash community (EUCALYPTUS TESSELLARIS), popular gum and bloodwood community (EUCALYPTUS PLATYPHYLLA and E INTERMEDIA) and forest red gum community (E TERETICORNIS). Forest red gum is one of the favoured food trees of the koala. The koala was introduced to Magnetic Island. Numbers are estimated to be of the order of 500. This is one of the largest and most concentrated population of koalas in North Queensland. Littoral scrub occurs on deep sandy soil eroded from the nearby granite hills at the southern end of Nelly Bay and the northern end of Florence Bay. Numerous species are present in the smaller tree and shrub layers. Active scrub fowl nests are present within this community. Approximately 188 species of birds have been recorded on Magnetic Island. Summer migrants include migratory waders, the Torresian Imperial pigeon, koel, dollar bird and channel billed cockatoo. Winter migrants include mainly small passerines (fantails, flycatchers and whistlers). Finches (double barred, chestnut breasted and nutmeg), the Australian magpie and the Australian raven have also been recorded when conditions in inland Queensland were very dry. The allied rock wallaby (PETROGALE ASSIMILIS) is found over most of the Island. Magnetic Island has a rich butterfly fauna and there are several locations on the island where large aggregations of butterflies occur. These aggregations may number hundreds of individuals, especially during the non-breeding season when they are known as over wintering populations. Most of the species involved are in the family Nymphalidae, sub-family Danainae, including such species as the blue tiger (TIRUMALA HAMATUS), the eastern crow (EUPLOEA TULLIOLUS) and the common crow (EUPLOEA CORE CORINNA). The first record of Europeans sighting or visiting the island is by James Cook, who named the Island, Magnetical Isle, on 6 June 1770, '...as the compass would not travel well when near it'. North of Arcadia along the ridge summit, fortifications were built in 1942-43 by the Queensland Main Roads Commission, for the Australian Navy, to protect shipping anchored off Florence Bay. This area was used to form convoys for travel to war zones further north. Other buildings included cookhouses, quarters, mess huts, latrines, QM stores, ration stores, casualty huts and workshops. Two searchlights platforms were also installed, one above Florence Bay and one above Horseshoe Bay. The concrete emplacements of the forts and the searchlight platforms are still in good condition and the remains of other installations can be found.

Significant Indigenous values are known to exist in this area. The Australian Heritage Commission is currently consulting with relevant indigenous communities about the amount of information to be placed on public record.

Condition and Integrity : At present most of the Island is in natural or near natural condition, but near urban areas fire, weeds and introduced animals threaten natural integrity. Several of the rare or unusual plants are confined to the rainforest areas behind Nelly and Florence Bays, which may be cleared or altered by urban and tourist development. Aboriginal middens also occur in areas subject to clearing. The fringing reef in the Nelly Bay area and Aboriginal sites at Bright Point have been significantly degraded by reclamation activity. The environmental integrity and water quality of the Lagoon at Horseshoe Bay is vulnerable to clearing and earthworks in its catchment area. Magnetic Island has a long history of bushfires. Areas that have experienced more frequent burning show the greatest increase in grass cover and have few trees overall. Many introduced species have become established on the Island and compete successfully with native grasses and herbs in areas opened up by frequent wildfires, or where there is serious disturbance by human activity. These include mintweed (HYPTIS SUAVEOLENS), lantana (LANTANA CAMARA), and rubber vine (CRYPTOSTEGIA GRANDIFLORA). (November 1993)

Location : About 4500ha, 8km north of Townsville, comprising the whole of the island to Low Water (Parish of Magnetic) except: . the whole of Section I, Town of West Point; . Portions 40, 40v, 41v, 42v, 43v, 44v, 46v and 82; . Portion 27; .Portions 175, 49v, R656, Sections I-XVII and XXII Town of Picnic Bay and all roads within that town; Portions 22, 18 and 169; . the whole of the Town of Nelly Bay except VCL, R772, R844 and Lot 2 Rp 35615; . the whole of the Town of Alma Bay except VCL, Portion 140, R685 and r131; . Portions 74, 170, 34, 129, 130, 198, 185, 88 and 192; and . the whole of the Town of Horseshoe Bay except VCL, R695 and R751.

Report produced : 31/1/2000
RNEDB URL : http://www.environment.gov.au/heritage/register/easydatabase/database.html
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**APPENDIX B1: VEGETATION OF GUSTAV CREEK CATCHMENT INCLUDING SECTIONS 1-4 OF THE URBAN RIPARIAN VEGETATION SURVEY AND VEGETATION TYPES LISTED BY QNWPS (SANDERCOE 1990). LETTERS IN BRACKETS REFER TO SKULL (1996) CLASSIFICATION.**

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ferns | | | | | | | | | | |
| ADIANTACEAE | *Acrostichum speciosum* | | | + | | | | | | |
| | *Adiantum aethiopicum* | + | | | | | + | | + | |
| | *Adiantum sp.* | + | | | | | | | | |
| | *Cheilanthes sp.* | | | | | + | | | + | + |
| | *Doryopteris concolor* | + | | | | | + | + | | |
| | *Paraceterach muelleri* | | | | | | + | | | |
| | *Pityrogramma calomelanos var. austroamericana** | | | | | | | | + | |
| DAVALLIACEAE | *Davallia sp.* | + | | | | | | | + | |
| POLYPODIACEAE | *Drynaria sparsisora* | | | | | | + | | | |
| | *Platycerium veitchii* | | | | | | | | + | |
| PTERIDACEAE | *Acrostichum speciosum* | | | | | | | | | |
| Grasses, sedges and rushes | | | | | | | | | | |
| CYPERACEAE | *Bulbostylis barbata* | | | | | + | | | | |
| | *Cyperus aquatilis* | | | | | | | | | + |
| | *Cyperus enervis* | | | | | | + | | | |
| | *Cyperus eragrostis** | | + | + | | | | | | |
| | *Cyperus fulvus* | | | | | + | | | | |
| | *Cyperus involucratus** | | | + | | | | | | |
| | *Gahnia aspera* | | | | | | + | + | | |
| | *Scleria sphacelata* | | | | | | + | + | | + |
| POACEAE | *Aristida sp.* | | | | | + | | + | | + |
| | *Bambusa sp.** | | + | + | | + | | | | |
| | *Chionachne cyathopoda* | | | | | + | | | | |
| | *Coelorachis rottboelioides* | | | | | + | | | | |
| | *Cymbopogon ambiguus* | | | | | + | | | | + |
| | *Cymbopogon queenslandicus* | | | | | + | | | | + |
| | *Cynodon dactylon* | | + | + | | | | | | |
| | *Dactyloctenium aegypticum** | | | | | + | | | | |
| | *Dichanthium sp.* | | | | | + | | | | |
| | *Digitaria sp.* | | | | | + | | | + | |
| | *Eragrostis cumingii* | | | | | + | | | | |
| | *Eragrostis leptostachya* | | | | | + | | | + | |
| | *Eriachne rara* | | | | | | | | + | |
| | *Eriachne squarrosa* | | | | | + | | | | |
| | *Heteropogon contortus* | | | | | + | | | + | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Heteropogon triticeus* | | | | | + | | | | |
| | *Imperata cylindrica* | | | | | + | | | | |
| | *Melinis repens** | | + | + | + | + | | | + | |
| | *Oplismenus aemulus* | + | | | | | | | + | |
| | *Panicum maximum** | + | + | + | | + | | | | |
| | *Panicum mitchellii* | | | | | + | + | | + | |
| | *Paspalidium gracile* | | | | | + | | | + | |
| | *Phragmites karka* | | | + | | | | | | |
| | *Saccharum officinarum** | | | + | | | | | | |
| | *Setaria australiensis* | | | | | | | | + | |
| | *Sorghum leiocladum* | | | | | + | | | + | |
| | *Sporobolus virginicus* | | | | + | | | | | |
| | *Themeda triandra* | | | | | | | | + | + |
| | *Triodia stenostachya* | | | | | | + | + | + | + |
| TYPHACEAE | *Typha orentalis* | | + | + | | | | | | |
| XANTHORRHOEACEAE | *Lomandra longifolia* | | | | | + | + | | + | |
| | *Xanthorrhoea johnsonii* | | | | | | | | + | + |
| Parasitic Herbs | | | | | | | | | | |
| LORANTHACEAE | *Amyema congener* | | | | | | + | | | |
| Epiphytic Herbs | | | | | | | | | | |
| ORCHIDACEAE | *Dendrobium discolor* | | | | | | + | + | | |
| | *Dendrobium teretifolium* | | | | | | + | + | | |
| Herbs | | | | | | | | | | |
| ACANTHACEAE | *Hypoestes floribunda* | | | | | | | + | | |
| AGAVACEAE | *Sansevieria trifasciata** | + | + | + | | | | | | |
| AMARANTHACEAE | *Alternanthera betzzickiana** | | | + | | | | | | |
| | *Alternanthera denticulata* | | | | | | | | + | |
| | *Deeringia amaranthoides* | | | | | + | + | | | |
| ARAILIACEAE | *Makinlaya macrosciada* | + | | | | | | | | |
| ASTERACEAE | *Ageratum houstonianum** | | + | + | | | | + | | |
| | *Eclipta prostrata** | | + | + | | | | | | |
| | *Helichrysum rupicola* | | | | | | | | + | + |
| | *Pterocaulon serrulatum* | | | | | | | | | + |
| | *Pterocaulon sphacelatum* | | | | | | | + | | |
| | *Vernonia cinerea* | | | | | + | | | + | |
| | *Vittadinia sp.* | | | | | | + | | + | |
| BALSAMINACEAE | *Impatiens sp.** | | | + | | | | | | |
| BORAGINACEAE | *Trichodesma zeylanicum* | | | | | + | | + | + | |
| CLUSIACEAE | *Hypericum gramineum* | | | | | | | + | | |
| COMMELINIACEAE | *Commelina cyanea* | + | | | | + | | | | |
| DROSERACEAE | *Drosera spatulata* | | | | | | | | + | + |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| EUPHORBIACEAE | *Chamaesyce hirta** | | + | + | | + | | | | |
| | *Chamaesyce vachellii* | | | | | + | | | | |
| | *Phyllanthus novae-hollandiae* | + | + | + | | | + | + | | |
| | *Phyllanthus virgatus* | | | | | + | + | | | |
| | *Sauropus albiflorus* | | | | | | | | | |
| FABACEAE | *Crotalaria dissitiflora* | | | | | | | | + | |
| | *Crotalaria goreensis** | | + | + | | | | | | |
| | *Crotalaria linifolia* | | | | | + | | | | |
| | *Crotalaria pallida** | | | | | + | + | + | + | |
| | *Desmodium rhytidophyllum* | | | | | + | | | | |
| | *Flemingia parviflora* | | | | | + | | | | |
| | *Indigofera brevidens* | | | | | | | | + | |
| | *Indigofera hirsuta* | | | + | | + | | | | |
| | *Macroptilium atropurpureum** | | + | + | + | + | | | | |
| | *Sesbania cannabina* | | | | | | | | | + |
| | *Stylosanthes sp.** | | + | + | | | | | | |
| | *Tephrosia juncea* | | | | | + | | | | |
| | *Tephrosia sp.* | | | | | | | | + | |
| LAMIACEAE | *Anisomeles malabarica* | | | | | + | | | + | |
| | *Hyptis suaveolens** | | | + | + | + | | | | |
| | *Plectranthus diversus* | | | | | | | | + | |
| LILIACEAE | *Molineria ensifolia* | | | | | + | | | | |
| | *Dianella caerulea* | + | | + | | + | + | + | + | |
| | *Iphigenia indica* | | | | | | | | + | |
| | *Proiphys amboinensis* | | | | | | + | | | |
| MALVACEAE | *Sida cordifolia* | | | | | + | | | + | |
| | *Sida magnifica* | | | | | | | | + | + |
| | *Sida rhombifolia** | | | + | | + | | | + | |
| | *Urena lobata** | + | | | | | | | + | |
| ONAGRACEAE | *Ludwigia octovalvis* | + | + | + | | | | | | |
| POLYGONACEAE | *Persicaria sp.* | | + | + | | | | | | |
| RUBIACEAE | *Hedyotis sp.* | | | | | + | | | | |
| | *Richardia brasiliensis** | | + | + | | | | | | |
| | *Spermacoce brachystema* | | | | | + | | | + | |
| SCROPHULARIACEAE | *Scoparia dulcis** | | + | + | | | + | | | |
| | *Striga curviflora* | | | | | + | | | | |
| STERCULIACEAE | *Waltheria indica* | | | | | | | | + | |
| TACCACEAE | *Tacca leontopetaloides* | + | | | | | | | + | |
| THYMELAEACEAE | *Pimelea sp.* | | | | | | | | + | + |
| TILIACEAE | *Triumfetta rhomboidea** | | | | | + | | | | + |
| VERBENACEAE | *Stachytarpheta jamaicensis** | + | + | + | | | | | | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| VIOLACEAE | *Hybanthus sp.* | | | | | | | | + | |
| ZINGIBERACEAE | *Alpinia caerulea* | + | | | | | | | | |
| Shrubs | | | | | | | | | | |
| ANNONACEAE | *Polyalthia nitidissima* | | | | | | + | | | |
| APOCYNACEAE | *Alyxia spicata* | + | | | | | + | + | + | |
| | *Carissa ovata* | | | | | | + | + | | |
| | *Tabernaemontana pandacaqui* | + | + | + | | | + | + | + | + |
| | *Tabernaemontana pubescens* | | | | | | + | | + | |
| CAESALPINIACEAE | *Cassia queenslandica* | | | | | | + | | | |
| | *Cassia retusa* | | | | | | | + | + | |
| | *Cassia sp.* | | | | | | | | + | |
| | *Labichea nitida* | | | | | | | | | + |
| CAPPARACEAE | *Capparis arborea* | | | | | | + | + | + | |
| CELASTRACEAE | *Cassine melanocarpa* | | | | | | + | + | | |
| | *Maytenus disperma* | | | | | | | | + | |
| EBENACEAE | *Diospyros geminata* | | + | + | | + | + | | + | |
| EPACRIDACEAE | *Leucopogon sp.* | | | | | | | | + | |
| EUPHORBIACEAE | *Alchornea ilicifolia* | | | | | | + | + | | |
| | *Antidesma parvifolium* | | | | | | + | + | + | |
| | *Breynia oblongifolia* | | | | | | | | + | |
| | *Croton magneticus (V)* | + | | | | | + | + | | |
| | *Flueggea virosa subsp. melanthesoides* | | | | | | | | + | + |
| | *Petalostigma pubescens* | | | | | | | | | + |
| FABACEAE | *Indigofera sericovexilla* | | | | | | | | + | |
| MALVACEAE | *Abelmoschus moschatus var. tuberosus* | | | | | + | | | + | |
| | *Abutilon auritum* | + | | + | | | | | | |
| | *Abutilon oxycarpum* | + | | | | | + | | | |
| | *Hibiscus divaricatus* | | | | | + | | + | + | |
| | *Hibiscus meraukensis* | | | | | | + | | + | |
| MELASTOMATACEAE | *Memecylon pauciflorum* | | | | | | | + | + | |
| MELIACEAE | *Aglaia elaeagnoidea* | + | | | | | + | + | | |
| | *Turraea pubescens* | | | | | | + | + | | |
| MIMOSACEAE | *Acacia bidwillii* | | | | | | | | + | |
| | *Acacia crassicarpa* | + | + | + | | | | | + | |
| | *Acacia flavescens* | | | | | | | | + | |
| | *Acacia jackesiana* | | | | | | | | + | |
| | *Acacia leiocalyx* | | | | | | | + | + | |
| | *Acacia leptostachya* | | + | + | | | + | + | + | + |
| | *Acacia simsii* | | | | | + | | | + | + |
| | *Acacia spirorbis ssp.solandri* | | | | | | + | + | + | |
| MORACEAE | *Maclura cochinchinensis* | | | | | | + | | | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| MYRSINACEAE | *Rapanea variabilis* | | | | | | | + | + | |
| MYRTACEAE | *Callistemon sp.* | | | | | | | | + | |
| | *Eugenia reinwardtiana* | + | | | | | | | | |
| PITTOSPORACEAE | *Bursaria incana* | | | | | | | | + | + |
| | *Bursaria spinosa* | | | | | | | | + | |
| RUBIACEAE | *Aidia racemosa* | + | | | | | + | + | | |
| | *Caelospermum paniculatum* | | | | | | | + | + | |
| | *Canthium attenuatum* | | | | | | | | + | |
| | *Canthium coprosmoides* | + | | + | | | + | | + | |
| | *Canthium odoratum* | | | | | | + | | + | |
| | *Canthium sp. nov.* | + | | | | | | | | |
| | *Larsenaikia ochreata* | | | | | + | + | + | + | + |
| | *Pavetta australiensis* | + | | | | | | + | + | + |
| | *Psychotria dallachiana* | + | | | | | | | | + |
| SAPINDACEAE | *Dodonaea lanceolata* | | | | | | | | + | |
| | *Dodonaea viscosa subsp. viscosa* | | | | | | + | + | + | |
| | *Ganophyllum falcatum* | + | | | | | | + | | |
| SAPOTACEAE | *Pouteria sericea* | + | | | | + | + | | + | |
| SOLANACEAE | *Daytura ferrox** | | | | | | | | + | |
| STERCULIACEAE | *Brachychiton bidwillii* | | | | | | | | + | |
| | *Helicteres semiglabra* | | | | | | | + | + | + |
| TILIACEAE | *Grewia retusifolia* | | | | | + | | + | + | + |
| ULMACEAE | *Trema tomentosa var. viridis* | + | + | + | | + | + | | + | |
| URTICACEAE | *Dendrocnide moroides* | + | | + | | | + | | | |
| | *Pipturus argenteus* | | + | + | | + | + | + | + | |
| VERBENACEAE | *Callicarpa candicans* | | | | | + | | + | + | + |
| | *Clerodendrum sp.1* | | | | | | + | | + | |
| | *Clerodendrum floribundum* | | | + | | | + | + | | |
| | *Lantana camara** | + | + | + | + | + | + | + | + | |
| Trees | | | | | | | | | | |
| ANACARDIACEAE | *Euroschinus falcata* | | + | + | | + | + | | + | + |
| | *Fitzalania heteropetala* | | | | | | | + | | |
| | *Mangifera indica** | + | | + | | | | | | |
| | *Pleiogynium timorense* | | + | + | | + | | + | + | + |
| ANNONACEAE | *Fitzalania heteropetala* | + | | | | + | + | | | |
| APOCYNACEAE | *Thevetia peruviana** | + | | | | | | | | |
| ARALIACEAE | *Schefflera actinophylla* | + | | | | + | | | + | |
| ARAUCARIACEAE | *Araucaria cunninghamii* | + | | | | | + | + | + | |
| ARECACEAE | *Archontophoenix alexandrae* | | | + | | | + | | | |
| | *Carpentaria acuminata** | | | + | | | | | | |
| | *Caryota mitis** | | | + | | | | | | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Cocos nucifera** | + | + | + | | | | | | |
| | *Livistona decipiens* | + | | | | | | | | |
| | *Livistona drudei (V)* | | | | | | + | | | |
| AVICENNIACEAE | *Avicennia marina* | | | + | | | | | | |
| BIGNONEACEAE | *Spathodea campanulata** | | + | + | | | | | | |
| BIXACEAE | *Cochlospermum gillivraei* | | + | + | | + | + | + | + | + |
| BURSERACEAE | *Canarium australianum* | + | + | + | | + | + | + | + | + |
| | *Garuga floribunda* | + | | | | + | + | | | |
| CAESALPINIACEAE | *Bauhinia monandra** | + | | | | | | | | |
| | *Lysiphyllum hookeri* | | | | | | | + | | |
| CARICACEAE | *Carica papaya** | + | | + | | | | | | |
| CASUARINACEAE | *Allocasuarina torulosa* | | | | | | | | + | |
| | *Casuarina equisetifolia* | | | | + | | | | | |
| COMBRETACEAE | *Lumnitzera sp.* | | | + | + | | | | | |
| | *Terminalia arenicola* | | | | | | + | + | | |
| | *Terminalia melanocarpa* | + | + | + | | | | | + | + |
| | *Terminalia muelleri* | + | + | + | | | + | + | + | + |
| | *Terminalia porphryocarpa* | | | | | | + | | | |
| EUPHORBIACEAE | *Croton arnhemicus* | | | | | | + | + | | |
| | *Drypetes deplanchei* | + | | | | | + | + | + | |
| | *Excoecaria agallocha* | | | + | + | | | | | |
| | *Glochidion apodogynum* | | | | | | + | + | | |
| | *Glochidion lobocarpum* | | | | | + | | | | |
| | *Macaranga tanarius* | + | + | + | | | + | | + | |
| | *Mallotus philippensis* | + | + | + | | + | + | + | + | |
| | *Omolanthus populifolius* | + | + | + | | | | + | | |
| | *Petalostigma pubescens* | | | | | | | | + | |
| | *Ricinus communis** | | + | + | | | | | | |
| FABACEAE | *Castanospermum australe* | + | | | | | | | | |
| | *Millettia pinnata* | + | + | + | | | | | + | |
| | *Tamarindus indica** | | | + | | | | | | |
| FLACOURTIACEAE | *Scalopia braunii* | + | | | | | | | | |
| GYROCARPACEAE | *Gyrocarpus americanus* | | | | | | + | + | | |
| LAURACEAE | *Cryptocarya hypospodia* | | | | | | + | | | |
| | *Cryptocarya sp.* | + | | | | | | | | |
| | *Cryptocarya triplinervis* | + | | + | | | + | + | + | |
| | *Litsea glutinosa* | | | | | | + | | | |
| | *Litsea reticulata* | | | | | | + | | + | |
| | *Litsea sp.* | | | + | | | | | | |
| | *Neolitsea australiensis* | + | + | + | | | + | + | | |
| LECYTHIDIACEAE | *Planchonia careya* | | + | + | | + | | + | + | + |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| MALVACEAE | *Hibiscus tiliaceus* | | | | + | | | | | |
| | *Thespesia populnea* | | | + | | | | | | |
| MELIACEAE | *Melia azedarach* | + | + | + | | | | | | |
| | *Xylocarpus sp.* | | | | + | | | | | |
| MIMOSACEAE | *Acacia aulacocarpa* | | | | | | | | + | |
| | *Paraserianthes toona* | | | | | | + | + | | |
| MORACEAE | *Ficus congesta* | + | + | + | | | + | | | |
| | *Ficus hispida* | + | + | + | | | + | | | |
| | *Ficus microcarpa* | + | | | | | + | + | | |
| | *Ficus opposita* | + | + | + | | + | + | + | + | |
| | *Ficus racemosa* | + | | + | | | + | | | |
| | *Ficus rubiginosa* | | + | + | | | + | + | + | |
| | *Ficus virens* | + | | | | | + | + | | |
| MYRTACEAE | *Austromyrtus bidwillii* | + | | | | | + | + | | |
| | *Corymbia dallachiana* | | | | | + | | | + | + |
| | *Corymbia erythrophloia* | | | | | | | | + | |
| | *Corymbia intermedia* | | | | | + | + | + | + | + |
| | *Corymbia maritima* | | + | + | | | | | | |
| | *Corymbia tesellaris* | + | + | + | | + | + | + | + | + |
| | *Corymbia trachyphloia* | | | | | | | | + | |
| | *Eucalyptus acmenoides* | | | | | + | + | + | + | + |
| | *Eucalyptus crebra* | | | | | | | + | + | + |
| | *Eucalyptus exserta* | | | | | | | | + | |
| | *Eucalyptus platyphylla* | | + | + | | + | + | + | + | + |
| | *Eucalyptus umbra* | | | | | | + | | + | + |
| | *Eugenia reinwardtiana* | | | | | | + | + | + | |
| | *Lophostemon confertus* | | | | | | | | + | |
| | *Lophostemon grandiflorus* | + | + | + | | + | + | + | + | + |
| | *Lophostemon suaveolens* | | + | | | | + | | | |
| | *Melaleuca leucadendra* | + | + | + | + | + | + | | | |
| | *Melaleuca viridiflora* | | | + | | | | | + | + |
| OLEACEAE | *Chionanthus ramiflora* | | + | + | | | + | | | |
| PANDANACEAE | *Pandanus sp.* | + | + | + | | + | + | + | + | + |
| PITTOSPORACEAE | *Citriobatus spinescens* | + | | | | | + | + | + | + |
| | *Pittosporum ferrugineum* | | + | + | | + | + | | | |
| PROTEACEAE | *Macadamia integrifolia* | + | | | | | | | | |
| | *Persoonia falcata* | | | | | + | | + | + | + |
| RHAMNACEAE | *Alphitonia excelsa* | | + | + | | + | + | + | + | + |
| RHIZOPHORACEAE | *Carallia brachiata* | + | | | | | | | | |
| | *Rhizophora stylosa* | | | + | + | | | | | |
| RUBIACEAE | *Ixora klanderiana* | | | | | + | + | | + | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Nauclea orientalis* | + | + | + | | | + | | | |
| | *Psychotria fitzalanii* | | | | | | + | + | + | + |
| | *Timonius timon* | | + | + | | + | + | | + | |
| RUTACEAE | *Achronychia laevis* | + | | | | | + | + | + | |
| | *Clausena brevistyla* | | | | | | + | + | | |
| | *Geijera salicifolia* | | | | | | + | + | + | |
| | *Glycosmis trifoliata* | + | | | | | + | | | |
| | *Micromelum minutum* | + | | | | | + | | | |
| SAPINDACEAE | *Alectryon tomentosus* | + | | | | | + | | | |
| | *Alectryon sp.* | | | | | | + | + | | |
| | *Arytera divaricata* | | | | | + | + | | | |
| | *Atalaya multiflora* | | | | | | + | + | | |
| | *Cupaniosis anacardioides* | | | + | | | + | + | + | |
| | *Ganophyllum falcatum* | | | | | | | | | |
| | *Harpullia pendula* | | | | | | + | | | |
| | *Jagera pseudorhus* | + | + | + | | + | + | + | + | |
| SAPOTACEAE | *Mimusops elengi* | | | | | | + | | | |
| | *Pouteria pohlmaniana* | + | + | + | | | + | + | + | |
| SOLANACEAE | *Solanum furfuraceum* | | | | | | + | | | |
| STERCULIACEAE | *Brachychiton australis* | | | | | | | + | | |
| | *Sterculia quadrifida* | + | | + | | | + | + | | |
| STRELITZIACEAE | *Ravenala madagascariensis** | + | | + | | | | | | |
| TILIACEAE | *Corchorus pascuorum* | | | | | | + | | | |
| ULMACEAE | *Aphananthe philippinensis* | + | | | | | + | | | |
| | *Celtis paniculata* | + | | | | | | | | |
| VERBENACEAE | *Clerodendrum sp. 2* | | | | | | | + | | |
| | *Premna serratifloia* | | + | + | | | + | | | |
| Vines and scramblers | | | | | | | | | | |
| ACANTHACEAE | *Thunbergia alata** | | + | | | | | | | |
| ANNONACEAE | *Melodorum leichhardtii* | | | | | | + | + | | |
| APOCYNACEAE | *Ichnocarpus frutescens* | | | | | | + | + | | |
| | *Parsonsia lanceolata* | + | | | | | | + | | |
| ARACEAE | *Monstera deliciosa** | | + | + | | | | | | |
| | *Pothos sp.* | | | + | | | | | | |
| | *Syngonium podophyllum** | + | + | + | | | | | | |
| ASCLEPIADACEAE | *Marsdenia brevifolia* | | | | | | | | + | |
| | *Hoya australia* | | | | | | + | | | |
| | *Sarcostemma viminale subsp. brunonianum* | | | | | | | + | | |
| | *Cryptostegia grandiflora** | | | | | | | | + | + |
| ASTERACEAE | *Wedelia trilobata ** | + | + | + | + | | | | | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| BIGNONEACEAE | *Pandorea pandorana* | | | | | | + | | | |
| COMBRETACEAE | *Quisqualis indica** | + | | | | | | | | |
| CONVOLVULACEAE | *Bonamia dietrichiana* | | | | | | | + | | |
| | *Evolvulus alsinoides* | | | | | + | | | | |
| | *Ipomoea abrupta* | | | | | | | | + | |
| | *Ipomoea pes-caprae* | | | + | + | | | | | |
| | *Jacquemontia paniculata* | | | | | | | | + | |
| | *Merremia dissecta** | | | | | | | | + | |
| | *Merremia quiniquefolia** | | + | + | | | + | + | + | |
| DIOSCOREACEAE | *Dioscorea bulbifera* | | | | | | | | + | |
| | *Dioscorea transversa* | + | | | + | | | + | | |
| EUPHORBIACEAE | *Tragia novae-hollandiae* | | | | | | | + | | |
| FABACEAE | *Abrus precatorius* | | | | | | + | | | |
| | *Cajanus reticulata* | | | | | | | | + | |
| | *Canavalia papuana* | + | + | + | | | + | | | |
| | *Clitoria ternatea** | | + | + | | | | | | |
| | *Entada phaseoloides* | | + | + | | | | | | |
| | *Desmodium rhytidophyllum* | | | | | | | | + | |
| | *Glycine tabacina* | | | | | + | | | | |
| | *Mucuna gigantea* | | | + | | | | | | |
| | *Rhyncosia minima var. minima* | | | | | + | | | | |
| FLAGELLARIACEAE | *Flagellaria indica* | + | | | | | + | | | |
| LAURACEAE | *Cassytha filiformis* | | | | + | + | | | | |
| MENISPERMACEAE | *Pachygone ovata* | | | | | | + | + | + | |
| | *Stephania japonica* | + | | | | | | | | |
| | *Tinospora smilacina* | | | | | | | + | | |
| MORACEAE | *Malaisia scandens* | | | | | | + | + | | |
| OLEACEAE | *Jasminum didymum* | + | + | + | | + | | + | + | + |
| PASSIFLORACEAE | *Passiflora aurantia var. aurantia* | | + | + | | | + | | + | |
| | *Passiflora foetida** | + | + | + | | | | | | |
| PIPERACEAE | *Piper sp.* | + | | | | | | | | |
| POLYGONACEAE | *Antigonon leptopus** | | | | | | + | | | |
| RUBIACEAE | *Morinda acutifolia* | | | | | | + | | | |
| SMILACACEAE | *Eustrephus latifolius* | + | | | | + | + | + | | |
| | *Smilax australis* | + | | + | | | + | + | + | |
| VERBENACEAE | *Clerodendrum inerme* | | | + | | | | | | |
| | *Glossocarya hemiderma* | | | | | | | + | | |
| VITACEAE | *Cayratia japonica* | | | | | | | | + | |
| | *Cayratia trifolia* | | | | | | | + | | |
| | *Cissus antarctica* | + | | + | | | | | | |
| | *Cissus oblonga* | + | | | | | + | + | | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Cissus opaca* | | | | | | + | + | + | |
| | *Cissus reniformis* | | | | | + | + | + | + | |
| | *Tetrastigma nitens* | | | | | | + | | | |
| | *Tetrastigma thorsborneorum* | + | | | | | + | | | |

**APPENDIX B2: WEEDS OF GUSTAV CREEK CATCHMENT INCLUDING SECTIONS 1-4 OF THE URBAN RIPARIAN VEGETATION SURVEY AND VEGETATION TYPES LISTED BY QNWPS (SANDERCOE 1990). LETTERS IN BRACKETS REFER TO SKULL (1996) CLASSIFICATION (# INDICATES GARDEN ESCAPE).**

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| Ferns | | | | | | | | | | |
| ADIANTACEAE | *Pityrogramma calomelanos var. austroamericana#* | | | | | | | | + | |
| Grasses, sedges and rushes | | | | | | | | | | |
| CYPERACEAE | *Cyperus eragrostis* | | + | + | | | | | | |
| | *Cyperus involucratus#* | | | + | | | | | | |
| POACEAE | *Bambusa sp#* | | + | + | | + | | | | |
| | *Dactyloctenium aegypticum** | | | | | + | | | | |
| | *Melinis repens* | | + | + | + | + | | | + | |
| | *Panicum maximum* | + | + | + | | + | | | | |
| | *Saccharum officinarum#* | | | + | | | | | | |
| Herbs | | | | | | | | | | |
| AGAVACEAE | *Sansevieria trifasciata#* | + | + | + | | | | | | |
| AMARANTHACEAE | *Alternanthera betzzickiana* | | | + | | | | | | |
| ASTERACEAE | *Ageratum houstonianum* | | + | + | | | | + | | |
| | *Eclipta prostrata* | | + | + | | | | | | |
| BALSAMINACEAE | *Impatiens sp.#* | | | + | | | | | | |
| EUPHORBIACEAE | *Chamaesyce hirta* | | + | + | | + | | | | |
| FABACEAE | *Crotalaria goreensis* | | + | + | | | | | | |
| | *Crotalaria pallida* | | | | | + | + | + | + | |
| | *Macroptilium atropurpureum* | | + | + | + | + | | | | |
| | *Stylosanthes sp.* | | + | + | | | | | | |
| LAMIACEAE | *Hyptis suaveolens* | | | + | + | + | | | | |
| MALVACEAE | *Sida rhombifolia* | | | + | | + | | | + | |
| | *Urena lobata* | + | | | | | | | + | |
| RUBIACEAE | *Richardia brasiliensis* | | + | + | | | | | | |
| SCROPHULARIACEAE | *Scoparia dulcis* | | + | + | | | + | | | |
| TILIACEAE | *Triumfetta rhomboidea* | | | | | + | | | | + |
| VERBENACEAE | *Stachytarpheta jamaicensis* | + | + | + | | | | | | |
| Shrubs | | | | | | | | | | |
| SOLANACEAE | *Daytura ferrox* | | | | | | | | | |
| VERBENACEAE | *Lantana camara** | + | + | + | + | + | + | + | + | |
| Trees | | | | | | | | | | |
| ANACARDIACEAE | *Mangifera indica#* | + | | + | | | | | | |
| APOCYNACEAE | *Thevetia peruviana#* | + | | | | | | | | |
| ARECACEAE | *Carpentaria acuminata#* | | | + | | | | | | |
| | *Caryota mitis#* | | | + | | | | | | |
| | *Cocos nucifera#* | + | + | + | | | | | | |

| FAMILY | GENUS | Section 1 | Section 2 | Section 3 | Section 4 | Type 9 (EP) | Type 13/14 (V) | Type 15 | Type 17 (EW) | Type 18 (AS) |
|---|---|---|---|---|---|---|---|---|---|---|
| BIGNONEACEAE | *Spathodea campanulata#* | | + | + | | | | | | |
| CAESALPINIACEAE | *Bauhinia monandra#* | + | | | | | | | | |
| CARICACEAE | *Carica papaya#* | + | | + | | | | | | |
| EUPHORBIACEAE | *Ricinus communis* | | + | + | | | | | | |
| | *Tamarindus indica#* | | | + | | | | | | |
| STRELITZIACEAE | *Ravenala madagascariensis#* | + | | + | | | | | | |
| Vines and scramblers | | | | | | | | | | |
| ACANTHACEAE | *Thunbergia alata#* | | + | | | | | | | |
| ARACEAE | *Monstera deliciosa#* | | + | + | | | | | | |
| | *Syngonium podophyllum#* | + | + | + | | | | | | |
| ASCLEPIADACEAE | *Cryptostegia grandiflora* | | | | | | | | + | + |
| ASTERACEAE | *Wedelia trilobata #* | + | + | + | + | | | | | |
| COMBRETACEAE | *Quisqualis indica#* | + | | | | | | | | |
| CONVOLVULACEAE | *Merremia dissecta* | | | | | | | | + | |
| | *Merremia quiniquefolia* | | + | + | | | + | + | + | |
| FABACEAE | *Clitoria ternatea* | | + | + | | | | | | |
| PASSIFLORACEAE | *Passiflora foetida* | + | + | + | | | | | | |
| POLYGONACEAE | *Antigonon leptopus#* | | | | | | + | | | |

## APPENDIX C: BIRD LIST FOR GUSTAV CREEK VINE FOREST (V) AND OTHER TERRESTRIAL VEGETATION COMMUNITIES (T), AND INCLUDING BIRDS LISTED FOR THE AREA BY WIENEKE (W) (1988).

| FAMILY (SUBFAMILY) | COMMON NAME | SCIENTIFIC NAME | V | T | W |
|---|---|---|---|---|---|
| Megapodiidae | Orange-footed scrubfowl | *Megapodius reinwardt* | x | | |
| Turnicidae | Red-backed button-quail | *Turnix maculosa* | | | x |
| Rallidae | Buff-banded rail | *Gallirallus philippensis* | x | | |
| | Bush-hen | *Amaurornis olivaceus* | | | x |
| Scolopacidae | Ruddy turnstone | *Arenaria interpres* | | | x |
| | Grey-tailed tattler | *Heteroscelis (Tringa) brevipes* | | | x |
| | Greenshank | *Tringa nebularia* | | | x |
| | Sharp-tailed sandpiper | *Calidris acuminata* | | | x |
| Burhinidae | Bush stone curlew | *Burhinus grallarius* | | x | |
| Accipitridae | Pacific Baza | *Aviceda subcristata* | | x | |
| | Black kite | *Milvus migrans* | | x | |
| | Whistling kite | *Haliastur (Milvus) sphenurus* | | x | |
| | Brahminy kite | *Haliastur (Milvus) indus* | | x | |
| | Wedge-tailed eagle | *Aquila audax* | x | | |
| | Brown goshawk | *Accipiter fasciatus* | x | | |
| | Collared sparrowhawk | *Accipiter cirrhocephalus* | x | | |
| | Grey (white)goshawk | *Accipiter novaehollandiae* | x | | |
| Falconidae | Peregrine falcon | *Falco peregrinus* | x | | |
| Columbidae | Wompoo fruit-dove | *Ptilinopus magnificus* | x | | x |
| | Superb fruit dove | *Ptilinopus cinctus* | x | | x |
| | Rose-crowned fruit-dove | *Ptilinopus regina* | x | | |
| | Torresian imperial-pigeon | *Ducula bicolor* | x | | |
| | Topknot pigeon | *Lopholaimus antarcticus* | x | | x |
| | White-headed pigeon | *Columba leucomela* | x | | x |
| | Feral pigeon (Rock dove) | *Columba livia* | | x | |
| | Brown cuckoo-dove | *Macropygia amboinensis* | x | | |
| | Peaceful dove | *Geopelia placida* | | x | |
| | Bar-shouldered dove | *Geopelia cuneata* | x | | |
| | Emerald dove | *Chalcophaps indica* | x | | |
| | Common bronzewing | *Phaps chalcoptera* | | x | x |
| Cacatuidae | Red-tailed black cockatoo | *Calyptorhynchus banksii* | | | x |
| | Galah | *Eolophus (Cacatua) roseicapillus* | | x | |
| | Little corella | *Cacatua sanguinea* | x | | |
| | Sulphur-crested cockatoo | *Cacatua galerita* | x | | |
| Psittacidae | Rainbow lorikeet | *Trichoglossus haematodus* | x | | |
| | Scaly-breasted lorikeet | *Trichoglossus chlorolepidotus* | x | | |
| | Double-eyed fig-parrot | *Cyclopsitta diopthalma* | | | x |
| Cuculidae | Oriental cuckoo | *Cuculus saturatus* | x | | |
| | Pallid cuckoo | *Cuculus pallidus* | x | | |
| | Brush cuckoo | *Cacomantis (Cuculus) variolosus* | x | | |
| | Fan-tailed cuckoo | *Cacomantis (Cuculus) flabelliformis* | x | | |
| | Horsfield's bronze cuckoo | *Chalcites (Chrysococcyx) basalis* | x | | |
| | Shining bronze-cuckoo | *Chalcites (Chrysococcyx) lucidus* | x | | x |
| | Common koel | *Eudynamys scolopacea* | x | | |
| | Channel-billed cuckoo | *Scythrops novaehollandiae* | x | | |
| Centropodidae | Pheasant coucal | *Centropus phasianinus* | x | | |
| Strigidae | Southern boobook | *Ninox novaeseelandiae* | x | | x |
| Tytonidae | Eastern grass owl | *Tyto capensis* | | | x |
| Caprimulgidae | White-throated nightjar | *Eurostopodus mystacalis* | | | x |

| | | | | | |
|---|---|---|---|---|---|
| Caprimulgidae | White-tailed nightjar | *Caprimulgus macrurus* | x | | |
| Apodidae | White-rumped swiftlet | *Aerodramus (Collocalia) esculenta* | | x | x |
| | Fork-tailed swift | *Apus pacificus* | | x | |
| Alcedinidae | Little kingfisher | *Alcedo pusilla* | | x | x |
| Alcedinidae | Laughing kookaburra | *Dacelo novaeguineae* | x | | |
| | Blue-winged kookaburra | *Dacelo leachii* | x | | |
| | Forest kingfisher | *Todiramphus macleayii* | x | | |
| | Red-backed kingfisher | *Todiramphus pyrrhopygia* | | x | |
| | Sacred kingfisher | *Todiramphus sanctus* | x | | |
| | Collared kingfisher | *Todiramphus chloris* | | x | |
| | Buff-breasted paradise kingfisher | *Tanysiptera sylvia* | x | | |
| Meropidae | Rainbow bee-eater | *Merops ornatus* | x | | |
| Coraciidae | Dollarbird | *Eurystomus orientalis* | x | | |
| Pittidae | Noisy pitta | *Pitta versicolor* | x | | x |
| Maluridae, Malurinae | Red-backed wren | *Malurus melanocephalus* | | x | |
| Maluridae , Pardalotinae | Striated pardalote | *Pardalotus striatus* | | x | |
| Maluridae, Acanthizinae | White-throated gerygone | *Gerygone olivacea* | x | | |
| | Mangrove gerygone | *Gerygone levigaster* | | x | |
| | Large-billed gerygone | *Gerygone magnirostris* | | x | |
| Meliphagidae | Helmeted friarbird | *Philemon buceroides* | x | | |
| | Noisy friarbird | *Philemon corniculatus* | | x | |
| | Blue-faced honeyeater | *Entomyzon cyanotis* | x | | |
| | Dusky honeyeater | *Myzomela obscura* | x | | |
| Pachycephalidae | Little shrike-thrush | *Colluricincla megarhyncha* | x | | |
| | Grey shrike-thrush | *Colluricincla harmonica* | x | | |
| | Rufous whistler | *Pachycephala rufiventris* | x | | |
| Dicruridae, Rhipidurinae | Grey fantail | *Rhipidura fuliginosa* | x | | |
| Dicruridae, Rhipidurinae | Rufous fantail | *Rhipidura rufifrons* | x | | |
| Dicruridae, Rhipidurinae | Willie wagtail | *Rhipidura leucophrys* | | x | |
| Dicruridae, Monarchinae | Leaden flycatcher | *Myiagra rubecula* | x | | |
| | Satin flycatcher | *Myiagra cyanoleuca* | x | | |
| | Shining flycatcher | *Myiagra alecto* | | x | |
| | Restless flycatcher | *Myiagra inquieta* | | | x |
| | Black-faced monarch | *Monarcha melanopsis* | x | | x |
| | Spectacled monarch | *Monarcha trivirgatus* | | x | x |
| | White-eared monarch | *Monarcha leucotis* | x | | x |
| | Magpie-lark | *Grallina cyanoleuca* | | x | |
| Dicruridae, Dicrurinae | Spangled drongo | *Dicrurus bracteatus* | x | | |
| Oriolodae | Olive-backed oriole | *Oriolus sagittatus* | x | | x |
| | Figbird | *Sphecotheres viridis* | x | | |
| Campephagidae | Black-faced cuckoo-shrike | *Coracina novaehollandiae* | x | | |
| | White-bellied cuckoo-shrike | *Coracina papuensis* | | | x |
| | Cicadabird | *Coracina tenuirostris* | x | | |
| | Varied triller | *Lalage sueurii* | x | | |
| Artamidae, Artaminae | White-breasted woodswallow | *Artamus leucorynchus* | | x | |
| Artamidae, Cracticinae | Pied butcherbird | *Cracticus nigrogularis* | x | | |
| | Australian magpie | *Gymnorhina tibicen* | | x | |
| | Pied currawong | *Strepera graculina* | x | | |
| Corvidae | Australian raven | *Corvus coronoides* | | x | |
| | Torresian crow | *Corvus orru* | x | | |
| Hirundinidae | Welcome swallow | *Hirundo neoxena* | x | | |
| Sylviidae, Megalurinae | Golden-headed cisticola | *Cisticola exilis* | | x | |
| | Tawny grassbird | *Megalurus timoriensis* | | x | |
| Passeridae | House sparrow | *Passer domesticus* | | x | |
| Estrildidae | Double-barred finch | *Taeniopygia bichenovii* | | x | |

| | | | | | |
|---|---|---|---|---|---|
| | Chestnut-breasted mannikin | *Lonchura castaneothorax* | | x | |
| Nectariniidae | Yellow-bellied sunbird | *Nectarinia jugularis* | X | | |
| Dicaeidae | Mistletoebird | *Dicaeum hirundinaceum* | X | | |
| Sturnidae | Metallic starling | *Aplonis metallica* | | | x |
| | Common myna | *Acridotheres tristis* | | x | |

## APPENDIX D: MAMMALS EXPECTED TO INHABIT THE GUSTAV CREEK CATCHMENT

| **Common name** | **Scientific name** |
|---|---|
| Brush-tailed possum | *Trichosurus vulpecula* |
| Allied rock-wallaby | *Petrogale assimilas* |
| Unadorned rock-wallaby | *Petrogale penicillata assimilis* |
| Echidna | *Tachyglossus aculeatus* |
| Water-rat | *Hydromys chrysogaster* |
| Black flying fox | *Pteropus alecto* |
| Little red flying fox | *Pteropus scapulatus* |
| Feral cat | *Felis catus* |
| Koala | *Phascolarctos cinereus* |
| Queensland tube-nosed bat | *Nyctimene robinsoni* |
| Queensland blossom bat | *Syconycteris australis* |
| Brown horseshoe bat | *Hopposideros ater* |
| Western broad-nosed bat | *Scotorepans balstoni* |
| Troughton's Eptesicus | *Eptesicus troughtoni* |
| Little bent-wing bat | *Miniopterus australis* |

**APPENDIX E: REPTILES AND FROGS OF THE GUSTAV CREEK CATCHMENT**

| REPTILES | Family | Scientific name | QPWS list | JCU |
|---|---|---|---|---|
| | | Oedura castelnaui | | *x* |
| Ocellated velvet gecko | Gekkonidae | Oedura monilis | *x* | |
| | Gekkonidae | *Oedura rhombifer* | x | |
| Prickly gecko | | *Heteronotia binoei* | x | x |
| | | *Gehyra dubia* | x | x |
| Legless lizard | | *Delma labialis* | x | |
| Burton's legless lizard | Pygopodidae | *Lialis burtonii* | x | x |
| | Varanidae | *Lialis timorensis* | | x |
| Monitor | Varanidae | *Varanus tristis* | x | |
| Skink | Scinidae | *Carlia jarnoldae* | | x |
| | | *Carlia pectoralis* | x | x |
| | | *Carlia rhomboidalis* | x | x |
| | | *Carlia schmeltzii* | x | x |
| | | *Cryptoblepharus virgatus* | x | x |
| | | *Cryptoblepharus littoralis* | x | |
| | | *Ctenotus eutaenius* | x | x |
| | | *Ctenotus robustus* | x | |
| | | *Lamphropholis mirabilis* | x | x |
| | | *Lygisaurus foliorum* | x | |
| | | *Lygisaurus timlowi* | x | |
| | | *Menetia greyi* | | x |
| | | *Morethia taeniopleura* | x | x |
| | | *Glaphyromorphus punctulatus* | x | x |
| | | *Sphenomorphus tenius* | *x* | |
| | | *Tiliqua scinoides* | | x |
| Spotted python | | *Liasis maculosus* | x | |
| Freshwater snake | | *Tropidonotus mairii* | x | |
| Brown tree snake | | *Boiga irregularis* | x | |
| Common tree snake | | *Dendrelaphis punctulatus* | x | |
| Death adder | | *Acanthophis antarcticus* | x | x |
| Black whip snake | | *Demansia atra* | x | |
| Collared whip snake | | *Demansia torquatus* | x | |
| Orange-naped snake | | *Furina ornata* | x | x |
| Cane toad | | Bufo marinus | | x |
| Tree frog | | *Litoria caerulea* | | x |
| Tree frog | | *Litoria lesueuri* | | x |

## APPENDIX F: COMMON BUTTERFLIES OF GUSTAV CREEK VINE THICKET

| Scientific Name | Common name | Comments |
|---|---|---|
| *Euploea core* | Common crow | Overwinters in vine thicket |
| *Euploea tulliolus* | | |
| *Tirumala hamatas* | | Overwinters in vine thicket |
| Malanitis leda | | |
| ***Mycalesis terminus*** | | |
| *Eurema hecabe* | | |
| *Cepora perimale* | | |

## APPENDIX G:SUMMARY OF WATER QUALITY GUIDELINES FOR RECREATIONAL WATERS (ANZECC 1992)

**APPENDIX I: WATER QUALITY DATA FROM GUSTAV CREEK, DECEMBER 7TH AND 15TH 1999.**

| **COLLECTION DATE 7/12/99** | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **Sample 1** | **Sample 2** | **Sample 3** | **Sample 4** | **Sample 5** |
| Time | 11.10 | 11.50 | 12.45 | 13.50 | 14.25 |
| pH | 8.51 | 7.30 | 8.08 | 7.03 | 8.36 |
| Conductivity µS/cm | 351 | 248 | 238 | 275 | 426 |
| Turbidity NTU | 2.5 | 2.8 | 67.4 | 1.3 | 34.4 |
| Colour Pt/Co apparent/true | 17/9 | 26/12 | 256/5 | 16/13 | 148/20 |
| Suspended solids mg/l | 2 | 1 | 41 | | 17 |
| Total N mg/l | 0.29 | 0.20 | 0.48 | 0.24 | 0.32 |
| Total filtered N mg/l | 0.21 | 0.20 | 0.48 | 0.24 | 0.32 |
| Total P mg/l | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Total filtered P mg/l | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Chloride mg/l | 87 | 60 | 50 | 74 | 91 |
| Sulphate mg/l | 8 | 10 | 11 | 7 | 18 |
| Ammonia µg/l | 18 | <5 | 85 | <5 | <5 |
| Dissolved Nitrate as N mg/l | 0.09 | 0.02 | 0.24 | 0.05 | 0.02 |
| Dissolved phosphate as P mg/l | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 |
| Faecal coliform organisms/100ml | 2900 | 4600 | 1800 | 1300 | 210 |
| *E. coli* organisms/100ml | 490 | <10 | 50 | 900 | 210 |
| **COLLECTION DATE 15/12/99** | | | | | |
| Faecal coliform organisms/100ml | 260 | 190 | 800 | 1200 | 200 |
| *E. coli* organisms/100ml | 40 | <10 | 60 | 300 | 60 |

## APPENDIX J: SUMMARY OF THE RELEASE QUALITY CHARACTERISTIC LIMITS FOR SEWAGE EFFLUENT UNDER THE TERMS OF THE LICENCE FOR THE NELLY BAY SEWAGE TREATMENT PLANT.

| QUALITY CHARACTERISTIC | RELEASE LIMIT | LIMIT TYPE |
|---|---|---|
| **BOD** five day | 20 mg/L | Long term 80 percentile |
| **BOD** five day | 35 mg/L | Short term 80 percentile |
| **BOD** five day | 58 mg/L | Maximum |
| **Suspended solids** | 30 mg/L | Long term 80 percentile |
| **Suspended solids** | 45 mg/L | Short term 80 percentile |
| **Suspended solids** | 8 mg/L | Maximum |
| **pH** | 6.5 to 8.5 | Range |
| **Dissolved oxygen** | 2 mg/L | Minimum |
| **Faecal coliforms**, based on a minimum of 5 samples collected at not less than weekly intervals | 1000 colonies per 100 mL sample | Median |
| **Faecal coliforms**, based on a minimum of 5 samples collected at not less than weekly intervals, with 4 out of 5 samples containing less than the maximum specified | 4000 colonies per 100 mL sample | Maximum |

N.B. Long term 80 percentile is measured over 50 consecutive samples.
Short term 80 percentile is measures over 5 consecutive samples.
Samples shall be grab samples taken at fortnightly intervals.

## APPENDIX K:INSTALLATION DETAILS FOR INSPECTION BORE DOWNSLOPE FROM THE NELLY BAY STP.