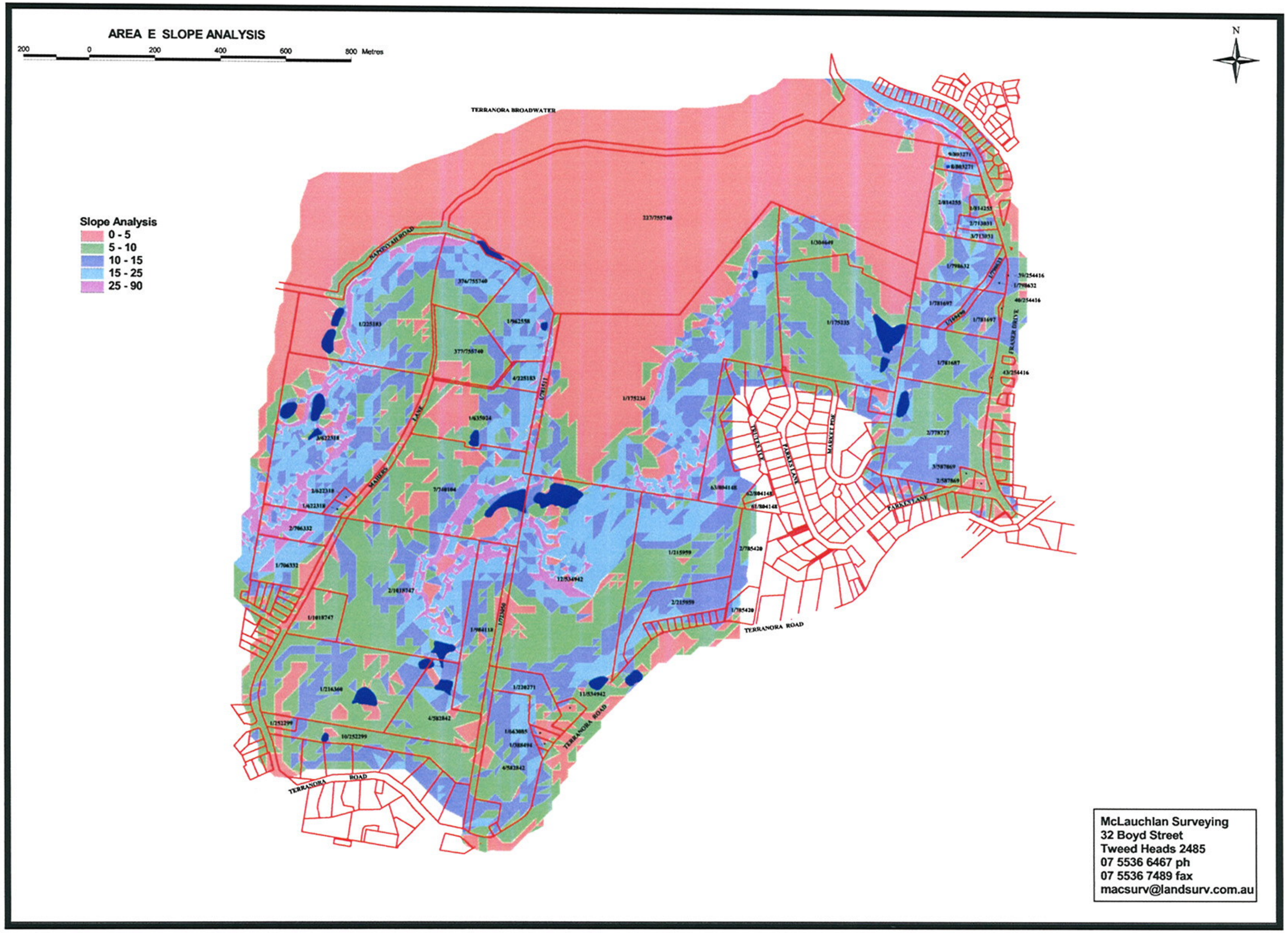


Figure 3-6: Slope Analysis (provided by McLauchlan Surveying)

3.2.2 Geology

A review of the Tweed Heads 1:250,000 Geological Series Sheet SH 56-3 (1972) was undertaken to determine the geology of Area E.

The Geological Mapping identifies the following (refer also to Figure 3.7):

- The area immediately adjacent to Trutes Bay as being comprised of Quaternary Age river gravels, alluvium, sand and clay(Qa).
- The area immediately north of Terranora Road being a component of the Tweed Range Lamington Area, Lamington Volcanics of the Tertiary Age. These Lamington Volcanics are comprised of basalt with members of rhyolite, trachyte, tuff, agglomerate, conglomerate (Tll).
- Areas not identified above are predominantly underlain by the Palaeozoic age Neranleigh – Fernvale Group, comprising greywacke, shale, and slate phyllite quartzite (Pzn).

With regard to the geological composition of Area E, Mineral Resources New South Wales (MRNSW) were contacted on 4 June 2003 for further LES input regarding any known or potential mineral or extractive resources. On 23 July 2003, MRNSW indicated in facsimile correspondence that with respect to Area E, 'the area does not include any known or potential mineral or extractive resources. No haulage routes are recognised in the vicinity of Area E'.

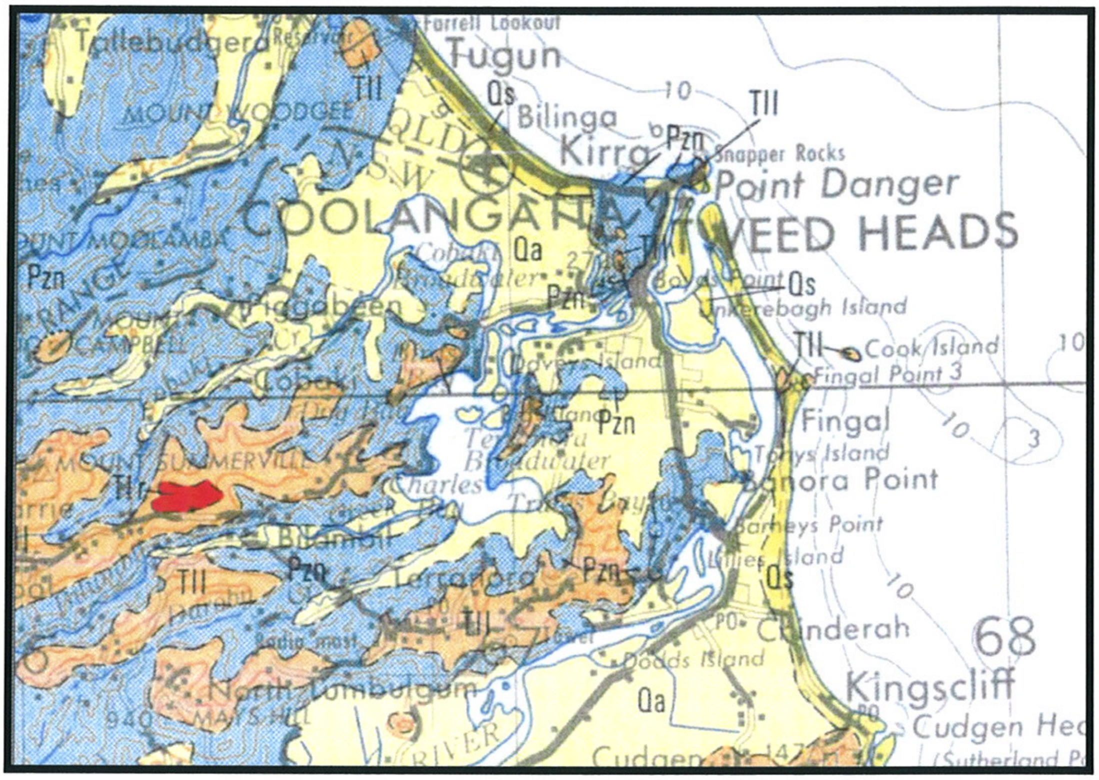


Figure 3-7: Geological Mapping for Area E. Trutes Bay generally depicted in centre of Figure. (Source: Tweed Heads 1:250,000 Geological Series Sheet SH 56-3 (1972))

3.2.3 Geological Stability

The previous 'Application to Tweed Council for Approval to Rezone Portion 227, DP 755740 Parish of Terranora, Fraser Drive, Terranora', by Master Planning Services 1995 included a stability assessment for the geological profiles of Area E.

This stability assessment was undertaken by Soil Surveys in December 1994, and identified four stability zones for development within Area E, being 'suitable', 'marginal', 'restrictive' and 'currently unsuitable'. These stability zones in turn were linked to a Stability Map (Drawing Number 294- 0419-04A - refer to Appendix E). It can be seen that there are two major tracts of 'currently unsuitable' land in the northern section of Area E. Marginal and restrictive categories of land are able to be developed however will require greater care with respect to construction methods and design. Analysis of this report indicates that the studies provide a reasonable level of information to identify any constraints associated with land instability.

Further, it is noted that while the abovementioned application included Lot 227 on DP 755740, this has been excluded from Soil Surveys stability assessment. It is noted from a contour survey provided by McLauchlan Surveys that this area is relatively flat supports littoral vegetation and is comprised of river gravels, alluvium, sand and clay. The area is known to contain acid sulfate soils (Clive Easton, pers. comm.) and has been identified in Tweed Shire Council reports as being of poor geological stability (Halliburton KBR, 2000) Given this land has been identified as containing acid sulfate soils, is flood prone and is included in SEPP 14, development of this area is not contemplated.

Coffey Partners International Pty Ltd (1992) undertook an assessment of a number of allotments not covered by the Soil Surveys Stability Assessment. This assessment identified a number of small areas of soil instability. The features are generally associated with steeper land where cut and fill for farm dams and roads has occurred. This report identified that with appropriate restoration and appropriate design of construction and drainage in these areas these issues should not arise in the future.

It should also be noted that Area E has similar underlying geology, soils and topography (including gradients) as much of the previously urbanised areas of Banora Point. These areas have been developed over the last 25 to 30 years. These areas have been developed with little or no significant issues relating to land instability except where significant cut and fill has occurred.

In summary, the majority of Area E is unencumbered by geological instability, which will not generally restrict the development of the site for urban purposes. It has a range of characteristics which are similar to the adjoining area of Banora Point which has previously been developed for urban residential uses.

However, areas identified as 'currently unsuitable' would normally be excluded from development while areas identified as marginal' and 'restrictive' are able to be developed but will require more sensitive design. The suitability of individual allotments for development uses, with respect to slope and geological stability, should be determined firstly during the preparation of the Development Control Plan, and secondly at such time that development applications are prepared by potential development proponents.

3.2.4 Acid sulfate soils

3.2.4.1 Background

The term 'acid sulfate soils' includes both 'potential' and 'actual' acid sulfate soils. Actual and potential acid sulfate soils are often found in the same soil profile, with actual acid sulfate soils generally overlying potential acid sulfate soil horizons.

"Actual acid sulfate soils" are soils containing highly acidic soil horizons or layers resulting from the oxidation of soil materials that are rich in sulfides, primarily pyrite. This oxidation produces acidity in excess of the sediment's capacity to neutralise the acidity resulting in soils of pH4.0 or less.

"Potential acid sulfate soils" are soils that contain iron sulfides or sulfidic material that has not been exposed to air and oxidised. The field pH of these soils in their unoxidised state is >4.0. They may be neutral or slightly alkaline.

Acid sulfate soils occur naturally over extensive low-lying coastal areas, predominantly below 5 metres AHD. These soils may be found close to natural ground level but may also be found at depth in the soil profile. Actual acid sulfate soils generally overlie potential acid sulfate soil horizons, but both may also occur within the same layer and may not be mutually exclusive.

Potential acid sulfate soils only become a problem when they are disturbed and exposed to air. Typically, excavating or otherwise removing soil or sediment, extracting groundwater or filling land causes disturbance of acid sulfate soils. These activities can be an intrinsic part of land uses such as canal estates, high rise residential units, golf courses, sand/gravel extraction, aquaculture, and roads and other infrastructure.

When potential acid sulfate soils are oxidised, sulfuric acid forms and the soil becomes strongly acidic (usually below pH 4). Strongly acidic soil can mobilise the naturally occurring metals in the soil. These actual acid sulfate soils, and any subsequent leachate, can have significant adverse effects on the natural and built environment, the economy and human health due to the presence of abundant acid, iron, aluminium, manganese and possibly other heavy metals. For example, the release of acid and metal contaminants can:

- have significant adverse effects on the ecology of wetlands and shallow freshwater and brackish aquifer systems by degrading water quality, habitat, and dependant ecosystems;
- have significant adverse consequences upon commercial and recreational fisheries and crop productivity;
- corrode concrete and steel infrastructure, such as culverts, pipes and bridges, reducing their functional lifespan; and
- lead to toxic concentrations of acid and metal contaminants which can cause dermatitis, while dust from disturbed acid sulfate soils may cause eye irritation.

The potential effects of disturbing acid sulfate soils need to be addressed when planning for, or undertaking, development. While it is preferable to avoid disturbing acid sulfate soils, the potential adverse effects of disturbance can be avoided or minimised by treatment and, in some cases, by ongoing management.

Therefore, the presence (or possible presence) of acid sulfate soils is a development constraint that should be subject to appropriate risk assessment. Determining the presence or absence of acid sulfate soils (and if required, treatment and management) can involve substantial costs that may compromise a project's design or financial viability.

These factors should therefore be taken into account as early as possible when considering projects in areas likely to contain acid sulfate soils.

The presence or absence of potential acid sulphate soils (PASS) needs to be assessed to indicate whether excavation of soils or lowering of water tables during re-development of the land has the potential to produce acid groundwater or runoff.

The Department of Infrastructure, Planning and Natural Resources (DIPNR) has produced a series of 1:25000 maps which identify the potential distribution of acid sulfate soils (ASS) in each NSW coastal estuary. These maps also indicate the likely depth of ASS. The Acid Sulfate Soil Risk Maps are available along the entire NSW coast to provide an initial assessment of the likelihood of ASS according to depth of PASS below the soil surface. Where land use activities are likely to disturb PASS, appropriate site assessment is essential, taking into account all the factors that may result in adverse effects on the environment. DIPNR has adapted the risk maps (series 1998) for use in council planning and development control processes. The planning maps have five classes of land based on the probability of ASS occurrence and the type of works which might disturb them. The classes are based on depth of PASS situated under the soil surface as extrapolated from the risk maps.

- Class 1 – PASS occurs between the soil surface and 0.5m in depth.
- Class 2 – PASS occurs between 0.5m and 1m in depth.
- Class 3 – PASS occurs between 1m and 2m in depth.
- Class 4 – PASS occurs between 2m and 3m in depth.
- Class 5 – PASS occurs greater than 3m in depth.

Planning scheme provisions have been developed in the Tweed LEP which require approval based on the Class of land and potential works being carried out. Table 3.4 indicates where development consent will be required for certain activities for each of the classes of land.

Table 3-4: Planning Classes for acid sulfate soils

Class 1	Any works.
Class 2	Works below natural ground surface. Works by which the watertable is likely to be lowered.
Class 3	Works beyond 1m below natural ground surface. Works by which the watertable is likely to be lowered beyond 1m below natural ground surface.
Class 4	Works beyond 2m below natural ground surface. Works by which the watertable is likely to be lowered beyond 2m below natural ground surface.
Class 5	Works within 500m of adjacent Class 1, 2, 3, or 4 land which are likely to lower the watertable below 1m AHD on adjacent Class 1,2,3 or 4 land.

3.2.4.2 Acid Sulfate Soils within Area E

The Acid Sulfate Soil Planning Mapping for Tweed Shire identifies a significant part of the study area in Class 2 (See Figure 3.8). Within this area works below the ground surface and works by which the watertable is likely to be lowered are likely to result in the acid sulfate soil events require approval.

The Draft Interim Strategic Plan – Cobaki/Bilambil Heights/Terranora (TSC, 1995) indicates that the area contains 'extensive deposits of acid sulphate soils which are a potential hazard to water quality and aquatic fauna'. This is supported by the identification of much of the lower lying areas of land as containing Class 2 Acid Sulfate Soils by Tweed Shire Council mapping.

In addition, a preliminary site investigation conducted by James Warren (Warren, 1995) outlined that a moderate to high level of PASS occur within sub-surface marine layers and that liming of soils would be required should excavation and exposure and of the soils occur.

This is confirmed by anecdotal evidence of acid sulfate soils events following flushing of the disturbed wetlands within Area E (Clive Easton pers. comm.).

Acid sulphate soils will affect development wherever excavation of PASS are proposed or where impacts to the local hydrological regime will result in lowering of the water table.

Prior investigations at and around the site indicate there is moderate to high potential for PASS at the site as indicated in Figure 3.8. A site visit undertaken during the preparation of this LES also identified topographical features of the land and red flocculated sediment in low-lying areas typical of ASS regimes.

It is recommended that areas below 5m AHD are assessed for PASS in accordance with NSW acid sulphate soils management guidelines. No current works are proposed which require the detailed assessment of PASS at this point in time. The area contains PASS and appropriate measures should be incorporated into the design to minimise potential impacts from soil disturbance or lowering of the groundwater table due to sealing of the site by urban development.

3.2.4.3 Potential Development and Impacts

Because of the flood prone nature of land likely to contain PASS and difficulties with developing these areas, wherever possible, development should be excluded from PASS areas.

ASS planning mapping for the site identifies significant areas of Class 2 land, however most if not all of this land is below the design flood level of 2.65m AHD. In addition the majority of this land is contained with the wetland complex and as such will not be subject to development.

While the design flood level for Area E is 2.65m AHD the site rises sharply from the edge of the flood plain and as such there is very little land between 2.65m HAD and 5m AHD. Development likely to occur below 5m AHD includes the following:

- the proposed Mahers Lane/Fraser Drive arterial road;
- open space (formal and informal);
- utilities;
- artificial wetlands and drainage structures; and
- wetland rehabilitation.

Based on the ASS planning maps and associated provisions in Class 2 works below natural ground surface and/or by which the watertable is likely to be lowered will require Council consent. This is likely to include all potential works identified above.

Filling below 5m AHD for residential development is likely to be limited due to the likelihood of these areas being required for the abovementioned uses.

The construction of the proposed road potentially poses the biggest issues with regard to ASS management as it is likely that earthworks will be required to provide adequate foundation conditions and to elevate the roadway above the design flood level. This has the potential to expose PASS to air through excavation and lowering the watertable. Tweed Shire and works contractors have constructed roads in similar situations throughout the Shire and there are well known and documented techniques for the management of PASS/ASS in these situations.

Flood plain areas within area E are already largely level and as such will require little or no earthworks for the establishment of active recreation areas. Regardless of this it will be necessary to assess the potential for disturbance/impacts of PASS and deal with these at the time.

The provision of utilities is also likely to occur on land below 5m AHD, including both below and aboveground infrastructure. For this infrastructure implications arise in terms of disturbance of PASS and protection of the asset from the potential impacts of ASS. Tweed Shire and works contractors have constructed utilities in similar situations throughout the Shire and there are well known and documented techniques for the management of PASS/ASS in these situations.

The stormwater management plan prepared for this LES identifies that significant artificial wetlands/drainage devices will be required to ensure that stormwater leaving the site is of adequate water quality and quantity. The construction of these wetlands has the potential to disturb PASS, but in the longer term should ensure that the watertable is elevated. Consideration will need to be given to PASS/ASS both in the design and construction of these structures.

The potential rehabilitation of the wetlands area is intended to restore freshwater wetland values in this area and would result in the raising of the watertable. Over the long term this would be desirable as it would prevent further ASS events occurring.

Current provisions in the Tweed LEP 2000 (Part 7, Clause 35) would require this issue to be addressed in greater detail should development be proposed within the area identified on Acid Sulfate Soil Planning Maps and these controls are considered to impose an appropriate framework for dealing with this issue.

Any works below 5m AHD should be assessed and managed in accordance with the requirements of the Acid Sulfate Soil Manual (ASSMAC, 1998). This manual identifies requirements for dealing with ASS including:

- Planning guidelines;
- Assessment guidelines;
- Management guidelines;
- Laboratory methods guidelines;
- Drainage guidelines;
- Groundwater guidelines;
- Management plan guidelines; and
- Industry guidelines.

This can only be done once development parameters have been identified. Subsequent investigations in accordance with the guidelines are likely to require specific management and design requirements to be incorporated into any works below 5m AHD.

3.2.5 Erosion and Sediment Control

Due to the steeper slopes, soil characteristics, rain fall in the area and the desire to protect water quality in Terranora Broadwater the control of erosion and sedimentation will be important both during any development on the site and post development.

Field inspections carried out during the preparation of this LES identified that the krasnozem soils (red volcanic) which are characteristic of much of the area are highly erodible when bare and exposed to rainfall and runoff.

Should urban development occur it will be necessary that construction is controlled in a manner which limits potential impacts arising from erosion and sedimentation. Tweed Shire Councils DCP 16 Subdivision Manual has specific requirements with respect to erosion and sediment control, namely:

- Erosion and sediment control must be in accordance with "Development Design Specification D7 - Stormwater Quality" and its Annexure A - "Code of Practice for Soil and Water Management on Construction Works".
- An Erosion and Sediment Control Plan is to be submitted with all development applications.

These measures should be sufficient to ensure that impacts can be controlled during any construction.

Post construction it will also be important to ensure that the catchment is managed in a manner which limits ongoing sediment and erosion. This LES proposes a detailed stormwater management plan to address this issue and is dealt with in greater detail in sections 3.3 and 3.4.

3.2.6 Earthworks

A significant issue for the potential development of steeper land within Area E is the control of cut and fill. In adjacent areas traditional development forms have resulted in significant cut and fill for the establishment of roads, infrastructure and house sites with resulting impacts on visual amenity, erosion and sedimentation and land stability. Recent examples of development which has required substantial retaining walls to allow traditional slab on ground housing forms to be accommodated can be found in adjacent development areas.

Area E is of similar topographical characteristics to these areas and as such control of earthworks will be important to ensure that issues such as visual impact, erosion and sediment control are encountered with the development of Area E.

Tweed Shire Council has developed Tweed Development Control Plan No 47 - Cut and Fill on Residential Land, which provides more detailed guidelines for the development of land having regard to the amount of cut and fill permitted on domestic forms of construction.

This DCP includes a range of specific controls which aim to:

- restrict and control excessive earth works in order to preserve as much as practicable the existing topography and amenity of the neighbourhood affected by the proposed development;
- ensure that the building design is appropriate for site conditions with consideration given to the stability and privacy of the adjoining properties.

- minimise the effect of disturbance on any land and ensure that dangerous excavations are avoided, or where necessary, are properly retained;
- prevent the siltation of waterways and erosion of land disturbed by the development;
- rehabilitate the site within a reasonable time frame upon completion of the development;
- minimise the removal and disposal of resultant spoil from the site;
- to retain topsoil on site; and
- to ensure adequate provision is made for drainage in relation to cut and fill practices.

In the case of Area E all of these controls are considered appropriate particularly on the steeper parts of the site. As such it is appropriate that the controls included in DCP 47 be continued for development within Area E in order to limit the extent to which earthworks are carried out on the site.

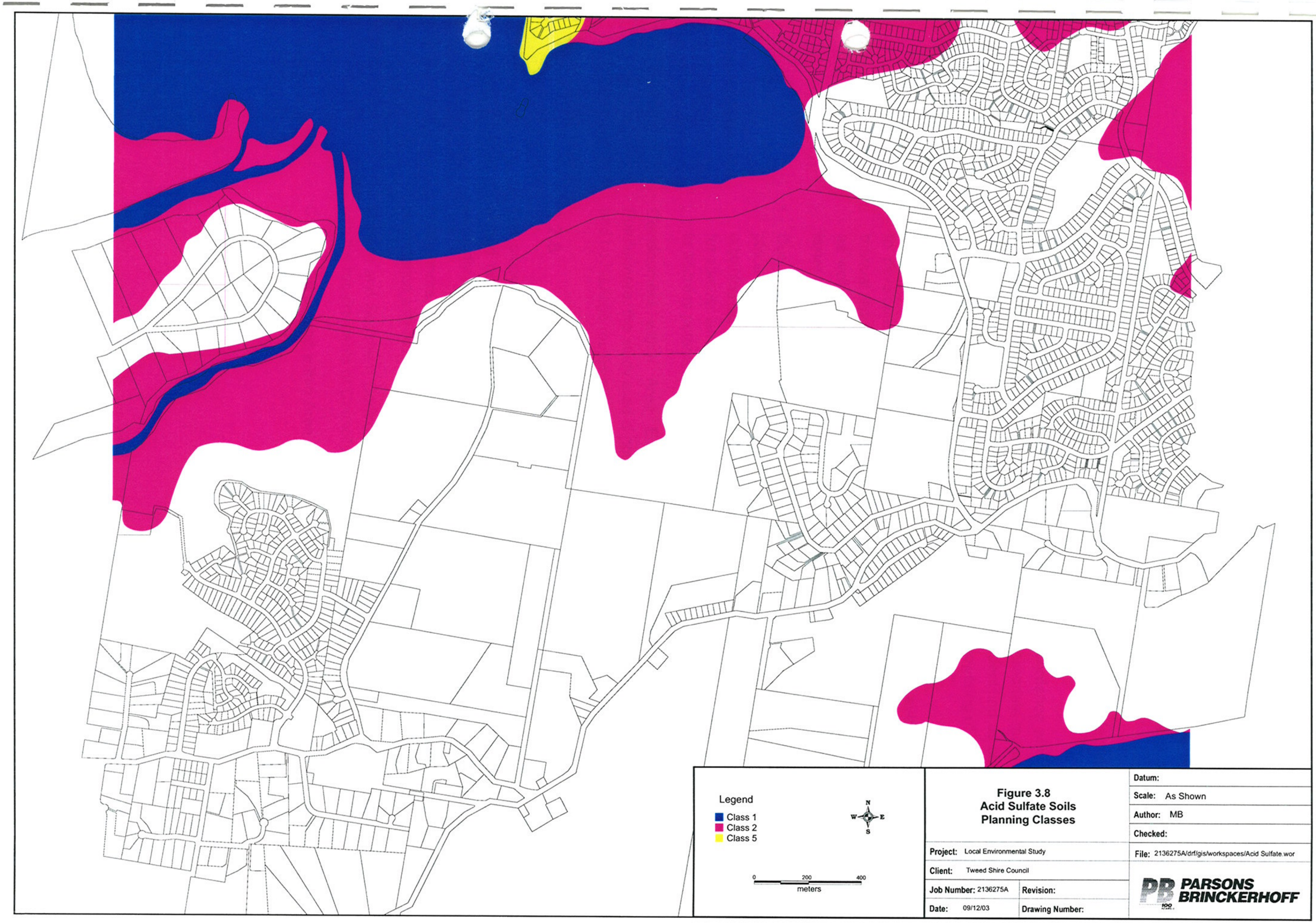


Figure 3.8
Acid Sulfate Soils
Planning Classes

Datum:	
Scale:	As Shown
Author:	MB
Checked:	
File:	2136275A/drf/gis/workspaces/Acid Sulfate.wor

Project:	Local Environmental Study	
Client:	Tweed Shire Council	
Job Number:	2136275A	Revision:
Date:	09/12/03	Drawing Number:

PARSONS BRINCKERHOFF

3.3 Flooding, drainage and water quality characteristics

3.3.1 Topography

The site slopes towards the north from Terranora Road, which generally runs along the top of the ridge at RL 130, to the Terranora Broadwater, which is at RL 1 (Martin Findlater & Associates Pty Ltd, 1995). The section of Area E that is adjacent to Terranora Broadwater is low-lying wetlands up to elevation 2.6m (Jim Glazebrook & Associates Pty Ltd, 2002). The majority of the catchment drains directly from the site to Terranora Broadwater while there is a section on the western fringe that directs water flows to the broadwater via Duroby Creek (Jim Glazebrook & Associates Pty Ltd, 2002).

There are two ridges that branch off from the main Terranora Road ridge and extend north near the western and eastern boundaries of the site along Mahers Lane and Parkes Lane. A valley is formed between the western and eastern ridges. The site varies in slope from generally flat adjacent to Terranora Broadwater to very steep (>25 % grade) (Jim Glazebrook & Associates Pty Ltd, 2002). The steepest land sections are found fringing the Mahers Lane and Parkes Lane ridges.

There is one existing dam on site, which is a small agricultural dam located in the upper reaches of the valley (Martin Findlater & Associates Pty Ltd, 1995). Aerial photography shows a number of small ponds distributed throughout the catchment.

Figure 3.9 highlights the topography of the catchment.

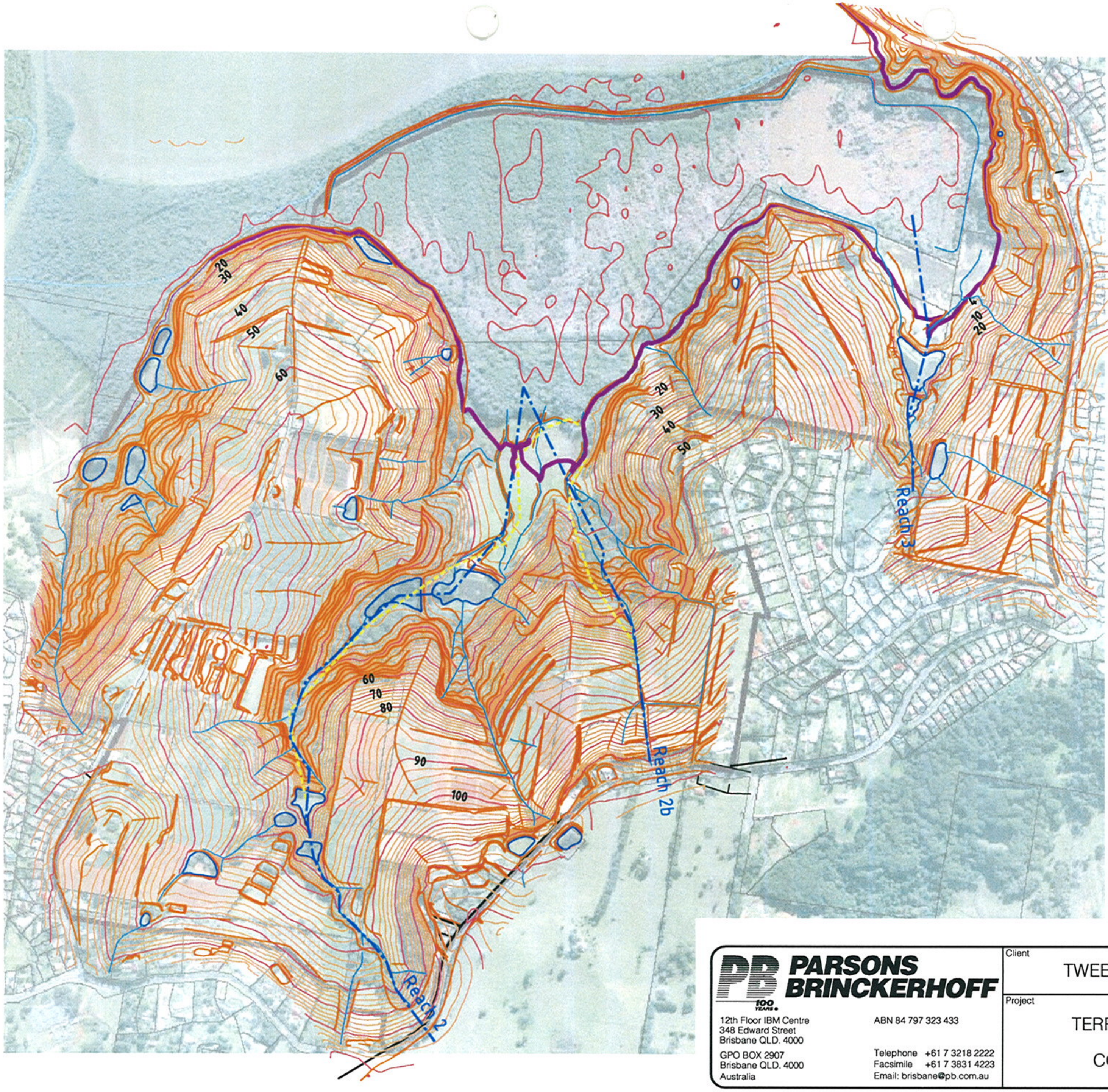
3.3.2 Flooding

The 1 in 100 year flood level is 2.6 m (Jim Glazebrook & Associates Pty Ltd, 2002). The majority of Area E is above the 2.6 m flood level with the inundated area comprising low lying wetlands (Jim Glazebrook & Associates Pty Ltd, 2002). The 1 in 100 year flood line is shown as a development constraint on Figure 3.9. Area E is above the 1 in 20 year flood level.

The low lying wetlands would be inundated relatively frequently during flooding of the Tweed River system but would not sustain significant flows from the Tweed River backwater, with only local runoff as a direct flow (WBM, 1995).

Using a calibrated flood model of the Tweed River system WBM modelled the affects of filling the south eastern section of Area E, a low lying section in the centre of Area E (adjacent to the proposed distributor road) and the proposed distributor road. The results of the WBM modelling showed no significant change in peak flood levels or flooding patterns on or adjacent to the site (WBM, 1995).

There is minimal filling proposed for the development of Area E and any filling has limited potential to significantly impact on flooding in or adjacent to Area E (pers comm. David Oxenham, 9 May 2003). The limited external flows through the site mean that upstream/local impacts of the development are not significant.



LEGEND

Natural Channels

River String

Q100 Flood Line (2.6m)

0 250

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Client	TWEED SHIRE COUNCIL
Job No	2136275A
Project	TERRANORA AREA 'E' CONTOUR PLAN
Drawing No	FIGURE 3-9
Cad File	FIG-3.17.dwg
Rev	1

Plot Date: 12/03/04 - 09:27 Cad File: H:\2136 Projects\2136275A\DRF\ACAD\FINAL\XREF\figures\FIG-3.9.dwg

3.3.3 Water quality values and objectives

A number of water quality studies and reports have been completed for the Tweed River and Terranora Broadwater catchments and receiving waters. They range from a broad, whole of catchment scale, to the identification of various environmental values and Water Quality Objectives (WQOs) that should be met to protect recognised values. The three documents referenced by this study and are discussed in detail include:

- Independent Inquiry into the North Coast Rivers, Healthy Rivers Commission, 2003;
- Water Quality and River Flow, Interim Environmental Objectives, NSW EPA, 2000; and
- Tweed Urban Stormwater Quality Management Plan, Tweed Shire Council, 2000.

3.3.3.1 Healthy Rivers Commission

The Independent Inquiry into the North Coast Rivers prepared by the Healthy Rivers Commission in May 2003 provides a summary of the Commission's findings about North Coast Rivers and sets out its recommendations for river health goals and strategies.

The report includes 10 recommendations that include river health goals, sustainable aquaculture, connectivity of stream networks and water cycle management which can be considered in identifying water quality objectives for the Terranora Broadwater. "The Commission takes a broad view of river Health. It holds that a healthy river is one whose conditions, as indicated by a broad range of environmental, social and economic characteristics, enables it to support the riverine ecosystems, commercial activities and social amenity as desired by the community." (HRC, 2003)

3.3.3.1.1 River health goals

The report highlights three categories of river health goals and associated management responses consisting of:

- **Conservation** – ecosystem structure and functioning should be protected and improved in existing near-natural areas that have high ecological values;
- **Sustainable use** – the condition of river corridors, river flows and water quality should be improved to support a healthy though modified ecosystem, whilst accommodating current and future commercial and recreational use goals; and
- **Protection of selected values** – targeted and specific purpose restoration, within the context of a highly modified environment.

The Terranora Broadwater catchment would fall under both the sustainable use and the conservation goal. The existing wetlands at the bottom of the catchment have been recognised by Tweed Shire Council (TSC) as having a high ecological value and would attract the conservation river health goals. The remainder of the catchment is not in a natural condition with key areas for the conservation of ecological integrity or a highly modified, urbanised river or estuary and would attract the sustainable used river health goal. Table 3.5 highlights the applicable areas and appropriate management responses recommended by the commission.

Table 3-5: Recommended river health goals and management responses

River health goal	Applicable areas	Appropriate management responses
Conservation	Upland sub-catchments in near natural condition and parts of the lower floodplain and estuary, especially key areas for conservation of ecological integrity (e.g. wetlands of national importance, estuarine marine parks) and habitat for vulnerable fish species.	▪ Protect native riparian and catchment vegetation. ▪ Conserve biodiversity. ▪ Prevent erosion and sedimentation. ▪ Preserve near-natural flows (including tidal flows where appropriate). ▪ Maintain water quality suitable for aquatic ecosystems, primary/secondary contact recreation and to minimise treatment for potable water use. ▪ Preserve natural ecosystem processes.
Sustainable use	Agricultural areas and parts of the coastal floodplain. Special attention should be given to key area for conservation of ecological integrity such as remnant native riparian vegetation (which may provide valuable habitat or habitat corridors, or contain endangered species), wetlands, and habitat for vulnerable fish species.	▪ Increase the extent of suitable aquatic habitat (for example, refuge pools) and preserve or enhance fish passage. ▪ Restore riparian and instream vegetation as practical. ▪ Employ 'river sensitive' methods for any bank stabilisation works. ▪ Preserve an appropriate portion of 'natural' streamflows. ▪ Maintain water quality suitable for agricultural use and primary/secondary contact recreation, and to minimise treatment for potable water use.
	Estuaries, especially oyster growing areas.	▪ Protect near-natural wetlands, foreshores and tidal flows. ▪ Maintain water quality suitable for aquatic ecosystems, primary/secondary contact recreation and seafood for human consumption. ▪ Restore native riverside vegetation. ▪ Rehabilitate degraded but potentially valuable floodplain wetlands and estuarine habitat where practical, including restoration of some river-floodplain connectivity.
	Tributary water courses in new urban areas.	▪ Use water sensitive urban design principles to preserve riverside vegetation, channel structure and habitat values whilst enhancing appearance and social amenity.

The report recommends that these *broad river health goals should be refined by reference to more detailed information about the stream condition as well as the community's desired land and water use goals*. The report provides guidance on the outcomes sought by the goals and the indicators of progress and consistency with its recommendations.

3.3.3.1.2 Sustainable aquaculture

The report also provides guidance for sustainable aquaculture to protect river health from any adverse impacts of aquaculture, and conversely the protection of identified aquaculture areas from adverse impacts from other land and water uses. The report proposes to identify and protect areas/estuaries where aquaculture is a priority intended outcome by the use of Aquaculture Industry Development Plans to ensure that the most stringent estuarine water quality is provided to produce oysters that are safe for human consumption.

3.3.3.1.3 Connectivity of stream networks

Multiple social and environmental goals can be achieved by restoring and protecting stream networks that provide valuable natural connectivity. The inquiry report highlights the necessary mechanisms, such as natural resource management plans and catchment blueprints, which promote the re-establishment and continuity of the riverbank vegetation. Stream networks can provide multi-use corridors for passive recreation, open space, Aboriginal access, protection of biodiversity and amenity.

3.3.3.1.4 Water cycle management

The report recommends that a whole system approach to water cycle management should be adopted to guide the selection of options for the provision of water supply, sewerage and stormwater management services. This approach can lead to optimum outcomes in terms of service standards, cost-effectiveness, river health, energy use, and green-house gas emissions.

3.3.3.2 NSW Environment Protection Authority

The NSW Government has developed interim water quality objectives through the Environment Protection Authority to ensure the long-term health of all waterways. Interim water quality and river flow objectives have been established to provide measurable objectives to protect environmental values such as aquatic ecosystems and recreation, and protect natural river flow patterns. The guidelines are intended for use mainly for river, water and groundwater committees to include in their water management plans. The objectives are broken up into the following categories:

- town water supply sub-catchments;
- mainly forested areas;
- waterways effected by urban development;
- uncontrolled streams; and
- estuaries.

The Terranora Broadwater catchment falls under the waterways affected by urban development and the estuary categories. Table 3.6 highlights the relative environmental values for water quality and river flow objectives for each category.

Table 3-6: Adopted environmental values

Objective	Urban Waterway	Estuarine	Adopted
Water Quality Objectives			
Aquatic ecosystem	✓	✓	✓
Visual amenity	✓	✓	✓
Secondary contact recreation	✓	✓	✓
Primary contact recreation	✓	✓	✓
Aquatic foods (cooked)		✓	✓
River Flow Objectives			
Mimic natural drying in temporary waterways	✓		
Maintain natural flow variability	✓		✓
Maintain natural rates of change in water levels	✓		✓
Manage groundwater for ecosystems	✓	✓	✓
Minimise effects of weirs and other structures	✓	✓	✓
Maintain wetland and floodplain inundation		✓	✓
Maintain or rehabilitate estuarine processes and habitats		✓	✓

3.3.3.2.1 Interim water quality objectives

The WQOs provide a benchmark or reference level for water quality parameters to protect desired environmental values. Achieving each WQO will assist in the improvement of poor water quality or maintain existing good water quality. The interim WQOs consist of three parts: environmental values, their indicators and numerical criteria that should be achieved to protect the value. The indicators and numerical criteria for each environmental value are those provided under the ANZECC (1992) guidelines and are presented in Table 3.7.

Table 3-7: Tweed River water quality objectives for estuaries

Indicator	WQO	Environmental Value
Total Phosphorous	10-100µg/L NSW EPA 10-20µg/L	**Aquatic ecosystem**
Total Nitrogen	100-750µg/L	**Aquatic ecosystem**
Chlorophyll-a	1-10µg/L	**Aquatic ecosystem**
Dissolved Oxygen	>6mg/L or 80-90 % saturation over a 24 hour period	**Aquatic ecosystem**
pH	5.0-9.0	**Primary contact recreation**
Chemical contaminants	Free from chemicals or pollutants that are either toxic to humans, animals, plants and other organisms or irritating to the skin or mucus membranes Refer to ANZECC (1992) guidelines for chemical contaminants and tainting substances.	**Aquatic ecosystem, Primary contact recreation.** **Aquatic Foods (cooked)**

Indicator	WQO	Environmental Value
Surface films and debris	Oils and petrochemical films should not be noticeable as a visible film nor detected by odour. Free from floating debris and litter.	**Primary contact recreation**
Faecal coliforms	Median over bathing season < 150 faecal coliforms per 100mL, with 4 out of 5 samples < 600/100mL	**Primary contact recreation**
	Median bacterial concentration < 14MPN/100mL; 10 % of samples > 43 MPN/100mL NSW SQAP medial faecal coliform level of 14 faecal coliforms/100mL	**Aquatic Foods (cooked)**
Turbidity	Approximately 6 NTU	**Primary contact recreation**

3.3.3.2.2 Interim river flow objectives

The river flow objectives (RFOs) are provided to maintain or improve river heath by altering flow patterns. The RFOs will not completely restore natural flow patterns where the community significantly benefits from altered flow patterns. The RFOs applicable to the Tweed River are presented below.

Table 3-8: River flow objectives for the Tweed River

Objective	Measures to achieve objective
Mimic natural drying in temporary waterways	Identify any unregulated streams where unnatural flows have greatly reduced drying periods. Assess potential short and long term environmental, economic and social effects of this change and of possible management alternatives Decide what, if any, action is appropriate to implement this objective in streams and wetlands on a case-by-case basis, after giving due consideration to local views
Maintain natural flow variability	Identify streams with unnatural flow variability and develop actions to mimic natural variability Identify streams or development proposals with potential for variability problems, and take early action
Maintain natural rates of change in water levels	Identify locations where water levels often rise or fall faster than they would naturally. Identify the reasons and impacts. Remedial action requires case-by-case assessment. Identify potential problems and take early action.
Manage groundwater for ecosystems	Implement the State Groundwater Policy (DLWC 1997a, 1998b). Identify any streams or ecosystems that may depend on high groundwater levels and assess whether impacts on these may be occurring due to changed recharge rates or excessive pumping. Identify long-term trends or changes in groundwater levels that are likely to threaten ecosystems or the quality of ground or surface water. Determine appropriate action to keep groundwater levels within acceptable bounds.
Minimise effects of weirs and other structures	Implement the NSW Weirs Policy (DLWC 1997b). Identify and take action to reduce the impacts on fish, other animals, plants and water quality of other structures that impede the two-way movement of water in streams (e.g. floodgates, tidal barriers, culverts).

Objective	Measures to achieve objective
Maintain wetland and floodplain inundation	In management plans and actions for waterways include strategies to: Maintain, restore or mimic natural patterns of inundation, water movement and drying in natural and semi-natural wetlands and remaining native floodplain ecosystems Ensure adequate access for native fish to and from floodplain wetlands. Flooding patterns should not be altered without proper environmental assessment.
Maintain or rehabilitate estuarine processes and habitats	Dredging beyond the minimum needed to maintain navigation channels should be subject to environmental assessment before being allowed to proceed. Minimise draining or disturbance of areas of potential acid sulfate soils. Tidal wetlands should continue to receive tidal flushing – minimise the impact of flood levees and gates, roads and other barriers. Ensure that water-based activities have minimal impact on fish habitat. Other processes affecting or potentially affecting estuary health to be addressed – e.g. where increased urbanisation is proposed, ensure that impacts are avoided or minimised.

3.3.3.3 Tweed Shire Council

Tweed Shire Council (TSC) in association with the New South Wales Stormwater Trust has prepared the Tweed Urban Stormwater Quality Management Plan (USQMP) in April 2000. The Tweed USQMP has defined environmental values for the Tweed River and Tweed Coast Estuaries which are generally based on the ANZECC Guidelines (1992). The relevant values for the Terranora Broadwater include:

- aquatic ecosystems protection;
- edible molluscs (raw);
- primary contact recreation; and
- secondary contact recreation.

Each value has water quality criteria to ensure that the water quality is adequate to protect the environmental values above. The interim water quality objectives defined by Council have adopted the most stringent criteria for each segment and are provided below in Table 3.9.

Table 3-9: Tweed Shire Council interim water quality objectives for estuarine segments

Parameter	Estuarine Segments	Units
pH	7 - 9	pH units
Dissolved oxygen	> 6	mg/L
Suspended solids	< 10	mg/L
Total Phosphorous	< 0.05	mg/L
Total Nitrogen	< 0.5	mg/L
Chlorophyll a	< 10	mg/L
Faecal Coliforms	< 14	No/100mL

Further investigations to determine locally specific water quality objectives have not been undertaken for this catchment, however long and short term objectives have been identified for existing urban areas and new urban development. The Tweed Urban Stormwater Quality Management Plan and its appendix (Development Design specification – D7 - Stormwater Quality), detail objectives and management devices for construction and operation phases.

The TSC Development Design specification – D7 - Stormwater Quality, requires (but is not limited to):

- preliminary erosion and sediment control plan for the construction phase of development;
- preliminary stormwater management plan for the occupational or use stage of the development;
- water quality features designed into land development if practical;
- end of pipe devices for additional treatment;
- constructed wetlands to remove sediments, pollutants and nutrients in accordance with Table 7.11-WS; and
- modelling of annual stormwater pollutant loads per hectare using AQUALM or MUSIC with Tweed standard rainfall data sets available on Council's website.

The requirements for a subdivision of greater than 50 ha from Development Design specification – 7 – Stormwater Quality are:

- grassed swale drainage in preference to pipes or hard lined channels for road and street drainage; and
- retention of litter and gross pollutants greater than 50 mm for flows up to the three month Average Recurrence Interval (ARI) storm by use of litter baskets or pits or litter racks for road and street drainage.

The TSC Stormwater Treatment Objectives for Post Construction from the Tweed Urban Stormwater Quality Management Plan are included in Table 3.10 below.

Table 3-10: Stormwater treatment objectives for post construction (operational) phase of new development

Pollutant		
Nutrients	Maximum permissible load that may be discharged (kg/ha/year)	
	TSC Average Year (1719 mm)	Revised TSC Guidelines
Suspended Solids (SS)	300	300
Total Phosphorous (TP)	0.8	1.65
Total Nitrogen (TN)	4.5	13
Litter	Retention of 70 % of annual litter load greater than 5mm	
Coarse Sediment	Retention of 90 % of annual load of sediment coarser than 0.125mm	
Oil and Grease (hydrocarbons)	< 10mg/Litre in flows up to 40 % of Q1 peak	

Preliminary modelling has indicated that the original TSC guidelines for an average year rainfall are extremely difficult to meet using the MUSIC model treatment defaults for a range of water quality treatments including wetlands, grassed swales and bio-filtration. TSC has subsequently reviewed their guidelines to better reflect the pollutant loads from a catchment with properties between a natural catchment and a rural landuse.

3.3.3.4 Water quality in Terranora Broadwater

Area E drains to the southern section of Terranora Broadwater, which then joins the Tweed River near its mouth via the Terranora Inlet. The water quality in the Broadwater is generally acceptable with the exception of turbidity, which is widespread due to the shallow muddy substrate being exposed to prevailing winds (TSC, 1994). A number of additional studies into the quality of the Broadwater have been completed with a summary of the Healthy Rivers Commission and the NSW Department of Land and Water Conservation findings presented below.

The Healthy Rivers Commission's Independent Inquiry into the North Coast Rivers has assessed the current health of a number of waterways, including the Tweed River. This reports states that the Tweed River has the following characteristics:

- the Tweed River is in a "worse than average" condition;
- riverside vegetation is less than 60 %;
- the river is highly stressed due to the extraction of water;
- poor water quality when measured against guidelines for primary contact recreation, edible seafood, potable water and protection of aquatic ecosystems; and
- macro invertebrate communities are in relatively poor condition.

The NSW Department of Land and Water Conservation Stressed Rivers Assessment Report indicates that the Terranora Broadwater sub catchment has a medium level of hydrological stress, a high level of environmental stress and identified conservation values for National Parks and Wildlife Services and Fisheries (NSW Department of Land and Water Conservation, 1999). An independent Public Inquiry into Coastal Lakes places Terranora Lake in a category of "healthy modified conditions" and provides indicative actions for the management of that category of coastal lake.

The Terranora Broadwater is one of the few remaining rich and diverse habitats in the Tweed River System (TSC, 1994). Maintaining and enhancing this habitat is necessary for the survival of the bird and marine life in the Tweed River System (TSC, 1994).

Turtles Bay, which is bounded to the south by Area E, is the most significant site in the Lower Tweed in species diversity and average numbers for foraging, roosting and breeding of estuarine birds (TSC, 1994). One of only two freshwater swamps in the Lower Tweed is found in the surrounding lowland at Turtles Bay and forms part of Area E. Within the Broadwater there are rare and vulnerable estuarine birds. The primary management objective is to preserve the existing bird and marine habitat while sustaining recreational and commercial use in the Terranora Broadwater. The mangrove habitat of Area E along the southern shore of Terranora Broadwater provides an important habitat for a wide variety of aquatic fauna (TSC, 1994).

Any catchment runoff has the potential to contribute to the silting of the mud basin in Terranora Broadwater (TSC, 1994).

The potential for development in the South Tweed Heads area to create acid runoff and nutrient problems is noted in the Terranora Broadwater Management Plan (TSC, 1994) and Stormwater Management on Area E would be required to mitigate these concerns. There are class2 acid sulphate soils on the southern shores of Terranora Broadwater, which is part of Area E.

Altered stormwater runoff from the development of Area E must not contribute to the proliferation of mosquitoes and biting midges in the Terranora Broadwater.

Water quality protection in the Tweed River catchment upstream of Bray park weir is required to ensure the future water supply quality in the Tweed River is maintained. The Terranora Broadwater joins the Tweed River downstream of the Bray park weir and doesn't affect water supply (Tweed Shire Council, 1996).

Any development to proceed must follow the Terranora Broadwater Management Plan.

3.4 Stormwater management

3.4.1 Adopted stormwater management objectives

The water quality objectives adopted for this study should reflect the recommended actions and strategies of the documents discussed in Section 3.3 to ensure the protection of desired environmental values. The principles of Ecologically Sustainable Development (ESD) is the basis for stormwater management objectives in Tweed Shire which is *generally defined as development that improves the quality of life both now and forever in a way that maintains the ecological process on which life depends (National Strategy for Ecologically Sustainable Development, 1992).* (TSC, 2000)

Both the TSC and NSW EPA interim guidelines are based on the ANZECC (1992) guidelines enabling the TSC interim water quality guidelines to be adopted. The river flow objectives identified by NSW EPA should also be adopted where appropriate to maintain or improve river heath by altering flow patterns to mimic natural processes where practical.

The adopted water quality objectives are provided below in Table 3.11.

Table 3-11: Adopted water quality objectives

Pollutant		
Nutrients	Concentration	Maximum permissible load that may be discharged (kg/ha/year)
		Average Year (1719 mm)
Suspended Solids (SS)	< 10 mg/L	300
Total Phosphorous (TP)	< 0.05 mg/L	1.65
Total Nitrogen (TN)	< 0.5 mg/L	13
pH	7 – 9 pH units	
Dissolved Oxygen	> 6 mg/L	
Suspended Solids	< 10 mg/L	
Chlorophyll a	< 10 mg/L	
Faecal Coliforms	< 14 No/10mL	
Litter		Retention of 70 % of annual litter load greater than 5mm
Coarse Sediment		Retention of 90 % of annual load of sediment coarser than 0.125mm
Oil and Grease (hydrocarbons)		< 10mg/Litre in flows up to 40 % of Q1 peak

3.4.2 Stormwater management issues

The main stormwater issues that need to be addressed to ensure the ESD of new development fall under stormwater quality and stormwater quantity. Stormwater quality looks at the concentration and long term load of specific pollutants from the developed site, while stormwater quantity looks at ensuring that the developed areas are above desired flood events and cater for frequent stormwater flows, in addition to ensuring that the change in impervious areas does not significantly alter the frequency and volume of river flows.

3.4.3 Water quality

3.4.3.1 Pollutant export modelling

PB has used the MUSIC modelling package developed by CRC for Catchment Hydrology (2002 Version 1.00) to estimate impacts of development and evaluate the relative performance of various management options. The model can be used to generate both pollutant concentrations and long term pollutant loads and is recognised as the most appropriate modelling software for the planning of stormwater treatment measures for urban catchments. The model can generate pollutant loads and event mean concentrations for Total Suspended Solids (TSS), Total Phosphorous (TP), and Total Nitrogen (TN) and current versions are limited to modelling only these pollutants together with gross pollutants. Other pollutants can be substituted, such as Chlorophyll a or faecal coliform, however long term statistical data on the generation of these pollutants is required. At this time this information is not available and PB have only modelled the default pollutants. Additional source controls and management actions can be adopted to limit these additional pollutants. Only the MUSIC default parameters have been included in detailed catchment modelling.

3.4.3.1.1 Modelling approach

The stormwater management philosophy for the development of Area E is based on:

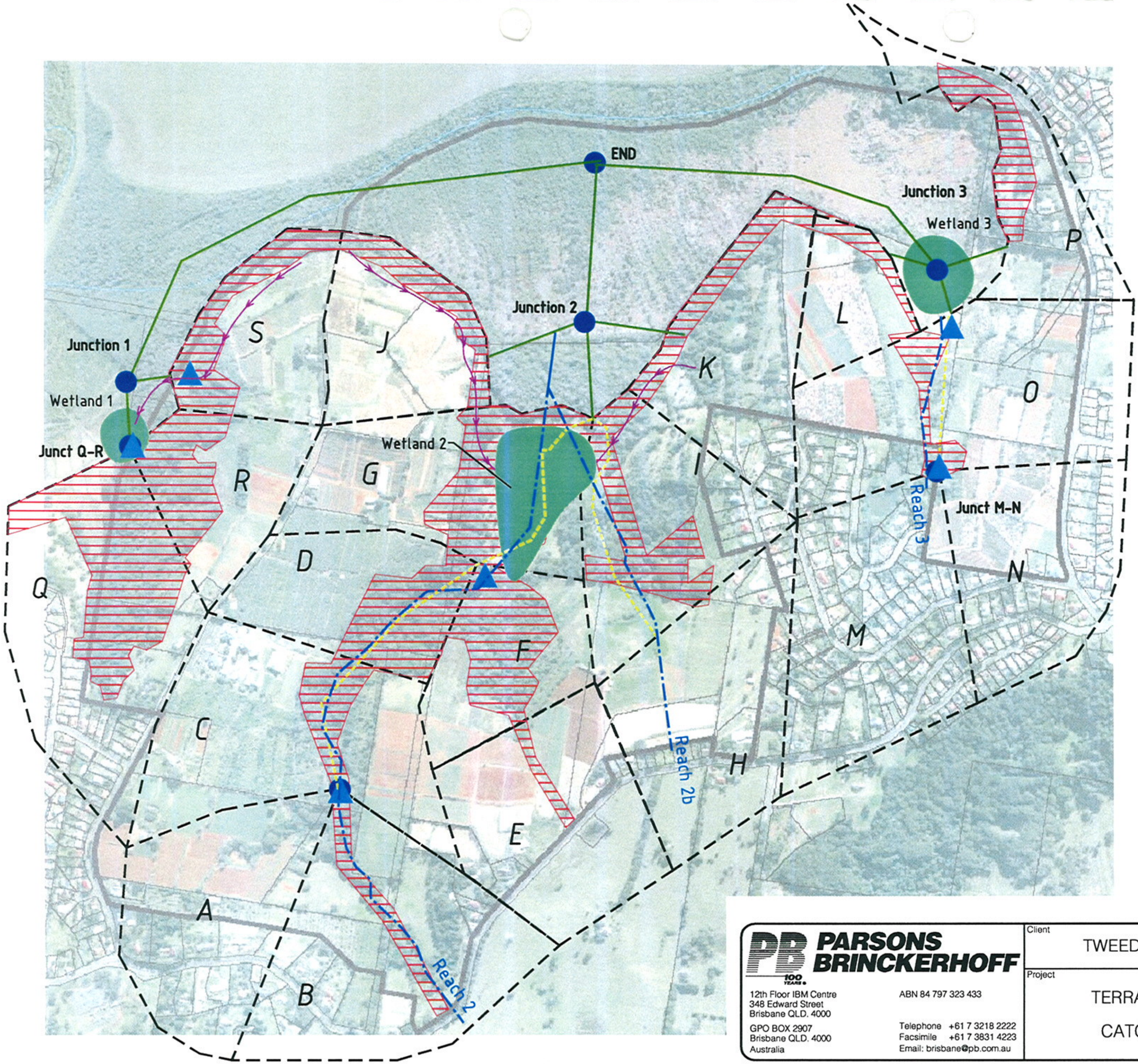
- conveying the quantity of stormwater from the site;
- limiting external stormwater flows through the site;
- treating the stormwater prior to discharge into wetland areas and the Terranora Broadwater and thus meeting TSC, State and Federal guidelines; and
- retaining existing vegetation and gullies on site.

The study area was broken up into three sections with a total of 19 sub-catchments as shown in Figure 3.10. The areas were determined and used together with parameters for an undeveloped area to estimate natural pollutant loads, pre-settlement. The existing case was modelled by determining the amount of rural areas from aerial photography and applying rural parameters where appropriate. The developed catchment areas were identified by assuming all of the catchment will eventually become developed except the areas that have been reserved for wetland buffer zones and riparian areas along natural water courses. Urban parameters were assigned to these areas together with the relevant parameters for the other land uses. The developed model was copied and three management options were trialled including:

- three regional wetlands;
- at source vegetated swales and bio-retention trenches; and
- rainwater tanks together with at source vegetated swales and bio-retention trenches.

The models were run with the average year rainfall (1978 – 1.693 m) and evapotranspiration values as provided by TSC on their website.

Sub-catchments were lumped where appropriate to simplify the model and lower saving, loading and run times of the program, without altering the accuracy of the results.



LEGEND

- Catchment Boundaries
- Natural Channels
- Junction Connections
- Potential Detention Basins
- Areas unsuitable for development
- Wetlands
- River String
- Diversion Drain

NOTE

Areas unsuitable for development include areas which are flood prone, steep slopes, drainage flow paths, vegetation buffer, overland flow path, wetlands buffer and land with geotechnical contraints

CATCHMENT	AREA (Ha)*
A	18.8
B	26.4
C	24.2
D	14.0
E	19.5
F	12.1
G	20.5
H	20.4
I	18.1
J	12.8
K	14.9
L	7.0
M	23.3
N	17.5
O	27.0
P	12.3
Q	25.7
R	11.6
S	12.1

* TOTAL AREA INCLUDING UNSUITABLE AREAS

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Client: TWEED SHIRE COUNCIL

Project: TERRANORA AREA 'E' CATCHMENT PLAN

Job No: 2136275A

Drawing No: FIGURE 3-10

Cad File: FIG-3.18.dwg

Rev: 1

Plot Date: 12/03/04 - 09:26 Cad File: H:\2136 Projects\2136275A\DRF\ACAD\FINAL\XREF\figures\FIG-3.10.dwg

3.4.3.1.2 Modelling parameters

The TSC modelling parameters for rainfall, evapotranspiration, urban node, rural node and undeveloped node were adopted as listed in Council's Development Design specification — D7 — Stormwater Quality.

The MUSIC model defaults of k and C* assist in the definition of treatment performance and are based on research and judgement by academics and industry leaders assisting the CRC for Catchment Hydrology. A conversation with Graham Jenkins (Griffith University/CRC) revealed that he believes that these should not be altered unless sufficient data exists to indicate more representative parameters. All modelling for this study has therefore used the default values for k and C*, with the exception of wetlands and ponds which have adopted a C* of 1.0mg/L for TN based on advice from TSC.

3.4.3.2 Base case assessment

The MUSIC model was developed with the same catchment layout used to develop catchment flows from the XP-RAFTS software (see Section 3.4.4). The 19 sub-catchments making up the 338.2 ha were assigned the TSC source nodes for the base case assessment. Two base cases were run, the first was the pre-existing case and the second was the existing case with rural land uses over the catchment.

The site can be divided into three sub-catchments as shown in Figure 3.10. The majority of the sub-catchments have large areas of pervious surfaces, typically comprising of rural farmland, grass and scattered small trees, with only minor areas of impervious surfaces comprising of buildings and pavement. The only significant existing development on Area E is the local High School, which is mostly impervious. The ridge running along Terranora Road acts as a catchment boundary and therefore there is minimal external area draining through Area E (Martin Findlater & Associates Pty Ltd, 1995). There is no existing constructed stormwater infrastructure on site and runoff is conveyed via natural gullies.

The total area of each sub-catchment is provided below in Table 3.12.

Table 3-12: Sub-catchment's Areas

Sub-catchment	Area (ha)
A	18.8
B	26.4
C	24.2
D	14.0
E	19.5
F	12.1
G	20.5
H	20.4
I	18.1
J	12.8
K	14.9
L	7.0
M	23.3
N	17.5

Sub-catchment	Area (ha)
O	27.0
P	12.3
Q	25.7
R	11.6
S	12.1
Total	**338.2**

There is an area of land at the foot of the central gully that is unsuitable for development based on geotechnical constraints. Figure 3.10 shows these, together with other development constraints such as flooding and wetland protection buffer zones. The lower areas of the site have been recommended as possible sites for stormwater quality treatment (Jim Glazebrook & Associates Pty Ltd, 2002). Regional treatments such as wetlands have been placed in these areas, just upstream of the natural wetlands to reduce stormwater pollutants.

3.4.3.3 Pre-rural case

The MUSIC model was set-up with each sub-catchment having the TSC undeveloped source node and pollutant generation characteristics. The MUSIC model produced the following pollutant loads for the three main sub-catchments and the total pollutant loads entering the Broadwater.

Table 3-13: Pre - rural pollutant loads and annual flow

Average Year Results	Junction 1	Junction 2	Junction 3	Total	Pollutant load	Ave daily concen.
					kg/ha/yr	mg/L
Flow (ML/yr)	372	1520	655	**2547**	**n/a**	**n/a**
Total Suspended Solids (kg/yr)	5800	23900	10500	**40200**	**118.9**	**7.1**
Total Phosphorous (kg/yr)	18.9	77.6	34.4	**130.9**	**0.39**	**0.14**
Total Nitrogen (kg/yr)	68.8	286	122	**476.8**	**1.41**	**0.79**

As expected the pollutant loads from the natural catchment are much less than that expected from a developed catchment, even with mitigation measures.

3.4.3.4 Existing case – rural

The natural MUSIC model was copied and each sub-catchment was assigned the appropriate area of rural or natural land use as identified from existing aerial photography. The TSC rural and undeveloped source nodes and pollutant generation characteristics were applied to each sub-catchment. The MUSIC model produced the following pollutant loads for the three main sub-catchments and the total pollutant loads entering the Broadwater.

Table 3-14: Existing case – rural pollutant loads and annual flow

Average Year Results	Junction 1	Junction 2	Junction 3	Total	Pollutant load	Ave daily concen.
					kg/ha/yr	mg/L
Flow (ML/yr)	453	1880	909	**3242**	**n/a**	**n/a**
Total Suspended Solids (kg/yr)	22200	95800	70000	**188000**	**555.9**	**8.3**
Total Phosphorous (kg/yr)	58.3	245	175	**478.3**	**1.41**	**0.10**
Total Nitrogen (kg/yr)	334	1400	1040	**2774**	**8.20**	**0.95**

The existing land use of Area E is agricultural with the majority of the site cleared for small crops. The current rural land use (small crops) has led to an increase in sediment pollutant loads from the natural site. The MUSIC model has estimated that TSS has increased by a factor of approximately 4.7 times the natural levels. Nutrient loads have also increased for both TP and TN with TP and TN increasing by a factor of approximately 3.7 and 5.8 respectively.

3.4.3.5 Developed case assessment

The catchment model was altered to contain the urban parameters for all sub-catchments with the exception of areas that have been reserved for buffer zones or riparian vegetation. The TSC default pollutant and flow characteristics were applied and no mitigation measures were included. The existing basins within the catchment were not included to provide a complete "no mitigation" option. The MUSIC model developed for this case is shown as Figure 3.11.

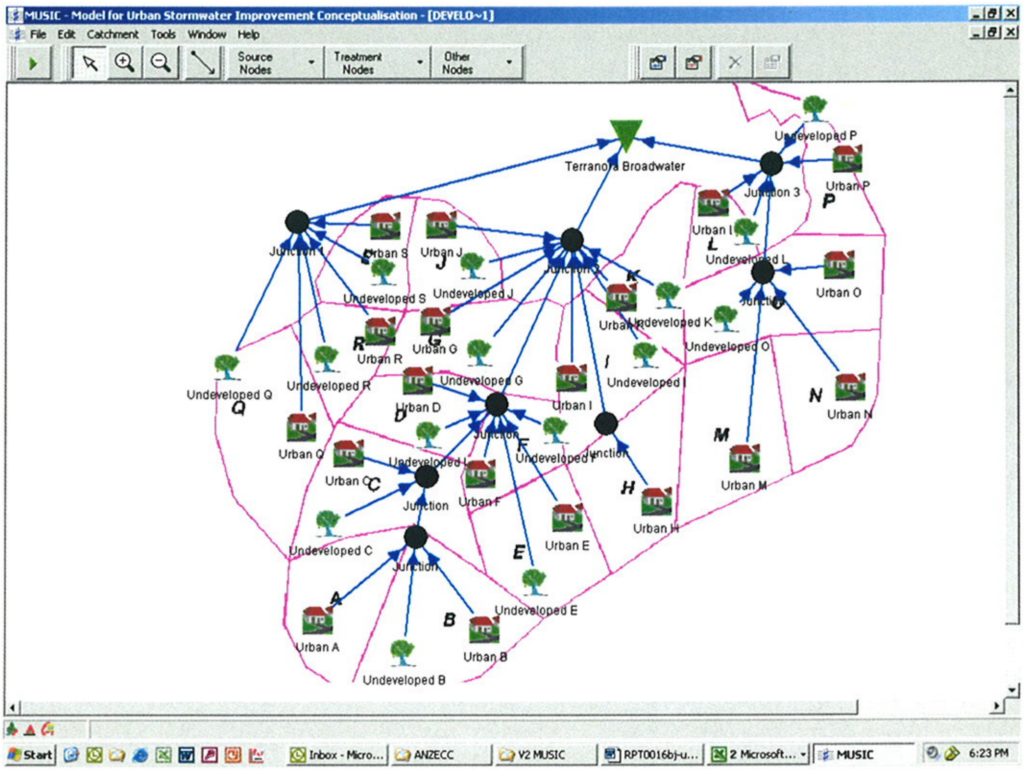

Figure 3-11: MUSIC model for the developed unmitigated case

The results of the MUSIC model run are provide below in Table 3.15.

Table 3-15: Developed unmitigated case – pollutant loads and annual flow

Average Year Results	Junction 1	Junction 2	Junction 3	Total	Pollutant load kg/ha/yr	Ave daily concen. mg/L
Flow (ML/yr)	515	2220	987	**3722**	n/a	n/a
Total Suspended Solids (kg/yr)	42100	204000	97300	**343400**	**1015.4**	**10.7**
Total Phosphorous (kg/yr)	106	509	238	**853**	**2.52**	**0.14**
Total Nitrogen (kg/yr)	634	3060	1450	**5144**	**15.21**	**0.83**
Gross Pollutants (Kg/yr)	5630	27800	13300	**46730**	**138.17**	n/a

The expected pollutant loads from a fully developed catchment exceed the natural loads by a factor of 8.5, 6.5 and 10.8 for TSS, TP and TN respectively. The loads are higher than the requirements set by the TSC with the TSS, TP and TN annual loads exceeding the water quality objectives by a factor of approximately 3.3, 1.5 and 1.2 respectively.

All three pollutants must be reduced substantially to meet TSC guidelines provided in Table 3.11. The required pollutant reductions required are provided below in Table 3.16.

Table 3-16: Required pollutant reductions

Pollutant	Required % Reduction to meet TSC Guidelines
Total Suspended Solids	70
Total Phosphorous	35
Total Nitrogen	15

3.4.3.6 Mitigation option 1 – wetland

Previous investigations have provided conceptual sizes for wetlands to provide treatment. The MUSIC model was used to evaluate the expected performance of the three wetlands as shown in Figure 3.18. As discussed previously, the default values for k and C* were adopted for this evaluation, with the exception of C* of 1.0 mg/L for TN. The TSC Development Design specification — D7 — Stormwater Quality section D7.9 was used to size the wetlands. The results of the modelling are provided below.

Table 3-17: Developed mitigated case wetlands – pollutant loads and annual flow

Average Year Results	Junction 1	Junction 2	Junction 3	Total	Pollutant load kg/ha/yr	Ave daily concen. mg/L
Flow (ML/yr)	496	2140	982	**3618**	n/a	n/a
Total Suspended Solids (kg/yr)	14400	69000	32500	**115900**	**342.7**	**6.6**
Total Phosphorous (kg/yr)	74.3	333	154	**561.3**	**1.66**	**0.09**