BALLINA SHIRE COUNCIL

SHAWS BAY, EAST BALLINA
ESTUARY MANAGEMENT PLAN

Volume 1
ESTUARY PROCESSES STUDY REPORT

FINAL

Issue No. 3
JANUARY 2000

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Document Amendment and Approval Record

Issue	Description of Amendment	Prepared by [date]	Verified by [date]	Approved by [date]
1	Draft for Committee Comment	PH	BMD	
2	Revision for Public Exhibition	PH	BMD	
3	Final	EC (24.12.99)	BMD (24.12.99)	

Note: This document is preliminary unless it is approved by a principal of Patterson Britton & Partners.

Document Reference: J3320/R2147
Time and Date Printed: 2:26 PM 4 January 2000

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1 INTRODUCTION

1.1 STUDY SETTING

Shaws Bay is a small tidal embayment located adjacent to the mouth of the Richmond River at Ballina. Around the turn of the century, training walls for the Richmond River were constructed to improve navigation through the entrance. The northern Richmond River training wall / breakwater was constructed a distance of approximately 700 metres south of the North Head headland and transected the then open entrance shoals.

With time, marine sands worked their way into the coastal embayment which was formed on the northern side of the northern training wall. A small water body at the western edge of the embayment is all that remains of the former Richmond River entrance channel. This water body is known as Shaws Bay.

Shaws Bay has been utilised by the local community for a long time, as the enclosed nature of the bay offers an environment which is protected from large waves, boating traffic and most marine stingers. Good sandy access into the water along the majority of the bay's foreshore, and a wide variety of fish life enclosed within the bay, have contributed to its popularity as one of Ballina's most utilised water-based recreational areas.

In recent years, seagrasses have begun to establish along much of the bay's shoreline. Although seagrasses have been present in the East Arm of the bay for many years, their encroachment onto the foreshores has been perceived by the community to be of major concern. In 1998, Ballina Shire Council formed the Shaws Bay Estuary Management Committee to address all future management issues concerning Shaws Bay, including the recent appearance of seagrasses. The Committee resolved to

> "*improve the recreational amenity of Shaws Bay and to ensure that the habitat and ecological values of the bay are maintained within an acceptable range*".

The Committee identified the key issues which they perceived to be of most concern to Shaws Bay, and which would need to be addressed to meet their management goal, as follows:

Tidal Exchange	between Shaws Bay and the Richmond River
Sedimentation	and its impact on recreational amenity and tidal exchange
Seagrass growth	and its affect on recreational amenity
Stormwater Runoff	and resulting poor water quality
Stormwater Management	associated with the 17 stormwater outlets draining into the bay
Foreshore Access	management and improvements

Fish Passage	between Shaws Bay and the Richmond River
Foreshore Vegetation	management and protection of important species
Conflicts	between the recreational use and the bay's natural environment
Improvements to Recreational	public reserves around the bay foreshores
Caravan Park	development and consistency of management objectives
Long-term Conservation	of important natural values of Shaws Bay

The overall outcome of the Committee is to be a balanced, long-term management plan of Shaws Bay, which addresses the above issues within the context of satisfying the Committee's overall goal.

1.2 THE ESTUARY MANAGEMENT PROCESS

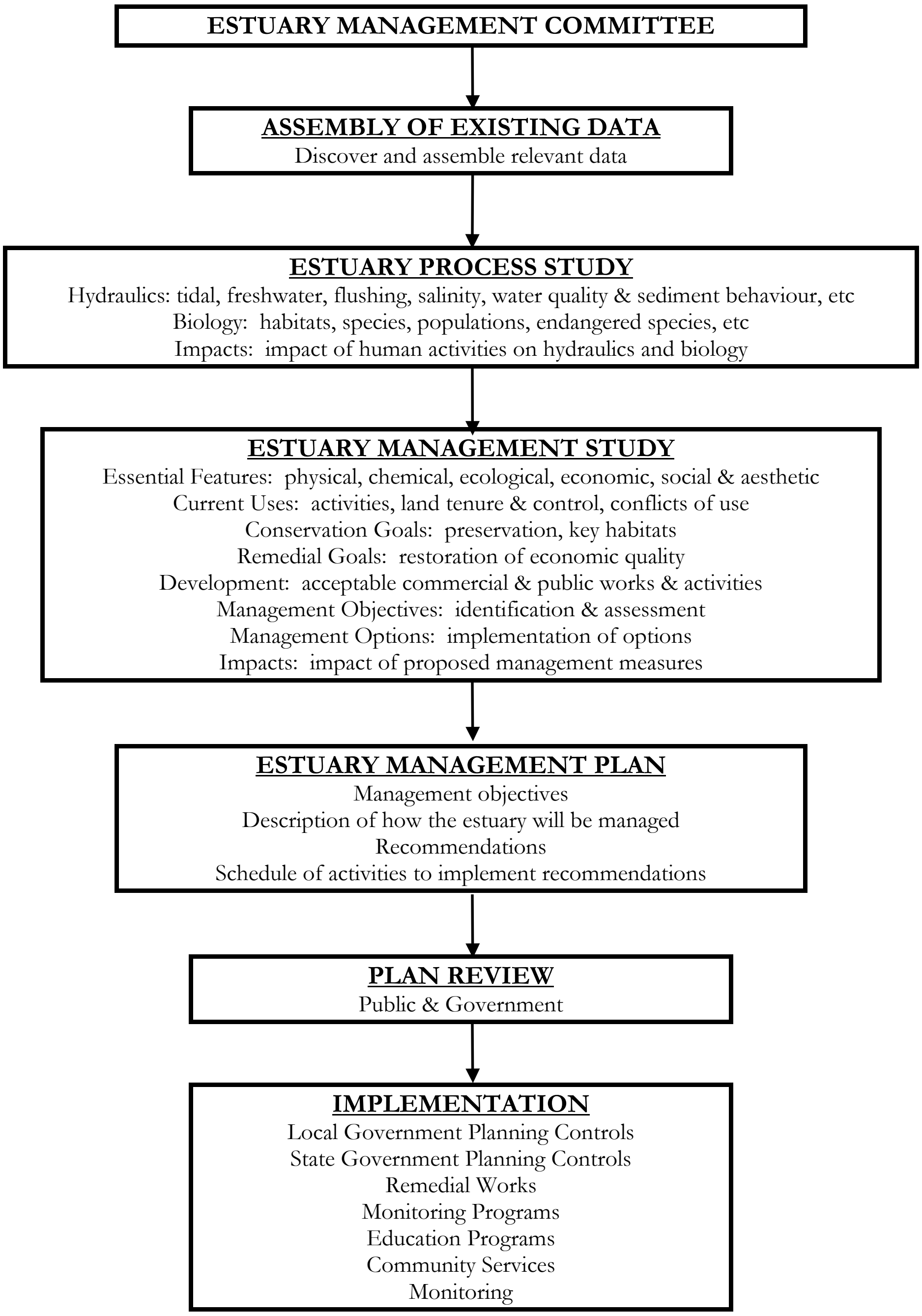
In 1987, the NSW State Government introduced an *Estuary Management Policy*, aimed at managing the growing pressures on estuarine ecosystems. The process of managing an estuary, in accordance with this Policy, is initiated by the establishment of an Estuary Management Committee. This Committee is then responsible for the development of an Estuary Processes Study, which outlines all the hydraulic, sedimentation, water quality and ecological processes within the estuary, and the impacts of human activities on these processes.

The Estuary Processes Study provides the necessary understanding of physical and biological processes for an Estuary Management Study. The Management Study identifies the essential features and the current uses of the estuary, and determines the overall objectives required for management of the estuary. The Management Study also identifies options for meeting these objectives, and determines hydraulic and ecological impacts of the proposed options.

From the findings of the Management Study, an Estuary Management Plan is prepared. The Plan describes how the estuary will be managed, gives recommended solutions to management problems, and details a schedule of activities for the implementation of the recommendations. Once the Plan has been accepted by both the Community and the relevant Government Departments, the Plan can be implemented through planning controls, works programs, monitoring programs, and education services.

This report (*Volume 1*) documents the findings of an Estuary Processes Study of Shaws Bay. It identifies and assesses the main hydrodynamic, sedimentation, water quality and ecological processes within the estuary. The impacts of human activities on all estuary processes have been reviewed to develop a list of issues which require more detailed consideration in the next phase of the Estuary Management Program; the Estuary Management Study and Plan, which will be documented in *Volume 2* of this series.

The general estuary management process, as established by the NSW Government, is as follows:



2 COMMUNITY CONSULTATION

Shaws Bay is recognised as a highly valued asset to the local community of East Ballina. As such, the Estuary Management Committee required an extensive program of consultation with the community. The main objective of this community consultation was to fully appreciate the issues associated with the bay, and to give the community an opportunity to have an input into the long term management of the waterway.

The community consultation consisted of a detailed questionnaire, a formal drop-in session, follow-up personal interviews, meetings with Government Authorities and a presentation of preliminary results. A review of archives held at the Richmond River Historical Society was also carried out, as was a review of books discussing the history of Ballina and surrounds.

During field investigations, representatives from Patterson Britton promoted the study and encouraged participation and attendance at the community consultation sessions through advertisements in the local newspapers (The Northern Star, North Coast Advocate), news-related interviews on the television (NBN News) and radio (2LM), and articles in the local newspaper (The Northern Star).

2.1 QUESTIONNAIRE

A community based questionnaire regarding various aspects of Shaws Bay was prepared at the beginning of the project. Approximately 600 copies of the questionnaire were disseminated throughout the community by letter-drop and post, and were made available at a number of key public access locations, both within the local area and within Ballina generally. A copy of the questionnaire is provided in **Appendix A**. Forty nine responses to the questionnaire were received. This was considered to be a good response given the relatively small community.

The questionnaire was designed to be multi-objective, in that it sought responses to many different aspects of the management of Shaws Bay. The collated responses provided a clear set of results for most of the objectives, as outlined below.

2.1.1 Waterway Usage

The primary activities within the bay and surrounds are shown in **Table 2.1**.

ACTIVITY	*# OF RESPONDENTS MENTIONING ACTIVITY (total = 49)*
Swimming	42
Walking	10
Snorkelling	9
Fishing	9
Bird Watching	7
Picnicking, BBQ, using playground etc	7
Canoeing, Paddle boating etc	7
Cycling	6
Relaxing etc	4
Bait Collection	2

Table 2.1 Primary Activities within Shaws Bay and Surrounds

Recreational fishers in Shaws Bay usually catch Bream, Flathead and Whiting. Bait for fishing is usually yabbies (collected from either North Creek or Shaws Bay sand flats), prawns (collected from Shaws Bay) or worm and prawns purchased from a bait shop.

The frequency of activities in and around Shaws Bay is shown in **Table 2.2**.

Every day	17
Few times a week	18
Once a week	3
Twice a month	3
Once a month	1
Twice a year	2

Table 2.2 Frequency of Use of Shaws Bay and Surrounds

Thirty two respondents also indicated that they used Shaws Bay and its surrounds more during the summer months than during the winter months.

A map was provided as part of the questionnaire so that respondents could indicate those areas of Shaws Bay that they use for their various activities. The maps which were annotated by the respondents were collated, the result of which is discussed further in **Chapter 8**.

2.1.2 Changes to Aquatic Life

Changes in the health, size, number or diversity of fish or invertebrates were not apparent from the responses to the questionnaire. Only a few changes were noted by two or more respondents, these being (in order of frequency of response):

- Reduction in number of Soldier / Sand Crabs;
- Fish within Shaws Bay are getting bigger;
- Reduction in the number of fish within Shaws Bay;
- Marine life in Shaws Bay has remained unchanged.

Changes to a population over time are difficult to gauge. The fact that the majority of the population is generally out of sight to the general public (ie underwater) makes it very difficult to determine existing numbers, health etc. Therefore, the lack of consistent responses does not indicate an unchanged aquatic environment, but rather, an unnoticed environment.

2.1.3 Changes to Seagrasses

The increase in coverage by seagrasses in Shaws Bay in recent years had been identified by the Estuary Management Committee as one of the main issues in the bay. The questionnaire asked for the community's view on the recent change in the extent and/or health of the seagrasses.

Fourteen respondents indicated that the coverage of seagrasses had increased over the last 2 to 10 years, with this additional coverage extending along the edge of the bay, and encroaching on areas used for swimming, thus making access into and out of the water unpleasant. It was also reported that the seagrasses were taking over former snorkelling areas, and were resulting in reduced tidal flows through the wall.

The health of the seagrasses were generally reported as good (ie lush growth), although there was one response that indicated the colour of the seagrasses had gone from green to brown (possibly coated by silt or algae), and another report that indicated a green slime covered the bottom of the bay about 3 years ago killing the seagrasses. Two respondents also indicated that some patches in the middle of the bay were dying off, possibly indicating the seagrasses were not as healthy in that area.

2.1.4 Siltation / Shoaling

Twenty two respondents indicated that there was siltation within Shaws Bay, while four respondents indicated there was no siltation in the bay. Of those who noted siltation, eleven indicated that it was occurring within the middle of the bay, five indicated siltation along the wall (particularly in the East Arm), three indicated siltation at the outlets of stormwater drains, while siltation was noted, by single respondents, in the northern section of the bay, in front of the Lakeside Holiday Park, along the western foreshore, and throughout the whole of the bay.

2.1.5 Shoreline Erosion

Fourteen respondents indicated that they had observed shoreline erosion within Shaws Bay. The majority of this erosion was identified along the northern shoreline of the East Arm of Shaws Bay. Other areas identified included some sections of Pop Denison Park (particularly after rainfall) and on the western shore, where the beaches are gradually slumping back into the bay after being built-up from the past dredging activities.

It is understood from one respondent that a retaining wall was constructed along the northern wall of the East Arm as part of an RED scheme, and that this wall had stemmed the shoreline erosion.

Eight respondents indicated that they had not noticed any shoreline erosion within Shaws Bay. It is likely that these respondents do not utilise the areas where shoreline erosion is occurring, particularly the northern foreshore of the East Arm.

2.1.6 Fish Kills

Only three respondents indicated that they had observed fish kills. One simply indicated that none had occurred recently, one indicated that a fish kill occurred several years ago in the south-east corner after heavy rainfall, and one indicated that a few fish had been killed near the Lakeside Holiday Park.

The lack of response to the question on fish kills suggests that acidic runoff from acid-sulphate soils in the Richmond River catchment does not affect the marine habitat of Shaws Bay. This is expected, as oceanic salts tend to neutralise the reduction in pH associated with acid sulphate soil runoff.

2.1.7 Algae Blooms

Algae blooms have not been observed in Shaws Bay by any of the questionnaire respondents.

2.1.8 Pollution

Twenty respondents indicated they had observed general pollution within Shaws Bay. This pollution was identified as having a number of sources, the most popular being the stormwater drains. Also identified was general pollution left by picnickers in Pop Denison Park and general refuse associated with the Shaws Bay Hotel. Also of concern were fishing lines left on the rock wall, and the odour emanating from the stormwater drains after rainfall. The water within Shaws Bay was observed as going brown after rainfall, however, this is related to sediment suspended in the water column, and not general pollution.

Seventeen respondents also indicated that they had observed slicks in the bay. The slicks were generally observed as an oily (or possibly detergent) film on the surface of the water, with some respondents indicating that the slicks concentrated at the northern end of the bay.

2.1.9 Foreshore Vegetation

Sixteen respondents indicated that the foreshore vegetation had changed in recent years, with the majority of these respondents referring primarily to the spreading of mangroves. Also of concern to the community, however, is the Burr Grass in front of the Shaws Bay Hotel, the spreading of the couch grass over the sandy beach areas, the spreading of spiky Buffalo Grass, the loss of shade trees, and the loss of ground cover from trampling and children pulling up the grass.

2.1.10 General Health of Bay

Some of the issues raised in this question included:

- Water quality of the bay is bad after rainfall;
- A green paper-like slime is killing seagrasses in some areas;
- Areas surrounding stormwater drains are dirty and smelly;
- Tidal flows have been restricted; and
- The water has become saltier, giving the impression that flushing is bad.

2.1.11 Main Issues or Problems

To supplement the list provided by the Estuary Management Committee, the general community were also asked to identify the main issues or problems which they thought affected the long-term management of Shaws Bay. The community identified a number of issues, which are shown in **Table 2.3**.

ISSUE / PROBLEM	*# OF RESPONDENTS MENTIONING ISSUE (total = 49)*
Stormwater drains / runoff	22
Siltation / shoaling	17
Too much seagrass	14
Reduced tidal flow / stagnant northern end	11
Weed growth	7
Erosion (general)	6
Overfishing	6
Public access (disabled also)	6
Need of facilities within bay area	5
Protection of aquatic life / habitat	4
Protection of terrestrial flora /fauna	4
Need for sand on beaches	4
Rubbish	3
Need for shade	3
Lack of beautification	3
Restriction of dogs swimming	3
Too many mangroves	3
Pollutant input	2
Tropical fish removal / catching	1
Sand flies	1
Decline of people using bay	1
Misuse of Pop Denison Park at night	1
Public health issues	1

Table 2.3 Main Issues or Problems Affecting Shaws Bay

As can be seen in this table, nearly 45% of all respondents indicated that catchment runoff entering the bay through the stormwater drains was a major issue, while approximately 35% of respondents indicated that siltation of the bay was also a long-term management concern.

29% of respondents indicated that there was too much seagrass within the bay and was affecting their primary activities of swimming and snorkelling, while 22% of respondents were concerned that there was not enough tidal flushing of the northern end of the bay.

2.1.12 Management Options

When asked what they thought should be done to Shaws Bay to address their main management issues, the community responded with a range of suggestions, as outlined in **Table 2.4**.

Management Issue / Problem	*Management Options Suggested by Community*
Stormwater	• Divert stormwater drains to the river • Control or restriction of stormwater drainage • Promote vegetation around drains as a filter • Gross Pollutant Traps (GPTs) • Pond stormwater in sand and let filter through
Siltation	• Dredging • Divert stormwater drains to river
Seagrasses	• Interpretive signage to educate public • Removal / eradication of some seagrasses • Add sand to beaches
Reduced tidal flushing of northern end of Shaws Bay	• Enhance tidal flows with pipes through wall • One way flow through secondary pond in Park
Fishing	• Restrict fishing to recreational anglers • Restrict fishing to children only • Enforce no spear fishing • Keep fishers away from swimming areas • Ban fishing from bay entirely
Shoreline vegetation	• Removal or spraying of weeds • Removal/eradication of mangroves
Shoreline erosion	• Bank stabilisation around perimeter • Erosion control (groynes, retaining walls etc)
Recreation Facilities	• Develop Pop Denison Park into sports fields • More showers at swimming access points • More toilets and change rooms • More picnic facilities (eg tables, BBQs etc) • More parking • Public phone • Improved Disabled Access (eg solid path) • More children's play equipment • Kiosk • More rubbish bins (and collection in summer) • Planting of more shade trees

	• Prune lower trees branches to provide shade • Formalise access around foreshore
Protection of aquatic and terrestrial habitats	• Interpretive signage to educate public • Plant appropriate native vegetation / trees
Dogs swimming in bay	• Enforce current dog restrictions • Install more signs saying no dog swimming • Allow dogs to swim in bay
Miscellaneous	• Employ caretaker to enforce restrictions • Carry out environmental studies (SCU) • On-going monitoring program • Appoint managerial committee • Neighbourhood watch program • Consultation with CMC and community • Leave things alone

Table 2.4 Suggested Management Options for Shaws Bay from Community

2.2 DROP-IN SESSION

A formal drop-in session was held from 5 – 9pm on Monday 19 July, 1999 in the La Balsa Room of the Ballina Beach Resort, East Ballina. The drop-in session was attended by about 50 members of the community. The objective of the drop-in session was to give the community an opportunity to provide any information to the consultants (in addition to that provided in the questionnaires), such as recent of historic photographs, plans etc. The session also provided an opportunity for the community to see preliminary results of initial works carried out on the project, results of the questionnaire responses, and allowed the community to reiterate concerns regarding the bay which they had particularly strong views.

Some key points that came out of the drop-in sessions which had not previously been identified were:

- Shaws Bay is an ideal area for kids and other novices to learn to snorkel, swim, fish, wind surf etc, as it is protected from waves and ocean swell, yet still provides a valuable and interesting habitat;
- The beaches along the foreshore were created by dredging the bay. This dredged material is now slowly working its way back into the bay;
- Better drainage is required to redirect the groundwater flow under Compton Drive, rather than over it;
- Access is required right around the bay, including in front of the Shaws Bay Hotel;
- Seagrasses were planted in Shaws Bay during the war years, possibly for the production of medical supplies such as penicillin;

- Before Compton Drive, the western foreshore of Shaws Bay was heavily vegetated with mangroves and other intertidal vegetation;
- A large part of the northern end of Shaws Bay was reclaimed when Compton Drive and the Shaws Bay residential development were constructed;
- Compton Drive was constructed by dredging of the bay in the 60s;
- Seagrasses were removed from the eastern end of the East Arm of Shaws Bay about eight years ago, but they have now re-established;
- There were old oyster beds in front of the Shaws Bay Hotel;
- A pipe at the water reservoir on Pine Avenue ruptured in the mid 80s, resulting in high velocity flooding and scour of adjacent Pine Avenue properties, and the deposition of a large quantity of scoured sediment on Compton Drive adjacent to the road reserve. This sediment was approximately 6 foot thick and had to be trucked away.

2.3 PERSONAL MEETINGS WITH COMMUNITY MEMBERS

Additional meetings with selected members of the community were carried out to follow-up on information provided previously and to gain a better understanding of specific issues relating to Shaws Bay. Meetings were held with Mr Jack Trevan, Mr and Mrs Lloyd and Connie Roberts, Mr Stan Lavender (operator of dredge in Shaws Bay in the 80s), Mr Mick O'Connor (Head of Science, Ballina High School) and Mr Peter Roberts (operator of paddle boats on Shaws Bay during summer).

Additional information collected from these personal meetings included:

- The diversity of fish species within the bay is high (with photos of selected species);
- Dredging of Shaws Bay was carried out in the early 80s, and then the late 80s. Material was removed to a depth of 12 feet, and pumped onto the beaches. Most of the bay was already at, or lower than 12 foot, except for the north-west corner of the bay, where depths were about 6 foot. The second dredging exercise extracted very little material. The shoal in the middle of the bay could have been accidentally missed by the dredging exercise.
- Ballina High School uses Shaws Bay for teaching students to swim, snorkel and row, as it is a good protected environment. The School would be interested in any ecological-based activities in Shaws Bay, such as transplanting and nurturing seagrasses and mangroves.
- Seagrasses in front of the Shaws Bay Hotel are moving northwards at a rate of about 3m/year.
- There is no conflict between people swimming in the bay and people using the paddle boats.

2.4 MEETINGS WITH AUTHORITIES

Representatives from Patterson Britton met with Sarah Fairfull of NSW Fisheries, and Richard Hagley and Gerry Ryan of the Department of Land and Water Conservation to discuss issues relevant to Shaws Bay. Significant factors coming out of these discussions included:

- The removal of seagrasses from within Shaws Bay would generally not be approved. However, the authorities might consider the removal of juvenile plants, as they become established in a small number of specified locations around the foreshore.
- Any major disturbance of existing habitat areas would generally not be approved. This includes raking of beaches or changes to the beach substrate in order to minimise the likelihood of biting midge breeding and larvae development.
- Works should not be carried out which are likely to impact on the existing seagrass beds. This includes putting pipes through the wall which would allow low tide in the bay to become lower.
- Pipes through the wall to promote fish passage are unlikely to be used by fish due to the high currents that would generally flow through the pipes. The passage may, also allow marine stingers to get into the bay. At present, the bay is protected from most stingers by the porous rock wall.

2.5 RICHMOND RIVER HISTORICAL SOCIETY AND HISTORICAL BOOKS ON BALLINA

The archives of the Richmond River Historical Society at Lismore were reviewed for information which may be relevant to this study. A number of items were found, which are presented in **Appendix B**, and are summarised below:

<u>The Ballina-Tintenbar Leader, 5 May, 1950</u>
Letter to the Editor by Windsor Lang who was concerned that the infilling of the East Arm of Shaws Bay was threatening the swimming area of Shaws Bay. He suggested pumping out the "sand and mud" which had accumulated over the sand flat on the East Arm of the bay. Also worthy of noting in the letter is reference to a statement by the Late James Ainsworth, who said "[Shaws Bay's] foreshores were literally piled high with the wreckage of vessels innumerable which had been 'lost on the bar'", and the fact that Shaws Bay had, at the time (1950), picturesque tree-clad foreshores on the western margin.

<u>The Northern Star, 12 December, 1981</u>
This article describes the reasoning behind the construction of breakwaters at the Richmond River entrance.

<u>Talk on Ballina Breakwaters, Mrs J Bell, August, 1955</u>
Discussed what the entrance was like before the breakwaters, and outlined the report prepared by Sir John Coode. Coode's report was accepted by Parliament, and the entrance works at the Richmond River entrance were carried out around the turn of the century, which included the construction of two parallel breakwaters, and the dredging of a navigation channel in between. The document describes how the breakwaters were constructed, and the difficulties faced during construction. With regard to Shaws Bay, the document indicated that the 'charming' waterway was unfortunately faced with its own silting problem. It is assumed that in 1955, the silting problem referred to was the build-up of sand in the East Arm as a result of storm waves breaking through the foredunes of the developing Lighthouse Beach, and the ingress of dune sand by wind transport.

Construction of Ballina Breakwaters, 1961
In an extract from a limited release booklet titled "Education and the Community", which occasioned the centenary of public education in Ballina, the article again outlines the politics and details of the construction of the Richmond River entrance training walls at the turn of this century.

Summerland News Pictorial, 18 May, 1967
Shows an old photograph of the old swimming hole at Shaws Bay. The swimming hole was an old quarry pit which was excavated to provide material for the construction of the northern breakwater. At the time of publication, the swimming hole had already been filled and was being used for the Shaws Bay Caravan Park, which remains its current use.

How the Richmond River could be opened up
Is a sketch by Captain JH Springall of the steamer 'Coraki', showing his suggestion for improving the entrance of the Richmond River. The sketch was drawn around 1883, prior to the release of Sir John Coode's report.

Survey of the Richmond River Entrance, 1853
Is an artistic-type sketch of the Richmond River entrance in 1853 showing the entrance shoals at the time, and depths through the main entrance channel, which was located in approximately the same position as the current channel. The soundings indicate that the depth over the entrance bar was about 11 feet. Shaws Bay, in this sketch, was a backwater area, with a large delta shoal extending south-west from North Head towards the Pilot Station.

1864 Survey
Is a more detailed survey showing soundings throughout the river entrance area. The lack of soundings in some areas indicated shallow intertidal shoals. This survey also shows that Shaws Bay was open to the ocean via The North Channel, which ran adjacent to the North Head, and connected the deeper parts of Shaws Bay with the ocean via a shallow bar with variable depth. In 1885, the SS Lismore was wrecked in 8 foot of water trying to cross the bar at this location. The entire area around the former North Channel was filled and now houses the Shaws Bay residential development.

In addition to the above articles relating to Shaws Bay, there has been two books produced by Ballina Shire Council which document the history of Ballina. Both of these books provide some historical accounts of Shaws Bay, as well as some very good historical photographs of the Shaws Bay area.

Across Three Bridges

- The area around Shaws Bay, particularly in the vicinity of the Kiosk (now the Shaws Bay Caravan Park) was very popular during warm summer days, with crowds estimated up to 5000.
- The Shaws Bay residential development was initiated in the late 1950s by the Department of Lands, with the first lots being sold in the early 1970s.

- In 1972, it was reported that there had been no significant silting in Shaws Bay near the breakwater for about 10 years, but records had not been kept for the balance of the waterway area.
- Dredging was carried out in 1975 and repeated in September 1982, with the provision that all dredged material was to stay on-site, and that the maximum depth was to be 2 metres below low water.
- The Norfolk Pine Tree along side the Shaws Bay Hotel was measured to be approximately 108 feet (33 metres) high in 1973.

<u>Port of Richmond River, Ballina 1840's to 1980's</u>

- Gives a very good account of the shipping that existed around the turn of the century, and the building of the breakwaters, with some good historical photographs.
- Shows a picture of an old slippery dip adjacent to the concrete steps at the southern end of Shaws Bay.
- Also shown is a good panoramic view of the beach inside the river entrance, just outside Shaws Bay, which was reproduced in the Summerland News Pictorial 18/4/1968. A good description of the key features of the photo was put together by an old timer in response to these photos.

<u>Between Wind and Water</u>
This book, written by Lenore Coltheart for the Department of Public Works and Services, describes the history of the ports and coastal waters of New South Wales. As well as providing a brief history of the Richmond River entrance training works, it contains an old photograph of Fenwick House and Shaws Bay in the 1930s. Of particular note in the photo is the low profile of the sandy area behind the Shaws Bay lagoon, which is considerably lower than the foredunes of Lighthouse Beach further behind. A copy of this photo is also shown in **Appendix B**.

3 CATCHMENT CHARACTERISTICS

3.1 CLIMATE

Shaws Bay falls within the Bureau of Meteorology Rainfall District 58, with an annual average rainfall of 1,689mm (MHL, 1999, MHL, 1996). Summer weather on average provides most of this precipitation total (approx. 65%) with heavy periodic rains, high temperatures and humidity. Winter weather supplies milder temperatures and some significant rain. Average daily temperatures vary from 19°C to 27°C in summer, and from 10°C to 19°C in winter (BOM, 1988).

Over the period from 1992-1996, the annual rainfall was consistently less than (roughly 60% of) the long-term average (MHL, 1999). Of important note, however, is the significant amount of precipitation which has taken place so far in 1999, with nearly 1900mm falling in the first half of the year.

Evaporation at Shaws Bay would be similar to that measured at the Alstonville Tropical Fruit Research Station, which has a median annual value of 1,535mm. Mean daily evaporation varies from about 5.5mm in summer to about 3mm in winter.

The dominant wind, as measured at Ballina Airport is, on average, from the south-east, with a speed 3.4 m/s. However, tropical cyclones during the period January to April may cause extreme winds, which are generally from the east and north-east.

3.2 TOPOGRAPHY, GEOLOGY AND SOILS

The topography of the Shaws Bay catchment falls into two categories:

- Steep, heavily vegetated escarpment, on the fringes of the catchment; or
- Flat, former entrance delta shoals and back barrier beach and washover deposits, which have been filled and compacted to a sound engineering foundation.

The Shaws Bay area was formerly part of the Richmond River entrance. Geologically, the escarpment represents old sea cliffs. The rock is basaltic in nature, and has a relatively thin coverage of sand, remnant from former transgressive dune development and aeolian sand accumulation.

The natural substrate material of the main Shaws Bay catchment (ie the Shaws Bay residential development) is marine sand. It is understood that some material was removed from the Shaws Bay lagoon to fill the development site, however, the majority of the fill material would have been trucked in possibly from North Creek. It is likely that the majority of the fill would also have been marine sand, while loamy material was then placed on top of the fill to an approximate thickness of about 0.5 metres.

The Shaws Bay development area is identified as having soil type XX – Disturbed on the local soil characteristics maps (DLWC), as it has been filled and is not indicative of a naturally formed substrate.

3.3 LANDUSE AND ZONING

Landuse within the Shaws Bay catchment is mostly residential and recreational reserve. The landuse is reflective of the zoning for the area, which is shown in **Figure 3.1**. This figure also shows the boundary of the Shaws Bay catchment.

As well as residential (2a) and Public Open Space (6a), the Shaws Bay catchment also contains a small amount of commercial land (3) and environmental protection lands (7f – scenic escarpment).

The consistency between the landuse and zonings indicates that there is no significant potential for the catchment to be further developed in the future without major changes to the current zoning.

While the majority of the public open space and escarpment area is owned by Council, a section of the escarpment in front of the Sulva Street lookout and reservoir is Crown Land.

3.4 FORESHORE FEATURES

Shaws Bay can be divided into three distinct areas:

- The northern section;
- The middle section; and
- The south-east Arm (referred to as the East Arm for the purposes of this study).

The northern section of the bay has gently sloping sandy beaches around the majority of its foreshore. The eastern shore is backed by Pop Denison Park, while the western foreshore is generally backed by a retaining which supports the Compton Drive road reserve.

The main section of the bay also has gently sloping sandy beaches on the eastern foreshore, which is backed by the Lakeside Holiday Park. The western foreshore is dominated by a retaining wall behind sandy beaches along Compton Drive, sandy beaches in front of the private properties, which includes Fenwick House, the Shaws Bay Hotel and the two adjacent, recently constructed, higher density apartments, and a high retaining wall on front of the Shaws Bay Caravan Park. The southern foreshore of the main section of Shaws Bay contains the rock training wall, which separates Shaws Bay from the Richmond River.

The northern foreshore of the East Arm typically has a low rock revetment, constructed within recent years to stem bank recession. While this has slowed and possibly stopped the recession along most of the foreshore, the western end of the northern foreshore is still experiencing shoreline erosion. The northern foreshore is backed by a public reserve, which continues from the Lakeside Holiday Park around the waterway to the rock training wall at the Coastguard Tower.

The southern foreshore of the East Arm contains the rock wall which trains Richmond River flows through the entrance.

Seventeen stormwater drains discharge into Shaws Bay from various locations around the shoreline, with pipes ranging in size from 100mm to 1200mm in diameter. These stormwater drains represent the major potential sources of pollutants to the bay from the catchment.

The other major source for pollutants into the bay is the Richmond River. Each tide, a large amount of water enters the bay from the river. While this water would generally be oceanic in origin, there may be occasions when pollutants in the river can enter the bay, eg during flood conditions.

The general foreshore features of Shaws Bay are shown in **Figure 3.2**.

3.5 BATHYMETRY

A bathymetric survey of Shaws Bay was carried out in June 1999 by DLWC. The results of this survey are shown in **Figure 3.3**. As shown in this figure, the depth to the bed varies significantly. In the East Arm, the bed is typically -0.5m AHD. At the East Arm delta drop-off, the bed level drops rapidly from –0.5m AHD to a level of between –5m AHD and –6m AHD. The main section of the Shaws Bay has a typical bed elevation of about –3m AHD to –5m AHD, however, there is a shallow section located towards the northern end of the main bay, where the bed is shallower than –2m AHD. Through the northern section of Shaws Bay, the bed elevation varies from between -2.5m AHD and –4.5m AHD.

Dredging of Shaws Bay was carried out in the mid 70s, early 1980s, and then again in the late 1980s. Discussions with the dredge operator for the two latter operations (Stan Lavender) indicated that the bay was dredged to a maximum depth of 12 feet (ie to approximately –3m AHD to –4m AHD, depending on the state of the tide). Mr Lavender indicated that a larger proportion of the bay was already deeper than 12 feet before dredging, and that the majority of material removed from the bay was sourced from the north-west corner, where approximately 6 feet of material was removed. Accurate survey control was not established during the dredging, and pre- and post-surveys were not carried out. Thus, the consistency of the dredging cannot be assured. The higher section in the middle of the bay is likely to have been missed by the dredging exercises, as there is no source for the isolated accumulation of such sediment between the 1980s and present.

4 TIDAL AND FRESHWATER HYDRODYNAMICS

4.1 EXISTING INFORMATION

Very little tidal or freshwater hydrodynamic information has been collected in or around Shaws Bay in the past. Available information is summarised below:

- Design drawings for the piped drainage system of the Shaws Bay residential development, which showed design flows and times of concentrations for the 1 in 10 year ARI rainfall event.
- Tidal levels have been monitored in Shaws Bay on a continuous basis since mid-March 1999. Also available were tidal levels monitored in the Richmond River, at the western end of the southern breakwater (known as the Ballina tide gauge).

4.2 ADDITIONAL DATA COLLECTED FOR THIS STUDY

Additional tidal data was collected as part of the Shaws Bay Estuary Management Plan during the field inspections. This data comprised:

- Tidal levels at five (5) sites around Shaws Bay and in the Richmond River, measured over an 8 hour period;
- Tidal velocity measurements in the main flow channel along the East Arm of Shaws Bay; and
- Velocities measurements of flow jets through the rock wall during the rising tide.

4.3 TIDAL HYDRAULICS OF SHAWS BAY

4.3.1 Comparison of Shaws Bay and Richmond River Tidal Levels

Figure 4.1 shows a comparison of tidal levels in Shaws Bay and the Richmond River during a typical spring tide. Two distinct features are shown by this comparison:

1. Low tide levels in Shaws Bay are not as low as low tide levels in the river. This is most likely due to a build-up of sediment within the rock wall, and on the Shaws Bay side of the wall, which effectively acts like a weir, keeping low tide water levels in Shaws Bay perched above the river levels.
2. High tide levels in Shaws Bay are very similar to the high tide levels in the Richmond River. This indicates that water from the river can enter Shaws Bay without any major restriction through the rock wall.

Note that Shaws Bay tidal levels were adjusted to compensate for an apparent uncertainty in gauge datum level. A 0.50m adjustment was made to the recorded Shaws Bay tidal levels to be relative to Richmond River Valley Datum (RRVD). Conversion to Australian Height Datum (AHD) was then carried out based on 0m AHD = 0.81m RRVD. Ballina tide gauge levels were recorded relative to LWOST, which is –0.86m AHD.

Complete records of tidal levels for Shaws Bay and the Richmond River over the period 18/3/99 to 6/7/99 are shown in **Figures 4.2** and **4.3**, respectively. **Figure 4.2** shows that a similar low tide level is achieved in Shaws Bay regardless of spring or neap tides, while a comparison between **Figures 4.2** and **4.3** shows that high tide levels in Shaws Bay are the same as those in the river during both spring and neap tide cycles.

4.3.2 Tidal Level Variations Within Shaws Bay

Tidal levels were recorded at five (5) locations around Shaws Bay for an eight (8) hour period on 21/7/99. Monitoring was carried out using temporary tide boards, which had been installed and levelled by Council's Surveying Department. The locations of these temporary tide boards are shown in **Figure 4.4**.

Figure 4.5 shows the variation of water levels through the tide at the five sites. A number of features can be identified from this figure:

- Tide boards 2, 4 and 5, which are located within the main, deeper sections of the bay, are all essentially the same (within the limits of accuracy), indicating that the vast majority of the bay acts as a level pool (ie no significant variation from north to south);
- There is a typically 0.1 metre difference in water level between the gauge at the end of the East Arm, and those gauges within the deeper sections of the bay. This water level difference is indicative of a sizeable flow along the East Arm of Shaws Bay during both the ebb and flood states of the tide;
- There is an approximate 0.1 metre difference in water level between the gauge in the river, and the gauge at the end of the East Arm. This difference indicates that water is passing through the wall with a reasonably significant head loss;
- There is an approximate 30 – 45 minute lag between high tide in the adjacent river and high tide in the main section of Shaws Bay;
- There is no difference in tidal levels or times between the main section of Shaws Bay and the northern section of the bay.

4.3.3 Distribution of Flow Through the Rock Wall

The distribution of flow through the rock wall was assessed during the incoming (flood) and outgoing (ebb) tides on 22/7/99. An estimate of the relative flow distribution through the wall is shown in **Figure 4.6**. During the incoming tide, once the water level in the river exceeds the water level in Shaws Bay, water starts to flood through the rock wall. Between the western end of the wall and the eastern end of the mangroves, very little water passes through the wall. Over this section, sand and finer sediment has built-up within and against the rock wall effectively creating an impervious structure. It is also possible that the core of the wall in this section of the wall has been impermeable since construction. Concrete steps on the Shaws Bay side of the wall, which extend below low water level, also inhibit the ingress of river water into the bay at this location.

Flow into the bay appears to be highest adjacent to the mangroves, and gently tapers off with distance eastward. The higher flows near the mangroves would likely be the result of a greater water level difference between the river and the bay (ie closer to 0.2m typical difference, as compared to 0.1m typical difference at the eastern end of the East Arm – refer **Section 4.3.2**).

Outgoing (ebb-tide) flows are likely to be similar for the majority of the tide, with more of the flow through the wall concentrating near the eastern end of the mangroves. However, once tidal levels are low (ie less than about 0m AHD), the portals through the wall near the mangroves would no longer convey much flow. During these times, the flow is directed to the eastern end of the East Arm, where it is then channelled into a limited number of deeper portals. The shallow depth and high friction associated with the flow traversing this greater distance contributes to the perching effect of the bay at low tide.

The average head loss through the wall over the section of inflow was assumed to be approximately 0.1 metres. Based on standard hydraulic principles, the effective area of the rock wall (ie the area capable of conveying flow) was determined to be about 20% of the total area, ie wall porosity is about 20%, with an average conveyance of about 0.015m^3/s per lineal metre.

Actual flow through each portal in the wall would vary significantly depending on its physical size. Flows through large portals were measured up to 0.06m^3/s per portal on the incoming tide of 22/7/99, with such portals located approximately every 5 metres or so along the wall. Given the relatively high velocities through the portals, and a head loss across the wall of approximately 0.1m, the portals could be up to 0.1 – 0.15m in diameter at some locations, however, a more typical size for the majority of the wall would be in the order of 0.01 to 0.02m.

4.3.4 Tidal Velocities

Tidal velocities were measured within the East Arm channel of Shaws Bay during the incoming tide of 22/7/99. In the open sandy sections of the channel, where the depth of flow was typically 0.6 metres deep, velocities were approximately 0.25 to 0.3 m/s. There was little variation in velocity with depth.

Within the sections of the channel that were heavily vegetated by seagrasses, tidal velocities, and hence flows, were significantly less. Within the seagrasses, tidal velocities were measured to be about 0.05 to 0.1 m/s, while narrow, sparsely vegetated channels in between seagrass beds had velocities of approximately 0.2 m/s.

The velocity of flow jets through the rock wall were typically of the order of 0.3 m/s, however, velocities were measured up to 0.6 m/s at a number of larger portals. Velocities reduced quickly with distance away (both horizontally and vertically) from the main portals through the wall.

4.3.5 Tidal Prism

The tidal prism of a waterway is the total volume that is exchanged with the ocean (or in this case, the river) each tide. This is simply the volume of water contained in the estuary between low and high tide levels. The tidal prism of Shaws Bay is approximately 130,000m^3 for spring tides and 90,000m^3 for neap tides. The tidal prism of the northern section of Shaws Bay is approximately 13% of the total Shaws Bay tidal prism, ie 17,500m^3 for spring tides and 11,500m^3 for neap tides.

The Tidal Prism Ratio (TPR) is the ratio of the tidal prism volume to the volume contained in the estuary at high tide(ie, TPR = TP / (TP+LW volume)). The TPR of Shaws Bay is approximately 0.30 for spring tides and 0.23 for neap tides.

4.4 FRESHWATER INFLOWS

4.4.1 Constant Groundwater Seepage Flows

Shaws Bay is located at the foot of a small, but steep partly encircling escarpment. This escarpment would have been sea cliffs during a previous era. As this escarpment is mostly solid bedrock, surface water which has infiltrated the upper plateau re-emerges through the escarpment as freshwater springs. Anecdotal reports suggest that the groundwater seepage from these springs flows all year round. During summer months, and periods of dry weather, however, the rate of flow would be reduced.

Generally, the groundwater seepage is collected at the foot of the escarpment in a catch drain. The flow is then directed under Compton Drive via a number of pipe culverts, before discharging into Shaws Bay.

During field investigations, the combined flow rate for all pipes draining the escarpment was estimated to be in the order of 1 to 2 litres/second. Although rain had not fallen for several days prior, the field investigations were carried out at a time when higher than average rainfall had dominated the weather for the previous six months. Therefore, this rate is likely to be higher than a typical dry weather value.

4.4.2 Flood Flows

Stormwater runoff enters Shaws Bay via 17 stormwater drains. While most of these drains service only a small area, some can generate a considerable storm discharge, particularly those which drain the urban areas. **Figure 4.7** shows the locations of the 17 stormwater outfalls, and their contributing catchments.

The piped urban drainage system for Shaws Bay was designed based on a storm with a 1 in 10 year average recurrence interval. Design discharges for these drains were provided by Council. For the remaining catchments, storm discharges were estimated based on standard hydrologic techniques (ARR, 1987). **Table 4.1** outlines the estimated flood flows from these stormwater drains for a storm event with an average recurrence interval of 1 in 10 years.

The total volume of flood waters discharging into Shaws Bay associated with a 1 in 10 year storm event was estimated to be approximately 44,000 m^3, which is approximately 10% of the volume held in Shaws Bay at high water, and is only about one third of the total volume of water exchanged with the river every spring tide.

Subcatchment	*Estimated Peak Flow (m^3/s) 1 in 10 yr ARI*	*Description of Subcatchment*
1	2.68	Urban (Line A)
2	0.65	Lakeside Holiday Park
3	1.41	Urban (Line B)
4	0.62	Lakeside Holiday Park
5	1.80	Urban (Line C)
6	2.81	Escarpment and Open space
7	0.29	Escarpment
8	0.27	Escarpment
9	0.19	Escarpment
10	0.11	Escarpment
11	0.12	Escarpment
12	0.14	Escarpment
13	0.96	Roads (Hill St) and Urban
14 15 16 17	0.18	Shaws Bay Caravan Park

Table 4.1 Estimated 1 in 10 year Flood Flows into Shaws Bay

In comparison, the total volume of stormwater runoff discharging to Shaws Bay during a 1 in 1 year storm event would be in the order of 20,000m^3, with peak inflow rates approximately half of those for the 1 in 10 year event. For a 1 in 100 year event, the total stormwater runoff is likely to be in the order of 76,000m^3, with peak inflow rates some 1.7 times greater than the 1 in 10 year peak flows.

4.5 TIDAL AND FRESHWATER FLUSHING OF SHAWS BAY

4.5.1 Development and Calibration of Computer Model

A two dimensional, depth averaged, computational model of Shaws Bay was developed to simulate the hydrodynamics of the waterway. The model was based on the bathymetry provided by DLWC (refer **Section 3.5**), and spring tide conditions.

The model was used to assess the overall flushing potential of the bay based on tidal interaction with the river, steady groundwater seepage flows, and circulation within the bay generated by prevailing wind conditions.

Due to low tidal velocities, the response of the model to changes in calibration parameters was small, meaning that the determining factor in model calibration was actually the adopted bathymetry of the model. Nonetheless, friction was increased within the East Arm to simulate the extensive seagrass beds, and to ensure a suitable water level difference between the end of the East Arm and the deeper sections of the bay.

Velocities along the East Arm predicted by the model (ie up to 0.25 m/s) were of the same order as velocities measured in the field (ie up to 0.3 m/s in sandy sections and 0.1 m/s in seagrass sections).

4.5.2 Wind Driven Circulation

The dominant wind at Shaws Bay is from the south-east at a velocity of 3.4 m/s (MHL, 1996). This wind regime was simulated by the model without any other inputs (such as tides or freshwater flows), to show the *depth-averaged* circulation patterns established within the bay under these conditions.

Figure 4.8 shows the circulation of Shaws Bay due to wind only. The East Arm of Shaws Bay is aligned in the south-east direction. As such, persistent winds could be expected to generate a net circulation of flow along this section of the bay. Also, higher currents would be generated in other shallow sections of the bay which are roughly aligned in the south-east direction, including some of the western shoreline, between the Shaws Bay Caravan Park and Compton Drive, and the shallow section on the eastern foreshore just south of the point which separates the main section of the bay from the northern section of the bay.

While wind driven currents in the East Arm could be up to about 0.01 m/s, the currents on the peripheral shallows of the main section of the bay are only likely to be half this value. Return currents through the deeper sections of the bay would be oriented in the opposite direction (ie *towards* the south-east) at velocities in the order of 0.001 m/s.

The northern section of Shaws Bay is relatively protected, as it is oriented generally in a north-east to south-west direction and therefore is not significantly influenced by the dominant south-east winds. However, it is likely that floatable litter and flotsam would end up in this section of the bay, due to the three-dimensional effects of wind shear on the water surface.

4.5.3 Flushing Times

To determine flushing times for the different sections of the bay, a simulation was carried out whereby the bay was filled with ‘dirty’ water. ‘Clean’ water from the river, and ‘clean’ water from the groundwater seepage inputs, as well as circulation due to wind, was then used to cleanse the bay. The adopted flushing time was taken as the time required to remove 90% of the ‘dirty’ water from that particular location.

Figure 4.9 shows a plot of flushing times around Shaws Bay. As seen in this figure, flushing times along the East Arm are less than 1 day, while the flushing times for the remainder of the bay is between 4 and 5 days. When compared to other estuaries in NSW these flushing times are very good, and indicates that the bay has a high tidal flushing capacity.

4.5.4 Impact of Groundwater Seepage

The good flushing of Shaws Bay is assisted to some extent by the constant input of groundwater seepage flows. To determine precisely the magnitude of this assistance, another simulation was carried out whereby the groundwater seepage flows were removed. The results of this simulation showed that without the additional base flows, the flushing time of the estuary, in the deeper sections of the bay, would be in the order of 7 to 8 days, rather than 4 to 5 days.

Although a flushing time of 7 to 8 days is still considered to be very good, this simulation highlights the importance of constant basal inflows in the overall flushing of the bay.

4.6 DILUTION AND DISPERSION CAPACITY OF SHAWS BAY

As outlined in **Section 4.4.2**, the volume of water contained in Shaws Bay, and the volume of water exchanged with the river each tide, are significant compared to the likely runoff volumes associated with storm events. As such, it was considered that the bay has a large potential to dilute and disperse inputs associated with flood events.

This potential was assessed using the two-dimensional model developed to determine flushing times of the bay. For this assessment, stormwater discharges associated with a 1 in 10 year event were input into the model. The stormwater flows contained 'dirty' water, while the bay was initially 'clean'. Tidal inflows also contained 'clean' water.

The state of the bay at the end of a two hour storm event is presented in **Figure 4.10a**. This figure shows that the 'dirty' water emanating from the stormwater outlets in the main section of the bay had only spread a small distance into the bay, however, most of the northern section of the bay had been affected by the stormwater outlets discharging into this section, with resulting concentrations in the bay ranging between 10% and 40% of the inflow concentration. The 'dirty' water had also concentrated around the stormwater outlet in the East Arm of Shaws Bay.

One hour after the end of the storm event, the bay had been able to dilute and dissipate much of the stormwater inflows, as shown in **Figure 4.10b**. The dirty water in the main section of the bay had been absorbed by the large volume of 'clean' water, while the 'dirty' water in the northern bay was starting to dissipate and move into the main section of Shaws Bay. Concentrations in the northern section of Shaws Bay had reduced to between 10% and 20% of the stormwater inflow concentration. The majority of the stormwater entering the East Arm had been advected out of the bay, and into the adjacent river, thereby not having *any* impact on the main section of the bay.

Six hours after the end of the storm event, concentrations within the northern section of the bay continued to reduce, as the 'dirty' water was dispersed and diluted with the water from the main section of the bay. As shown in **Figure 4.10c**, the concentration in the northern section of Shaws Bay had reduced to about 10% of the initial inflow concentration.

Figure 4.10d shows the state of the bay 12 hours (ie one tidal cycle) after the storm event. This figure shows that throughout the bay, the 'dirty' water associated with stormwater inflows had been effectively diluted and dispersed by the resident volume of Shaws Bay, and the 'clean' water associated with tidal inflows.

4.7 CONCEPTUAL MODEL OF HYDRODYNAMIC PROCESSES

A conceptual model of the hydrodynamic processes in Shaws Bay has been developed, and is shown in **Figure 4.11**. The model draws upon all existing data and field investigations, and considers all the features of the hydrodynamic processes which have been discussed within this Chapter.

The most significant hydrodynamic related issues highlighted in the model include:

- ❑ Exchange of tidal waters with the river occurs through the eastern half of the rock training wall only.
- ❑ Between 90,000 and 130,000m^3 of water is exchanged between the bay and the river during every tide.
- ❑ Tidal velocities in the East Arm of the bay are up to 0.3 m/s within the channelised sections and 0.05 m/s amongst the seagrass beds. Tidal velocities within the main section and northern section of the bay are in the order of 5 mm/s.
- ❑ The northern section of the bay is more influenced by freshwater inputs, as it has a smaller resident volume to dilute and disperse the freshwater (ie catchment derived) inflows.
- ❑ The flushing time of the East Arm is less than 1 day (ie is fully exchanged with the river every tide), while the flushing times of the main section and northern section of the bay are approximately 4 – 5 days. Flushing times in these deeper sections of the bay increase to about 7 – 8 days if there is not a constant input of groundwater seepage flows.
- ❑ There are 17 stormwater drains discharging fresh water into the bay during rainfall events. The volume of inflows associated with a 1 in 10yr ARI storm event is equivalent to only about 10% of the resident high water volume of the bay, and is only about one third of the volume exchanged with the river each tide.
- ❑ Wind contributes to the mixing of the waters within the East Arm of the bay and the main section of the bay. The northern section of the bay is misaligned with the dominant wind direction, and as such, is not significantly influenced by wind driven circulation patterns.

5 SEDIMENTS

5.1 EXISTING INFORMATION

There was no existing information relating to the sediments in Shaws Bay. Anecdotal reports have described the bed of the bay as oozy black mud, while the foreshores were largely sandy.

5.2 SEDIMENT DATA COLLECTED FOR THIS STUDY

The sediments of Shaws Bay were assessed as part of this study, including:

- Collection and sedimentological analysis of 31 samples of the bed surface material;
- Vibrocoring to depths of about 3 metres at three (3) locations within the bay;
- Sedimentological review of the material extracted from the vibrocores;
- Geochemical analysis of the sediments within the cores.

5.2.1 Results of Surface Sediment Analysis

Thirty one (31) sediment samples were collected from various locations around Shaws Bay including the intertidal and sub-tidal zones, as well as from main drainage channels. The locations of these samples are shown in **Figure 5.1**. A sedimentological analysis was carried out on the sediments sampled, which included assessment of the following parameters:

- Percentage Lithics;
- Percentage Iron Staining;
- Percentage Shell;
- Grain size;
- Mud content;
- Origin of material.

The detailed results of this analysis are provided in **Appendix C1**. A summary of the findings is provided below.

Lithics

Lithics are rock fragments as distinct from the majority of quartz grains. Examples of lithics include basalt, blue metal and bitumen. In Shaws Bay, lithics were more concentrated at the head of the northern bay, adjacent to Compton Drive, and in the vicinity of the large stormwater outfall on the eastern shoreline (Line B). This pattern is consistent with the areas that would most likely be affected by the generation of lithics from human activities, ie roads and urban catchments.

Iron Staining

Iron Staining refers to the proportion of sediment grains which have a coating (light or heavy) of iron oxide. Elevated percentages of iron staining can indicate sediments which have been exposed to iron rich groundwater. The Shaws Bay surface sediments show a general iron staining of about 5 – 10%, which is typical of marine sands. However, there were a couple of sites which contained very high iron staining, most notably on the western foreshore (within a patch of bright orange sand approximately 3m x 2m), and within the headcut to the immediate north of the Lakeside Holiday Park. It may be possible that groundwater emanating from these locations is first travelling through a lens of iron-rich strata before discharging into Shaws Bay.

Shell

The concentration of fragile shell fragments within the sediment relates to the relative proximity of shellfish (typically small bivalves / molluscs). Once the shellfish die, their relatively fragile shells become broken up as they are reworked with the sediment. The more they are reworked, the finer and finer the shell fragments become.

In Shaws Bay, shell fragments (larger than the quartz grains) were present in the sediment samples collected along the East Arm. A small amount of shell was present in samples collected from other intertidal beach areas around the bay, while very little to no shell was present in the sediment samples collected from around the northern section of the bay. This distribution pattern indicates that shellfish are present in the East Arm of Shaws Bay, probably within the seagrass beds.

Grain Size

Generally sandy sediments were collected from the surface of the intertidal and shallow sub-tidal areas, while muddy sediments were collected from the surface of the middle of the bay, where depths are in excess of about 3 metres.

Along the East Arm, there was a general fining (ie, reduction in size) of sand grain size with distance into the bay, from coarse-medium at the eastern end to medium grained at the western distal edge of the delta. As the sand is transported along the delta by tidal currents, the smaller grains tend to be transported more easily than the coarser grains. As a result, the current tends to sort the grains according to grain size. The fining of sediment size with distance into the bay is evidence of active sand transport in that direction.

There was also a general fining of sediment with distance away from the large stormwater outfall at the northern end of the bay. Coarse and medium grained sands are deposited on the local delta, while finer grained sands and silts are deposited further into the bay.

Sieve analysis of selected samples indicated that the D_{50} for the medium grained sands is in the order of 0.35mm.

Mud Content

As noted above, sands were generally recovered from the foreshores of the bay, while muds were recovered from the deeper sections. The sands on the foreshores, however, did contain a certain amount of mud. The amount of mud in the sand generally relates to the relative dynamics of the sediment. If the sediment is subjected to higher energy (eg wind waves or tidal currents), then it would be relatively clean. If the sediment was collected from a more quiescent area, then it is likely to be siltier or muddier.

In Shaws Bay, cleans sands were found along most of the foreshore areas, indicating that wind wave action would be resuspending finer material, moving it into the deeper sections of the bay. The northern bay, however, generally contained siltier material along the foreshore. This indicates that wave energy in this section of the bay is probably not as significant as other part of the bay. This is consistent with the findings of the wind driven circulation assessment (refer **Section 4.5.2**), which concluded that this section of the bay was relatively well protected from the dominant south-easterly winds.

Slightly siltier sediments were also noted at the eastern end of the East Arm of the bay. The computer model also showed that velocities in this little pocket of the bay were small, as the majority of flow entering and exiting the bay through the wall did so to the west of this location. Therefore, this area acts as a small backwater, with finer, siltier sediment being able to settle out of suspension, giving an overall muddy appearance.

Origin

All sands sampled in Shaws Bay were of marine origin. The grains were quartzose, generally well sorted, and their shape was sub-angular to rounded.

The origin of the muds in the bay are discussed further in **Section 5.4**.

5.2.2 Vibrocores

Three (3) vibrocores were carried out in Shaws Bay by DLWC during June 1999. The locations of these three sites is shown in **Figure 5.2**, while the logs of the cores are shown in **Appendix C2**.

Site VC1, located at the northern end of Shaws Bay contained mostly medium grained quartz sand to a total depth of 1800mm. A layer of mud, 50mm thick, was present approximately 400mm from the top. The top 2000mm of core VC2, located at the edge of the East Arm delta drop-off, contained medium grained quartz sand. Below this was a 600mm layer of mud, which overlayed more quartz sand with thin intercalations of mud.

Core VC3, which was located adjacent to the Shaws Bay Caravan Park retaining wall in deep water, contained mud in the top 700mm. Quartz sand was present below the mud with grain size and shell content increasing with depth. 45mm rounded pebbles were located at a depth of 1500mm below the surface, which was just above bright red-orange oxidised stiff muddy sand, which was in the bottom 300mm of the core. This stratum is interpreted as a former surface soil from a time when the sea level was many metres lower than the present level (ie Pleistocene Age).

5.2.3 Sediment Quality Analysis

Five (5) sediment samples taken from the cores described above were sent to Australian Environmental Laboratories for geochemical analysis. Samples were taken from Core VC1 (northern end of Shaws Bay) at a depth of 400mm, from Core VC2 (delta drop-off) at depths of 100mm and 2400mm, and from Core VC3 (deep section of Shaws Bay) at depths of 50mm and 500mm.

The results of the sediment quality analysis are summarised in **Table 5.1**. Full laboratory results are presented in **Appendix C3**.

Parameter	*Core 1: north*	*Core 2: delta drop-off*		*Core 3: deeper section of bay*		*ANZECC Guidelines*	
	400mm	*100mm*	*2400mm*	*50mm*	*500mm*	*B'ground*	*Env. Inv.*
Arsenic *(mg/kg)*	< 5	< 5	6	< 5	< 5	0.2 – 30	20
Chromium *(mg/kg)*	10	<5	49	24	26	0.5 – 100	50
Copper *(mg/kg)*	4	< 3	24	10	12	1 – 190	60
Lead *(mg/kg)*	< 5	< 5	< 5	8	< 5	< 2 – 200	300
Mercury *(mg/kg)*	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.001–0.1	60
Nickel *(mg/kg)*	4	< 4	33	10	16	2 – 400	60
Zinc *(mg/kg)*	20	< 5	84	57	46	2 – 180	200
OC Pesticides *(mg/kg)*	all < 0.1	all < 0.1	all < 0.1	all < 0.1	all < 0.1	-*	-*
OP Pesticides *(mg/kg)*	all < 0.1	all < 0.1	all < 0.1	all < 0.1	all < 0.1	-*	-*
Total Phosph. *(mg/kg)*	46	16	580	430	360	< 400**	> 700**
Tot Kjl N: *TKN (mg/kg)*	190	65	680	660	430	-	-
Nitrite: NO_2 *(mg/kg)*	< 2	< 2	< 2	< 2	< 2	-	-
Nitrate: NO_3 *(mg/kg)*	< 5	< 5	< 5	< 5	< 5	-	-
Total Nitrogen *(mg/kg)* = $TKN + NO_2 + NO_3$	190	65	680	660	430	< 1000*	> 2000*

*** Guideline value from NSW EPA*
< # indicates value was less than the detection limit
** EPA guidelines for Biosolids has the following categorisation:*
< 0.02 mg/kg (and < 0.5 mg/kg for DDT/DDD/DDE) = Grade A: unrestricted use
< 0.2 mg/kg (and < 0.5 mg/kg for DDT/DDD/DDE) = Grade B: no household use
< 0.5 mg/kg (and < 1.0 mg/kg for DDT/DDD/DDE) = Grade C: above + town landscaping use
< 1.0 mg/kg (and < 1.0 mg/kg for DDT/DDD/DDE) = Grade D: above + no agricultural use
> 1.0 mg/kg (and > 1.0 mg/kg for DDT/DDD/DDE) = Grade E: landfill disposal only

Table 5.1 Results of Sediment Quality Analysis

The results of the sediment quality analysis show that the sediments within Shaws Bay do not exceed recommended guideline values, and generally reflect typical background conditions. Of the samples, Core 2 (delta drop-off) - Depth 2400mm had consistently higher concentrations of metals and nutrients, however, these concentrations were still mostly well within the guidelines. Reasons for the slightly higher concentrations at this location and at this depth are not known, however, natural variations may account for the differences.

There were no pesticide residuals detected within any of the cores. This indicates that pesticides used for agricultural management within the Richmond River catchment are not being deposited within the sediments of Shaws Bay in any detectable quantity.

5.3 ANALYSIS OF AIR PHOTOS

An analysis of air photos was carried out for photos dating back to 1947. Copies of these air photos are provided in **Appendix C4**. Significant features of the photos are discussed below.

5.3.1 1947

Lighthouse Beach was fully developed by 1947, with a relatively high foredune. This foredune was possibly lower immediately adjacent to the wall, which may have allowed storm waves to break through into the lagoon behind on occasions. Behind the higher foredune of Lighthouse Beach was a low-lying very flat area of swampy sand, partially vegetated by saltmarsh species. Washover deposits and wind-blown sand was slowly building up this area, as well as infilling remnant sections of former waterway, particularly at the base of the escarpment at the northern boundary of the Shaws Bay area. The photo shows specifically areas where the wind-blown sand was building up amongst the vegetated escarpment.

The western shoreline of the Shaws Bay lagoon was characterised by vegetation down to the high tide, and then a flat muddy/sandy beach. It appears that there were seagrasses growing in the shallow sub-tidal areas along the western shoreline of the bay.

The bay extended further north than what it does today, indicating substantial reclamation associated with the construction of Compton Drive and the development of the area for residential purposes. The northern section of the bay was also much narrow in 1947 than today, suggesting that dredging and removal of sand from this area occurred, which again would have been associated with the construction of Compton Drive and/or the residential development. A comparison of the 1947 photo with the present cadastral features and high water boundary, indicates that the eastern foreshore of the bay has been cut back by up to 70 metres, while the western foreshore has been reclaimed by about 40 metres (refer **Figure 5.3**).

Adjacent to the rock wall, in the vicinity of the current East Arm of Shaws Bay, a channel had been excavated within the delta. The reason for this is not known, however, the very regular nature of the channel confirms that it was not formed naturally. Review of old photographs from the 1930s suggest that the channel was not there at that time, while the 1967 air photo shows no sign of a former channel, ie it had been infilled by sand. Anecdotal reports from the community indicate that seagrasses had been planted in Shaws Bay during the 1940s and harvested for medical supplies. It is possible that the channel excavated along the wall was used for this purpose. Unfortunately, the detail in the photo is insufficient to be certain whether the channel contains seagrasses or not.

5.3.2 1967

In contrast to 1947, the shape of Shaws Bay in 1967 was essentially the same as at present. The East Arm of Shaws Bay contained an extensive amount of sand, with very little seagrasses. The western foreshore was characterised by sandy beaches in front of Compton Drive. Wide sandy beaches were also in front of the Shaws Bay Hotel and Fenwick House. The eastern shoreline appeared to be irregular in shape. This indicates that the dominant sand transport process on the eastern foreshore beaches was wind blown sand into the bay from the extensive area of sand behind.

5.3.3 1973

The Shaws Bay residential development was in progress. The land had been filled and compacted, and the roads had been constructed. No houses had been built in the development at this time. There was still wide sandy beaches around the majority of the foreshore, particularly in from of the Shaws Bay Hotel and Fenwick House.

The eastern foreshore appeared to be smoother than 1967, indicating that wind-blown transport of sand into Shaws Bay had stopped, and longshore transport of sand in the shallow foreshore area was the dominant sediment dynamic process within the bay. There was a small sediment fan emanating from the large drain on the eastern foreshore, which services the new development. This was either deposition of sediment washed into the drain during construction of the development, or was the reworking of the longshore sediment by the higher flows coming out of the drain, which were oriented perpendicular to the longshore direction.

5.3.4 1980

Numerous houses had been built within the Shaws Bay residential development, while the Lakeside Holiday Park occupied half its existing site. Non-developed areas around Shaws Bay were generally covered by grass, thereby minimising losses due to surface runoff and wind transport.

Wide unvegetated sandy beaches typified the western foreshore of Shaws Bay. Sand lobes were present on the western beaches, all oriented to the north, indicating active longshore sand transport along this shoreline. The eastern foreshore, although still sandy beaches, did not contain sand lobes, unlike the western shoreline, and unlike eastern shoreline of today (refer **Section 5.3.8**).

The East Arm of Shaws Bay was considerably deeper than in the 60s. The distal edge of the delta had prograded further into the bay. Seagrasses had become reasonably well established within the East Arm adjacent to the rock wall. Seagrasses were also along the shallow sub-tidal area in front of the Lakeside Holiday Park.

5.3.5 1986

By 1986, the Shaws Bay residential area was nearly fully developed. There appeared to be much more sand on the eastern foreshore of Shaws Bay than in 1980, with this sand worked into lobes, which were again oriented to the north. The western foreshore also contained wide sandy beaches, which had started to be vegetated, possibly with couch grass above the high tide level.

The distal edge of the East Arm delta had advanced further into the bay, while seagrass beds in the East Arm had become more dense, and occupied a slightly larger area within the inlet.

Terrestrial vegetation along the foreshore was also starting to become more established, and mangroves had taken root at the very northern end of the bay, which had previously been dominated by saltmarshes (possibly Juncus spp). Former mangrove seedlings located along the rock wall and on the opposite bank of the East Arm were starting to mature.

5.3.6 1991

The eastern foreshore contained wide sandy beaches with very few seagrasses in the adjacent sub-tidal area. The wide beach on the eastern shoreline extended into the northern section of the bay, where lobes had established around the point which separates the northern bay from the main section of Shaws Bay.

Minor reworking of sediments within the East Arm was evident with a change in seagrass patterns near the distal edge of the delta. All the seagrasses in the eastern end of the East Arm had been physically removed.

The western foreshore still contained sandy beaches, with some sand lobes oriented to the north.

5.3.7 1994

There was very little change between 1991 and 1994, except that seagrasses had begun to re-establish within the section of the East Arm from which they were previously removed. Also, there were more sand lobes along both the eastern and western foreshores of the bay. The distal edge of the East Arm delta had not changed significantly.

5.3.8 April 1999

There had been some minor readjustment of the distal edge of the East Arm delta, with a small progradation of the drop-off into the bay. There was also more minor reworking of sediments within the East Arm, with small sediment lobes/fans covering former seagrass beds.

Sand lobes were evident along both the eastern and western foreshores in the main section of the bay. The point dividing the northern bay from the main section of the bay had prograded slightly into the bay.

Seagrasses had also become more established along the western foreshore, while the mangroves at the northern end and along the wall were continuing to spread.

Bank erosion was evident on the northern shoreline of the East Arm.

5.4 SEDIMENT DYNAMICS

5.4.1 Historical Sequence of Events

The history of sediment dynamics of Shaws Bay has been pieced together from a number of historical records, such as old survey plans and photographs, historical air photos, and good anecdotal reports from long time residents of the area.

Prior to Breakwater Construction

Prior to the construction of the Richmond River entrance training breakwaters at the turn of the century, the river entrance was very dynamic, capable of moving by up to about 2 kilometres, depending on prevailing ocean conditions, and relative flood discharges from North Creek and the Richmond River. Towards the end of last century, the North Channel, which flowed adjacent to North Head, appeared to be the main navigation route through the entrance. The SS Lismore was shipwrecked in the North Channel in 1885 in eight foot of water. The shipwreck is now covered by the Ballina Beach Resort, and the old north channel has been filled and now forms part of the Shaws Bay residential area.

Figure 5.4 shows a comparison of the Shaws Bay area in 1864 and at present.

Construction of the breakwaters and dredging of the main navigation channel was carried out between about 1890 and 1910.

1900 – 1960s

After the construction of the breakwaters, marine sand was able to move into the former north channel and backwater area formerly known as Bog Bay. It is understood that prior to the breakwaters, ballast from empty ships was discarded in deep holes in this area.

By the 1960s, a significant amount of marine sand had moved into the area forming extensive sand deposits behind the beach foredunes, and a new stable ocean beach had developed, Lighthouse Beach. Long time residents recall that during large seas, ocean water was able to penetrate into the remnant lagoon behind the sand dunes through a shallow channel just on the north side of the northern breakwater. Under these conditions, sand was likely to have been pushed into the East Arm of the remnant lagoon (now known as Shaws Bay).

Although sometimes open to the ocean, tidal variations of Shaws Bay would predominantly have been the result of flows through the rock wall. Unlike at present, flow through the wall was probably consistent along its length, meaning that sand deposited in the East Arm of Shaws Bay by marine ingress was unlikely to be transported away.

Wind-blown sand would also have been slowly filling in Shaws Bay, which in the late 1800s had depths of up to 20 feet.

1960s

Compton Drive was gazetted as a public road in1965. Prior to construction of the road, the western foreshore of Shaws Bay extended to the foot of the escarpment and was 'picturesque' and 'tree-clad' (refer **Section 2.5**). Compton Drive was constructed by infilling of the former foreshore (which one community member recalled to be vegetated mostly with mangroves) with sand probably derived from the Shaws Bay lagoon and/or other local sources, such as North Creek. A retaining wall was constructed along the waterway edge to minimise the amount of fill required to construct the road. Sand was then pumped or placed against the retaining wall to form a new sandy foreshore.

The low-lying sand flats between the Shaws Bay lagoon and the high beach dunes were filled to their present elevation in about 1962, in preparation for urban development of the area (pers comm. Bruce Trees). It is understood that some fill material was sourced from the Shaws Bay lagoon. This would be consistent with the comparison of the 1947 air photo and the current high water boundary (refer **Figure 5.3**), which shows that all of the eastern shoreline of the lagoon has been cut back by between 30 and 70 metres.

In the mid 1960s, the Public Works Department decided to extend the northern breakwater. To do this, they first needed to construct an access road along the high dunes behind Lighthouse Beach. In constructing this road, the shallow channel along the northern side of the breakwater was filled in, thereby preventing any further ingress of marine sands into Shaws Bay.

With no more marine ingress of sand, tidal flows along the East Arm would have started to rework the sands already in this section of the bay. The sand would have generally been pushed into the deeper section of the bay by the tidal flows. Anecdotal reports indicate that the East Arm of Shaws Bay at this time was very shallow, and could be easily waded across at low tide.

1970s

In the early to mid 1970s, the land between Shaws Bay lagoon and Lighthouse Beach was stabilised and a residential development was constructed. Stabilisation of the area meant that wind-blown sand no longer infilled Shaws Bay.

The reworking of marine sand from the East Arm along the training wall allowed the establishment of a small stand of mangroves mid way along the wall. Further siltation adjacent to the wall effectively plugged the western half of the rock wall to tidal flows. All water entering and exiting Shaws Bay did so through the eastern half of the rock wall. As a result, tidal flows along the East Arm were relatively high, and sand continued to be reworked in this area.

Some of the reworked sands were transported along the eastern foreshore of Shaws Bay due to small wind wave associated with the dominant south-east winds. This longshore transport of sand started to 'smooth' the foreshore, which was previously quite 'ragged' due to the ingress of wind blown sand and the extraction, or cutting back of the foreshore, as discussed above. The point on the eastern foreshore, which separates the main section from the northern section of Shaws Bay started to become a repository for the sand transported along the foreshore, and subsequently started to prograde further into the bay through the formation of sand lobes.

With the channel becoming deeper in the East Arm due to reworking of the sediments, conditions became ideal for seagrasses, and they established relatively quickly.

Dredging of Shaws Bay in the mid 1970s involved the pumping of dredge spoil onto the foreshores to form sandy beaches, particularly on the western side of the bay, where sandy beaches were not formed naturally. Reworking of this material by wind waves would also have occurred with the sand generally being transported in a northerly direction, and also reworking itself back into the deeper sections of Shaws Bay.

1980s

With stabilised sand deposits and a closed ocean channel, all sources of coarse sediment had been stemmed. However, during the 80s, tidal flows through the East Arm would have continued to rework the sands into the bay, essentially prograding the delta drop-off, and along the eastern foreshore.

In the early 1980s and again in the mid to late 80s, dredging was again carried out in Shaws Bay to a depth of 12 feet. The dredge spoil was again pumped onto the beaches. Discussions with the dredge operator indicated that most of Shaws Bay was already at a depth of 12 feet, except for a section in the north-west corner, along Compton Drive.

Wind generated waves would have been the main mechanism for transportation of this dredge spoil along the beaches, and back into the bay.

1990s

In the early 1990s, a long reach excavator was used to pull sand up onto the beach areas from the deeper sections of the bay. This sand was subsequently reworked by wind waves along the beaches and back into the bay. The current bathymetric survey suggests that most of the beach material is reworked along the shoreline to a point near the narrow section of the bay, where it is then deposited in the middle of the bay. This section of the bay currently has a depth in the order of about 2 - 2.5 metres, which is probably about 0.5 - 1 metre shallower than in the late 1980s.

The northern bank of the East Arm began eroding. Reasons for this bank erosion are discussed further in **Section 5.4**, however, the sediment generated from this erosion was starting to contribute somewhat to the overall sediment dynamics of the East Arm.

Since the early 1990s, no physical works have been carried out around the bay that affect the sediments. It is likely that the resulting relatively stable shoreline (ie not being covered by dredge spoil or being actively reworked back into the bay) is the likely reason why seagrasses have become established around the perimeter of the bay foreshore only in the last 5 years or so.

5.4.2 Current Sediment Dynamics

When compared to the past, sediments in Shaws Bay are currently relatively static. Nonetheless, there are a number of processes which are still capable of moving some sediments around the bay, as outlined below. These processes have been incorporated into the conceptual model of sediment processes, which is discussed later and presented in **Figure 5.6**.

- There is minor reworking of the sand on the bed of the East Arm. Tidal velocities can get high enough to just mobilise the small sand grains, while wind waves can move sand along the foreshore. Sand is slowly being sorted within the main East Arm channel and directed towards the distal edge of the delta, while sand on the shallow shoals can move in either direction (ie eastwards or westwards) depending on the dominant wind regime at the time.
- The encroachment of the seagrass beds into the main flow channels has also resulted in a concentration of tidal flows. The resulting higher tidal currents are more capable of transporting sand along the bed of the channel. The expansion of seagrasses in the East Arm has also pushed the main flow channel hard against a small stand of mangroves on the northern shoreline, with minor erosion around the trees roots.
- The erosion of the shoreline on the northern side of the East Arm is a source of sediment. The finer loamy material eroded from the top of the soil stratum is generally being deposited within channel where seagrasses are proliferating. The sand coming from the substratum of the bank is being reworked along the inter-tidal beach mostly in a westerly direction.
- The eastern end of the East Arm is protected from the dominant south-easterly wind. As such, sand and finer material is being transported into this section of the bay by tidal currents and wind waves from other directions (eg westerlies), resulting in a very slow accumulation of slightly muddy sediment.
- Sand lobes are evident along the majority of the bay foreshores, which are all generally oriented to the north. Some sand lobes drop-off steeply into the deeper sections of the bay, indicating a net loss of material from the foreshore into the bay. The lobes are indicative of active sand transport in the intertidal and shallow sub-tidal areas of the bay. The dominant transport mechanism would be wind generated waves. Under persistent wind conditions, waves of up to 5 centimetres could be generated within the bay, however, high wind associated with coastal storms could generate wind waves in Shaws Bay of up to 0.3 metres or more.

5.5 EROSION OF THE FORESHORE

5.5.1 Bank Erosion in the East Arm

The northern foreshore of the East Arm is receding at a relatively slow rate. However, the recession has outflanked a previous attempt to remediate the erosion and has been identified by the local community as an important issue. The location of this bank erosion is shown in **Figure 5.5**.

The eroding bank consists of a half metre layer of poorly sorted sandy loam overlying medium grained marine sand. The loam was imported to the site as overburden during development of the area, and was placed over the existing sand as well as sand that had been imported to the site, which had been compacted to a stable state.

Details of the development of the site are not clear, however, it is unlikely that a stable beach was ever created along the northern foreshore of the East Arm. With increasing tidal currents, wind waves action, and surging of the water levels due to long period ocean waves (ie about 40 second period), the bank has eroded in an attempt to create a flatter, stable beach slope.

As the shoreline slowly recedes, the material removed from the bank is deposited on the lower beach face. To some extent, removal of some of this material from the lower beach face by tidal currents and wind waves perpetuates the bank erosion, as more material then has to be eroded from the bank to reform the beach. It is considered that a relatively stable beach will eventually be formed at a slope in the order of 1(v) in 10(h), given the median grain size (D_{50} approx 0.3mm).

The rock revetment which has not been outflanked by the recession is providing short term stability. It is considered that in time, sand will be removed from between the rocks, because a rubble filter, or geotextile, was not incorporated into the revetment design.

It is also considered that poor drainage from the reserve behind the bank has contributed to the erosion. The sandy loam on the surface can be quite impervious, resulting in pondage of rainwater, which can flow directly into the bay via surface runoff.

5.5.2 Gully Erosion in Pop Denison Park

Like the reserve to the north of the East Arm of Shaws Bay, Pop Denison Park has no formal drainage, relying mostly on infiltration of direct rainwater into Shaws Bay. However, the sandy loam soil of Pop Denison Park has become quite impervious, resulting in considerable pondage of water following rain. In some locations, the relative impermeability of the soil has concentrated surface flows.

As these flows discharge into the bay, they cause dislodgment, or erosion, of the loose sandy substratum. With continued flow concentration, more of the sandy substrate is removed and the foreshore is undermined, resulting in the collapse of the overlying loamy soil. This mechanism of bank failure in similar to gully erosion, with an active headcut at the upstream end of the gully, where the substrate sediment is being dislodged and the overlying soil is collapsing.

Locations of gully erosion sites in and around Pop Denison Park are shown in **Figure 5.5**.

5.6 SOURCES OF SEDIMENT

5.6.1 Coarse sediment

Historically, coarse sediment has been added to the active sediment pathways of Shaws Bay by wave action through the shallow channel on the north side of the breakwater, and by wind-blown transport of sand from the adjacent sand flats. However, once these sources were eliminated through development of the area, the only significant source of coarse sediment was the regular extraction of material from the bottom of Shaws Bay and placement on the intertidal and supratidal beaches. As this practice has not been carried out since the early 1990s, the only current source of coarse sediment is the relatively minor bank recession along the northern shoreline of the East Arm, and the slow recession of the gully erosion headcuts.

Assuming a recession of about 0.15 metres/year for the East Arm bank erosion, and about 0.3 m/year for the gully erosion, approximately 12m^3/year would be entering the current coarse sediment system of Shaws Bay. This value is very small when compared to the likely historical input of sediment from the shallow ocean channel or from wind-blown sand transport, or from the placement of dredge spoil on the beaches.

5.6.2 Fine Sediment

There are two sources of fine sediment entering Shaws Bay: local catchment runoff; and flooding in the Richmond River.

Local catchment runoff is likely to generate approximately 45,000 kilograms of suspended sediment per year (refer **Section 6.3.1**), which is equivalent to a bulk volume of approximately 75 m^3/yr. Flooding in the Richmond River results in sediment laden waters filling Shaws Bay. Assuming, on average, six significant floods or freshes per year and a typical surface water suspended sediment concentration of 150 mg/L, the amount of fine sediment being deposited in Shaws Bay from Richmond River flooding was calculated to be approximately 400m^3/year.

Assuming that the sediment from both these sources are distributed equally throughout the sub-tidal area of Shaws Bay, the net infilling of the bay due to fine sediment would be of the order of 5mm/year. This rate is consistent with typical fine sediment infilling rate of most estuaries in NSW (Roy, 1983).

5.7 FATE OF SEDIMENT IN SHAWS BAY

5.7.1 Coarse Sediment

Although there is very little coarse sediment entering the Shaws Bay sediment system, a considerable quantity of sediment is still resident within the active pathways, ie within the intertidal and shallow sub-tidal beaches on both the eastern and western foreshores of the main bay.

As the coarse sand moves along these pathways, some of the sand is reworked into the fringing deeper sections of the bay, however, most is likely to remain within the pathway. The sediment which is lost to the bay would be deposited close to the foreshore, and depending on the amount of sand lost, would form a shallow sub-tidal beach. The majority of this reworking of sediments from the beach would have occurred relatively quickly after placement of the dredge spoil, however, the presence of sand lobes with steep drop-offs suggest that some loss of sand from the pathway is still occurring.

The northern section of Shaws Bay is relatively well protected from the dominant south-east winds, and as such, does not allow much longshore transport of coarse sand. Therefore, the coarse sand being transported along the foreshores is generally reworked into the deeper section of Shaws Bay near the entrance to the northern bay, which is reflected in a general shallowing of the bay at this location.

The current bathymetric survey suggests that a volume in the order of 1,500 – 2,000 m^3 may have been deposited in this area since the time of the last major dredging, which was in the late 80s. Therefore, a deposition rate for coarse sand in this area could be in the order of 150 m^3/year, or about 0.1 m/year.

This deposition rate is unsustainable in the long-term, as there is no continuing infeed of coarse sediment, however, it is possible that the sand already on the beaches may continue to infill this area for a number of years into the future.

5.7.2 Fine Sediment

Fine sediment would enter Shaws Bay either through the breakwater, or from the stormwater drains. In either case, the relatively good mixing and dispersion characteristics of the bay would quickly spread this sediment, which would still be suspended within the water column, around the bay to a relatively equal concentration. In the deeper sections of the bay, tidal velocities are small enough not to keep the sediment in suspension. Therefore, the sediment settles, and deposits on the bed of the bay. In the shallow sections, tidal velocities and agitation due to wind waves would prevent the sediment from settling, until it has been worked into the quieter, deeper, sections of the bay.

The surface sediment analysis also showed that fine sediment is only located in the deeper sections of the bay, and not in the intertidal, or shallow sub-tidal areas.

Fine sediment in Shaws Bay is likely to settle at a rate in the order of 0.01 to 0.1 mm/second (Graf, 1971). Therefore, based on a typical depth of about 3 metres, the bay should clear in less than about 3 days, assuming no further input of sediment from the river or local catchment. This is consistent with the observations of local residents.

5.8 CONCEPTUAL MODEL OF SEDIMENT PROCESSES

A conceptual model of the sedimentary processes in Shaws Bay has been developed, and is shown in **Figure 5.6**. The model draws upon all existing data, field investigations and air photo interpretation, and considers all the features of the sediment processes which have been discussed within this Chapter.

The most significant sediment related issues highlighted in the model include:

- Coarse sediment pathways are located along the western and eastern shorelines of the main section of the bay. The dominant mechanism for transport of sediment along these pathways is wind generated wave action.

- Coarse sediment is deposited just inside the northern section of the bay, where dominant winds can no longer penetrate. The bed of the bay at this location is slowly accreting at a rate in the order of 0.1 m/yr. Coarse sediment is also being lost from the sediment pathways by falling into the deeper section of the bay (ie out of the influence of wind waves).

- Coarse sediment has entered these pathways by physical placement. On at least 5 occasions over the past 30 years, material has been extracted from the deeper parts of the bay (usually by dredger) and placed on the eastern and western foreshores to form sandy intertidal and supra-tidal beaches. This last occurred in about 1992.

- Fine sediment originating from catchment runoff and from Richmond River flooding is being deposited in the deeper sections of the bay, where tidal velocities are small enough for the fine sediments to settle. The rate of fine sediment accretion in the bay is in the order of 5 mm/yr.

- There is minor reworking of the sediments within the East Arm of the bay, resulting in occasional smothering of existing seagrass beds or the formation of lobes. However, there is no significant source of sediment that is contributing to long term accretion of this area.

- Bank erosion is evident on the northern foreshore of the East Arm. It is considered that this would be supplying only a relatively small amount of sediment to the bay.

6 WATER QUALITY

6.1 EXISTING INFORMATION

Existing water quality information for Shaws Bay consisted of the following:

- Bacteria levels, measured by Council since the late 1960s; and
- Standard water quality parameters measured by fixed location probes (ie data logger) since March 1999.

6.1.1 Council's Bacteriological Data

Council has tested the bacteria levels in Shaws Bay since the late 1960s, however, actual locations of sample sites for these earlier years has not been established. Since 1991, Council has been routinely monitoring Faecal Coliform concentrations at three locations in the northern section of the bay. Samples were collected and analysed about once per month, independent of state of the tide, wind, weather conditions, or antecedent rainfall.

Figure 6.1 shows the results of this bacterial analysis between 1991 and present. **Figure 6.1** also shows the ANZECC and NSW Health recommended guideline values for primary contact with the water, such as swimming and snorkelling. The ANZECC guidelines (1992) require the median value of no less than 5 samples taken at regular intervals not exceeding one month to be less than 150 organisms/100mL *(with four out of five samples containing less than 600 organisms/100mL)*. The NSW Health guidelines (1982) require the geometric mean of 3 samples taken at the same time to be less than 300 organisms/100mL, with an upper limit of 2000 organisms/100mL in any one sample. In general, the ANZECC guidelines relate to the long-term analysis of a waterbody, whereas the NSW Health guidelines provides an immediate indication of the suitability of the water for primary contact activities, such as swimming and snorkelling.

As can be seen in **Figure 6.1**, the vast majority of samples collected in the northern section of Shaws Bay were below the recommended ANZECC guideline limit of 150 organisms/100mL, and the geometric mean of the samples was generally below the NSW Health guideline of 300 organisms/100mL. However, there were a number of occasions when both of these guidelines were exceeded. It is uncertain whether these samples corresponded to rainfall events. Nonetheless, Council has carried out additional studies of faecal coliforms in Shaws Bay and has determined that elevated concentrations do not persist for longer than about 24 hours (pers comm Tim Fitzroy, BSC). The good tidal flushing of the bay, combined with the saline conditions, means that any bacteria which are discharged into the bay cannot persist at high concentrations.

The bacteria sampling by Council has targeted the worst area in Shaws Bay, as highlighted by the results of the computer model (refer **Section 4.6**). It is expected that bacteria levels in the main section of Shaws Bay, where the majority of the public utilise the waterway, would be considerably less than that measured in the northern section of the bay.

6.1.2 DPWS Data Logger

In March 1999, DPWS installed a data logger in Shaws Bay to continuously monitor water level and selected water quality parameters. The results from the first four months operation of the data logger are provided in **Appendix D**. Water quality parameters monitored by the data logger include conductivity / salinity, pH, temperature, dissolved oxygen and turbidity. Also shown in the results is the daily rainfall for the Lake Ainsworth station, located some 5 kilometres to the north of Shaws Bay. The data logger is located at the western edge of the delta, towards the southern end of Shaws Bay.

Conductivity / Salinity
Conductivity is a measure of the dissolved salts in the water. In an estuarine environment, conductivity is directly related to salinity.

Salinity at the data logger was relatively consistent throughout the four month sampling period at about 25 to 28 ppt. During normal weather conditions, the salinity in Shaws Bay would be nearly the same as the ocean, ie salinity would be 35 ppt, however, the persistent rainfall over the past 6 months has resulted in considerable freshwater in the Richmond River and elevated freshwater baseflow into Shaws Bay. The reduction in salinity measured in Shaws Bay since March would be indicative of these freshwater influences.

pH
pH in Shaws Bay was very consistent over the four month period with a value of about 8.2 to 8.3. This pH level is characteristic of oceanic conditions.

Temperature
Water temperature generally decreased from about 25°C in March to about 19°C in June.

Dissolved Oxygen
Dissolved oxygen measured by the data logger in Shaws Bay was quite variable, compared to the other water quality parameters. While concentrations generally varied between about 4 mg/L and 8 mg/L, there was also a diurnal variation of up to 1 mg/L. Diurnal variations in oxygen are indicative of the photosynthesis / respiration process of waterplants and algae. It is considered that photosynthesis of the large beds of seagrass in the East Arm was elevating local oxygen levels, while during the non-daylight hours, respiration was likely to lowered local oxygen levels.

Although variable, the dissolved oxygen concentrations are typical of a healthy estuarine environment.

Turbidity
Turbidity is the measure of the clarity of the water. In Shaws Bay, turbidity is mostly influenced by the amount of suspended sediment particles in the water. The data logger results show that turbidity is low for the four month period from March to June 1999, with

the exception of a couple of isolated measurements. It is possible that these spikes are erroneous, or were the result of a local disturbance of bed sediments.

Rainfall

During the period of deployment (to 30 June 1999), rain fell on 65 out of the 110 days, producing a total of 986mm of rainfall. This is nearly twice the average rainfall for this number of days.

6.2 ADDITIONAL DATA COLLECTED FOR THIS STUDY

While the results from the data logger provided a good assessment of temporal variations in water quality, it was considered that a better understanding of the spatial variation of water quality was needed. As such, the water quality of Shaws Bay was assessed during field inspections using a hand-held HORIBA water quality probe provided by Council. pH, conductivity, turbidity, dissolved oxygen, temperature and salinity were measured at 17 different locations within the bay at low water slack, and at high water slack. Measurements were generally taken at the surface, at the bed at the mid-depth, however, for the shallow East Arm sections, only a mid-depth measurement was recorded, while in the deeper sections of the bay, a ¾ depth measurement was also included in the assessment. The locations of the 17 monitoring sites is shown in **Figure 6.2**, while the results of the assessment are presented in **Figures 6.3** to **6.8**. These results are presented as an x-y plot, with the x-axis representing distance along the estuary from the eastern end of the East Arm. Therefore, the data points on the left hand side of the plots relate to the water quality within the East Arm, while the data points on the far right of the plot relate to the water quality in the northern most section of Shaws Bay. The different symbols on the plots indicate the water quality at the different depths, as outlined in the legend.

6.2.1 pH

Refer ***Figure 6.3***

pH was relatively consistent throughout the bay, varying no more than about 0.25 units. There was negligible variation in pH values with depth.

6.2.2 Conductivity

Refer ***Figure 6.4***

Refer to salinity section for discussion (**Section 6.2.6**).

6.2.3 Turbidity

Refer ***Figure 6.5***

Turbidity is generally low, ie less than 5 NTU, except at the bottom of the water column. Although turbidity measurements at the bottom are likely to have been artificially increased due to the monitoring procedure, the higher turbidity levels are expected due to the general presence of very fine material on the bottom of the bay.

6.2.4 Dissolved Oxygen

*Refer **Figure 6.6***

Dissolved oxygen concentrations varies significantly with depth and with the state of the tide. Concentrations at low water slack in the East Arm showed a substantial increase from west to east. As the water flows out of the bay, it travels through a large area of seagrass. These seagrasses photosynthesise during the day, effectively pumping the water with oxygen. By the time the water is discharge into the river, it had a dissolved oxygen concentration of approximately 12 mg/L. This is more oxygen that what the water can retain, and as such, would be releasing oxygen into the atmosphere. It is expected that during the night time, water which is travelling over the seagrasses would be reducing in dissolved oxygen, as the seagrasses would be respiring, thereby using up the oxygen in the water.

Dissolved oxygen in the middle of the bay varies with depth. At the surface, dissolved oxygen is high, being nearly at saturation conditions (ie 8 – 9 mg/L). At the bed, however, the dissolved oxygen was generally in the order of about 4 mg/L. The lower dissolved oxygen is likely to be caused by the decay of organic material resident on the bottom of the bay, such as leaves and old seagrass fronds. Although suppressed, the oxygen levels at the bottom of the bay are not low enough to affect the marine ecology of the bay.

6.2.5 Temperature

*Refer **Figure 6.7***

Temperature also varied with depth, particularly in the northern section of Shaws Bay, where surface waters were up to 4°C cooler than the water only a metre or so below. The surface waters reflect catchment runoff from recent rainfall events. As well as being cooler, the catchment runoff was also fresh, and as such, concentrates on the surface of the bay (refer **Section 6.2.6**).

The temperature of the ocean water on the day of monitoring (23/7/99) was approximately 19.3°C, as indicated by the consistent temperature along the East Arm at high water slack. At low water slack, the water being discharged into the river was nearly 2°C warmer than the ocean temperature. This is due to the discharge of warmer water from the deeper part of the bay, as well as overall warming of the water by solar radiation, particularly in the shallow East Arm section of the bay, which contains a large amount of seagrasses.

6.2.6 Salinity

*Refer **Figure 6.8***

Salinity in Shaws Bay varies both in location and depth within the water column. The northern section of the bay had less saline water at the surface, which reflected freshwater inputs from constant groundwater seepage and antecedent rainfall runoff. The fresher water is not as dense as salt water, and therefore remains at the surface. Such stratification of the water column is more apparent at low water slack than at high water slack, when saltier water from the main section of Shaws Bay is pushed up into the northern part of the bay, resulting in mixing.

The salinity of the water entering Shaws Bay from the river was 32 ppt. This is still less than full oceanic conditions (35 ppt), indicating that at the time of monitoring, freshwater flows down the Richmond were still influencing salt concentrations at the entrance.

6.3 CATCHMENT RUNOFF

6.3.1 Estimated Pollutant Runoff Loads

The Shaws Bay catchment was broken up into 14 separate subcatchments, based on the individual catchments of each stormwater drain. Note that the four stormwater outlets draining the Shaws Bay Caravan Park were considered as one source.

There are two areas of the Shaws Bay catchment which are not directly serviced by stormwater drains. These areas are the public reserve on the north side of the Shaws Bay East Arm, and Pop Denison Park. Drainage of these areas is primarily by infiltration through the soil (albeit slow) into the groundwater. As such, it was considered that runoff from these undrained areas do not contribute significantly to the pollutant loads entering Shaws Bay.

Subcatchment delineation was shown previously in **Figure 4.7**.

Pollutant runoff loads from the subcatchments were determined in accordance with NSW EPA guidelines (*EPA, 1997*) and were based on the following equation:

$$\textit{Pollutant Load (kg/year)} = P \times C_v \times C \times A \qquad \textbf{Equation 1}$$

Where:
P = average annual rainfall (*mm*)
Cv = annual average volumetric runoff coefficient (*dimensionless*)
C = average (*log-mean*) event mean pollutant concentration (*EMC mg*/l)
A = subcatchment area

The EPA guidelines present collated information regarding studies carried out on pollutant runoff from urban and rural catchments. *Appendix F* of those guidelines outlines the results (*EMC values*) for recent studies for Suspended Solids, Total Phosphorus, Total Nitrogen and Faecal Coliforms (*E Coli*). **Table 6.1** shows the adopted Event Mean Concentrations (EMC) for the Shaws Bay subcatchments.

	URBAN	*FOREST / NATIVE VEGETATION*	*OPEN SPACE / RESERVE*
Suspended Solids (mg/l)	100	10	150
Total Phosphorus (mg/l)	0.4	0.02	0.2
Total Nitrogen (mg/l)	2.5	0.2	1
E. Coli (cfu/100ml)	35,000	1,000	8,000

Table 6.1 Adopted EMC values for Calculating Pollutant Runoff Loads

The remaining parameters in *Equation 1* above were adopted as follows:

Average Annual Rainfall = 1,689 mm (*MHL, 1999, MHL, 1996*);

Volumetric Runoff Coefficient = 0.6 urban, 0.3 open space, 0.15 native vegetation (*source: adapted from EPA guidelines*)

Subcatchment Areas – refer **Table 6.2**

Subcatchment	*AREA (m^2)*	*Approx. % Urban*	*Approx. % Native Veg.*	*Approx. % Open Space*
1	126,400	100	0	0
2	32,500	50	0	50
3	66,300	100	0	0
4	31,400	50	0	50
5	84,900	100	0	0
6	151,500	0	50	50
7	15,700	0	100	0
8	14,600	0	100	0
9	10,000	0	100	0
10	5,700	0	100	0
11	6,700	0	100	0
12	7,300	0	100	0
13	45,200	100	0	0
14 - 17	8,800	50	0	50
TOTAL	***607,000****	***59%***	***23%***	***18%***

* *Total area including undrained reserves = 687,800m^2, comprising 52% urban, 20% native vegetation and 28% open space / reserve.*

Table 6.2 Subcatchment Areas of Shaws Bay

Table 6.3 shows the pollutant runoff loads (kg/year) for the four runoff constituents determined by *Equation 1*: Suspended Solids, Total Phosphorus, Total Nitrogen and Faecal Coliforms (cfu x 10^6/year).

Subcatchment	*Suspended Solids (kg/year)*	*Total Phosphorus (kg/year)*	*Total Nitrogen (kg/year)*	*E. Coli (cfu x 10^6/year)*
1	12809	51.2	320.2	4483
2	2882	8.2	49.4	642
3	6719	26.9	168.0	2352
4	2784	8.0	47.7	621
5	8604	34.4	215.1	3011
6	5949	8.1	42.2	326
7	40	0.1	0.8	4
8	37	0.1	0.7	4
9	25	0.1	0.5	3
10	14	0.0	0.3	1
11	17	0.0	0.3	2
12	18	0.0	0.4	2
13	4581	18.3	114.5	1603
14 – 17	780	2.2	13.4	174
TOTAL	***45260***	***157.6***	***973.6***	***13227***

Table 6.3 Annual Pollutant Runoff Loads from the Shaws Bay Subcatchments

Table 6.3 shows that the highest pollutant loads come from Subcatchments 1, 3 and 5, which all drain the Shaws Bay residential area. Notable pollutant loads were also generated from the caravan park catchments (ie 2, 4 and 14 – 17), the Subcatchment containing the northern creek (ie No. 6) and the Subcatchment draining the small urban area along the top of the escarpment (ie No. 13).

Subcatchments draining the escarpment only (ie Subcatchments 7 to 12) contribute only a minimal amount of pollutant loads to Shaws Bay.

6.3.2 Impacts of Runoff on Shaws Bay Water Quality

As outlined in **Section 6.3.1**, Shaws Bay receives pollutant loads from the surrounding catchment. However, these annual loads were considered to be small, and as such, are unlikely to have a major impact on the overall water quality of the bay.

To confirm this, the computer model developed to assess flushing was used to predict the increase in Shaws Bay water quality resulting from a 1 in 10 year ARI rainfall event. For the assessment, the increase in water quality concentrations at two locations were determined: the middle of the northern section of the bay, and the middle of the main section of Shaws Bay. Discharges from the main drains discharging into Shaws Bay were assessed individually so that the outlets could be compared in terms of their impact on the bay.

Tables 6.4 to **6.7** shows the results of the assessment of storm discharges impacts on suspended sediment, total phosphorus, total nitrogen and faecal coliform concentrations in Shaws Bay. Numbers quoted in **Tables 6.4** to **6.7** are the *increases* in water quality concentrations (mg/L and counts/100mL) as a result of the stormwater input. The increases in concentrations were determined at various times after the end of the storm event.

For suspended sediment, this assessment assumed that there was no settlement of the sediment particles within the first 96 hours. Although it is likely that the sediment would settle in less than 3 days (refer **Section 5.6.2**), this assumption provides a *conservative* estimate of suspended sediment concentrations in the bay. A large proportion of the total phosphorus entering the waterway would do so attached to sediment particles. As the sediment particles settle out, this phosphorus becomes separated from the general water quality of the bay. This assessment conservatively assumed that this particulate phosphorus remained within the water column of the bay for at least the first 96 hours after the storm events.

Actual E. Coli concentrations would reduce quickly after discharge into the bay due to the natural mortality of the bacteria. For this assessment, it was assumed that the natural mortality of E. Coli was defined with a T_{90} value of 10 hours. That is, it takes 10 hours for the coliform concentrations to reduce by 90% of its initial concentration. Experiments carried out by Sydney Water on coliform die-off rates for the Sydney ocean outfalls indicate that median T_{90} values of between about 2 and 12 hours could be expected, with the rate affected by many environmental factors, as well as the time of day (ie solar radiation). As some of these environmental factors may not be the same in Shaws Bay as in the offshore locations, a rate was chosen which reflected the more conservative end of the scale.

Time after storm	1 hr	6 hrs	12 hrs	24 hrs	48 hrs	96 hrs
Impact on Northern Bay						
Subcatchment 3 Line B – Shaws Bay middle	0.05	0.50	0.90	0.93	0.45	0.27
Subcatchment 5 Line C – Shaws Bay north	9.13	6.08	3.18	1.20	0.38	0.28
Subcatchment 6 Creek at northern end	10.39	6.97	3.67	1.37	0.43	0.25
Subcatchment 7 – 13 Compton Drive inputs	0.15	0.37	0.59	0.63	0.48	0.14
Sum	*19.72*	*13.92*	*8.35*	*4.13*	*1.73*	*0.95*
Impact on Main Bay						
Subcatchment 3 Line B – Shaws Bay middle	2.16	1.64	1.25	0.77	0.45	0.24
Subcatchment 5 Line C – Shaws Bay north	0.04	0.54	0.68	0.56	0.34	0.22
Subcatchment 6 Creek at northern end	0.05	0.62	0.77	0.64	0.39	0.22
Subcatchment 7 – 13 Compton Drive inputs	0.78	0.86	0.70	0.48	0.35	0.13
Sum	*3.02*	*3.65*	*3.41*	*2.44*	*1.54*	*0.81*

Table 6.4 Impact of Stormwater Inputs on SUSPENDED SEDIMENT Concentrations (mg/L)

Time after storm	*1 hr*	*6 hrs*	*12 hrs*	*24 hrs*	*48 hrs*	*96 hrs*
Impact on Northern Bay						
Subcatchment 3	0.0002	0.0020	0.0036	0.0037	0.0018	0.0011
Subcatchment 5	0.0365	0.0243	0.0127	0.0048	0.0015	0.0011
Subcatchment 6	0.0143	0.0096	0.0051	0.0019	0.0006	0.0004
Subcatchment 7 – 13	0.0006	0.0014	0.0022	0.0024	0.0018	0.0005
Sum	*0.0515*	*0.0373*	*0.0236*	*0.0128*	*0.0057*	*0.0031*
Impact on Main Bay						
Subcatchment 3	0.0086	0.0065	0.0050	0.0031	0.0018	0.0010
Subcatchment 5	0.0002	0.0022	0.0027	0.0022	0.0014	0.0009
Subcatchment 6	0.0001	0.0008	0.0011	0.0009	0.0005	0.0003
Subcatchment 7 – 13	0.0029	0.0032	0.0026	0.0018	0.0013	0.0005
Sum	*0.0118*	*0.0128*	*0.0114*	*0.0080*	*0.0050*	*0.0026*

Table 6.5 Impact of Stormwater Inputs on TOTAL PHOSPHORUS Concentrations (mg/L)

Time after storm	*1 hr*	*6 hrs*	*12 hrs*	*24 hrs*	*48 hrs*	*96 hrs*
Impact on Northern Bay						
Subcatchment 3	0.001	0.013	0.023	0.023	0.011	0.007
Subcatchment 5	0.228	0.152	0.080	0.030	0.009	0.007
Subcatchment 6	0.078	0.052	0.028	0.010	0.003	0.003
Subcatchment 7 – 13	0.004	0.009	0.014	0.015	0.012	0.004
Sum	*0.311*	*0.226*	*0.144*	*0.079*	*0.036*	*0.019*
Impact on Main Bay						
Subcatchment 3	0.054	0.041	0.031	0.019	0.011	0.006
Subcatchment 5	0.001	0.014	0.017	0.014	0.009	0.006
Subcatchment 6	0.000	0.005	0.006	0.005	0.003	0.002
Subcatchment 7 – 13	0.019	0.021	0.017	0.012	0.009	0.003
Sum	*0.074*	*0.080*	*0.071*	*0.050*	*0.031*	*0.016*

Table 6.6 Impact of Stormwater Inputs on TOTAL NITROGEN Concentrations (mg/L)

Time after storm	1 hr	6 hrs	12 hrs	24 hrs	48 hrs	96 hrs
Impact on Northern Bay						
Subcatchment 3	13	37	14	1	0	0
Subcatchment 5	2462	446	49	1	0	0
Subcatchment 6	451	82	9	0	0	0
Subcatchment 7 – 13	36	25	8	0	0	0
Sum	*2962*	*590*	*80*	*2*	*0*	*0*
Impact on Main Bay						
Subcatchment 3	581	120	19	1	0	0
Subcatchment 5	11	40	10	0	0	0
Subcatchment 6	2	7	2	0	0	0
Subcatchment 7 – 13	192	57	10	0	0	0
Sum	*786*	*224*	*41*	*1*	*0*	*0*

Table 6.7 Impact of Stormwater Inputs on E. COLI Concentrations (counts/100mL)

As stated earlier, the values shown in the above tables represent the actual increase in concentrations in the bay due to the pollutant inputs from the stormwater drains. To determine the actual water quality concentrations in the bay, these increases need to be added to general background concentrations of the water quality parameters. As Shaws Bay is predominantly influenced by the incoming tides from the entrance, it was considered that general background concentrations would reflect typical oceanic conditions, which can be taken to be:

- Suspended sediment: 10 mg/L;
- Total Phosphorus: 0.015 mg/L;
- Total Nitrogen: 0.3 mg/L; and
- E. Coli: 0 counts/100mL

Table 6.8 outlines the likely water quality concentrations in the two key areas of Shaws Bay within the first 96 hours after a major storm event.

Time after storm	*1 hr*	*6 hrs*	*12 hrs*	*24 hrs*	*48 hrs*	*96 hrs*	*ANZECC Guidelines*
Northern Bay							
Suspended Solids (mg/L)	29.72	23.92	18.35	14.13	11.73	10.95	-
Total Phosphorus (mg/L)	0.067	0.052	0.039	0.028	0.021	0.018	*0.01 – 0.1*
Total Nitrogen (mg/L)	0.61	0.53	0.44	0.38	0.34	0.32	*0.1 – 0.75*
E. Coli (counts/100mL)	2962	590	80	2	0	0	*150*
Main Section of Bay							
Suspended Solids (mg/L)	13.02	13.65	13.41	12.44	11.54	10.81	-
Total Phosphorus (mg/L)	0.027	0.028	0.026	0.023	0.020	0.018	*0.01 – 0.1*
Total Nitrogen (mg/L)	0.37	0.38	0.37	0.35	0.33	0.32	*0.1 – 0.75*
E. Coli (counts/100mL)	786	224	41	1	0	0	*150*

Table 6.8 Predicted Water Quality Concentrations in Shaws Bay After Major Storm Event

Also shown in **Table 6.8** are the recommended ANZECC guideline values for primary contact (which includes swimming, snorkelling etc). Comparison of the resulting water quality in the bay with these guidelines shows that after a major storm event, water quality is still within recommended guideline limits, with the exception of E. Coli. However, higher than recommended E. Coli concentrations are only likely to persist for less than 12 hours after the storm event. These results are supported by the bacteriological sampling carried out in Shaws Bay by Council following rainfall events (refer **Section 6.1.1**).

Also shown in **Table 6.8** is the fact that the resulting water quality in Shaws Bay is better in the main section of the bay than in the northern section. The reason for this is that after a major rainfall event, the stormwater rainfall actually makes up a higher proportion of the water in the northern bay than it does in the main section of the bay, due to its smaller resident volume.

This assessment was carried out based on a major rainfall event (ie a 1 in 10 year average recurrence interval event). For more frequent rainfall events, less impact on the water quality in Shaws Bay could be expected.

6.4 CONCEPTUAL MODEL OF WATER QUALITY PROCESSES

A conceptual model of water quality processes in Shaws Bay has been developed, and is presented in **Figure 6.9**. This model was developed using all available information (including community responses to questionnaires), results from field inspections, and from desk top analyses.

The most significant issues identified in the model include:

- Dissolved oxygen is lower at the bed within most deeper sections of the bay, probably due to oxygen demand associated with decay of organic bed material, and relatively minimal vertical mixing.

- The northern section of the bay, and the main bay in the vicinity of Compton Drive contains fresher water at the surface following periods of rainfall.

- The main section of the bay has a large dilution capacity, meaning that pollutants discharged directly into this part of the bay have a relatively minor affect on the overall water quality.

- The northern section of the bay has a reduced dilution capacity due to its smaller resident volume, and as such, pollutants discharged into this section of the bay have more of an influence on the residual water quality. However, good tidal flushing of the area means that these impacts are relatively short-lived, with the pollutants being dispersed and advected out of the northern bay relatively quickly.

- The largest sources of pollutants are the three stormwater outlets draining the urban area to the east of Shaws Bay. The discharge from the East Arm drain is advected directly to the river with negligible impact on the main section of the bay.

- The water quality in the East Arm generally reflects the water quality of the adjacent river, as this area of the bay is completed exchanged with the river each tide.

7 AQUATIC AND TERRESTRIAL FLORA AND FAUNA

7.1 BACKGROUND

The Shaws Bay environment observed today is ‘artificial’ in the sense that it is enclosed by a human-made structure, resulting in the alteration of its natural hydrodynamics. The bay is bounded on all sides by what is classified as urban development – high and medium density residential, commercial (Shaws Bay Hotel) and sealed roads. The Bay also is the receiving water for 17 stormwater drains ranging in diameter from 150mm to 1300mm.

Nonetheless, Shaws Bay has evolved into a diversity of habitats which provide sanctuary, breeding areas and feeding stations for a wide variety of flora and fauna. It is this diversity which helps maintain the overall good health of the bay.

Shaws Bay and its environs are also actively utilised by humans, for activities such as exercise (swimming, walking, running, cycling), snorkelling, fishing, and general enjoyment of the Bay and its surrounding facilities.

The flora and fauna species discussed in this Chapter were observed and confirmed (unless otherwise noted) during a two week site investigation period in July, 1999. Further information and documentation on faunal sitings is included in **Appendix E** from various reports, lists from community members, anecdotal evidence compiled over the course of the study, as well as listings from the NSW National Parks & Wildlife Service Atlas of NSW Wildlife database (refer **Section 7.1.1**), and the NSW Fisheries marine species database.

All descriptions of flora locations and extent referred to within the following text are shown in **Figure 7.1**. Plate references can be found in the **Photographs** section of this report.

7.1.1 National Parks & Wildlife Flora and Fauna Database

Listings of sitings of flora and fauna were obtained from the NSW National Parks & Wildlife Service (Hurstville) Atlas of NSW Wildlife (NPWS, 1999). Records were processed by sorting according to location and degree of protection. Species noted within the vicinity of Shaws Bay (approximately a 2.5 km radius) have been included in a table in **Appendix E**, along with the NPWS detailed database. It is important to note that these listings are by no means complete, serving primarily to give an indication of flora and fauna species that have been actively sighted within particular areas (eg. for studies looking specifically for protected flora and fauna).

The above assessment has determined that 1 species of endangered flora, 2 species of vulnerable flora and 4 species of unprotected flora have been recorded in the NPWS database for the Shaws Bay area. Also, 6 species of endangered fauna, 144 species of protected fauna, 29 species of vulnerable fauna and 3 species of unprotected fauna have been recorded within the area.

7.2 TERRESTRIAL VEGETATION

7.2.1 Rainforest Community

Remnant littoral rainforest exists on the hillside surrounding the western and northern sides of Shaws Bay and is classified as Suballiance No. 17: *Cupaniopsis anacardioides* (Floyd, 1990). This type of rainforest can withstand greater exposure to wind-blown salt and therefore forms a buffer zone along the coastal margin.

This suballiance is characterised by scattered, emergent *Banksia integrifolia* specimens above a canopy up to 15m high in which *Cupaniopsis anacardioides* is the primary species. Other species commonly include *Cryptocarya triplinervis* (smooth-leaved form) and *Endiandra sieberi* (Hard Corkwood). Occasionally, *Drypetes australasica*, *Glochidion ferdinandi*, and *Celtis paniculats* can be found.

Vines and scramblers are prevalent, particularly *Lantana camara* in disturbed sections. The primary woody vine is *Cissus antarctica*, and wiry vines such as *Smilax australis* and *Stephania japonica* are commonly found.

It is important to note that *Cryptocarya triplinervis*, *Cupaniopsis anacardioides*, *Aronychia imperforata* and *Alectryon coriaceus* are restricted solely to the littoral rainforest.

In general, the existing remnant rainforest appears healthy, with a well developed canopy and understorey. However, particular areas of the forest (*especially in the northwest corner adjacent to the Bay*) appear to be under threat from weed invasion (refer **Plate 7.1**). Weed species in abundance include Green cestrum (*Cestrum parqui*), Lantana (*Lantana camara*), Madeira vine (*Anredera cordifolia*) and Coastal Morning Glory (*Ipomoea cairica*).

The rainforest provides shelter for many species of fauna and would be regarded to have high conservation status both in the local and regional sense. In particular, threatened species such as the Wompoo Fruit Dove, Rose-crowned Fruit Dove, White-eared Monarch, Common Blossom Bat, and Small-leaved Myrtle are dependant on such habitat for their survival. The Grey-headed flying fox (*Pteropus poliocephalus*) and two species of tree frog (to be identified) were observed utilising the rainforest habitat during the site visit.

7.2.2 Other Terrestrial Communities

Vegetation outside of the immediate influence of the Bay, including that within the Holiday Park and nearby residential area, consists primarily of casuarina, acacia, banksia and eucalypts, though other species are present in fewer numbers. The majority of these trees have been planted during the development of the Lakeside Holiday Park and surrounding residential area, and so are less than 30 years of age.

A variety of avifauna was observed utilising the native vegetation, including Rainbow lorikeets, Kookaburra, Wattlebirds and White-cheeked Honeyeaters (*refer* **Section 7.6.4**). The Grey-headed flying fox (*Pteropus poliocephalus*), was also observed utilising the trees (primarily *banksia*) at night.

7.3 FORESHORE / SEMI-AQUATIC VEGETATION

7.3.1 Salt Couch Community

The vegetation along the foreshore surrounding Shaws Bay is fairly uniform, though pockets of salt marsh and mangroves occur in select locations. Salt couch grass grows along most of the sandy beaches, often reaching below the high tide mark. Though restricted at this boundary (ie. the grass would not survive saline inundation for extended periods), the couch grass appears to have had a successful growing season and has spread landwards to the retaining walls (along the western side) or the limit of other terrestrial vegetation (ie grass lawn and/or trees). This grass serves to stabilise sediment, aiding in erosion reduction / prevention and providing a stable substrate allowing other plants to germinate.

Within the couch grass, mangrove seedlings (both *Aegiceras corniculatum* and *Avicennia marina*), saltwort / samphire (*Sarcocornia quinqueflora*), Beach morning glory (*Ipomoea brasiliensis*), and pigface (*Carpobrotus glaucescens*) were observed. The presence of saltwort (refer **Plate 7.2**) is indicative of salt marsh communities, though, in this instance, does not appear to be well-established or stable.

7.3.2 Salt Marsh Community

As mentioned above, saltwort (*Sarcocornia quinqueflora*) is indicative of a salt marsh community, though it alone does not constitute an area being recognised as such.

The northern head of the Bay exhibits growth of couch grass and mangroves, as well as the rush *Juncus krausii*, bounded on the landward side by casuarina. This is as close to the classical definition of salt marsh as one would expect to find in such an altered environment. Juncus also occurs in a small area next to the stand of mangroves along the western side of the Bay.

It may be important to monitor the spread of both mangroves and casuarina in salt marsh areas, as both have been put forward as a potential reason for diminishing salt marsh extents in New South Wales (Rob Williams, pers. comm.)

7.3.3 Mangrove Community

Mature stands comprising two mangrove species, the Grey mangrove (*Avicennia marina*) and River mangrove (*Aegiceras corniculatum*) can be found within the Shaws Bay environment. The areas supporting these stands are generally restricted to four locations. These include a 1220 m^2 stand along the training wall (of which approximately 200 m^2 is River mangrove), a 400 m^2 area adjacent to the southern side of the Lakeside Holiday Park (where there are a few individual River mangroves), a small (approximately 50 m^2) area along the western edge of the Bay, and the largest section of approximately 1400 m^2 in the northern head of the Bay (though this is dissected by Compton Drive). Prior to the construction of Compton Drive, it is likely that the area of mangroves would have included this section of road.

Another area containing two individual, much older mangroves exists on the point in front of the shelters at Pop Denison Park. These trees appear to have been vandalised in the past and are struggling, with reduced photosynthetic capabilities, to survive. Similarly, there would have been a mature stand of grey mangroves along the western side of the Bay, though in recent times they have been sawed off at their base.

It should be noted that, due to successful seed dispersion and germination in the recent past (and currently) as evidenced by the appearance of mangrove seedlings around much of the Bay, the mangrove population could possibly increase significantly in the near future (refer **Plates 7.3 & 7.4**).

A study of the aquatic flora and fauna of Shaws Bay carried out in 1993 (Johnson, 1993) reported that the Grey mangrove was the only species growing within the Bay. Although it is unlikely that the River mangroves have established and grown to maturity during the last six years, it is possible that they were in a more juvenile state and were simply overlooked as a different species. Also, one of the characteristics of the River mangrove is that it has no pneumatophores (peg roots that protrude from the mud). As this stand of River mangroves is surrounded completely by Grey mangroves, pneumatophores are present uniformly throughout the stand thus obscuring an indicator of their existence.

It is suggested and highly likely that shoreline disturbance in the past in the form of dredging and excavation has significantly restricted the growth and spread of mangroves (as well as seagrasses – refer **Section 7.4.1**) within the Bay. Currently, as there is no disturbance of this sort, the mangroves are thriving and have the potential to spread considerably in the coming years.

7.4 AQUATIC VEGETATION (SEAGRASS & ALGAL) COMMUNITIES

Seagrasses and algae are an integral part of any healthy marine or brackish environment, providing food resources, increased habitat diversity and improving water quality by assimilating excess nutrients and increasing dissolved oxygen concentrations in their immediate vicinity. Seagrasses also provide excellent shelter for breeding fish and invertebrates, as well as an effective nursery for the young once hatched. Some faunal species even utilise seagrass blades as attachment surfaces for their eggs. There are herbivores which feed directly on seagrasses, while the vast majority of organisms living within the beds feed on the epiphytes (both plant and animal) growing along the surface of the leaves.

The robustness of seagrasses varies between species, from the heartiness of Eelgrass (*Zostera spp*) to the fragility of Paddleweed (*Halophila ovalis*). Each has particular ranges of salinity, water depth, temperature, current velocity and other parameters within which they are most likely to establish and survive. Seagrasses are also influenced (often negatively) by anthropogenic inputs such as excess nutrients, foot traffic, boat propellers / anchors, and increased nutrients and turbidity from catchment runoff.

Snorkelling of the entire bay took place during the two week site reconnaissance to assess the health and extent of aquatic vegetation. The visibility during this exercise was unfortunately quite poor due to turbidity remaining from the unusual amounts of rainfall so far this year. Given this limitation, the aquatic vegetation of the Bay was delineated and its general health assessed.

The majority of aquatic vegetation within Shaws Bay consists of dense beds of eelgrass (*Zostera spp*), with an area of approximately 20,000 m^2 (refer **Plate 7.5**). A second species of seagrass, Paddleweed (*Halophila ovalis*) fringes many of these beds (refer **Plate 7.6**). What was thought to be a third species of seagrass, which was found entirely within the intertidal zone (*ie. completely exposed at low tide*), fringing the landward edge of many of the Zostera beds on the western side of the Bay (*and some on the eastern side*), was identified by the Botany Department of the University of Queensland to be a morph of the common eelgrass *Zostera Capricorni* (refer **Plate 7.7**). Sea lettuce (*Ulva lactuca*) can be found in abundance among the Zostera beds in the northern arm of the Bay (refer **Plate 7.8**), with patches also occurring at the eastern edge in front of the Lakeside Holiday Park. *Sargassum spp* occurs in small clumps attached to rocks in front of the steps near the western end of the training wall. There is probably more Sargassum within the Bay, though visibility precluded further assessment.

Though Ulva growth is not thought by NSW Fisheries to be of particular concern, it is suggested that further monitoring of the spread of the algae be carried out. The study undertaken in 1993 noted that Ulva was present only in small clumps along the rock wall on the southern side of the Bay (Johnson, 1993). It is clear that areas which were most likely previously occupied by Zostera (primarily in the northern end of the Bay), appear to now be dominated by Ulva. Ulva responds quickly to any slight increases in nutrient input, and could potentially be of concern within this section of the Bay.

7.4.1 Historical Seagrass Extents

Aerial photograph assessment was undertaken using historical and current aerial photography of Shaws Bay supplied by Ballina Shire Council and Department of Land & Water Conservation. Seagrass extent was delineated from 1947, 1973, 1986, 1991, 1994 and 1999 aerial photography, and resulting extents transcribed . Although photograph clarity was variable, a reasonably accurate depiction of indicative changes in seagrass extent over the years has been obtained (refer **Figure 7.2**).

It has been suggested that seagrasses were introduced to Shaws Bay (along the wall) during the war years for the purpose of harvesting seagrass crops for medicinal purposes. Assessment of aerial photography from 1947 suggests that a portion of this statement may be true, as it appears a trough in the East Arm of the Bay was constructed quite possibly for this purpose. A small pathway even leads down from the wall to the edge of this trough. Further assessment of the photograph shows extensive seagrass growth along many sections of the Bay, suggesting the presence of seagrasses throughout the Bay for quite some time. Indeed, mapping created prior to the construction of the entrance training walls suggests that what was once "New Chums Bay" (now Shaws Bay) could have been a suitable environment for seagrass growth, protected from the open ocean by extensive entrance shoals.

At various stages during the development of the residential communities of Shaws Bay and East Ballina (ie. the 1960s, 70s and 80s), dredging and excavation of the Bay and its foreshore have been undertaken, significantly altering the location of the shoreline and therefore affecting foreshore and aquatic vegetation (mangroves, seagrasses, etc.). For example, excavation of the north-east shoreline of the Bay relocated it 30-70m to the east, while the western shoreline has been shifted 20-30m to the east as fill for the creation of Compton Drive was added. Seagrasses as well as foreshore vegetation could have been removed / killed during these procedures (as recently as 1975, 1982 and the early 1990s), requiring significant time to re-establish.

It has also been suggested that seagrasses have only begun to spread rapidly along the foreshores of the bay within the last few years. The aerial photo analysis and history of works within the Bay supports the argument that seagrasses have been in Shaws Bay for quite some time. Only recently, however, have they been left undisturbed and, as with the spread of mangroves discussed above, it is likely that seagrasses will continue to flourish now that there is little disturbance to their growth. The shallow depth, good water quality and low flows within Shaws Bay combine to create an environment fully suited for seagrass growth.

7.5 TERRESTRIAL FAUNA

Due to the highly populated and urbanised environment and the resulting extensive human activity surrounding Shaws Bay, terrestrial fauna would not be expected to be in abundance, even in the littoral rainforest adjacent to the Bay. However, there are certainly a few resident animals and others may utilise this area of forest as shelter when moving from one location to another.

Two mammals (or evidence of) were observed during the site reconnaissance. A substantial colony of Grey-headed Flying Foxes (*Pteropus poliocephalus*) of >200 individuals (possibly more) utilise banksia as well as the littoral rainforest within the Shaws Bay area to hang in during the day and move about in at night. Tracks of the Water Rat (*Hydromys chrysogaster*) were found on a sandy beach along the western side of the Bay (refer **Plate 7.9**). This mammal would tend to forage at night, feeding on fish, snails, clams and crabs.

Two species of frogs were utilising the rainforest and its boggy fringes (refer **Plate 7.10** for one of the species).

7.6 AVIFAUNA

A wide variety of bird species were observed during the site assessment, with most of the birds utilising Shaws Bay directly as a food source. Many birds were also observed utilising the Bay's surrounding habitats such as trees, shrubs and open grassy areas. The birds using Shaws Bay, particularly those feeding on fish and invertebrates in the Bay itself, are indicative of a healthy estuarine environment. As predators, they add to the ecological balance by keeping in check the

Bay's other populations of animals (fish / invertebrates), which may have no other natural predators.

7.6.1 Raptors

Brahminy Kites (*Haliastur indus*) and Osprey (*Pandion haliaetus*) were observed, though their nests are not located within the vicinity of Shaws Bay. Two Brahminy Kites were seen on a daily basis for five consecutive days, but the Osprey was only seen on two of those days. On several occasions, the birds fed directly on fish (appeared to be sea mullet) directly from Shaws Bay and also from the Richmond River immediately adjacent to the northern training wall.

7.6.2 Seabirds

Silver Gull (*Larus novaehollandiae*), Common Tern (*Sterna hirundo*), Australian Pelican (*Pelicanus conspicillatus*), Little Black Cormorant (*Phalacrocorax sulcirostris*), and Pied Cormorant (*Phalacrocorax varius*) were all observed within the Bay feeding and/or swimming.

7.6.3 Wading Birds / Shorebirds

White Faced Heron (*Egretta novaehollandiae*), Australian White Ibis (*Threskiornis molucca*), Great Egret (*Ardea alba*), and Bar-Tailed or Black-Tailed Godwit (*Limosa spp*) were observed feeding directly on worms, snails, clams, fish and soldier crabs along the edges of the Bay and within the seagrass beds (refer **Plate 7.11**).

7.6.4 Songbirds / Land-Based Birds

Masked lapwing (*Vanellus miles*), Willy Wagtail (*Rhipidura leucophrys*), Crested Pigeons (*Ocyphaps lophotes*), Galah (*Cacatua roseicapilla*), Kookaburra (*Dacelo novaeguineae*), Rainbow Lorikeet (*Trichoglossus haematodus*), Little Wattlebird (*Anthochaera chrysoptera*), and White-cheeked Honeyeater (*Phylidonyris nigra*) were observed utilising habitat surrounding Shaws Bay. Many were utilising the native vegetation (acacia, banksia) for food and shelter, while grassy areas around the Lakeside Holiday Park served as nesting grounds for two pairs of Masked Lapwing.

7.7 INTERTIDAL & AQUATIC FAUNAL COMMUNITIES

7.7.1 Snorkelling & Intertidal Survey

Assessment of aquatic faunal communities was undertaken over a three day period and included extensive snorkelling and land based surveying. Due to low visibility, the quality of both snorkelling and land based visual inspection was reduced. A variety of intertidal and aquatic fauna was observed, including juvenile Sea mullet and Flathead, school prawns, snapping prawns, sea cucumbers, mud crabs, moray eel (refer **Plate 7.12**), and numerous gastropods such as Sydney whelks and moon snails (refer **Plates 7.13 & 7.14**). Sea mullet were also frequently observed jumping throughout the Bay.

The intertidal communities within the Bay at the time of the survey were very active, with extensively bioturbated sediments from polychaete worm and gastropod (snail) activity (refer **Plate 7.15**), as well as a number of bird species feeding on the organisms. The soldier crab (*Mictyris longicarpus*) community also appears quite hearty, with an adult population of more than 500 individuals and what appears to have been a successful breeding season, as indicated by tens of thousands of juvenile soldiers inhabiting the intertidal and supratidal beach along the foreshores of the East Arm of the Bay (refer **Plates 7.16, 7.17 & 7.18**).

7.7.2 Benthic Macroinvertebrate Sampling

Sampling of benthic organisms was undertaken at 27 sites around the Bay (refer **Figure 7.3**) to determine the general abundance or paucity of marine invertebrate life. Note that statistical analyses were not undertaken as this was not intended to be a formal sampling exercise. Benthic sampling was undertaken using a 150mm diameter cylinder pushed into the sediment to a depth of approximately 300mm and removing the core. The sediment was then sieved using a 1mm mesh size. Organisms retained were sorted, identified to family level, counted, then returned to the water. Tabulated sampling results have been provided in **Appendix E**.

The majority of organisms obtained during the sampling were polychaete worms, with gastropods such as the Sydney whelk (*Pyrazus ebeninus*), Comptess's top shell (*Prothalotia comtessi*), and Small whelk (*Batillaria australis - formerly Velacumantis australis*) also being quite numerous. Amphipods and bivalve molluscs (clams) were also present in many of the samples.

It is important to note also that biological surveys undertaken in winter can generally underestimate the biological activity of an area due to cooler water temperatures. It is therefore expected that Shaws Bay would be even more highly biologically active during the warmer months of the year.

7.7.3 Aquatic Fauna Recruitment to the Bay

Planktonic organisms (*ie. plants and animals whose location is determined by water movement*), including larval stages of many large fish or invertebrates, may enter and exit the Bay by being carried through the wall by tidal flows. It is possible, though highly unlikely, that aquatic organisms more mature than larvae negotiate the interstices of the wall. There is therefore little or no mobility of mature aquatic fauna in or out of the Bay.

Interestingly, there are mature specimens of fish within Shaws Bay that, although they would occasionally return to estuaries for various reasons such as feeding or spawning, would normally live out much of their adult lives within the open ocean such as trevally, parrotfish and sea mullet (which would venture to the open sea to spawn).

7.8 BIOLOGICAL IRRITANTS WITHIN SHAWS BAY

There is evidence of the existence of organisms in and around Shaws Bay which can cause significant irritation to people using the Bay and its surroundings. The following discussion deals with the issue of biting midge, as well as the possible existence of an aquatic organism which causes "Bather's itch" (often referred to as "Pelican itch") or cercarial dermatitis.

7.8.1 Biting Midge

A study was undertaken by the Entomological Unit of Tweed Shire Council to determine the existence of a biting midge population within or in the vicinity of Shaws Bay. The full report, which incorporates all sampling results and management options, is provided in **Appendix F**.

Due to the time of year (*July*), adult populations were not available for assessment. Rather, sampling was undertaken to determine the extent of larval populations along the sandy foreshores of the Bay. This served to flag particular areas utilised as breeding areas for the midge. Areas along the Richmond River were also assessed to determine if populations bred along the river then travelled to Shaws Bay to feed.

Two species of biting midge, *Culicoides molestus* and *Culicoides subimmaculatus*, were found in Shaws Bay. The study determined that the biting midge breeding area most likely affecting Shaws Bay is the sandy beach which runs along the length of the Lakeside Holiday Park. Due to the suitable sandy environment and excellent source of food during the summer months (*ie. visitors to the Holiday Park*), larval populations were higher here than those found in the canal estates on the Tweed River and Gold Coast (refer **Appendix F**).

Several management options are also discussed within the report including the use of pesticides, beach raking, and change of substrate.

7.8.2 Cercarial Dermatitis

The faunal and benthic macroinvertebrate sampling exercises undertaken in Shaws Bay have confirmed the presence of the gastropod *Batillaria australis* (*formerly Velacumantis australis*) or Small whelk. This particular snail is an intermediate host for the larval stage of a trematode worm (*larval stage = Cercaria variglandis v. pyrazi, adult worm = Austrobilharzia terrigalensis*). The definitive hosts include the seagull, duck and black swan, while humans are often a non-definitive host in infested areas. The larval worms (*cercaria*) can burrow into human skin resulting in a severely itchy, bump rash known as cercarial dermatitis (*also known as Bather's Itch, Pelican Itch, Schistosome Dermatitis, Marine Dermatitis, Paddy Itch, Toukley Itch, Tuggerah Itch, or Weed Itch*)(Edmonds, 1981).

The skin irritation resulting from contact with this animal are not to be confused with the rash one obtains from sea lice (*from swimming in the ocean*), biting midge, or jellyfish larvae which can also sting, but tend to result in a rash coinciding with the water line on a wading person's legs.

The rash begins with a prickly sensation which is followed by a mild, red rash which fades within an hour but may recur over the next day or so. In 2-10 days, bumps 1-2mm in diameter appear which may blister and fill with blood- these are surrounded by a red halo, and the entire area becomes inflamed. The affected area is extremely itchy. These symptoms subside rapidly after a week or so, though the skin may be marked for more than a month. If any of these symptoms appear, a doctor's professional assistance should be sought.

Although the intermediate host *Batillaria australis* exists within Shaws Bay, it is not certain that cercarial dermatitis is or will be an issue. Descriptions of rashes obtained by some of the Bay's users have not resulted in cause for alarm, though the potential presence of this problem can not be completely ruled out.

7.9 HABITAT VALUES

Figure 7.4 indicates the various habitats within and surrounding Shaws Bay, and provides some insight into why these habitats are important to the survival of the organisms inhabiting it, and indeed, to the survival of the Bay itself. The various habitats have been addressed in the preceding sections and their values and potential concerns pertaining to some are summarised below in **Table 7.1**.

Habitat type	Value	Potential concerns
Rainforest	• habitat for native flora / fauna, often protected species • source of food for native fauna • improvement to runoff water quality by acting as filter	• needs protection from weed infestation • prevent removal by future development
Other native vegetation	• habitat for native flora / fauna • source of food for native fauna • improvement to runoff water quality by acting as filter	• prevent removal by future development • casuarina encroachment on salt marsh
Open grassy areas	• breeding habitat for native fauna • source of food for native fauna improvement to runoff water quality by acting as filter	• lack of adequate drainage in some areas creates boggy situation, suitable for mosquito breeding
Couch grass	• effectively stabilises sediment to reduce / prevent erosion • habitat for native flora / fauna, including various salt marsh species	• growth can be out of control and can be classified as a weed
Sandy beach	• habitat for native fauna • food source and breeding habitat for native fauna	• suitable habitat for breeding populations of biting midge • actively addressing the biting midge issue would have significant implications for other resident fauna
Salt marsh	• habitat for native flora / fauna • improvement to runoff water quality by acting as a filter	• exists in very small area of the Bay, and is therefore fragile / vulnerable • potential encroachment by mangroves and casuarina
Mangrove	• habitat for native flora / fauna • improvement to runoff water quality by acting as a filter • stabilises muddy, potentially erodable sediments	• illegal removal of seedlings and destruction of adult trees • permit must be obtained from Fisheries to legally manage the growth / spread of mangroves
Seagrass	• habitat for native flora / fauna • food source and breeding area for many organisms • improvement to water quality • backbone of the health of the Bay	• potential competitive exclusion from Ulva lactuca (sea lettuce) in northern arm of Bay • human impacts such as trampling or mechanical removal (eg. excavating) • unidentified species may be tropical species at its southernmost range

Table 7.1 Habitat Values and Concerns

8 WATERWAY USAGE

Shaws Bay and its surrounding lands is highly utilised by both the local community, and visitors to the area, with two caravan parks located on its immediate foreshores. The waterway itself provides for a variety of uses, including fishing, swimming, snorkelling, canoeing, paddle boating, wind surfing and acquisition of bait. The bay also receives locally derived stormwater, via surface runoff and 17 stormwater drains.

The uses and their potential effects on Shaws Bay are discussed below and are shown in **Figure 8.1**.

8.1 FISHING

Fishing takes place both from foreshore beaches and from the rock wall. All extents of the bay are viable fish habitat and attract fishers of all ages, but particularly children who are learning to catch fish. Primary fish species caught include Bream, Whiting and Flathead. Anecdotal reports suggest that large Mulloway (Jewfish) and Trevally have been caught, and that a Mangrove Jack caught in Shaws Bay holds the present record for size, although this is unconfirmed. Species lists for fish observed in Shaws Bay are presented in **Appendix E**.

It is possible that fish caught in Shaws Bay could be larger than what might be caught in other estuaries, as the rock wall restricts the number of predator fish to only those which have grown within the bay itself. Fishing also includes prawning, which some fishers use as bait.

The number of people fishing in Shaws Bay would vary seasonally. As there are two caravan parks located on the bay foreshores, the number of fishers on Shaws Bay is likely to reflect occupancy rates, with higher numbers during the summer months and school holiday periods.

Commercial fishing and netting is not allowed within Shaws Bay. Spear-fishing is also not allowed within Shaws Bay.

<u>Potential affect on the waterway:</u>

- as Shaws Bay is only a limited size, it would be possible to remove enough fish to have a significant affect on the existing stocks within the bay. Being a ‘closed’ system, the bay is likely to have been able to reach an equilibrium with respect to the numbers of various fish, ie lots of very small fish (fry), which are preyed on by a lesser number of small fish, which are preyed on by a lesser number of larger fish, and so on. Removing a large number of the more predatory fish, such as Mulloway or Trevally, may have a significant impact on the numbers of all other fish species in the bay.
- NSW Fisheries does not consider recreational fishing in Shaws Bay to be of major concern to fish stocks within the waterway, providing that it is carried out using lines only (ie no nets or traps).

8.2 SWIMMING AND SNORKELLING

Swimming is the dominant activity within Shaws Bay. Many permanent residents of Ballina use Shaws Bay for swimming and snorkelling on a regular (mostly daily) basis during the summer months, while some keen swimmers use Shaws Bay during winter months as well. Itinerant residents and daytime visitors of Ballina also use the bay for swimming and snorkelling, as it provides a safe environment, protected from the waves and surges associated with the open coastal beaches and main river areas.

It is understood that sports clubs, such as the local triathlon club and the surf lifesaving club, also use Shaws Bay for swimming training and sometimes competitions, while Ballina High School marine studies students regularly snorkel within the bay.

Potential affect on the waterway:

- the only impact that swimming and snorkelling would have on the bay is associated with access into and out of the water. At present, there is no formal access locations, and as such, the general public enter and exit the water wherever they please. While this dispersed entry and exit would minimise the impact on benthic biota, it sometimes occurs within areas of seagrasses. Regular wading through seagrass beds to access the water would be harmful to the seagrass in the long-term, potentially uprooting and/or damaging fronds, increasing turbidity, and impeding growth of immature plants.

8.3 ACQUISITION OF BAIT

Related to the popularity of fishing in Shaws Bay is the fact that some people utilise portions of the waterway to obtain bait. Yabby pumping takes place on the sand flats on the edges of the bay, particularly in the East Arm of the bay. The process obtains yabbies by inserting a tube into the sand which extracts cores of sediment and any yabbies contained within those cores. The material is placed in a sieve through which all of the sediment escapes, leaving the yabbies behind.

Potential affects on the waterway:

- localised turbidity increases (affected by sediment type, ie. coarse sand or finer muds)
- if done within or along edges of seagrass beds, could damage the beds and organisms contained within them
- if too much is carried out at one time within a localised area, the process could damage the yabby population in that area (unlikely to cause significant damage if there are few fishers and gathering activity is spread around)

8.4 PUBLIC ACCESS ALONG FORESHORES

Sandy intertidal and supra-tidal beaches / sandflats exist around the majority of the bay, which are utilised for swimming access, fishing, relaxing, sunbaking etc. Some tracks have been worn linking public areas with the sandy beaches, such as along the embankment on the northern foreshore of the East Arm.

Potential effect on the waterway:

- rubbish introduced by people leaving glass and plastic bottles and paper, cardboard or styrofoam containers behind. This has been reported by some respondents to the community questionnaire (refer **Section 2.1**).
- continual usage of access tracks can trample vegetation, possibly resulting in die-off and exposure of bare soils, which could then erode by surface runoff or wind blown transport.

8.5 PADDLE-BOATING, CANOEING AND WIND-SURFING

Approximately six paddle-boats operate on Shaws Bay during the warmer months of the year (October to April). The paddle-boats are rented from a local base (in front of Fenwick House), and generally remain within the main section of the bay. Canoeing and wind-surfing would generally occur within the deeper sections of the bay. The protected nature of the bay makes it attractive to people learning these particular watersports. Canoeists and wind-surfers would generally access the bay along Compton Drive, where parking is available close to the waters edge.

Potential effect on the waterway:

- paddle-boat paddles, canoe paddles and bottoms, and wind-surfboard keels can potentially damage seagrasses if the activity occurs over the shallow seagrass beds.
- As for swimming and snorkelling, access into and out of the water can also affect seagrasses if regular access through the beds occurs.

8.6 MOTOR BOATING

Although not prohibited from Shaws Bay, very little motor boating occurs within the bay. Reasons for this include:

- No formal access for trailable boats (ie no boat ramp);
- Small size of Shaws Bay means that the boats cannot travel very far;
- All of the bay is accessible by walking around the foreshore.

Potential effect on the waterway:

- local effect of introduction of oil and/or petrol into the waterway, potentially spreading upstream during incoming tides
- noise associated with engines could disturb established native fauna not acclimatised to such disturbances
- any type of boating (*especially propeller driven*) can damage seagrass beds or other benthic habitats (*eg. sandy / muddy bottom*)

These potential effects would be minimal considering the very little motor boat activity on Shaws Bay.

8.7 STORMWATER DRAINAGE

There are seventeen stormwater drains which discharge into Shaws Bay. These drains service the vast majority of the local Shaws Bay catchment, with individual sub-catchments ranging from about 6,000m^2 to over 150,000m^2, generating a range of flood flows and pollutant loads (refer **Sections 6.3.1** and **4.4.2**).

Potential effect on the waterway:

- decreased water quality through increased input of nutrients and other pollutants.
- Possible erosion or sediment accretion in vicinity of drains

As outlined in **Sections 4.6** and **6.3.2**, the pollutants entering the bay from stormwater runoff is diluted and dispersed within the bay relatively quickly. Hence, any potential impacts of the stormwater drainage on water quality is likely to be short-lived.

As outlined in **Sections 5.6.2** and **6.3.1**, the amount of sediment generated from the catchment is likely to be small, and much less than the amount of fine sediment entering the bay from the river during times of flooding.

9 HUMAN IMPACTS

Shaws Bay is a tidal lagoon that was produced as a by-product of human activities in the Richmond River entrance. By this very nature, Shaws Bay has had human impacts ever since it was formed. **Table 9.1** outlines the basic chronology of events over the last 100 years which have resulted in impacts on the estuary processes of Shaws Bay.

Year	*Human Activity*	*Impact on Shaws Bay Estuarine Processes*
~1900	Construction of the northern breakwater of the Richmond River entrance	• Resulted in the isolation of Shaws Bay from the rest of the Richmond River estuary. • Tidal inundation of the bay required passage through the rock wall first. • In the following years, sediment would have built up on the inside of the wall, restricting tidal flow through the wall at low tide.
1940s	Construction of channel adjacent to the breakwater	• Possible seeding and harvesting of seagrasses within the channel • Would have filled in due to reworking of surrounding sediments and sand washover during ocean storms
late 1950s – early 1960s	Construction of Compton Drive with possible extraction from Shaws Bay	• Reclamation of approximately 30 metres of the western and northern foreshores, smothering former mangrove and seagrass habitats • Possible extraction from deeper areas of Shaws Bay would have disturbed benthic biota as well as increased the low water volume of the bay, thereby reducing flushing potential of the bay • Collection of escarpment seepage in catch drains and direction into the bay via stormwater pipes under the road

Table 9.1 Chronology of Human Impacts on Shaws Bay Estuary Processes

Year	*Human Activity*	*Impact on Shaws Bay Estuarine Processes*
1962	Filling of low-lying sand swamps between Shaws Bay and the beach dunes with extraction from Shaws Bay	• Extraction of source fill material would have included resident benthic biota, and would have affected the habitat for itinerant marine life • Increase in the size of the northern bay would have increased tidal prism, which may have improved flushing • Potential extraction from deeper parts of Shaws Bay would have disturbed benthic biota as well as increased the low water volume of the bay, thereby reducing flushing potential
mid 1960s	Construction of access road for breakwater extension	• Infilled the former low dunes on the northern side of the breakwater preventing any further washover of beach sand into the bay behind
early 1970s	Development of filled area as a residential site	• Stabilisation of sandy soil through ground cover vegetation, effectively terminating any further reworking of sediments into the bay by wind transport • As the amount of impervious area increased by the addition of more houses, so did the peak stormwater flows and volumes discharging into Shaws Bay • Introduction of nutrients and organic matter from subdivision gardens and lawns
1975	Dredging of Shaws Bay to create beaches along foreshores	• Removal of material would have affected resident benthic biota in areas of sub-tidal removal and intertidal and supra-tidal disposal • Added sand to the longshore transport pathway, which was subsequently reworked along the foreshore and back into the bay • Would have smothered any establishing seagrasses along the foreshore • Would have increased low water volume of bay and reduced tidal prism, thereby reducing flushing potential of the bay

Table 9.1 Chronology of Human Impacts on Shaws Bay Estuary Processes cont'd.

Year	*Human Activity*	*Impact on Shaws Bay Estuarine Processes*
1982	Dredging of Shaws Bay	• Removal of material would have affected resident benthic biota from area of sub-tidal removal as well as area of intertidal and supra-tidal disposal • Added sand to the longshore transport pathway, which was subsequently reworked along the foreshore and back into the bay • Would have smothered any establishing seagrasses along the foreshore • Would have increased low water volume of bay and reduced tidal prism, thereby reducing flushing potential of the bay
~1986	Dredging of Shaws Bay, however, only a small volume of material was extracted	• Removal of material would have affected resident benthic biota from area of sub-tidal removal as well as area of intertidal and supra-tidal disposal • Added sand to the longshore transport pathway, which was subsequently reworked along the foreshore and back into the bay • Would have smothered any establishing seagrasses along the foreshore • Would have increased low water volume of bay and reduced tidal prism, thereby reducing flushing potential of the bay
~1991	Removal of seagrasses from the East Arm channel	• As well as actually reducing the total biomass of seagrasses in the bay, it would have significantly reduced viable habitat area for many marine species, and would have killed most benthic biota living amongst the grasses

Table 9.1 Chronology of Human Impacts on Shaws Bay Estuary Processes cont'd.

Year	*Human Activity*	*Impact on Shaws Bay Estuarine Processes*
~1992	Nourishment of beaches using long-reach excavator to source material from bay	• Removal of material would have affected resident benthic biota from area of sub-tidal removal as well as area of intertidal and supra-tidal disposal • Added sand to the longshore transport pathway, which was subsequently reworked along the foreshore and back into the bay • Would have smothered any establishing seagrasses along the foreshore

Table 9.1 Chronology of Human Impacts on Shaws Bay Estuary Processes cont'd.

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FIGURES

Figures can be found under the Figures directory on CD (see list on following page).

PHOTOGRAPHS

Photograph images can be found under the Plates directory on CD:

Plates 7.1, 7.2, 7.3 and 7.4 ..\Plates\Plates1-4.doc

Plates 7.5, 7.6, 7.7 and 7.8 ..\Plates\Plates5-8.doc

Plates 7.9, 7.10, 7.11 and 7.12 ..\Plates\Plates9-12.doc

Plates 7.13, 7.14, 7.15 and 7.16 ..\Plates\Plates13-16.doc

Plates 7.17 and 7.18 ..\Plates\Plates17-18.doc

APPENDIX A

COPY OF COMMUNITY QUESTIONNAIRE
can be found under the Appendix directory on CD:

Page 1 …… Appendix/ A_questionaire1.pdf
Page 2 …… Appendix/ A_questionaire2.pdf
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APPENDIX B

INFORMATION COLLECTED FROM RICHMOND RIVER HISTORICAL SOCIETY can be found under the Appendix directory on CD:

"Port Improvements" and "Shaw's Bay" newspaper articles dated 5th May 1950

"Solution to shipping problems brought added bonus benefits" newspaper article Northern Star supplement dated 12th Dec 1981

"Talk on the Ballina breakwater prepared from the historical society's records and from the records of the harbour and marine branch of the Department of Public works"
Prepared and delivered by Mrs J Bell dated August 1955 Page 1
……………………………………………………….….. Page 2
……………………………………………………….….. Page 3
……………………………………………………….….. Page 4

"Flashbacks on Ballina" newspaper article dated 18th May 1967

"How the Richmond river could be opened up" proposed drawing

"Survey of the Entrance of the Richmond River" 1853 drawing not legible

"Survey of the Entrance of the Richmond River" 1864

Photos of Shaws Bay in 1930, Forster entrance from Tuncurry in 1924 and locomotive used in eastern breakwater at Coffs Harbour.

APPENDIX C1

SURFACE SEDIMENTOLOGICAL ANALYSIS

can be found under the Appendix directory on CD:

APPENDIX C2

VIBROCORE LOGS

can be found under the Appendix directory on CD:

APPENDIX C3

SEDIMENT QUALITY ANALYSIS

can be found under the Appendix directory on CD:

APPENDIX C4

COPIES OF HISTORICAL AIR PHOTOS

can be found under the Appendix directory on CD:

APPENDIX D

DATA FROM THE DPWS DATA LOGGER IN SHAWS BAY

can be found under the Appendix directory on CD:

APPENDIX E

FLORA & FAUNA INFORMATION FROM VARIOUS SOURCES

can be found under the Appendix directory on CD:

APPENDIX F

ASSESSMENT OF BITING MIDGES IN SHAWS BAY

BY

CLIVE EASTON
ENTOMOLOGICAL UNIT, TWEED SHIRE COUNCIL

can be found under the Appendix directory on CD: