Port Stephens Council
December 1995

Anna Bay Catchment Drainage/Flood Study Masterplan

Final Report

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Contents

1. Introduction

This study of the Anna Bay catchment area was commissioned by Port Stephens Shire Council in July 1993. The boundary of the defined study catchment is shown in **Figure 1.1**. The catchment includes both urban areas, in particular part of Anna Bay township, and agricultural areas.

There are some existing drainage problem areas in the study area, particularly along Gan Gan Road in the vicinity of Anna Bay township. With urban development occurring in the catchment, there are concerns that drainage/flooding problems should not be made worse and that downstream water quality should not be adversely affected. The overall aim of the study is to provide a framework for planning and implementation of trunk drainage, flood mitigation and water quality control measures in the catchment.

The specific objectives of Council's Brief are:

- To assess the existing drainage system in relation to adequacy for current and future discharge.
- To identify where drainage/flooding problems would occur in a totally developed catchment and hence establish the maximum sustainable development potential.
- To satisfy Council's design standards, as well as relevant guidelines given in Australian Rainfall & Runoff (1987) and the Pollution Control Manual for Urban Stormwater (1989).
- To assess the impacts of any proposed drainage works recommended, with regard to existing and future uses.

An important output of the study will be preliminary cost estimates for improvement schemes, for use in preparation of a draft Section 94 contribution plan.

The following sections of the report describe the major tasks and findings of the study, including:

- A description of the catchment and its major subcatchments.
- An assessment of the existing drainage system.
- An overview of the future development scenario for the catchment.
- An assessment of trunk drainage improvements and water quality control measures required in conjunction with future development, with preliminary cost estimates.

Figure 1.1
STUDY CATCHMENT
Anna Bay Catchment Drainage/Flood Study

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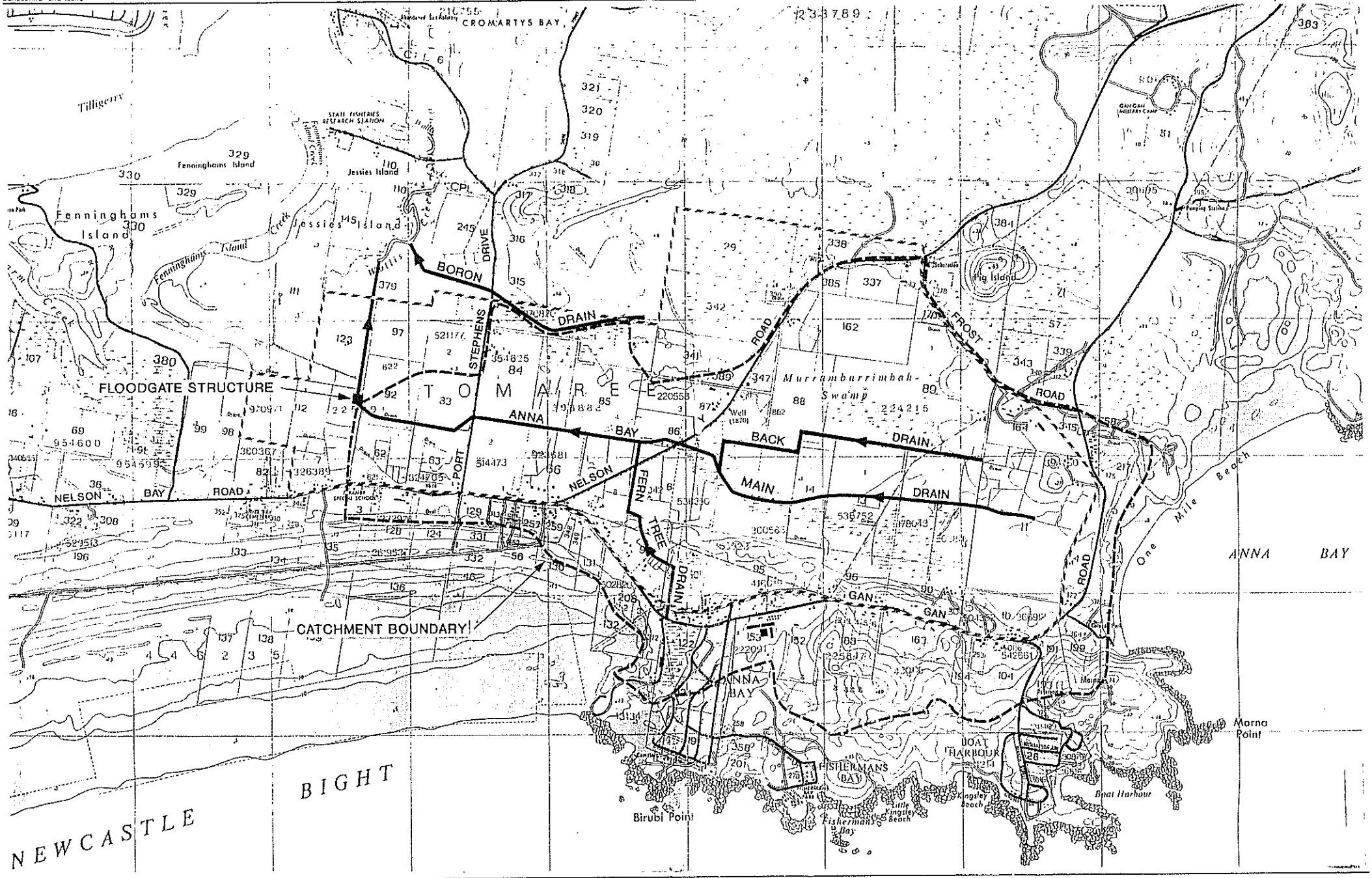

The findings of an investigation into acid sulphate soils and groundwater monitoring in the study catchment are provided in the **Addendum**. These investigations were undertaken by Coffey Partners International Pty Ltd.

2. Catchment Description

2.1 General

The study catchment, as shown in **Figure 1.1**, has a total area of about 12 km^2. The catchment includes a substantial part of the Anna Bay township, as well as development along Gan Gan Road to the west and east of the township. Most of the catchment area is currently utilised for agriculture, including grazing and orchards. This land includes the Murrumburrimbah Swamp area.

The catchment is drained via Anna Bay Main Drain which flows west, then north to Wallis Creek. Wallis Creek is a tributary of Tilligerry Creek which flows into Port Stephens. A floodgate structure constructed on the main drain prevents the entry of high tides and salt water into the upstream area.

The floodgate structure operates as a hydraulic control on flows out of the catchment and is downstream of the potential development areas. Hence it is an appropriate downstream boundary for the purposes of the study.

The Anna Bay township area is drained to Anna Bay Main Drain by means of an open channel known as Fern Tree Drain. Council has obtained and is continuing to obtain easements along this drain for the purposes of maintenance. Council has also obtained easements for a network of local drains near the upstream end of the Anna Bay Main Drain. These drains were constructed as part of a subdivision known as Ocean Side Country Estate and comprising primarily 0.4 ha lots.

2.2 Anna Bay Drainage Union

The Anna Bay Drainage Union has various powers and duties under the Drainage Act, 1939; including:

- Maintain efficiently the works under its charge and review such works where necessary.
- Construct, alter or extend works in accordance with any authority and consent given under the Act.
- Make, levy and collect rates.

The gazetted works for which the Union is responsible are:

- Anna Bay Main Drain.
- A large drain on the north side of and contributing to the main drain east of Nelson Bay Road (known as Back Drain).

- A large drain to the north of the study catchment and with outlet to Wallis Creek (known as Boron Drain).

There are no easements for the drains controlled by the Union.

The boundary of the proclaimed Union area is shown in **Figure 1.1**. The Union is empowered to collect rates from the property owners, including new subdivisions, within the proclaimed area.

Some of the catchment draining to the Anna Bay Main Drain is outside the proclaimed area, including substantial existing and potential future residential developments south of Gan Gan Road and Old Main Road. The Union has the power to refuse to accept any new artificial drainage from outside the proclaimed area.

With the increasing number of development proposals both within and outside the proclaimed area, the Union is concerned about the potential impacts of development on the performance of the drainage system.

2.3 Catchment Subdivision

The total catchment area may be divided into a number of subcatchments, as shown in **Figure 2.1**, and based primarily on existing drainage patterns. There are three main areas within the catchment:

- The area bounded by the undulating dunes to the north and south of Gan Gan Road (Subcatchment Nos 1 to 5) - see **Figure 2.2**. This area contains most of the existing urban development within the defined study area and is experiencing on-going residential development.

- The remaining area east of Nelson Bay Road. This area is mostly of low relief and includes Murrumburrimbah Swamp (Subcatchment Nos 6 to 10) - see **Figure 2.3**. The area is recognised as having potential for development. In particular, a major development, known as the Jacaranda Tourist Resort, was previously proposed to cover about 330 ha over a number of properties in this area.

- The area west of the Nelson Bay Road-Gan Gan Road intersection (Subcatchment Nos 11 to 14). It is envisaged that any development in this area will be on the higher land adjacent to Nelson Bay Road.

The main features of the subcatchments are summarised below:

Subcatchment No 1 (17 ha)
This subcatchment is almost undeveloped, and contains heavily timbered area and some cleared area. The runoff potential is low at present, and any runoff would accumulate in low lying area near the Gan Gan Road-

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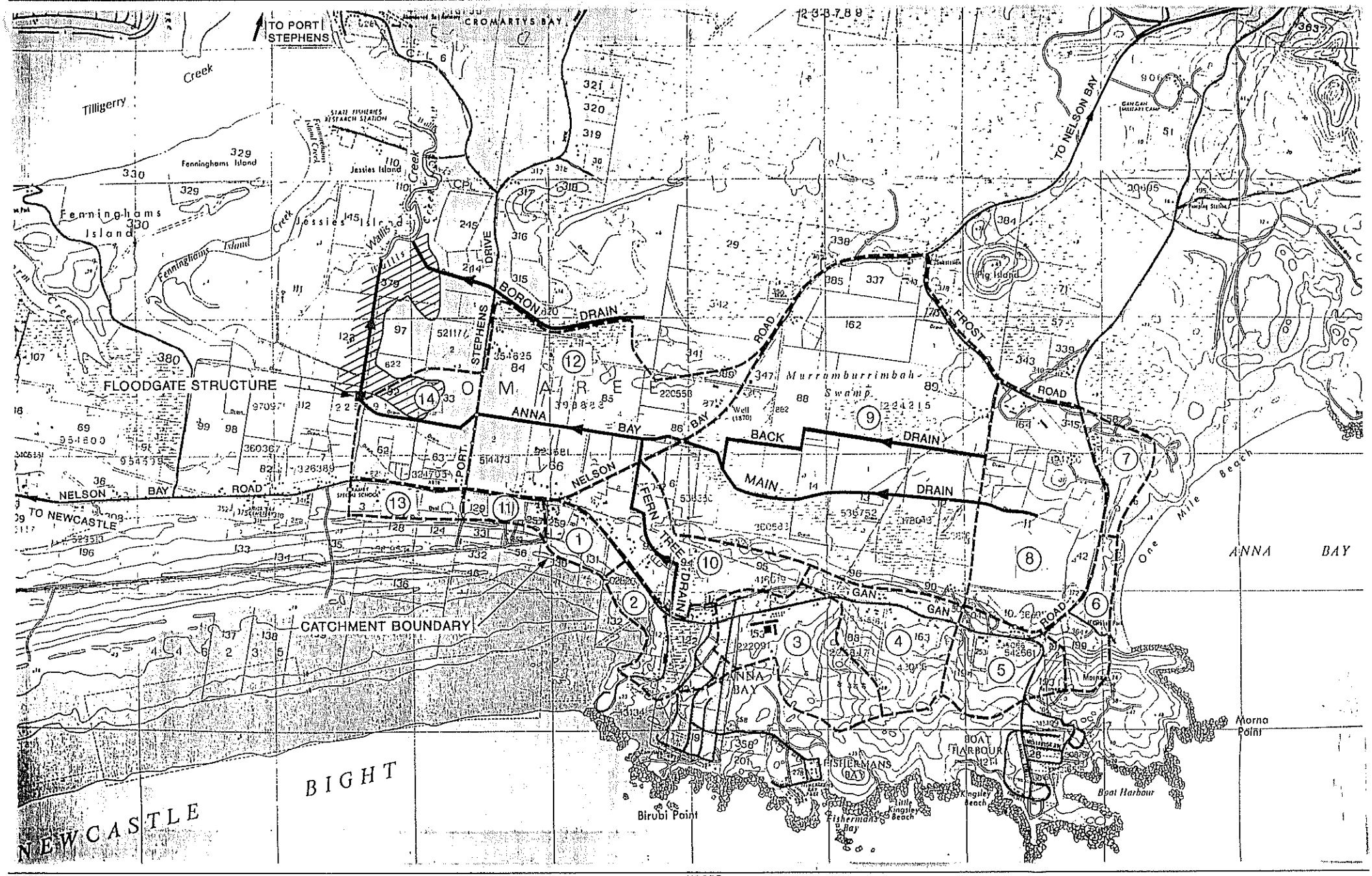
Figure 2.1
MAJOR SUBCATCHMENTS
Anna Bay Catchment Drainage/Flood Study



LEGEND
(1) SUBCATCHMENT NUMBER
SEPP 14 WETLAND

NOTES
REFER TO TOMAREE PENINSULA ENVIRONMENTAL STUDY (1989) FOR FULL EXTENT OF WETLAND

N

0 0.5 1.0 km

Figure 2.2
SUBCATCHMENTS
SOUTH OF GAN GAN ROAD
Anna Bay Catchment Drainage/Flood Study

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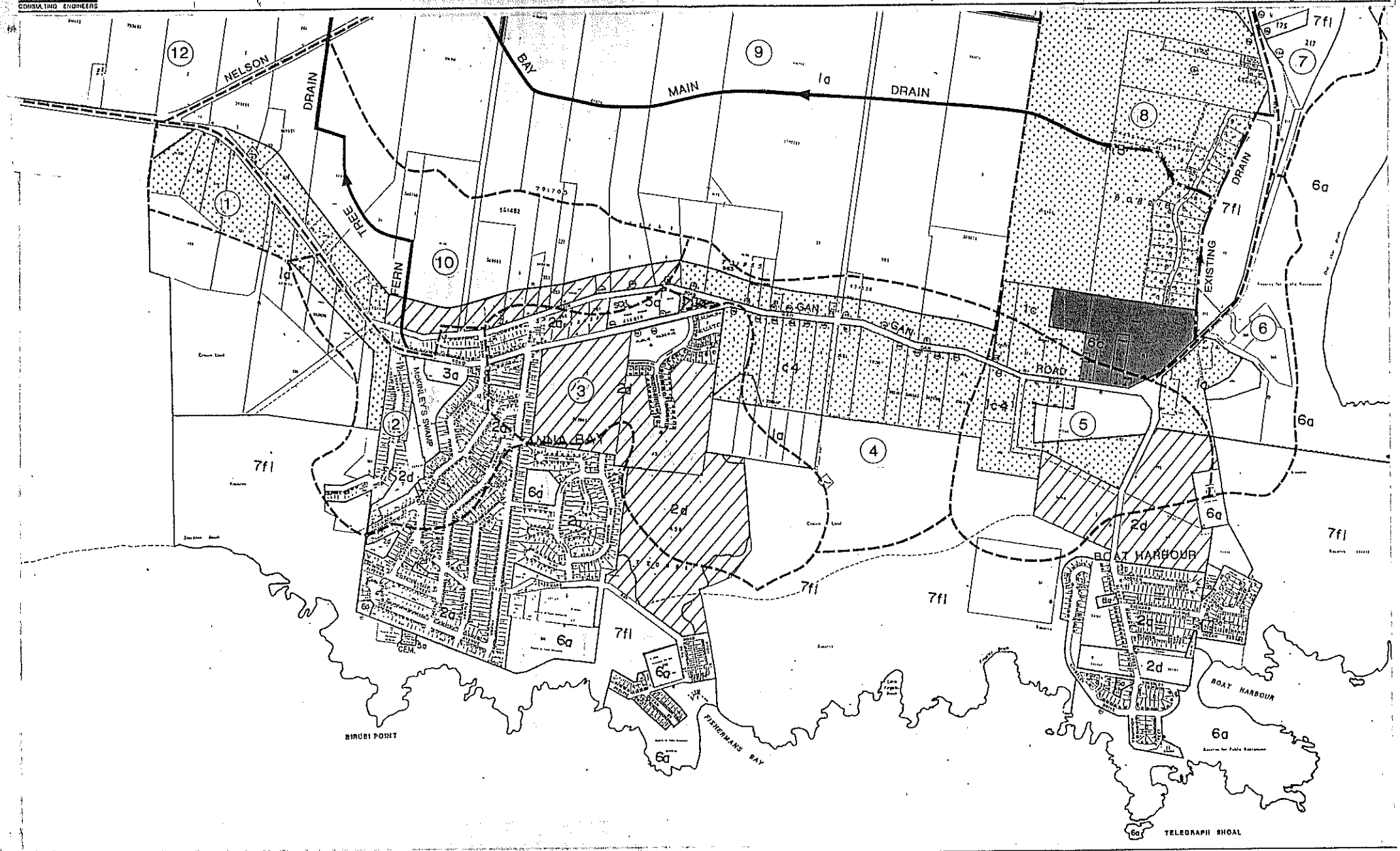

LEGEND

(1) SUBCATCHMENT NUMBER

MAJOR POTENTIAL DEVELOPMENT AREAS

- RESIDENTIAL
- PRIVATE RECREATION
- RURAL RESIDENTIAL

N

0 0.5 1.0 km

Figure 2.3
SUBCATCHMENTS
NORTH OF GAN GAN ROAD
Anna Bay Catchment Drainage/Flood Study

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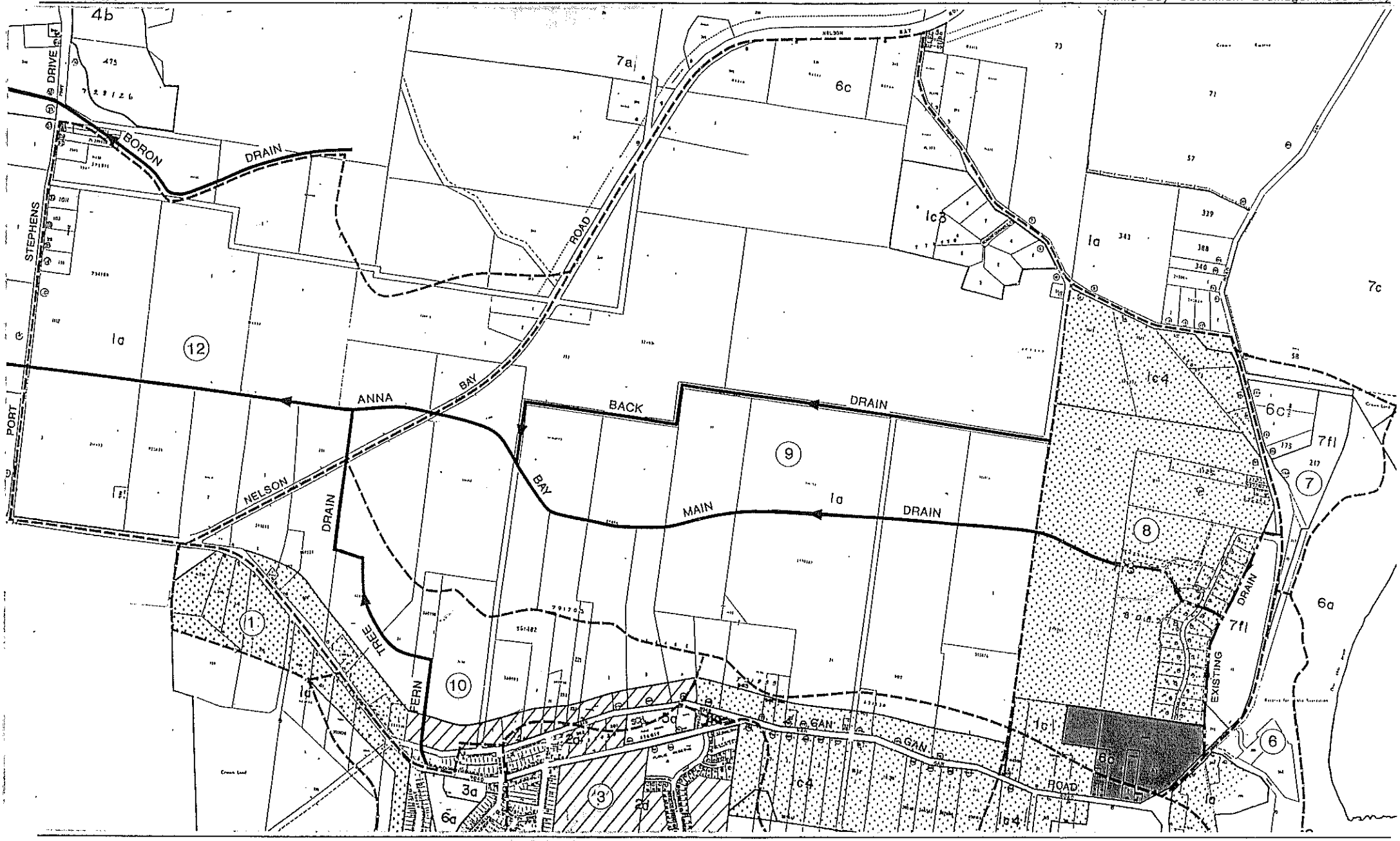

LEGEND
(1) SUBCATCHMENT NUMBER

MAJOR POTENTIAL DEVELOPMENT AREAS
RESIDENTIAL
PRIVATE RECREATION
RURAL RESIDENTIAL

N

0 0.5 1.0 km

The modelled peak discharges at the floodgate structure under existing conditions for low tailwater conditions are:

- 10 year ARI 11.0 m^3/s
- 100 year ARI 13.7 m^3/s

The modelling results indicate that existing floodplain storage, particularly in the Murrumburrimbah Swamp area, has a major effect in attenuating peak discharges.

3.4 Overview of Existing System

An overview of the existing drainage system has been undertaken based on site reconnaissance and the incidence of flooding, as well as the above modelling. Potential problem areas are considered as either;

- major problems, where significant damages may occur due to flooding; or
- minor problems where inadequate drainage is likely to cause nuisance.

It appears that the drainage of agricultural areas is generally considered to be adequate for the existing uses. However, one identified problem is the lack of capacity of Anna Bay Main Drain at Port Stephens Drive because of the limited culvert waterway area under the road.

The overview of existing problems is summarised in **Table 3.1**, together with concept options to remedy these problems. The major problem areas and remedial options are also shown in **Figure 3.1**.

Nelson Bay Road intersection. There is no provision for drainage across Gan Gan Road to the main drainage system.

Subcatchment No 2 (41 ha)
This subcatchment drains to McKinley's Swamp which is a natural detention basin on the southern side of Gan Gan Road. The area contributing to the swamp comprises mainly developed parts of Anna Bay township. There are a number of pipe drainage systems which discharge to the swamp, as well as overland flow paths in events where the pipe capacities would be exceeded. However some of these paths are through private property and may be hindered by structures such as fences.

It is understood that in the past, there was filling at the edges of the swamp for the purposes of development and some residences were threatened with inundation by high water levels in the swamp. In response to this problem, Council replaced the outlet under Gan Gan Road by a larger size pipe (900 mm diameter) at a lower elevation in 1990. This pipe discharges to Fern Tree Drain.

Subcatchment No 3 (72 ha)
This subcatchment contains an established urban area to the west of Morna Point Road and a partly developed area to the east of Morna Point Road. On the east side and south of Gan Gan Road, there is an urban subdivision currently under construction, a disused poultry farm and Department of Housing Property for which urban development is proposed, and part of Tomaree National Park. On the north side of Gan Gan Road, there is some development including a church, a tourist/souvenir centre and Anna Bay Public School.

Runoff from the subdivision is controlled by means of a stormwater detention pond. The pipe outlet from the basin discharges to an open drain on the south side of Gan Gan Road. This drain conveys all runoff south of Gan Gan Road towards the Morna Point Road intersection.

The drainage system on the north side of Gan Gan Road is not well developed. There are open drains at Morna Point Road with a pipe drainage system along the adjoining length of Gan Gan Road. However, further to the east, there is neither sub-surface drainage nor a well defined table drain adjacent to the road.

Stormwater is conveyed from the Gan Gan Road-Morna Point Road intersection to McKinley's Swamp by means of a 600 to 750 mm diameter pipe. However this vicinity is low-lying and there is no overland flow path away from the area. Hence severe ponding occurs in major rainfall-runoff events when the pipe system capacity is exceeded. This ponding has lead to inundation of the road and some adjacent buildings.

Subcatchment No 4 (68 ha)
This subcatchment is mostly undeveloped with a few houses along either side of Gan Gan Road. It is reported that runoff occurs mainly from the slopes on the south side after extended periods of heavy rainfall. This is likely to be as a result of filling of the available storage within the sandy soils.

Although there is a small diameter culvert under Gan Gan Road, there is no surface drainage path out of the subcatchment. Hence there is ponding of runoff in low lying areas until water is removed by seepage into the soil.

Subcatchment No 5 (51 ha)
This subcatchment drops steeply from Blanch Street (the road to Boat Harbour township) towards Gan Gan Road. Runoff from the subcatchment accumulates in a natural depression from which the only outflow is by means of seepage under Gan Gan Road into the low lying area to the north.

The area is presently undeveloped and heavily timbered. Residential development is proposed for part of the area.

Subcatchment No 6 (31 ha)
This subcatchment drains back from the Morna Point headland and dune ridge of One Mile Beach towards Gan Gan Road. Runoff is conveyed to the drainage network to the west by means of a 525 mm diameter culvert under Gan Gan Road, south of Hannah Parade. The existing major development in this subcatchment is a caravan park (One Mile Beach Holiday Park).

Subcatchment No 7 (21 ha)
This subcatchment also drains west from the dune of One Mile Beach. There is a large caravan park in the subcatchment (Middle Rock Park). Runoff from this park is carried south in an open channel and west under Gan Gan Road via a 375 mm diameter culvert. No further development is expected in this subcatchment.

Subcatchment No 8 (132 ha)
This subcatchment covers the part of the low relief area opposite One Mile Beach and immediately west of Gan Gan Road, which has been zoned by Council for development. The presently subdivided area consists mainly of 0.4 ha lots and construction of some dwellings has commenced. These dwellings are built on areas which have been filled to above Council's designated flood level of RL 2.0 m AHD for the 100 year ARI event.

Subcatchment No 9 (410 ha)
This subcatchment covers the remaining area contributing to Anna Bay Main Drain east of Nelson Bay Road. Most of the area has low relief and is presently subject to flooding. There is some flood-free land, mainly adjacent to Frost Road and the northern section of Nelson Bay Road. The major existing development is the Sea Winds Village caravan park located near the intersection of these two roads.

Subcatchment No 10 (78 ha)
This subcatchment covers the area contributing to Fern Tree Drain between Gan Gan Road and Nelson Bay Road. The area is mostly undeveloped except for scattered holdings along Gan Gan Road. There is also an agricultural drain about 200 m west of Fern Tree Drain which conveys runoff from this area to Anna Bay Main Drain.

Subcatchment No 11 (12 ha)
This subcatchment contains some development along the south side of Nelson Bay Road. Provision has been made for pipe drainage of the runoff from the Bay View Relocatable Home Park under Nelson Bay Road and through private property to the north, with outlet to an open drain in the low-lying agricultural area. The pipe drain may also pick up some runoff from Nelson Bay Road, although there are not well-defined table drains along the road.

Subcatchment No 12 (177 ha)
This subcatchment covers the remaining area between Nelson Bay Road and Port Stephens Drive. There is some development along the high level area along the north side of Nelson Bay Road and along the east side of Port Stephens Drive north of Anna Bay Main Drain. However most of the subcatchment is low-lying agricultural land.

Subcatchment No 13 (16 ha)
This subcatchment along the south side of Nelson Bay Road west of Port Stephens Drive is largely undeveloped at present. There is no provision for transfer of runoff to the north side of Nelson Bay Road. The road is constructed roughly at natural surface level with poorly defined drainage.

Subcatchment No 14 (67 ha)
This subcatchment covers the remaining area between Port Stephens Drive and the floodgate structure. The area is predominantly low-lying agricultural land.

2.4 Existing Main Drains

Anna Bay Main Drain has a total length of about 5 km from just west of Gan Gan Road (opposite One Mile Beach) to the floodgate structure. The drain is unlined and has a trapezoidal section. The drain was cleaned out most recently by the Anna Bay Drainage Union in 1992. The channel width may be increased marginally during cleaning out operations. Material removed from the drain has been placed along the bank to form a bund, particularly in the lower reaches. This bund serves to limit overbank flooding. Drainage of low-lying agricultural areas commonly involves local drainage systems with a limited number of outlets to the main drain.

There are culvert installations at road crossings; namely, twin 3.0 m x 1.5 m box culverts at Nelson Bay Road and four 1350 mm diameter culverts at Port Stephens Drive. The floodgate structure was reconstructed in 1991 and contains three 1.8 m x 1.5 m waterway openings. The top level of the structure is RL 1.35 m AHD and is sufficient to prevent tidal events from affecting upstream areas.

The outlet channel from the floodgate structure to Wallis Creek is also an unlined trapezoidal channel. This channel is maintained by the Union and was cleaned out in 1990 and 1992.

Fern Tree Drain has a length of 1.5 km from Gan Gan Road to its junction with Anna Bay Main Drain just west of Nelson Bay Road. The initial section of drain between Gan Gan Road and Old Main Road is an open unlined channel within a 7.5 m wide drainage easement. The 900 mm diameter pipe section under Old Main Road is contained within a 3 m wide easement, and the downstream open channel to the main drain is predominantly within a 7 m to 10 m wide easement. The crossing at Nelson Bay Road incorporates three (3) 600 mm diameter and one (1) 1050 mm diameter pipe culverts.

2.5 History of Flooding

Flooding has been experienced in some areas of Anna Bay township, particularly in the vicinity of the Gan Gan Road-Morna Point Road intersection. The most recent flooding occurred following heavy rains in August 1990. Some residences and a tourist business in the area were inundated. This area was also flooded to varying extents prior to 1990. It appears that the roads and some adjoining properties are affected about one in 3 to 5 years on the average.

There has also been flooding of Gan Gan Road to the east of the township. In particular, it is reported that there was washout of the road and substantial surface ponding in Subcatchment No 4 in August 1990.

The low relief agricultural area north of Anna Bay has been subject to substantial inundation in the past, but there is little information on flood heights. It has been indicated that during the 1955 flood in the Lower Hunter Valley, flood levels around 2.0 m AHD were experienced in areas to the north-east of Fullerton Cove and that floodwaters flowed into Tilligerry Creek (Public Works Department 1993). This would have led to substantial flow of floodwaters into the study catchment.

3. Assessment of Existing Drainage System

3.1 Meteorological Factors

3.1.1 Rainfall

The study area has a mean annual rainfall of about 1300 mm. Because of the sandy soils in the higher relief parts of the catchment, runoff in undeveloped areas occurs mainly after extended periods of heavy rainfall when the storage capacity of the soils is exceeded. As urban development proceeds and the percentage of impervious surfaces increases, it is expected that runoff in developed areas will be governed mainly by the response to major storm events.

The basis for estimation of runoff rates from rural and urban catchments is outlined in Council's Subdivision Code (March 1993).

3.1.2 Downstream Hydraulic Controls

Tides within Port Stephens are semi-diurnal and approximate tidal levels are as follows:

	Level (m) Relative to	
	Chart Datum	AHD
Mean High Water Springs (MHWS)	1.6	0.6
Mean Sea Level (MSL)	1.0	0
Mean Low Water Springs (MLWS)	0.3	-0.7

Based on predictions for Newcastle, it is expected that Highest Astronomical Tide (HAT) level will be about 1.1 m AHD. The tidal levels downstream of the Anna Bay floodgate structure may vary somewhat from the above values due to local effects.

The Public Works Department (PWD) is currently undertaking a flood study of Port Stephens. Stage 1 of the study involving examination of historical tide records has been completed to draft report stage (June 1993). The draft report provides estimates of design flood levels for various average recurrence intervals. The estimates for still water levels (the combination of astronomical tides and storm surge) at Tomaree are:

ARI (years)	Still Water Level (m AHD)
20	1.42
50	1.46
100	1.50

For preliminary estimation of 100 year ARI near shore water levels for Tilligerry Creek, the report indicates the following adjustments to the above level, based on past studies;

- Tidal gradient in Port Stephens — add 0.18 m
- Freshwater flood surcharge in Port Stephens — add 0.5 m

No estimates were made by the PWD for wind set-up and wave set-up.

Reliable design flood levels for Tilligerry Creek will be dependent on further stages of the Port Stephens Flood Study. However, the above estimates indicate that a 100 year ARI flood level of around 2.0 to 2.2 m AHD may be applicable for the creek outlet, and therefore for low-lying areas in the Anna Bay catchment. This level will apply for setting of floor levels for developments in low relief areas.

It will be appropriate to adopt a lower downstream water level for assessment and design of the drainage system within the Anna Bay Catchment. Freshwater flood surcharge in Port Stephens will result primarily from flood events in the Karuah River and Myall River which have catchment areas of 1500 km^2 and 780 km^2 respectively. There will be a very low probability of joint occurrences of flood peaks in the large river catchments and the Anna Bay Catchment.

There will be some correlation between heavy rainfall in the study catchment and high water levels in Port Stephens, but the combined probability is difficulty to quantify. The range of cases appropriate for hydraulic analysis is;

- Catchment flood events coincident with MSL (0.0 m AHD) (i.e., low tailwater conditions)
- Catchment flood events coincident with maximum storm surge (1.7 m AHD) (i.e. high tailwater conditions)

3.2 Hydrologic Modelling

The RAFTS-XP runoff routing model was used to determine peak discharges in the trunk drainage system under existing catchment conditions. Modelling was carried out for the 10 year and 100 year ARI events. Initial and continuing loss values for pervious areas in each subcatchment were adopted according to soil conditions, as given in Table A.3 of Appendix A.

The effect of McKinley's Swamp as a detention basin in controlling outflows from Subcatchment No 2 was included in the model. The existing swamp area of about 2.6 ha provides an estimated storage volume of 20 000 m^3 at the design flood level of RL 3.0 m AHD. The modelled peak flood levels in the swamp and peak outflows to Fern Tree Drain, assuming no inflows from Subcatchment No 3, are:

10 year ARI	RL 2.6 m AHD	1.3 m^3/s
100 year ARI	RL 3.1 m AHD	1.6 m^3/s

The flood levels would be higher for the existing situation where flows from Subcatchment No 3 are piped into the swamp.

Subcatchment Nos 1, 3, 4, 5 and 13 were not included in the model of the total area contributing to the existing trunk drainage system. There are currently no effective drainage systems out of these subcatchments under flood conditions. Further information on the RAFTS-XP model of the study catchment is given in **Appendix** B.

3.3 Hydraulic Modelling

The HEC-2 program for steady, one dimensional flow conditions was used initially for estimation of water surface profiles in Anna Bay Main Drain and Fern Tree Drain. Channel cross-sections and structure and culvert details were taken from Council plans and two tailwater levels were considered, 0.0 m AHD and 0.6 m AHD.

The modelling results showed that the floodgate structure and the lower reaches of Anna Bay Main Drain have a capacity of about 18 m^3/s at bank full level, unaffected by either of the tailwater levels considered, that is, independent of low tailwater conditions. However, the capacity of the existing culverts at Port Stephens Drive is limited to about 13 m^3/s to road level and the capacity of the Main Drain is only about 10 m^3/s to bank full level in the upstream agricultural area.

These results are consistent with previous Council estimates of the capacity of the downstream section of Anna Bay Main Drain. They represent indicative estimates of capacity, because of the limited available information on channel cross-sections and bank levels.

There was no information available to enable assessment of the hydraulic capacity of the channel downstream of the floodgate, as well as of Wallis Creek. It is assumed that the existing downstream system does not provide a capacity constraint.

For large flood events, overbank flow will occur and peak discharges and water levels will be influenced by the substantial floodplain storage in low relief areas. Because of the importance of storage, hydraulic modelling of flood events was undertaken using the MIKE-11 program for unsteady flow conditions. Flood plain cross-sections for the model were taken from 1:4000 orthophoto plans. Further information on the MIKE-11 model of the study catchment including the run cases considered is given in **Appendix** B.

The peak discharges at key locations in the trunk drainage system, as obtained from the hydrologic and hydraulic modelling, are given in **Section B.3** of **Appendix** B.

Figure 3.1
EXISTING FLOODING PROBLEMS
AND REMEDIAL OPTIONS
Anna Bay Catchment Drainage/Flood Study

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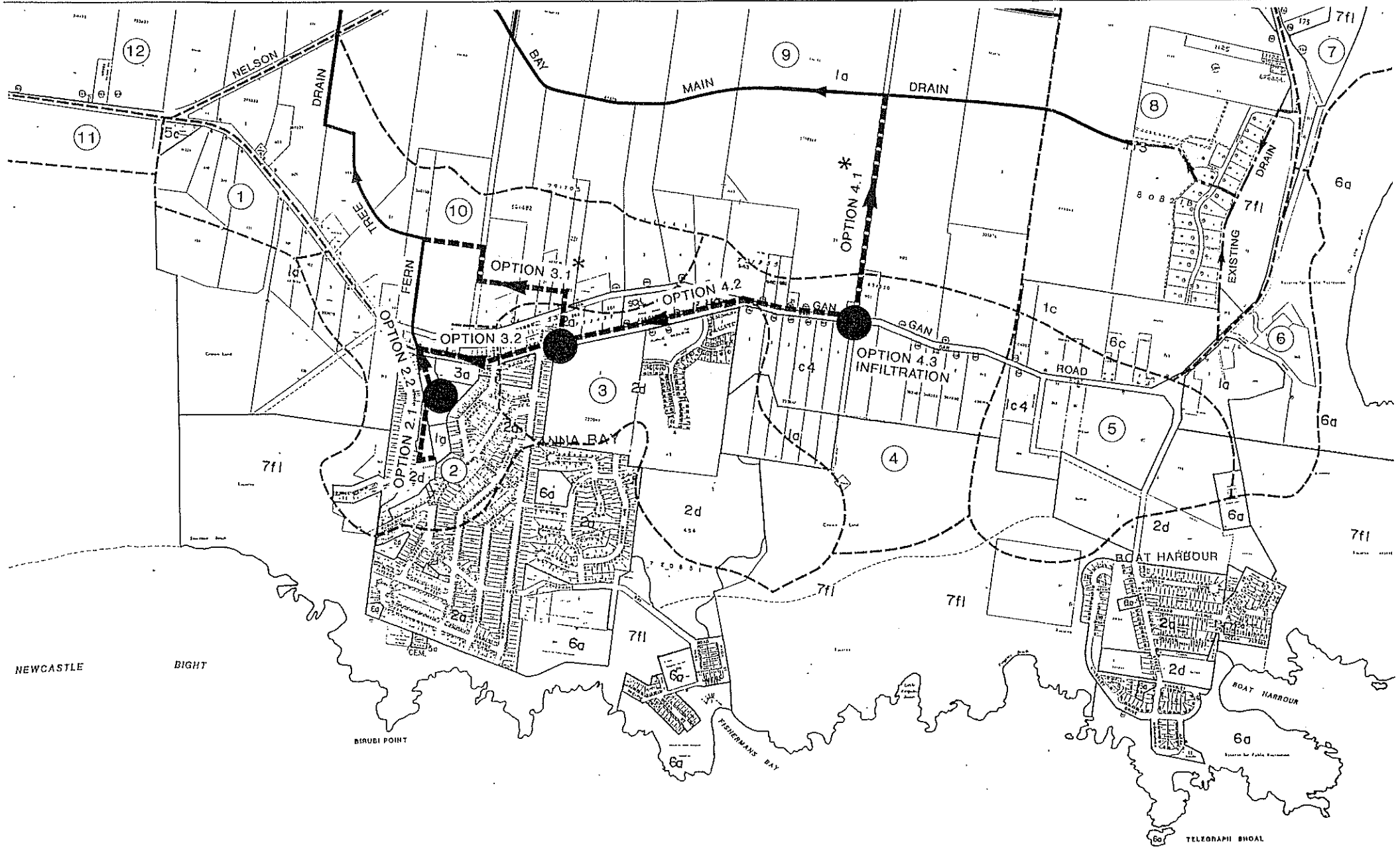


LEGEND
(1) SUBCATCHMENT NUMBER
FLOODING PROBLEM AREA
REMEDIAL OPTION
* PROPOSED OPTION

N

0 0.5 1.0 km

Table 3.1 - Overview of Existing Drainage Problems and Concept Remedial Options

Subcatchment No	Description
Potential Major Problems	
2	**Problem:** High water levels in McKinley's Swamp. **Options:** 2.1 Increase storage capacity of swamp. 2.2 Increase outlet capacity to Fern Tree Drain. 2.3 Remove inflow from Subcatchment No 3.
3	**Problem:** Surface flooding. **Options:** 3.1 Construct drain to north with outlet to Fern Tree Drain (as per Council proposal). 3.2 Construct drain along Gan Gan Road to Fern Tree Drain.
4	**Problem:** Surface ponding for extended durations **Options:** 4.1 Construct drain to north with outlet to agricultural drainage system (Subcatchment No 9). 4.2 Construct drain to west to Subcatchment No 3. 4.3 Construct infiltration system in ponding area. 4.4 Provide local protection to existing development.
Potential Minor Problems	
11, 12, 13 & 14	**Problem:** Poor drainage along Nelson Bay Road. **Options:** □ Improve road drainage and provide outlet to north to main drainage system.
12	**Problem:** Flooding of low-lying recreational development (golf course) near main drain. **Options:** □ Local protection measures, provided that there are no adverse impacts on other areas.
12	**Problem:** □ Flooding of agricultural land due to inadequate culvert capacity of Anna Bay Main Drain at Port Stephens Drive **Options:** □ Install additional culverts at Port Stephens Drive

3.4.1 Major Existing Problems

The options for relief of major existing problems are discussed as follows:

Subcatchment No 2

The results of the hydrologic modelling indicate that McKinley's Swamp has reasonable storage capacity for existing conditions in Subcatchment No 2. The design flood level of RL 3.0 m AHD is exceeded by only 100 mm in the 100 year event (assuming no inflow from Subcatchment No 3).

The storage capacity could be increased by excavation of the open area adjoining the south-west part of the existing swamp (Option 2.1). This additional storage could also provide for further development in the subcatchment. A preliminary estimate is that the storage could be increased by 1100 m^3, at a cost of $40 000 (assuming there are no constraints on the available land).

The option of increasing the outlet capacity to Fern Tree Drain would require upgrading of the pipe under Gan Gan Road (Option 2.2). Some increase in outlet capacity could be achieved without the need to amplify the downstream pipe under Old Main Road. However there would be a minor increase in flood level downstream of Gan Gan Road. The estimated cost of this option is $25 000.

The removal of inflow from Subcatchment No 3 is considered to be the best option for adequate flood protection (Option 2.3). This action should be undertaken in conjunction with drainage improvements for Subcatchment No 3.

Since there would be only a minor exceedance of the design flood level with the inflow from Subcatchment No 3 removed, it is not considered necessary to undertake further works for existing catchment conditions.

Subcatchment No 3

Council has previously proposed a scheme to relieve flooding problems in this subcatchment. The major components of this scheme include:

- A 190 m length of pipe drainage from Gan Gan Road north through the low sand ridge (pipe size up to 1200 mm diameter with capacity of 2.2 m^3/s).
- A 600 m length of open channel improvement to Fern Tree Drain.

This scheme is shown as Option 3.1 in Figure 3.1 and has an estimated total construction cost of $340 000. In addition, there will be land acquisition and compensation costs, estimated by Council at $60 000.

This alternative also incorporates the lowest cost solution for Subcatchment No 2.

An alternative proposal is to construct the drainage line along Gan Gan Road with outlet to Fern Tree Drain downstream of McKinley's Swamp (Option 3.2). This would require a pipe length of 520 m together with amplification of the 75 m long pipe under Old Main Road. A pipe size of 1650 mm diameter would be required to achieve the same hydraulic capacity as the Council proposal. The estimated indicative cost of this alternative is $750 000.

The drain alignment (Option 3.1) proposed by Council is preferred because of the substantially lower cost. This route would also provide the open channel needed to serve potential residential development in Subcatchment No 10.

Subcatchment No 4

The most direct route for a constructed drainage system out of Subcatchment No 4 is north from Gan Gan Road to Anna Bay Main Drain (Option 4.1). The major components of this option would be:

- A 200 m length of pipe drainage, including about 100 m length constructed by jacking through a high sand ridge
- A 590 m length of open channel

A drainage collection system including increased culvert capacity under Gan Gan Road would also be required.

Since the area is zoned rural residential, infrequent short-duration ponding will be acceptable and it will not be necessary to size the drainage system for peak runoff rates. A capacity of about 3 m^3/s could be achieved with a 1 200 mm diameter pipe at 0.5% grade.

An indicative cost estimate for this proposal is $330 000. This estimate may be subject to significant variation because of the limited available information on geotechnical conditions. There is an existing road reserve from the ponding area north to Anna Bay Main Drain. If the drainage line was located in this reserve, the additional costs for land acquisition would be minimised.

An alternative drainage route would be west along Gan Gan Road to join with the proposed drainage system out of Subcatchment No 3 (Option 4.2). This would require 1 140 m length of pipe along Gan Gan Road as well as amplification of the proposed line to Fern Tree Drain. The hydraulic capacity of this option would be lower than the capacity of the northern route with the same pipe size because of the lower available

slope. The preliminary cost estimate for this option, based on 1 200 mm pipe diameter, is $920 000.

A potential option would involve removal of ponded water by infiltration (Option 4.3), rather than by surface drainage. The soil profile of the piezometer installed at this location for groundwater monitoring indicates the presence of a 0.5 m thick indurated sand layer. It is likely that this layer prevents the rapid removal of surface water. The remedial option would involve an infiltration system consisting of a pond or trenches penetrating the indurated layer to allow seepage into the underlying sands.

A detailed site investigation would be required to establish the feasibility of Option 4.3. This investigation would involve drilling and pump testing to determine the capacity of the groundwater system to accept the drainage flows and to provide the required sizing for the infiltration system.

A fourth option is to accept the existing ponding situation and to protect existing dwellings by local measures (Option 4.4). It would also be necessary to protect Gan Gan Road; by raising the road level and constructing additional culverts. The floor levels for future buildings would be set above the estimated maximum ponding levels. This option would have a substantially lower cost than the above three options; however, as further development and increased runoff occur, there would be increasing problems in protection of existing development and removal of ponded water within a reasonable time period.

On the basis of the information available at this stage, it is considered that Option 4.1 is likely to be the most cost-effective option for solution of the existing drainage problem. Hence this option was adopted for further assessment in this study. The potential for a lower cost option involving an infiltration system should be considered further prior to the design stage.

3.4.2 Minor Existing Problems

With regard to existing minor drainage problems, there would be some benefit in upgrading the culverts at Port Stephens Drive (between Subcatchment Nos 12 and 14) to achieve the same capacity as the downstream channel. This could be achieved by a previous proposal of installation of two 1 500 mm diameter pipe culverts at an estimated cost of $40,000.

There are sections of Nelson Bay Road in the western part of the study area which are poorly drained (between Subcatchment Nos 11 and 12 and Subcatchment Nos 13 and 14). Improved road drainage would be required to alleviate potential problems. However the major need for

drainage works in this area is likely to arise from future development of the land adjoining the road.

The remedial works proposed for solution of existing drainage problems are summarised in Table 3.2.

Table 3.2 - Summary of Proposed Remedial Works for Existing Drainage Problems

Subcatch-ment No	Option No	Description	Estimated Cost ($)
2	2.3	Remove inflow from Subcatchment No 3.	-
3	3.1	Drainage works and roadworks - Gan Gan Road/Moma Point Road	155 000
		Piped outlet to north (1 050-1 200 mm Ø, 190 m length)	170 000
		Open channel to Fern Tree Drain (600 m length)	15 000
4	4.1	Culvert under Gan Gan Road (1 200 mm Ø, 20 m length)	20 000
		Piped outlet to north (1 200 mm Ø, 200 m length)	260 000
		Open channel to Anna Bay Main Drain (590 m length)	50 000
12	-	Additional culverts at Anna Bay Main Drain under Port Stephens Drive (2 - 1 500 mm Ø, 15 m length)	40 000
Total			$710 000

Note: Land acquisition and compensation costs are not included.

The above works are proposed for inclusion in a trunk drainage improvement scheme for the developed catchment, as outlined in Section 5.

4. Future Development

4.1 Major Constraints to Development

The constraints to development in the area were identified in the Tomaree Peninsula Environmental Study for Port Stephens Shire Council (1988). The limits to growth in the peninsula were considered under the broad headings of;

- community infrastructure (including both social infrastructure and physical infrastructure such as water supply, sewerage, electricity supply, stormwater disposal, roads and telephone services).
- land tenure, and
- the natural and physical environment.

The 1988 study concluded that no aspect of community infrastructure represents an absolute constraint to future growth since infrastructural problems can be solved if sufficient money is spent. This conclusion was adopted for the present study, with the exception of disposal of stormwater which is a key aspect to be reviewed in the study.

Land tenure is not generally a constraint to development in the study catchment, except for the area taken up by the Tomaree National Park. The park takes up an area of about 70 ha in Subcatchment Nos 3 to 7 and has been excluded from consideration for future residential or other development.

The environmental factors identified in the 1988 study included climate, geomorphology, soils and topography, vegetation, wetlands, fauna and flora, hydrology, landscape values, rural capability, water quality and water values, and fire regime. The factors which may be significant constraints on development in the catchment were considered further in this study and are discussed briefly as follows:

Soils

Peat and soft clays are present in much of the low relief areas of the study catchment. These soils may have an effect on the layout of any proposed development, as well as requiring removal of compressible material and placement of suitable fill. It is considered that the geotechnical aspects of any development will be a matter for resolution by the intending developer.

Acid sulphate soils are also present in the low relief area. These soils have the potential to cause corrosion of building materials, to affect the growth of plant species, and to cause contamination of water bodies. An overall assessment of acid sulphate soils in the catchment has been carried out as part of this study, with the findings outlined in the **Addendum**. Detailed site specific investigations will be required for particular development proposals. It is assumed that any problems with acid sulphate soils at particular sites can be resolved by the intending developer.

Hence, soil conditions are not considered an absolute constraint on development at this stage.

Topography

The undulating dunes in the vicinity of Anna Bay township and Gan Gan Road were considered to be unsuitable for residential development where slopes exceed 14 degrees (25 percent). This constraint applies to areas near the top of the dunes. The hind dune area immediately west of Anna Bay township is unstable due to clearance of the original dune vegetation. This area was considered to be unsuitable for development.

Vegetation

Council has prepared a vegetation map covering most of the study catchment. The mapping indicates substantial areas of prime habitat, particularly for Koalas. It will be important to retain habitat corridors to facilitate Koala movement. To achieve this requirement, rural residential development (typically involving lots of 0.4 ha or larger) will be more appropriate than extensive urban development in much of the catchment.

Hydrology

At present, Council has adopted a 1 in 100 year flood level of RL 2 m AHD for the low relief area north of Anna Bay. Much of this area is around or below RL 1 m AHD, so there is substantial flood storage under existing conditions. Development of low lying areas will require filling above existing ground. Council requires a minimum floor level of RL 2.5 m AHD for habitable dwellings in this area. The required minimum level for filling is generally RL 2.0 m AHD. However, fill levels of RL 1.8 m AHD for building areas and RL 1.6 m AHD for roads were adopted along Eucalyptus Drive in the Ocean Side Country Estate development.

The potential loss of flood storage and the increase in runoff associated with development are important aspects which have been addressed in this study. High groundwater conditions will also be an important consideration for development. Groundwater levels have also been assessed as part of the study.

Wetlands

The wetlands which are considered to be most worthy of protection are those defined as Coastal Wetlands under State Environmental Planning Policy (SEPP 14). The aim of the policy is to preserve and protect these wetlands by restriction of development or works in the designated wetland areas.

The SEPP 14 wetlands on the Tomaree Peninsula are generally outside the study catchment. However, a major SEPP 14 wetland area extends into the northern part of Subcatchment No 14, as shown in Figure 2.1. Moreover, the outlet channel from the floodgate structure to Wallis Creek and the creek are within this wetland area. There are likely to be major

limitations on any works such as clearing, draining or filling within SEPP 14 wetland areas. It is also considered highly unlikely that approval would be given for any works to modify the outlet channel; for example, to increase its hydraulic capacity.

Rural Capability

The original land classification survey for the study catchment determined that most of the area falls within land suitability Classes 4 and 5, with some areas of Class 3. A general survey undertaken by the Department of Agriculture indicated that there are considerable areas of well-drained sandy soil with an assured water supply which could be developed for horticultural enterprises. Some of the wet areas could also be developed with the provision of subsoil drainage. However the land does not currently have a high agricultural value.

Water Quality and Water Values

A critical issue with respect to water quality is protection of the oyster farming areas of Port Stephens, including the Tilligerry Creek estuary. This area is one of the most important oyster producing areas in New South Wales.

Tilligerry Creek and the adjoining part of Port Stephens are classified as Class P: Protected Waters under the Clean Waters Act, 1970. The requirements for discharges into Class P waters are set out in Table 4.1. They provide a guide to the acceptable quality of flows in Wallis Creek. Preliminary verbal advice from the Environment Protection Authority indicates that any sewer overflows from upstream areas would not be permitted to discharge through the trunk drainage system to Tilligerry Creek.

The public health criteria used for testing of oysters are summarised in Table 4.2. These criteria provide bacterial standards for both the growing medium (water) and the oyster meat. NSW Fisheries advises that Port Stephens is currently classified as an approved area for oyster growing. However, it would be subject to future re-classification as a restricted area if a proposal to construct a wastewater treatment plant at Karuah with discharge of treated effluent is implemented. The maximum acceptable level of faecal coliforms is more stringent for oyster growing than for discharges under the Clean Waters Act 1970.

The potential effect of urbanisation is one issue of concern raised by both representatives of the oyster farmers and NSW Fisheries. This concern is based on the adverse impacts of development on oyster quality in other, more urbanised areas of the State. At present, there is no systematic monitoring of water quality in Wallis Creek or Tilligerry Creek. In the absence of water quality measurements, existing conditions are considered to be generally satisfactory.

Table 4.1 - Requirements for Discharges into Class P: Protected Waters

Regulation 8 under the Clean Waters Act, 1970,
Prescribed Classes of Waters.

8. For the purpose of Section 11(1) of the Act, waters shall be classified as follows:–

CLASS S: *Specially Protected Waters* – waters into which –

(a) no wastes are to be discharged; and

(b) only Class P waters flow.

CLASS P: *Protected Waters* – waters into which –

(a) wastes are not to be discharged except as provided in respect of this classification;

(b) where sewerage is available, wastes which are of a type acceptable to the sewerage authority are not to be discharged otherwise than by way of a sewer;

(c) overflows from sewers, wastes pumping stations, treatment works or other parts of a sewerage system are not to be discharged;

(d) organic wastes are not to be discharged unless they are so treated that the resulting effluent has –

  (i) where the relative proportion of water to the wastes is 19:1 or more – a biochemical oxygen demand of not more than twenty milligrams per litre and a non-filtrable residue of not more than thirty milligrams per litre; or

  (ii) where the relative proportion of water to the wastes is less than 19:1 and the oxygen content of the waters is, or is likely to be, reduced as a result of the discharge – such a lower biochemical oxygen demand and non-filtrable residue as may be approved;

(e) wastes are not to be discharged unless the concentration of plant nutrients in the wastes is controlled so as to prevent excessive plant growth in, abnormal variation in dissolved oxygen or pH levels in, or degradation of the appearance of, the waters;

(f) infectious wastes or wastes in which faecal coliforms are likely to be present are not to be discharged unless –

  (i) the wastes are treated in an approved manner; and

  (ii) in the case of waters likely to be used for bathing – the faecal coliform density as determined in an approved manner after sampling at an approved location does not exceed 200 per 100 millilitres;

(g) wastes are not to be discharged unless they are visually free of grease, oil, solids and unnatural discolouration and free of settleable matter;

(h) wastes are not to be discharged if the resulting concentration of the wastes in the waters –

  (i) is or is likely to be harmful, whether directly or indirectly, to aquatic life or water-associated wildlife;

  (ii) gives rise to or is likely to give rise to abnormal concentrations of the wastes in plants or animals; or

  (iii) in the case of fresh water, is likely to affect the use of the waters for human consumption, domestic or industrial purposes, watering of stock or the irrigation of land;

(i) wastes are not to be discharged if the concentration of any restricted substance in the wastes exceeds the concentration specified opposite that substance in Schedule 2;

(j) wastes are not to be discharged into the waters if the pH value of the wastes is less than 6.5 or more than 8.5 or if the discharge induces a variation in the pH value of the waters of more than 0.2;

(k) wastes are not to be discharged if the radioactivity level of the wastes exceeds the levels specified in Schedule 3;

(l) thermal wastes are not to be discharged into the waters.

Table 4.2 - Public Health Criteria for Oysters

Growing Area (Water)			
Total Coliforms	Approved Area	(NHMRC & NSSP)	70/100 mL and not more than 10% above 230/100 mL
	Restricted Area	(NSSP)	700/100 mL and not more than 10% above 2 300/100 mL
	Closed Area	(NSSP)	Greater than above
Faecal Coliforms	Approved Area	(NSSP)	14/100 mL and not more than 10% above 43/100 mL
	Restricted Area	(NSSP)	88/100 mL and not more than 10% above 260/100 mL
E coli	Approved Area	(NHMRC)	2.3/100 mL and no more than 10% above 7/100 mL
Oysters Before Purification			
Maximum Standard Plate Count		(NHMRC)	100 000/g and not more than 20% above 500 000/g
E coli		(NHMRC)	2.5/g and not more than 20% above 7g
Oysters After Purification			
Maximum Standard Plate Count		(NHMRC)	100 000/g and not more than 20% above 500 000/g
		(NSWFA)	500 000/g
E coli		(NHMRC)	0.5/g and not more than 20% above 3.0/g
Faecal Coliforms		(NSWFA)	2.3/g

Notes:

Approved Area classification does not require purification.
Restricted Area classification requires relaying or purification.
NHMRC = National Health and Medical Research Council, Australia.
NSSP = National Shellfish Sanitation Program, United States.
NSWFA = New South Wales Food Act, 1989.

Source: P D Bird, NSW Department of Health, 1991.

Urbanisation may lead to increased loadings in a range of water quality constituents including sediments, faecal coliforms, nutrients, heavy metals, and oils and grease. Any significant increase in the loading of any constituent will detrimentally affect the growth and marketability of oysters.

The potential increase in freshwater flow rates with urbanisation is also a concern. Experiments by NSW Fisheries at the Brackish Water Fish Culture Research Station, Salamander Bay have shown that there is an optimum salinity range for survival and growth of oysters (Nell and Holliday, 1988). Significant changes to the existing salinity regime would be expected to have a detrimental effect on the oyster industry.

The general criterion considered acceptable for protection of oyster growing areas is that the quality of stormwater flows out of the Anna Bay catchment under post-development conditions should be no worse than the stormwater quality under existing conditions. Given that there has been limited development in the catchment until recently, it would be desirable to achieve the stormwater quality for rural conditions. Furthermore the flow quantities should be controlled, as far as practicable, to retain existing flow patterns.

The overall means to achieve these requirements are envisaged to include:

- Sedimentation basins and associated works for capture of sediment during the land development and building construction stages.

- Wetland(s) and/or water pollution control pond(s) together with flood detention storage for control of runoff quality and quantity in the habitation stage.

4.2 Land Use Zonings

Council has identified maximum potential development areas as shown in Figures 2.2 and 2.3. This has been done for the purpose of runoff calculations only. These areas are generally compatible with existing land use zonings and the above environmental constraints. The potential development areas are summarised as follows:

- Rural residential development on both sides of Gan Gan Road on the lower levels of the undulating dune area to the north of Old Main Road and Gan Gan Road (Subcatchment Nos 4 and 5), on the south side of Gan Gan Road (Subcatchment Nos 3, 4 and 5), and near One Mile Beach - in the south-western corner of Subcatchment No 6 and to the west of Gan Gan Road (Subcatchment No 8).

- Residential development on both sides of Anna Bay Public School and major residential developments on the south side of Gan Gan Road to the east of Morna Point Road and north of Fishermans Bay Road (Subcatchment No 3), development to the north of Old Main Road (Subcatchment No 10), and development off Blanch Street (Subcatchment No 5).

- Private recreation development opposite Blanch Street (Subcatchment Nos 5 and 8).

As retention of flood storage is an important consideration, viable options can involve only limited filling of the floodplain.

4.3 Drainage, Flooding and Water Quality Criteria

From the above considerations, key issues with regard to total catchment development are:

- The constraints of the downstream SEPP 14 wetlands and the need for protection of oyster farming areas at the catchment outlet.
- The need to prevent development having significant adverse impacts on other areas within the catchment.

In response to these issues, the appropriate criteria for assessment of development proposals are:

Drainage and Flooding

The development should not have a significant adverse impact on the drainage or flood immunity of other properties in the catchment. Also the downstream trunk drainage system should have sufficient capacity to accept any increase in peak discharge which might result from development.

Water Quality

The development should not result in any impact on water quality which might adversely affect downstream users, particularly in the receiving waters.

4.4 Concept Drainage Improvements

The form of trunk drainage improvements required in association with future development will vary according to the characteristics of the major subcatchments. In general terms, they are likely to involve:

- Formalisation of a drainage system where no works are required for existing conditions (eg Subcatchment No 5).
- Implementation of works as required for relief of existing problems with provision for future development (eg Subcatchment Nos 2, 3 and 4).
- Implementation of works in the low relief areas to accommodate increased peak discharges from upstream areas, as well as potential loss of flood storage due to development.

The assessment of trunk drainage improvements in conjunction with development in the major subcatchments is discussed in Section 5.

5. Trunk Drainage Improvements

5.1 Development Scenario

Assessment of trunk drainage requirements was based on full development of subcatchments which are of predominantly high relief (Subcatchment Nos 1 to 6, 11 and 13) in accordance with Council zonings. No further development is proposed in Subcatchment No 7.

Subcatchment Nos 8, 9, 10, 12 and 14 contain substantial areas of low relief (areas below RL 2 m), estimated from 1:4000 orthophoto plans as follows:

Subcatchment No	Area (ha)		
	below RL 2 m	above RL 2 m	Total
8	94	38	132
9	287	123	410
10	31	47	78
12	95	82	177
14	61	6	67
Sum	568	296	864

The following development scenario was considered for these areas:

Subcatchment No 8: Rural Residential and Private Recreation Development (typically 0.4 ha lots) involving filling of low relief areas, similar to the Ocean Side Country Estate development. Two filling scenarios were considered, namely filling of 50% and 100% of the low relief areas respectively.

Subcatchment Nos 9 & 10: Urban and Rural Residential Development above RL 2 m, no development below RL 2 m.

If it is possible that there may be future development proposals involving works in areas below RL 2 m in Subcatchment Nos 9 and 10. Any such proposals would need to be designed to prevent any runoff, flooding or water quality impacts not provided for in the above development scenario. For example, it will be appropriate to ensure that there would be no net loss of flood storage due to filling.

5.2 Trunk Drainage Concept

The proposed concept for extension of the trunk drainage system to accommodate future development in high relief subcatchments in summarised in Table 5.1.

The existing trunk drainage system through low relief areas will require amplification to accommodate the increase in runoff from development in Subcatchment Nos 8, 9 and 10 as well as from upstream areas.

Table 5.1 Trunk Drainage Concept Extensions for Future Development

Subcatchment No	Description
1	Drain to Fern Tree Drain upstream of Nelson Bay Road
2	Storage capacity of McKinley's Swamp increased
3	Drain north to Fern Tree Drain in accordance with Council proposal
4	Drain north to Anna Bay Main Drain
5	Natural depression formalised as detention storage Drainage out of storage to Subcatchment No 8
6	Drain to Subcatchment No 8 (as for existing conditions)
7	Maintain existing drain, as no further development is proposed.
11	Drain to Anna Bay Main Drain upstream of Port Stephens Drive (as for existing conditions)
13	Drain to Anna Bay Main Drain upstream of floodgate.

5.3 Hydrologic Modelling

The RAFTS-XP model was modified to reflect future catchment conditions including increased impervious areas and the connection of Subcatchment Nos 1, 3, 4, 5 and 13 to the trunk drainage system. Particular aspects of the modelling are summarised as follows:

Subcatchment No 2: The volume of McKinley's Swamp was increased by 1 100 m^3 to limit the 100 year ARI flood level to RL 3.1 m AHD; i.e. the same level as estimated for existing conditions.

The option of increasing the storage of McKinley's Swamp is preferred to the option of increasing the outlet capacity at Gan Gan Road. The latter option would result in an increase (albeit small) in downstream flood levels. However both options should be reviewed at the detail design stage.

Subcatchment No 3: The runoff rates from the existing and proposed residential subdivisions on the south side of Gan Gan Road were based on the estimated peak outflow rates from detention basins in these subdivisions. Preliminary investigations by Clarke Craig Consulting indicated that the peak outflow rates for the recommended detention scheme are 0.63 m^3/s for the 10 year ARI event and 0.79 m^3/s for the 100 year ARI event. With this scheme, the uncontrolled area contributing runoff in Subcatchment No 3 will be about 12.5 ha.

The modelled outflow rate from the catchment was limited to 2.2 m^3/s based on the 1 200 mm diameter outlet proposed by Council. The modelled upstream ponding level in the 100 year ARI event with this outlet capacity was RL 3.3 m AHD. The modelled level is in acceptable agreement with Council's design flood level of RL 3.2 m AHD and is below the proposed minimum floor level of RL 3.5 m AHD for the area.

Subcatchment No 4: The peak outflow rate from this subcatchment was limited to 3 m^3/s, for a proposed 1 200 mm diameter pipe outlet to the north. The modelled upstream ponding level in the 100 year ARI event was RL 5.6 m AHD, indicating a maximum ponding depth of about 0.6 m.

Subcatchment No 5: The pipe outlet from the natural depression has been constructed at 375 mm diameter. The model was used to determine the resulting water level in the depression in the 100 year ARI event. The nearby sewage pumping station has a surveyed minimum RL of 4.00 m AHD.

From orthophoto mapping, the depression is estimated to have a storage capacity of about 74 000 m^3 at a level of 4.0 m AHD.

The model estimated the 100 year ARI flood level to be 3.54 m AHD. The model was also run assuming that the continuous loss rate in this subcatchment was reduced from 10 mm/hr to 6 mm/hr; ie. allowing for significant low permeability areas in the catchment. For this case the model estimated the 100 year ARI flood level to be 3.86 m AHD.

It is therefore considered that the 375 mm diameter outlet not cause inundation of the sewage pump station in a 100 year ARI flood event. However, only a more detailed study of the local catchment including survey of the natural depression can confirm this.

5.4 Hydraulic Modelling

The MIKE-11 model was run for the future catchment conditions with increased runoff hydrographs due to development and partial loss of flood storage in Subcatchment No 8 due to filling. Various run cases were considered. These and the main results of the modelling are given in Section B.3 of Appendix B.

Initially the model was run with only culvert improvements to the drainage system, namely:

- Installation of two additional culverts at Anna Bay Main Drain under Port Stephens Drive (2 - 1 500 mm diameter), as required for relief of existing drainage problems.

- Installation of three additional culverts at Fern Tree Drain under Nelson Bay Road (3 - 1 050 mm diameter), as proposed by Council as part of an upgrading scheme for the drain.

The model results indicated flood level increases of up to 160 mm in the 100 year ARI event for full development and 50% of Subcatchment No. 8 filled, and up to 170 mm (450 mm within the channel within Subcatchment No. 8) for full development and 100% of Subcatchment No. 8 filled. The greatest increases were at the upstream end of Fern Tree Drain and in Subcatchment No. 8 at the eastern end of the Murrumburrimbah Swamp.

The model was rerun with the following channel improvements:

- Anna Bay Main Drain widened by 3 m along its full length.

- Fern Tree Drain widened by 0.5 to 1 m to a minimum bed width of 4 m for about 600 m downstream of the junction of the proposed inflow from Subcatchment No 3.

The additional culverts at Port Stephens Drive were increased to 2 - 1 800 mm diameter to take account of increased peak discharges under future conditions.

Flood detention storage associated with a 7 ha water pollution control pond constructed near the catchment outlet was also included in the model. The basis for this pond is discussed in **Section 5.5**.

With these improvements, there would be only minor flood level increases in the 10 year ARI event and maximum increases of 50 mm and 80 mm in Murrumburrimbah Swamp and 100 mm and 110 mm in Fern Tree Drain in the 100 year ARI event with full development and for 50% and 100% filling of Subcatchment No. 8 respectively. It is considered that flood level increases of this low frequency and magnitude would not have a significant adverse impact on adjacent agricultural areas. There should also be scope for reducing the flood level increases through refinement of the modelling and improvement works at the design stage.

The above culvert and channel improvements will lead to increased peak discharges and a higher water level at the floodgate structure. The modelled peak flows out of the catchment for full development and for 50% filling of Subcatchment No. 8 are:

- 10 year ARI 14.3 m^3/s
- 100 year ARI 18.0 m^3/s.

For full development and 100% filling of Subcatchment No. 8 they are:

- 10 year ARI 14.4 m^3/s
- 100 year ARI 18.2 m^3/s

These peak discharges represent increases of about 30% above the discharges for existing conditions. However the modelled peak discharges approximate the capacity of the existing floodgate structure (estimated at 18.0 m^3/s).

The modelled 100 year ARI outflow hydrographs for existing and developed conditions with 50% filling of Subcatchment No. 8 are shown in **Figure 5.1**. These hydrographs are for a 12 hour storm duration, which is the critical duration with respect to peak discharge. The effect of development is to increase both peak discharges and total runoff volumes, but the duration of high discharges is not changed significantly. Hence it is considered unlikely that the increased volume of floodwaters will have a significant impact on the overall salinity regime in downstream oyster growing areas.

The modelled culvert and channel improvements are considered appropriate for the catchment development scenario and are proposed for implementation.

The MIKE-11 hydraulic model will also be an appropriate tool for assessment of alternative development scenarios; in particular, if major works are proposed in the floodplain. It is recommended that any such development proposals should be tested using the model or similar technique.

5.5 Water Quality Modelling

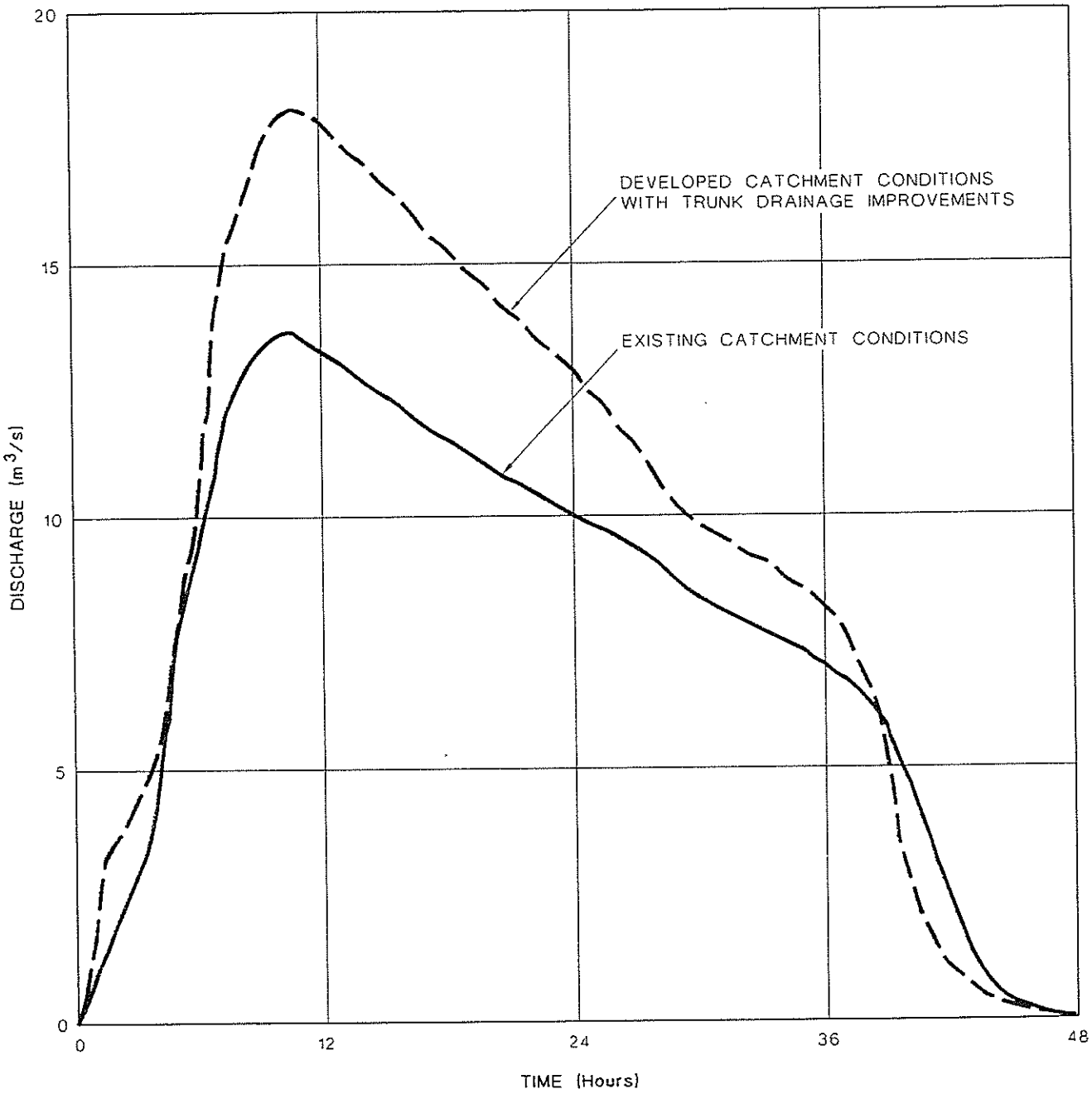
The major potential impacts on downstream receiving waters of stormwater runoff from the urbanised catchment are:

- Increases in pollutants during the land development and building construction stages, particularly sediment loads.
- Increases in pollutant loads during the long-term habitation stage, particularly nutrients.

It is expected that appropriate controls will be applied to individual developments during the land development and building construction stages; for example, sedimentation basins for on-site sediment and erosion control. The development phase is the critical period with respect to sediment control. After full development and establishment of the urban area, the sediment yields are likely to be comparable to or below the yields for agricultural conditions (Marsalek 1992).

A water quality control scheme for the total catchment will be required for the habitation stage. The major component of the scheme will be a water pollution control pond for control of the long-term export of pollutants.

Figure 5.1
100 YEAR ARI HYDROGRAPHS
AT FLOODGATE STRUCTURE
Anna Bay Catchment Drainage/Flood Study



NOTE:
MODELLED HYDROGRAPHS ARE FOR 12 HOUR DURATION STORM

The controlling criterion for sizing the pond is generally the requirement to limit phosphorus loads to pre-development levels.

The AQUALM-XP program was applied to provide estimates of :

- The phosphorus loads for the existing catchment, which has an effective contributing area of 969 ha and is largely rural in character.
- The phosphorus loads for the developed catchment with a contributing area of 1193 ha. Based on the above development scenario, the area will be comprised of about 137 ha urban, 426 ha rural residential, and 630 ha rural.
- The size of a water pollution control pond required to limit post-development phosphorus loads to pre-development loads.

The AQUALM-XP model of the catchment was run for the 1985 calendar year in which the recorded rainfall at Nelson Bay was 1430 mm; ie about 10% above mean annual rainfall. Because of the lack of streamflow data, it was not possible to calibrate the model to the catchment. Further information on the AQUALM-XP model is provided in **Appendix B**.

The estimated annual phosphorus loads from the catchment are;
- Rural conditions 366 kg
- Developed conditions 773 kg

These estimates are considered to be reasonable based on reported values for phosphorus generation rates for particular land uses. The modelled rates for this catchment are compared with typical rates reported by CSIRO Division of Water Resources (1993) as follows:

Land Use	Phosphorus Generation Rate (kg/ha/yr)	
	Modelled	Reported
Rural (unfertilised grazing)	0.38	0.25 ± 0.10
Urban	1.52	1.30 ± 0.40
Rural Residential	0.83	0.60 ± 0.30

The proposed water pollution control pond was modelled with a macrophyte regime; ie controlled aquatic growth including emergent and submerged macrophytes is used to enhance sedimentation and the uptake of nutrients. The information from the geotechnical investigation indicates that soils are likely to be non-dispersive, and hence the proposed pond should perform satisfactorily.

Table 5.2 - Summary of Trunk Drainage Improvements

Subcatchment No	Description	Estimated Cost ($)
Improvements Attributable to Individual Subcatchments		
1.	Table drain along south side of Gan Gan Road (700 m length). Culvert under Gan Gan Road (900 mm Ø, 20 m length). Table drain along east side of Nelson Bay Road to Fern Tree Drain (600 m length)	15 000 15 000 20 000
2.	Increased storage in McKinley's Swamp (1 100 m^3)	40 000
3.	Drainage works and road works - Gan Gan Road/Moma Point Road Piped outlet to north (1050 - 1200 mm Ø, 190 m length) Open channel to Fern Tree Drain (600 m length)	*155 000 *170 000 *15 000
4.	Culvert under Gan Gan Road (1200 mm Ø, 20 m length) Piped outlet to north (1200 mm Ø, 200 m length) Open channel to Anna Bay Main Drain (590 m length)	*20 000 *260 000 *50 000
5.	Works to formalise detention basin south of Gan Gan Road Piped outlet to north east (450 mm Ø, 150 m length) Table drain along north side of Gan Gan Road (150 m length)	5 000 70 000 5 000
6.	Additional culvert under Gan Gan Road (525 mm Ø, 20 m length) and improved drain to Ocean Side Estate (30 m length)	10 000
11.	Table drain along south side of Gan Gan Road (650 m length) Additional culvert under Gan Gan Road (750 mm Ø, 20 m length)	10 000 15 000
12.	Table drain along north side of Gan Gan Road (650 m length)	10 000
13.	Table drain along south side of Gan Gan Road (800 m length) Culvert under Gan Gan Road (750 mm Ø, 20 m length)	10 000 15 000
14.	Table drain along north side of Gan Gan Road (800 m length)	10 000
Improvements Attributable to Combined Subcatchments		
5,6.	Augmentation of drains through Ocean Side Estate to Anna Bay Main Drain (950 m length)	25 000
4,5,6,8,9.	Widening of Anna Bay Main Drain to Nelson Bay Road (2 900 m length)	95 000
1,3,10.	Widening of Fern Tree Drain (600 m length). Additional culverts at Fern Tree Drain under Nelson Bay Road (3-1050 mm Ø, 20 m length)	10 000 45 000
11,12.	Piped outlet to low relief area (900 mm Ø, 100 m length) Open channel to Anna Bay Main Drain (440 m length)	55 000 20 000
13,14.	Piped outlet to low relief area (900 mm Ø, 30 m length) Open channel to Anna Bay Main Drain (450 m length)	20 000 20 000
All	Widening of Anna Bay Main Drain from Nelson Bay Road to floodgate structure (2 300 m length).	95 000
✗	Additional culverts at Anna Bay Main Drain under Port Stephens Drive (2-1800 mm Ø, 15 m length)	*50 000
All	Water quality control pond and associated works (8 ha).	1 700 000
	Sub Total	3 055 000
	Contingency, 10%	305 000
	Survey, Design and Supervision, 7%	215 000
	TOTAL	3 575 000

Notes:

* indicates improvement required mainly for relief of existing flooding problems (refer Section 3.4). Land acquisition and compensation costs are not included.

Cost associated with acid sulphate soils are not included and will be determined at the design stage.

5.8 Land Acquisition and Compensation

There will be land requirements for implementation of some components of the scheme. The major items of land acquisition are summarised in Table 5.3, together with preliminary estimates of the areas and drain lengths involved. The estimates should be refined at the design stage.

Table 5.3 - Summary of Land Acquisition Requirements

Subcatchment No	Item	Amount
3	Easement for piped outlet and open channel to Fern Tree Drain.	*
5	□ Reserve for detention basin. □ Drainage easement along north side of Gan Gan Road to Ocean Side Country Estate.	7 ha 200 m
11, 12	Drainage easement from Nelson Bay Road to Anna Bay Main Drain.	540 m
13, 14	Drainage easement from Nelson Bay Road to Anna Bay Main Drain.	480 m
All	□ Drainage easement for widening of Anna Bay Main Drain. □ Reserve for Water pollution Control Pond/detention storage.	5 200 m 8 ha

Note: * Cost of required acquisition and compensation previously estimated at $60 000 by Port Stephens Shire Council.

At this stage, it is expected that drainage works for Subcatchment Nos 1 and 4 can be accommodated within existing road reserves and that there will be no land acquisition required to provide increased storage in McKinley's Swamp (Subcatchment No 2). These areas should also be reviewed at the design stage.

It is expected that any required improvements to Fern Tree Drain can be achieved within the drainage easements currently being obtained by Council.

6. Conclusions

This study was commissioned to provide a Masterplan for development of the Anna Bay catchment draining to Wallis Creek and the results of the study will allow planners, developers and engineers to develop the catchment in a manner which will not be detrimental to the environment.

There are a number of a major constraints to development of parts of the catchment. They include;

- extensive oyster leases in the downstream receiving waters
- acid sulphate soils
- low lying areas subject to flooding
- poor existing drainage network
- wildlife areas and corridors
- flat grades on land in some areas
- existing flooding problems.

The catchment has been divided into 14 subcatchments and the existing constraints and future development potential have been identified for each subcatchment.

Some areas adjacent to Gan Gan Road are subject to flooding due to inadequate drainage. In addition, the limited culvert capacity for Anna Bay Main Drain at Port Stephens Drive increases the frequency of flooding of upstream agricultural areas. An integrated scheme has been developed to relieve existing flooding problems and to allow appropriate development.

The benefit and cost of works in the subcatchments with existing flooding problems are summarised below.

Subcatchment No	Benefits	Cost ($)
2	Reduce flood levels.	*
3	Eliminate flooding.	340 000
4	Reduce frequency and duration of flooding, allow limited development.	330 000
12	Reduce flooding of agricultural areas.	40 000
		$710 000

Note: * Cost of minor works for Subcatchment No 2 are included in cost for Subcatchment No 3.

This study also examined the potential for development of the major rural catchments draining to Wallis Creek and concluded that some development could be permitted subject to careful water quality and quantity controls designed to protect the oyster leases.

The following works are required as part of the development;

- upgrading of drains along Gan Gan Road
- three drains through the sand hills to the north of Gan Gan Road
- enlargement of the drains through the swamp area
- increased culvert capacity under Gan Gan Road, Nelson Bay Road and Port Stephens Drive
- a major water quality control pond and gross pollutant trap.

The estimated cost of this work, including the cost to eliminate existing flooding problems, is about $3.6 million.

These works would allow the following ultimate potential development within the catchment.

Subcatchment No	Area (ha)			
	Urban	Rural Residential	Rural	Total
1	0	17	0	17
2	24	10	7	41
3	59	7	6	72
4	0	49	19	68
5	14	21	16	51
6	0	11	20	31
7	5	2	14	21
8	12	108	12	132
9	14	109	287	410
10	9	38	31	78
11	0	12	0	12
12	0	20	157	177
13	0	16	0	16
14	0	6	61	67
Total	137	426	630	1 193

Notes: Urban includes residential and private recreation uses.
Rural includes agricultural, public recreation, national park and environmental protection uses.

Potential developments can be assessed against the maximum land use capability developed for this report and the effect on flood levels and water quality can be assessed using the computer models RAFTS-XP, MIKE-11 and AQUALM developed for this study.

This report can also be used as the basis for developing a Section 94 Contribution plan for development within the catchment.

7. References

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