Riverside at Tea Gardens
Concept Plan and Project Application

Environmental Assessment Report
Volume 3A

for Crighton Properties Pty Ltd

January 2009

0043707 - Final

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Principal Consultant:	*Steve O'Connor*
Date:	*January 2009*

Environmental Resources Management Australia Pty Ltd Quality System

This report has been prepared in accordance with the scope of services described in the contract or agreement between Environmental Resources Management Australia Pty Ltd ABN 12 002 773 248 (ERM) and the Client. The report relies upon data, surveys, measurements and results taken at or under the particular times and conditions specified herein. Any findings, conclusions or recommendations only apply to the aforementioned circumstances and no greater reliance should be assumed or drawn by the Client. Furthermore, the report has been prepared solely for use by the Client and ERM accepts no responsibility for its use by other parties.

Volume 3A:

Construction Environmental Management Plan

Integrated Water Management, Including:

Assessment Of Water Quality Options

Groundwater Assessment Report

Fish Community Survey Report

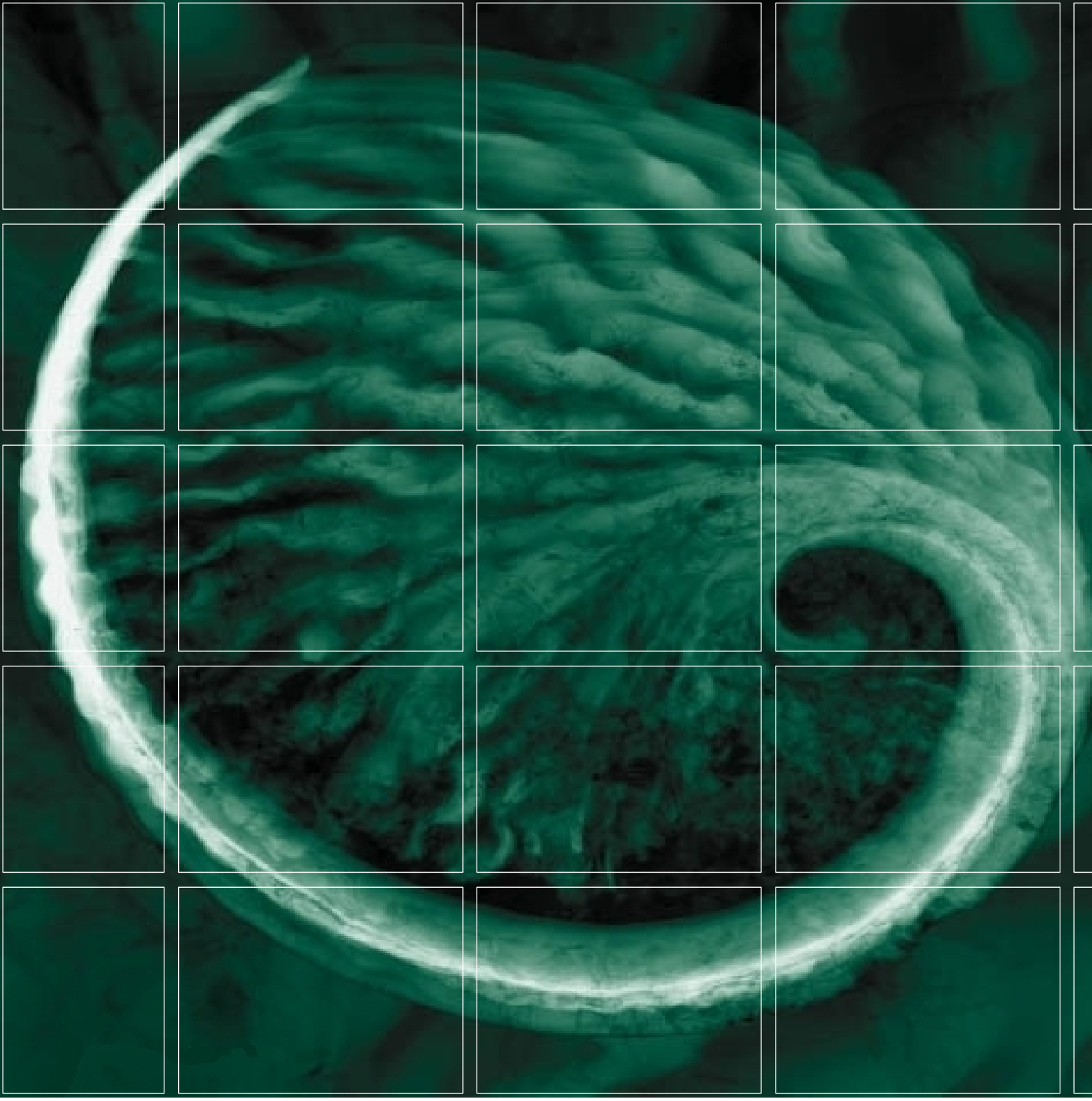
Practical Considerations Of Climate Change

Probable Maximum Flood Assessment

Geotechnical And Acid Sulphate Soil Assessment

Detention Lake Sediment Sampling

Volume 3A: Construction Environmental Management Plan



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Construction Environmental Management Plan

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Approved by:	*Steve O'Connor*
Position:	Principal Consultant
Signed:	
Date:	*27 January 2009*

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1 INTRODUCTION

1.1 BACKGROUND

Crighton Properties Pty Ltd (Crighton) is seeking concept approval for a residential, tourist and commercial development at the Riverside site in Tea Gardens and project approval for the initial stages (stages 1, 2, 3, 4, 5, 6, 7, 8 and 9) of the residential and commercial development, under Part 3A of the *Environmental Planning and Assessment Act, 1979 (*EP&A Act).

This Construction Environmental Management Plan (CEMP) has been prepared by Environmental Resources Management (Australia) Pty Ltd (ERM) for the initial stages of the residential and commercial development and details the proposed environmental management procedures that will be implemented during construction.

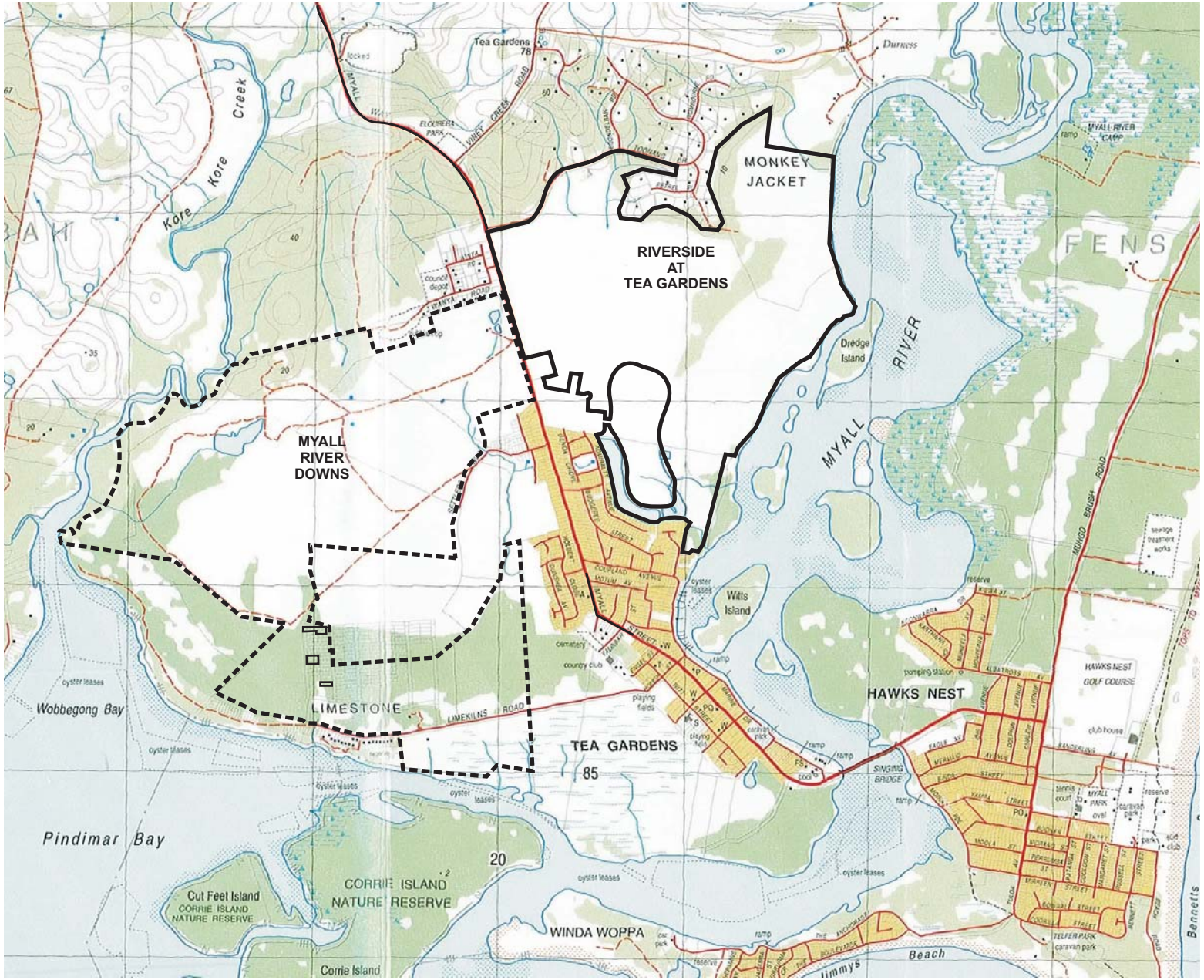
1.2 SITE DESCRIPTION

The Riverside at Tea Gardens site ('the site') comprises Lot 1 DP 270100, Lot 10 DP 270100, Lot 19 DP 270100, Lot 30 DP 270100, Lot 40 DP 270100, lot 5 DP 270561, Pt Lot 1 DP 270561 and Pt Lot 2 DP 270561 and is approximately 229 hectares in area. The site is bounded by Myall River to the east and Myall Street to the west. The Shearwater Residential Estate lies to the north of the site and residential development of Tea Gardens is to the south. The site has approximately a one kilometre frontage to Myall Street and two kilometre frontage to the Myall River. State Environmental Planning Policy No. 14 – Coastal Wetlands (SEPP 14) applies to wetlands within a portion of the eastern boundary of the site adjacent to the Myall River. These wetlands were clearly identified along with a buffer to the wetlands and zoned for environment protection when the site was rezoned in 2000. The remainder of the site is available for urban purposes and zoned for mixed use urban development.

The site is flat with generally sandy soils. The majority of the site was previously used for a pine plantation and has been substantially cleared of native vegetation. Some scattered isolated occurrences of both pines and natives currently exist on the site. A locality plan is provided in *Figure 1.1*.

1.3 PROJECT DESCRIPTION

Riverside at Tea Gardens will include a residential / mixed use development over the majority of the site and a tourist and residential component located within the north eastern portion of the site. The key elements of the overall concept plan includes:



Legend

Riverside at Tea Gardens
Site Boundary

Figure 1.1

Locality Plan

Client:	Crighton Properties Pty Ltd		
Project:	Environmental Assessment Riverside at Tea Gardens		
Drawing No:	0043707hv_EA_CEMP_01		
Date:	25/08/08	Drawing size:	A4
Drawn by:	JD	Reviewed by:	AA
Source:	1:25,000 Topo Series Port Stephens Sheet		
Scale:	Refer to Scale Bar		

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- an extension of the existing town centre on the north side of Shoreline Drive;
- a residential subdivision to accommodate 1045 dwellings;
- an internal road network, upgrading of intersections and associated road and other construction works, such as cycleways;
- an open space network of approximately 127 hectares;
- water sensitive urban design (WSUD) measures including a two hectare extension of the existing detention lake and the creation of three new freshwater detention basins and numerous additional ponds surrounded by parklands and widening of the existing channel linking the detention lake to the Myall River to provide water quality management; and
- an 8 hectare tourist/residential development (including a conference centre and accommodation) and a foreshore park of 5.6 hectares.

The concept plan for Riverside at Tea Gardens is provided in *Figure 1.2*.

The area proposed to be developed has been defined by a detailed analysis of the constraints and opportunities of the site to determine the most appropriate development footprint.

The project application relates to stages 1, 2, 3, 4, 5, 6, 7, 8 and 9 of the residential subdivision as illustrated in *Figure 1.3*. The project application yield, facilities and associated urban structure is detailed in *Figure 1.4*.

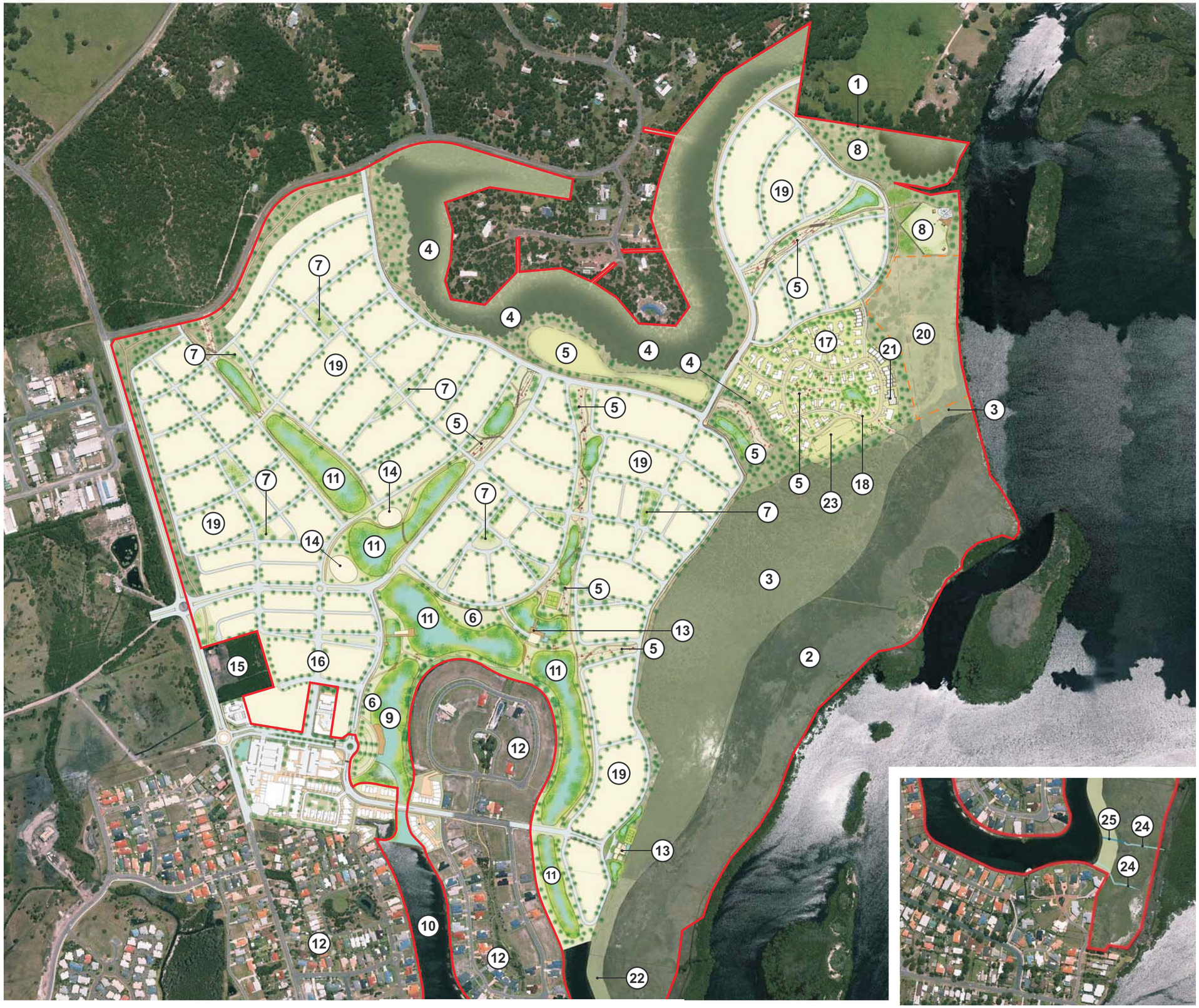
The subdivision will be created under Community Title, as part of the existing approved Community Title residential development.

This Construction Environmental Management Plan (CEMP) is for the project plan application which involves the construction of a residential estate to accommodate 381 dwellings on residential lots ranging in area from greater than 650m^2 to less than 450m^2 and associated infrastructure and access roads as shown on *Figure 1.4*. The CEMP relates to the construction of the subdivision and associated infrastructure only and does not address construction of dwellings once the construction of the subdivision is complete.

1.4 CONSTRUCTION ACTIVITIES

Activities associated with the construction of the subdivision, and which are covered by this plan include:

- clearing of vegetation in accordance with the project approval;
- stripping and stockpiling of topsoil;



Item	Description
1	Extent of concept plan area 'Riverside' at Tea Gardens.
2	Existing 7(a) wetland zone.
3	Existing 7(b) buffer zone.
4	Wildlife movement corridor.
5	Water management & open space corridors.
6	Community parks incorporating walking/cycle ways, BBQs, children's play area equipment.
7	Community pocket parks.
8	Myall foreshore park including structured and unstructured open space.
9	Extended lake area for water detention & water quality management (2.0 Ha).
10	Existing detention and water quality lake.
11	New fresh water water quality management & detention ponds.
12	Existing residential development.
13	Precinct community facilities.
14	Future precinct community facilities.
15	Site area currently owned by Great Lakes Council.
16	Super Lots for future development.
17	Tourist lodgings precinct.
18	Conference & community facilities, associated low rise town house accommodation.
19	Proposed residential lot development to be developed under community title.
20	Future development site.
21	Existing house.
22	DCP buffer.
23	Location of known midden & buffer.
24	Existing drain outlet to Myall River.
25	Existing drain to Myall River to be extended to connect with existing lake.

Land Use Legend

Total Site	Ha	%
Open Space		
- Wetlands (zoned 7a)	28.4	12.4
- Buffer Zones (zoned 7b)	20.6	9.0
- Additional Conservation Buffer	1.4	0.6
- Wildlife Corridors	27.3	11.9
- Myall Foreshore Park	5.6	2.4
- Drainage Corridors, Ponds & Large Parks	35.1	15.4
- Pocket Parks	2.6	1.1
- Existing detention & water quality lake	6.7	2.9
Total	**127.7 Ha**	**55.7%**
Built Upon Area		
- Residential (including roads & community facilities)	83.6	36.5
- Tourist/Residential (Lodgings)	8.4	3.7
- Future Development Site	5.0	2.2
- Commercial/Retail	4.3	1.9
Total	**101.3 Ha**	**44.3%**
Total	**229.0 Ha**	**100%**

Figure 1.2

Concept Plan for Riverside at Tea Gardens

Client:	Crighton Properties Pty Ltd		
Project:	Environmental Assessment Riverside at Tea Gardens		
Drawing No:	0043707hv_EA_CEMP_02		
Date:	27/01/09	Drawing size:	A3
Drawn by:	JD	Reviewed by:	AA
Source:	Crighton Properties - Plan R.C - 03		
Scale:	Refer to Scale Bar		

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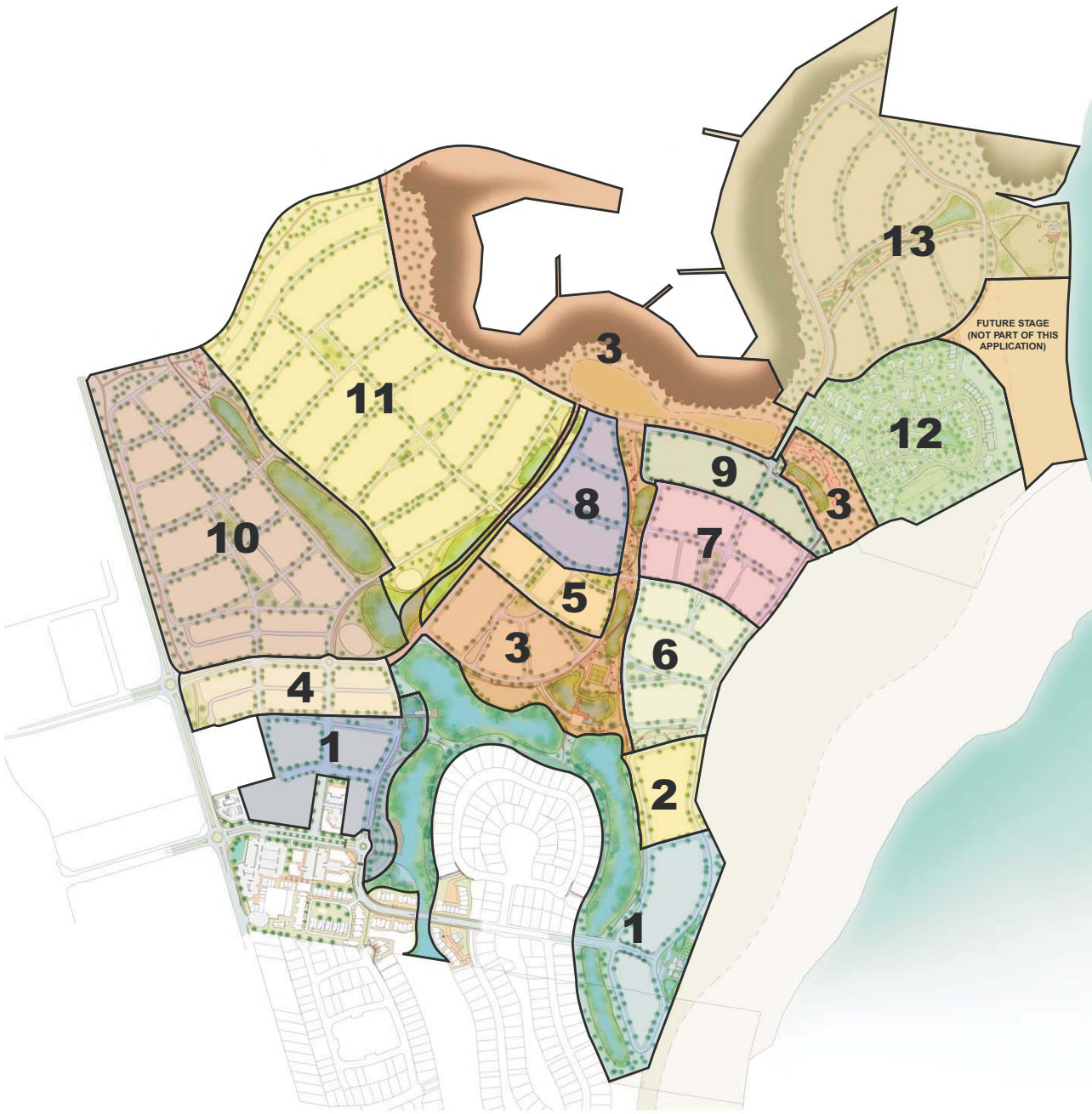

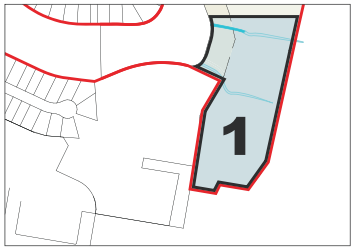

INSET 1 - DRAIN OUTLETS TO MYALL RIVER

STAGING DETAILS (INDICATIVE)

Stage	No. of Dwellings	Details other Inclusions	Approx Registration Date (year)
1	48	Stage 1 to include establishment & partial embellishment of primary community water management ponds & commercial centre infrastructure. Northern drain to Myall River to be extended.	2008
2	23		2009
3	44	Includes completion of embellishment of community park, wildlife movement corridor & temporary drainage line establishment through stage 8 & 11. Includes provision of second community facility. Second access to Riverside.	2009
4	37		2009
5	28		2010
6	53		2010
7	62		2011
8	45	Includes finalisation of temporary drainage line.	2011
9	41		2012
10	166 (Approx)	Includes new access to Toonang Drive & 4th community facility.	2013
11	293 (Approx)	Includes final access to Toonang Drive.	2015
12	65 (Approx) Lodge/ Townhouse		2016
13	140 (Approx)		2017
Total	1045		

Figure 1.3

Staging Plan

Client:	Crighton Properties Pty Ltd		
Project:	Environmental Assessment Riverside at Tea Gardens		
Drawing No:	0043707hv_EA_CEMP_03		
Date:	27/01/09	Drawing size:	A4
Drawn by:	JD	Reviewed by:	AA
Source:	Crighton Properties- Plan R.C - 08		
Scale:	Refer to Scale Bar		

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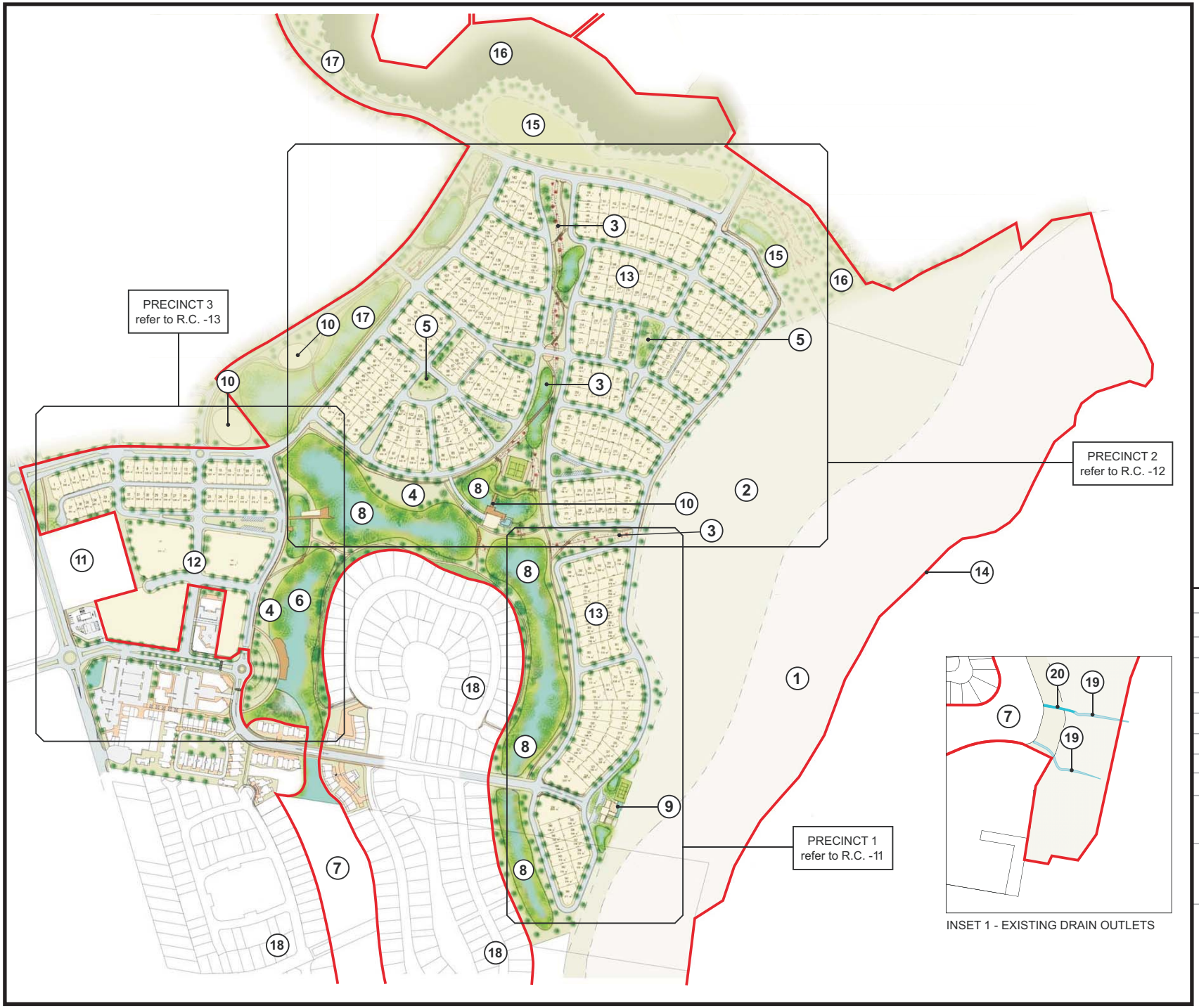

INSET 1 - EXISTING DRAIN OUTLETS

PROJECT APPLICATION YIELD TABLE

Lot Size Range	No. of Dwellings	% of Total
Multiple Dwellings <450m^2	61	16.0%
<450m^2	17	4.5%
450-550m^2	74	19.4%
550-650m^2	150	39.4%
>650m^2	79	20.7%
Total	381	100%

Note: *Total Area 29.3 Ha @ 13 Dwellings per Ha*

Item	Description
1	Existing 7(a) wetland zone (to be further protected as community land).
2	Existing 7(b) wetland buffer zone (to be further protected as community land).
3	Water management & open space corridors.
4	Community parks incorporating walking/cycle ways, BBQs, children's play area equipment.
5	Community pocket parks.
6	Extended lake area for water detention & water quality management (2.0 Ha).
7	Existing detention and water quality lake.
8	New fresh water quality management & detention ponds.
9	Precinct community facilities. Refer to R.C. -31, R.C. -32 , R.C. -33, & R.C. -34
10	Future precinct community facilities.
11	Site area currently owned by Great Lakes Council.
12	Super Lots for future development.
13	Proposed residential lot development to be developed under community title.
14	Extent of project application.
15	Establishment of upper catchment. Dry & wet basins, as well as swales.
16	Augmentation & management of wildlife movement corridor.
17	Temporary works required in these areas to establish drainage & diversions (refer to engineering drawings).
18	Existing residential development
19	Existing drain outlet to Myall River
20	Existing drain to Myall River to be extended to connect with existing lake.

Figure 1.4

Project Application Plan

Client:	Crighton Properties Pty Ltd		
Project:	Environmental Assessment Riverside at Tea Gardens		
Drawing No:	0043707hv_EA_CEMP_04		
Date:	27/01/09	Drawing size:	A4
Drawn by:	JD	Reviewed by:	AA
Source:	Crighton Properties - Plan R.C -10		
Scale:	Refer to Scale Bar		

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- widening of the existing drainage channel;
- construction of road pavements, kerb and guttering, and associated piped stormwater drainage and water quality controls;
- construction of telecommunications, electricity, and reticulated water and sewer services and infrastructure;
- earthworks; and
- revegetation of exposed soils following completion.

1.5 OPERATING HOURS

Proposed operating hours are within the following:

- Monday to Friday, 7:00 am to 6:00 pm;
- Saturday, 8:00 am to 4:00 pm if inaudible at residential premises, alternatively hours will be 8:00 to 1:00pm; and
- no construction on Sundays or public holidays.

2 CONSTRUCTION MANAGEMENT

2.1 OBJECTIVES OF THE CEMP

The objectives of the CEMP are to:

- ensure that the construction activities comply with current environmental legislation and best practice environmental management;
- comply with the relevant project approval for the site; and
- minimise the risk to public safety, and to protect the amenity of adjoining residents and the public generally.

2.2 ENVIRONMENTAL MANAGEMENT STRUCTURE AND RESPONSIBILITIES

This plan is to be updated prior to the commencement of construction with appropriate roles and responsibilities relating to environmental management. Tasks and responsibilities are summarised in *Annex A* of this CEMP.

2.3 APPROVAL AND LICENSING REQUIREMENTS

The project requires approval from the NSW Minister for Planning under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act). Construction and subdivision certificates will be required to be obtained once the Minister for Planning has granted approval under Part 3A.

2.4 TRAINING AND SITE INDUCTION

All employees and subcontractors will undergo environmental awareness training as part of the site induction to ensure they understand their obligations and responsibilities under this CEMP. The site induction will include:

- familiarisation with the requirements of the CEMP and other relevant management plans (ie erosion and sediment control plan);
- environmental emergency response procedures; and
- familiarisation with site environmental controls.

Records of all site inductions will be kept and maintained by the site supervisor.

2.5 *EMERGENCY CONTACT AND RESPONSE*

In the event of an environmental emergency, the following person can be contacted 24 hours per day, seven days per week:

Name:	Peter Childs
Position/Responsibility:	Crighton Project Manager
Contact Number:	02 4352 4352
Alternative Contact Number:	0419 971 666

Emergency services contact details are as follows:

Emergency Hotline:	000
Ambulance:	000
NSW Fire Service:	000
(Tea Gardens) Police Station:	(02) 4997 0244
SES:	13 2500
WIRES (injured wildlife):	0500 559 559

All on-site information relating to hazardous materials, including Material Safety Data Sheets and spill containment materials will be kept at the Site Office.

3 SITE CONTROLS

3.1 PUBLIC SAFETY, AMENITY, AND SITE SECURITY

Procedures for the management of public safety, amenity and site security include:

- all vehicular access/egress associated with the construction works will be via the main site entrance (refer to Sheet 66, *Volume 2* of the Environmental Assessment Report);
- main entrance and site office will be appropriately signposted;
- signage will be placed at site boundary to provide appropriate safety warnings, and include contact details of construction company and/or site supervisor;
- no materials will be stored within the road reserve or placed where it will hinder public access across adjoining public land;
- exposed areas will be kept to a minimum to minimise visual impact as well as reduce air and water pollution; and
- safety fencing will be erected and maintained around specific areas of the work site as appropriate (to be identified in an occupational health and safety plan).

3.2 FLORA AND FAUNA

The following measures are intended to minimise the impact of construction activities on flora and fauna in accordance with the requirements of the Ecological Site Management Strategy for Riverside at Tea Gardens (Conacher Environmental Group, 2008) (refer to *Annex B*):

- clearing activities will be restricted to only those areas nominated on construction plans for each stage;
- cleared vegetation is to be chipped / mulched on site for reuse in landscaping;
- vehicle movements within uncleared areas will be restricted;
- weed control will be undertaken during construction as required to ensure there is no spread of weeds on or off site;
- prior to construction commencing, areas that are to be retained as corridors and reserves and their adjacent APZ's are to be delineated on site plans and

survey marked in the field. This will minimise the risk of damage to vegetation contained within retained areas and APZ's during construction;

- where trees are identified for retention and are in areas adjacent to construction areas, tree protection fencing will be erected to eliminate risk of damage during construction. Fencing will be erected to adequately protect the critical root zone of trees from excavation or compaction damage;

- where corridor or reserve areas are adjacent to construction areas temporary fencing will be erected to indicate these as no go areas. This will be supported by site contractor inductions notifying personnel of protection areas and restricted access to these;

- to minimise the impact on hollow dependant fauna during tree felling operations the following measures will be used were considered appropriate;

  - identification and marking of hollow bearing trees required to be cleared;

  - inspection of tree hollows prior to clearing to determine if hollows are being utilised by tree dwelling fauna, including threatened species. Fauna occupying hollows will be carefully removed by an experienced and licensed fauna expert and relocated to another tree away from the area of clearing;

  - implementation of a trapping program prior to tree clearing to trap any mammal fauna within areas proposed for staged clearing. Any trapped animals will be released into appropriate areas on dusk;

  - restriction of clearing hollow bearing trees during the breeding season for microchiropteran bats and the Squirrel Glider (September-March);

  - implementation of hollow log salvage and re-erection program in order to retain roosting and nesting opportunities for hollow dependent fauna, including Owls, Squirrel Gliders and threatened bat species; and

- two options are available for removing tree hollows or felling hollow bearing trees. These are:

  - hollow bearing trees containing fauna are to be sectionally dismantled. This will be carried out in accordance with Council's established procedure and involve a representative from WIRES and/ or the Project Ecologist;

  - where machinery is required to fell hollow trees, the blade or bucket of the machinery will be tapped against the base of the tree to disturb any fauna present. The tree will then be felled as gently as possible. All

hollow limbs will be inspected after felling for occupation by fauna. Any fauna will be removed and relocated to adjoining bushland;

- any felling of hollow bearing trees will be supervised by a qualified fauna ecologist with experience in the handling of fauna;

- all hollow limbs will be removed from those trees felled by a licensed contractor. These hollow limbs will be returned to the fauna ecologist for re-use at a later date within the corridor areas of the site; and

- any injured wildlife will be reported to WIRES or similar organisation immediately for rescue.

3.3 NOISE AND VIBRATION CONTROLS

Noise emissions associated with bulk earth works, particularly in relation to the construction of the fresh stormwater quality management and detention ponds at the proposed Riverside Estate, Tea Gardens have the potential to impact on the acoustic amenity of several adjacent residential receptors. The EPA criteria for noise from construction sites are assessed at residential properties and the following are applicable during construction of the subdivision:

- for a cumulative period of exposure to noise from construction activity of between 4 weeks and 26 weeks duration, the LA10 (15minute) noise level emitted by the works, when measured at a residential receiver, should not exceed the LA90 (15minute) RBL more than 10 dBA; and

- for a cumulative period of exposure to noise from construction activity in excess of 26 weeks duration, the LA10 (15minute) noise level emitted by the works, when measured at a residential receiver, should not exceed the LA90 (15minute) RBL by more than 5 dBA.

The Construction Noise Assessment for Riverside at Tea Gardens undertake by ERM (2008) (refer to *Annex C*) recommends the implementation of the following mitigation and management procedures during construction activities:

- where practical, pushing topsoil or fill to form earth mounds between the construction site and residences during initial stripping. Barrier calculations identify that noise levels may be reduced by up to 15 dBA if a 3.5 metre earth mound is established between the sources and residences;

- where possible barriers should be placed nearest to plant and equipment to maximise barrier attenuation;

- maximise the offset distance between noisy plant items and nearby noise sensitive receivers;

- avoiding any coincidence of noisy plant working together in close proximity simultaneously near to sensitive receivers;
- minimising the occurrence of consecutive days works in the same locality;
- orienting noisy plant or equipment away from sensitive areas;
- carrying out loading and unloading away from noise sensitive areas, if loading near sensitive receivers acoustic enclosures or barriers of a suitable height should be constructed to minimise the noise impacts;
- where noise complaints arise, monitor construction noise levels to quantify potential impact at most sensitive residences; and
- the contractor must take reasonable steps to manage and control noise from all plant and equipment. Examples of appropriate noise management and control may include installation of acoustic silencers, low noise mufflers and alternatives to reversing alarms.

No construction activities are to be undertaken outside the operating hours nominated in this plan to minimise the impact of noise on nearby residences.

All combustion engine plants, such as generators, compressors and welders, will be maintained and kept in good working order to ensure they produce minimal noise. Where practical, machines will be operated at low speed or power and switched off when not being used rather than be left idling for prolonged periods.

Machines found to produce excessive noise compared to industry best practice will be removed from the site or stood down until repairs or modifications can be made.

Once noisy construction activity commences close to any residence, it is to be completed with the minimum of undue delay. In any case, all reasonable attempts will be made to complete significant noisy activities within a short period.

While the above measures will not necessarily result in meeting the construction noise criteria, they will serve to reduce impacts to levels most residents will find acceptable considering the relatively short-term nature of construction work.

3.4 AIR AND DUST MANAGEMENT

Management of air quality and dust impacts on the site during construction will include:

- exposed soil areas will be regularly watered down during hot and windy days, or as needed;

- vehicle movements will be restricted to sealed or dedicated areas;
- truck and vehicle speeds will be below 20km/hr on unsealed roads;
- all vehicles containing loads that may generate dust travelling to or from the site will be covered to prevent dust emissions; and
- all site vehicles and machinery will be kept in good working order to minimise exhaust emissions.

3.5 SOIL AND WATER MANAGEMENT

All management measures outlined in the Erosion and Sediment Control Plan and the Soil and Water Management notes (refer to *Annex D*) will be implemented and maintained on site prior to and during construction activities. All soil, water and sediment control and management will be undertaken generally in accordance with the requirements of the *Managing Urban Stormwater: Soils and Construction* (Landcom, 2004) (Blue Book). Erosion and sediment control measures will be in place as required until exposed areas are appropriately stabilized following construction.

General requirements for stormwater and sediment control during construction activities include:

- the estate should be developed in stages to minimise the potential for soil erosion and water pollution and enable progressive rehabilitation as the development proceeds;
- sediment control measures are to be installed and maintained throughout all construction areas prior to and during construction activities in accordance with the erosion and sediment control plan;
- all erosion and pollution control devices will be inspected at least weekly and following every rainfall event greater than 5mm, with appropriate maintenance or additional measures initiated as required;
- erosion and sediment control measures must be maintained until landscaping has been completed and becomes established;
- temporary rehabilitation is to be undertaken on disturbed areas where works have stopped and soils are expected to remain exposed for two months;
- as soon as practicable after the completion of earthworks for each stage, lots will be re-seeded to establish a fast growing cover crop which will minimise erosion and movement of sediment across and off site;
- wherever possible, the site will remain grassed and otherwise undisturbed until construction commences;

- topsoil and excess soil will be stockpiled separately in designated areas and protected from surface run off by diversion drains or similar and surrounded on downstream sides by silt fencing. Stockpiles will be suitably compacted in inhibit erosion. Where the stockpiling period exceeds four weeks, the stockpile shall be seeded to encourage vegetative regrowth; and

- entry into the site during construction will be restricted to designated ingress and egress areas.

All rubbish and waste materials will be stored appropriately to ensure they do not enter nearby drains and waterways. Chemicals, oils, and fuels will not be stored on site, or alternatively, will be stored in suitable containers, in a secure storage area.

3.6 ACID SULPHATE SOILS

All measures detailed within the Acid Sulphate Soils Management Plan (Coffey, 2007) provided within Annex E are to be implemented, including:

- management of exposed acid sulphate soils through neutralisation methods (the application of lime for example);

- management of dewatering processes to minimise the impact of acidic groundwater;

- monitoring pH levels of soils;

- monitoring pH levels of groundwater removed during dewatering operations; and

- contingencies for use of additional neutralising agents as required.

3.7 WASTE AND MATERIALS RE-USE

The objectives of waste management during construction activities will be to:

- ensure that the construction activities comply with current environmental legislation and best practice environmental management;

- comply with all relevant approvals for the site; and

- minimise the risk to public safety, and protect the amenity of adjoining residents and the public generally.

The consideration of waste minimisation during the design and planning phases of a project is more likely to maximise reuse opportunities and minimise the waste generated.

There are a number of practical techniques outlined in the 'WasteWise Construction Program – Handbook Techniques for reducing construction waste' (Department of the Environment and Heritage, 2005) that assist with construction managers with site waste management. Various procedures will be implemented by the successful contractor including the nomination of an appropriate person to be responsible for waste management.

It is estimated that approximately 460,200m^3 of soil will be generated through site cutting during the construction of the subdivision. The majority of this, approximately 422,200m^3, will be reused on site for the following purposes:

- filling and shaping in areas of the site where fill material is required, including roads, east / west drainage basin, commercial site regrading, allotments, level spreader and diversion bank construction;

- the creation of earth mounds proposed to be constructed between the Riverside at Tea Gardens construction site and existing residences within the adjacent Myall Quays residential area. The earth mounds will be created at the commencement of construction of the water detention lake as a noise mitigation measure and following construction the mounds will be reshaped to remove the mound and provide a shaped, landscaped area adjacent to the water storage lake; and

- shaping of landscaped and open space areas throughout the Riverside at Tea Gardens site.

The Bulk Earthworks Plan for the development detailing quantities and location of cut and fill works is provided in *Annex F*.

The bulk of topsoil stripped will be reused on the Riverside at Tea Gardens site during rehabilitation and landscaping works. All green waste generated through clearing will be chipped / mulched on site and used in landscaping throughout the site.

The remaining excess topsoil, being approximately 38,000m^3 will be transported to the site of the proposed sporting complex on the western side of Myall Street to facilitate site filling and improvement works required for the construction of the sporting complex. The transport of this material will be undertaken in accordance with the Bulk Haulage and Traffic Control Plans detailed on Sheet 66 within *Volume 2* of the EA.

To achieve adequate reuse and recycling of materials, appropriate areas for the separation and storage of waste will be provided.

Appropriate training and supervision of staff will be conducted to ensure that the objectives of the waste management plan are implemented and that contamination of the recyclable waste streams is avoided.

The successful construction contractor will ensure any subcontractor's waste streams are also included in the planning process and comply with the CEMP.

Waste segregation is the practice of classifying waste and placing it into the appropriate waste container immediately after the waste is generated. In order to achieve effective recycling and reuse, appropriate waste segregation will be carried out on site.

3.7.1 Avoidance

Purchasing policies will ensure that excessive waste is avoided through simple product substitutions for those with less packaging (or packaging that can be recycled), and avoiding over-ordering of items with expiry periods.

3.7.2 Reduction

Products will be assessed prior to purchase in terms of potential to generate excess waste. Products that include minimal packaging would be favoured, without compromising product performance. Pre-fabricated products that avoid the production off-cuts will be preferred.

3.7.3 Re-Use

Whenever possible, practical and cost effective to do so, re-usable waste from the construction of the first stage of the subdivision will be utilised later in the development. Items that will be considered for reuse include:

- green waste will be mulched, stockpiled, and used in landscaping;
- topsoil will be stripped, stockpiled and reused to revegetate exposed areas following construction and in landscaping;
- excess fill will be used onsite for filling purposes, with remaining soil to be transported to the proposed sporting complex site on the western side of Myall Street and reused in the filling and improvement works required at that site; and
- waste timber, and other suitable items will be reused as formwork.

3.7.4 Recycling

Plastic, paper, cardboard and other recyclable products will be disposed of in dedicated receptacles, and, stored for recycling collection. Pallets, if used, will be stored and returned to the supplier, or recycled.

3.7.5 Waste Management Plan

A preliminary waste management plan has been prepared as shown in *Table 3.1.* It outlines the waste streams expected to be generated during the construction of the subdivision, and outlines the proposed reuse/recycling/ or disposal methods for those waste streams.

Specific areas on site will be dedicated to the storage and segregation of waste. This will include skip bins dedicated to particular recyclable materials (ie scrap metal) with a separate receptacle for mixed waste.

Prior to the construction phase commencing, this plan will be finalised in more detail – including nomination of contractors and specific destinations.

Table 3.1 Preliminary Construction Waste Management Plan

Materials Generated On-Site	Destination		
	Reuse and Recycling		Disposal
	On-Site (proposed reuse/recycling method)	Off-Site (contractor/recycling outlet)	Contractor / disposal site
Green waste (from clearing)	Green waste will be chipped / mulched and stockpiled for later use in site landscaping.		
Excavated material	Engineering design will aim to minimised excess fill by balancing cut and fill. Approximately 422,200m^3 of excavated soil will be reused on site.	Remaining excavated topsoil of approximately 38,000m^3 will be stockpiled for reuse at the proposed sporting complex site on the western side of Myall Street.	
Topsoil	Stockpiled on site for reuse in site rehabilitation and landscaping		
Weathered rock	Stockpiled on site for reuse in site landscaping.		
Concrete	Any excess used for footpaths/minor works.	Place in dedicated skip bin – excess will be taken to nearest recycling contractor.	
Timber pallets		To be collected by supplier.	
Timber - other	Ordered to suit - offcuts reused on site ie formwork	Suitable pieces will be taken to nearest recycling contractor.	Only pieces not suitable for recycling will be sent to landfill.
Steel reo	Ordered to suit - offcuts reused.	Place in dedicated skip bin – remove to a metal recycling facility.	
Scrap metal		Place in dedicated skip bin – remove to a metal recycling facility.	
Other - mixed waste			Skip bins will be placed on site, taken to landfill as required.

3.8 EXTENSION OF EXISTING DRAINAGE CHANNEL

Riverside at Tea Gardens development incorporates an extension to an existing drainage channel connecting the lake to the Myall River to facilitate the management of water. The proposed extension of the drainage channel is detailed in *Annex G*. A Wetland Management Plan is to be prepared prior to the commencement of construction. The plan will identify mitigation and management measures for the protection of the SEPP 14 wetland from construction activities. Works associated with the extension of an existing drainage channel adjacent to the SEPP 14 wetland will involve:

- construction works will be short term, occurring over a period of two days;
- approximately 60m^3 of material, including 150m^2 of vegetation removal will occur as a result of the extension to the drainage channel; and
- the proposed construction method involves the use of a small dredge which will be floated out to the site on a barge. The existing temporary water treatment pond constructed for Stage 5 could be utilised to contain and treat the dredge water.

The erosion and sediment control measures to be implemented during the channel extension works are detailed in *Annex H*. These works will include sediment fencing on each side of the excavation, a straw bale sediment trap across the front of the existing channel and a sediment curtain around the excavation area and along the length of the lake edge to the spoil area.

3.9 TRAFFIC MANAGEMENT

Pedestrian and cycle access is available along Myall Street adjacent to the site. Construction works will impact vehicular traffic and pedestrian flows as the site access way enters Myall Street. The accessway will be signposted with warning signage to alert pedestrians, cyclists and drivers.

The following measures will be taken to minimise any disruption to local traffic during the demolition works:

- all vehicular access/egress associated with the construction works will be via the Myall Street entrance (to be noted to personnel during site inductions);
- staggering the arrival of vehicles where possible;
- heavy vehicle movements to/from the site shall be restricted to the operating hours noted in *Section 1.5*;

- oversize vehicle movements will obtain appropriate permits from the Roads & Traffic Authority and comply with any conditions contained therein;

- all vehicles will be accommodated within on-site parking areas;

- all loading and unloading will be carried out within the boundaries of the site;

- use of advisory signage to warn pedestrians and cyclists of heavy vehicle movements; and

- where traffic movements associated with the construction works will cause delays in traffic flows on the surrounding road network, appropriate traffic control plans will be developed and implemented.

REFERENCES

Department of the Environment and Heritage (2005) **WasteWise Construction Program – Handbook Techniques for Reducing Construction Waste.** Australian Government.

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Annex A

Construction Environmental Management Plan Checklist

Table A.1 Construction Environmental Management Plan Checklist

Environmental Management Control	Person Responsible	Timing/Frequency	Completed (Initials/date)	Reference/Notes
General Site Issues				
Conduct site induction training for all personnel to alert them to sensitive work areas, explain the requirements of this CEMP, outline each individual's responsibilities, outline emergency response procedures. Documented evidence to be kept and maintained of site inductions.	Environmental Manager	Before commencing work and ongoing during operations		
Public Safety, Amenity and Site Security				
Ensure all vehicles access site via Myall Street entrance only.	Site Supervisor	Ongoing during operations		CEMP Section 3.1, CEMP Section 3.5
Ensure site compound and Myall Street entrance are clearly signposted.	Site Supervisor	Before commencing work		CEMP Section 3.1
Safety signage erected around site compound and at site entrance.	Safety Manager	Before commencing work		CEMP Section 3.1
No materials are to be stored/placed within public road reserve.	Site Supervisor	Ongoing during operations		CEMP Section 3.1
Areas of work to be kept to minimum required to minimise visual impact (as well as dust emissions and sediment generation).	Site Supervisor	Ongoing during operations		CEMP Section 3.1
Safety fencing erected around work areas in accordance with the site safety plan.	Safety Manager	Before commencing work and ongoing during operations		CEMP Section 3.1
Flora and Fauna				
Clearing activities restricted to only those areas nominated on construction plans for each stage	Site Supervisor	Ongoing during operations		CEMP Section 3.2
Cleared vegetation chipped / mulched on site and reused in landscaping	Environmental Manager	Ongoing during operations		CEMP Section 3.2
Vehicle movements in uncleared areas restricted	Site Supervisor	Before commencing work and ongoing during operations		CEMP Section 3.2

Environmental Management Control	Person Responsible	Timing/Frequency	Completed (Initials/date)	Reference/Notes
Weed control undertaken as required to control spread of weeds on or off site	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Delineation of retained areas (corridors, reserves, APZ's) on site plans and field survey	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Ensure conservation areas are protected with polyweb fencing or similar before commencing vegetation clearing. Maintain fencing during works to keep vehicles out of designated areas.	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Tree protection fencing installed around trees to be retained, including protection of tree root zone	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Temporary fencing installed where construction is adjacent to corridors or reserve areas to delineate area as no go areas	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Hollow bearing trees identified and marked in field prior to clearing	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Inspection of tree hollows prior to clearing to determine use by fauna	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Removal and release (nearby) of fauna from hollows by experienced and licensed fauna expert	Environmental Manager	Ongoing during operations		CEMP Section 3.2
Trapping program undertaken prior to tree clearing to trap any mammal fauna wihtin areas proosed for staged clearing. Fauna to be released in appropriate areas on dusk.	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
No clearing of hollow bearing trees during the breeding season for microchiropteran bats and the Squirrel Glider (Sept – Mar)	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Hollow logs cleared are salvaged and re-erected to create roosting / nesting opportunities	Environmental Manager	Ongoing during operations		CEMP Section 3.2
Clearing of hollow bearing trees via sectional dismantling including inspection of each section by a fauna ecologist and removal, released of fauna by qualified expert.	Environmental Manager	Ongoing during operations		CEMP Section 3.2

Environmental Management Control	Person Responsible	Timing/Frequency	Completed (Initials/date)	Reference/Notes
Clearing of hollow bearing trees via felling to include tapping of base of tree to disturb any fauna present prior to felling. All limbs to be inspected following feeling and fauna removed and released in appropriate areas.	Environmental Manager	Ongoing during operations		CEMP Section 3.2
All felling of hollow bearing trees to be supervised by qualified fauna ecologist	Environmental Manager	Ongoing during operations		CEMP Section 3.2
Any injured wildlife is to be reported to a fauna rescue organisation for rescue and care.	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.2
Noise and Vibration				
Plant and equipment maintained and kept in good working order to reduce potential noise impacts	Site Supervisor	Before commencing work and ongoing during operations		CEMP Section 3.3
Where practical, machines operated at low speed or power and switched off when not being used and not left idling for prolonged periods	Site Supervisor	Ongoing during operations		CEMP Section 3.3
Machines producing excessive noise (in comparison to industry standards) removed from the site or stood down until repairs / modifications made	Site Supervisor	Ongoing during operations		CEMP Section 3.3
Barriers placed nearest to plant and equipment to maximise barrier attenuation where possible in areas in close proximity to residences	Site Supervisor	Before commencing work and ongoing during operations		CEMP Section 3.3
Avoiding any coincidence of noisy plant working together in close proximity simultaneously near to sensitive receivers	Site Supervisor	Ongoing during operations		CEMP Section 3.3
Minimising the occurrence of consecutive days work in the same locality	Site Supervisor	Ongoing during operations		CEMP Section 3.3
Maximise the offset distance between noisy plant items and nearby noise sensitive receivers, orienting noisy plant or equipment away from sensitive areas	Site Supervisor	Ongoing during operations		CEMP Section 3.3

Environmental Management Control	Person Responsible	Timing/Frequency	Completed (Initials/date)	Reference/Notes
Carrying out loading and unloading away from noise sensitive areas. If loading near sensitive receivers, acoustic enclosures or barriers of a suitable height constructed to minimise the noise impacts;	Site Supervisor	Ongoing during operations		CEMP Section 3.3
Where noise complaints arise, monitor construction noise levels to quantify potential impact at most sensitive residences	Environmental Manager	Ongoing during operations as required		CEMP Section 3.3
Check that all work is being conducted within prescribed operation hours.	Site Supervisor	Daily		CEMP Section 1.5
Air Quality				
Check vehicles are keeping to sealed and/or designated areas.	Site Supervisor	Ongoing during operations		CEMP Section 3.4
Check machines are complying with emission standards (i.e. emissions not visible for more than 10 seconds).	Site Supervisor	Ongoing during operations		CEMP Section 3.4
Enforce 20km/h speed limit on unsealed tracks/roads.	Site Supervisor	Ongoing during operations		CEMP Section 3.4
Ensure a mobile water tanker equipped with a pump and sprays is used to suppress dust from unsealed roads when in use and other areas as required.	Site Supervisor	Ongoing during operations		CEMP Section 3.4
All vehicles leaving and entering a site with loads that may generate dust will be covered at all times except during loading/unloading.	Site Supervisor	Ongoing during operations		CEMP Section 3.4
Stormwater and Sediment Control				
Construction works undertaken in stages to minimise potential soil erosion and water pollution and enable progressive rehabilitation	Site Supervisor	Ongoing during operations		CEMP Section 3.5
Sediment control measures installed and maintained throughout all construction areas in accordance with Erosion and Sediment Control Plan and maintained until landscaping is established	Site Supervisor	Prior to commencement of work and inspected weekly thereafter and following every rainfall event greater than 5mm		

Environmental Management Control	Person Responsible	Timing/Frequency	Completed (Initials/date)	Reference/Notes
Temporary rehabilitation undertaken on disturbed areas where works are stopped and soils are expected to remain exposed for two months	Site Supervisor	Ongoing during operations		
Lots re-seeded with a fast growing cover crop immediately following completion of earthworks	Site Supervisor	Ongoing during operations		
Site remained grassed and undisturbed until construction commences, wherever possible	Site Supervisor	Prior to commencement of work		
Topsoil / excess soil stockpiles separated in designated area and sediment control devices installed (eg diversion drains, silt fencing). Stockpiles compacted to reduce erosion and where stockpiling exceeds four months, stockpile is seeded to encourage vegetative growth	Site Supervisor	Ongoing during operations		
Ensure all hazardous materials are appropriately stored.	Site Supervisor	Prior to commencement of work		CEMP Section 3.5
Acid Sulphate Soils				
All measures detailed within the Acid Sulphate Soils Management Plan (Coffey, 2007) are implemented.	Environmental Manager	Before commencing work and ongoing during operations		CEMP Section 3.6
Waste Management				
During clearing, vegetation will be stockpiled for mulching and use in landscaping on-site.	Environmental Manager	During clearing operations		CEMP Section 1.5, CEMP Section 3.6
Topsoil and excess fill will be reused on site wherever possible.	Site Supervisor	Prior to commencement of work		CEMP Section 3.6
Waste materials will be reused on site wherever possible prior to recycling or disposal.	Site Supervisor	Prior to commencement of work		CEMP Section 3.6
Provide an area for the segregation, storage and recycling of waste.	Site Supervisor	Prior to commencement of work		CEMP Section 3.6

Environmental Management Control	Person Responsible	Timing/Frequency	Completed (Initials/date)	Reference/Notes
Traffic Management				
Heavy vehicle movements to/from the site shall be restricted to the operating hours.	Site Supervisor	Ongoing during operations		CEMP Section 3.7
Oversize vehicle movements will obtain appropriate permits from the Roads & Traffic Authority and comply with any conditions contained therein.	Site Supervisor	Ongoing during operations		CEMP Section 3.7
Ensure the main access is not used for parking, loading, marshalling or standing of any semi-trailer, heavy plant floats or wide loads.	Site Supervisor	Ongoing during operations		CEMP Section 3.7
Ensure all vehicles can be accommodated within on-site parking areas.	Site Supervisor	Prior to commencement		CEMP Section 3.7
All loading and unloading will be carried out within the boundaries of the site.	Site Supervisor	Ongoing during operations		CEMP Section 3.7
Erect advisory signage to warn pedestrians and cyclists of heavy vehicle movements.	Site Supervisor	Prior to commencement		CEMP Section 3.7
Where traffic movements associated with the construction works will cause delays in traffic flows on the surrounding road network, appropriate traffic control plans will be developed and implemented.	Site Supervisor	Ongoing during operations		CEMP Section 3.7

Annex B

Ecological Site Management Strategy

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Construction Noise Assessment

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Erosion and Sediment Control Plan and Soil and Water Management Notes

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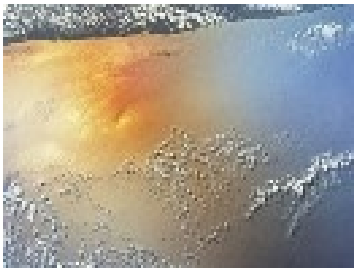

Volume 3A: Integrated Water Management, including:
Assessment of Water Quality Options
Groundwater Assessment Report
Fish Community Survey Report
Practical Considerations of Climate Change

Cardno Willing

Shaping the Future

Riverside at Tea Gardens

Integrated Water Management

CRIGHTON PROPERTIES

NOVEMBER 2008 JOB NO. W4332-7

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Riverside at Tea Gardens
Integrated Water Management

Final Report
November 2008

Client	Crighton Properties			
Document	Riverside at Tea Gardens, Integrated Water Management			
Status	Preliminary	☐	**Author**	Stephen Yu, Dr Shangyou Zhang
	Draft	☐	**Signature**	
	Draft Final	☐	**Date**	October 2008
	Final	■	**Reviewer**	Dr Brett C Phillips
	Superseded	☐	**Signature**	
	Other Specify	☐	**Date**	10 November 2008

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EXECUTIVE SUMMARY

BACKGROUND

As an extension of it's earlier involvement with the Myall Quays Project, in 2003 Cardno Willing was engaged by Crighton Properties Pty Ltd. to formulate a sustainable water management strategy for future (mixed use) development of the then Myall Quays site in Tea Gardens.

The site, which was rezoned for urban purposes in 2000 adjoined another residentially zoned parcel which by 2003, had been fully developed into 240 existing residential lots with an existing constructed extended detention lake around 6.0 ha in size This extended detention lake was constructed prior to the enactment of SEPP 50.

With the enactment of SEPP 71 a new masterplan was required to be developed and approved to permit further residential development within the site. A major component of the masterplan is an Integrated Water Cycle Management (IWCM) strategy for the site.

Cardno Willing has, over the last four years formulated an the IWCM strategy based on water Sensitive Urban Design (WSUD) principles for the Riverside at Tea Gardens site (formerly Myall Quays). The strategy has been based upon;

- Intensive analysis of existing site conditions;
- A significant assembly of base data regarding performance of the existing surface and groundwater systems and in particular the existing detention lake;
- Detailed computer modelling and assessment of a range of development options against performance criteria and legislative requirements;
- Refinement of the selected management strategy;
- Modelling of likely future performance and impacts of the selected management strategy; and
- Considerable consultation with specialized consultants and designers, the community at large, Council and other Authorities.

SITE CONDITIONS

The Riverside at Tea Gardens site consists of a sand plain adjoining the shoreline of the Myall River. The site is fringed for a major part of its frontage to the Myall River by SEPP 14 wetlands. A buffer zone was established at the time of rezoning to protect the SEPP 14 wetlands.

The surface water catchment extends well beyond the boundaries of the Riverside at Tea Gardens site and requires the consideration of how best to manage the significant runoff from adjacent Rural Residential development and its likely quality.

The site is virtually flat in profile and the ground level rises only a couple of metres over more than a kilometre. The shallow grades across the site, combined with a high water table and sandy soils pose challenges for traditional drainage and WSUD techniques particularly if the stormwater conveyance systems are forced to be connected to the existing detention lake in the southern boundary of the site. This approach would require the importation of massive quantities of fill material to establish even minimal grades on swales and floodways and to fill residential lots to the required level above 100 yr ARI flood levels.

The site presents only three real opportunities for stormwater runoff to discharge from the site. From the south to north these opportunities are;

(i) The existing outlet at the southern end of the lake outlet that discharges into an area adjoining the Myall River (under existing conditions the 100 yr ARI peak outflow is around 14.7 m^3/s)
(ii) Dispersed flows across the existing Conservation Zone the abuts the SEPP 14 wetland (under existing conditions the 100 yr ARI peak outflow is around 10.9 m^3/s)
(iii) To the Myall River via an existing watercourse in the north of the site (under existing conditions the 100 yr ARI peak outflow from the site is around 1.25 m^3/s)

A significant determining factor with regard to water movement across the site and detention requirements relates to the gradient available to drain water to each of these outlets and the peak flow limitations at each outlet.

OPTIONS

A detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible the existing lake water quality and its ancillary role as a fish was undertaken in September 2004.

A Do Nothing option and six schemes to mitigate the impact of planned future development on lake water quality were assessed. These schemes were:

1. Do nothing – keep the current water body as it is without increasing the size (but with BASIX implemented).
2. Existing lake (6 ha) with increased tidal flushing (x4);
3. **Extended lake (13.5 ha) with increased tidal flushing (x2);**
4. Existing lake with increased tidal flushing (x1.6) and a new freshwater lake (12 ha);
5. **Partially extended lake (8 ha) with increased tidal flushing (x1.8) and new freshwater lake (6.5 ha);**
6. Existing lake (6 ha) with increased tidal flushing (x1.6) and new wetlands (16 ha); and
7. Existing lake (6 ha) and dry swales.

Possible stormwater quantity (retardation) management strategies were also assessed. Retardation modelling was undertaken for Schemes 2 – 6.

A multi-criteria assessment of water quality performance, environmental impacts and viability was undertaken. The assessment criteria included:

- Water Quality
  - Salinity
  - Dissolved Oxygen
  - Algae
  - Total Nitrogen
  - Total Phosphorous

- Environmental Impacts
  - Impact on existing water body
  - Impact on SEPP 14 wetlands
  - Impact on Myall River
  - Impact on Groundwater

- Viability
  - Loss of potential lots
  - Aesthetic/Health
  - Landtake for Basins
  - Landtake for Ponds / Wetlands
  - Filling

The ranking of the seven schemes in order of performance and benefit was:

Rank	Scheme
1	Scheme 3
2	Scheme 5
3	Scheme 4
4	Scheme 6
5	Scheme 2
6	Scheme 7
7	Scheme 1

What won't work?

It was concluded from the multi-criteria assessment that attempting to implement a water management scheme without extending the existing detention lake is not viable and would deliver sub-optimal water quality and environmental outcomes. In particular a scheme based on swales that discharging into the existing detention lake (Scheme 7) would require the importation of massive quantities of fill material to establish even minimal grades on the swales and floodways and to fill residential lots to the required level above 100 yr ARI flood levels.

Likewise the changes in water quality in the existing detention lake (in particular salinity and TN) that result from retaining the existing outlet only has the potential to adversely impact on the existing aquatic ecology and may even change the mix of fish species.

What will work?

While it was concluded from the multi-criteria assessment that extending the tidally flushed lake to a 13.5 ha water body in combination with ancillary local ponds and local wetlands (Scheme 3) is the most viable approach and delivers the best overall outcomes for water quality and the environment it was also concluded that the partial extension of the existing detention lake in combination with a freshwater lake(s) and ponds and wetlands (Scheme 5) could deliver similar water quality and environmental outcomes.

Since September 2004 the development concept has evolved considerably including the removal of the nine hole golf course, an increase in the number of dwellings upon the site and wholesale changes to the site planning and layout in keeping with planning best practice. Despite these substantial changes to the proposed layout since September 2004, the principal conclusions of the comparative assessment presented in the 2004 report remain valid today and supported the detailed assessment of Schemes 3 and 5. The assessments of hydrology, hydraulics, stormwater quality and lake water quality described in this study follow the assessment approaches adopted in 2004. In relation to the stormwater quality assessment the previous **xpaqualm** modelling has been updated and undertaken using MUSIC.

It was concluded from the assessments described herein that the flooding, drainage and water quality objectives for the development could be met by either:

(i) Extending the existing detention lake (with increased tidal flushing) and constructing additional ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 3); or

(ii) Partially extending the existing detention lake ((with increased tidal flushing) and constructing additional freshwater lakes, ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 5).

Discussions held with the NSW Department of Planning highlighted a number of concerns held by NSW Government stakeholder with concept Scheme 3. Consequently the preferred approach to integrated water management is based on Scheme 5.

The proposed outlet configuration is to retain the existing outlet channel unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel. The second outlet channel would be constructed without disturbing the SEPP 14 wetland. It would connect to a second existing drain located within the SEPP 14 wetland zone.

LEGISLATIVE REQUIREMENTS

The Director-General's Environmental Assessment Requirements for water cycle and aquaculture management are in part as follows:

> "Address potential impacts on the water quality of surface and groundwater having regard to the relevant State Groundwater, River, Wetlands and Estuary Policies. Consideration must be made for water impacts to the Myall River and identified SEPP 14 Wetlands.
>
> …. Stormwater management should be designed to ensure ongoing protection of the groundwater aquifer in accordance with the principles of ANZECC & ARMCANZ: Guidelines for Groundwater Protection in Australia, National Water Quality Management Strategy, Commonwealth of Australia, 1995."

The compliance of any extension of the existing detention in the context of State Environmental Planning Policy 50 – Canal Estate Development has been reviewed previously.

Under SEPP50, canal estate development in part means development that:

> '… .incorporates wholly or in part a constructed canal, or other waterway or waterbody, that is inundated by or drains to a natural waterway or natural waterbody by surface water or groundwater movement (not being works of drainage, or for the supply or treatment of water, that are constructed by or with the authority of a person or body responsible for those functions and that are limited to the minimal reasonable size and capacity to meet a demonstrated need for the works)……..'

The proposed partial extension of the lake is not the only measure proposed to mitigate the impacts of planned development and to protect the receiving waters. The water management scheme includes a series of freshwater lakes, swales, local ponds and wetlands and basins in addition to the partially extended detention lake. This approach is similar to the successful implementation of a number of measures at varying scales within the development completed to date.

The review concluded that the partial lake extension was the minimum reasonable size and capacity to meet statutory requirements and the management objectives of the LEP and DCP and would be in accordance with the provisions of SEPP50.

MITIGATING THE IMPACTS OF THE DEVELOPMENT

Mitigating Surface Water and Groundwater Impacts

The planned development will increase the rate of local runoff and peak flows. A number of basins have been sized to ensure that the post development peak flows in the 100yr ARI event is no greater than under existing conditions.

Groundwater modelling of the planned development with an extended lake indicates that groundwater levels in the northern, eastern and southern parts of the site will be similar to those under existing conditions. Groundwater levels to the north of the existing lake will be lowered by up to about 1 m due to the extension of the lake with groundwater to the west and north of the extended lake tending to flow towards the extended lake. As a result, general groundwater flow directions in the area will change slightly and a higher volume of groundwater will be discharged into the lake.

Groundwater levels along the SEPP 14 wetlands are assessed to be similar to the existing levels, with a marginal decrease in groundwater levels (less than 0.1 m drawdown) on the western edge of the SEPP 14 wetland area. It is considered that the minimal extent of groundwater changes associated with the proposed development is unlikely to affect SEPP 14 wetland vegetation.

The planned development will also increase the average annual export of pollutants from the site. Catchment water quality assessments of the planned development demonstrate that the preferred water management scheme (that utilises reclaimed water instead of rainwater harvesting):

- Reduces the average annual export of TSS, TP and TN from the catchment by greater than 80%, 45% and 45% respectively; and
- Reduces the export of TSS and TP under Developed Conditions to the wetland zone by 78%, 33% than the TSS and TP exports under Existing Conditions;
- Slightly increases the export of TN under Developed Conditions to the wetland zone by 3% than the TN export under Existing Conditions.

It was concluded from lake modelling that under developed conditions the freshwater lakes and the partially extended detention lake will continue to deliver water quality comparable to existing lake water quality. The installation of ancillary local ponds or local wetlands (without any change in the tidal flushing regime) is necessary to manage the water quality in the freshwater lakes and would further improve the water quality in the extended lake.

Practical Consideration of Climate Change

The planned development is subject to flooding from both the Myall River and from runoff from the local catchment. Sensitivity assessments of climate change were undertaken for the scenarios given in the 2007 DECC Guideline titled “Practical Consideration of Climate Change”. These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

To mitigate the impacts of climate change, the planned development has adopted an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

Elsewhere in the planned development the adoption of a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

While under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading. Even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

Flood Warning

It was also noted from the 1980 Myall River flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

MANAGEMENT, MAINTENANCE AND MONITORING

The management responsibilities of various stakeholders including the landowner, contractors/builders Myall Quays Community Association (Residents), Great Lakes Council and the Department of Environment and Climate Change are identified.

In view of the potential presence of acid sulphate soils a generic plan has been prepared for management of ASS in future earthworks that occur within the Riverside Estate that include the laying of sewer and drainage lines and the excavation of stormwater treatment basins. A concise version of this plan will be provided as a reference to all lot purchasers and contractors required to work on any home within the site. This plan has been formatted in a way to assist individual land owners obtaining DA approvals by outlining methods to control and manage ASS during the development of each lot. The plan will also guide the management of any future excavation to extend the detention lake.

Maintenance activities for constructed ponds and wetlands and the extended detention lake are outlined. The management of aquatic weeds in constructed pond and wetland systems and the extended detention lake will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside estate and the Myall River Downs estate and for the existing detention lake.

A monitoring program is proposed for the SEPP 14 wetlands, constructed ponds and wetlands and the extended detention lake. The management actions proposed to rectify any failures to meet the water quality objectives are also identified.

RECLAIMED WATER

Many water needs can be satisfied using reclaimed water as long as it is adequately treated to ensure water quality is appropriate for the proposed use (NSW DEC, 2004).

Based on the signature of key chemical constituents, three alternative approaches to the use of reclaimed water for the purposes of irrigation are identified as follows:

1. Treatment of the reclaimed water to meet health standards including pathogens. The reclaimed water may be used for irrigation if 10% of the reclaimed water is mixed with 90% of fresh water.
2. Treatment of the reclaimed water to limit P to an average concentration of 1.5 mg/L and NO_3 to an average concentration of 1.4 mg/L. If this level of treatment is obtained then a mixture of 50% of reclaimed water and 50% of fresh water may be used for irrigation.
3. Treatment of the reclaimed water to limit P to an average concentration of 0.4 mg/L and NO_3 to an average concentration of 0.7 mg/L. If this level of treatment is obtained then 100% of the reclaimed water may be used for irrigation purposes, assuming partial uptake of nutrients by vegetation.

The potential for reclaimed water applied for irrigation and garden watering to contaminate the groundwater was assessed. It is considered that irrigation of parks and open spaces within the development is unlikely to adversely impact groundwater or the water in the lake if one of the above reclaimed water use options is adopted.

There are a number of approaches to meeting the BASIX Water target for new development including the adoption of water efficient appliances and the installation of rainwater tanks to supply water for external and a number of internal household uses. An alternative to rainwater tanks is to install a reclaimed water supply system to meet external and a number of internal household demands. The decision to reticulate reclaimed water to the site as a non-potable water supply rather than to install rainwater tanks on all residential lots was influenced by a number of key considerations including:

(i) A reclaimed water supply is a more reliable source of water than rainwater tanks that are dependant on rainfall and the maintenance regime implemented by each individual lot owner,

(ii) A reclaimed water system can be integrated into all lots during the development phase;

(iii) Reclaiming water at the local Wastewater Treatment Plant can delay the need to expand an existing plant capacity and allow a plant to continue to meet effluent disposal limits and at the same time creating capacity to treat effluent from additional local development;

(iv) The adoption of a reclaimed water supply system for the Riverside estate is critical to the feasibility of implementing a reclaimed water system by the local water authority and would enable reclaimed water connections to be offered to other local users.

ARCHITECTURAL AND LANDSCAPE TREATMENT

In addition to the environmental performance of the proposed system, a number of opportunities are presented with regard to visual and physical interaction with the system that intelligent architectural and landscape design can capitalise upon, such as foreshore parks, walkways, cycleways, placement of public buildings etc.

The internalisation of the water management system and the unfettered public access which is proposed to be provided to all new waterbodies and detention basins will ensure ongoing adoption of maintenance regimes due to the surveillance and public amenity that the system provides.

This maintenance discipline has been proven to date, even though the existing lake does not enjoy the same level of public visibility (due to site layout) as the design currently proposed.

ONGOING PERFORMANCE

Demonstrated Performance

Detailed water quality data collected since 1996 has demonstrated the effective performance of the existing water management system, which is similar to that proposed for the planned development. It gives confidence of the likely future success of the proposal – it is rare to have this level of technical support.

Community Ownership and Maintenance

The Community Title ownership of the lake ensures a body exists in perpetuity as well as providing a funding mechanism to ensure the ongoing maintenance and monitoring of the system.

Fish Habitat

In addition to it's primary function of water management the existing lake functions as an evolving biological asset with its fish stocks and marine biodiversity - the proposed water management scheme is expected to augment this marine system whereby the benefits will likely exceed the mere extension of a greater area of lake.

It also offers an opportunity to increase the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds.

Asset and Amenity

Above and beyond the expected performance of the proposed system and its benefits to the environment, the resulting design will likely become a proud community asset by providing a level of recreational and visual amenity that will help to ensure its ongoing sustainability and proper management. There exists a distinct opportunity whereby careful design and embellishment of the extended lake itself (particularly in the vicinity of the Town Centre) to take on the characteristics of the Tea Gardens waterfront and could assist in the continued attraction of tourists to the Tea Gardens area.

CONCLUSIONS

In summary, the integrated water management system proposed for the Riverside site is based on a strategy which collects, detains and treats stormwater runoff in an integrated train of local, neighbourhood and regional facilities.

It is also proposed to reticulate reclaimed water to the site as a non-potable water supply rather than to install rainwater tanks on all residential lots. This has the added advantage of delaying the need to expand the capacity of the local Wastewater Treatment Plant and will allow the plant to continue to meet effluent disposal limits while at the same time creating capacity to treat effluent from additional local development.

It is concluded that a water management scheme comprising the a number of local ponds, local wetlands, swales, basins, freshwater lakes and the partial extension of the existing detention lake we believe will meet the water quality, and quantity objectives for the site set down by the various relevant authorities.

The elements of the treatment train are summarised below.

It is our opinion that the proposed water management scheme delivers the best overall outcomes for water quality and the environment whilst meeting the performance requirements set down by the relevant authorities.

It is also our opinion, that this scheme is the most likely to succeed in the long term and, if properly managed in accordance with the plan provided in this report is likely to continue to perform at or near the already demonstrated performance levels.

The proposed scheme also offers an opportunity to increase the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds that is rarely available in new developments.

Element	Description	Usage / Role
1	Swales and a Retarding Basin located in the northern open space corridor	To direct runoff from the upper catchment along the northern corridor to a swale that distributes runoff along the boundary of the Conservation Zone prior to its distributed discharge into the Conservation Zone.
2	Swales located within open space corridors in the development	To direct convey local urban runoff (at minimum grades) to local constructed ponds or wetlands and/or to convey runoff to the extended detention lake.
3	Constructed local ponds and wetlands (4.7 ha)	To pre-treat urban runoff prior to its discharge to the freshwater lakes and the partially extended detention lake. Constructed ponds and wetlands can also assist the conveyance of runoff in areas where there is insufficient grade for swales. The active storage above constructed ponds and wetlands also assist in managing peak flows in major storms.
3	Constructed freshwater lakes (6.5 ha)	To further treat urban runoff prior to its discharge to the extended detention lake. Freshwater lakes can also assist the conveyance of runoff in areas where there is insufficient grade for swales. The active storage above the freshwater lakes will also assist in managing peak flows in major storms.
4	Extension of existing brackish detention lake (2 ha)	To further treat urban stormwater runoff to meet water quality requirements prior to discharge to the Myall River while maintaining the existing water quality regime of the existing lake.

1. INTRODUCTION

As outlined previously by ERM (2006), Crighton Properties or its affiliated companies are the owner of two substantial development sites at Tea Gardens on the Mid North Coast. The location of these development sites is illustrated in **Figure 1**.

In 1991 Crighton Properties bought the 230 hectare site currently known as 'Riverside at Tea Gardens' (formerly 'Myall Quays') which lies immediately to the west of the Myall River and to the east of Myall Road (the main road linking Tea Gardens / Hawks Nest with the Pacific Highway). The location of the Riverside at Tea Gardens site is shown as **Figure 2**.

The second development site owned by Crighton Properties is known as the 'Myall River Downs' site and comprises approximately 320 hectares of land located to the west of the Riverside at Tea Gardens site and on the western side of Myall Road. An aerial photograph of the sites is provided at **Figure 3**.

The following overviews of the history of the Riverside at Tea Gardens site and project description are drawn from ERM, 2006.

1.1 SITE HISTORY

The Riverside at Tea Gardens Estate is currently being developed and comprises a range of residential, retail/commercial, recreation and tourist development including over 240 completed residential lots. The part of the site remaining to be developed and covered by the concept plan comprises Lot 34 and Lot 10 DP 270100.

In 1989, Crighton Properties predecessor in title lodged a rezoning request with Great Lakes Council for a multi-stage residential/resort type development on the site. The Council resolved to prepare a draft Local Environmental Plan (LEP) subject to the findings of a formal local environmental study (LES). The LES was prepared in 1991 and the site was finally rezoned to 2(f) mixed commercial residential in 2000.

In 2002 Crighton Properties began the process of seeking approval to develop a substantial portion of this site for residential purposes and for a nine hole golf course and tourist facilities. Following the introduction of State Environmental Planning Policy No 71 – Coastal Protection (SEPP 71) in November 2002, a master plan was required to be adopted by the Minister for Planning before any further residential subdivisions could be approved.

A Planning Focus Meeting was held on site on 28 December 2003 to discuss the master plan and the various development proposals. The Director- General's requirements for the EIS were subsequently issued by the Department of Infrastructure, Planning and Natural Resources in January 2004 (Ref: N91/00721) for the artificial water detention body and the residential/tourist/recreational components. The Department also provided requirements regarding the preparation of a master plan for the development under SEPP 71 (Ref: S03/03010).

1.2 SITE DESCRIPTION

The Riverside at Tea Gardens site is bounded by Myall River to the east and Myall Road to the west. The Shearwater Residential Estate lies to the north of the site and residential development of Tea Gardens is to the south. The site has approximately a one kilometre frontage to Myall Road and two kilometre frontage to the Myall River. State Environmental Planning Policy No. 14 – Coastal Wetlands (SEPP 14) applies to wetlands within a portion of the eastern boundary of the site adjacent to the Myall River. These wetlands have been clearly identified along with a buffer to the wetlands and zoned accordingly when the site was rezoned in 2000. The remainder of the site is available for urban development and zoned accordingly.

The site is flat with generally sandy soils. There is a slight fall to the south. The site ranges in height from 0.6m Australian Height Datum (AHD) (along the foreshore of the Myall River) to 20m AHD (at the northern end of the side adjacent to the Shearwater Estate). However most of the site varies in height from between 1.6m AHD to 5.0m AHD.

The majority of the site was previously used for a pine plantation and has been substantially cleared of native vegetation. Some scattered isolated occurrences of both pines and natives currently exist on the site.

1.3 PROJECT DESCRIPTION

The Riverside at Tea Gardens site is already zoned 2(f) – Mixed Residential – Commercial for urban development (refer **Figure 4**). The concept plan for the development of the Riverside at Tea Gardens site consists of a residential / mixed use precinct proposed for the majority of the site and a tourist and larger lot component located in the NE corner of the site. Substantial areas of the 2(f) zoned land are proposed to be protected and enhanced as open space / wildlife movement corridors, over and above those already protected within the 7(a) and 7(b) zones.

The proposed development concept plan is provided in **Figure 6**.

1.4 PLANNING CONTEXT

ERM, 2006 discuss in detail the planning provisions that apply to the site and whether the project is permitted under the prevailing instruments, plans, policies and strategies.

It was concluded that the proposed development is consistent with the following instruments/plans/policies/strategies.

- Great Lakes LEP 1996
- DCP 30 – Residential – Urban Areas
- DCP 31 – Subdivision
- Stormwater Quality DCP
- Tea Gardens Hawks Nest Conservation & Development Strategy
- Draft Tea Gardens Hawks Nest Housing Strategy (2nd Draft)

- Recovery Plan for the Hawks Nest & Tea Gardens Endangered Koala Population
- Hunter REP 1989
- Hunter's Coast – Hunter Coastal Urban Settlement Strategy
- SEPP (Major Projects)
- SEPP 11 – Traffic Generating Developments
- SEPP 14 – Coastal Wetlands
- SEPP 44 – Koala Habitat Protection
- SEPP 50 – Canal Estate Development
- SEPP 71 – Coastal Protection
- NSW Coastal Policy 1997
- Coastal Design Guidelines for NSW

The proposed development is partly consistent with DCP 22 – Myall Quays Estate. As discussed by ERM (2006) DCP 22 is outdated as it was prepared prior to recent environmental studies and investigations into the capabilities and suitability of the site. While many of the management principles actions outlined in the DCP remain relevant, some of the specific controls are no longer appropriate as they are based on a previous master plan that has little resemblance to the current (and proposed) development of the site, nor in any event, can this masterplan be realised, given the current planning legislation. It is anticipated that the DCP will be repealed and replaced by a concept plan for the Riverside at Tea Gardens and Myall River Downs Estates.

1.5 CONSULTATION

Crighton Properties has been continually liaising with Great Lakes Council regarding the development of both sites over many years.

During the site's long history many government agencies have been consulted regarding other residential/recreation uses of the site and are aware of the site and its opportunities and constraints (ERM, 2006). The agencies that have been consulted include but were not limited to the following:

- Department of Planning
- NSW Fisheries
- Department of Environment and Climate Change including
    - NSW EPA in the former DEC
    - the former DNR

1.6 PREVIOUS STUDIES

A number of studies of surface water and groundwater issues for the Riverside at Tea Gardens site have been undertaken previously. These studies are overviewed in chronological order as follows:

Coffey Partners International Pty Ltd (1996a) *"*Myall Quays Development - Groundwater and Surface Water Study*", Report No. G39811-AJ*, prepared for Paterson Britton & Partners, February.

This study reported on existing site groundwater conditions. The report included:

- review of existing conditions,
- assessment of the need for further field studies,
- additional field testing,
- modelling of groundwater and surface flows, and
- assessment of the effects of proposed development.

Field monitoring of 10 bores was also undertaken in the Myall Quays area during 1994 -1995 including high rainfall events in May and June 1995. In most cases the peak groundwater level associated with a rainfall event followed within about a week of the rainfall. It was reported that a high level of groundwater response occurred under existing conditions, suggesting that little rainfall runs off and most reports to the groundwater system.

Water quality tests were performed on the bore water by Hunter Water Laboratories and the results are reported in CPI, 1996a. Bores close to the Myall River showed concentrations similar to seawater, while other bores were less saline. Lead levels exceeded guidelines for human consumption in many of the samples. It was considered that the lower salinity groundwater could be used for golf course irrigation provided that sodium levels were monitored.

Coffey Partners International Pty Ltd (1996b) "Myall Quays Development - Groundwater and Surface Water Study, Estuarine Lake Option*", Report No. G39811-AS*, prepared for Paterson Britton & Partners, June.

This study examined the groundwater and freshwater impacts of an Estuarine Lake option.

Cardno Willing (2003a) “Myall Quays Drainage and Water Quality Management Plan”, *Draft Report*, prepared for Crighton Properties, April.

This report was prepared to provide background information on water quality solutions to address the potential impacts of proposed future stages of the Myall Quays development at Tea Gardens, NSW.

It was concluded that the existing detention lake on the site would need to be enlarged in order to maintain the existing water quality and its ancillary role as a fish habitat. Preliminary calculations and computer modelling showed that an increase in size to about 18 hectares may be needed in order to prevent more rapid and extreme changes in salinity and dissolved oxygen (DO), levels which would adversely affect the aquatic habitat. An increase in tidal flushing would be also necessary in order to maintain the mean salinity at the present value of about 12,000 ppm. Draft ecological principles for the extension of the existing detention lake were also formulated.

Cardno Willing (2003b) “Myall Quays Precincts 7 and 8, Water Management Plan”, *Final Report*, prepared for Crighton Properties, September.

A Water Management Plan for Precincts 7 and 8 (that is now constructed) was prepared to address Great Lakes Council Deferred Commencement Conditions No. 2 and No. 4 as detailed in the Minutes of the Planning & Development Committee of the Great Lakes Council held on 25th March 2003.

The Plan identifies the water quality performance criteria to be achieved within the water quality treatment system for the site and the procedures for ensuring that the specified water quality performance criteria are met.

The Plan also outlines a monitoring program to ensure the long term viability of the water quality treatment system, including details of the monitoring procedure for ensuring the performance of the pollutant control function, with regard to nutrient stripping.

The Plan identifies the persons responsible for the monitoring and maintenance, including responsibility for costs for maintaining scenic and water quality of the water treatment system, and further identifies those persons responsible for any remediation actions or costs required to Improve scenic, recreation and water quality of the water quality treatment system.

Cardno Willing (2003c) “Myall Quays Development”, *Options Paper*, prepared for Crighton Properties, July.

This paper discusses water management options to protect the aquatic environment that has been already established in the first stage of the detention lake by maintaining existing water quality under the ultimate developed condition.

Based on an assessment of water quality impacts and the advantages and disadvantages of each option it was concluded that the option that is best able to protect the aquatic environment that has been already established in the existing detention lake is to extend the lake to an 18 ha detention lake in combination with existing practices of implementing OSR on lots draining directly to the lake and construction of mini ponds and wetlands in strategic locations within the future developed areas.

Cardno Willing (2003d) “Myall Quays Water Quality Detention Lake, Applicability of SEPP50”, Position paper, prepared for Crighton Properties, July.

As part of the planned development of the Myall Quays site it was proposed to extend the detention lake to mitigate the impacts of the development of the remaining area of the southern catchment while maintaining the aquatic environment that has been already established in the first stage of the detention lake. This paper reviewed the proposed detention lake extension in the context of State Environmental Planning Policy 50 – Canal Estate Development.

It was concluded that the lake extension was the minimum reasonable size and capacity to meet statutory requirements and the management objectives of the LEP and DCP and would be in accordance with the provisions of SEPP50.

Cardno (2004) "Myall Quays Development, Tea Gardens, Assessment of Water Management Options", Final Report, prepared for Crighton Properties, September.

This report provides background information on the proposed Myall Quays development at Tea Gardens, NSW. It overviews the LEP, DCP gazetted in 2000, zoning constraints, environmental constraints, development constraints and community constraints.

A detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible to maintain the existing lake water quality and its ancillary role as a fish habitat is outlined.

A Do Nothing option and six schemes to mitigate the impact of planned future development on lake water quality were assessed. These schemes were:

0. Existing conditions ie. a 6 ha lake;
1. Do nothing – keep the current water body as it is without increasing the size (but with BASIX implemented).
2. Existing lake (6 ha) with increased tidal flushing (x4);
3. **Extended lake (13.5 ha) with increased tidal flushing (x2);**
4. Existing lake with increased tidal flushing (x1.6) and a new freshwater lake (12 ha);
5. **Partially extended lake (8 ha) with increased tidal flushing (x1.8) and new freshwater lake (6.5 ha);**
6. Existing lake (6 ha) with increased tidal flushing (x1.6) and new wetlands (16 ha); and
7. Existing lake (6 ha) and dry swales.

Possible stormwater quantity (retardation) management strategies were also assessed and outlined. Retardation modelling was undertaken for Schemes 2 – 6.

The modelling of the various Schemes has been conducted to maintain, as close as possible, the existing (estimated) 100 year outflow to Myall River. The total volume of retardation required and other possible engineering interventions were considered for each of the Schemes and are outlined.

A multi-criteria assessment of water quality performance, environmental impacts and viability was undertaken. The assessment criteria included:

- Water Quality
  - Salinity
  - Dissolved Oxygen
  - Algae
  - Total Nitrogen
  - Total Phosphorous

- Environmental Impacts
  - Impact on existing water body
  - Impact on SEPP 14 wetlands
  - Impact on Myall River
  - Impact on Groundwater

- Viability
  - Loss of potential lots
  - Aesthetic/Health
  - Landtake for Basins
  - Landtake for Ponds / Wetlands
  - Filling

The three highest ranked schemes in order of performance and benefit were:

Rank	Scheme
1	Scheme 3
2	Scheme 5
3	Scheme 4

Cardno (2004) “Myall Quays Development EIS”, partially prepared for Crighton Properties.

An EIS report was partially completed in response to the previous Director General requirements. This partially completed report is unpublished.

Coffey Geosciences Pty Ltd (2004) *"Groundwater Assessment, Myall Quays Development, Tea Gardens",* Report No. E12752/3-AF, prepared for Crighton Properties, December.

This report presents the results of a groundwater study and modelling program undertaken to assess the impact of a proposed development in Tea Gardens on local groundwater movements. The purpose of the assessment was to provide information to address specific issues raised by the Department of Infrastructure, Planning and Natural Resources (DIPNR) (Ref: N91/00721, 5 January 2004) for the Myall Quays development, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for groundwater contamination associated with the detention basin and resulting from the residential development and the proposed open space recreational areas;
- Beneficial uses of groundwater; and
- Contingency and remediation plans for the detention basin and aquifer in the event of detention basin pollution and/or eutrophication.

Coffey Geotechnics (2007a) "Proposed Subdivision – Riverside Estate Stage 9, Tea Gardens*", Report No. GEOTSGTE20248AA-AC*, prepared for Tattersalls Surveyors Pty Ltd, May.

The purpose of the assessment was to provide comments and recommendations on acid sulfate soils within the proposed development area. A generic Acid Sulfate Soils (ASS) Management Plan has been provided for Riverside Estate Stage 9 and subsequent stages.

The assessment also provides preliminary geotechnical information for the design and construction of road pavements and residential footings. On site soils have been assessed and preliminary site classifications in accordance with AS2870-1996 are provided.

Coffey Geotechnics (2007b) "Groundwater Assessment*", Draft Report No. GEOTLCOV23225AA-AC*, prepared for Crighton Properties, May.

This report presents the results of a groundwater study and modelling program undertaken to assess the Scheme 3 concept layout for the proposed Riverside development at Tea Gardens on local groundwater movements. The purpose of the study was to address the issues noted in the amended Director-General's Environmental Assessment Requirements (Ref.: MP 06_0010, dated 29 December 2006) for the site, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for impact on existing groundwater with respect to the latest concept layout for the development;
- Beneficial uses of groundwater; and
- The potential impact of reuse of reclaimed water and the quality required to minimise impact on
- groundwater.

Coffey Geotechnics (2007c) "Myall Quays Detention Lake Sediment Sampling and Analysis*", Letter Report*, prepared for Crighton Properties, 24 October.

The objectives of this investigation were to assess the lake sediments with regards to the potential for the lake to become a 'pollutant sink' resulting in the build up of nutrients and persistent chemical pollutants. The scope of work included:

- Fieldwork including sediment sampling at selected locations on the lake floor;
- Laboratory analysis of a selected number of samples for heavy metals (Sb, As, Cd, Cr, Cu, Pb, Ni, Ag, Sn, Zn, Hg), total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene and xylenes (BTEX), Polynuclear aromatic hydrocarbons (PAH), organochlorine pesticides (OCP), polychlorinated biphenyls (PCB), total phosphorous, total oxidised nitrogen (NOx) and total Kjeldahl nitrogen (TKN);
- Data assessment and reporting.

The assessment concluded that:

- The sediment samples analysed from Myall Quay's Detention Lake show low heavy metals (Cr, Cu, Pb, Hg, Ni and Zn) concentrations which are below the adopted warning levels and may possibly be at background levels.
- OCP and PCB were not detected above the laboratory reporting limits. PAH were detected in sample D1 (duplicate of S1) at concentrations below the warning levels for this investigation.
- Nutrient concentrations (total nitrogen and total phosphorous) indicate they have not accumulated to levels typical of urban ponds and lakes.

Coffey Geotechnics (2007d) "Geotechnical and Acid Sulphate Assessment for Riverside Estate Project Application and Master Plan Area, Tea Gardens*", Report GEOTSGTE20248AA-AE*, prepared for Crighton Properties, 24 October.

This report presents the results of geotechnical and acid sulphate assessments of the Riverside Estate Master Plan area. The scope of work for the geotechnical assessment included providing recommendations on:

- Site preparation;
- Excavation conditions;
- The suitability of the site soils for use as fill and on fill construction procedures;
- Acid sulfate soil conditions and requirements for an acid sulfate soils management plan;
- Preliminary site classification to AS2870–1996;
- Preliminary pavement design and construction;
- Special requirements for construction procedures and or site drainage.

A generic plan for management of ASS in future earthworks that occur within the Riverside Estate was also prepared. It is understood that the plan will be provided as a reference to all lot purchasers and contractors required to work on the site. It has been formatted in a way that will be useable to individual land owners to assist in obtaining DA approvals and in controlling and managing ASS during the development of each lot.

Coffey Geotechnics (2007e) "Groundwater Assessment*", Report No. GEOTLCOV23225AA-AD*, prepared for Crighton Properties, 26 October.

This report presents the results of a groundwater study and modelling program undertaken to assess the Scheme 5 concept layout for the proposed Riverside development at Tea Gardens on local groundwater movements. The purpose of the study was to address the issues noted in the amended Director-General's Environmental Assessment Requirements (Ref.: MP 06_0010, dated 29 December 2006) for the site, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for impact on existing groundwater with respect to the latest concept layout for the development;

- Beneficial uses of groundwater; and
- The potential impact of reuse of reclaimed water and the quality required to minimise impact on
- groundwater.

This assessment of groundwater issues is summarised in Section 3 and is attached in **Appendix G**.

Harris Research (2007) Fish Community Survey of the Riverside Lake, Summary Report, prepared for Crighton Properties, May, 5 pp + Apps.

The fish community of the Riverside lake (previously Myall Quays) was surveyed in April 2007 as part of a series of biological studies to record the aquatic ecological development of the lake. Seine netting and gill netting captured numbers of both individual fish and fish species that were well in excess of previous surveys. Substantially larger-bodied fish and some fisheries species were caught including yellow-fin bream, striped mullet, sand mullet and silver biddies. The distribution patterns and occurrence of aquatic plants in the lake were similar to those recorded in 2002.

Increased biological diversity and abundance of the fish community show that the Riverside lake is continuing its development towards the ecological condition of the surrounding Myall River estuary and supports casual observations of recreational fishing in the lake. Habitat conditions, water quality and the food web are continuing to develop, supporting fish recruitment and productivity. Fish recruitment and growth in the lake are contributing to biological values in the estuary as a whole and this should increase as ecological processes mature further.

It is recommended that previous recommendations for enhancing the amount and quality of aquatic habitats remain relevant and should be pursued in the design of any extension of the existing lake system, particularly with respect to increasing the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds.

This fish survey is attached in **Appendix H**.

1.7 THIS STUDY

As discussed above, a detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible the existing lake water quality and its current ancillary role as a fish habitat was reported in 2004 (Cardno, 2004).

Since September 2004 the development concept has evolved considerably including the removal of the nine hole golf course, an increase in the number of dwellings upon the site and wholesale changes to the site planning and layout in keeping with planning best practice.

Despite these substantial changes to the proposed layout over the period to date from September 2004, the principal conclusions of the comparative assessment presented in the Cardno, 2004 report remain valid today and support the adoption of either of the two highest ranked water management options (Scheme 3 or Scheme 5). Both these schemes were further developed (refer **Figures 5** and **6**). In the interests of completeness the Cardno, 2004 report is included in **Appendix F**. The assessments of hydrology, hydraulics, stormwater quality and lake water quality described in Appendices **B, C, D** and **E** follow the assessment approaches adopted in 2004. In relation to the stormwater quality assessment the previous **xpaqualm** modelling has been updated and undertaken using MUSIC.

The aims of the current study were to update the previous hydrological, hydraulic, groundwater and water quality assessments of the two highest ranked water management schemes (Scheme 3 and Scheme 5) to reflect the current concept development and to refine and develop each scheme and any other measures that may be required to mitigate the impacts of the planned development. This report has been specifically prepared to accompany a Part 3A Concept Plan and Project Application to be submitted to the NSW Department of Planning and to address the Director General Requirements for Environmental Assessment dated 6 March 2007 (Ref.: MP 06_0010, dated 29 December 2006).

2. FLOODING AND DRAINAGE

2.1 Hydrology

The aims of the hydrological analyses were to

- Assemble an **xprafts** rainfall/runoff model of the Riverside at Tea Gardens catchment;
- Estimate catchment runoff under existing catchment conditions as a benchmark for comparison with proposed development conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI event;
- Estimate catchment runoff under proposed development conditions; and
- If needed, size detention structure(s) to reduce the 100y ARI peak flow downstream of the proposed development areas to no greater than the 100 yr ARI peak flow under existing conditions.

Estimates of runoff from the Riverside at Tea Gardens catchment during design storms were obtained using the **xprafts** rainfall/runoff model.

The hydrological analyses of the Riverside at Tea Gardens catchment are described in **Appendix B**.

2.1.1 Existing Conditions

The catchment of Riverside at Tea Gardens is bounded to the north by the ridge line of the ridge outcrop, and to the south-west by Myall Road. Riverside at Teagardens represents a major portion of the catchment. With the exception of the portion at the south of the site that has already been developed, there is little natural development of surface drainage features and as the surface soils are generally sandy such that a high level of rainfall infiltration to the groundwater system takes place. As a result, significant surface runoff is unlikely except during periods of high rainfall.

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. However a number of shallow drains have been previously constructed to convey runoff from the western areas of the site to the east to join with runoff from the eastern area of the site that flows east towards the SEPP 14 wetlands and the Myall River.

During wet periods, water ponds in low lying areas in the western and northern areas of the site.

The Riverside at Tea Gardens catchment layout is presented in **Figure 7**

The estimated peak 100 yr ARI outflows from the Riverside at Tea Gardens site are summarised in **Table B.4**.

Table 1
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Existing Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
5.3 *(9)*	9.8 *(9)*	17.1 *(2)*	Total inflow to the existing detention lake
3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Outflow from the existing detention lake
6.9 *(9)*	8.7 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zoned
0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

2.1.2 Developed Conditions – Scheme 3

In concept it is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary of the development and then south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the proposed extended detention lake.

The developed catchment layout is presented in **Figure 8.**

The estimated peak 100 yr ARI outflows under developed conditions (without ancillary retarding basins) are summarised in **Table 2.**

2.1.3 Scheme 3 Developed Conditions with Basins

The impact of integrating a major retarding basin into the open space corridor was assessed as was the performance of a separate basin to reduce peak flows from the area of planned development that discharges directly to the Myall River (subcatchment N42). A concept retarding basin was also sized to manage runoff from an area of planned development that could discharge directly to the conservation zone (subcatchment N43).

Table 2
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Total inflow to the extended detention lake
5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Aggregated flow to the Conservation Zone
1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

Basin Properties

Concept basin sizes and outlet configuration were sized iteratively. In the case of Basin EW the aim was to either:

(i) limit the 100 yr ARI peak discharge to the Conservation Zone under developed conditions to no greater than the existing peak 100 yr ARI discharge to the Conservation Zone, or to
(ii) limit basin outflows to around 6 m^3/s based on the feasibility of constructing a waterway through rising ground to the east of the concept basin wall.

It was found that the latter aim controlled the basin size.

In the case of Basins N42 and N43 the aim of the basins was to limit 100 yr ARI peak flows to no greater than the 100 yr ARI peak flow under existing conditions.

The adopted basin properties are detailed in **Appendix B.4.**

The estimated peak basin water levels for 20 yr ARI, 50 yr ARI and 100 yr ARI events are summarised in **Table 3**. The peak basin outflows and resulting peak discharges to the Conservation Zone under developed conditions are summarised in **Tables 4** and **5**.

Table 3
Estimated Peak Basin Water Depths

Basin	5 yr ARI	20 yr ARI	100 yr ARI
EW	0.97	1.22	1.58
N42	0.55	0.79	0.92
N43	0.53	0.78	0.87

Table 4
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basins EW and N42

5 yr ARI	20 yr ARI	100 yr ARI	Comment
24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Total inflow to the extended detention lake
5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Existing outflow from the existing detention lake
9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Inflow to Basin EW
1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Outflow from Basin EW
5.5 *(9)*	7.1 *(9)*	9.0 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
6.9 *(9)*	8.7*(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions
1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Inflow to Basin N42
0.55 *(9)*	0.83 *(9)*	1.25 *(9)*	Outflow from Basin N42
0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Existing outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

Table 5
Estimated Peak Flows (m^3/s) at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basin N43

5 yr ARI	20 yr ARI	100 yr ARI	Comment
1.4 *(1.5)*	1.9 *(1.5)*	2.4 *(1.5)*	Inflow to Basin EW
0.53 *(9)*	0.77 *(9)*	1.2 *(9)*	Outflow from Basin EW
0.51 *(9)*	0.77 *9)*	1.2 *(9)*	Peak runoff under existing conditions
5.4 *(9)*	6.8 *(9)*	8.8 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
6.9 *(9)*	10.9 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

2.1.4 Scheme 5 Developed Conditions with Basins

The model of future developed Scheme 3 conditions with retarding basins was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5. Under the Scheme 5 concept it is also proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary to a major retarding basin with outflows from the basin discharging south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the a series of ponds and freshwater lakes that will discharge into the proposed extended detention lake.

The 5 yr ARI, 20 yr ARI and 100 yr ARI hydrographs under Scheme 5 developed conditions were estimated and input into the hydraulic model of the Scheme 5 development to estimate peak outflows from the detention lake as well as the 5 yr ARI, 20 yr ARI and 100 yr ARI flood levels.

2.2 Hydraulics

The aims of the hydraulic analyses were to

- Assemble an **xpswmm** hydraulic model of the main drainage lines under proposed developed conditions with concept waterways and basins in place; and
- Estimate peak flows and peak flood levels under developed conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI events.

2.2.1 Concept Sizing of Waterways

Prior to assembling an hydraulic model of the main drainage lines, the concept grading and concept sizing of each of the main drainage lines was undertaken. Four main drainage lines were identified. The East Branch, West Branch, North Branch and EastWest Branch drainage lines are identified in **Figure C.1**.

Hydraulic assessments of the sensitivity of maximum channel depth, channel top width and maximum flow velocity were undertaken using spreadsheet models of a single trapezoidal channel.

The adopted properties of the single trapezoidal channel are given in **Figure C.2**.

The channel capacity and maximum flow velocity for each assumed overall channel top width. The assumed bed slopes for each reach were guided by the concept grading bed. The assumed Manning roughness value was an average of 0.065 across all sections ie. some sections of a channel may be lightly vegetated while other sections of the channel may be more heavily vegetated.

Waterways were assessed for the 100 yr ARI event with basins in place.

The concept waterway dimensions for the East Branch, West Branch, North Branch and EastWest Branch are given in **Tables D.1, D.2, D.3** and **D.4** respectively. The highlighted cells are the channel widths that were selected for inclusion in the **xpswmm** model. These tables disclose the "trade-off" between channel width v flow depth v velocity for other channel dimensions.

An **xpswmm** hydraulic model was assembled for Riverside at Tea Gardens under the proposed Developed Conditions. The model includes the four main drains and a concept retarding basin located on the EastWest Branch.

2.2.2 Flood Levels under Scheme 3 Developed Conditions

The layout of the **xpswmm** model of the Scheme 3 developed condition is shown in **Figure C.1**.

The **xpswmm** model was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels. Based on the outcomes of the hydrological analysis the **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the extended detention lake and the flood level in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table 6**. The estimated peak discharges to the Conservation Zone without and with the major basin on the EastWest Branch (Basin EW) in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table 7**. This table also summarise the estimated peak basin water levels.

Table 6
Estimated Peak Outflows (m^3/s) from the Extended Detention Lake under Scheme 3 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
4.23 *(0.867)*	7.12 *(0.960)*	11.8 *(1.028)*	Outflow from the extended detention lake

Note: The estimated peak basin water level (in m AHD) is reported in brackets

Table 7
Estimated Peak Outflows (m^3/s) from Basin EW under Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.73 *(0.86)*	4.65 *(1.07)*	5.48 *(1.30)*	Outflow from Basin EW
6.07	8.16	11.77	Aggregated flow to the Conservation Zoned (without Basin EW)
4.59*)*	5.93	7.45	Aggregated flow to the Conservation Zone (with Basin EW)

Note: The estimated peak basin water level (in m) is reported in brackets

The estimated 100 yr ARI peak flows, flood levels and flood depths within the hydraulic study area for storm bursts of 1.5 hours and 9 hours are presented in **Figures 9** and **10** respectively.

2.2.3 Flood Levels under Scheme 5 Developed Conditions

The **xpswmm** hydraulic model that was assembled for Riverside at Tea Gardens under the proposed Scheme 3 Developed Conditions was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5.

The concept Scheme 5 layout of waterways, ponds and lakes is given in **Figure C.5.**

The Scheme 5 hydraulic model includes a number of small ponds, three large ponds, three freshwater lakes and a partial extension of the detention lake. It also includes the four main drains and a concept retarding basin located on the EastWest Branch. The active storage available above the extended detention lake, freshwater lakes and ponds was represented as flood storage at selected nodes.

The Scheme 5 **xpswmm** model was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels under the proposed Scheme 5 development. Based on the outcomes of the hydrological analysis the **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the extended detention lake in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table 8.**

Table 8
Estimated Peak Outflows from the Extended Detention Lake under Scheme 5 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.47 *(0.83)*	7.17 *(0.96)*	12.57 *(1.09)*	Outflow from the extended detention lake

Note: The estimated peak basin water level (in m AHD) is reported in brackets

The estimated 100 yr ARI peak flows, flood levels and flood depths within the hydraulic study area for storm bursts of 1.5 hours and 9 hours are presented in **Figures 11** and **12** respectively.

The estimated 5 yr ARI and 20 yr ARI flood levels under 1.5 hour and 9 hour storm bursts are presented spatially in **Figures C.7** to **C.10**.

2.3 Practical Consideration of Climate Change

The planned development is subject to flooding from both the Myall River and from runoff from the local catchment. Sensitivity assessments of climate change were undertaken for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change". These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

It was concluded from the results of the sensitivity runs for the Myall River that:

- The current adopted 100 yr ARI level of 2.1 m AHD could accommodate up to a 30% increase in rainfall under conditions where there is no increase in sea level;
- The increase in 100 yr ARI levels in the Myall River in the vicinity of Riverside due to increases in rainfall reduce as the sea level rise increases ie. a 30% increase in rainfall increases 100 yr ARI levels in the Myall River by

- 0.06 m to 0.07 m under a sea level rise of 0.18 m
- 0.04 m to 0.06 m under a sea level rise of 0.55 m
- 0.03 m to 0.04 m under a sea level rise of 0.91 m

- Under the +0.18 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is around 0.43 to 0.25 m depending on the adopted increase in rainfall intensity;
- Under the +0.55 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is only around 0.02 to 0.07 m depending on the adopted increase in rainfall intensity;
- Under the +0.91 m sea level rise scenario Council's Flood Planning Level of 2.6 m AHD is exceeded by 0.26 m to 0.3 m depending on the adopted increase in rainfall intensity; and
- It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios.

It was concluded from the river flooding inundation plots that:

- River flooding under either a low or a medium climate change scenario would not inundate any unimproved lots;
- River flooding under a high climate change scenario would partially inundate around 180-220 unimproved lots (but not over floors) to a maximum depth of 0.3 m;
- Under a low climate change scenario there would be minimal inundation of planned roads;
- Under a medium climate change scenario there would be inundation of a number of planned roads by up to 0.5 m (which would be Low Hazard due to the expected very low velocity of the fringes of the river flooding through the development); and
- Under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading.

It was concluded from the results of the sensitivity runs for the local catchment that:

- In areas where the estimated 100 yr ARI flood level is greater than 2.1 m AHD the 1.5 hour storm burst gives higher local 100 yr ARI flood levels than the 9 hour storm burst;
- The East Branch and North Branch Flood Planning Levels are controlled by the Myall River under a +0.18 m or greater sea level rise;
- The Flood Planning Levels adjacent to the West Branch are controlled progressively by the Myall River as the sea level rise increases;

- The Flood Planning Levels adjacent to the lower reaches of the East West Branch are controlled progressively by the Myall River as the sea level rise increases; and
- The greatest increase in the 100 yr ARI flood level in the East West Branch in the reach unaffected by sea level rise is 0.28 m.

It is noted that an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD has been adopted fro planned development in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD for all homes in the planned development will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

Elsewhere in the planned development consideration a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

While under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading. Even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

It was also noted from the 1980 flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

The climate change assessment is attached in **Appendix I**.

3. GROUNDWATER

The following assessment of groundwater issues is drawn directly from the groundwater assessment undertaken by Coffey Geotechnics in October 2007. A copy of this assessment is attached in **Appendix G**.

3.1 Topography and Geology

Within the study area the ground surface generally slopes gently south-east towards the Myall River with ground levels below 3 m AHD. A series of sand ridges trending roughly north-south are present across the site. An elevated bedrock outcrop, rising to about 25 m AHD, is present at the northern end of the site. Elevated bedrock levels are also present at the north-western limit of the site.

Soils in low lying areas are generally silty sand and topsoil overlying fine to medium grained sand containing cemented layers (coffee rock) and peaty bands. Basement rock occurs at a depth of 10 m to 20 m over much of the site, rising steeply at the northern end of the site forming an outcrop. A surface clay layer of 1m to 2.5 m thickness exists at the north-west of the site accompanied by an underlying layer of peat.

The sand aquifer is underlain by basement sandstone at a depth of up to approximately 20 m. Sand thickness varies from 0m in the elevated areas in the north of the site to about 20 m at the southern limit of the proposed development.

3.2 Groundwater Conditions

The subsurface sands form an aquifer characterised by moderate to high transmissivity, previously estimated at 200m^2/day, which is present over much of the development site and over the SEPP 14 wetland area. Previous groundwater levels indicated shallow water tables are present over the site. generally within 1m of the surface and at the western limit of the SEPP 14 wetlands and Myall River, groundwater levels are within 0.5m of the ground surface. Groundwater flow is south-east toward the Myall River and groundwater is relatively fresh in the main body of the sand aquifer. There is a secure town water supply well to the north of the area and currently groundwater is not used except for minor home irrigation.

The shallow rock levels to the north of the site provide a barrier to groundwater inflow from that direction. The sand aquifer is expected to extend to the south and west of the site and be in hydraulic contact with the waters of the Myall River to the south, Wobbegong Bay and Pindimar Bay (Port Stephens) to the south-west and Kore Kore Creek to the west.

During periods of low rainfall, losses from the groundwater system will occur due to seepage to the Myall River and evapotranspiration from areas of shallow water table. Evapotranspiration losses from the water table reduce with increasing depth of the water table in a non-linear fashion (CPI, 1996).

Rainfall infiltration forms the main groundwater recharge mechanism. Previous monitoring results from the bores over the site show marked groundwater level response to rainfall events.

The aquifer is in contact with saline water in the Myall River and also in contact with the brackish water in the lake in the south of the site. This results in the development of an interface between high quality fresh groundwater and saline water. The depth of the fresh/salt water interface is a function of the density difference between fresh and salt water and the height of the groundwater surface.

The proposed development (Scheme 5) involves the extension of the existing lakes on the western side and a series of stepped freshwater lakes on the eastern side. Evaporation from these lake extensions would be greater than evapotranspiration losses from the water table over a similar area. These increased evaporative losses are expected to be balanced in part by the reduced evapotranspiration losses that would accompany covering part of the ground surface for residential development.

3.3 Existing Groundwater Levels

A network of twelve groundwater monitoring bores (Bore 1 to Bore 12) was installed by DJ Douglas & Partners in 1994 and four monitoring bores (Bore 21 to Bore 24) were installed by Coffey in 2006. Four of the bores (Bore 1, Bore 2, Bore 3 and Bore 7) have been destroyed or lost between the March 2007 and previous monitoring rounds in April and May 2004. The remaining available bores formed a network for Coffey's 2007 monitoring program.

One round of groundwater level monitoring was undertaken from the existing monitoring network using a dip meter. Table 1 in **Appendix G** presents a summary of groundwater monitoring data from the previous and recent monitoring rounds.

The depth to groundwater at the site has decreased since April 2004 at all locations with the exception of Bore 21. Groundwater level ranges from 0.5m to 1.7m below ground surface and tends to be shallower in the vicinity of the Myall River and the lake (Bores 4, 10, 21, 22, 23 and 24) and deeper further from the river (Bores 5, 8, 9, 11 and 12). The shallow groundwater conditions at the site will limit the capacity of the groundwater system to accept rainfall recharge.

Previous groundwater level data collected by automatic loggers indicates that the measured groundwater levels respond to rainfall events. Groundwater levels measured in March 2007 are typically 0.3 m lower than corresponding levels measured in April 2004. The largest reductions were recorded for Bore 11 (reduction of 0.87 m) and Bore 12 (reductions of 1.1 m). These monitoring bores are in elevated ground and are the two bores most distant from the existing lake of the bores for which comparisons could be made.

As groundwater levels respond to prevailing climatic conditions that a decrease in groundwater levels would be experienced during periods of lower than average rainfall. Lower than average rainfall has been experienced on the mid central coast of NSW in recent years. It is most likely that this is the cause of groundwater level decreases observed.

3.4 Acid Sulphate Soils

An assessment of potential acid sulfate soils was undertaken at the site (Coffey 2007d). The laboratory results indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area.

Groundwater modelling indicates that the lake extension will cause groundwater level reductions by approximately up to 0.75 m. To date there is no indication of the potential for sulfate production in the area but a number of bores were drilled within close proximity of the lake extension. Several test holes were drilled and the soils tested for the potential to produce acid sulfate soils. BH37 is located in the area where the maximum drawdown has been predicted and the results of SPOCAS analysis indicate that from 2 m below surface, samples tested exceed the Acid Sulfate Soil Management Advisory Committee (ASSMAC) action criteria. The potential to produce acid soils increased with depth with the interval 2.0 – 2.5 m just exceeding the criteria.

Groundwater levels in this area are approximately 1.5 m below surface and a 0.75 m groundwater level decline will lower groundwater levels into this zone however, the area affected would be restricted to the 0.75 m drawdown contour indicated in Figure 14 of the geotechnical report attached in **Appendix G**.

A comparison of pH from previous investigations conducted in April 2004 with recent results collected in March 2007 indicates that there has been no discernable change in groundwater pH. This suggests that even with the groundwater level reductions assessed to be affected by lower than average rainfalls in the last few years, there has been no additional increase in acid production resulting from the drying of acid producing soils..

In view of the potential presence of acid sulphate soils, Coffey Geotechnics, 2007d has prepared a generic plan for management of ASS in future earthworks that occur within the Riverside Estate that include the laying of sewer and drainage lines and the excavation of stormwater treatment basins. A concise version of this plan will be provided as a reference to all lot purchasers and contractors required to work on any home within the site. This plan has been formatted in a way to assist individual land owners obtaining DA approvals by outlining methods to control and manage ASS during the development of each lot. The plan will also guide the management of any future excavation to extend the detention lake.

3.5 Groundwater Quality

Laboratory results from the groundwater bores selected for analysis indicate that groundwater quality has not changed significantly since the last monitoring round in 2004. The 2004 report indicated that groundwater chemistry had not changed significantly since the groundwater quality monitoring undertaken in 1994/1995.

The results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations.

Evidence of significant heavy metal contamination in the groundwater samples was not observed however the concentrations of zinc, chromium and copper slightly exceed the guidelines in some samples.

Groundwater from monitoring bores closer to the Myall River tend to be characterised by higher EC and a similar anion to cation ratio as seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.

Groundwater quality was compared to the Australian Drinking Water Guidelines (NHMRC, 2004) and is not potable due to concentrations of a range of analytes exceeding the drinking water guidelines. Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) that do not meet the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC guidelines.

Groundwater away from the Myall River may be considered for irrigation purposes, however high concentrations of phosphorus have the potential to result in bioclogging of irrigation equipment (ANZECC 2000).

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

3.6 Potential Impacts of Development on Groundwater Levels

The results from the current monitoring round indicate groundwater levels have decreased across the majority of the site since 2004, when development at the site commenced. The decrease in groundwater levels has been in the order of 0.1mAHD to 0.2mAHD in the majority of wells and a maximum of 0.47mAHD. Groundwater levels respond to prevailing climatic conditions and the decrease in groundwater levels experienced are likely to be the result of lower than average rainfall which has occurred on the mid central coast of NSW in recent years.

Groundwater modelling indicates that groundwater level contours are altered in the vicinity of the lake extension with the greatest impact at the north-western most point of the proposed lake extension. This will induce groundwater flow towards the lake within the vicinity of the lake which will act to prevent the intrusion of saline water into the aquifer from Myall River and brackish water from the lake.

The enclosed nature of the groundwater system within the localised Riverside area limits the potential impacts on other groundwater users further afield.

It is considered the proposed development is unlikely to affect the groundwater in the vicinity of the SEPP 14 wetland vegetation.

3.7 Potential for Groundwater Contamination resulting from the Development

Potential Impact on Adjacent Ecosystems

Groundwater quality results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations. Groundwater quality modelling indicates that the salt water interface would not be significantly affected by the development and groundwater level modelling indicates that there will be little impact within the wetland area. Groundwater level changes resulting from the proposed development are assessed to be below 0.25 m beyond 300 m from the development and 0.1 m within the wetland area. Changes of this magnitude would be within the existing groundwater level variability and are therefore considered unlikely to adversely affect adjacent ecosystems.

Impact on Potential Future Use of Groundwater as a Potable water Source

Groundwater quality is not considered to be potable due to concentrations of a range of analytes exceeding the drinking water guidelines (ANZECC 2000). Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) above the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC (2000) guidelines.

The groundwater results indicate that it is generally select parameters, namely pH, ammonia and salinity (or TDS) that are limiting the potential use of the groundwater rather than a wide range of parameters. Consequently, some treatment of groundwater with respect to these parameters is likely to increase the potential uses of the groundwater across the Site. It is also noted that groundwater away from the Myall River tends to have greater potential usability, primarily due to lower salinity (or TDS) and lower concentrations of sodium and chloride.

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

Re-use of reclaimed water

A laboratory developed a water sample with similar concentrations of nitrate, phosphorus and pH to th reclaimed water data supplied by Mid Coast Water. This water was used as a leaching agent for three soil samples collected from the site.

The concentration of nitrate in the leachate water was similar or greater than the concentration of nitrate in the lab-produced reclaimed water. This indicates that the potential for nitrate adsorption on the soil is low and the travel time of nitrate through the soil is likely to be similar to the rate of water through the soil.

The concentration of phosphorus in the leachate water was consistently significantly below the concentration of phosphorus in the lab-produced reclaimed water. These results indicate the soil at the site has the capacity to adsorb the phosphorus present in the reclaimed water and that the travel time of phosphorus through the soil is very slow.

These initial results show that with respect to phosphorus, the reclaimed water may be used for irrigation purposes. However, Coffey recommend further testing when a sample of reclaimed water from Mid-Coast Water is available. The following provides groundwater quality and indicative concentration parameters for key chemical constituents.

Parameter	Average Concentration in Groundwater (mg/L)	ANZECC Guidelines (mg/L)	Indicative Concentration of STP Effluent (mg/L)
NO_3	0.02	0.7	5
NH_4	0.53	1200	1
P	0.79	0.05	2.2

The groundwater results from the current monitoring round suggest that the reclaimed water may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of the reclaimed water with water of higher quality.

Based on the signature of key chemical constituents present above, three re-use options are presented as possible scenarios for the use of reclaimed water for the purposes of irrigation:

1. Treatment of the reclaimed water to meet health standards including pathogens. The reclaimed water may be used for irrigation if 10% of the reclaimed water is mixed with 90% of fresh water.
2. Treatment of the reclaimed water to limit NO_3 to an average concentration of 0.7 mg/L. If this level of treatment is obtained on an average basis, 100% of the reclaimed water may be used for irrigation purposes, assuming partial uptake of nutrients by vegetation.
3. Treatment of the reclaimed water to limit NO_3 to an average concentration of 1.4 mg/L. If this level of treatment is obtained on an average basis, a mixture of 50% of reclaimed water and 50% of fresh water may be used for irrigation.

Calculations of the average time required for the groundwater to migrate from the development area to the lake or river indicated that the groundwater moves at a rate of approximately 10 m/year. This is based on an assumed hydraulic conductivity of 8 m/day, a porosity of 35 % and a groundwater gradient of 0.12 %. The leaching tests indicate that nitrate will move at a similar rate to the groundwater and that phosphorus will move at a significantly slower rate.

Given this low rate of groundwater movement, Coffey consider that the irrigation impacts can be considered on a time averaged basis. With respect to use of reclaimed water for irrigation purposes, it is considered that irrigation of parks and open spaces within the development is unlikely to adversely impact groundwater or the water in the lake if one of the above treatment options is employed. It is concluded that appropriate monitoring of irrigated areas should however be employed to ensure key indicators remain within relevant guidelines.

4. WATER QUALITY

4.1 Existing Lake Water Quality

A water quality monitoring programme for the existing detention lake was established in 1996 firstly by the developer, and more recently taken over by the Myall Quays Community Association. Hunter Water Laboratories collects and analyses samples at 5 lake locations approximately every 3 months. Sampling locations are shown on **Figure A.1**.

Initial testing involved the following parameters:

- pH
- Salinity
- Turbidity
- Suspended solids
- Kjeldahl nitrogen
- Oxidised nitrogen
- Ammonia#
- Nitrates#
- Nitrites#
- Phosphate
- Chlorophyll#
- Dissolved oxygen
- Faecal coliforms

(# denotes testing commenced in November 1997)

The results are reported in Hunter Water Laboratories, 2002 and summarised together with subsequent sampling results for Sites 1 to 5 in **Tables A.5** to **A.9.**

4.1.1 Salinity

The sampling indicates that the lake water is brackish having a 50th percentile value of salinity of 12.9 g/L, which is approximately one third of the salinity of seawater. There is variability in the salinity concentration due to both catchment (freshwater) runoff as well as the influence of tides and varying salinity in the Myall River. The observed salinity varied from 4.4 g/L to 25.9 g/L (between the 10th percentile and 90th percentile values).

4.1.2 Dissolved Oxygen

The 50th percentile of all Dissolved Oxygen (DO) values (120 readings) in the lake for the sampling period is 6.7 mg/L, with a 10th percentile level of 4.9 mg/L. The 4.9 mg/L level is just below the recommended ANZECC trigger value of 5.0 mg/L for freshwater fish. A comparison of the DO levels measured within the existing lake and the Myall River disclosed that the ANZECC guidelines for DO are not currently met at all times, in either the lake or river (at Copeland Ave Wharf). As indicated in **Figure 13**, DO levels in the existing lake are often better than in the Myall River.

4.1.3 Suspended Solids

The sampling indicates that the 50th percentile value of suspended solids for the lake is 24.5 mg/L. In comparison the 50th percentile value of suspended solids for the Myall River (at Site 5) was 44 mg/L. As indicated in **Figure 14**, the TSS levels in the existing lake are often better than in the Myall River.

4.1.4 Nutrients

The adopted ANZECC, 2000 trigger value for Phosphorus (TP) is 0.03 mg/L for estuarine systems. Most of the samples have been below the recommended value with a 50th percentile (120 readings) of 0.005 mg/L. Higher P levels occurred soon after the lake was constructed, possibly due residual P released from exposed soil. The TP levels in the existing lake are compared with the TP levels in the Myall River in **Figure 15**

The ANZECC, 2000 trigger value for Nitrogen (TN) is 0.3 mg/L, NO_x is 0.015 mg/L and Ammonia is 0.015 mg/L for estuarine systems. TN values could not be calculated from the available data. The 50th percentile of all NO_x values (44 readings) in the lake for the sampling period was 0.0105 mg/L. The 50th percentile of all Ammonia values (104 readings) in the lake for the sampling period is 0.03 mg/L. The Ammonia levels in the existing lake are compared with the Ammonia levels in the Myall River in **Figure 16**

The nutrient levels measured in the lake have generally been low, contributing to the overall good water quality in the existing lake. The nutrient levels in the existing lake are often better than in the Myall River.

4.2 Water Quality Objectives

4.2.1 Water Quality Objective identified in the Environmental Assessment Requirements

The Director-General's Environmental Assessment Requirements for water cycle and aquaculture management are in part as follows:

> "Address potential impacts on the water quality of surface and groundwater having regard to the relevant State Groundwater, River, Wetlands and Estuary Policies. Consideration must be made for water impacts to the Myall River and identified SEPP 14 Wetlands.
>
> …. Stormwater management should be designed to ensure ongoing protection of the groundwater aquifer in accordance with the principles of ANZECC & ARMCANZ: Guidelines for Groundwater Protection in Australia, National Water Quality Management Strategy, Commonwealth of Australia, 1995."

4.2.2 Water Quality Objective for DCP No. 22

As identified in Myall Quays Estate DCP No. 22, Section 2.4.1 the stated objective was that:

> "the standard of water from the site to the Myall River is to meet primary contact recreation requirements".

In Section 2.4.1, subparagraph (iii) it is further stated that the performance criteria for the water quality treatment system are specified in the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 1992).

The ANZECC, 1992 water quality guidelines for primary contact recreational waters are summarised in **Table 9**.

Table 9
ANZECC Guidelines for Primary Contact Recreational Waters

Parameter	Guideline
Microbiological	The median bacterial content in samples of water should not exceed: • 150 faecal coliform organisms per 100ml (minimum of 5 samples taken at regular intervals not exceeding one month, with 4 out of 5 samples containing less than 600 organisms per 100ml); • 35 enterococci organisms per 100ml (maximum number in any one sample = 60-100 organisms per 100ml) Pathogenic free-living protozoans should be absent (to be sampled only when water temperature is greater than 24˚C.
Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, sewage fungus, leeches, etc. should not be present in excessive amounts. Large numbers of midges & aquatic worms should be avoided.
Visual clarity & colour	To protect the aesthetic quality of a water body: • the natural visual clarity should not be reduced by more than 20%; • the natural hue of the water should not be changed by more than 10 points on the Munsell Scale; • the natural reflectance of the water should not be changed by more than 50%.
pH	The pH of the water should be within the range 5.0-9.0, assuming that the buffering capacity of the water is low.
Temperature	For prolonged exposure, temperature should be in the range 15-35˚C.

Toxic chemicals	Water containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed levels given for untreated drinking water.
Surface films	Oil and petrochemicals should not be noticeable as a visible film on the water nor should they be detectable by odour.

As discussed by HWR, 2001 these guidelines relate to water bodies used for primary recreational purposes rather than water flowing into such water bodies. For example, the guidelines for visual clarity and colour are only relevant to the Myall River itself and are difficult to interpret for water flowing into the Myall River.

As discussed by HWR, 2001 algal mats, phytoplankton blooms, midge outbreaks, etc. occur in eutrophic or high nutrient waters. Accordingly, it is desirable to adopt an objective for nutrient status of the discharge water at a level that would not encourage algal blooms, etc.

4.2.1 Lake Water Quality Objectives

The existing lake meets multiple objectives for flood detention, water quality, aquatic habitat and amenity.

In 1998 Australian Museum Business Services (AMBS) undertook a baseline survey of the lake (AMBS, 1998) (refer **Appendix H**). In September 2002, AMBS carried out a further ecological survey of the existing lake to assess the aquatic habitats present and determine changes to the assemblages since the baseline survey in 1998. An evaluation of the health of the lake was carried out by comparing historical water quality parameters with those recommended in the ANZECC Guidelines with relevance to the seagrass, macroalgae, fish and macroinvertebrates present. It was concluded by AMBS that the variable salinity regime is more favourable to those species that are able to withstand fluctuations in salinity levels.

During this study seven species of fish were collected. The lake was found to be supporting a number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye.

Harris Research, 2007 reports that seine netting and gill netting undertaken in April 2007 captured numbers of both individual fish and fish species that were well in excess of previous surveys. Substantially larger-bodied fish and some fisheries species were caught including yellow-fin bream, striped mullet, sand mullet and silver biddies. The distribution patterns and occurrence of aquatic plants in the lake were similar to those recorded in 2002.

Increased biological diversity and abundance of the fish community show that the Riverside lake is continuing its development towards the ecological condition of the surrounding Myall River estuary and supports casual observations of recreational fishing in the lake. Habitat conditions, water quality and the food web are continuing to develop, supporting fish recruitment and productivity. Fish recruitment and growth in the lake are contributing to biological values in the estuary as a whole and this should increase as ecological processes mature further.

Consultation that has occurred at several stages during the planning process has highlighted also the value that the community places on the existing lake and the aquatic habitat and species it supports.

The proposed water quality objective for the development is to maintain as far as possible in an extended detention lake the water quality regime that exists within the existing lake. The measures of water quality that have been adopted include salinity, DO, TN, TP and algal concentrations (chlorophyll 'a').

As is demonstrated in **Figures 13** to **16** the water quality in the existing lake is often better than the water quality in the Myall River. It is concluded that the achievement of the adopted lake water quality objective will therefore protect the Myall River.

4.2.1 Treatment Objectives for Stormwater Discharges

The adopted treatment objectives for runoff from development that flows directly into the Myall River or into the Conservation Zone are the stormwater treatment objectives established by the NSW EPA in the 1997 Draft Managing Urban Stormwater: Council Handbook. These objectives include:

- 85% retention of the average annual load of TSS
- 45% retention of the average annual load of TN
- 45% retention of the average annual load of TP

4.3 Catchment Water Quality

The aims of the catchment based water quality modelling were to

- Create MUSIC models of the Pre-existing and Existing conditions based on the approaches adopted in 2004 catchment based water quality (**xpaqualm**) assessments;
- "Calibrate" the MUSIC model parameters against the unit area results previously calculated using the **xpaqualm** model(s);
- Estimate catchment exports under the Pre-existing and Existing conditions for input into models of the Pre-existing detention lake and Existing detention lake;
- Create MUSIC models of the proposed concept development with and without rainwater tanks and run the generate for inputs into the Scheme 3 Pond model; and
- If needed, size ancillary pond(s) and/or wetland(s) to achieve the receiving water quality objectives for the receiving waters.

4.3.1 Catchment Water Quality Models

MUSIC water quality models were assembled for the Existing and Scheme 3 and Scheme 5 Developed Conditions.

The approach to MUSIC modelling is described in **Appendix D**.

The various assumptions and model parameters that were adopted for the water quality modelling are also outlined in **Appendix D**. Model parameters for MUSIC were "calibrated" to match as far as possible to match the runoff and pollutant export rates previously estimated using **xpaqualm** in 2004. The MUSIC parameters adopted by Patterson Britton and Partners in 2006 for the adjacent Myall River Downs development were also considered.

The adopted period of modelling was 1/01/1982 – 31/05/2004 in which 22 calendar years (1/01/1982 – 31/12/2003) were selected for generating statistics.

4.3.2 Pre-Existing and Existing Conditions

The Pre-existing Condition was defined as the conditions that existing in the early 1990s with a lake area of around 5 ha, subcatchments R1 & R2 were fully developed and there were a limited number of dwellings in subcatchments L1L, L2R, WQB1 and Nat3 (refer **Figure D.1** for location).

The Existing Condition was defined as the conditions at around 2004 with the lake area extended to 6 ha, and more dwellings constructed in subcatchments L1L, L2R, WQB1, and Nat3.

The layout of the model of Pre-existing and Existing Conditions is shown in **Figure D.3**.

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands are summarised in **Table 10**.

The average annual runoff and TSS, TN and TP exports that would be estimated if the existing diversion drains were not in place were also estimated and are summarised in **Table 10**.

4.3.3 Developed Conditions

A number of MUSIC models of Developed Conditions were created based on Scheme 3 and Scheme 5 from the 2004 assessment and concept development plans. These models were of the following scenarios:

(i) Developed with the Scheme 3 extended detention lake only;
(ii) Developed with the Scheme 3 extended detention lake plus rainwater tanks;

Table 10
Estimated Runoff and Pollutant Exports under Existing Conditions

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
Lake Inflow	74.4	1040	318	28700	55	459	
Lake Outflow			229	4190	22	263	
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
Lake Inflow	209.7	2934	874	124000	247	1850	
Lake Outflow			785	21190	92	1131	
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone

Subcatchment N42 discharges direct to the Myall River
Total Discharge to Conservation Zone = Myall-2 + N43
Discharge to Wetland Zone = Lake Outflow + Myall-2 + N43

(iii) Scenario (ii) plus a series of proposed major ponds and wetlands to treat runoff from residential development discharging to the Myall River (subcatchment N42) or to the Conservation Zone (subcatchment N43) plus a 770m swale along the eastern edge of the development (to distribute flow to the Conservation Zone) – the wetlands were sized to achieve target reductions of 80%, 45% and 45% in the average annual export of TSS, TP and TN respectively);
(iv) Scenario (iii) but with rainwater tanks removed
(v) Scenario (iii) but reconfigured to include four small ponds, three large ponds, three freshwater lakes and an extension of detention lake in accordance with Scheme 5; and
(vi) Scenario (v) but with rainwater tanks removed.

The layouts of the developed conditions model with and without rainwater tanks are shown in **Figure D.4, D.5** and **D.6** (Scenarios (iii), (iv) and (v)) respectively.

Scheme 3

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the four Scheme 3 scenarios are summarised in **Table 11**. The adopted properties of the lake, ponds, wetlands and swale and rainwater tanks are summarised in **Tables D.11** and **D.12** respectively.

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks. In the case of wetlands these were re-sized if possible to account for differences in runoff from developed areas with or without rainwater tanks eg. Wetland N42 (with rainwater tanks in place) and Wetland N42 nrwt (no rainwater tanks) (refer **Table D.11**). Under Scenario (iv) it was necessary to include a bio-filter upstream of Wetland N44 to meet the treatment objectives.

It was concluded from the results that under Scheme 3 Developed Conditions:

(i) The extended detention lake in combination with rainwater tanks, ponds, wetlands and a swale:
- Delivers greater than 80%, 45% and 45% reductions in the average annual export of TSS, TP and TN respectively from the proposed development;
- Reduces the export of TSS, TP and TN under Developed Conditions to the wetland zone by 80%, 39% and 5% less than the TSS, TP and TN exports under Existing Conditions;

(ii) The extended detention lake in combination with, ponds, wetlands and a swale but without rainwater tanks:
- Delivers greater than 80% and 45% reductions in TSS and TP respectively and close to a 45% TN reduction from the proposed development;
- Reduces the export of TSS and TP under Developed Conditions to the wetland zone by 78%, 33% than the TSS and TP exports under Existing Conditions;
- Slightly increases the export of TN under Developed Conditions to the wetland zone by 3% than the TN export under Existing Conditions;

(iii) Additional ponds/wetlands beyond those already proposed may not be needed if rainwater tanks are deleted in preference to a reclaimed water supply.

Scheme 5

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the two Scheme 5 scenarios are summarised in **Table 12**. The adopted properties of the lakes, ponds, wetlands and swale are summarised in **Tables D.14.** The rainwater tank properties are as given in **Table D.15** respectively.

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks.

It was concluded from the results that under Scheme 5 Developed Conditions:

(i) The partially extended detention lake in combination with freshwater lakes, rainwater tanks, ponds, wetlands and a swale:
- Delivers greater than 80%, 45% and 45% reductions in the average annual export of TSS, TP and TN respectively from the proposed development;
- Reduces the export of TSS, TP and TN under Developed Conditions to the wetland zone by 80%, 41% and 8% less than the TSS, TP and TN exports under Existing Conditions;

(ii) The extended detention lake in combination with freshwater lakes, ponds, wetlands and a swale but without rainwater tanks:
- Delivers greater than 80%, 45% and 45% reductions in the average annual export of TSS, TP and TN respectively from the proposed development;
- Reduces the export of TSS and TP under Developed Conditions to the wetland zone by 78%, 33% than the TSS and TP exports under Existing Conditions;
- Slightly increases the export of TN under Developed Conditions to the wetland zone by 3% than the TN export under Existing Conditions;

(iii) Additional ponds/wetlands beyond those already proposed may not be needed if rainwater tanks are deleted in preference to a reclaimed water supply.

Table 11
Estimated Runoff and Pollutant Exports under Scheme 3 Developed Conditions

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Developed + No RWT + Extended Lake							
N42	15.8	220	78	9180	20	157	Discharges direct to Myall River
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	418	65430	134	988	Discharges to Conservation Zone
	102.7	1437	486	72800	150	1120	Total Discharge to Conservation Zone
				39%	*37%*	*36%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1320	129000	277	2170	Southern lake inflow
Lake Outflow			1154	20800	116	1370	
				84%	*58%*	*37%*	*Reduction to Developed Conditions*
			1640	93600	266	2490	Discharge to Wetland Zone
			N	Y	N	N	Less than Current Conditions?
Developed + RWTs + Extended Lake							
N42	15.8	220	68	8610	18	142	Discharges direct to Myall River
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	409	4760	55	711	Discharges to Conservation Zone
	102.7	1437	468	11600	69	828	Total Discharge to Conservation Zone
				90%	*71%*	*53%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1190	121000	249	1960	Southern lake inflow
Lake Outflow			1022	17800	102	1222	
				86%	*63%*	*44%*	*Reduction to Developed Conditions*
			1490	29400	171	2050	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Developed + RWTs + Extended Lake + Ponds + Swale							
N42	15.8	220	63	1160	5	86	Downstream of constructed wetland
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	406	3660	53	700	Discharges to Conservation Zone
	102.7	1437	465	10500	67	817	Total Discharge to Conservation Zone
				91%	*72%*	*54%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1140	50600	144	1520	Southern lake inflow
Lake Outflow			975	14400	93	1103	
				89%	*66%*	*49%*	*Reduction to Developed Conditions*
			1440	24900	160	1920	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + Extended Lake + Ponds + Swale							
N42	15.8	220	68	994	5.3	87	Downstream of constructed wetland
				89%	*74%*	*45%*	*Reduction to Developed Conditions*
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	416	3430	53	713	Discharges to Conservation Zone
	102.7	1437	484	10800	69	845	Total Discharge to Conservation Zone
				91%	*71%*	*52%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1260	54000	161	1700	Southern lake inflow
Lake Outflow			1096	16100	106	1245	
				88%	*62%*	*43%*	*Reduction to Developed Conditions*
			1580	26900	175	2090	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Subcatchment N42 discharges direct to the Myall River
Total Discharge to Conservation Zone = Myall-2 + N43
Discharge to Wetland Zone = Lake Outflow + Myall-2 + N43

Table 12
Estimated Runoff and Pollutant Exports under Scheme 5 Developed Conditions

ID	Area (ha)	Rainfall (ML/yr)	Flow and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
	74.4	1040	318	28700	55	459	Existing Lake Inflow
			229	4190	22	263	Existing Lake Outflow
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
	209.7	2934	874	124000	247	1850	Existing Lake Inflow
			785	21190	92	1131	Existing Lake Outflow
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone
Developed + No RWT + Fresh Lakes + Extended Lake							
N42	15.8	220	78	9180	20	157	Discharges direct to Myall River
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	418	65430	134	988	Discharges to Conservation Zone
	102.7	1437	486	72800	150	1120	Total Discharge to Conservation Zone
				39%	*37%*	*36%*	*Reduction to Current Conditions*

			813	86400	185	1410	Fresh Lake Inflow
			724	13400	74	904	Fresh Lake Outflow
			502	41900	90	727	Local Inflows
			1226	55300	164	1631	Saline Lake Inflow
			1120	17200	107	1280	Saline Lake Outflow
				87%	*61%*	*40%*	*Reduction to Developed Conditions*
			1606	90000	257	2400	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake							
N42	15.8	220	68	8610	18	142	Discharges direct to Myall River
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	409	4760	55	711	Discharges to Conservation Zone
	102.7	1437	468	11600	69	828	Total Discharge to Conservation Zone
				90%	*71%*	*53%*	*Reduction to Current Conditions*
			729	81700	167	1280	Fresh Lake Inflow
			641	12300	66	803	Fresh Lake Outflow
			462	39700	81	662	Local Inflows
			1103	52000	147	1465	Saline Lake Inflow
			995	15500	96	1140	Saline Lake Outflow
				88%	*65%*	*47%*	*Reduction to Developed Conditions*
			1463	27100	165	1968	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	63	1160	5	86	Downstream of constructed wetland
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	406	3660	53	700	Discharges to Conservation Zone
	102.7	1437	465	10500	67	817	Total Discharge to Conservation Zone
				91%	*72%*	*54%*	*Reduction to Current Conditions*
			675	22500	77	845	Fresh Lake Inflow
			587	8470	56	663	Fresh Lake Outflow
			457	29600	67	609	Local Inflows
			1044	38070	122	1272	Saline Lake Inflow
			936	13700	88	1030	Saline Lake Outflow
				89%	*68%*	*52%*	*Reduction to Developed Conditions*

			1401	24200	155	1847	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	68	994	5.3	87	Downstream of constructed wetland
				89%	*74%*	*45%*	*Reduction to Developed Conditions*
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	416	3430	53	713	Discharges to Conservation Zone
	102.7	1437	484	10800	69	845	Total Discharge to Conservation Zone
				91%	*71%*	*52%*	*Reduction to Current Conditions*
			758	24500	87	955	Fresh Lake Inflow
			670	9520	63	755	Fresh Lake Outflow
			497	30900	73	668	Local Inflows
			1167	40420	136	1423	Saline Lake Inflow
			1060	15300	100	1160	Saline Lake Outflow
				88%	*64%*	*46%*	*Reduction to Developed Conditions*
			1580	26900	175	2090	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Subcatchment N42 discharges direct to the Myall River

Total Discharge to Conservation Zone = Myall-2 + N43

Discharge to Wetland Zone = Saline Lake Outflow + Myall-2 + N43

4.4 Lake Water Quality

The aims of the lake modelling were to

- Re-run the Pond models of the Pre-existing and Existing detention lakes using catchment inputs calculated using the MUSIC model and to confirm that similar results to previous runs were obtained;
- Re-run the Scheme 3 Pond model and Scheme 5 Pond models for catchment inputs under developed conditions and compare with the 2004 results; and
- If needed, size pond(s) and/or wetland(s) to achieve the receiving water quality objectives for receiving waters.

The approach to lake modelling is described in **Appendix E**.

The various assumptions and 2004 model calibration of the lake water quality model are outlined in **Appendix E**.

4.4.1 Pre-Existing and Existing Conditions

The Pond models of the Pre-existing detention lake and the Existing detention were re-run using inputs calculated using the MUSIC model to compare with the previous results reported in 2004. The results are compared in **Table 13**.

It was concluded that the calculated lake water quality using inputs generated by MUSIC are very similar to the lake water quality previously calculated using inputs generated by **xpaqualm**.

Table 13
Comparison of Lake Water Quality under Pre-existing and Existing Conditions

Percentile	Pre-existing Condition		Existing Condition	
	2004 Study	This Study	2004 Study	This Study
DO Bottom				
5%	1.0	0.7	1.5	1.6
20%	4.5	4.3	4.6	4.4
50%	5.9	5.8	5.9	5.8
80%	7.2	7.1	7.2	7.1
95%	8.2	8.1	8.1	8.1
DO % Saturation				
5%	12%	8%	21%	20%
20%	59%	57%	61%	59%
50%	78%	76%	78%	77%
80%	88%	88%	89%	88%
95%	95%	94%	95%	95%
TP				
5%	0.0014	0.0014	0.0011	0.0010
20%	0.0028	0.0026	0.0019	0.0019
50%	0.0055	0.0055	0.0040	0.0040
80%	0.0124	0.0135	0.0094	0.0106
95%	0.0283	0.0371	0.0221	0.0278
TN				
5%	0.29	0.27	0.31	0.29
20%	0.34	0.31	0.36	0.33
50%	0.41	0.39	0.42	0.40
80%	0.50	0.51	0.50	0.51
95%	0.68	0.77	0.64	0.72
Algal Biomass				
50%	0.0010	0.0010	0.0010	0.0010
70%	0.0011	0.0011	0.0010	0.0010
90%	0.0016	0.0021	0.0012	0.0014
95%	0.0034	0.0048	0.0022	0.0026
100%	0.0374	0.0323	0.0268	0.0265

4.4.2 Developed Conditions

Scheme 3

The Pond model of Developed Conditions with the extended detention lake was run with inputs calculated using the MUSIC model. Three scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and the extended detention lake;

(ii) Developed Conditions with rainwater tanks and the extended detention lake and ancillary ponds or wetlands; and

(iii) Developed Conditions without rainwater tanks and with the extended detention lake and ancillary ponds or wetlands.

The results of this assessment are compared with the previous results reported in 2004 in **Table 14**.

It was concluded from the results of this assessment that:

(i) Under Scheme 3 Developed Conditions with rainwater tanks and the extended detention lake it is estimated that the:
- median salinity, DO levels, TN concentrations and algal levels were close to the results reported in 2004;
- median TP concentration is higher than estimated in 2004; and
- the maximum algal concentration is also higher than estimated in 2004 (and was similar to the maximum algal concentration estimated under Pre-existing and Existing Conditions).

(ii) The installation of ancillary ponds or wetlands (without any change in the tidal flushing regime) is estimated to:
- slightly increase the median salinity and DO levels;
- slightly decrease the median TP and TN concentrations to levels lower than the median concentration estimated in 2004;
- have no effect on the estimated median algal concentration; and
- slightly decrease the maximum algal concentration.

(iii) Constructing the extended detention lake and ancillary ponds and/or wetlands but not installing rainwater tanks (due to the possible installation of a reclaimed water system) is estimated to:

- Further reduce the median salinity;
- Provide DO levels the same as estimated in 2004;
- Slightly increase TP and TN concentrations above the estimated levels with rainwater tanks but still achieve levels lower than estimated in 2004;
- have no effect on the estimated median algal concentration; and
- slightly decrease the maximum algal concentration.

Table 14
Estimated Lake Water Quality under Scheme 3 Developed Conditions

Percentile	Scheme 3				
	2004 Study	This Study RWT + Lake	This Study RWT + Lake + Ponds	This Study No RWT + Lake + Ponds	ANZECC, 2000 Trigger Value / Ranges
Salinity (g/L)					
5%	3.4	3.8	3.8	3.7	3-20 g/L
20%	8.2	7.9	8.0	7.7	
50%	13.7	14.0	14.4	13.7	
80%	21.6	22.6	23.3	22.0	
95%	26.7	28.1	28.8	27.7	
DO Bottom (mg/L)					
5%	2.8	2.0	3.0	2.6	
20%	5.8	5.7	6.1	5.9	
50%	7.1	6.9	7.2	7.1	
80%	8.2	7.9	8.2	8.1	
95%	9.1	8.8	9.0	9.0	
DO Saturation (%)					
5%	32%	22%	33%	30%	80%-100%
20%	69%	66%	73%	70%	
50%	86%	84%	87%	86%	
80%	94%	93%	95%	94%	
95%	99.3%	98.1%	99.6%	99.2%	
TP (mg/L)					
5%	0.0023	0.0028	0.0019	0.0020	0.03
20%	0.0051	0.0057	0.0038	0.0043	
50%	0.0103	0.0130	0.0077	0.0085	
80%	0.0240	0.0310	0.0175	0.0179	
95%	0.0527	0.0579	0.0362	0.0373	
TN (mg/L)					
5%	0.27	0.23	0.18	0.21	0.3
20%	0.34	0.30	0.24	0.27	
50%	0.45	0.41	0.33	0.36	
80%	0.59	0.63	0.50	0.52	
95%	0.91	0.91	0.76	0.78	
Algal Biomass (mg/L)					
50%	0.0011	0.0011	0.0011	0.0011	0.004
70%	0.0012	0.0012	0.0012	0.0012	
90%	0.0016	0.0018	0.0018	0.0019	
95%	0.0023	0.0035	0.0031	0.0034	
100%	0.0191	0.0305	0.0282	0.0253	

Scheme 5

Scheme 5 comprises a partial extended saline lake (8 ha) with increased tidal flushing and new freshwater lakes (6.5 ha in total); supported by additional ponds or wetlands as needed (total area of pons draining to the lakes is 4.7 ha). The Developed Conditions Pond models of the freshwater Lakes and a separate linked model of the partially extended saline lake were run with inputs calculated using the MUSIC model.

Four scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake;

(ii) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands;

(iii) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake; and

(iv) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands.

The results of the assessment of the original Scheme 5 are compared with the previous results reported in 2004 in **Table 15**. The original Scheme 5 was based on widening the existing outlet channel by 80% and lowering the outlet channel uniformly by 0.09 m.

It was concluded from the results of this assessment that:

(i) Under Scheme 5 Developed Conditions with rainwater tanks and the partially extended detention lake and freshwater lakes it is estimated that the:

- median salinity and DO levels are slightly lower in the saline lake and freshwater lakes;
- median TN and TP concentrations are slightly higher in the saline ;
- median algal levels were close to the results reported in 2004;and
- maximum algal concentration is also higher than estimated in 2004 (particularly in the freshwater lakes).

(ii) The installation of ancillary ponds or wetlands (without any change in the tidal flushing regime) is estimated to:

- slightly increase the median salinity and DO levels;
- slightly decrease the median TP and TN concentrations to levels lower than the median concentration estimated in 2004;
- have minimal effect on the estimated median algal concentration; and
- significantly decrease the maximum algal concentration.

Table 15
Estimated Lake Water Quality under Scheme 5 Developed Conditions

Percentile	Scheme 5									ANZECC, 2000 Trigger Value / Ranges
	2004 Study		This Study							
	Saline Lake	Fresh Lake(s)	RWTs only		RWTs + Ponds		No RWTs		No RWT + Ponds	
			Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	
Salinity (g/L)											
5%	3.3		1.4		3.5		1.4		3.4		3-20 g/L
20%	8.2		5.9		7.9		5.6		7.6		
50%	14.1		12.5		15.2		11.5		14.3		
80%	22.8		22.1		25.1		20.2		23.7		
95%	28.9		30.4		32.2		27.9		30.4		
DO Bottom (mg/L)											
5%	2.7	5.9	1.5	3.1	3.6	4.8	1.4	2.7	3.6	4.4	
20%	4.6	7.9	4.4	6.9	4.7	7.6	4.3	6.6	4.8	7.4	
50%	6.0	8.6	5.9	8.1	6.2	8.6	5.9	7.9	6.2	8.5	
80%	7.4	9.4	7.2	8.8	7.5	9.2	7.1	8.8	7.6	9.1	
95%	8.4	10.1	8.2	9.4	8.5	9.8	8.1	9.4	8.5	9.8	
DO Saturation (%)											
5%	35%	62%	19%	33%	51%	52%	15%	29%	50%	46%	80%-100%
20%	65%	85%	61%	71%	72%	80%	57%	69%	71%	78%	
50%	80%	94%	79%	86%	82%	93%	77%	84%	82%	92%	
80%	88%	100%	87%	99%	89%	100%	86%	98%	89%	100%	
95%	93.0%	100.0%	92.8%	100.0%	93.8%	100.0%	92.5%	100.0%	93.5%	100.0%	
TP (mg/L)											
5%	0.0041	0.0007	0.0037	0.0007	0.0028	0.0007	0.0039	0.0007	0.0029	0.0007	0.03
20%	0.0065	0.0015	0.0066	0.0011	0.0049	0.0007	0.0073	0.0012	0.0052	0.0007	
50%	0.0098	0.0055	0.0126	0.0097	0.0081	0.0019	0.0140	0.0115	0.0086	0.0024	
80%	0.0174	0.0206	0.0247	0.0467	0.0142	0.0150	0.0261	0.0486	0.0147	0.0164	
95%	0.0332	0.0572	0.0490	0.0821	0.0251	0.0332	0.0506	0.0849	0.0258	0.0354	
TN (mg/L)											
5%	0.24	0.87	0.22	0.75	0.18	0.53	0.25	0.76	0.20	0.56	0.3
20%	0.30	0.92	0.29	0.81	0.23	0.56	0.32	0.81	0.24	0.58	
50%	0.39	0.98	0.42	0.92	0.30	0.62	0.45	0.92	0.32	0.63	
80%	0.52	1.08	0.64	1.19	0.43	0.75	0.66	1.19	0.45	0.77	
95%	0.77	1.30	0.94	1.39	0.63	0.97	0.96	1.40	0.65	0.99	
Algal Biomass (mg/L)											
50%	0.0012	0.0010	0.0012	0.0010	0.0011	0.0010	0.0013	0.0010	0.0012	0.0010	0.004
70%	0.0013	0.0010	0.0014	0.0010	0.0013	0.0010	0.0015	0.0011	0.0013	0.0010	
90%	0.0017	0.0013	0.0020	0.0016	0.0016	0.0014	0.0021	0.0016	0.0017	0.0015	
95%	0.0021	0.0017	0.0027	0.0026	0.0019	0.0018	0.0028	0.0027	0.0019	0.0022	
100%	0.0105	0.0304	0.0323	0.1397	0.0052	0.0592	0.0344	0.1860	0.0065	0.0912	

(iii) Partially extending the detention lake and constructing the freshwater lakes and ancillary ponds and/or wetlands but not installing rainwater tanks (due to the possible installation of a reclaimed water system) is estimated to:

- further reduce the median salinity;
- provide DO levels similar to the levels estimated in 2004;
- slightly increase TP and TN concentrations above the estimated levels with rainwater tanks but still achieve levels lower than estimated in 2004;
- have no effect on the estimated median algal concentration; and
- slightly decrease the maximum algal concentrations in the lakes.

Final Scheme 5

Concerns expressed by several stakeholders regarding any modification of the existing outlet channel within the SEPP 14 wetland zone meant that consideration was given to a different outlet arrangement. Under this outlet configuration the existing outlet channel remains unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel. The second outlet channel would connect to a second existing drain located within the SEPP 14 wetland zone.

These two channels were represented as the existing channel width increased by 100% and the channel invert levels uniformly lowered by 0.05 m.

For comparison the impact on water quality in the saline lake of retaining the existing outlet channel unchanged without a second outlet channel was also assessed.

The results of the assessment of the retaining the existing outlet channel unchanged with and without a second outlet channel are compared with the original Scheme 5 results in **Table 16**.

It was concluded that the impacts of retaining the existing outlet channel unchanged would:

(i) significantly reduce the median salinity from around 14.0 mg/L under existing conditions to around 6.3 – 6.9 mg/L ie. the extended detention lake would become “fresher” and would experience a lower range of salinities;

(ii) increase the median DO from around 5.8 mg/L under existing conditions to around 7.1 mg/L

(iii) increase the median TP from around 0.004 mg/L under existing conditions to around 0.0047 – 0.0050 mg/L

(iv) increase the median TN from around 0.4 mg/L under existing conditions to around 0.42 – 0.43 mg/L

(v) slightly decrease the 95th percentile algal biomass from 0.0026 under existing conditions to around 0.018 mg/L

It was concluded that the impacts of retaining the existing outlet channel unchanged and constructing a second channel of equal width is constructed with invert levels that are uniformly 0.09 m lower than the existing channel would:

(i) achieve a median salinity of around 12.5 – 13.4 mg/L which is only slightly lower than the median salinity of around 14.0 mg/L under existing ie. the existing salinity regime in the extended detention lake would preserved;

(ii) increase slightly the median DO from around 5.8 mg/L under existing conditions to around 6.4 mg/L

(iii) increase the median TP from around 0.004 mg/L under existing conditions to around 0.0073 – 0.0077 mg/L (which is lower than estimated for the existing Scheme 5);

(iv) lower the median TN from around 0.4 mg/L under existing conditions to around 0.32 -0.34 mg/L

(v) slightly decrease the 95th percentile algal biomass from 0.0026 under existing conditions to around 0.0018 mg/L

It is concluded that on balance constructing a second outlet is preferable to retaining the existing channel (unmodified) only because the changes in water quality in the lake (in particular salinity and TN) that result from retaining the existing outlet only has the potential to adversely impact on the existing aquatic ecology and may even change the mix of fish species.

The proposed outlet configuration is to retain the existing outlet channel unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel.

Table 16
Estimated Lake Water Quality under Final Scheme 5 Developed Conditions

	Original Scheme 5		Existing Outlet Only		Final Scheme 5	
Channel Widening Factor	1.8		1.0		2.0	
Ave Lowering of Channel (m)	0.09		0.0		0.05	
Percentile						
Salinity	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.5	3.4	1.3	1.2	3.0	2.9
20%	7.9	7.6	3.1	2.8	6.9	6.6
50%	15.2	14.3	6.9	6.3	13.7	12.8
80%	25.1	23.7	12.2	10.8	23.1	21.6
95%	32.2	30.4	16.7	15.2	30.2	28.2
DO Bottom	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.6	3.6	4.4	4.4	3.7	3.8
20%	4.7	4.8	6.1	6.1	5.0	5.0
50%	6.2	6.2	7.1	7.1	6.3	6.4
80%	7.5	7.6	8.3	8.3	7.7	7.7
95%	8.5	8.5	9.0	9.0	8.6	8.6
DO % Saturation	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	51%	50%	54%	53%	52%	51%
20%	72%	71%	75%	74%	73%	71%
50%	82%	82%	85%	84%	83%	82%
80%	89%	89%	92%	92%	90%	89%
95%	94%	94%	97%	96%	95%	94%
TP	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.0028	0.0029	0.0009	0.0010	0.0022	0.0023
20%	0.0049	0.0052	0.0017	0.0019	0.0039	0.0043
50%	0.0081	0.0086	0.0047	0.0050	0.0074	0.0078
80%	0.0142	0.0147	0.0127	0.0134	0.0139	0.0148
95%	0.0251	0.0258	0.0252	0.0258	0.0256	0.0265
TN	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.18	0.20	0.31	0.33	0.20	0.21
20%	0.23	0.24	0.35	0.37	0.25	0.26
50%	0.30	0.32	0.42	0.44	0.32	0.34
80%	0.43	0.45	0.55	0.56	0.45	0.47
95%	0.63	0.65	0.73	0.75	0.66	0.67
Algal Biomass	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
50%	0.0011	0.0012	0.0010	0.0010	0.0011	0.0011
70%	0.0013	0.0013	0.0011	0.0011	0.0012	0.0013
90%	0.0016	0.0017	0.0014	0.0014	0.0016	0.0016
95%	0.0019	0.0019	0.0017	0.0018	0.0018	0.0019
100%	0.0052	0.0065	0.0049	0.0060	0.0053	0.0066

WSUD 1 Scheme with RWTs + Ponds
WSUD 2 Scheme without RWTs + Ponds

5. INTEGRATED WATER MANAGEMENT PLAN

The concept plan for the development of the Riverside at Tea Gardens site consists of a residential / mixed use precinct proposed for the majority of the site and a tourist and larger lot component located in the NE corner of the site. Substantial areas of the land are proposed to be protected and enhanced as open space / wildlife movement corridors, over and above those already protected in the Conservation Zone and the Wetland Zone.

The flooding, drainage and water quality objectives for the development could be met by either:

(i) Extending the existing detention lake (with increased tidal flushing) and constructing additional ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 3); or

(ii) Partially extending the existing detention lake ((with increased tidal flushing) and constructing additional freshwater lakes, ponds and/or wetlands, swales and a biofilter as appropriate (Scheme 5).

Discussions held with the NSW Department of Planning highlighted a number of concerns held by NSW Government stakeholder with concept Scheme 3. Consequently the preferred approach to integrated water management is based on Scheme 5.

The preferred development concept plan is provided in **Figure 6**.

5.1 Flooding & Drainage

It is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary of the development and then south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the proposed extended detention lake.

Four main drainage lines have been identified within the development. One of these drainage lines lies within the proposed open space corridor located on the northern boundary of the development. It is proposed to convey floodwaters down these drainage lines in wide, shallow swales.

It is proposed to integrate a major retarding basin into the open space corridor as well as to construct a local basin to reduce 100 yr ARI peak flows from the area of planned development that discharges directly to the Myall River (subcatchment N42) and to the Conservation Zone.

Under the preferred scheme the partial extension of the existing lake in combination with additional freshwater lakes and ponds will create additional active storage that will mitigate the increases in peak runoff up to the 100 yr ARI event due to the planned development.

A concept retarding basin has been also sized to manage runoff from an area of planned development that could discharge directly to the conservation zone (subcatchment N43) if required.

5.2 Water Quality

5.2.1 Temporary Controls

Sediment and erosion control measures will be implemented in the construction phases in accordance with the requirements of the current edition of the Managing Urban Stormwater – Soils and Construction (Blue Book) released by the NSW Department of Housing.

5.2.2 Permanent Controls

The stormwater treatment objectives and lake water quality objectives will be met by:

(i) Partially extending the existing detention lake to create a to a water body with a 8.0 ha water surface;
(ii) Constructing three cascading freshwater lakes upstream of the saline lake with a combined surface area of 6.55 ha;
(iii) Constructing a number of ancillary ponds (with a combined surface area of around 4.7 ha) to pre-treat runoff discharged to the freshwater lakes and the partially extended detention lake;
(iv) Constructing local wetlands to treat runoff from residential development discharging to the Myall River (subcatchment N42) or to the Conservation Zone (subcatchment N43), as well as
(v) Constructing a 440m swale along the eastern edge of the development (to distribute flow to the Conservation Zone).

It should be noted that experience to date in Tea Gardens has shown that there is little need to install GPTs as even sediment is highly controlled from the individual lots as part of a comprehensive Community Title arrangement that imposes strict controls on individual builders during construction

5.3 Maintenance Activities

5.3.1 Pond and Wetland Maintenance

The maintenance activities for the pond and wetland systems will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside at Tea Gardens and the Myall River Downs estate. The following maintenance activities are expected to be undertaken but may not be required at all times:

- Routine inspection of inlet and outlet points to identify any area of scour, litter build up and blockages;
- Inspection and removal of accumulated litter and debris from inlet and outlet structures (every 3 months);
- Periodic draining and desilting of the ponds (every 5 -10 years);
- Inspection and removal of noxious and invasive weeds from within the macrophyte zone (every 1-3 months during establishment phase);
- Replacement of plants that have died with plants of equivalent size and species (as needed);
- A macrophyte zone will need to be 'reset' every 20 to 50 years depending on the pollutant loading rate on the system.

Design attributes that will facilitate maintenance activities include:

- Inlet zone for the removal of coarse particulates;
- Provision of an access and entry point to the macrophyte zone for the periodic removal of accumulated material; and
- Access to outlet structure for routine inspections.

5.3.2 Lake Maintenance

The maintenance activities for the extended lake will be based on the practices already implemented for existing detention lake by contractors experienced in this type of work acting under instructions from the Community Association Manager. The maintenance activities generally include:

Maintenance activities for the lakes would involve:

- Inspection and removal of accumulated debris and litter from inlets and outlet structures;
- Inspection and removal of noxious weeds from within the water body;

- Inspection and removal of any vegetation that may invade the outlet channel to maintain the outlet capacity;
- Inspection and removal of accumulated sediment from inlet zones as needed.

Design attributes that will facilitate maintenance activities include:

- Provision of access to inlets and to the perimeter of the extended detention lake; and
- Provision of access to the outlet channel for routine inspections and removal of accumulated debris and/or invasive vegetation.

5.4 Management of Aquatic Weeds

The management of aquatic weeds in constructed pond and wetland systems and the extended detention lake will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside at Tea Gardens and the Myall River Downs estate and for the existing detention lake. Aquatic plants are inspected periodically to control pest species and to promote the desired mix of plants for conservation and landscape purposes.

The constructed Wetlands Manual defines an aquatic weed as a plant 'out of place' or a plant that interfere with the objectives of the wetland or its desired function.

Weed management in constructed wetlands is important to ensure that weeds do not out compete the species planted for the particular design requirements. This may also include some native species like Phragmites that naturally can appear in constructed wetlands and out-compete other more important planted species.

It is possible to minimise and control weeds by incorporating the following:

- Buying seed that is either known to be free of weeds or certified free of weed seeds, preventing weeds from being introduced;
- Timing activities to minimise weed germination;
- Applying pre-emergent herbicides;
- Manual removal; and
- Competition with a dense, health crop to crowd out potential weeds.

5.5 Management of Aquatic Species and Birdlife

Wetlands and lakes usually provide a sanctuary for waterbirds and other animals.

During the early stages of wetland establishment, water birds can be a major nuisance due to their habit of pulling out recently planted species. Interlocking planting systems (i.e. where the maintenance activities for the pond and wetland systems will be based on the practices already implemented for existing ponds and wetlands located within developed areas of Riverside at Tea Gardens and the Myall River Downs estate several plants are grown together in a single container such as 'floral edges') can be used, as water birds find it difficult to lift the interlocking plants out of the substrate unlike single plants grown in tubes.

Harris Research, 2007 also recommend that the 2002 recommendations for enhancing the amount and quality of aquatic habitats remain relevant and should be pursued, particularly with respect to increasing the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds (refer **Appendix H**, Report Appendix 3). These recommendations for optimising the quality of aquatic habitats, which are incorporated in current proposals to extend the lake area, include:

- Influencing the water-quality regime to increase habitat diversity and stability.
- Continuing effective management of the series of runoff-treatment ponds.
- Increasing variability of depth profiles by introducing physical structures such as submerged logs, rockwork or other artificial reefs
- Experimentally introducing indigenous submerged and emergent aquatic plants and planting littoral trees, shrubs and grasses and
- Introducing shoreline complexity in newly created waterway areas.

5.6 Monitoring Program

The proposed monitoring program is based on the monitoring program previously adopted in late 2003 for Precincts 7 and 8 of Riverside at Tea Gardens as follows.

5.6.1 SEPP 14 Wetland

The monitoring program for the SEPP 14 wetland is based on:

- The establishment of 3 transects in the vicinity of Precincts 7 and 8, perpendicular to the environmental gradient;
- Hand-auguring, small bore piezometers at intervals along the transects;
- Collecting further data on groundwater depth and salinity at each piezometer at regular intervals to supplement the data previously collected from Bores 3 and 6 (refer CPI, 1996a); and

- Undertake a quantitative plot based vegetation monitoring program to determine species composition, relative abundance and plant condition.

The timetable that was proposed was three monthly monitoring:

- immediately after construction (for 36 months),
- 5 years after the initial 3 years of monitoring (for 12 months), and
- 10 years after the initial 3 years of monitoring (for 12 months).

Comparison of post-construction data with the baseline dataset would generally be undertaken using non-parametric multivariate techniques, such as analysis of similarities (ANOSIM), which would provide a statistical assessment of whether changes had occurred.

Technical detail on methods would be provided in a methods statement in a baseline survey report to be submitted to Council within 3 months of the date of commencement.

Reports on the groundwater observations and vegetation monitoring would be provided after every 12 month period of monitoring.

5.6.2 Constructed freshwater Lakes, Ponds and Wetlands

The proposed monitoring program of both basin inflow and outflow is detailed in **Table 17**. It is proposed that the key stakeholders including the landowner, the Myall Quays Community Association, Great Lakes Council and DECC officers meet to review the outcomes of the monitoring program after three (3) years and to agree on the scope of any ongoing monitoring program and the timing of any subsequent review.

Table 17
Monitoring Program for Constructed Ponds and Wetlands (after HWR, 2001)

Parameter	Frequency	Test
Microbiological	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Water samples for laboratory analysis
Nuisance organisms	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Visual during storm events and water samples for laboratory analysis
Visual clarity & colour	Two (2) event monitoring periods per year. Storm event to be at least 15 mm with first flush to be targeted	In-situ analysis at time of sampling during storm events

pH	Two (2) event monitoring periods per year. Storm event to be at least 15 mm with first flush to be targeted	In-situ analysis at time of sampling during storm events
Toxic chemicals	In response to actual or potential toxic spills in Precincts 7 or 8.	Water samples for laboratory analysis
Surface films	Two (2) event monitoring periods per year. Storm event to be at least 15 mm with first flush to be targeted	Visual & smell at time of sampling during storm events
Phosphorus	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Water samples for laboratory analysis
Nitrogen	Two (2) event monitoring periods per year with a minimum of 4 samples during each storm event. Storm event to be at least 15 mm with first flush to be targeted	Water samples for laboratory analysis

The frequency of monitoring would be increased in the event of a potential pollution incident within a basin's catchment.

5.6.3 Extended Detention Lake

It is proposed to continue the current monitoring program of the existing detention lake for at least a further three years. This current program comprises sampling and testing of lake water at five sites (refer **Figure A.1**) at three monthly intervals. The parameters that are monitored include:

- pH
- Salinity
- Dissolved oxygen,
- Turbidity, Suspended Solids
- Oxidised nitrogen, ammonia, nitrates, nitrites, phosphate
- Chlorophyll 'a'

It is proposed that the key stakeholders including the landowner, the Myall Quays Community Association, Great Lakes Council and DECC officers meet to review the outcomes of the monitoring of the detention lake after three (3) years and to agree on the scope of any ongoing lake monitoring program and the timing of any subsequent review.

It is further proposed to:

- undertake 6-monthly algae testing/analysis including one (1) summer assessment;

- Undertake additional sampling and testing of lake water if more than 50 mm of rain falls in a two day period or less. Council requires no more than two (2) such sampling events per year.

5.7 Management Responsibilities and Actions

The responsibilities of various stakeholders are summarised in **Table 18**.

Table 18
Responsibilities of Stakeholders

Parameter	Management Action
Landowner	Responsible for preparing and submitting management plans in accordance with Council requirements. Responsible for implementing the approved Soil and Water Management Plan and for maintaining the effectiveness of all measures during the construction and building phases. Responsible for undertaking remedial actions to reinstate the effective operation of measures during the construction/building phase as may be directed by the Superintendent, Great Lakes Council and/or DECC (NSW EPA).
Contractors/ Builders	Responsible for implementing the approved Soil and Water Management Plan and for maintaining the effectiveness of all measures during the construction and building phases. Responsible for undertaking remedial actions to reinstate the effective operation of measures during the construction/building phase as may be directed by the Superintendent, Great Lakes Council and/or DECC (NSW EPA).
Myall Quays Community Association (Residents)	Responsible for the operations and maintenance of permanent stormwater management measures and the detention lake and undertaking any remedial actions to reinstate the effective operation of measures as may be directed by Great Lakes Council and/or DECC (NSW EPA).. Responsible for commissioning the SEPP 14 wetland monitoring program detailed above and submitting reports on the monitoring undertaken and the conclusions drawn at the end of each 12 month period. Responsible for commissioning a qualified agent to undertake post-construction monitoring of water bodies as detailed above. Reports are to be provided to Great Lakes Council at 3 monthly intervals. Each report is to provide details on the testing undertaken, including full results and will include an overview of water quality performance during the relevant period.

Great Lakes Council	Responsible for periodic review of soil and water management measures during the construction/building phase and the post-construction phase and issuing of directions to the appropriate stakeholder(s) to rectify any significant defects in the measures. Responsible for reviewing submitted reports on water quality and discussing any concerns regarding water quality trends with the Myall Quays Community Association and/or NSW EPA as appropriate.
DECC (NSW EPA).	Responsible for providing advice to Great Lakes Council on water quality issues that may be of concern to Council. Responsible for undertaking any site inspections that may be requested by Great Lakes Council in relation to water quality issues of concern.

As stated above it is proposed that the key stakeholders including the landowner, the Myall Quays Community Association, Great Lakes Council and DECC officers meet to review the outcomes of the monitoring of the constructed ponds and wetlands and the detention lake after three (3) years and to agree on the scope of any ongoing pond, wetland and lake monitoring programs and the timing of any subsequent review.

The management actions proposed to rectify any failures to meet the water quality objectives are set out in **Table 19**. These proposed actions have been adapted from HWR, 2001. In addition to these actions, if a potential pollution event (e.g. oil spill or chemical spill) occurs within the development, this event would trigger immediate sampling of the water bodies that may be affected for all water quality parameters, and the frequency of monitoring will be increased above that listed in **Table 17** until it is certain that any effect of the event has either been prevented from reaching the water body or has passed through the water body.

These measures should ensure that water discharged from the development does not impact upon the primary contact recreational condition of the Myall River.

Table 19
Management Actions to Address Failure to Meet Water Quality Objectives
(after HWR, 2001)

Parameter	Management Action
Microbiological	Search for and rectify potential human sources of bacteria such as sewerage overflows. If source of bacteria is found to be non human eg birds or animals then consult with Great Lakes Council and other stakeholders as appropriate regarding appropriate management actions.
Nuisance organisms	Check correlation between nuisance organisms and nutrient levels. If nutrient levels excessive, follow actions under 'Nutrients' below. If nutrient levels are not excessive, consider other actions that may include aeration and/or increased flushing.
Visual clarity & colour	Search for and rectify potential sources of turbidity and/or colour.
pH	Search for and rectify potential sources of acidity or basicity as appropriate.
Toxic chemicals	Implement measures to prevent future contamination from spill, etc.
Surface films	Search for and rectify potential sources of oils. Implement measures to prevent future contamination.
Phosphorus	Assess water body loadings by comparing input levels with output levels. If input levels are excessive, search for and rectify potential sources of phosphorus. If water body performance is unsatisfactory, enhance water body performance by redesign and/or other actions that may include aeration and/or increased flushing.
Nitrogen	Assess water body loading by comparing input levels with output levels. If input levels are excessive, search for and rectify potential sources of nitrogen. If water body performance is unsatisfactory, enhance water body performance by redesign and/or other actions that may include aeration and/or increased flushing.

6. QUALIFICATION

It is important to recognise that any modelling studies provide only an estimate of the predicted flood levels, flows, pollutant loads and/or treatment efficiencies. Although these estimates are based on the best data available at the time of writing, new data obtained in the future may lead to a revision of the estimates.

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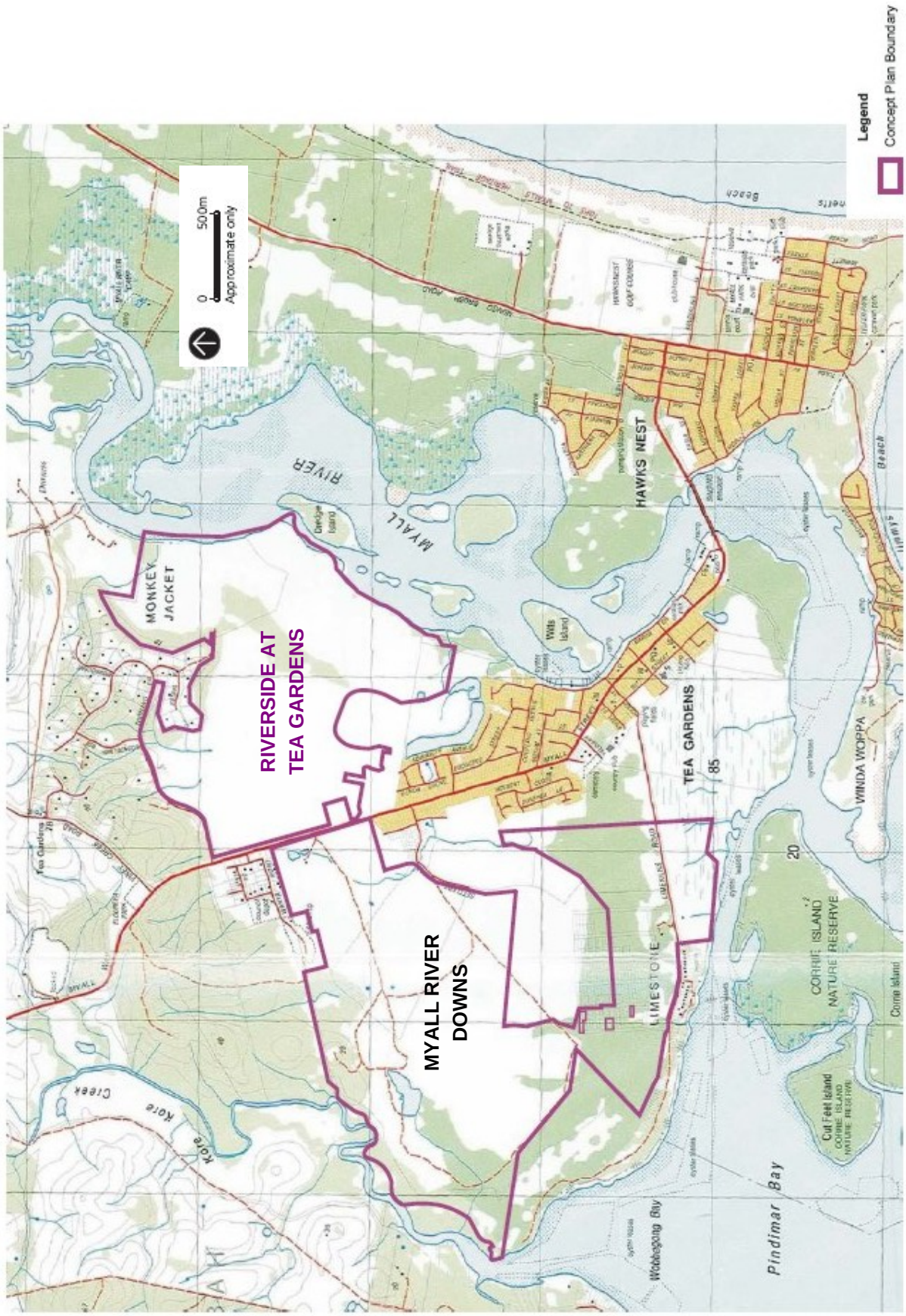


Figure 1
Locality Plan (after ERM, 2006)

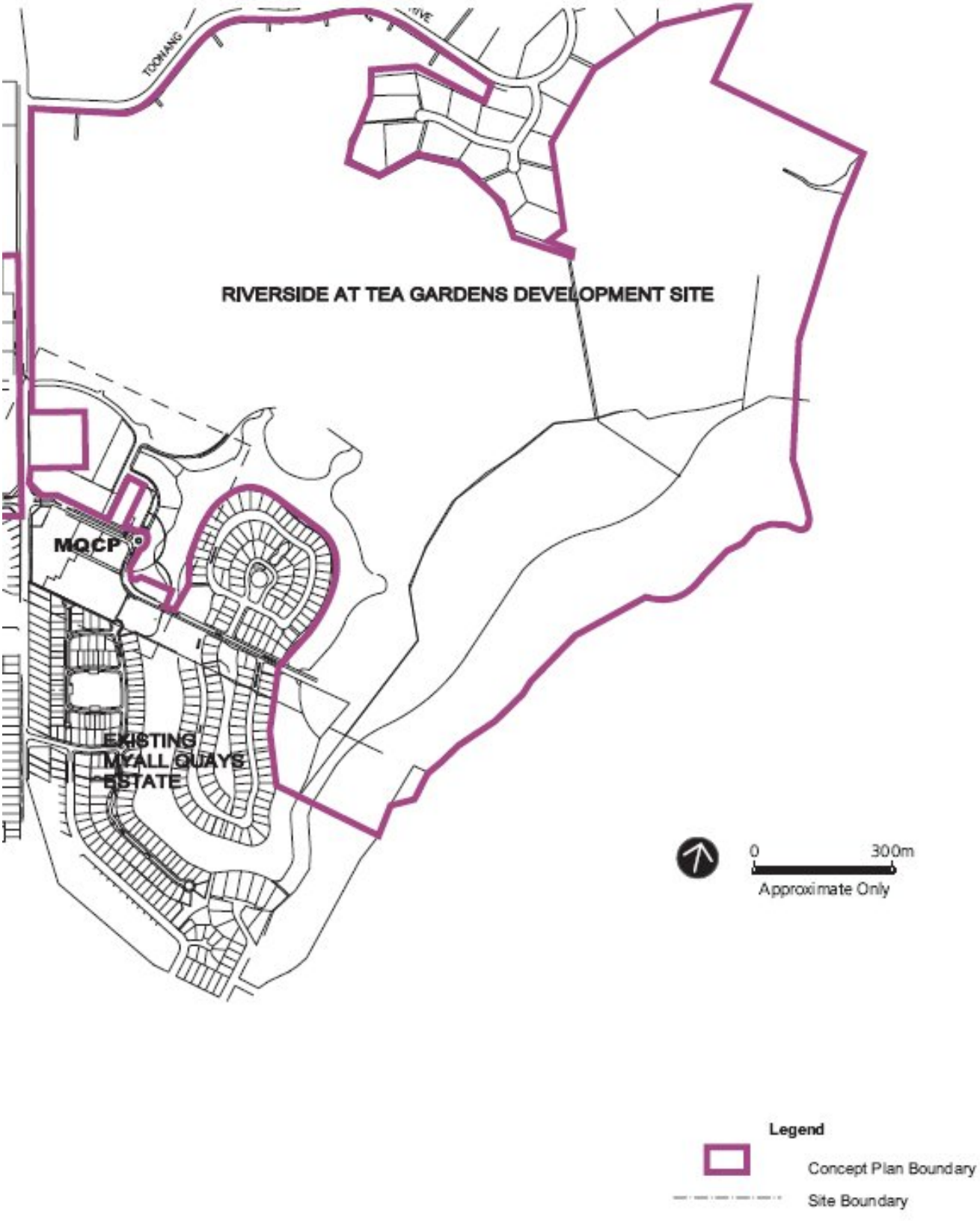


Figure 2
Riverside at Tea Gardens Site Plan (after ERM, 2006)

Figure 3
Aerial Photograph (after ERM, 2006)

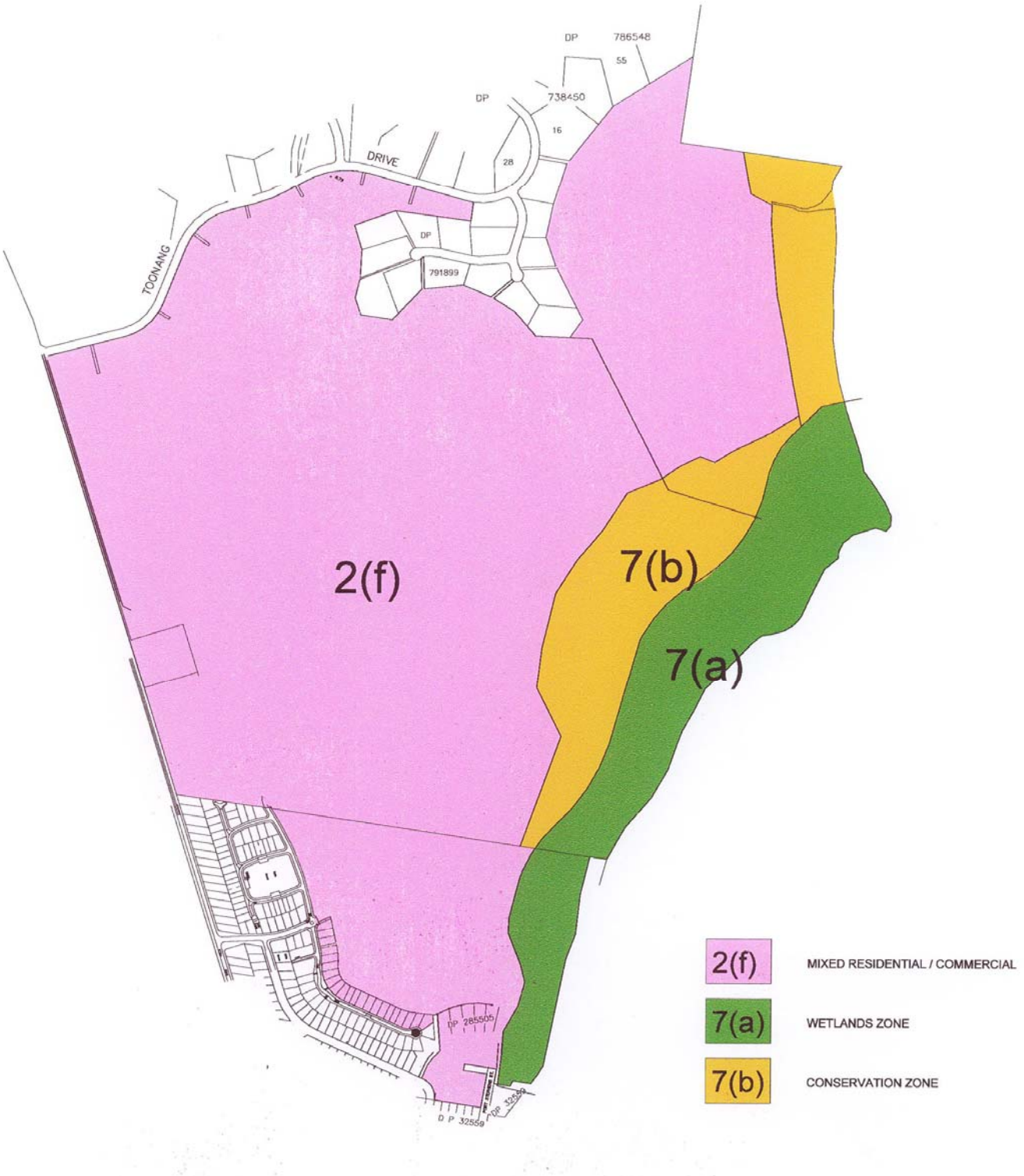
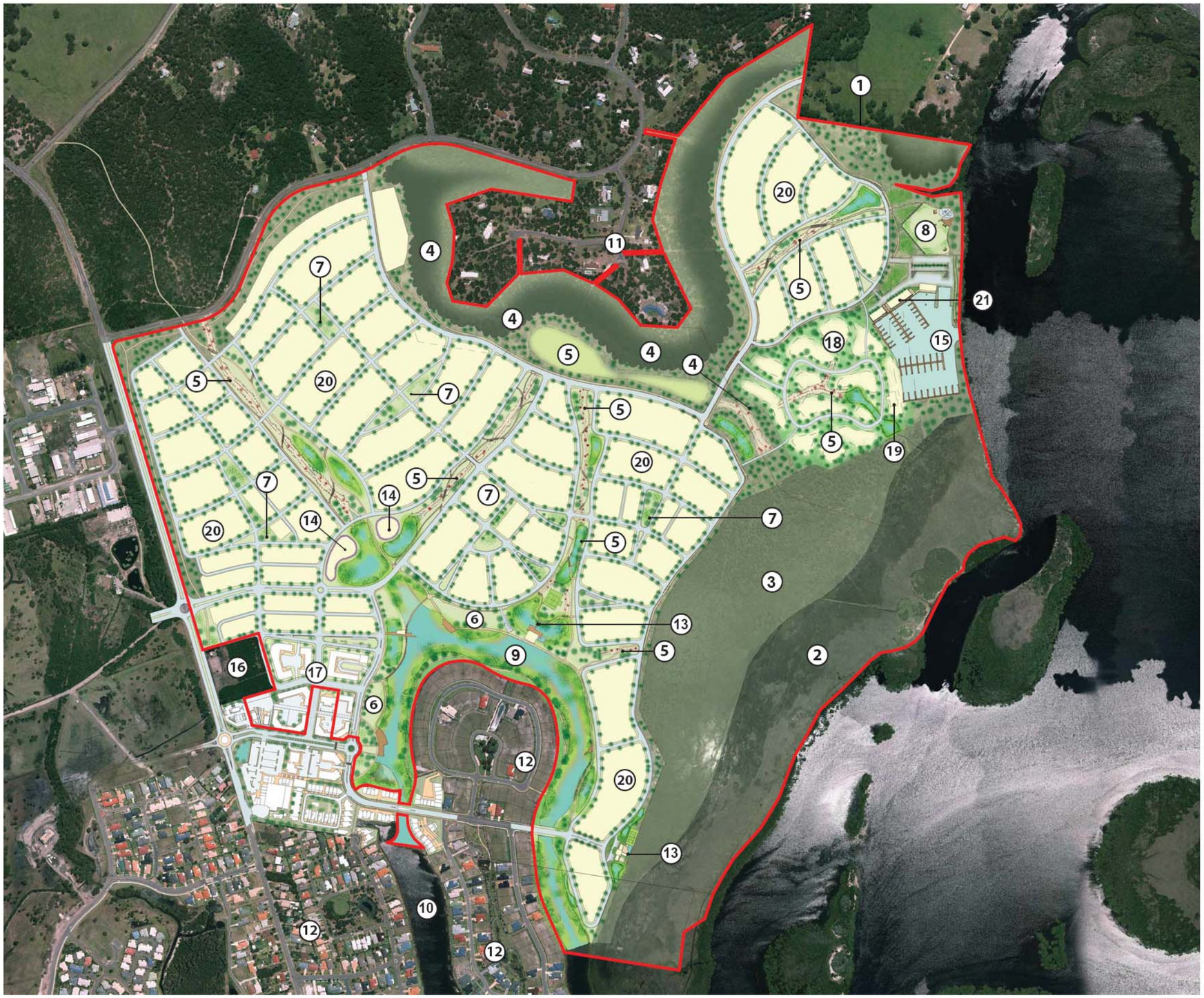


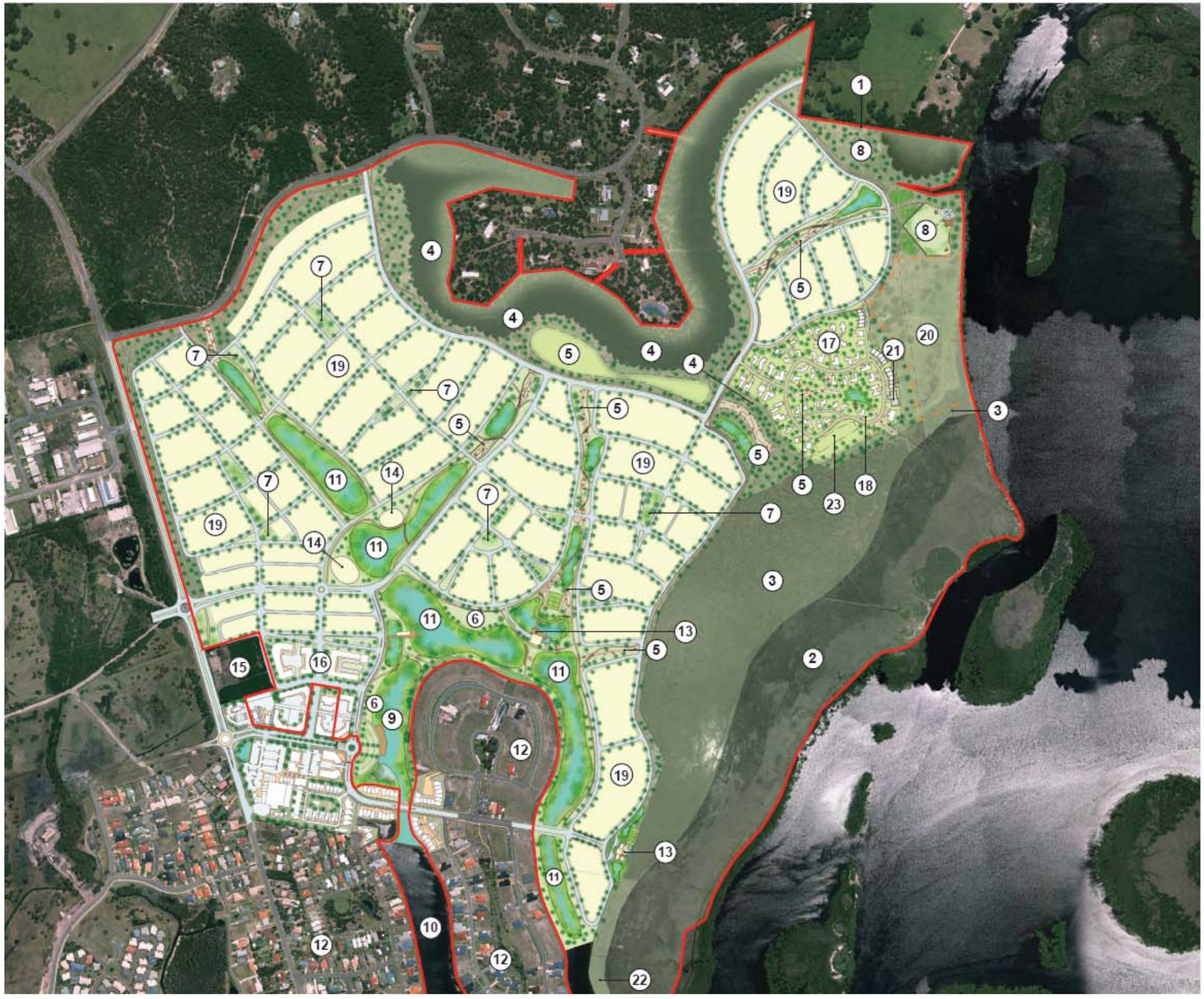
Figure 4
Riverside at Tea Gardens Zoning Plan



Item	Description
1	Extent of site holding 'Riverside' at Tea Gardens.
2	Existing 7(a) wetland zone.
3	Existing 7(b) buffer zone.
4	Wildlife movement corridor.
5	Water management & open space corridors.
6	Community parks incorporating walking/cycle ways, BBQ's, children's play area equipment.
7	Community pocket parks.
8	Myall foreshore park.
9	Extended lake area for water detention & water quality management (6.5 Ha).
10	Existing detention and water quality lake.
11	Existing rural residential estate 'Shearwater'.
12	Existing residential development.
13	Precinct community facilities.
14	Future precinct community facilities.
15	100 berth marina - including boat ramp.
16	Site area currently owned by Great Lakes Council
17	Extension of existing commercial precinct. Waiver received (Dept. of Planning).
18	Low density 'tourist lodgings'.
19	Conference & community facilities, associated low rise town house accommodation
20	Proposed residential lot development to be developed under community title.
21	Marina facilities buildings including office, chandlery, slip way, etc.

Land Use Legend		
Total Site	**Ha**	**%**
Open Space		
- Wetlands (zoned 7a)	24.4	11.2
- Wetland Buffer Zones (zoned 7b)	21.1	9.7
- Wildlife Corridors	27.3	12.6
- Myall Foreshore Park (incl parking)	7.6	3.5
- Drainage Corridors, Lake & Large Parks	35.1	16.1
- Pocket Parks	2.6	1.2
Total	118.1	54.3
Built Upon Area		
- Residential (including roads & community facilities)	83.6	38.4
- Tourist/Residential (Lodgings)	8.4	3.9
- Marina Basin and facilities	3.0	1.4
- Commercial Total	4.3	2.0
Total	99.3	45.7
Total	**217.4**	**100%**

Figure 5
Riverside at Tea Gardens Scheme 3 Concept Development Plan



Item	Description
1	Extent of concept plan area 'Riverside' at Tea Gardens.
2	Existing 7(a) wetland zone.
3	Existing 7(b) buffer zone.
4	Wildlife movement corridor.
5	Water management & open space corridors.
6	Community parks incorporating walking/cycle ways, BBQs, children's play area equipment.
7	Community pocket parks.
8	Myall foreshore park.
9	Extended lake area for water detention & water quality management (2.0 Ha).
10	Existing detention and water quality lake.
11	New fresh water water quality management & detention ponds.
12	Existing residential development.
13	Precinct community facilities.
14	Future precinct community facilities.
15	Site area currently owned by Great Lakes Council.
16	Extension of existing commercial precinct. Waiver received (Dept. of Planning).
17	Low density tourist residential lodgings.
18	Conference & community facilities, associated low rise town house accommodation
19	Proposed residential lot development to be developed under community title.
20	Future development site
21	Existing house
22	DCP buffer
23	Location of known midden & buffer

Land Use Legend		
Total Site	**Ha**	**%**
Open Space		
- Wetlands (zoned 7a)	28.4	12.4
- Buffer Zones (zoned 7b)	20.6	9.0
- Additional Conservation Buffer	1.4	0.6
- Wildlife Corridors	27.3	11.9
- Myall Foreshore Park	5.6	2.4
- Drainage Corridors, Ponds & Large Parks	35.1	15.4
- Pocket Parks	2.6	1.1
- Existing detention & water quality lake	6.7	2.9
Total	**127.7 Ha**	**55.7%**
Built Upon Area		
- Residential (including roads & community facilities)	83.6	36.5
- Tourist/Residential (Lodgings)	8.4	3.7
- Future Development Site	5.0	2.2
- Commercial/Retail	4.3	1.9
Total	**101.3 Ha**	**44.3%**
Total	**229.0 Ha**	**100%**

Figure 6
Riverside at Tea Gardens Scheme 5 Concept Development Plan

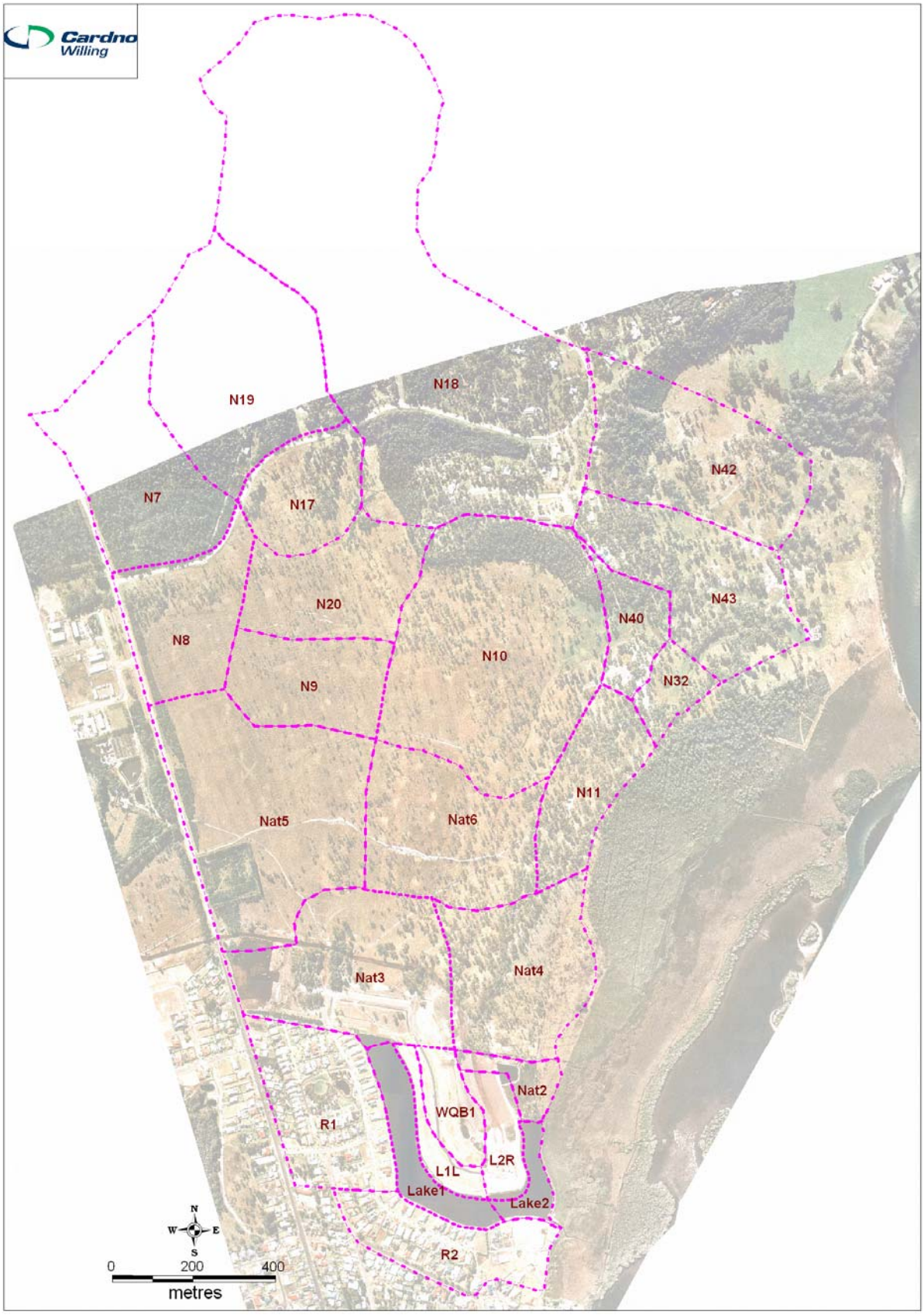


Figure 7
Catchment Layout - Existing Conditions

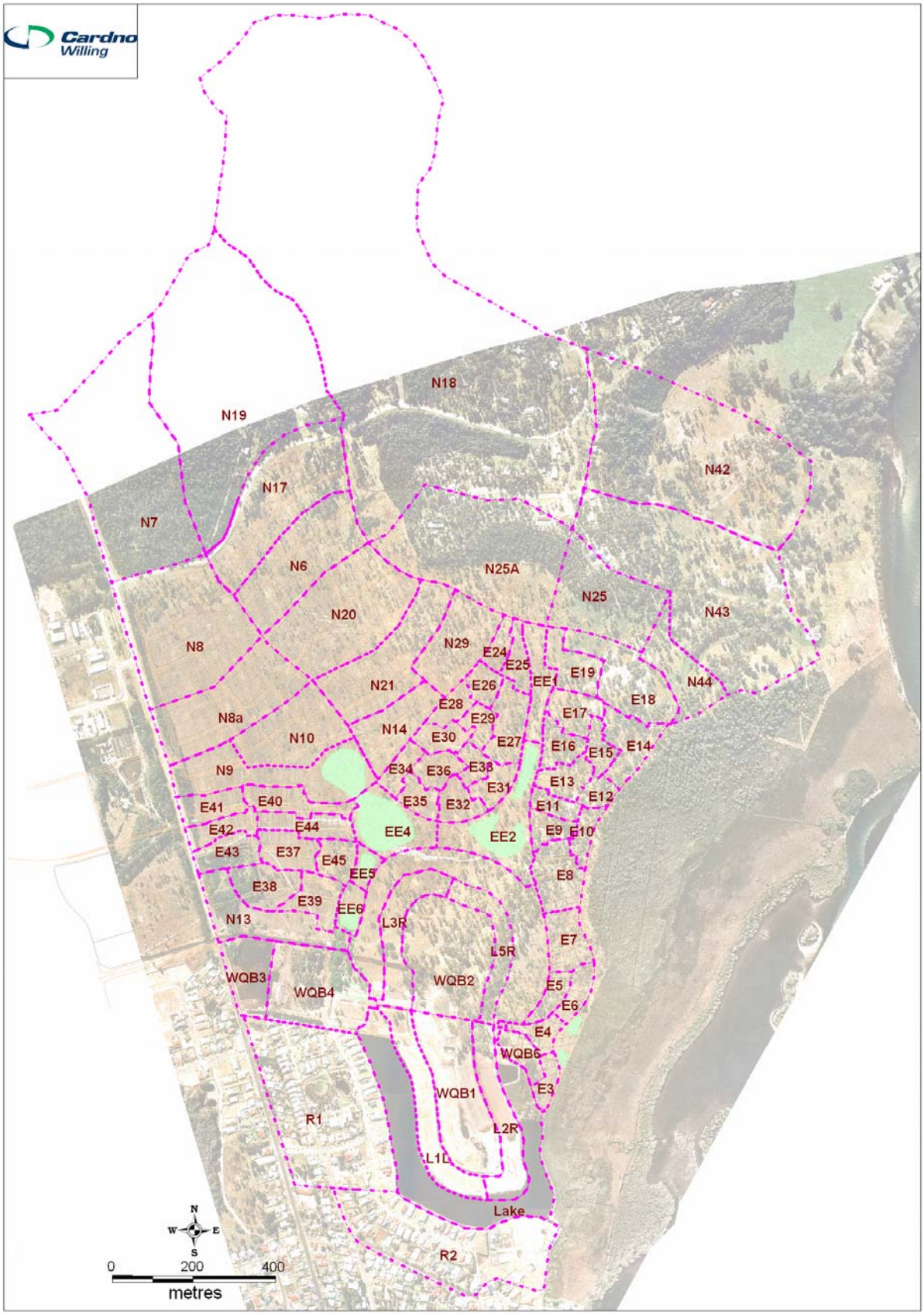


Figure 8
Catchment Layout - Developed Conditions

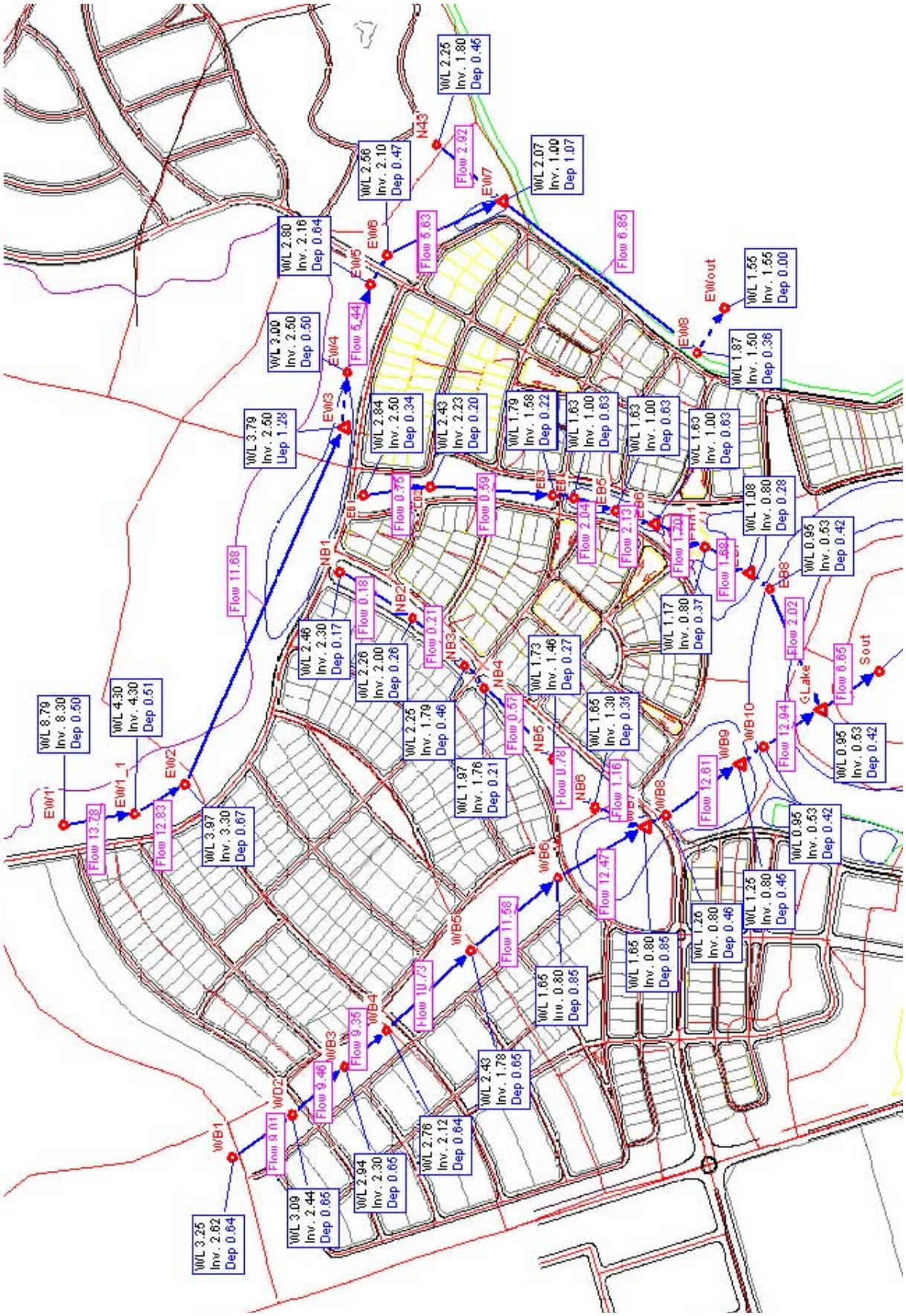


Figure 9

100 yr ARI Peak Flows, Flood Levels and Flood Depths for 1.5 hour Storm Burst – Scheme 3

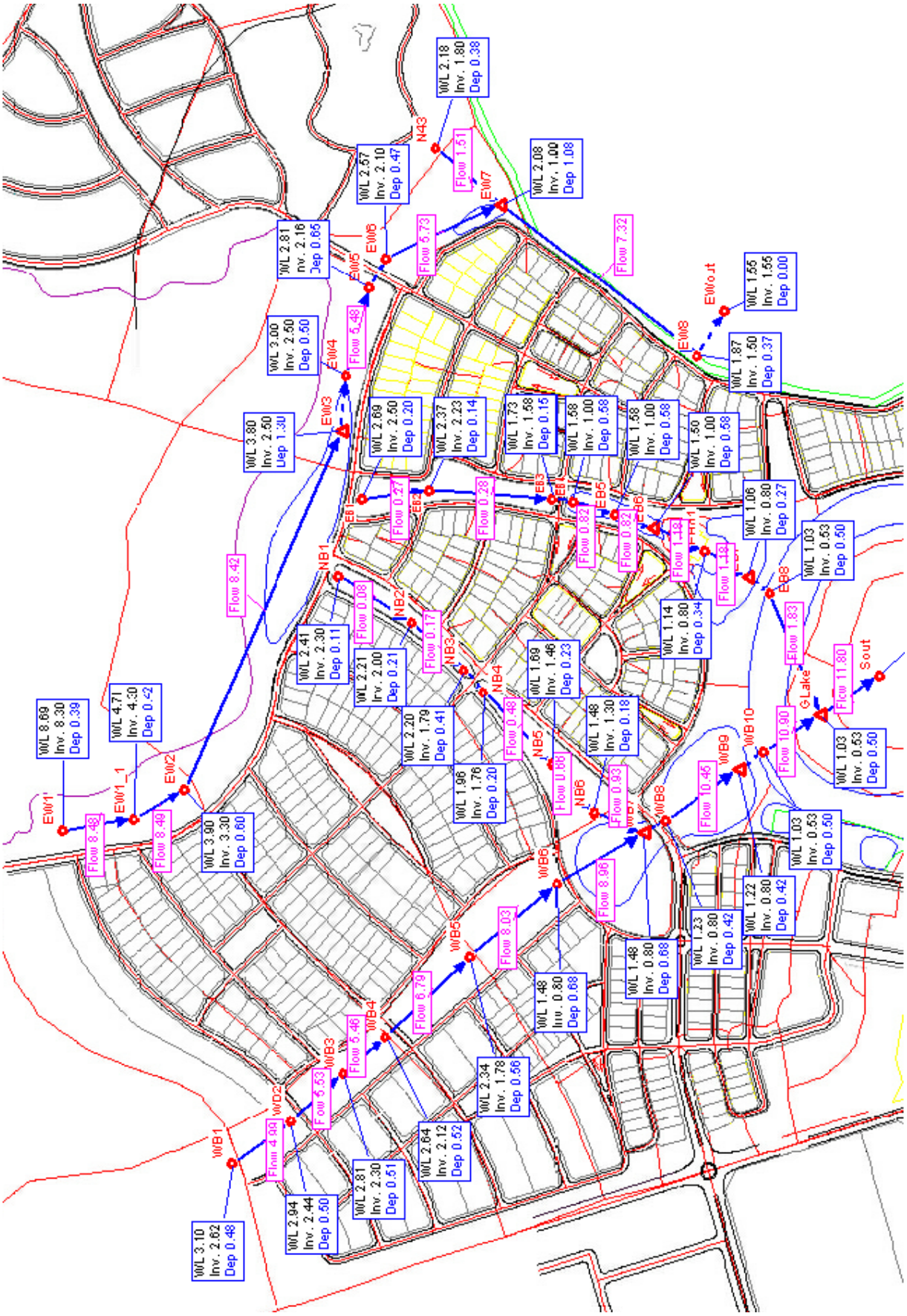


Figure 10

100 yr ARI Peak Flows, Flood Levels and Flood Depths for 9 hour Storm Burst – Scheme 3

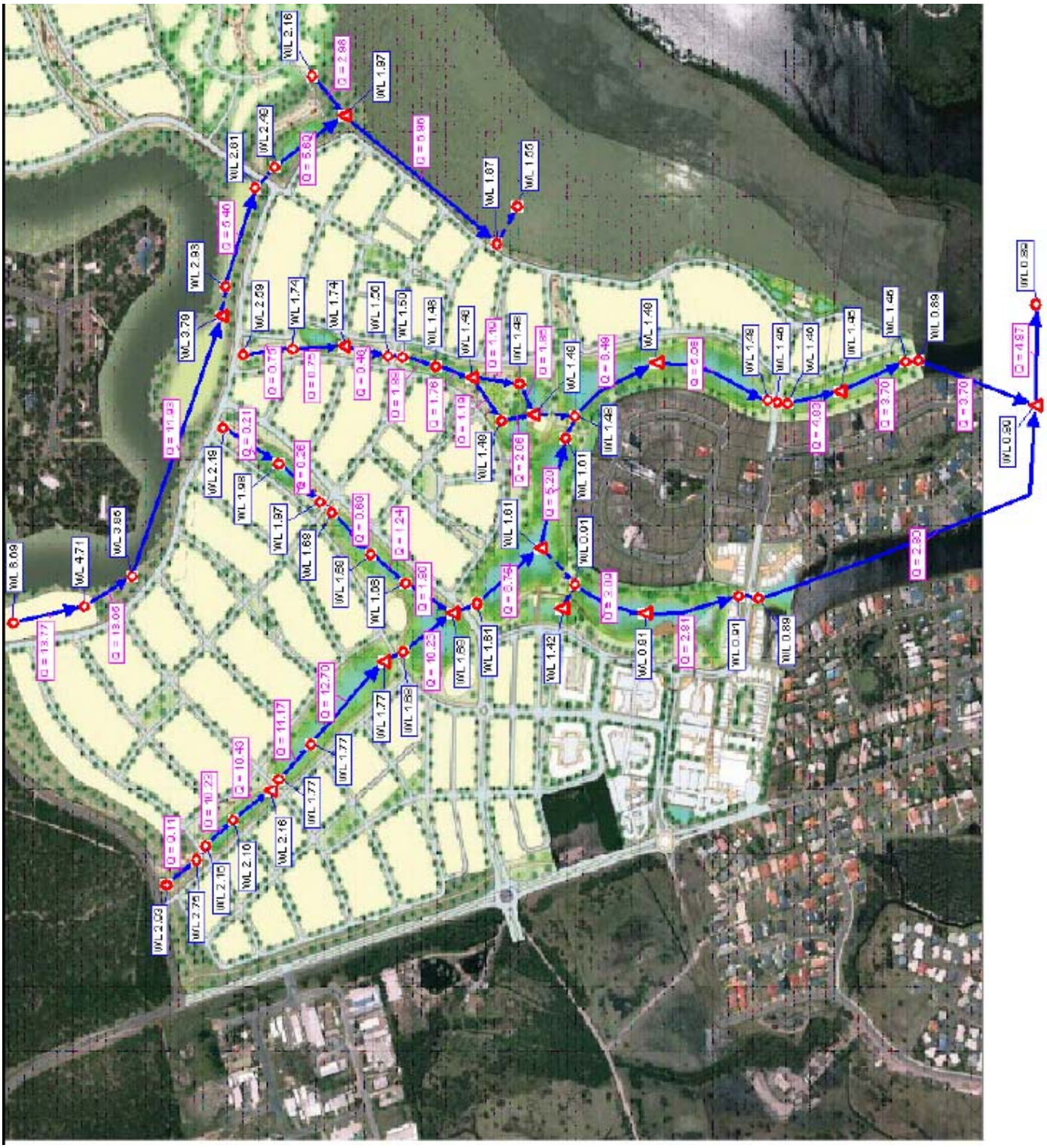


Figure 11
100 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst – Scheme 5

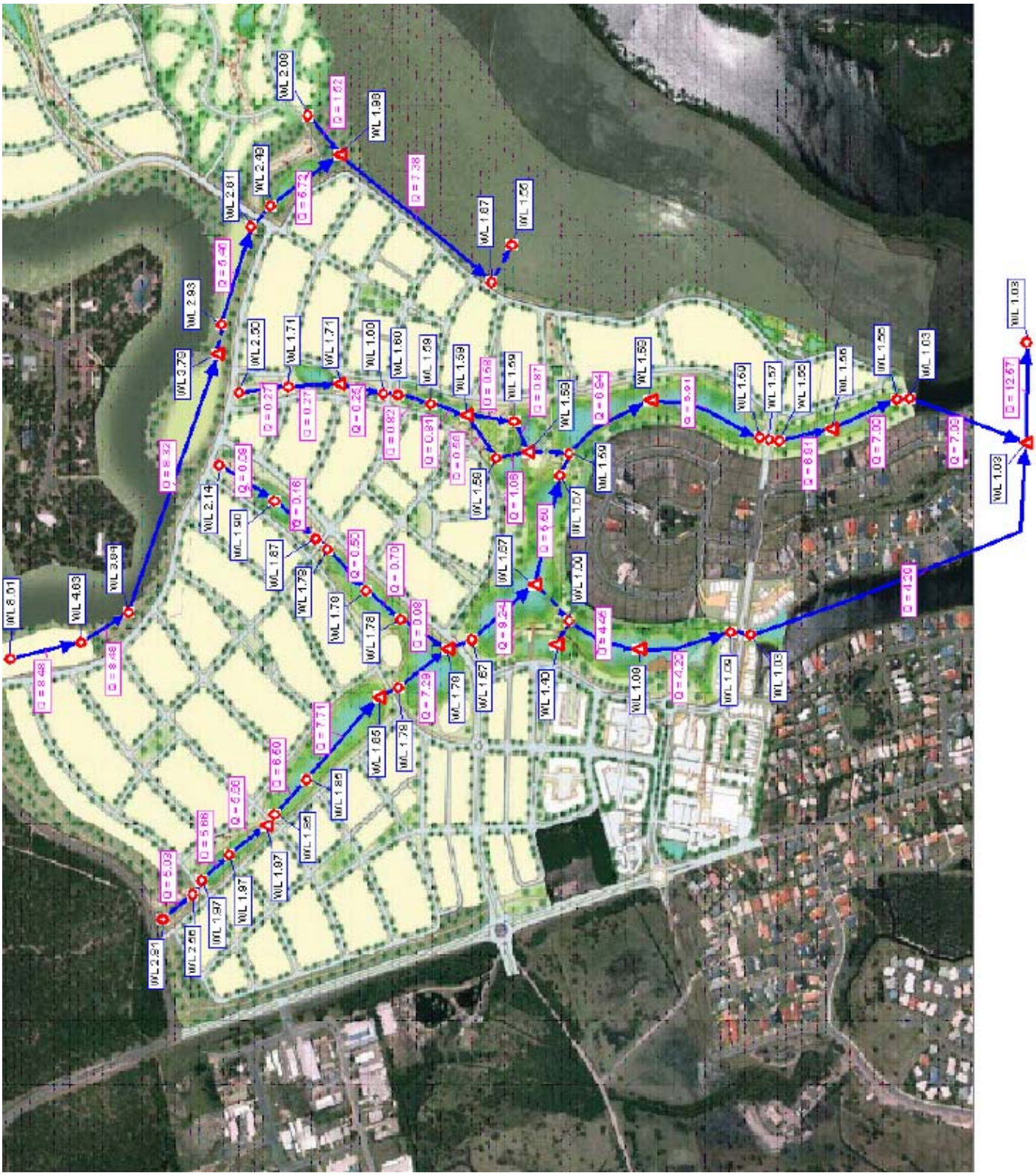


Figure 12
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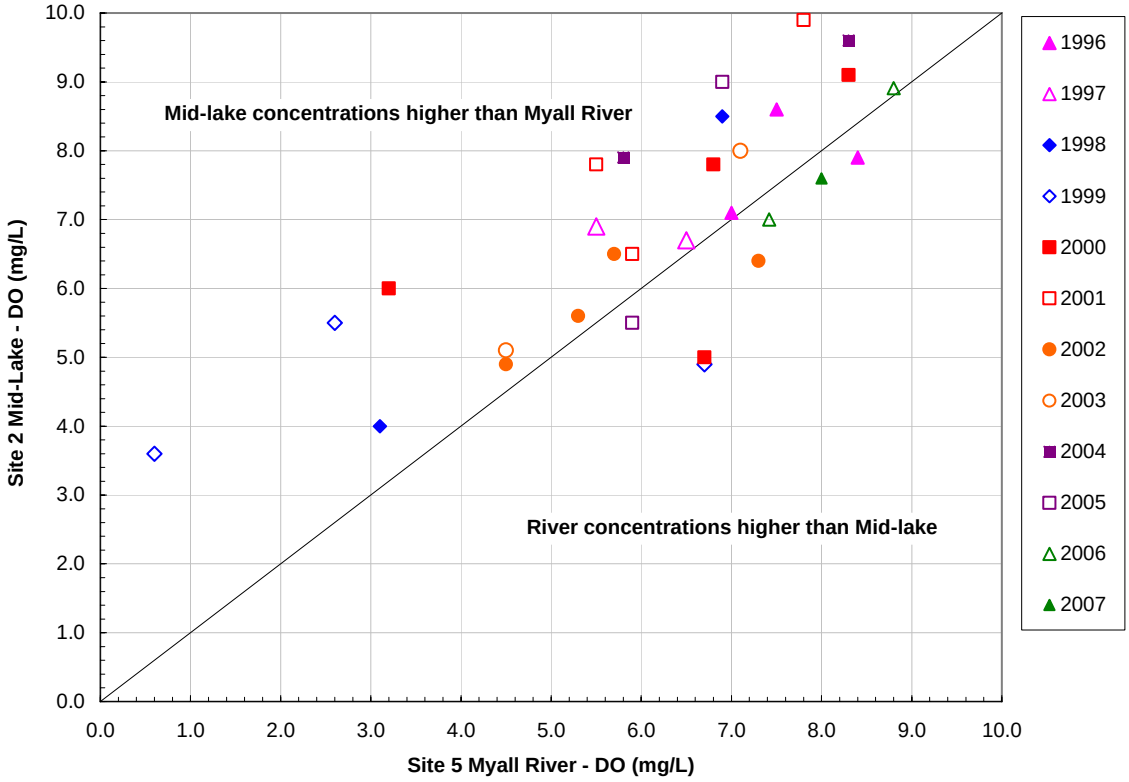


Figure 13
Comparison of DO Levels in the Existing Lake and the Myall River

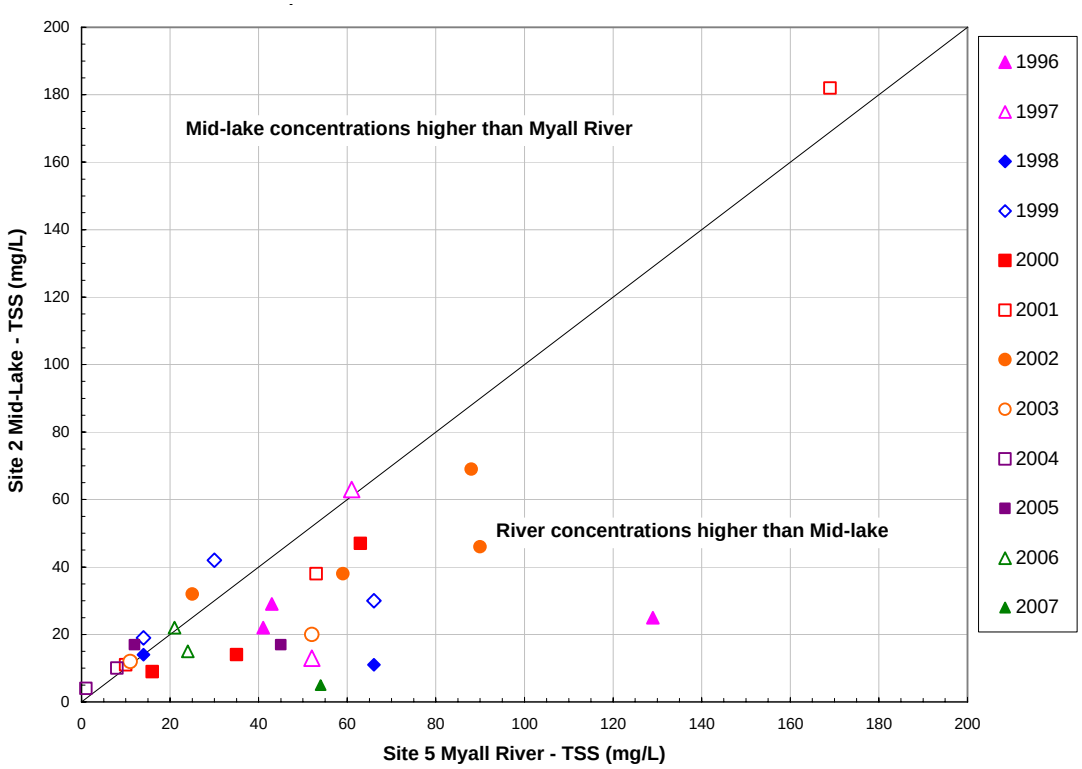


Figure 14
Comparison of TSS Levels in the Existing Lake and the Myall River

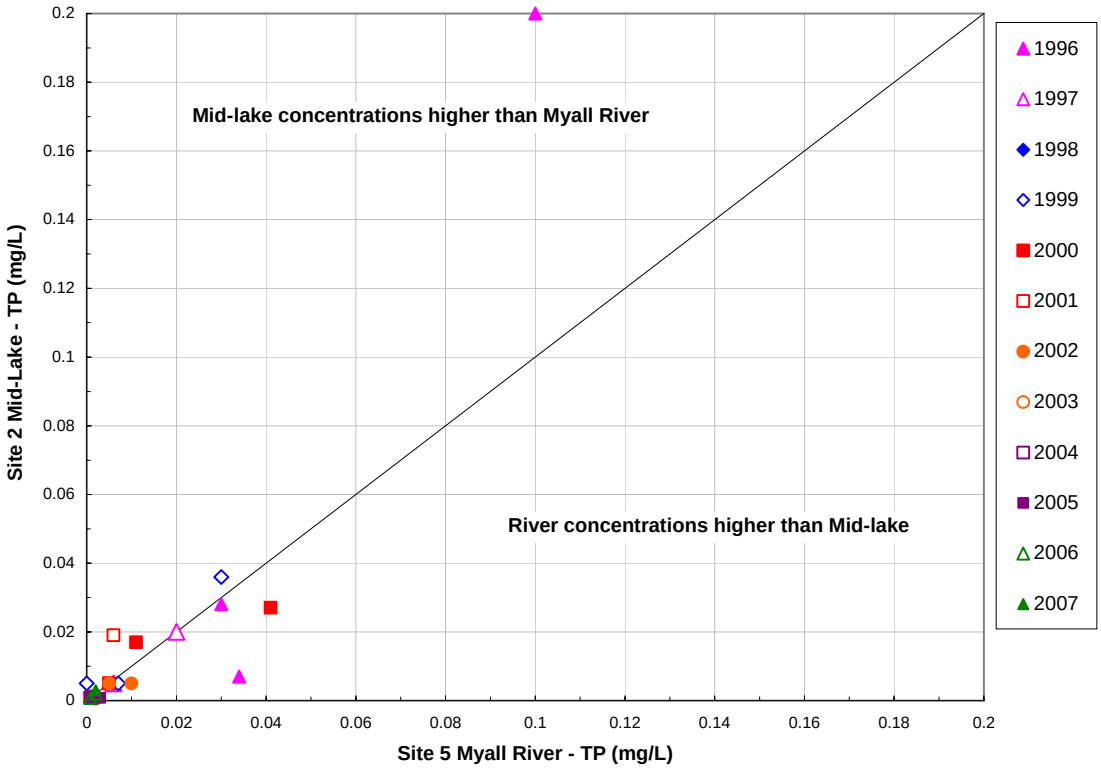


Figure 15
Comparison of TP Levels in the Existing Lake and the Myall River

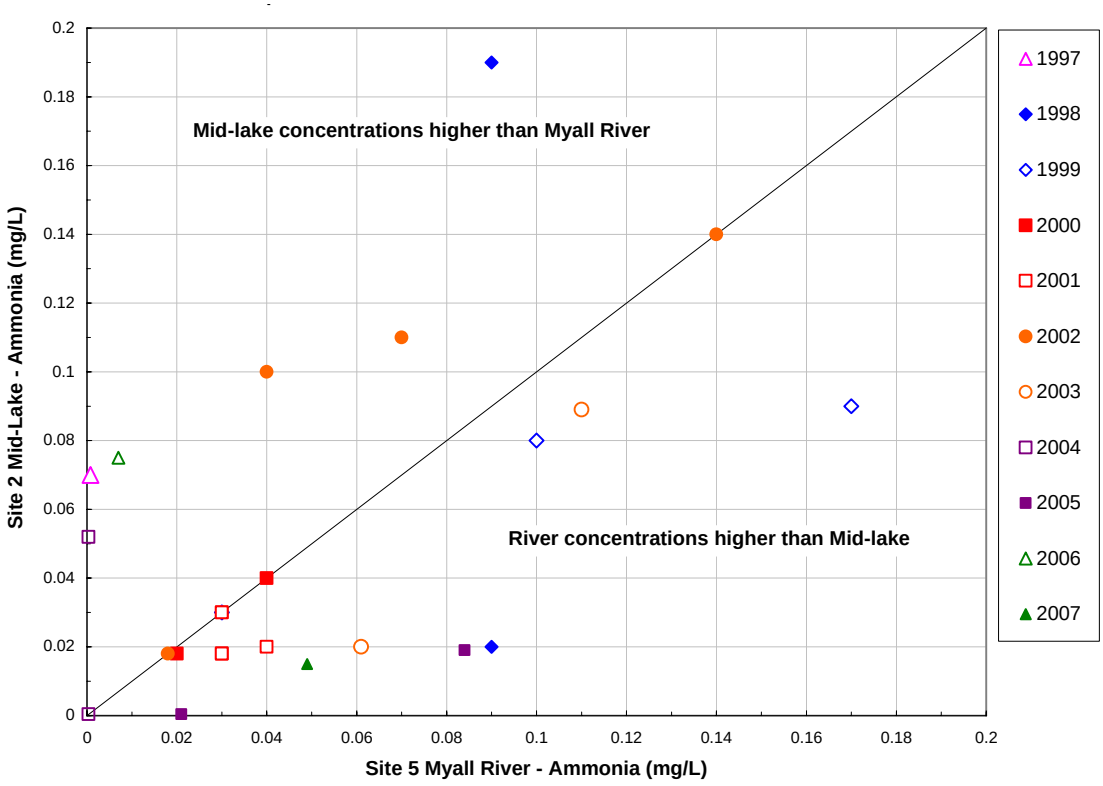


Figure 16
Comparison of Ammonia Levels in the Existing Lake and the Myall River

Cardno Willing

Shaping the Future

Riverside at Tea Gardens

Integrated Water Management

Appendices

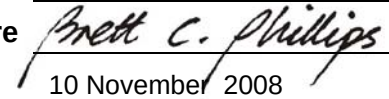
CRIGHTON PROPERTIES

NOVEMBER 2008 JOB NO. W4332-7

CRIGHTON PROPERTIES

Riverside at Tea Gardens
Integrated Water Management

Final Report
November 2008

Client	Crighton Properties			
Document	Riverside at Tea Gardens, Integrated Water Management, Appendices			
Status	Preliminary	☐	**Author**	Stephen Yu, Dr Shangyou Zhang
	Draft	☐	**Signature**	
	Draft Final	☐	**Date**	October 2008
	Final	■	**Reviewer**	Dr Brett C Phillips
	Superseded	☐	**Signature**	
	Other Specify	☐	**Date**	10 November 2008

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AVAILABLE INFORMATION

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A.3	**STREAMFLOW**	**A.3**
A.4	**MYALL RIVER TIDES**	**A.3**
A.5	**WATER QUALITY**	**A.3**

A.1 Rainfall

Daily Rainfall

Daily rainfall data was obtained from the Bureau of Meteorology station at Hawks Nest (Langi St) [Station 60123]. Although some daily rainfall data is available for the study catchment it does not yet cover a sufficiently long period.

The data covers daily rainfall record (March 1981 – present). The average annual rainfall recorded at Hawks Nest over 25 years (1982-2006) is 1,380.5 mm. In comparison, the long term (104 years) average annual rainfall recorded at Nelson Bay (Nelson Head) (Station 06154) is 1,347 mm.

Table A.1
Annual Rainfall at Hawks Nest (Langi St) (Station 060123)

Year	Rainfall (mm)	Comment
1982	1660	
1983	1289	
1984	1210	
1985	1484	
1986	1092	
1987	1292	50th %tile (median) year
1988	1571	
1989	1372	
1990	2524	
1991	1116	
1992	1543	
1993	918	
1994	1184	
1995	1134	
1996	1068	
1997	1524	
1998	1760	
1999	1670	
2000	1076	10th %tile (dry) year
2001	1712	90h %tile (wet) year
2002	1187	
2003	1385	Average year
2004	1298	
2005	1215	
2006	1228	

A summary of the recorded annual rainfall for the period 1/01/1982 to 31/05/2004 is given in **Table A.1**. The average rainfall year is 2003 (1,385 mm), the 10% dry year is 2000 (1,076 mm), and the 90% wet year is 2001 (1,712 mm).

Design Storm Bursts

The IFD data was generated based on the method outlined in Australian Rainfall and Runoff (Engineers Australia, 1999). The IFD coefficients utilised are shown in **Table A.2** while the estimated design storm burst rainfall intensities are given in **Table A.3**.

Table A.2
Design IFD Parameters for Tea Gardens

Parameter	Value
2 Year ARI 1 hour Intensity	36.9 mm/hr
2 Year ARI 12 hour Intensity	7.3 mm/hr
2 Year ARI 72 hour Intensity	2.3 mm/hr
50 Year ARI 1 hour Intensity	72.4 mm/hr
50 Year ARI 12 hour Intensity	14.4 mm/hr
50 Year ARI 72 hour Intensity	4.5 mm/hr
Location Skew	0.0
F2	4.32
F50	16.05

Table A.3
Design Rainfall Intensities (mm/h) for Tea Gardens

Duration (hrs)	Average Recurrence Interval (years)						
	1	2	5	10	20	50	100
0.5	42.06	54.05	69.21	77.95	89.52	104.61	116.06
1	28.65	36.9	47.52	53.67	61.79	72.4	80.47
1.5	22.14	28.52	36.74	41.51	47.79	56.01	62.26
2	18.37	23.67	30.5	34.46	39.68	46.51	51.7
3	14.08	18.15	23.39	26.43	30.44	35.68	39.67
4.5	10.86	13.99	18.04	20.39	23.48	27.53	30.62
6	8.92	11.5	14.83	16.76	19.31	22.64	25.18
9	6.89	8.88	11.45	12.94	14.92	17.49	19.45
12	5.66	7.3	9.42	10.65	12.28	14.4	16.02
18	4.43	5.71	7.36	8.32	9.59	11.25	12.5
24	3.72	4.79	6.17	6.97	8.03	9.41	10.47
48	2.38	3.06	3.95	4.46	5.13	6.01	6.68
72	1.79	2.30	2.96	3.34	3.84	4.50	5.00

Pan Evaporation and Potential Evapotranspiration (PET)

The available pan evaporation data was average monthly pan evaporation data collected at Williamstown Air Base. An evaporation multiplier of 0.85 was applied to the pan evaporation data to calculate the potential evapotranspiration (PET).

The adopted average monthly potential evapotranspiration (PET) for Tea Gardens is summarised in **Table A.4**.

Table A.4
Average Monthly PET for Tea Gardens

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Year**
PET	182	150	132	97	69	66	66	93	127	148	166	192	1487

A.3 Streamflow

There is no recorded streamflow data for the study area.

A.4 Myall River Tides

Tide data for the Myall River was obtained from CPI (1996b).

A.5 Water Quality

Since 1996 a water quality monitoring program has been undertaken by the developer, and lately by the Myall Quays Community Association. Hunter Water Laboratories is contracted to collect and analyse samples at 5 locations approximately every 3 months.

Sampling locations are shown on **Figure A.1**.

Initial testing involved the following parameters:

pH
salinity
turbidity
suspended solids
Kjeldahl nitrogen
Oxidised nitrogen
Phosphate
Faecal coliform
Ammonia#
Nitrates#
Nitrites#
Chlorophyll#
Dissolved oxygen

(# denotes testing commenced in November 1997)

The results are reported in Hunter Water Laboratories, 2002 and summarised together with subsequent sampling results for Sites 1 to 5 in **Tables A.5** to **A.9.**

Table A.5
Observed Water Quality at Site 1

Site 1 North East Corner Lake near drain out

Date	pH	Salinity	Turbidity N.T.U	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature °C	Nitrites mg/L as N
		g/kg	NTU	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	6.9	3.87	4	25	0.57	0.13	0.014	0	Not Tested	Not Tested	Not Tested	7.2	-	Not Tested
13/05/1996	7.3	4.37	3	33	0.36	<0.01	0.039	60	Not Tested	Not Tested	Not Tested	8.6	-	Not Tested
24/10/1996	7.3	15.60	2.4	38	1.2	0.05	0.200	4	Not Tested	Not Tested	Not Tested	6.8	-	Not Tested
31/01/1997	7.4	16.50	3.9	45	0.69	0.04	0.020	480	Not Tested	Not Tested	Not Tested	7.1	-	Not Tested
26/11/1997	7.7	7.22	4.3	13	-	0.01	0.005	2	0.06	<0.01	2.56	6.6	-	-
2/04/1998	7.5	12.76	1.4	28	-	0.05	0.005	58	0.05	0.05	9.61	6.9	-	-
23/11/1998	7.1	4.50	3.1	17	-	0.02	0.005	4	0.06	0.02	2.31	3.5	-	-
11/03/1999	7.4	12.90	1.1	20	-	0.14	0.007	2	0.08	0.14	2.78	4.8	-	-
9/06/1999	7	9.40	2.1	35	-	0.02	0.005	20	0.1	0.02	2.67	5.4	-	-
30/09/1999	7.5	6.20	1.1	34	-	0.01	0.029	12	0.05	0.01	2.72	7.3	-	-
19/01/2000	7.5	8.90	1.1	17	-	<0.01	0.011	0	<0.02	<0.01	1.37	6.3	-	-
27/04/2000	7.2	4.50	2.8	9	-	<0.01	0.031	91	<0.02	<0.01	11.3	6.0	-	-
19/07/2000	7.3	12.90	2.9	39	-	0.06	0.005	140	0.03	0.06	2.76	8.5	-	-
11/10/2000	7.4	16.30	2.8	47	-	<0.01	0.005	12	0.09	<0.01	2.14	4.0	-	-
25/01/2001	7.9	25.50	1.3	142	-	<0.01	0.013	1	0.03	<0.01	1.62	6.1	-	-
16/05/2001	6.8	4.70	2.3	12	-	0.04	<0.01	14	0.02	0.03	4.14	8.1	-	-
8/08/2001	7.1	8.20	0.6	15	-	<0.01	<0.01	0	0.03	<0.01	0.49	9.1	-	-
16/01/2002	7.6	22.80	1.9	98	-	0.01	<0.01	250	<0.02	<0.01	3.01	5.6	-	-
11/04/2002	7.5	21.10	2.8	29	-	0.03	<0.01	12	0.12	<0.01	3.78	6.6	-	-
12/08/2002	7.4	16.60	3	44	-	0.03	0.005	10.0	0.07	0.03	<1	7.3	15.6	<0.01
14/11/2002	7.6	19.10	0.5	19	-	<0.01	0.005	15.0	0.02	<0.01	1.01	5.4	22.7	<0.01
12/03/2003	7.4	15.00	0.8	13	-	0.007	0.001	33.0	0.088	<0.005	1.51	5.3	24.2	0.003
21/07/2003	7.1	8.40	1.4	32	-	0.11	0.004	3	0.005	0.01	2	7.4	13.5	<0.002
23/04/2004	7.3	6.90	1.3	5	-	0.012	0.002	15	0.023	0.007	<2.0	7	22	0.005
16/9/2004	7.7	12.80	0.8	1	-	<0.005	<0.001	2	0.012	<0.005	<2.0	9.4	15.9	<0.003
11/03/2005	7.5	14	1.8	12		0.007	<0.001	~155	0.005	0.007	<02	6.5	24.4	<0.003
14/11/2005	7.8	14.3	2	12		0.022	0.015	2	0.025	0.017	<2	8.3	24.8	0.004
30/06/2006	7.4	17.5	0.7	13		0.036	0.002	0	0.32	0.032	<2	6.64	12.7	0.004
19/10/2006	7.4	11.1	1.8	9		0.031	<0.001	1	0.23	0.028	<2.0	7.81	23.2	0.003
9/03/2007	7.5	9.1	2.3	10		<0.005	0.004	21	<0.005	<0.005	16	7.3	23.5	<0.003

- No data available

Table A.6
Observed Water Quality at Site 2

Site 2 Southern Corner Lake

Date	ph	Salinity	Turbidity N.T.U	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature C	Nitrites mg/L as N
		g/kg	NTU	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	6.9	3.38	4	25	0.57	0.13	0.007	0	Not Tested	Not Tested	Not Tested	7.1	-	Not Tested
13/05/1996	7.2	4.20	3	22	0.22	<0.01	0.028	60	Not Tested	Not Tested	Not Tested	8.6	-	Not Tested
24/10/1996	7.2	15.80	2.4	29	2.3	0.7	0.200	4	Not Tested	Not Tested	Not Tested	7.9	-	Not Tested
31/01/1997	7.8	22.80	5.8	63	0.78	0.03	0.020	144	Not Tested	Not Tested	Not Tested	6.9	-	Not Tested
26/11/1997	7.5	7.22	4.2	13	-	0.01	0.005	6	0.07	<0.01	2.26	6.7	-	-
2/04/1998	8	11.69	1.3	11	-	0.05	0.005	77	0.07	0.05	5.34	8.5	-	-
23/11/1998	7.1	4.60	3	14	-	0.02	0.005	12	0.07	0.02	2.77	4.0	-	-
11/03/1999	7.3	13.30	1.1	19	-	0.02	0.005	2	0.08	0.01	3.92	5.5	-	-
9/06/1999	6.7	9.70	4.7	42	-	0.01	0.005	27	0.08	0.01	2.67	3.6	-	-
30/09/1999	6.9	6.10	1	30	-	0.01	0.036	2	0.05	0.01	1.87	4.9	-	-
19/01/2000	7.1	8.80	1.5	14	-	<0.01	0.017	3	<0.02	<0.01	1.44	5.0	-	-
27/04/2000	7.4	4.40	3.2	9	-	<0.01	0.027	230	<0.02	<0.01	10.9	7.8	-	-
19/07/2000	7.2	13.60	1.7	47	-	0.02	0.005	180	0.04	0.02	1.41	9.1	-	-
11/10/2000	7.5	16.40	3.7	52	-	<0.01	0.005	7	0.04	<0.01	3.47	6.0	-	-
25/01/2001	7.9	25.60	1.4	182	-	<0.01	0.019	1	0.03	<0.01	1.37	6.5	-	-
16/05/2001	6.6	4.60	1.9	11	-	0.04	<0.01	18	0.02	0.003	3.42	7.8	-	-
8/08/2001	6.9	8.40	2.1	38	-	<0.01	<0.01	2	0.02	<0.01	0.97	9.9	-	-
16/01/2002	7.7	23.10	2.1	69	-	0.01	<0.01	330	<0.02	<0.01	2.56	5.6	-	-
11/04/2002	7.5	21.00	4.3	38	-	0.02	<0.01	32	0.09	<0.01	15.4	6.5	-	-
12/08/2002	7.2	17.60	1.4	46	-	0.02	0.005	43.0	0.07	0.01	1.09	6.4	15.5	0.01
14/11/2002	7.4	18.80	0.7	32	-	<0.01	0.005	5.0	<0.02	<0.01	<1	4.9	22.5	<0.01
12/03/2003	7.5	15.30	0.8	20	-	0.008	0.001	27.0	0.082	0.005	1.11	5.1	24.5	0.003
21/07/2003	6.9	8.70	2.2	12	-	0.11	<0.001	2	0.02	0.009	9.5	8.0	14.4	0.002
23/04/2004	7.3	7.30	1.3	10	-	0.012	0.001	14	0.026	0.007	3	7.9	22	0.005
16/9/2004	7.7	13.00	0.8	4	-	<0.005	<0.001	2	<0.005	<0.005	<2.0	9.6	16.1	<0.003
11/03/2005	7.4	14.2	1.8	17		0.007	<0.001	~155	<0.005	0.007	<2.0	5.5	24.3	<0.003
14/11/2005	7.8	14.8	1.4	17		0.021	<0.001	2	0.019	0.018	<2	9	24.8	0.003
30/06/2006	7.3	17.8	1.7	22		0.034	0.002	7	0.33	0.03	<2	7	13.2	0.004
19/10/2006	7.5	11.2	2.4	15		0.026	<0.001	3	0.075	0.026	2.1	8.91	23.7	<0.003
9/03/2007	7.3	9.1	1.7	5		<0.005	0.003	22	0.015	<0.005	13.9	7.6	23.9	<0.003

- No data available

Table A.7
Observed Water Quality at Site 3

Site 3 North Western Corner Lake

Date	ph	Salinity	Turbidity	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature C	Nitrites mg/L as N
		g/kg	N.T.U	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	6.8	3.64	3.9	29	0.66	0.13	0.012	0	-	-	-	6.9	-	-
13/05/1996	7.1	4.08	2.7	32	0.29	<0.01	0.022	40	-	-	-	8.3	-	-
24/10/1996	7.4	16.1	3.7	38	1.2	<0.03	0.100	<2	-	-	-	7.8	-	-
31/01/1997	7.3	16.1	2.7	24	0.72	0.04	0.020	720	-	-	-	7.5	-	-
26/11/1997	7.2	7.22	3.8	22	-	0.02	0.005	2	0.07	0.01	1.55	6.5	-	-
2/04/1998	7.8	11.52	1.4	30	-	0.09	0.005	83	0.19	0.09	5.07	8.3	-	0.01
23/11/1998	6.7	2.7	5.2	12	-	0.02	0.005	0.08	0.02	1.44		5.3	-	<0.01
11/03/1999	7.1	13.3	1.2	15	-	0.01	0.005	2	0.09	0.01	4.13	5.0	-	0.005
9/06/1999	7.1	10	1	40	-	0.01	0.000	10	0.08	0.01	2.14	6.7	-	0.002
30/09/1999	7	6.1	0.6	32	-	0.01	0.027	1	0.03	0.01	1.31	6.2	-	0.005
19/01/2000	7	8.8	1.1	10	-	<0.012	0.009	1	<0.02	<0.01	1.5	5.0	-	<0.003
27/04/2000	6.7	2.5	6.1	9	-	<0.01	0.036	9	<0.02	<0.01	6.73	5.9	-	<0.003
19/07/2000	7.3	14.3	2.5	46	-	0.02	0.005	110	0.03	0.02	1.51	9.8	-	<0.003
11/10/2000	7.3	16.3	3.7	51	-	<0.01	0.005	27	0.04	<0.01	2.14	6.1	-	0.003
25/01/2001	7.8	25.8	1.6	103	-	<0.01	0.032	0	0.02	<0.01	2.01	5.8	-	<0.003
16/05/2001	6.8	4.8	1.7	7	-	0.05	<0.01	31	<0.02	0.04	4.63	7.8	-	0.004
8/08/2001	7.3	8.5	1.1	14	-	<0.01	<0.01	29	0.03	<0.01	1.41	9.7	-	-
16/01/2002	7.5	21	4	66	-	0.01	<0.01	27	<0.02	<0.01	1.39	5.6	-	-
11/04/2002	7.5	21.1	3.4	39	-	0.03	<0.01	17	0.14	<0.01	7.12	6.5	-	-
12/08/2002	7.1	10.4	1.7	52	-	0.02	0.005	7.0	0.11	0.01	1.55	4.4	15.8	0.01
14/11/2002	6.9	11.2	70	48	-	0.01	0.050	~700	0.1	0.01	5.96	5.8	20.4	<0.01
12/03/2003	7.1	13.9	1.7	19	-	0.009	0.002	200.0	0.089	<0.005	1.83	5.5	23.5	0.005
21/07/2003	6.9	9	1.3	15	-	0.012	<0.001	10	0.02	0.01	3.1	6.1	15.7	0.002
23/04/2004	7.2	7.3	1.9	4	-	0.01	0.002	38	0.052	0.005	<2.0	6.8	22	0.005
16/9/2004	7.6	13	1.4	<1	-	<0.005	<0.001	3	<0.005	<0.005	<2.0	9.2	16	<0.003
11/03/2005	7.4	14.5	1.4	15		<0.005	<0.001	182	<0.005	<0.00	<2	5.7	25.4	<0.003
14/11/2005	14.7	7.6	2	15		0.026	<0.001	27	0.044	0.024	<2	6.2	24.8	<0.003
30/06/2006	7.2	18.3	2	18		0.026	0.002	33	0.32	0.23	<2	6.15	14.9	0.003
19/10/2006	7.3	10.4	4	14		0.018	<0.001	93	0.033	0.018	2.7	8.49	20.3	<0.003
9/03/2007	7.2	8.4	2.1	13		0.007	0.004	270	0.024	<0.005	13.5	7.1	22.9	0.004

- No data available

Table A.8
Observed Water Quality at Site 4

Site 4 Drain to river from Lake

Date	ph	Salinity	Turbidity N.T.U	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature C	Nitrites mg/L as N
		g/kg	NTU	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	6.9	3.53	4.8	42	0.66	0.13	0.012	0	-	-	-	7.1	-	-
13/05/1996	8.1	5.31	1.7	48	0.36	<0.01	0.032	120	-	-	-	7.8	-	-
24/10/1996	8.4	33.6	0.9	74	0.9	<0.03	0.200	12	-	-	-	8.0	-	-
31/01/1997	7.1	11.9	10.3	60	0.69	0.04	0.020	180	-	-	-	4.3	-	-
26/11/1997	8.2	37.3	1.3	6		<0.01	*0.005*	3	0.03	<0.01	1.81	5.9	-	-
2/04/1998	8.3	32.53	4.6	46		0.09	0.005	16	0.09	0.09	3.08	8.6	-	-
23/11/1998	7	3.1	8	20		0.04	0.005	32	0.08	0.04	11.2	6.1	-	-
11/03/1999	7.3	10.8	3.8	15		0.01	0.007	118	0.12	<0.01	6.88	2.4	-	-
9/06/1999	7.3	10.2	3.8	38		0.01	0.005	58	0.07	0.01	2.46	6.4	-	-
30/09/1999	7.9	16.3	4.1	78		0.01	0.017	6	0.03	0.01	6.22	6.3	-	-
19/01/2000	8.1	33.2	1.5	93		0.012	0.012	34	0.02	<0.01	1.21	6.4	-	-
27/04/2000	7.4	2.8	79	162		0.02	0.046	280	<0.02	0.01	30.3	6.9	-	-
19/07/2000	7.7	19.4	3.3	64		0.02	0.005	60	0.02	0.02	1.94	7.5	-	-
11/10/2000	7.8	32.3	5.3	97		<0.01	0.005	54	0.05	<0.01	3.42	4.3	-	-
25/01/2001	7.8	34.6	3.1	156		<0.01	0.020	3	<0.02	<0.01	2.22	5.7	-	-
16/05/2001	6.7	1.8	12	11		0.02	<0.01	60	<0.02	0.01	3.8	6.6	-	-
8/08/2001	7.8	14.3	3.5	37		0.04	<0.01	10	0.1	0.03	1.92	8.1	-	-
16/01/2002	7.3	23	3.2	89		0.17	<0.01	48	<0.02	0.16	0.99	5.3	-	-
11/04/2002	7.9	20.3	2.7	31		0.2	<0.01	73	0.3	<0.01	2.56	5.5	-	-
12/08/2002	8	30	1.7	70		<0.01	0.005	80	0.09	<0.01	1	7.0	17	<0.01
14/11/2002	7.7	35.8	3.2	24		<0.01	0.010	8	0.03	<0.01	2.46	3.9	22.1	<0.01
12/03/2003	7.3	26.6	6.8	53		0.007	0.001	530	0.1	<0.005	2.56	4.3	23.9	0.003
21/07/2003	7.2	8.8	1.4	19		0.007	<0.001	83	<0.005	0.007	1.4	7.0	14	<0.003
23/04/2004	7.8	15.1	1.8	9		<0.005	0.001	39	<0.005	<0.005	2.6	7.2	21.4	0.005
16/9/2004	8.1	22	2.7	6		<0.005	0.001	17	<0.005	<0.005	<2.0	8.4	16.1	<0.003
11/03/2005	7.9	32.8	1.8	3		<0.005	0.005	37	0.01	<0.005	<2.0	5.3	24.3	<0.003
14/11/2005	8	33.5	2	40		0.027	<0.001	6	0.023	0.026	<2	7.5	22.2	<0.003
30/06/2006	7.9	24.4	1	30		<0.005	0.004	13	0.44	<0.005	<2	7.28	14	<0.003
19/10/2006	7.7	14.5	3.1	14		0.007	<0.001	91	<0.005	<0.00	2	8.61	23.5	<0.003
9/03/2007	7.9	32.9	1.7	32		0.007	0.004	71	0.038	0.007	2	7.1	22.5	<0.003

- No data available

Table A.9
Observed Water Quality at Site 5

Site 5 Copeland Avenue Wharf

Date	ph	Salinity	Turbidity N.T.U	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature C	Nitrites mg/L as N
		g/kg	NTU	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	8.4	9.74	1.8	129	0.53	0.12	0.034	0	-	-	-	7.0	-	-
13/05/1996	8.2	5.48	1.6	41	0.69	<0.01	0.030	60	-	-	-	7.5	-	-
24/10/1996	8.3	35.6	1.6	43	1.2	0.06	0.100	2	-	-	-	8.4	-	-
31/01/1997	8.2	32.5	2.1	61	0.13	0.03	0.020	72	-	-	-	5.5	-	-
26/11/1997	8.3	38.7	2.1	52	-	0.01	0.006	3	<0.01	<0.01	6.5	6.5	-	-
2/04/1998	8.3	37.68	3.9	66	-	0.05	0.006	9	0.09	0.05	6.9	6.9	-	-
23/11/1998	6.9	2.4	5.6	14	-	0.06	0.006	126	0.09	0.06	3.59	3.1	-	-
11/03/1999	7.5	11.9	4	14	-	0.02	0.007	64	0.17	0.02	5.45	2.6	-	-
9/06/1999	7.5	9.2	3.1	30	-	0.06	0.000	58	0.1	0.06	3.04	0.6	-	-
30/09/1999	7.8	15.1	1.5	66	-	0.01	0.030	13	0.03	0.01	5.29	6.7	-	-
19/01/2000	8.1	33.6	1.8	35	-	<0.01	0.011	24	0.02	<0.01	1.47	6.7	-	-
27/04/2000	7.2	2.1	11.2	16	-	0.1	0.041	110	0.03	0.09	13.8	6.8	-	-
19/07/2000	7.7	20	3	63	-	0.02	0.005	30	0.03	0.02	1.06	8.3	-	-
11/10/2000	8.1	33.6	2.4	103	-	<0.01	0.005	7	0.04	<0.01	1.29	3.2	-	-
25/01/2001	8	34.6	2.6	169	-	0.01	0.006	4	0.04	<0.01	2.01	5.9	-	-
16/05/2001	6.7	1.4	9.2	10	-	0.03	<0.01	67	0.03	0.02	2.07	5.5	-	-
8/08/2001	7.8	14.5	2.2	53	-	0.04	<0.01	10	0.03	0.03	3.93	7.8	-	-
16/01/2002	8	33.3	1.4	88	-	0.01	<0.01	15	<0.02	<0.01	1.44	5.3	-	-
11/04/2002	8.1	30.3	1.6	59	-	0.02	<0.01	45	0.14	<0.01	1.53	5.7	-	-
12/08/2002	8.1	29.9	2.4	90	-	<0.01	0.005	10.0	0.07	<0.01	<1	7.3	16.6	0.01
14/11/2002	7.9	35.9	0.7	25	-	<0.01	0.010	7.0	0.04	<0.01	1.54	4.5	21.6	<0.01
12/03/2003	7.5	28.9	2.8	52	-	0.007	0.001	480.0	0.11	0.005	2.54	4.5	22.8	0.002
21/07/2003	7	2.7	2.1	11	-	0.038	0.002	11	0.061	0.029	2.3	7.1	14	0.009
23/04/2004	7.7	14.7	1.5	8	-	0.005	0.001	78	<0.005	<0.005	2.3	5.8	21.3	0.002
16/9/2004	8.1	23.9	2.2	<1	-	<0.005	0.001	13	<0.005	<0.005	<2.0	8.3	16	<0.003
11/03/2005	8.1	34.1	3.3	12		<0.005	0.003	19	0.021	<0.005	<2.0	5.9	23.3	<0.003
14/11/2005	8.1	34.8	2	45		0.031	<0.001	6	0.084	0.03	<2.0	6.9	21.7	<0.003
30/06/2006	7.9	24.4	1.1	21		<0.005	0.002	25	0.43	<0.005	<2.0	7.42	13.6	<0.003
19/10/2006	7.9	15.6	3.2	24		<0.005	<0.001	79	0.007	<0.005	2.3	8.8	22.8	<0.003
9/03/2007	7.9	33.4	2.1	54		0.007	0.002	-174	0.049	0.007	2	8	22.4	<0.003

- No data available

Figure A.1
Water Quality Sampling Site Locations

APPENDIX B

HYDROLOGY

B.1	AIMS	B.1
B.2	CATCHMENT MODEL AND PARAMETERS	B.1
B.3	EXISTING CONDITIONS	B.3
B.4	DEVELOPED CONDITIONS – SCHEME 3	B.4
B.4	DEVELOPED CONDITIONS – SCHEME 5	B.8

B.1 Aims

The aims of the hydrological analyses were to

- Assemble an **xprafts** rainfall/runoff model of the Riverside at Tea Gardens catchment;
- Estimate catchment runoff under existing catchment conditions as a benchmark for comparison with proposed development conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI event;
- Estimate catchment runoff under proposed development conditions; and
- If needed, size detention structure(s) to reduce the 100y ARI peak flow downstream of the proposed development areas to no greater than the 100 yr ARI peak flow under existing conditions.

B.2 Catchment Model and Parameters

Estimates of runoff from the Riverside at Tea Gardens catchment during design storms were obtained using the **xprafts** rainfall/runoff model.

Design Storm Bursts

The IFD data was generated based on the method outlined in Australian Rainfall and Runoff (Engineers Australia, 1999). The IFD coefficients utilised are shown in **Table B.1** while the estimated design storm burst rainfall intensities are given in **Table B.2**.

Table B.1
Design IFD Parameters for Tea Gardens

Parameter	Value
2 Year ARI 1 hour Intensity	36.9 mm/hr
2 Year ARI 12 hour Intensity	7.3 mm/hr
2 Year ARI 72 hour Intensity	2.3 mm/hr
50 Year ARI 1 hour Intensity	72.4 mm/hr
50 Year ARI 12 hour Intensity	14.4 mm/hr
50 Year ARI 72 hour Intensity	4.5 mm/hr
Location Skew	0.0
F2	4.32
F50	16.05

Table B.2
Design Rainfall Intensities (mm/h) for Tea Gardens

Storm Burst Duration (hrs)	Average Recurrence Interval (years)						
	1	2	5	10	20	50	100
0.5	42.06	54.05	69.21	77.95	89.52	104.61	116.06
1	28.65	36.9	47.52	53.67	61.79	72.4	80.47
1.5	22.14	28.52	36.74	41.51	47.79	56.01	62.26
2	18.37	23.67	30.5	34.46	39.68	46.51	51.7
3	14.08	18.15	23.39	26.43	30.44	35.68	39.67
4.5	10.86	13.99	18.04	20.39	23.48	27.53	30.62
6	8.92	11.5	14.83	16.76	19.31	22.64	25.18
9	6.89	8.88	11.45	12.94	14.92	17.49	19.45
12	5.66	7.3	9.42	10.65	12.28	14.4	16.02
18	4.43	5.71	7.36	8.32	9.59	11.25	12.5
24	3.72	4.79	6.17	6.97	8.03	9.41	10.47
48	2.38	3.06	3.95	4.46	5.13	6.01	6.68
72	1.79	2.30	2.96	3.34	3.84	4.50	5.00

The synthetic design storms were assumed to be uniformly distributed across the catchments. Considering the size of the study catchments an areal reduction factor was not applied.

Rainfall Losses

The rainfall losses adopted in the **xprafts** model in the current study are shown in **Table B.3**.

Table B.3
Adopted Rainfall Losses for xprafts Model

Surface Type	Initial Loss (mm)	Continuing Loss (mm/h)
Impervious	1	0
Clay soils	10	2
Loam soils	10	5
Sand soils	50	25

Imperviousness

The area of impervious and pervious surfaces within each subcatchment was based on the areas of roads, roofs and paving and areas of the three soil types present in a subcatchment.

Vector Average Slope

The vector average slope for each subcatchment was determined from available topographic maps or supplied survey. Values ranged from a nominal 0.5% for the flatter areas of the study area up to 10% in the steeper upper subcatchments.

Surface Roughness

For each subcatchment, a surface roughness was entered for each surface type. The adopted surface roughness values ranged from 0.025 to 0.06 depending on the surface type.

Hydrograph Routing

Simple lagging of hydrographs was adopted for the drainage lines. The time of travel (or lag) for each reach (link) was calculated as the length of the reach divided by an average velocity of flow.

B.3 Existing Conditions

The catchment of Riverside at Tea Gardens is bounded to the north by the ridge line of the ridge outcrop, and to the south-west by Myall Road. Riverside at Tea Gardens represents a major portion of the catchment. With the exception of the portion at the south of the site that has already been developed, there is little natural development of surface drainage features and as the surface soils are generally sandy such that a high level of rainfall infiltration to the groundwater system takes place. As a result, significant surface runoff is unlikely except during periods of high rainfall.

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. However a number of shallow drains have been previously constructed to convey runoff from the western areas of the site to the east to join with runoff from the eastern area of the site that flows east towards the SEPP 14 wetlands and the Myall River.

During wet periods, water ponds in low lying areas in the western and northern areas of the site.

The Riverside at Tea Gardens catchment was subdivided into 25 subcatchments ranging in size from 1.66 ha to 56.6 ha.

The subcatchment layout is presented in **Figure B.1**.

The existing condition model includes a shallow basin to represent depression storage and shallow ponding of runoff in low lying areas in the western and northern areas of the site. The flows in the shallow drains that convey runoff from the western areas of the site to the east is represented as a diversion link. This diversion link conveys frequent runoff up to around the 1 yr ARI flow (around 4 m^3/s) east towards the SEPP 14 wetlands and the Myall River.

Flows greater than the adopted threshold flow are split with 90% of flows in excess of the threshold flow discharging south to the existing detention lake and the remaining 10% of flows in excess of the threshold flow discharging east.

The active storage available in the existing detention lake and the existing lake outlet were also represented as a retarding basin in the existing condition model.

The estimated peak 100 yr ARI outflows from the Riverside at Teagardens site are summarised in **Table B.4**.

Table B.4
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Existing Conditions

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
EExtLake	5.3 *(9)*	9.8 *(9)*	17.1 *(2)*	Inflow to the existing detention lake
ESout	3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Outflow from the existing detention lake
ENout1	6.9 *(9)*	8.7 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zoned
EN42	0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

B.4 Developed Conditions – Scheme 3

B.4.1 Scheme 3 Developed Conditions

A model of future developed conditions was also assembled based on a detailed concept layout of planned future stages of the Scheme 3 development. In concept it is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary and then south east to swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the proposed extended detention lake.

The catchment was re-subdivided into 129 subcatchments to reflect the planned development. These subcatchments ranged in size from 0.5 ha to 63.9 ha.

The subcatchment layout for Scheme 3 development is presented in **Figure B.2**.

The active storage available in the proposed extended detention lake and a widened lake outlet were also represented as a retarding basin in the developed condition model.

The estimated peak 5 yr ARI, 20 yr ARI and 100 yr ARI outflows under Scheme 3 developed conditions (without ancillary retarding basins) are summarised in **Table B.5**.

Table B.5
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
Lake	24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Inflow to the extended detention lake
Lake	5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
N_out1	9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Aggregated flow to the Conservation Zone
N42	1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

B.4.2 Scheme 3 Developed Conditions with Basins

A model of future developed Scheme 3 conditions with retarding basins was also assembled based on a detailed concept layout of planned future stages of the development. In concept it is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary to a major retarding basin with outflows from the basin discharging south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. A separate basin was also sized to reduce peak flows from the area of planned development that discharges directly to the Myall River (subcatchment N42).

A concept retarding basin was also sized to manage runoff from an area of planned development that could discharge directly to the conservation zone (subcatchment N43).

Basin Properties

Concept basin sizes and outlet configuration were sized iteratively. In the case of Basin EW the aim was to either:

(i) limit the 100 yr ARI peak discharge to the Conservation Zone under developed conditions to no greater than the existing peak 100 yr ARI discharge to the Conservation Zone, or to
(ii) limit basin outflows to around 6 m^3/s based on the feasibility of constructing a waterway through rising ground to the east of the concept basin wall.

It was found that the latter aim controlled the basin size.

In the case of Basins N42 and N43 the aim of the basins was to limit 100 yr ARI peak flows to no greater than the 100 yr ARI peak flow under existing conditions.

The concept basin properties are summarised as follows:

Basin	Surface Area (ha)	Concept Outlet
EW	2.7	2 x 1.8 (W) x 0.6 (H)
N42	0.47	2 x 750 Diam RCP
N43	0.44	2 x 750 Diam RCP

The concept grading of Basin EW is as follows:

Level (m AHD)	Surface Area (ha)	Comment
2.5	0.45	Approx 0.5 m cut
3.0	1.11	Less than 0.5 m cut
3.5	1.95	Existing contour
4.0	2.64	Existing contour

Results

The estimated peak basin water levels for 20 yr ARI, 50 yr ARI and 100 yr ARI events are summarised in **Table B.6**.

The peak basin outflows and resulting peak discharges to the Conservation Zone under developed conditions are summarised in **Tables B.7** and **B.8**.

Table B.6
Estimated Peak Basin Water Depths

Basin	5 yr ARI	20 yr ARI	100 yr ARI
EW	0.97	1.22	1.58
N42	0.55	0.79	0.92
N43	0.53	0.78	0.87

Table B.7
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basins EW and N42

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
Lake	24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Inflow to the extended detention lake
Lake	5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
ESout	3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Existing outflow from the existing detention lake
EW	9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Inflow to Basin EW
EW	1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Outflow from Basin EW
N_out	5.5 *(9)*	7.1 *(9)*	9.0 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
ENout1	6.9 *(9)*	8.7*(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions
N42	1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Inflow to Basin N42
N42	0.55 *(9)*	0.83 *(9)*	1.25 *(9)*	Outflow from Basin N42
EN42	0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Existing outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

Table B.8
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basin N43

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
N43	1.4 *(1.5)*	1.9 *(1.5)*	2.4 *(1.5)*	Inflow to Basin EW
N43	0.53 *(9)*	0.77 *(9)*	1.2 *(9)*	Outflow from Basin EW
EN43	0.51 *(9)*	0.77 *(9)*	1.2 *(9)*	Peak runoff under existing conditions
N_out	5.4 *(9)*	6.8 *(9)*	8.8 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
ENout1	6.9 *(9)*	10.9 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

B.5 Developed Conditions - Scheme 5

Subsequent to discussions held with the NSW Department of Planning regarding NSW Government stakeholder concerns regarding the concept Scheme 3 development a concept development based on Scheme 5 was investigated in detail.

The model of future developed Scheme 3 conditions with retarding basins was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5. Under the Scheme 5 concept it is also proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary to a major retarding basin with outflows from the basin discharging south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the a series of ponds and freshwater lakes that will discharge into the proposed extended detention lake.

The 5 yr ARI, 20 yr ARI and 100 yr ARI hydrographs under Scheme 5 developed conditions were estimated and input into the hydraulic model of the Scheme 5 development to estimate peak outflows from the detention lake as well as the 5 yr ARI, 20 yr ARI and 100 yr ARI flood levels.

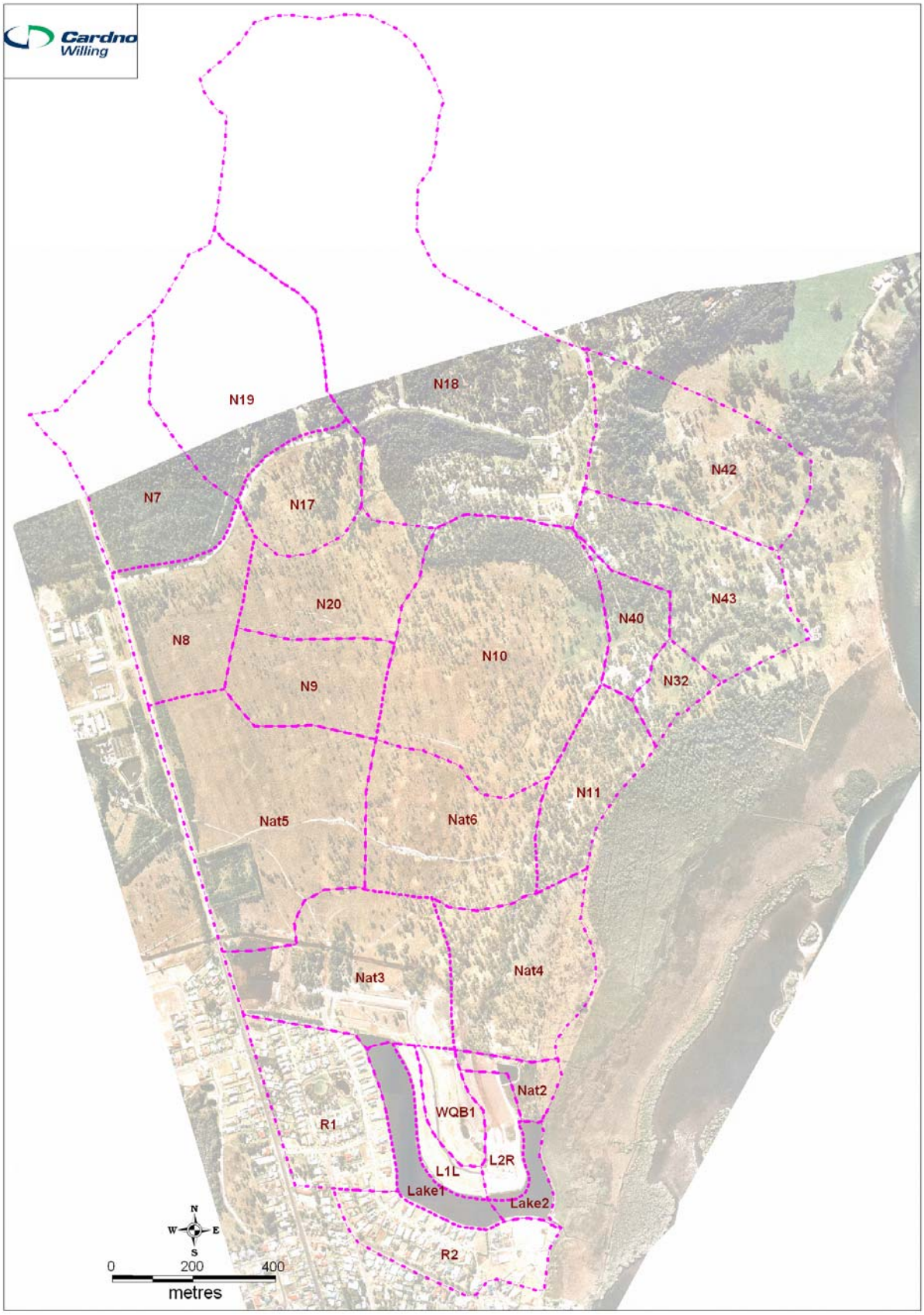

Figure B.1
Catchment Layout - Existing Conditions

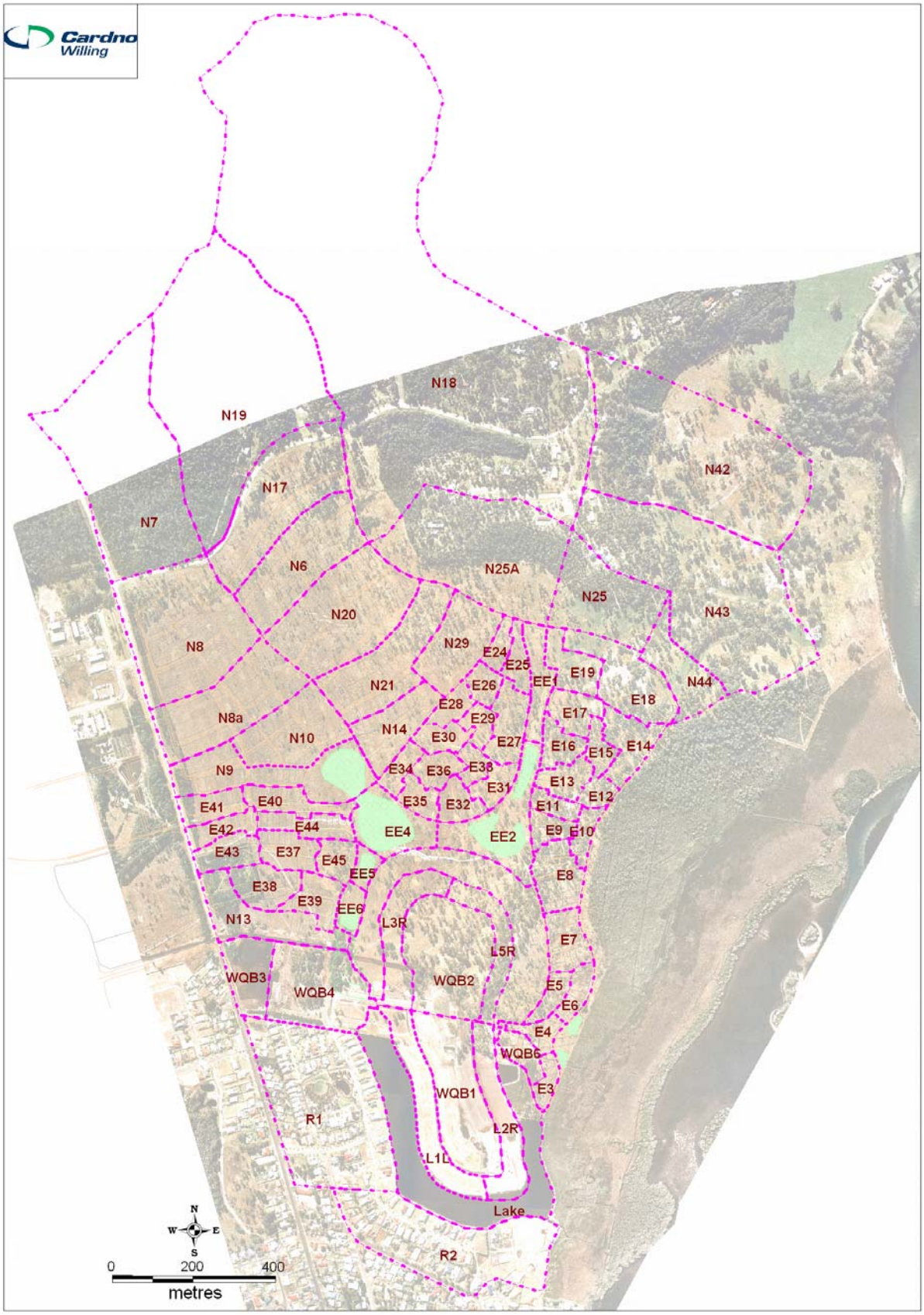

Figure B.2
Catchment Layout – Developed Conditions

APPENDIX C

HYDRAULICS

C.1	AIMS	C.1
C.2	CONCEPT SIZING OF WATERWAYS	C.1
C.3	HYDRAULIC MODELLING	C.6
C.4	RESULTS	C.8

C.1 Aims

The aims of the hydraulic analyses were to

- Assemble an **xpswmm** hydraulic model of the main drainage lines under proposed developed conditions with concept waterways and basins in place; and
- Estimate peak flows and peak flood levels under developed conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI events.

C.2 Concept Sizing of Waterways

Prior to assembling an **xpswmm** model of the main drainage lines, concept grading and concept sizing of each of the main drainage lines was undertaken. Four main drainage lines were identified. The East Branch, West Branch, North Branch and EastWest Branch drainage lines are identified in **Figure C.1**.

Hydraulic assessments of the sensitivity of maximum channel depth, channel top width and maximum flow velocity were undertaken using spreadsheet models of a single trapezoidal channel.

The adopted properties of the single trapezoidal channel are given in **Figure C.2**.

Each section was subdivided into 22 subsections. The top width, area, wetted perimeter, conveyance, discharge and velocity of flow were calculated for each subsection. The channel capacity was calculated as the sum of the flows in each subsection. The overall channel top width was calculated as the sum of the top widths of each subsection. The overall maximum velocity was the maximum of the velocities calculated for all subsections.

The assumed bed slopes for each reach were guided by the concept grading bed.

The assumed Manning roughness value was an average of 0.065 across all sections ie. some sections of a channel may be lightly vegetated while other sections of the channel may be more heavily vegetated.

Waterways were assessed for the 100 yr ARI event with basins in place.

The concept waterway dimensions for the East Branch, West Branch, North Branch and EastWest Branch are given in **Tables D.1, D.2, D.3** and **D.4** respectively. The highlighted cells are the channel widths that were selected for inclusion in the **xpswmm** model. These tables disclose the "trade-off" between channel width v flow depth v flow velocity for other channel dimensions.

Table C.1
Concept Waterway Dimensions for East Branch

Reach between EB1 and EB2

Q100 = 0.75 m3/s

Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	0.440	0.487
10	0.276	0.355
15	0.225	0.309
20	0.205	0.288
25	-	-
30	-	-

Reach between EB6 and EBd1

Q100 = 1.7 m3/s

Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	-	-
10	0.471	0.509
15	0.354	0.419
20	0.308	0.380
25	0.284	0.359
30	0.271	0.347

Reach between EB2 and EB3

Q100 = 0.75 m3/s

Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	0.350	0.418
10	0.240	0.324
15	0.200	0.285
20	-	-
25	-	-
30	-	-

(without influence from crossing at EB3)

Reach between EBd1 and EB7

Q100 = 1.7 m3/s

Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	-	-
10	0.471	0.509
15	0.354	0.419
20	0.308	0.380
25	0.284	0.359
30	0.271	0.347

Table C.2
Concept Waterway Dimensions for West Branch

Reach between WB1 and WB2
Q100 = 9.01 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.957	0.667
30	0.718	0.548
40	0.624	0.497
50	0.575	0.469
60	0.548	0.453

Reach between WB2 and WB3
Q100 = 9.48 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.990	0.682
30	0.739	0.559
40	0.640	0.506
50	0.589	0.477
60	0.560	0.459

Reach between WB3 and WB4
Q100 = 9.35 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.983	0.679
30	0.735	0.557
40	0.637	0.504
50	0.586	0.475
60	0.558	0.458

Reach between WB4 and WB5
Q100 = 10.73 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	1.090	0.727
30	0.798	0.589
40	0.686	0.530
50	0.628	0.498
60	0.595	0.479
70	0.575	0.466

Reach between WB5 and WB6
Q100 = 11.58 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	1.160	0.758
30	0.837	0.608
40	0.716	0.546
50	0.654	0.512
60	0.617	0.491
70	0.596	0.478

Table C.3
Concept Waterway Dimensions for North Branch

Reach between NB1 and NB2

Q100 = 0.18 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	0.205	0.239
10	0.140	0.183
15	0.125	0.169
20	0.120	0.163
25	-	-
30	-	-

Reach between NB4 and NB5

Q100 = 0.57 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	-	-
10	0.265	0.282
15	0.217	0.246
20	0.198	0.230
25	-	-
30	-	-

Reach between NB2 and NB3

Q100 = 0.21 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	0.230	0.258
10	0.150	0.192
15	0.134	0.177
20	0.128	0.170
25	-	-
30	-	-

(without influence from crossing at NB3)

Reach between NB5 and NB6

Q100 = 0.78 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	-	-
10	0.320	0.321
15	0.256	0.275
20	0.229	0.254
25	-	-
30	-	-

Table C.4
Concept Waterway Dimensions for EastWest Branch

Reach between EW1 and EW1_1
Q100 = 13.78 m3/s
Channel Slope = 2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.592	1.527
30	0.478	1.317
40	0.431	1.223
50	-	-
60	-	-

Reach between EW4 and EW5
Q100 = 5.44 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.600	0.597
30	0.483	0.514
40	0.436	0.477
50	0.413	0.458
60	0.403	0.448
70	-	-

Reach between EW1_1 and EW2
Q100 = 12.83 m3/s
Channel Slope = 1%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.705	1.214
30	0.555	1.031
40	0.494	0.949
50	0.464	0.906
60	-	-

Reach between EW6 and EW7
Q100 = 5.73 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.619	0.609
30	0.497	0.524
40	0.447	0.486
50	0.423	0.466
60	0.412	0.455
70	-	-

Reach between EW2 and EW3
Q100 = 11.68 m3/s
Channel Slope = 0.15%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	-	-
30	0.915	0.559
40	0.777	0.500
50	0.705	0.467
60	0.662	0.446
70	0.637	0.433

C.3 Hydraulic Modelling

In this study **xpswmm** was selected to model the proposed Riverside at Tea Gardens development because it is a 1D/2D full unsteady flood routing package that is able to estimate flood levels under conditions of low gradients on floodwaters.

C.3.1 Scheme 3 Hydraulic Model

An **xpswmm** hydraulic model was assembled for Riverside at Tea Gardens under the proposed Scheme 3 Developed Conditions. The model includes the four main drains and a concept retarding basin located on the EastWest Branch. The active storage available above the extended detention lake and major ponds and wetlands was represented as flood storage at selected nodes.

The adopted concept grading of Basin EW was as follows:

Level (m AHD)	Surface Area (ha)	Comment
2.5	0.45	Approx 0.5 m of cut
3.0	1.11	Less than 0.5 m of cut
3.5	1.95	Existing contour
4.0	2.64	Existing contour

The adopted stage-storage-discharge relationship for the extended detention lake was as follows:

Stage (m AHD)	Storage (ML)	Outflow (m^3/s)
0.530	0.0	0
0.590	8.1	0.2
0.643	15.3	0.5
0.702	23.2	1
0.761	31.2	2
0.858	44.3	4
0.934	54.5	6
0.979	60.6	8
1.030	67.5	12
1.064	72.1	15
1.114	78.8	20
1.156	84.5	25
1.194	89.6	30
1.230	94.5	35

The layout of the **xpswmm** model of the proposed Scheme 3 developed condition is shown in **Figure C.1**.

C.3.2 Scheme 5 Hydraulic Model

Subsequent to discussions held with the NSW Department of Planning regarding NSW Government stakeholder concerns regarding the concept Scheme 3 development a concept development based on Scheme 5 was investigated in detail.

The **xpswmm** hydraulic model that was assembled for Riverside at Tea Gardens under the proposed Scheme 3 Developed Conditions was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5.

The concept Scheme 5 layout of waterways, ponds and lakes is given in **Figure C.5.**

The Scheme 5 hydraulic model includes a number of small ponds, three large ponds, three freshwater lakes and an extension of detention lake. It also includes the four main drains and a concept retarding basin located on the EastWest Branch. The active storage available above the extended detention lake, freshwater lakes and ponds was represented as flood storage at selected nodes.

Discharges between freshwater lakes and the freshwater lakes and the extended detention lake is controlled by four land bridges (refer **Figure C.5**). The same concept geometry was adopted for each land bridge. The concept geometry comprises a 2 m wide and 0.3 m deep low flow channel in combination with a 30 m wide flat broad crested weir section. The assumed concept invert levels for the low flow channel and the broad crested weir section are summarised as follows:

	Low Flow Channel Invert Level (m AHD)	**Broad Crested Weir Level (mAHD)**
Land Bridge A	0.90	1.20
Land Bridge B	0.95	1.25
Land Bridge C	1.0	1.30
Land Bridge D	1.0	1.40

The assumed static water levels in the major ponds and freshwater lakes are summarised as follows (refer **Figure C.5**):

Pond or Lake	**Static Water Level (m AHD)**
Lake FA	0.80
Lake FA	0.85
Lake FA	0.90
N10	0.95
N10U	1.00

The layout of the **xpswmm** model of the proposed Scheme 5 developed condition is shown in **Figure C.6**.

C.4 Results

C.4.1 Scheme 3 Results

The **xpswmm** model of Scheme 3 was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels under the proposed Scheme 3 development. Based on the outcomes of the hydrological analysis the **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the extended detention lake and the flood level in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table C.5.** The estimated peak discharges to the Conservation Zone without and with the major basin on the EastWest Branch (Basin EW) in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table C.6**. This table also summarise the estimated peak basin water levels.

Table C.5
Estimated Peak Outflows from the Extended Detention Lake under Scheme 3 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
4.23 *(0.867)*	7.12 *(0.960)*	11.8 *(1.028)*	Outflow from the extended detention lake

Note: The estimated peak basin water level (in m AHD) is reported in brackets

Table C.6
Estimated Peak Outflows from Basin EW under Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.73 *(0.86)*	4.65 *(1.07)*	5.48 *(1.30)*	Outflow from Basin EW
6.07	8.16	11.77	Aggregated flow to the Conservation Zoned (without Basin EW)
4.59	5.93	7.45	Aggregated flow to the Conservation Zone (with Basin EW)

Note: The estimated peak basin water level (in m) is reported in brackets

The estimated 100 yr ARI peak flows, flood levels and flood depths within the hydraulic study area for storm bursts of 1.5 hours and 9 hours are presented in **Figures C.3** and **C.4** respectively.

C.4.2 Scheme 5 Results

The Scheme 5 **xpswmm** model was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels under the proposed Scheme 5 development. Based on the outcomes of the hydrological analysis the **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the extended detention lake in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table C.7.**

Table C.7
Estimated Peak Outflows from the Extended Detention Lake under Scheme 5 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.47 *(0.83)*	7.17 *(0.96)*	12.57 *(1.09)*	Outflow from the extended detention lake

Note: The estimated peak basin water level (in m AHD) is reported in brackets

The estimated 5 yr ARI, 20 yr ARI and 100 yr ARI flood levels under 1.5 hour and 9 hour storm bursts are presented spatially in **Figures C.7** to **C.12**.

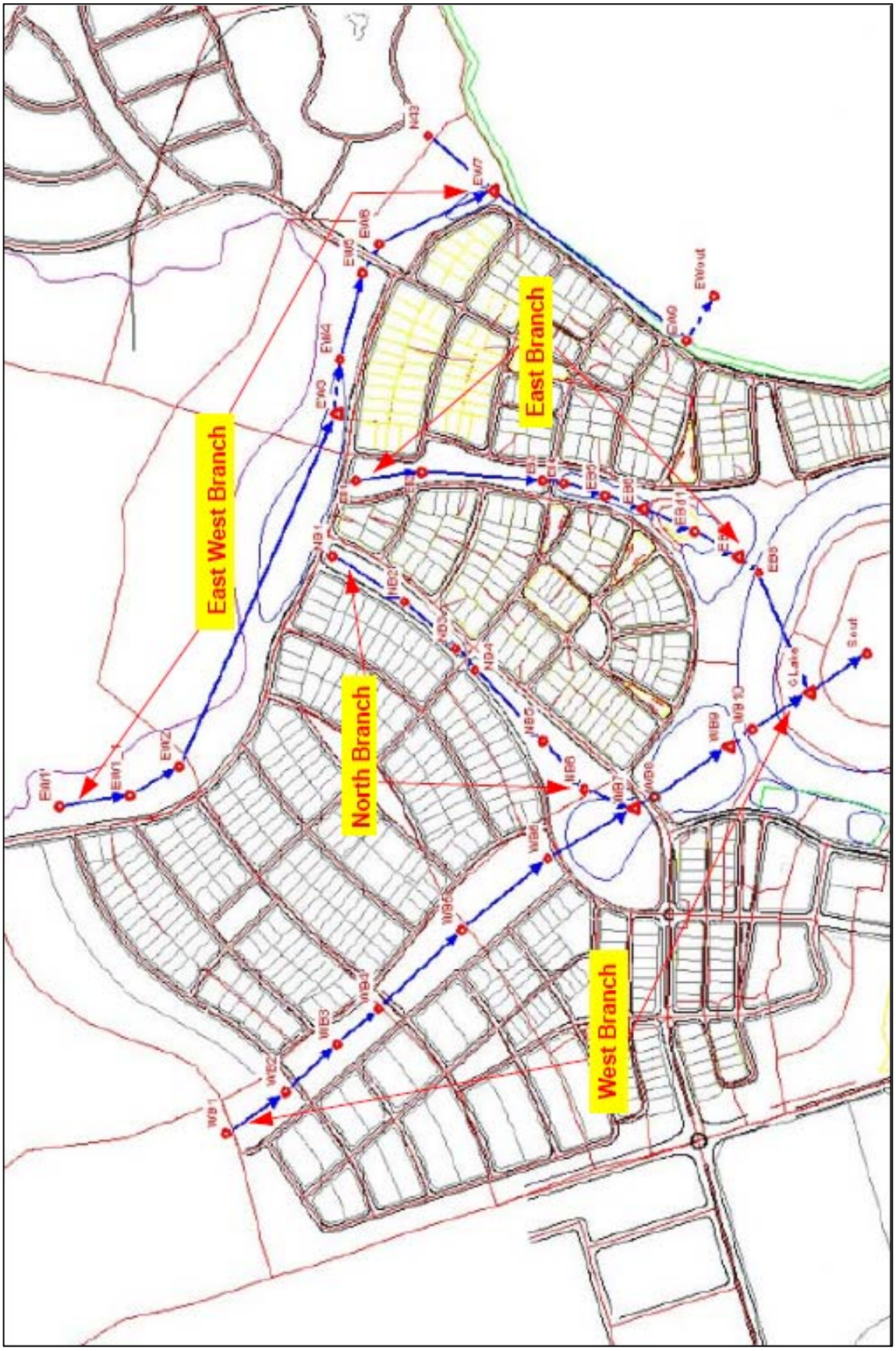

Figure C.1
Location of Main Drainage Lines

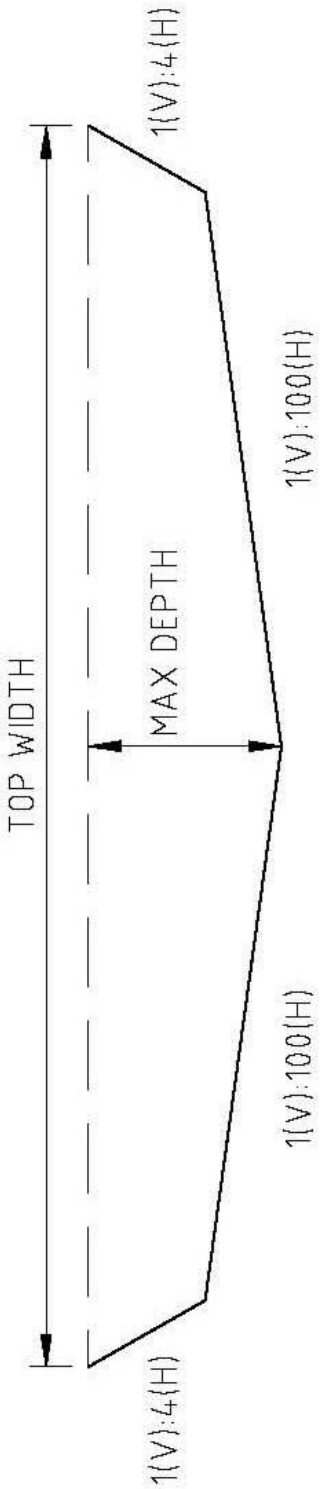

Figure C.2
Concept Waterway Geometry

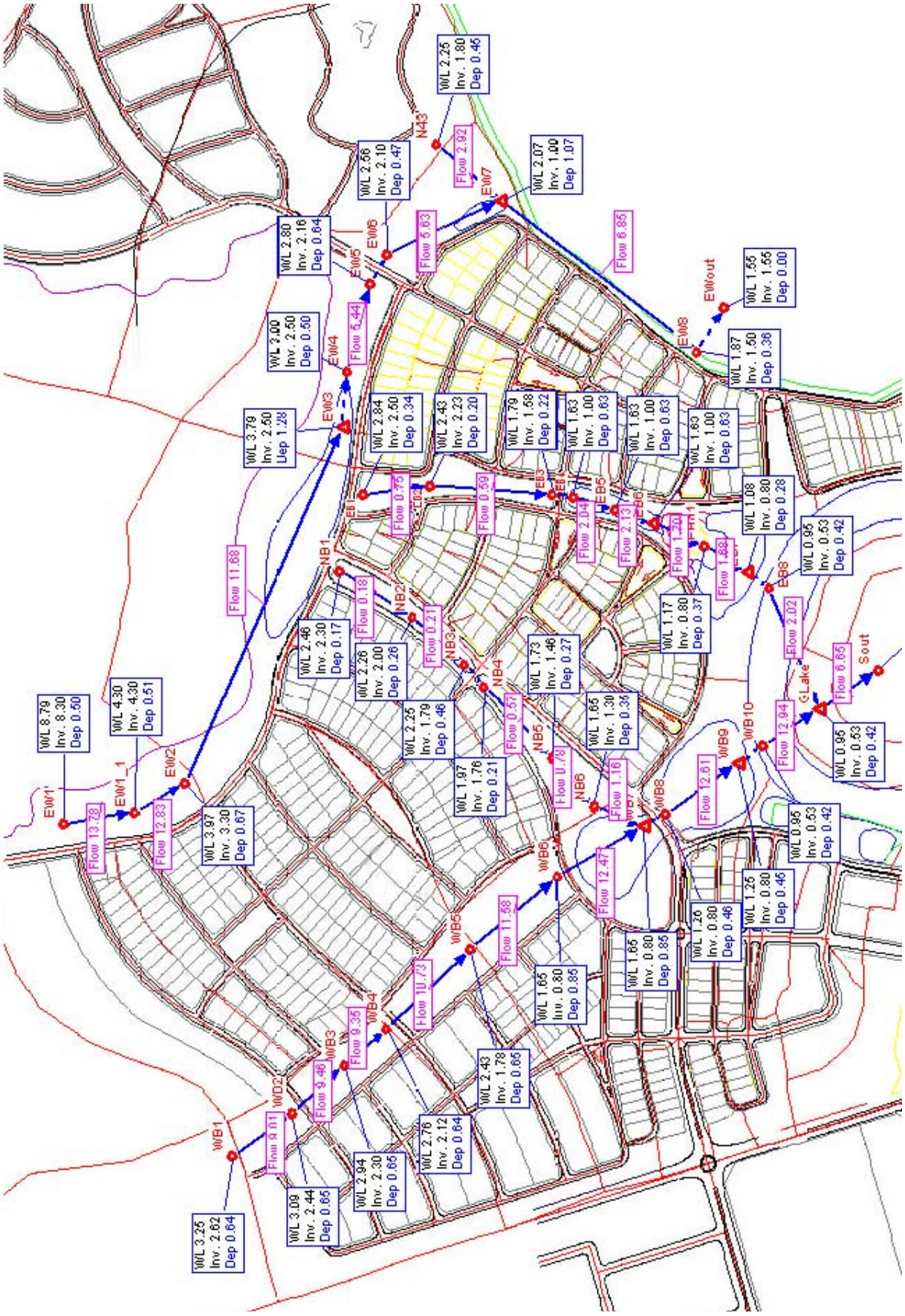

Figure C.3
100 yr ARI Peak Flows, Flood Levels and Flood Depths for 1.5 hour Storm Burst - Scheme 3

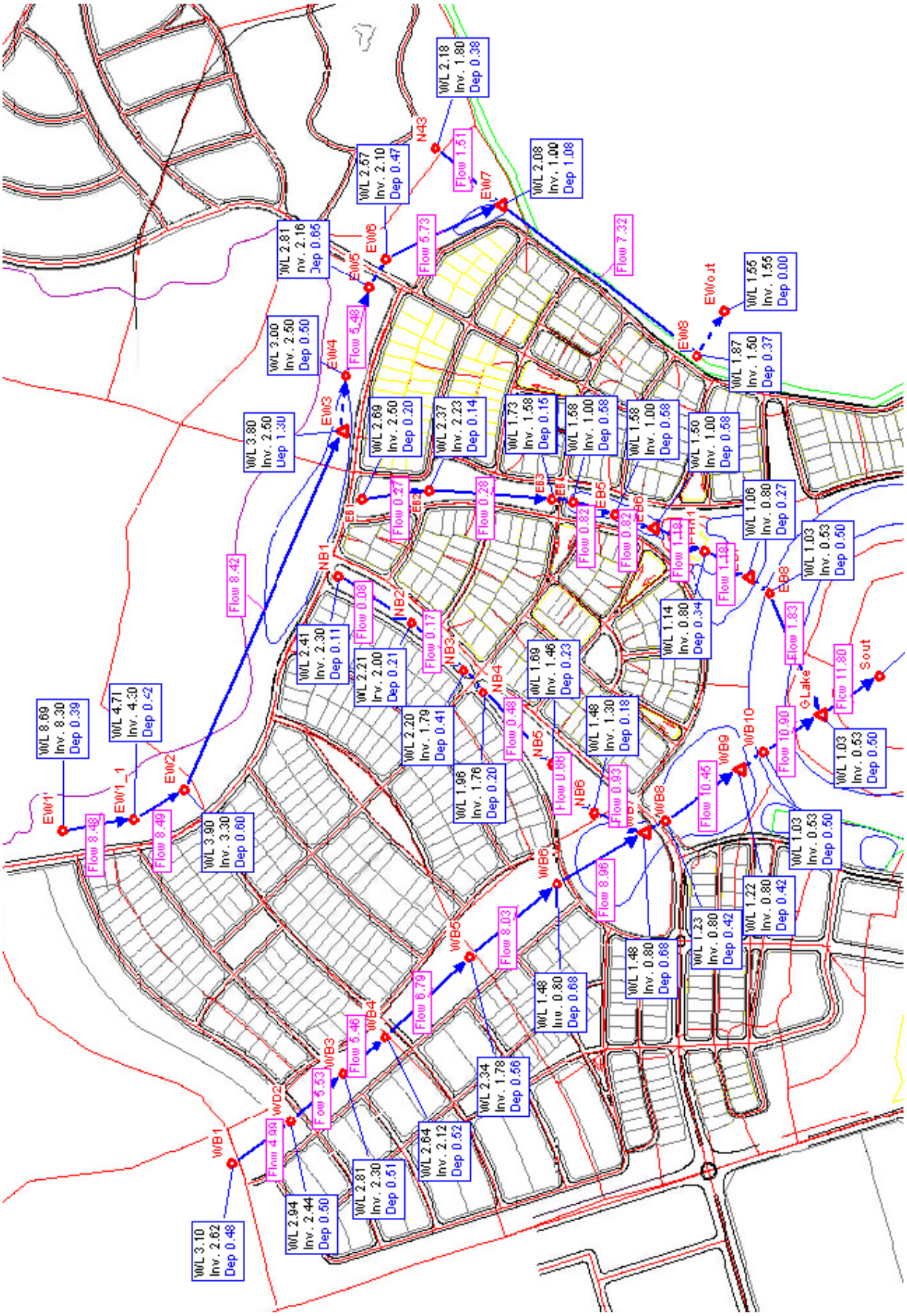

Figure C.4

100 yr ARI Peak Flows, Flood Levels and Flood Depths for 9 hour Storm Burst – Scheme 3

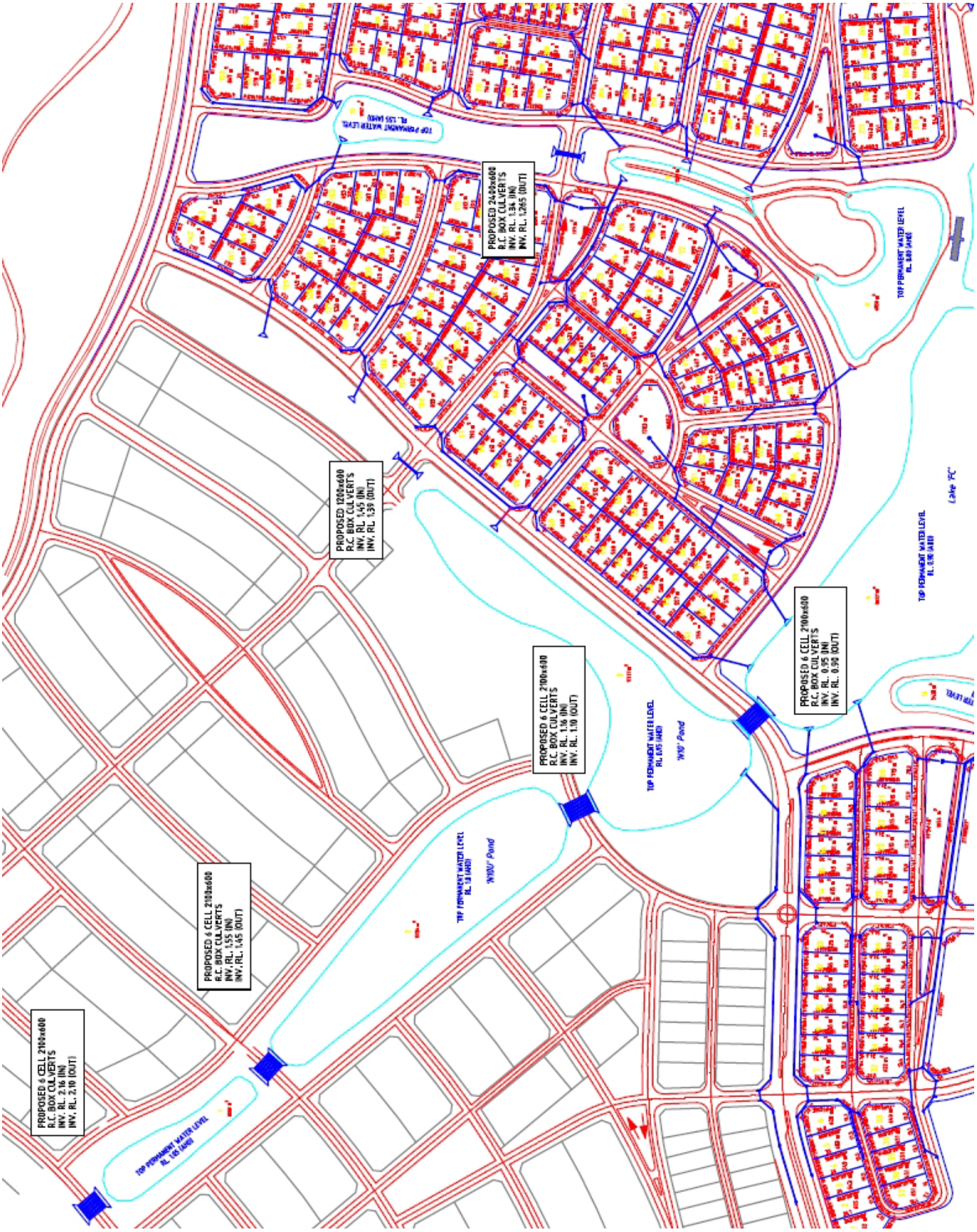

Figure C.5 (a)
Concept Layout and Crossing Details for Concept Scheme 5 Development

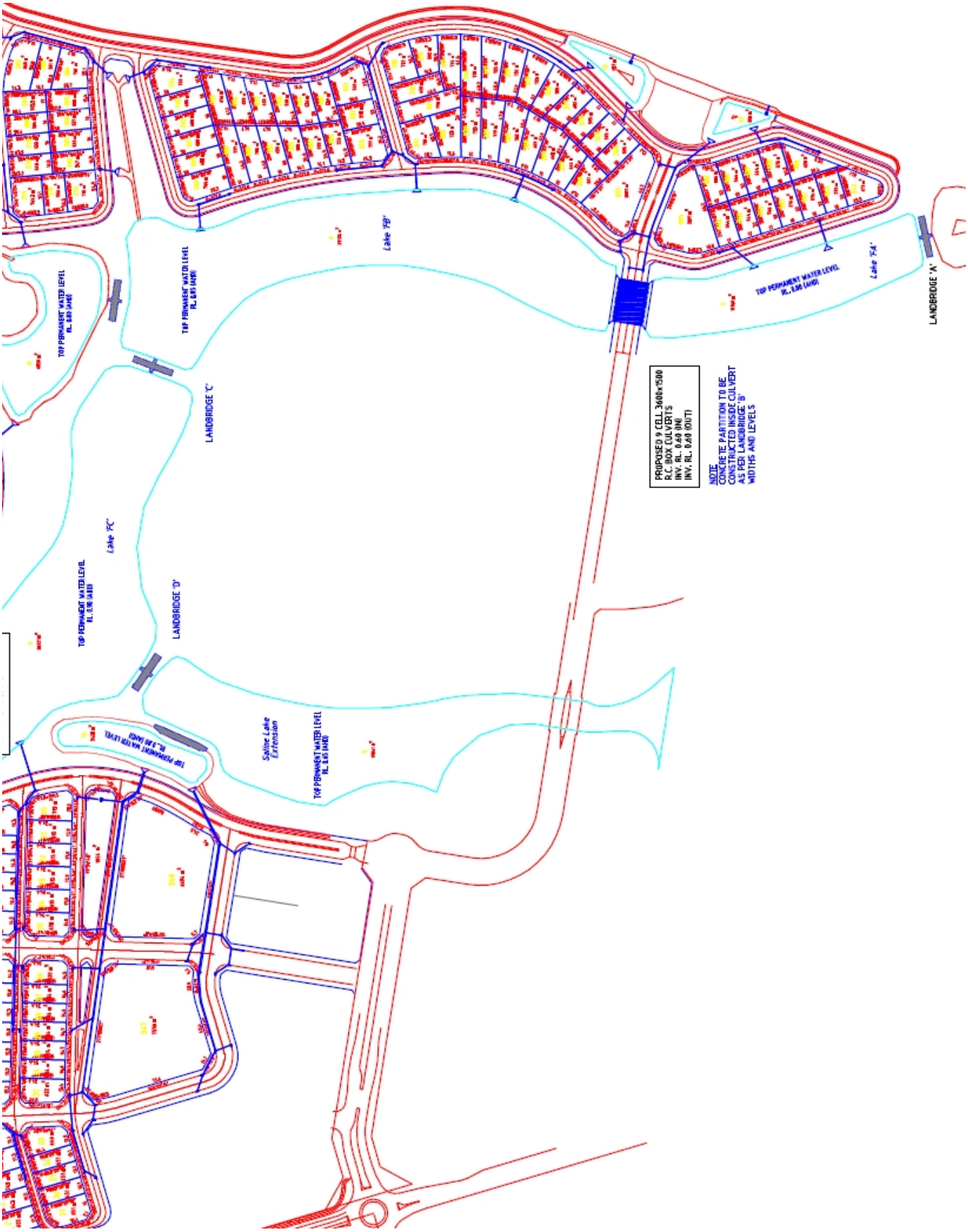

Figure C.5 (b)
Concept Layout and Crossing Details for Concept Scheme 5 Development

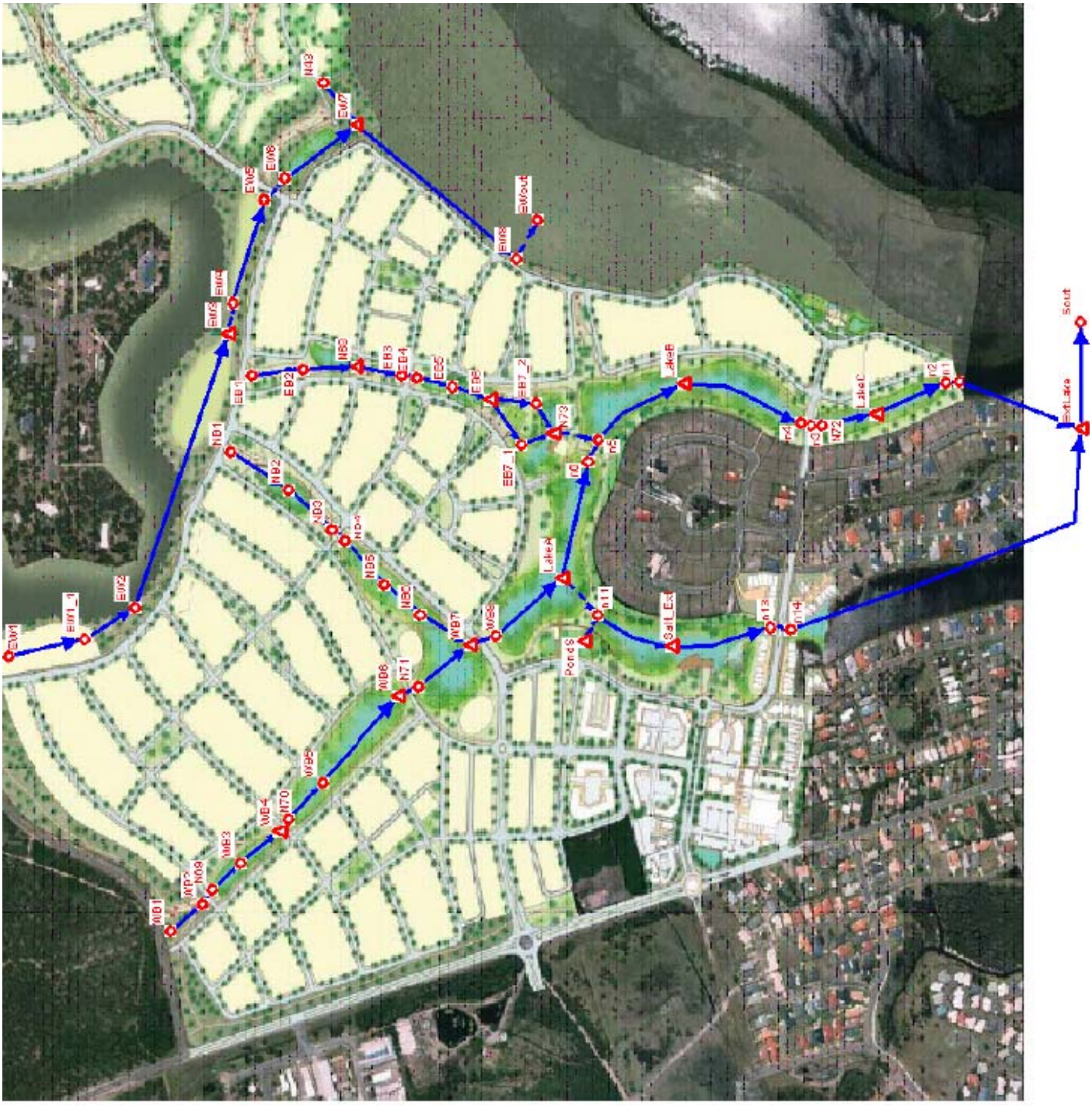

Figure C.6
Scheme 5 Hydraulic Model Layout

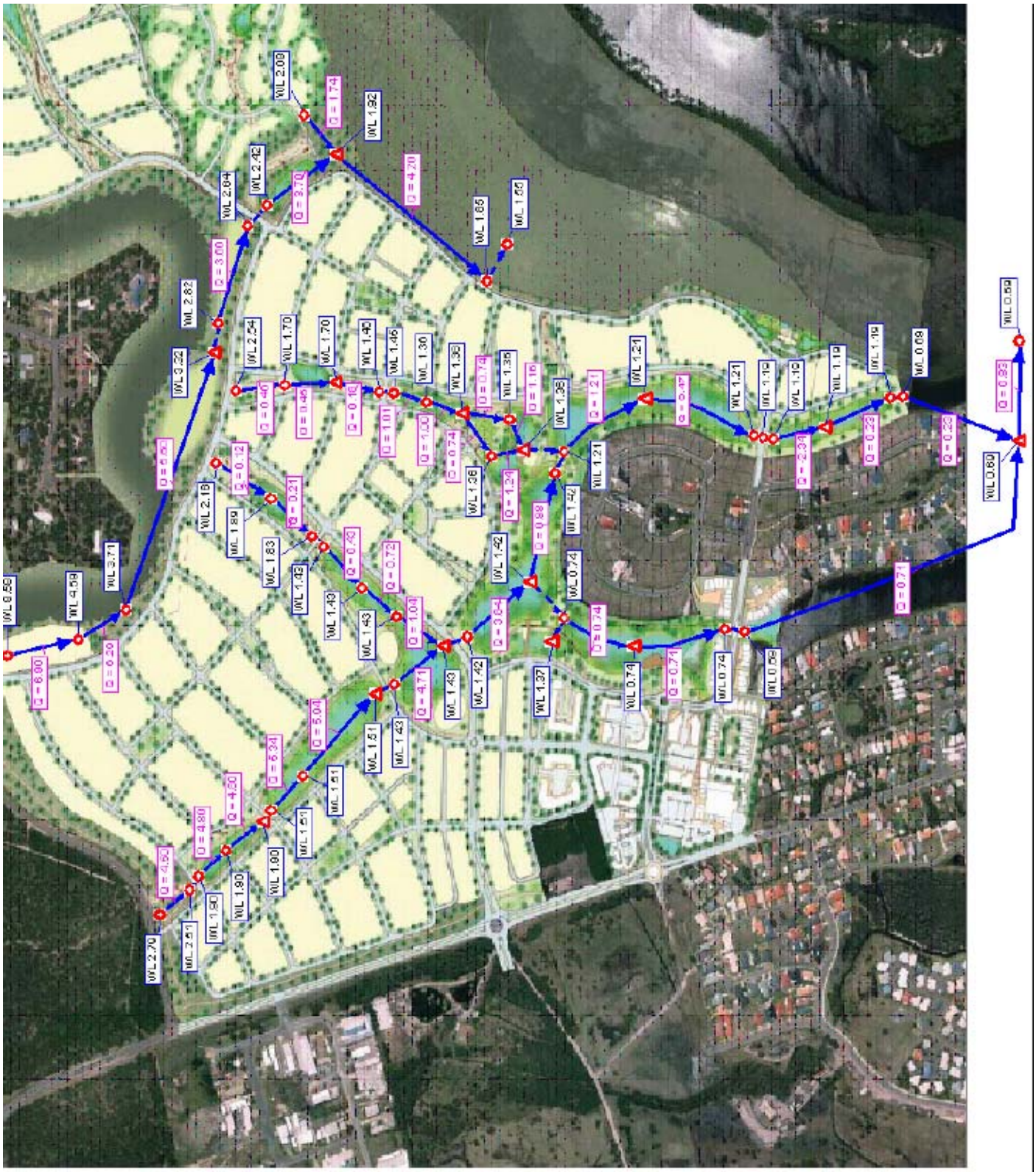

Figure C.7
5 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst

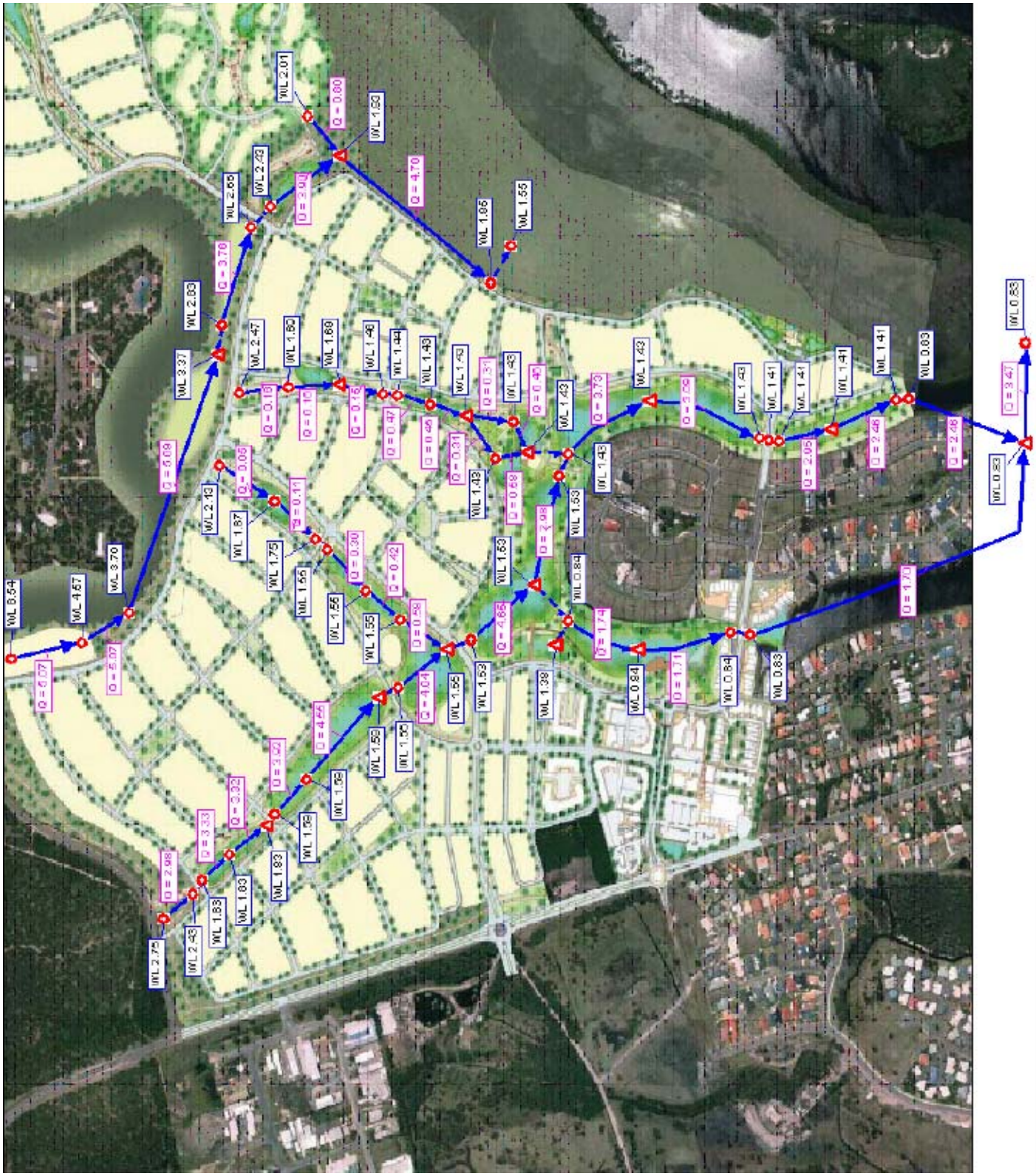

Figure C.8
5 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst

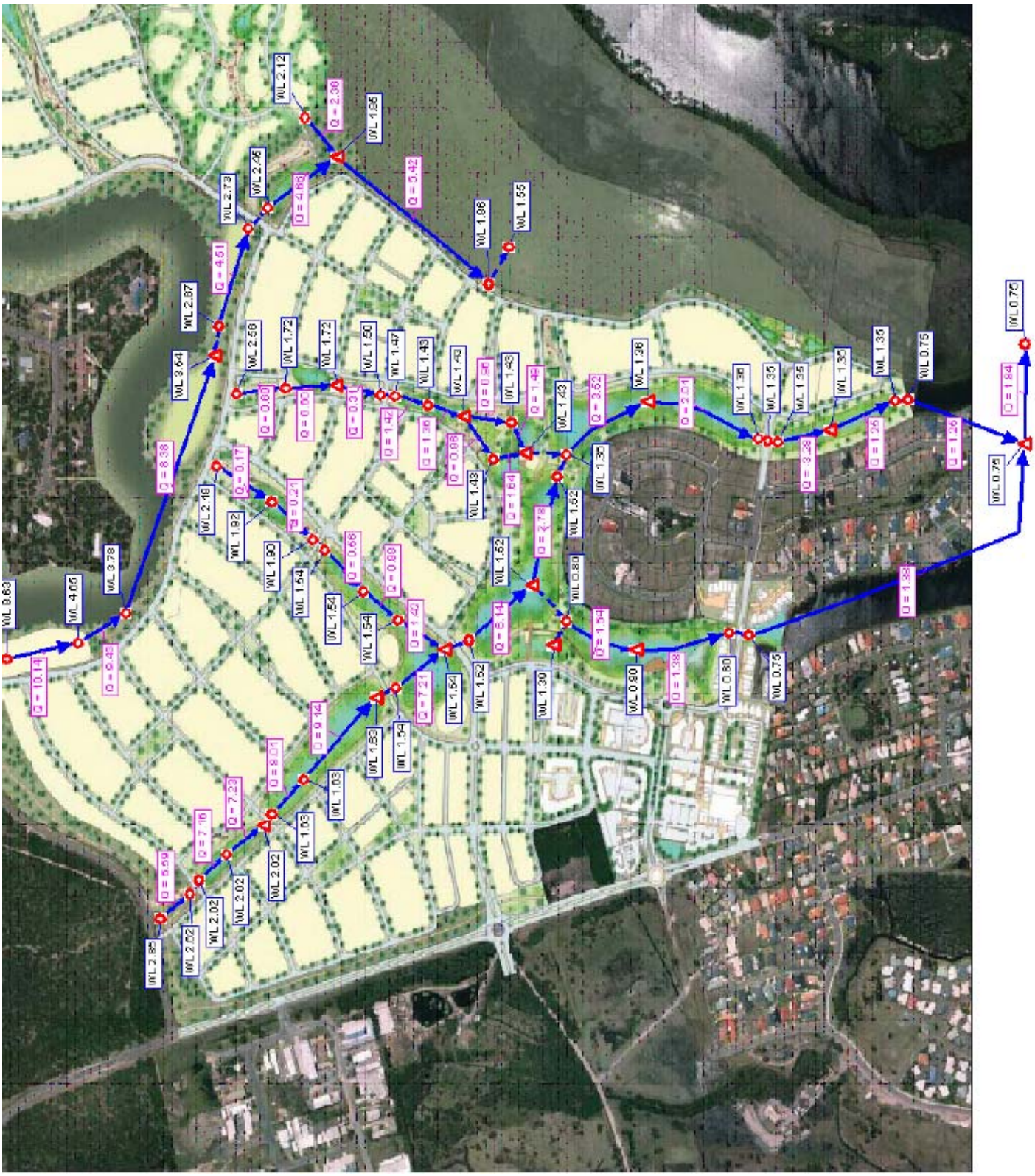

Figure C.9
20 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst

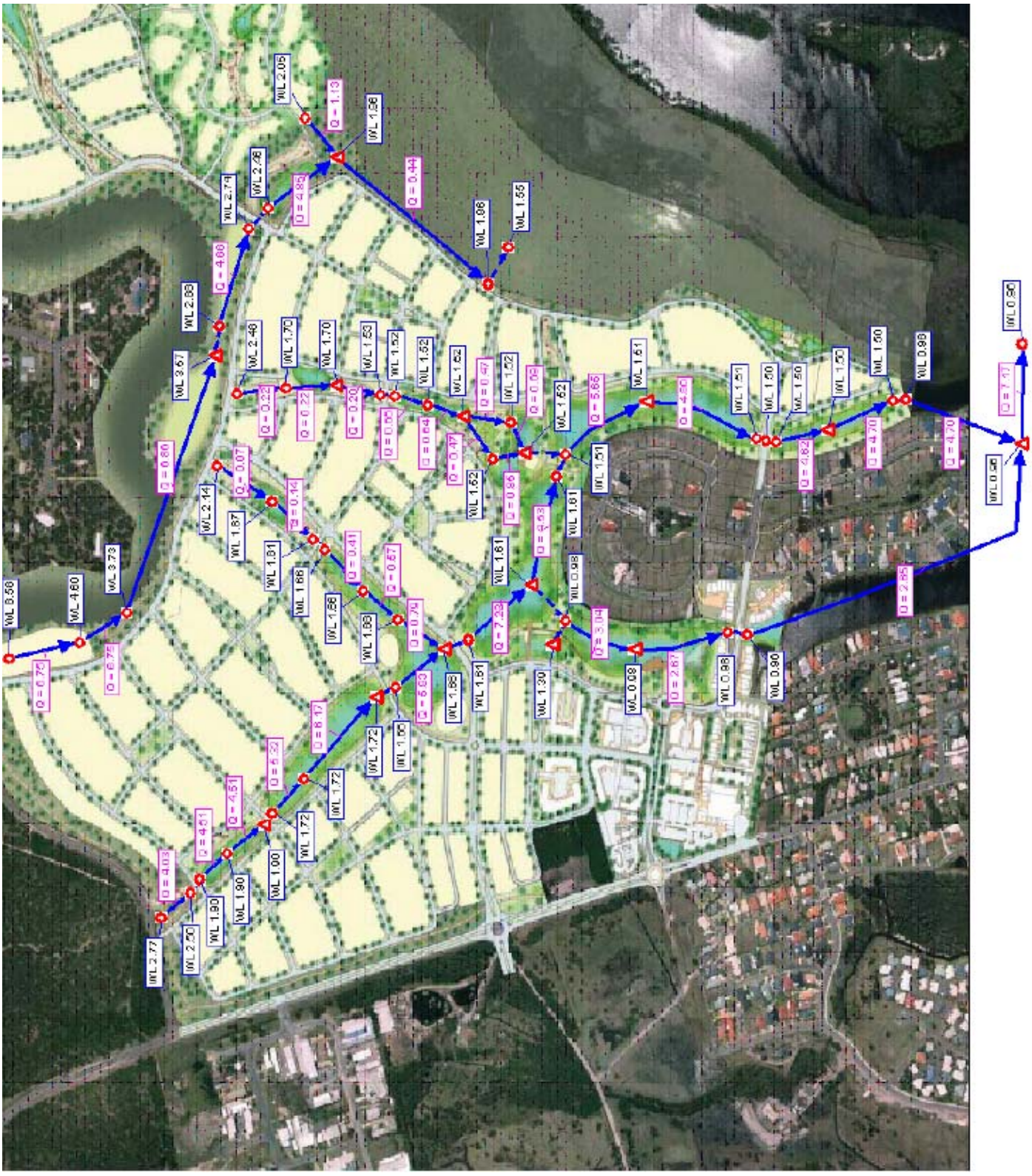

Figure C.10
20 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst

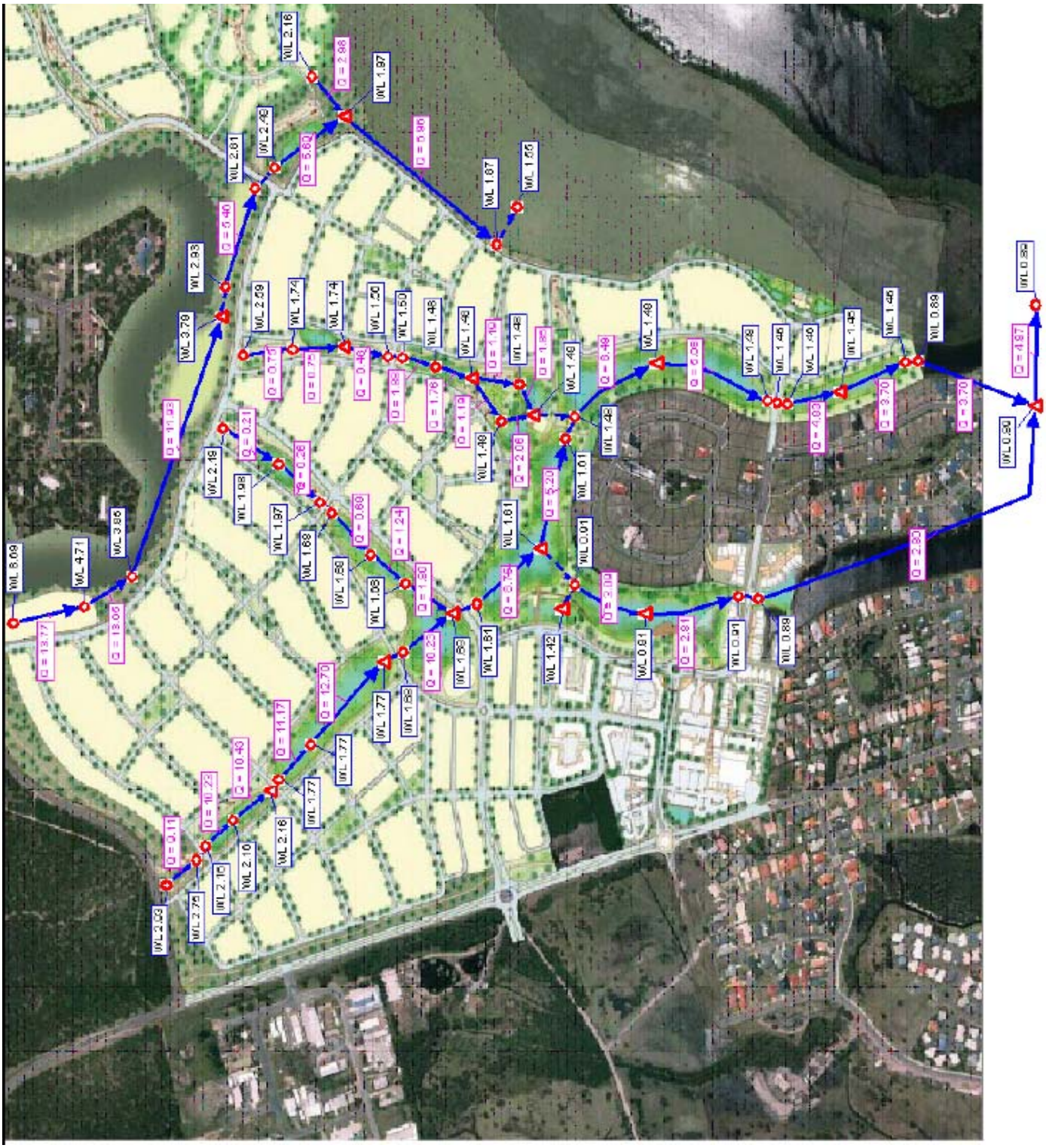

Figure C.11
100 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst

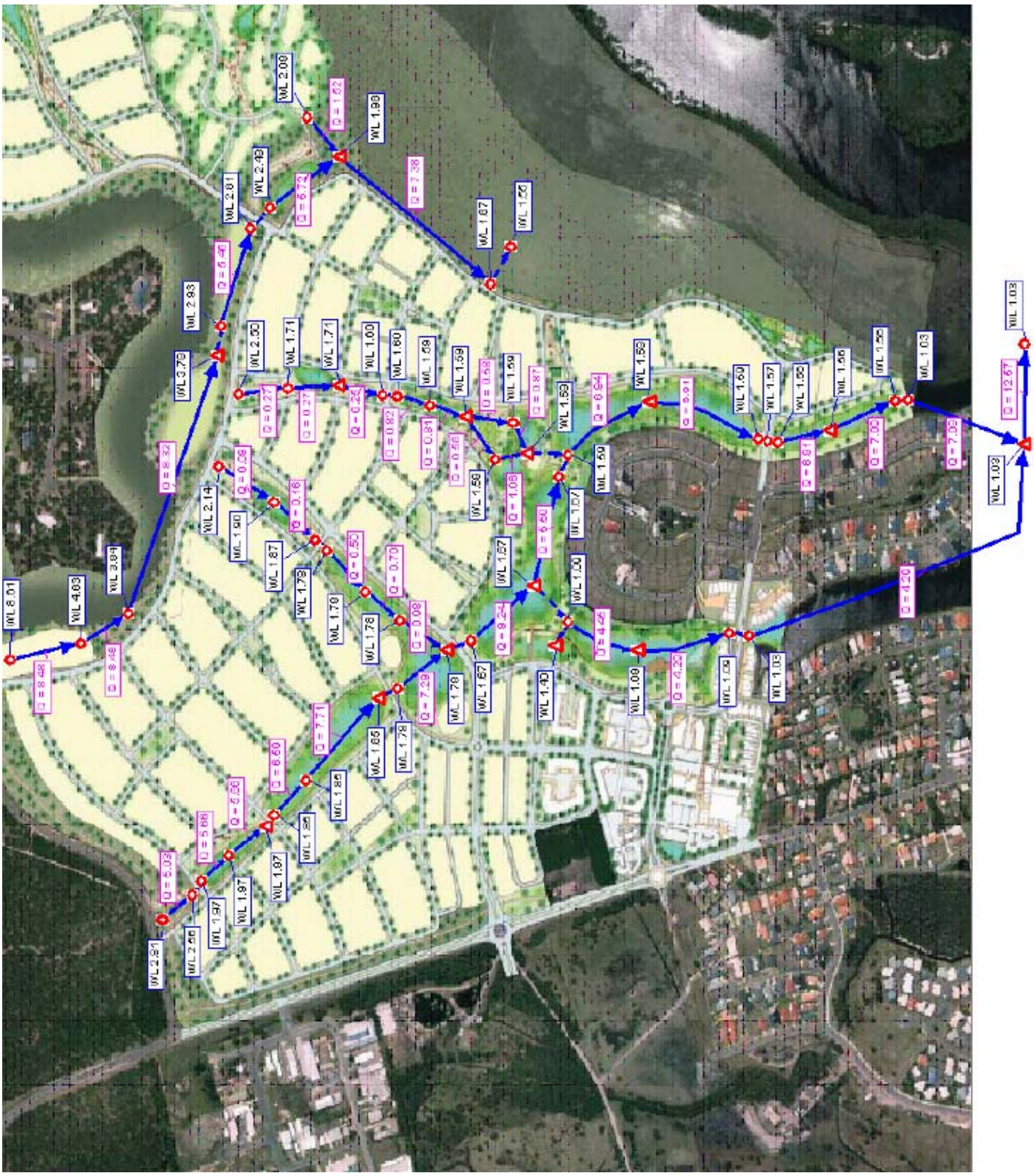

Figure C.12
100 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst

APPENDIX D

CATCHMENT WATER QUALITY MODELLING

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D.1 Aims

The aims of the catchment based water quality modelling were to

- Create MUSIC models of the Pre-existing and Existing conditions based on the approaches adopted in 2004 catchment based water quality (**xpaqualm**) assessments;
- "Calibrate" the MUSIC model parameters against the unit area results previously calculated using the **xpaqualm** model(s);
- Estimate catchment exports under the Pre-existing and Existing conditions for input into models of the Pre-existing detention lake and Existing detention lake;
- Create MUSIC models of the proposed concept development with and without rainwater tanks and run the generate for inputs into the Scheme 3 lake model;
- Create MUSIC models of the proposed concept development with and without rainwater tanks and run the generate for inputs into the Scheme 5 lake model; and
- If needed, size ancillary pond(s) and/or wetland(s) to achieve the receiving water quality objectives for the receiving waters.

D.2 MUSIC Overview

The CRC for Catchment Hydrology (CRCCH) has developed a Model for Urban Stormwater Improvement Conceptualisation (MUSIC), which packages the results of many research activities undertaken at the CRCCH and other organisations into a user-friendly stormwater management tool.

MUSIC enables urban catchment managers to (a) determine the likely water quality emanating from specific catchments, (b) predict the performance of specific stormwater treatment measures in protecting receiving water quality, (c) design an integrated stormwater management plan for a catchment, (d) evaluate the success of a treatment node or treatment train against a range of water quality standards, and (e) analyse the lifecycle costs of a treatment node or treatment train.

D.2.1 Background

MUSIC has modules for runoff and pollutant generation in source nodes and modules to assess stormwater treatment processes in treatment nodes. Four categories of source node are available in Version 3.01: agricultural, forest and urban source nodes and a user defined source node. These source nodes differ only in their default baseflow and stormflow pollutant concentrations.

In MUSIC Version 3.01, four default pollutants are modelled: total suspended solids (TSS), total nitrogen (TN), total phosphorous (TP) and gross pollutants.

The treatment devices that can be modelled in MUSIC include rainwater tank, buffer zone, gross pollutant trap (GPT), bio-retention, swale, sediment basin, infiltration system, pond and wetland.

The model outputs include runoff, pollutant concentrations and pollutant loads at each node as time series, from which monthly and annual loads and other statistics can be calculated.

Other features of MUSIC include:

- Multiple interconnected catchments (source nodes) and treatment devices (treatment nodes) in a network;
- Graphical import, export and editing of data;
- Graphical/tabular/statistical interpretation, presentation and export of modelling results;
- Multiple treatment devices to form a treatment train;
- Import of rainfall and evaporation data in BOM format or from ASCII files;
- Flexible time steps from 6 minute to daily;
- Import of data from upstream catchments (time series);
- Stochastic generation of pollutant concentrations;
- Direct export of results into other receiving waters model; and
- Life cycle cost estimates.

D.2.2 Rainfall/Runoff Model

MUSIC model simulates runoff using a modified version of the rainfall-runoff model developed by Chiew *et al* (1997). This model predicts runoff from rainfall based on an accounting of evaporation, and surface and soil moisture storages.

The concept structure of the rainfall /runoff model in Version 3.01 of MUSIC is presented diagrammatically in **Figure D.1**.

Moisture Stores

As shown in **Figure D.1**, three moisture stores are incorporated in the rainfall/runoff model as follows:

- Impervious Store;
- Pervious Store; and
- Groundwater Store.

A loss of moisture to a deep ground store is also accounted for in the model.

A number of coefficients for each of these moisture stores can be adjusted based on measured data. These coefficients relate to soil type and soil permeability.

Stormwater Reuse

MUSIC can account for the reuse of stormwater harvested from treatment devices such as pond, wetland or a sediment basin. Potential reuse of stormwater was not considered in this assessment.

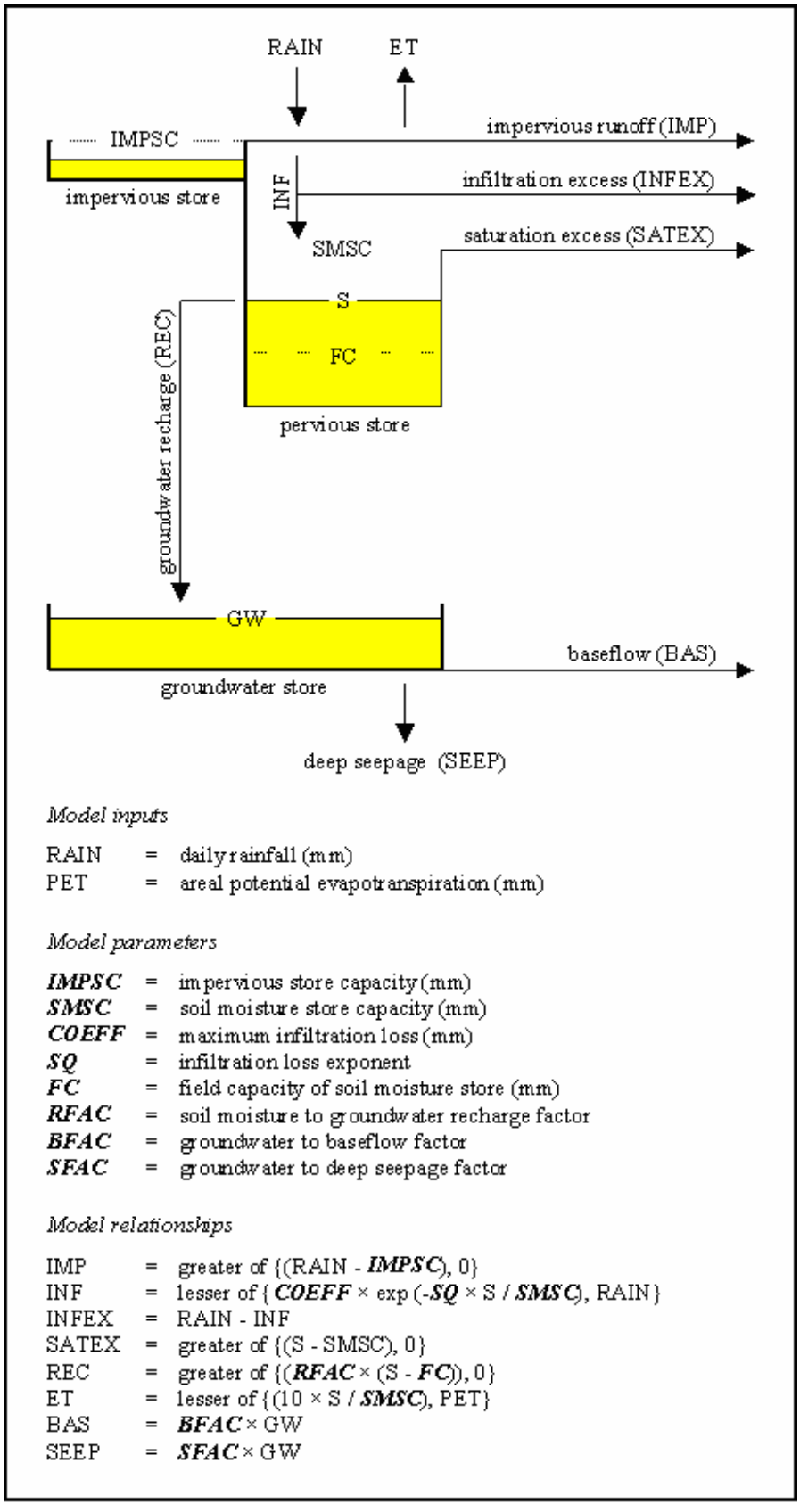


Figure D.1
MUSIC Rainfall/Runoff Models
(Adapted from MUSIC Manual)

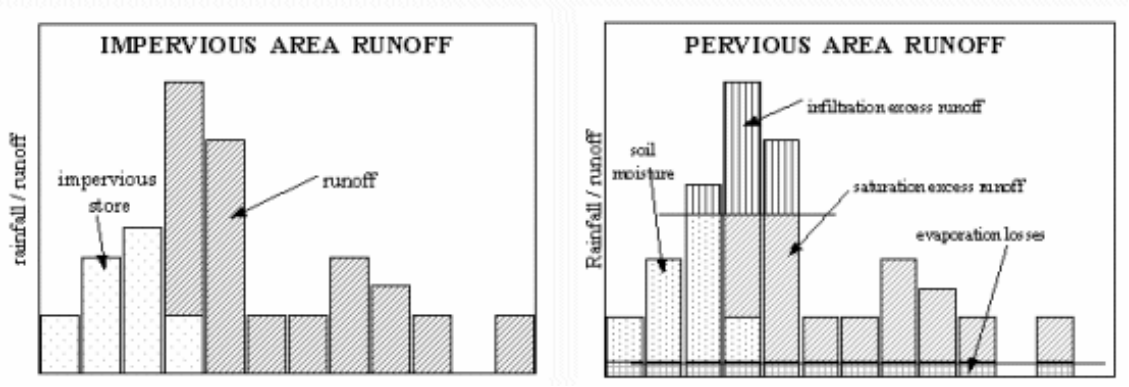


Figure D.2
MUSIC Runoff Components
(Adapted from MUSIC Manual)

Runoff

Runoff generated from source nodes includes impervious area runoff and pervious area runoff. The latter comprises infiltration excess runoff, saturation excess runoff and baseflow. These components of runoff are illustrated in **Figure D.2**.

Runoff Routing

Runoff from source and treatment nodes is routed in MUSIC using links. Runoff can be either routed without lag, with lag (pure translation) or with routing (Muskingum-Cunge procedure).

D.2.3 The Universal Stormwater Treatment Model

The second component of the MUSIC model is the Universal Stormwater Treatment Model (USTM). Two basic modelling procedures are adopted in the USTM – hydrological routing to simulate the movement of water through a treatment system, and a first order kinetic model to simulate the removal of pollutants within the treatment system.

The first order kinetic model which controls the pollutant removal processes is governed by an exponential decay equation which describes the physical movement of particulate pollutants. The process is expressed algebraically as:

$$(C_{out} - C^*) / (C_{in} - C^*) = e^{-k/q}$$

where C* is the background concentration, C_{in} is the input concentration, C_{out} is the output concentration, k is the rate constant, and q is the hydraulic loading (flow rate per surface area) of the treatment measure. Thus, a higher k means a faster approach to equilibrium, and hence a higher treatment capacity (provided C* is less than C_{in}).

The same algorithm is used for sedimentation basins, ponds, wetlands, swales, and temporary ponding above a bioretention system by changing the four main inputs – the storage-discharge relationship, the background concentration, the exponential decay coefficient and the number of CSTRs (Continuously Stirred Tank Reactors). No chemical or biological processes are considered in MUSIC. As such, dissolved pollutants are not modelled.

D.3 Rainfall and Evaporation

Daily rainfall data used for the analysis was obtained from the Bureau of Meteorology station at Hawks Nest (Langi St) [Station 60123]. Although some daily rainfall data is available for the study catchment it does not yet cover a sufficiently long period.

Table D.1
Annual Rainfall at Hawks Nest (Langi St) (Station 060123)

year	Rainfall (mm)	Comment
1982	1660	
1983	1289	
1984	1210	
1985	1484	
1986	1092	
1987	1292	
1988	1571	
1989	1372	Average year
1990	2524	
1991	1116	
1992	1543	
1993	918	
1994	1184	
1995	1134	
1996	1068	10th %tile (dry) year
1997	1524	
1998	1760	
1999	1670	
2000	1076	
2001	1712	90th %tile (wet) year
2002	1187	
2003	1385	
1/01 – 31/05/2004	503	5 months only

The data covers daily rainfall record (March 1981 – present). The average annual rainfall recorded at Hawks Nest over 22 years (1982-2003) is 1,399 mm. In comparison, the long term (104 years) average annual rainfall recorded at Nelson Bay (Nelson Head) (Stn 06154) is 1,347 mm.

For the purposes of catchment based water quality modelling, the MUSIC models representing the pre-existing, existing, and the latest Concept Plan were run from 1/01/1982 to 31/05/2004 inclusive. The rainfall data was applied uniformly over the Riverside at Tea Gardens catchments.

Table D.1 summarises the recorded annual rainfall for the period 1/01/1982 to 31/05/2004. The average rainfall year is 1989 (1,372 mm), the 10% dry year is 1996 (1,068 mm), and the 90% wet year is 2001 (1,712 mm).

Pan evaporation data was adopted from a previous catchment based water quality modeling for Myall River Downs west of Riverside at Tea Gardens. The evaporation data adopted for the Myall River Downs assessment were average monthly pan evaporation collected at Williamstown Air Base. An evaporation multiplier of 0.85 was applied to the pan evaporation data to calculate the potential evapotranspiration (PET) for the catchments.

The adopted average monthly potential evapotranspiration (PET) for Tea Gardens is summarised in **Table D.2**.

Table D.2
Average Monthly PET for Tea Gardens

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Year**
PET	182	150	132	97	69	66	66	93	127	148	166	192	1487

D.4 MUSIC Model Parameters

Model parameters for MUSIC were “calibrated” to match as far as possible to match the runoff and pollutant export rates previously estimated using **xpaqualm** in 2004. The MUSIC parameters adopted by Patterson Britton and Partners in 2006 for the adjacent Myall River Downs development were also considered.

D.4.1 Runoff Parameters

Based on the previous approach to catchment based water quality modelling a unit area MUSIC model comprising eight (8) source nodes was assembled. The sources nodes represent the following adopted surface types and/or landuses - rooves, roads, driveways, rural (lawn) sand, rural (lawn) clay, urban sand (with watering), urban clay (with watering), and open water (lake surface). Source nodes reflect the presence of both clay soils and sandy soils within the Riverside at Teagardens development.

Table D.3
Adopted MUSIC Rainfall/Runoff Parameters

Landuse	Adopted Parameter Values								
	Roof	Road	Driveway	Lake	Lawn Clay	Lawn Sand	Urban Clay	Urban Sand	PBP, 2006 All landuses
Imperviousness (%)	100%	100%	100%	100%	2%	0%	2%	0%	varies
Impervious area rain threshold (mm/day)	1.2	1.2	1.2	1.2	2.5	2.5	2.5	2.5	2.5
Pervious area soil storage capacity (mm)	150	150	150	150	150	150	150	150	150
Pervious area soil initial storage (% cap)	25	25	25	25	25	25	25	25	25
Field capacity (mm)	100	100	100	100	100	81	100	85	100
Pervious area infiltration capacity coefficient - a	200	200	200	200	200	200	200	200	200
Pervious area infiltration capacity exponent - b	1	1	1	1	1	1	1	1	1
Groundwater initial depth (mm)	10	10	10	10	10	10	10	10	10
Groundwater recharge rate (%)	25	25	25	25	25	25	25	25	25
Groundwater baseflow rate (%)	4	4	4	4	2	1	3	1	4
Groundwater deep seepage rate (%)	1	1	1	1	1	25	1	25	1

The adopted rainfall/runoff parameters are summarised in **Table D.3.** The adopted values are compared with the values adopted by Patterson Britton and Partners in 2006 for the adjacent Myall River Downs development. The landuse categories adopted by Patterson Britton and Partners included parks, industrial, eco-resort, marina, urban, forest and rural landuses.

D.4.2 Water Quality Parameters

The same approach was also adopted to "calibrate" MUSIC water quality parameters ie. MUSIC parameter values were calibrated to the **xpaqualm** unit area pollutant export rates for total suspended solids (TSS), total nitrogen (TN), and total phosphorous (TP).

TSS, TN and TP

The unit area MUSIC model was run and water quality parameters were adjusted in an iterative manner until the **xpaqualm** unit area export rates for TSS, TP and TN were matched.

The MUSIC water quality parameters that were adopted are summarised in **Table D.4**.

Table D.4
Adopted EMC Values (mg/L)

Landuse	Adopted Parameter							
	Roof	Road	Drive	Lake	Lawn Clay	Lawn Sand	Urban Clay	Urban Sand
Stormflow TSS Mean (mg/L)	35	250	100	2	200	105	200	100
Stormflow TP Mean (mg/L)	0.18	0.3	0.25	0	0.4	0.21	0.40	0.20
Stormflow TN Mean (mg/L)	1.60	2.20	1.80	0.02	2.80	2.10	2.80	2.00
Baseflow TSS Mean (mg/L)	16	16	16	1	200	100	200	100
Baseflow TP Mean (mg/L)	0.14	0.14	0.14	0.00	0.40	0.20	0.40	0.20
Baseflow TN Mean (mg/L)	1.30	1.30	1.30	0.01	2.80	2.00	2.80	2.00

BOD

BOD is an important water quality parameter for the lake model. In 2004 BOD was included as one of the pollutants modelled using **xpaqualm**. In contrast to the flexibility in the number of pollutants that can be modelled in **xpaqualm**, MUSIC has only three "pres-set" pollutants, namely TSS, TN and TP.

In order to estimate BOD exports to the existing lake under Existing conditions and the future extended lake under Developed Conditions two empirical correlations between daily BOD and TN exports were established using the 2004 **xpaqualm** model. The first correlation was for BOD exports under Pre-existing and Existing Conditions while the second correlation was for BOD exports under Developed Conditions. These correlations then applied to the daily TN exports estimated using MUSIC to create a daily BOD time series for the lake model(s).

The empirical BOD~TN relationships were established as follows –

- The lake inflow BOD and TN time series (kg/day) were extracted from the 2004 **xpaqualm** model for Existing conditions;
- A power function form of correlation was assumed;
- A manual regression analysis was performed with 3 objectives: to match the total BOD loads (fitted and original over the period of modelling), achieve a unity gradient for the trend line between the fitted and original BOD time series data (to ensure the empirical relationship being unbiased), and to maximise the correlation coefficient (R^2).

This procedure was repeated using the Developed Condition data.

The resulting BOD~TN relationships are –

Pre-existing and Existing Conditions:

$$BOD = 11.38TN^{0.80} \qquad (R^2 = 0.980)$$

Developed Conditions:

$$BOD = 9.0TN^{0.90} \qquad (R^2 = 0.985)$$

D.4.3 Comparison of Runoff and Pollutant Exports

The MUSIC and **xpaqualm** average annual runoff and pollutant export rates are compared in **Table D.5**.

Table D.5
Comparison of Average Annual Unit Runoff and Pollutant Exports

Landuse	Runoff (ML/ha)		TSS (kg/ha)		TP (kg/ha)		TN (kg/ha)	
	xpaqualm	MUSIC	**xpaqualm**	MUSIC	**xpaqualm**	MUSIC	**xpaqualm**	MUSIC
Roof	12.6	12.6	441	442	2.27	2.27	20.2	20.3
Road	12.6	12.6	3156	3160	3.78	3.79	27.7	27.9
Driveway	12.6	12.6	1260	1260	3.15	3.16	22.7	22.8
Lake	12.6	12.6	0	25	0.00	0.01	0.0	0.3
Lawn Sand	1.08	1.08	114	112	0.23	0.23	2.3	2.3
Lawn Clay	3.42	3.41	686	681	1.37	1.37	9.6	9.6
Urban Sand	1.10	1.14	117	114	0.23	0.23	2.3	2.3
Urban Clay	3.68	3.64	738	727	1.47	1.46	10.3	10.2

As is indicated in table D.5 the average annual runoff and TSS, TN and TP exports for MUSIC very closely matched the **xpaqualm** average annual runoff and pollutant export rates adopted in 2004.

D.4.4 Parameters for Treatment Measures

Rainwater Tanks

Under the scenario with rainwater tanks in place on all new residential developments it was assumed that a 5 kL rainwater tank would be installed on each residential property.

The sizing of the rainwater tanks for residential areas was based on the following assumptions –

- All new residential development is separate dwelling with 3 bedrooms;
- The average roof area is 270 m^2
- The average garden areas is 224 m^2; and
- The harvested roof runoff will be used for toilet flushing and garden watering only.

Based on the above assumptions, the BASIX calculator indicated that a 5 kL rainwater tank in combination with water efficient appliances would comply with BASIX Water requirements. However, the BASIX calculator does not report the estimated reuse demand. Consequently, the daily usage of rainwater stored in the rainwater tanks was estimated based on the Western Sydney WSUD Guidelines (UPRCT, 2003) as follows –

- Indoor use (toilet flushing for 3 effective persons) = 140 L/day/lot
- Outdoor use = 260 L/day/lot
- Total usage = 400 L/day/lot

Ponds and Wetlands

When analysing ponds/wetlands the following assumptions were made:

- the ponds/wetlands are freshwater only;
- the average depth of a permanent pool is 1.0 m for ponds and 0.3 m for wetlands;
- the extended detention depth is 0.10 m;
- the equivalent pipe diameter for extended detention was sized such that the best treatment efficiency could be achieved.

D.5 Pre-existing and Existing Conditions

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. However a number of shallow drains have been previously constructed to convey runoff from the western areas of the site to the east to join with runoff from the eastern area of the site that flows east towards the SEPP 14 wetlands and the Myall River.

The hydrological model of existing conditions includes a shallow basin to represent depression storage and shallow ponding of runoff in low lying areas in the western and northern areas of the site. The flows in the shallow drains that convey runoff from the western areas of the site to the east is represented as a diversion link. This diversion link conveys frequent runoff up to around the 1 yr ARI flow (around 4 m^3/s) east towards the SEPP 14 wetlands and the Myall River.

Consequently the MUSIC model layout reflected this diversion of frequent runoff from the western areas of the site to the east.

The layout of the model of Pre-existing and Existing Conditions is shown in **Figure D.3**.

D.5.1 Landuse

The Pre-existing Condition was defined as the conditions that existing in the early 1990s with a lake area of around 5 ha, subcatchments R1 & R2 were fully developed and there were a limited number of dwellings in subcatchments L1L, L2R, WQB1 and Nat3 (refer **Figure D.1** for location).

The Existing Condition was defined as the conditions at around 2004 with the lake area extended to 6 ha, and more dwellings constructed in subcatchments L1L, L2R, WQB1, and Nat3.

The breakdowns of landuse areas by subcatchment under Pre-existing and Existing conditions are given in **Tables D.6** and **D.7** respectively.

Table D.6
Landuse Areas (ha) under Pre-existing Conditions

Catch ID	Roof	Road	Driveway	Lawn/urban Clay	Lawn/urban Sand	Open Water
Lake1						4.08
Lake2						0.92
WQB1	0.23	0.45	0.21		2.25	
L1L	0.15	0.30	0.14		1.51	
L2R	0.11	0.22	0.10		3.39	
Nat5					23.61	
R1	2.81	1.51	0.68		5.87	
Nat3	0.38	0.75	0.35	0.83	13.37	
R2	2.02	1.08	0.49		4.21	
Nat2					2.06	
N9				7.44	0	
N8				6.58	3	
Nat6				5.83	8.74	
N7				14.46	0	
N19	0.77	0.41	0.19	17.75	0	
N18	5.42	2.92	1.32	54.73	3	
N20				10.2	0	
N17				3.59	3.58	
Nat4					13.67	
N32					1.79	
N40				0.825	3.725	
N11					8.44	
N10				14.87	13	
N43				2.286	11.192	
N42				4.501	11.258	
Total	**11.90**	**7.65**	**3.49**	**143.89**	**137.66**	**5.00**

Table D.7
Landuse Areas (ha) under Existing Conditions

Catch ID	Roof	Road	Driveway	Lawn/urban Clay	Lawn/urban Sand	Open Water
Lake1						4.08
Lake2						1.66
WQB1	0.46	0.65	0.30		1.73	
L1L	0.31	0.44	0.20		1.16	
L2R	0.23	0.32	0.15		2.39	
Nat5					23.61	
R1	2.81	1.51	0.68		5.87	
Nat3	0.77	1.09	0.49	0.83	12.50	
R2	2.02	1.08	0.49		4.21	
Nat2					2.06	
N9				7.44		
N8				6.58	3	
Nat6				5.83	8.74	
N7				14.46		
N19	0.77	0.41	0.19	17.75		
N18	5.42	2.92	1.32	54.73	3	
N20				10.2		
N17				3.59	3.58	
Nat4					13.67	
N32					1.79	
N40				0.825	3.725	
N11					8.44	
N10				14.87	13	
N43				2.286	11.192	
N42				4.501	11.258	
Total	**12.80**	**8.42**	**3.81**	**143.89**	**134.93**	**5.74**

D.5.2 Results

The adopted period of modelling was 1/01/1982 – 31/05/2004 in which 22 calendar years (1/01/1982 – 31/12/2003) were selected for generating statistics. The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands are summarised in **Table D.8**. The average annual runoff and TSS, TN and TP exports that would be estimated if the existing diversion drains were not in place were also estimated and are summarised in **Table D.8**.

Table D.8
Estimated Runoff and Pollutant Exports under Existing Conditions

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
Lake Inflow	74.4	1040	318	28700	55	459	
Lake Outflow			229	4190	22	263	
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
Lake Inflow	209.7	2934	874	124000	247	1850	
Lake Outflow			785	21190	92	1131	
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone

Subcatchment N42 discharges direct to the Myall River
Total Discharge to Conservation Zone = Myall-2 + N43
Discharge to Wetland Zone = Lake Outflow + Myall-2 + N43

It was concluded from the results the effect of the existing diversion drains has been to redistribute runoff that would otherwise flow to the existing lake and to instead increase the runoff discharging directly to the Conservation zone (to the East) from around 148 ML/yr to 704 ML/yr with similar significant increases in the TSS, TP and TN exports direct to the Conservation Zone.

D.6 Developed Conditions

A number of MUSIC models of Developed Conditions were created based on Scheme 3 and Scheme 5 from the 2004 assessment and concept development plans. These models were of the following scenarios:

(i) Developed with the Scheme 3 extended detention lake only;
(ii) Developed with the Scheme 3 extended detention lake plus rainwater tanks;
(iii) Scenario (ii) plus a series of proposed major ponds and wetlands to treat runoff from residential development discharging to the Myall River (subcatchment N42) or to the Conservation Zone (subcatchment N43) plus a 770m swale along the eastern edge of the development (to distribute flow to the Conservation Zone) – the wetlands were sized to achieve target reductions of 80%, 45% and 45% in the average annual export of TSS, TP and TN respectively);
(iv) Scenario (iii) but with rainwater tanks removed
(v) Scenario (iii) but reconfigured to include four small ponds, three large ponds, three freshwater lakes and an extension of detention lake in accordance with Scheme 5; and
(vi) Scenario (v) but with rainwater tanks removed.

The layouts of the developed conditions model with and without rainwater tanks are shown in **Figure D.4, D.5** and **D.6** (Scenarios (iii), (iv) and (v)) respectively.

D.6.1 Landuse

The areas of roof, road, driveway and gardens in each subcatchment under Developed Conditions were estimated based on indicative unit areas advised by Crighton Properties in July 2006. The adopted unit areas were:

- Each lot has an internal lot area of approximately 577 m^2;
- Each lot has an external road reserve area of 192 m^2;
- the combined lot/road area per a lot is thus 769 m^2 which gives a around 13 lots per hectare; and
- Within each lot: 270 m^2 roof, 83 m^2 driveway + pavement, and 224 m^2 soft landscaping (garden).

Landuse areas were estimated for each developed subcatchment using the following fractions of road, roof and driveway and lawn/garden surface:

Road	Roof	Driveway	Lawn	Total
0.125	0.350	0.135	0.390	1.000

These fractions were not applied to designated open spaces or to water surfaces as shown on the latest Masterplan. The breakdown of landuse areas by subcatchment under Developed Conditions is given in **Tables D.9**.

Table D.9
Landuse Areas (ha) under Developed Conditions

Catch ID	Roof	Road	Driveway	Lawn/urban Clay	Lawn/urban Sand	Open Water
N18	5.42	2.92	1.32	51.29	3.00	
N19	0.77	0.41	0.19	18.42		
N42	2.32	0.83	0.89	4.41	7.31	
N43	2.18	0.78	0.84	2.30	8.71	
E4	0.26	0.09	0.10		0.28	
N44	1.69	0.60	0.65		4.21	
EE1	2.41	0.86	0.93	0.64	3.68	
N25				9.79	5.08	
E2	0.44	0.16	0.17		0.49	
L1L	0.78	0.42	0.19		1.65	
N7				13.05		
R1	2.81	1.51	0.68		5.86	
L2R	0.68	0.37	0.17		1.41	
L3R	0.64	0.34	0.16		1.34	
R2	2.02	1.08	0.49		4.24	
WQB2	1.44	0.78	0.33		2.99	
L5R	0.46	0.25	0.11		0.97	
WQB1	1.28	0.69	0.31		2.68	
Lake						14.21
E8	2.46	0.88	0.95	2.12	3.64	1.09
EE6	1.96	0.70	0.76		2.84	0.17
EE5	1.14	0.41	0.44		1.65	0.20
EE4	4.82	1.72	1.86	5.93	4.77	2.32
N10	6.00	2.14	2.32	7.51	2.31	
N8	4.68	1.67	1.81	5.70	6.27	
WQB4	1.65	0.89	0.40		3.48	
E1	0.30	0.11	0.12		0.33	
E6	0.71	0.25	0.27		0.79	
Total	**49.31**	**20.86**	**16.44**	**121.17**	**79.95**	**17.99**

D.6.2 Results

Scheme 3

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the four scenarios (Scenarios (1) to (iv)) are summarised in **Table D.10**. The adopted properties of the lake, ponds, wetlands and swale and rainwater tanks are summarised in **Tables D.11** and **D.12** respectively.

Table D.10
Estimated Runoff and Pollutant Exports under Developed Conditions – Scheme 3

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Developed + No RWT + Extended Lake							
N42	15.8	220	78	9180	20	157	Discharges direct to Myall River
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	418	65430	134	988	Discharges to Conservation Zone
	102.7	1437	486	72800	150	1120	Total Discharge to Conservation Zone
				39%	*37%*	*36%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1320	129000	277	2170	Southern lake inflow
Lake Outflow			1154	20800	116	1370	
				84%	*58%*	*37%*	*Reduction to Developed Conditions*
			1640	93600	266	2490	Discharge to Wetland Zone
			N	Y	N	N	Less than Current Conditions?
Developed + RWTs + Extended Lake							
N42	15.8	220	68	8610	18	142	Discharges direct to Myall River
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	409	4760	55	711	Discharges to Conservation Zone
	102.7	1437	468	11600	69	828	Total Discharge to Conservation Zone
				90%	*71%*	*53%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1190	121000	249	1960	Southern lake inflow
Lake Outflow			1022	17800	102	1222	
				86%	*63%*	*44%*	*Reduction to Developed Conditions*
			1490	29400	171	2050	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Developed + RWTs + Extended Lake + Ponds + Swale							
N42	15.8	220	63	1160	5	86	Downstream of constructed wetland
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	406	3660	53	700	Discharges to Conservation Zone
	102.7	1437	465	10500	67	817	Total Discharge to Conservation Zone
				91%	*72%*	*54%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1140	50600	144	1520	Southern lake inflow
Lake Outflow			975	14400	93	1103	
				89%	*66%*	*49%*	*Reduction to Developed Conditions*
			1440	24900	160	1920	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + Extended Lake + Ponds + Swale							
N42	15.8	220	68	994	5.3	87	Downstream of constructed wetland
				89%	*74%*	*45%*	*Reduction to Developed Conditions*
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	416	3430	53	713	Discharges to Conservation Zone
	102.7	1437	484	10800	69	845	Total Discharge to Conservation Zone
				91%	*71%*	*52%*	*Reduction to Current Conditions*
Lake Inflow	187.2	2619	1260	54000	161	1700	Southern lake inflow
Lake Outflow			1096	16100	106	1245	
				88%	*62%*	*43%*	*Reduction to Developed Conditions*
			1580	26900	175	2090	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Subcatchment N42 discharges direct to the Myall River
Total Discharge to Conservation Zone = Myall-2 + N43
Discharge to Wetland Zone = Lake Outflow + Myall-2 + N43

Table D.11
Adopted Properties of Stormwater Quality Improvement Devices – Scheme 3

	Pond / Lake							Swale	Wetland					BioFilter
Location	EE2	EE4	Lake	EE5	EE6	E2	E4	Swale	N42 nrwt	N42	N43 nrwt	N43	N44 nrwt	N44	N44 Bio
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100	100	100	100	100		100	100	100	100	100	100	100
Inlet pond volume	0	0	0	0	0	0	0		0	0	0	0	0	0	
Area (sqm)	10880	23220	135000	2019	1696	659	1050		5600	3152	5500	3030	2500	1430	200
Extended detention depth (m)	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Permanent pool volume (cum)	10880	23220	241700	2019	1696	659	1050		1680	945.6	1650	909	750	429	
Average Depth (m)	*1.0*	*1.0*	*1.79*	*1.0*	*1.0*	*1.0*	*1.0*		*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	
Proportion vegetated	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.5	0.5	0.5	0.5	0.5	0.5	
Equivalent pipe diameter (mm)	450	675	1350	300	300	300	300		350	350	600	600	600	450	
Overflow weir width (m)	100	100	10	3	3	3	3		3	3	10	10	10	10	10
Notional Detention Time (hrs)	2.03	1.92	5.59	0.846	0.71	0.276	0.44		1.72	0.97	0.576	0.317	0.262	0.266	
Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6	0.6	0.6		0.6	0.6	0.6	0.6	0.6	0.6	
Weir coefficient	1.7	1.7	1.7	1.7	1.7	1.7	1.7		1.7	1.7	1.7	1.7	1.7	1.7	1.7
Number of CSTR cells	2	2	2	2	2	2	2	10	5	5	5	5	5	5	3
Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	8000	1500	1500	1500	1500	1500	1500	8000
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	20	6	6	6	6	6	6	20
Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	14	6	6	6	6	6	6	
Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	6000	1000	1000	1000	1000	1000	1000	6000
Total Phosphorus C* (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	0.13
Total Phosphorus C** (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	
Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	500	150	150	150	150	150	150	500
Total Nitrogen C* (mg/L)	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	1.4
Total Nitrogen C** (mg/L)	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	
Extraction for Re-use	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Constant Daily Re-use Demand (kL)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Filter area (sqm)															200
Filter depth (m)															0.6
Filter median particle diameter (mm)															0.24
Saturated hydraulic conductivity (mm/hr)															100
Voids ratio															0.3
Length (m)								437.5	0						
Bed slope								0.01	1.25						
Base Width (m)								6							
Top width (m)								10							
Vegetation height (m)								0.25							
Seepage Rate (mm/hr)	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Evap Loss as proportion of PET	1	1	1	1	1	1	1			1.25	1.25	1.25	1.25	1.25	
Depth in metres below the drain pipe															0

Table D.12
Adopted Properties of Rainwater Tanks – Scheme 3

	Rainwater Tanks																				
Location	N8	N10	EE4	EE1	N44	N43	N42	E8	L5R	WQB2	L3R	L2R	WQB1	L1L	EE5	EE6	E1	E2	E4	E6
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Inlet pond volume	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area (sqm)	433	555	452	223	171	275	215	324	43	133	60	63	118	72	105	182	27	40	24	66
Extended detention depth (m)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Permanent pool volume (cum)	867	1111	893	447	313	403	429	455	85	267	119	126	237	144	211	363	55	81	47	131
Average Depth (m)																				
Proportion vegetated	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equivalent pipe diameter (mm)	300	300	300	300	300	300	300	300	50	50	50	50	50	50	50	218	50	50	50	300
Overflow weir width (m)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Notional Detention Time (hrs)	0.257	0.329	0.268	0.132	0.101	0.163	0.13	0.19	0.917	2.84	1.28	1.34	2.52	1.54	2.24	0.204	0.576	0.85	0.51	0.039
Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Weir coefficient	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Number of CSTR cells	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Total Phosphorus C* (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Phosphorus C** (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Total Nitrogen C* (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Total Nitrogen C** (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Extraction for Re-use	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Constant Daily Re-use Demand (kL)	69	89	71	36	25	32	34	36	7	21	9	10	19	12	17	29	4	6	4	11
Filter area (sqm)																				
Filter depth (m)																				
Filter median particle diameter (mm)																				
Saturated hydraulic conductivity (mm/hr)																				
Voids ratio																				
Length (m)																				
Bed slope																				
Base Width (m)																				
Top width (m)																				
Vegetation height (m)																				
Seepage Rate (mm/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evap Loss as proportion of PET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depth in metres below the drain pipe																				

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks. In the case of wetlands these were re-sized if possible to account for differences in runoff from developed areas with or without rainwater tanks eg. Wetland N42 (with rainwater tanks in place) and Wetland N42 nrwt (no rainwater tanks) (refer Table D.11). Under Scenario (iv) it was necessary to include a bio-filter upstream of Wetland N44 to meet the 80/45/45 targets.

Scheme 5

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the two Scheme 5 scenarios are summarised in **Table D.13**. The adopted properties of the lakes, ponds, wetlands and swale are summarised in **Tables D.14.** The rainwater tank properties are as given in **Table D.15** respectively.

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks.

Table D.13
Estimated Runoff and Pollutant Exports under Developed Conditions – Scheme 5

ID	Area (ha)	Rainfall (ML/yr)	Flow and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
	74.4	1040	318	28700	55	459	Existing Lake Inflow
			229	4190	22	263	Existing Lake Outflow
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
	209.7	2934	874	124000	247	1850	Existing Lake Inflow
			785	21190	92	1131	Existing Lake Outflow
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone
Developed + No RWT + Fresh Lakes + Extended Lake							
N42	15.8	220	78	9180	20	157	Discharges direct to Myall River
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	418	65430	134	988	Discharges to Conservation Zone
	102.7	1437	486	72800	150	1120	Total Discharge to Conservation Zone
				39%	*37%*	*36%*	*Reduction to Current Conditions*

			813	86400	185	1410	Fresh Lake Inflow
			724	13400	74	904	Fresh Lake Outflow
			502	41900	90	727	Local Inflows
			1226	55300	164	1631	Saline Lake Inflow
			1120	17200	107	1280	Saline Lake Outflow
				87%	*61%*	*40%*	*Reduction to Developed Conditions*
			1606	90000	257	2400	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake							
N42	15.8	220	68	8610	18	142	Discharges direct to Myall River
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	409	4760	55	711	Discharges to Conservation Zone
	102.7	1437	468	11600	69	828	Total Discharge to Conservation Zone
				90%	*71%*	*53%*	*Reduction to Current Conditions*
			729	81700	167	1280	Fresh Lake Inflow
			641	12300	66	803	Fresh Lake Outflow
			462	39700	81	662	Local Inflows
			1103	52000	147	1465	Saline Lake Inflow
			995	15500	96	1140	Saline Lake Outflow
				88%	*65%*	*47%*	*Reduction to Developed Conditions*
			1463	27100	165	1968	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	63	1160	5	86	Downstream of constructed wetland
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	406	3660	53	700	Discharges to Conservation Zone
	102.7	1437	465	10500	67	817	Total Discharge to Conservation Zone
				91%	*72%*	*54%*	*Reduction to Current Conditions*
			675	22500	77	845	Fresh Lake Inflow
			587	8470	56	663	Fresh Lake Outflow
			457	29600	67	609	Local Inflows
			1044	38070	122	1272	Saline Lake Inflow
			936	13700	88	1030	Saline Lake Outflow
				89%	*68%*	*52%*	*Reduction to Developed Conditions*

			1401	24200	155	1847	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	68	994	5.3	87	Downstream of constructed wetland
				89%	*74%*	*45%*	*Reduction to Developed Conditions*
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	416	3430	53	713	Discharges to Conservation Zone
	102.7	1437	484	10800	69	845	Total Discharge to Conservation Zone
				91%	*71%*	*52%*	*Reduction to Current Conditions*
			758	24500	87	955	Fresh Lake Inflow
			670	9520	63	755	Fresh Lake Outflow
			497	30900	73	668	Local Inflows
			1167	40420	136	1423	Saline Lake Inflow
			1060	15300	100	1160	Saline Lake Outflow
				88%	*64%*	*46%*	*Reduction to Developed Conditions*
			1580	26900	175	2090	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Subcatchment N42 discharges direct to the Myall River

Total Discharge to Conservation Zone = Myall-2 + N43

Discharge to Wetland Zone = Saline Lake Outflow + Myall-2 + N43

Table D.14
Adopted Properties of Stormwater Quality Improvement Devices – Scheme 5

	Pond									Lake		Swale	Wetland					BioFilter
Location	N10Pond	EE5Pond	EE6Pond	E4Pond	E2Pond	E8Pond	EE1Pond	N10UPond	EE0Pond	N8Pond	FLake	SLake	Swale	N42 nmt	N42	N43 nmt	N43	N44 nmt	N44	N44 Bio
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100	100	100	100	100	100	100	100	100	100		100	100	100	100	100	100	100
Inlet pond volume	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
Area (sqm)	17007	2019	1696	1050	659	6058	1269	10100	1957	3539	65542	80000		5600	3152	5500	3030	2500	1430	200
Extended detention depth (m)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.4	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Permanent pool volume (cum)	17007	2019	1696	1050	659	6058	1269	10100	1957	3539	98313	168000		1680	945.6	1650	909	750	429	
Average Depth (m)														*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	
Proportion vegetated	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.5	0.5	0.5	0.5	0.5	0.5	
Equivalent pipe diameter (mm)	600	300	300	300	300	450	375	600	375	600	1350	1350		350	350	600	600	600	450	
Overflow weir width (m)	100	3	3	3	3	100	100	100	100	100	10	10		3	3	10	10	10	10	10
Notional Detention Time (hrs)	1.78	0.846	0.71	0.44	0.28	1.13	0.34	1.06	0.53	0.37	2.71	3.31		1.72	0.97	0.576	0.317	0.262	0.266	
Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6		0.6	0.6	0.6	0.6	0.6	0.6	
Weir coefficient	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7		1.7	1.7	1.7	1.7	1.7	1.7	1.7
Number of CSTR cells	2	2	2	2	2	2	2	2	2	2	2	2	10	5	5	5	5	5	5	3
Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	400	400	400	400	400	8000	1500	1500	1500	1500	1500	1500	8000
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	20	6	6	6	6	6	6	20
Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	14	6	6	6	6	6	6	
Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	300	300	300	300	300	6000	1000	1000	1000	1000	1000	1000	6000
Total Phosphorus C* (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	0.13
Total Phosphorus C** (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	
Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	40	40	40	40	40	500	150	150	150	150	150	150	500
Total Nitrogen C* (mg/L)	1	1	1	1	1	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	1.4
Total Nitrogen C** (mg/L)	1	1	1	1	1	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	
Extraction for Re-use	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Constant Daily Re-use Demand (kL)													n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Filter area (sqm)																				200
Filter depth (m)																				0.6
Filter median particle diameter (mm)																				0.24
Saturated hydraulic conductivity (mm/hr)																				100
Voids ratio																				0.3
Length (m)													437.5	0						
Bed slope													0.01	1.25						
Base Width (m)													6							
Top width (m)													10							
Vegetation height (m)													0.25							
Seepage Rate (mm/hr)													0		0	0	0	0	0	0
Evap Loss as proportion of PET	0	0	0	0	0	0	0	0	0	0	0	0			1.25	1.25	1.25	1.25	1.25	
Depth in metres below the drain pipe	1	1	1	1	1	1	1	1	1	1	1	1								0

Table D.15
Adopted Properties of Rainwater Tanks – Scheme 5

		Rainwater Tank																													
	Location	N8RWT	N10RWT	EE4RWT	EE1RWT	N44RWT	N43RWT	N42RWT	E8RWT	L5RRWT	L3RRWT	L2RaRWT	L2RRWT	L1LRWT	EE5RWT	EE6RWT	E1RWT	E2RWT	E4RWT	E6RWT	N10aRWT	N10bRWT	EE0RWT								
	Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
	Hi-flow bypass rate (cum/sec)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100								
	Inlet pond volume	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
	Area (sqm)	346	380	168	179	156	201	215	175	132	104	54	58	142	349	182	27	40	24	66	173	14	101								
	Extended detention depth (m)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2								
	Permanent pool volume (cum)	692	759	235	349	313	403	429	350	264	207	108	115	284	698	363	55	81	47	131	347	28	203								
	Average Depth (m)																														
	Proportion vegetated	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
	Equivalent pipe diameter (mm)	300	300	300	300	300	300	300	300	50	50	50	50	50	50	218	50	50	50	300	300	300	300								
	Overflow weir width (m)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10								
	Notional Detention Time (hrs)	0.205	0.225	0.1	0.106	0.092	0.119	0.13	0.1	2.82	2.22	1.15	1.24	3.03	7.44	0.2	0.576	0.853	0.51	0.04	0.1	0.01	0.06								
	Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6								
	Weir coefficient	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7								
	Number of CSTR cells	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2								
	Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400								
	Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12								
	Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12								
	Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300								
	Total Phosphorus C* (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13								
	Total Phosphorus C** (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13								
	Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40								
	Total Nitrogen C* (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4								
	Total Nitrogen C** (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4								
	Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500								
	Extraction for Re-use	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On								
	Constant Daily Re-use Demand (kL)	55	60.7	18.8	27.9	25	32	34	28	21	17	9	9	23	56	29	4	6	4	11	27.8	2.2	16.2								
	Filter area (sqm)																														
	Filter depth (m)																														
	Filter median particle diameter (mm)																														
	Saturated hydraulic conductivity (mm/hr)																														
	Voids ratio																														
	Length (m)																														
	Bed slope																														
	Base Width (m)																														
	Top width (m)																														
	Vegetation height (m)																														
	Seepage Rate (mm/hr)																														
	Evap Loss as proportion of PET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
	Depth in metres below the drain pipe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								

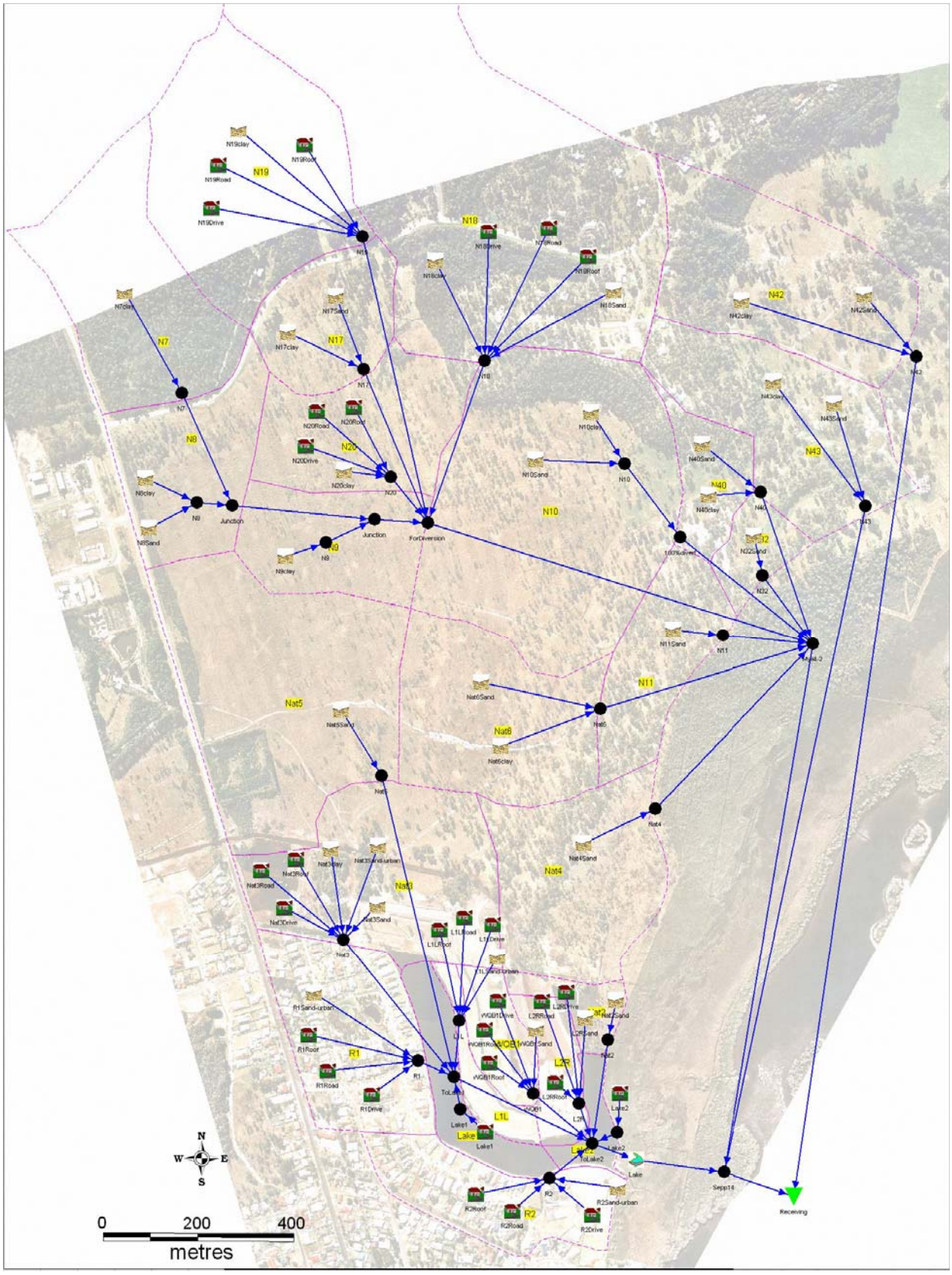


Figure D.3
MUSIC Model Layout for Pre-Existing and Existing Conditions

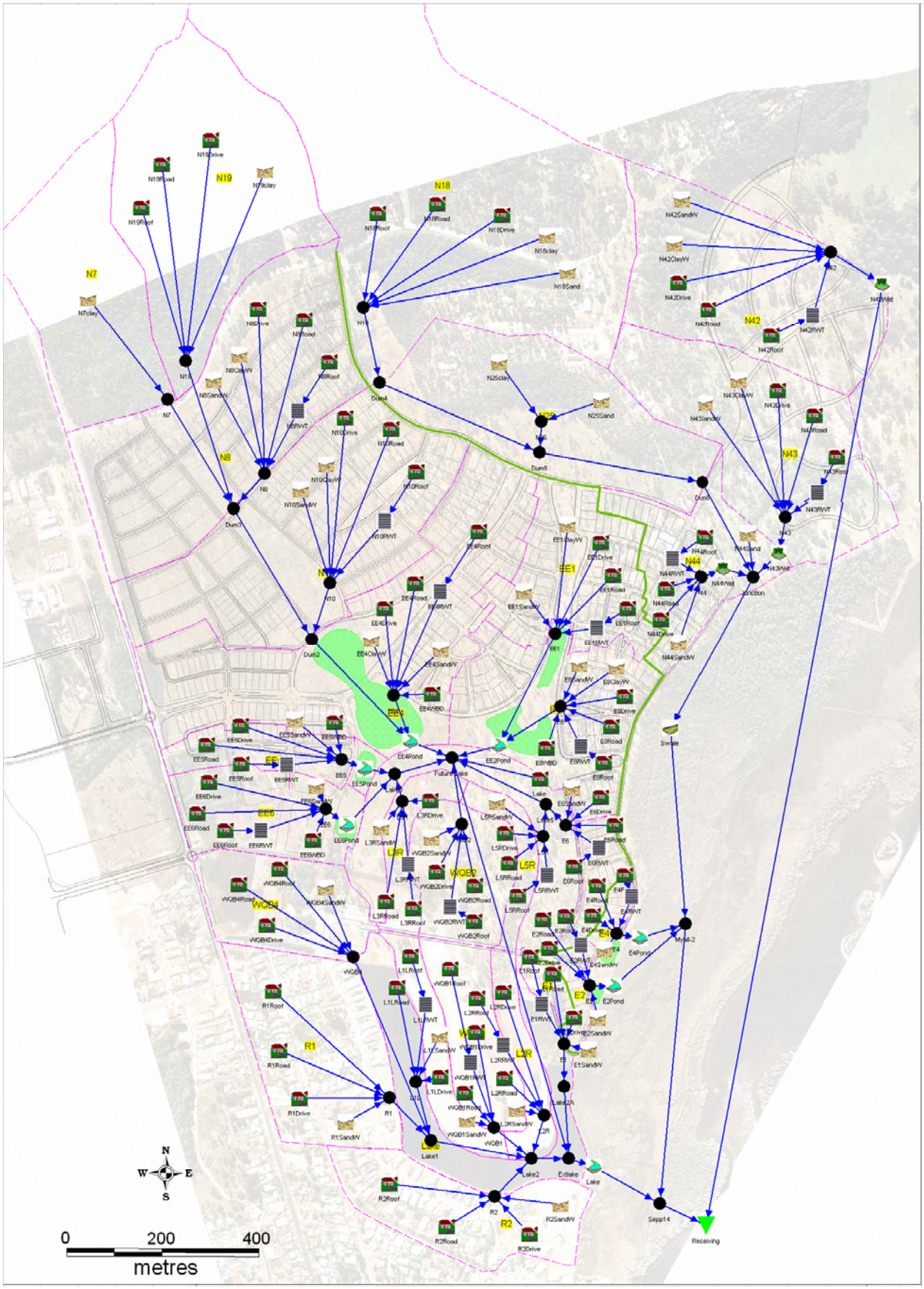


Figure D.4
MUSIC Model Layout for Developed Conditions with Rainwater Tanks – Scheme 3

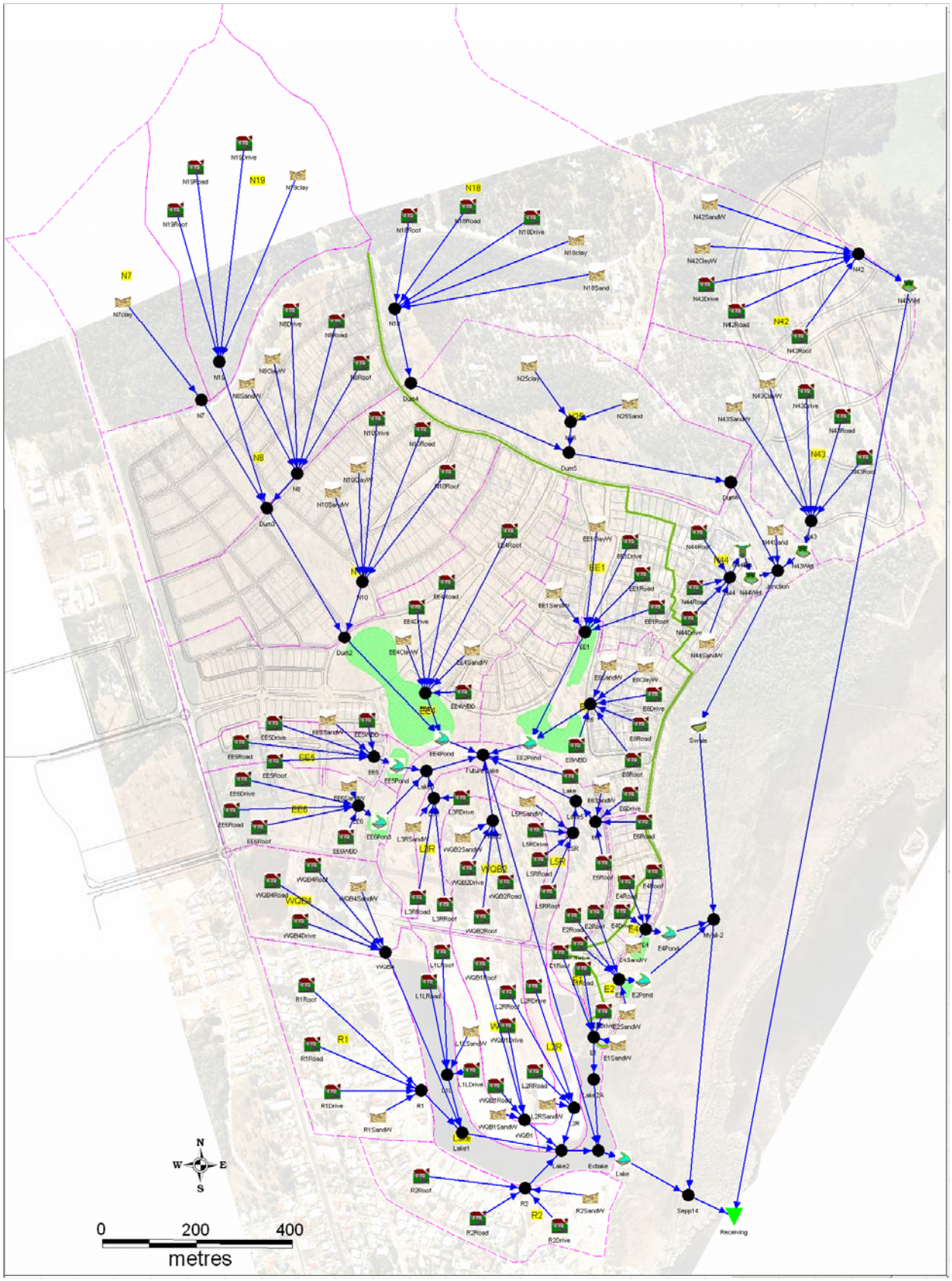


Figure D.5
MUSIC Model Layout for Developed Conditions without Rainwater Tanks – Scheme 3

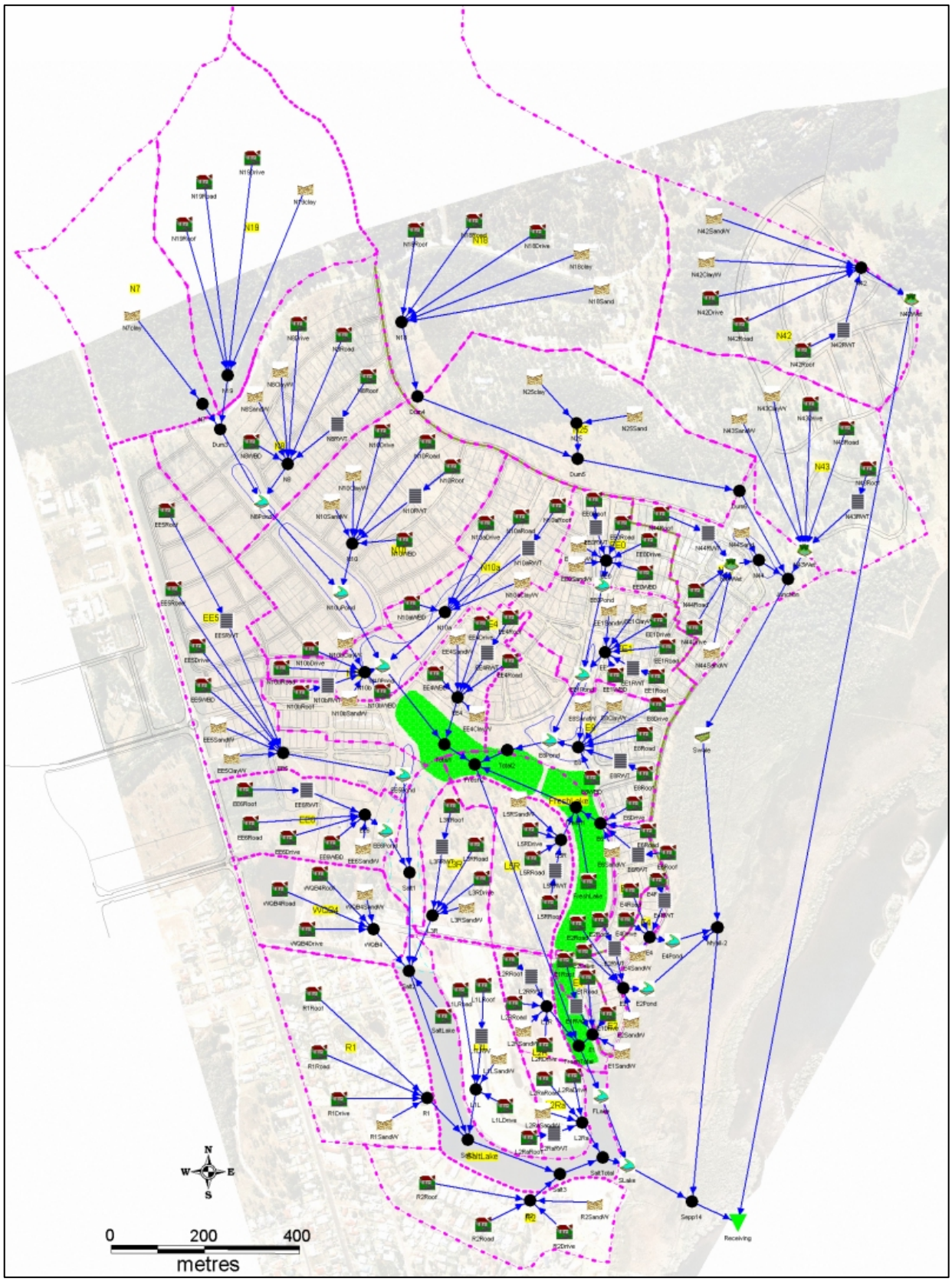


Figure D.6
MUSIC Model Layout for Developed Conditions with Rainwater Tanks - Scheme 5

APPENDIX E

LAKE MODELLING

E.1	AIMS	E.1
E.2	BACKGROUND	E.1
E.3	THE CRCFE POND MODEL	E.2
E.4	OBSERVED WATER QUALITY	E.3
E.5	2004 LAKE MODELLING	E.4
E.6	PRE-EXISTING AND EXISTING CONDITIONS	E.5
E.7	DEVELOPED CONDITIONS	E.6

E.1 Aims

The aims of the lake modelling were to

- Re-run the Pond models of the Pre-existing and Existing detention lakes using catchment inputs calculated using the MUSIC model and to confirm that similar results to previous runs were obtained;
- Re-run the Scheme 3 Pond model and Scheme 5 Pond models for catchment inputs under developed conditions and compare with the 2004 results; and
- If needed, size pond(s) and/or wetland(s) to achieve the receiving water quality objectives for receiving waters.

E.2 Background

Surface waters drain partly toward the existing detention lake and then through the wetland zone and partly toward the conservation zone that provides a buffer to the wetland zone on the eastern boundary of the site.

The primary aim for the existing management of water quality is to protect the wetland zone by directing the runoff from the developed areas of the catchment to a weakly tidally flushed lake. This is also supported by a number of smaller ponds and wetlands located within existing residential areas.

Water quality impacts on the existing detention lake at Riverside at Tea Gardens are due to event-driven loads from runoff, decay of in-lake algae and releases from sediments. Tidal inflows can also impact on water quality. The stormwater runoff impacts can be expected to increase with urban development in the northern part of the project site unless remedial measures are provided and / or the lake is increased in size.

A detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible to maintain the existing lake water quality and its current role as a fish habitat was reported in 2004 (Cardno, 2004).

A Do Nothing option and six schemes to mitigate the impact of planned future development on lake water quality were assessed. These schemes were:

0. **Existing conditions** ie. a 6 ha lake;
1. **Do nothing** – keep the current water body as it is without increasing the size (but with BASIX implemented).
2. **Existing** lake (6 ha) with **increased tidal flushing** (x4);
3. **Extended lake** (13.5 ha) with **increased tidal flushing** (x2);
4. Existing lake with **increased tidal flushing** (x1.6) and **a new freshwater lake** (12 ha);
5. **Partially extended lake** (8 ha) with **increased tidal flushing** (x1.8) and **new freshwater lake** (6.5 ha);
6. Existing lake (6 ha) with **increased tidal flushing** (x1.6) and **new wetlands** (16 ha); and
7. Existing lake (6 ha) and **dry swales**.

A multi-criteria assessment of water quality performance, environmental impacts and viability was undertaken. The assessment criteria included:

- Water Quality
  - Salinity
  - Dissolved Oxygen
  - Algae
  - Total Nitrogen
  - Total Phosphorous

- Environmental Impacts
  - Impact on existing water body
  - Impact on SEPP 14 wetlands
  - Impact on Myall River
  - Impact on Ground Water

- Viability
  - Loss of potential lots
  - Aesthetic/Health
  - Landtake for Basins
  - Landtake for Ponds / Wetlands
  - Filling

The highest ranked scheme to mitigate the impacts of planned development was Scheme 3. The second highest ranked scheme to mitigate the impacts of planned development was Scheme 5.

E.3 The CRCFE Pond Model

The CRC for Freshwater Ecology (now eWater) released a pond model (PDMOD) in 2001 for industry use. The model is daily time step spreadsheet model of inflow, mixing, sedimentation, sediment reduction and oxidation, and algal growth and washout processes.

The major model components comprise:

(i) advective mixing and washout associated with storm event driven inflows high in suspended solids, nutrients, organic matter and toxicants;

(ii) adsorption of nutrients, metals and organic material on surfaces of suspended solids and their removal by sedimentation in the period after the storm event;

(iii) decomposition of sedimented organic material after each event, by benthic heterotrophic bacteria, with the associated depletion of dissolved oxygen, denitrification and the potential for reduction of insoluble ferric iron to dissolved ferrous iron and the release of ortho-phosphate previously bound to ferric iron into the water column; and the

(iv) rapid uptake of released ortho-phosphate and other nutrients by algae under conditions of post storm low inflows and extended detention.

Significant modifiers of the sediment redox processes incorporated into the model include:

(v) transfer of atmospheric oxygen by wind mixing, through the water surface and water column to the sediments, offsetting sediment BOD;

(vi) heating of turbid surface waters under low wind and high summer solar radiation conditions, resulting in steep thermal gradient and the limitation of oxygen transfers;

(vii) the role of emergent macrophytes in directly transferring oxygen to their sediment rhizome root zone.

The application of the CRCFE Pond Model to the assessment of water quality in a number of freshwater ponds and lakes under Sydney, Cairns and Tea Gardens conditions have been previously outlined by Lawrence and Phillips, 2001 and Phillips et al, 2003 and Phillips and Wade, 2006 respectively.

E.4 Observed Water Quality

A water quality monitoring programme was established in 1996 firstly by the developer, and more recently taken over by the Myall Quays Community Association. Hunter Water Laboratories collects and analyse samples at 5 lake locations every 3 months.

Salinity

The sampling indicates that the lake water is brackish having a 50th percentile value of salinity of 12.8 g/L, which is approximately one third of the salinity of seawater. There is variability in the salinity concentration due to both catchment (freshwater) runoff as well as the influence of tides and varying salinity in the Myall River. The observed salinity varied from 4.2 g/L to 25.6 g/L (between the 10th percentile and 90th percentile values).

Dissolved Oxygen (DO)

The 50th percentile of all Dissolved Oxygen (DO) values (100 readings) in the lake for the sampling period is 6.6 mg/L, with a 10th percentile level of 4.8 mg/L. The 4.8 mg/L level is just below the recommended ANZECC trigger value of 5.0 mg/L for freshwater fish. A comparison of the DO levels measured within the existing lake and the Myall River disclosed that the ANZECC guidelines for DO are not currently met at all times, in either the lake or river (at Copeland Ave Wharf). As indicated in **Figure 9** the DO levels in the existing lake are often better that in the Myall River.

Nutrients

The adopted ANZECC, 2000 trigger value for Phosphorus (TP) is 0.03 mg/L for estuarine systems. Most of the samples have been below the recommended value with a 50th percentile (100 readings) of 0.005 mg/L. Higher P levels occurred soon after the lake was constructed, possibly due residual P released from exposed soil.

The ANZECC, 2000 trigger value for Nitrogen (TN) is 0.3 mg/L, (NO_x) is 0.015 mg/L and Ammonia is 0.015 mg/L for estuarine systems. TN values could not be calculated from the available data. The 50th percentile of all NO_x values (24 readings) in the lake for the sampling period was 0.0105 mg/L. The 50th percentile of all Ammonia values (84 readings) in the lake for the sampling period is 0.03 mg/L.

The nutrient levels measured have generally been low, contributing to the overall good water quality in the existing lake.

E.5 2004 Lake Modelling

E.5.1 2004 Model Calibration

The challenge faced in using the Pond model to assess options to maintain observed levels of water quality in the existing lake at Riverside at Tea Gardens using the CRCFE pond model is that the lake is partially flushed by high tides in the adjacent Myall River.

The Pond model was therefore modified to reflect the dominant process in a lake that is partially flushed on the top of tides. The model was also extended to include a salinity submodel.

The inflows to the model include catchment runoff and tidal inflows from the Myall River. The catchment runoff and pollutant exports under pre-existing and existing conditions were estimated previously using an **xpaqualm** model of the catchment.

Tidal inflows were estimated using a hydrodynamic model of the SEPP 14 wetlands at the south eastern end of the existing lake and the Myall River.

The salinity of tidal inflows was observed to vary in response to varying salinity levels in the Myall River. An algorithm was developed to estimate daily salinity in the Myall River based on daily rainfall.

A further challenge was that the original lake was enlarged in early 2003.

The models were calibrated against observed data collected during the following periods:

- Salinity 24 October 1996 – 23 May 2004
- Temperature 13 May 1996 – 20 October 2003
- Dissolved Oxygen 13 May 1996 – 20 October 2003
- Chlorophyll ‘a’ 13 May 1996 – 20 October 2003

The Pond models were run for the period 1 January 1996 – 31 May 2004.

A comparison of predicted and observed salinity in the Myall River and the existing lake is given in **Figure E.1** while a comparison of the predicted and observed dissolved oxygen (DO) , water temperature and algal levels (chlorophyll ‘a’) are given in **Figures E.2** and **E.3**. It was concluded that very good agreement with observed water quality was achieved.

E.5.2 2004 Assessment of Water Quality Management Options

Six schemes were formulated to mitigate the impact of planned future development on lake water quality. These six schemes as well as a Do Nothing scheme were assessed.

Representative results of the predicted variations in salinity and TP concentrations in each of the proposed water bodies, using the calibrated models, are given in **Figure E.4.** Results of the assessments of the variations in salinity, DO, TN, TP and Chlorophyll 'a' concentrations in each of the proposed water bodies, using the calibrated models, are given in Cardno, 2004 (refer **Appendix F**).

Table E.1
Comparison of Lake Water Quality under Pre-existing and Existing Conditions

Percentile	Pre-existing Condition		Existing Condition	
	2004 Study	This Study	2004 Study	This Study
DO Bottom				
5%	1.0	0.7	1.5	1.6
20%	4.5	4.3	4.6	4.4
50%	5.9	5.8	5.9	5.8
80%	7.2	7.1	7.2	7.1
95%	8.2	8.1	8.1	8.1
DO % Saturation				
5%	12%	8%	21%	20%
20%	59%	57%	61%	59%
50%	78%	76%	78%	77%
80%	88%	88%	89%	88%
95%	95%	94%	95%	95%
TP				
5%	0.0014	0.0014	0.0011	0.0010
20%	0.0028	0.0026	0.0019	0.0019
50%	0.0055	0.0055	0.0040	0.0040
80%	0.0124	0.0135	0.0094	0.0106
95%	0.0283	0.0371	0.0221	0.0278
TN				
5%	0.29	0.27	0.31	0.29
20%	0.34	0.31	0.36	0.33
50%	0.41	0.39	0.42	0.40
80%	0.50	0.51	0.50	0.51
95%	0.68	0.77	0.64	0.72
Algal Biomass				
50%	0.0010	0.0010	0.0010	0.0010
70%	0.0011	0.0011	0.0010	0.0010
90%	0.0016	0.0021	0.0012	0.0014
95%	0.0034	0.0048	0.0022	0.0026
100%	0.0374	0.0323	0.0268	0.0265

E.6 Pre-Existing and Existing Conditions

The Pond models of the Pre-existing detention lake and the Existing detention lake were re-run using inputs calculated using the MUSIC model to compare with the previous results reported in 2004. The results are compared in **Table E.1**.

It was concluded that the calculated lake water quality using inputs generated by MUSIC are very similar to the lake water quality previously calculated using inputs generated by **xpaqualm**.

E.7 Developed Conditions

E.7.1 Scheme 3

The highest ranked scheme to mitigate the impacts of planned development that was assessed in 2004 was Scheme 3. Scheme 3 comprises an extended detention lake with increased tidal flushing supported by additional ponds or wetlands as needed. The Pond model of Developed Conditions with the extended lake was run with inputs calculated using the MUSIC model. Three scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and the extended detention lake;
(ii) Developed Conditions with rainwater tanks and the extended detention lake and ancillary ponds or wetlands; and
(iii) Developed Conditions without rainwater tanks and with the extended detention lake and ancillary ponds or wetlands.

The results of this assessment are compared with the previous results reported in 2004 in **Table E.2**.

E.7.2 Scheme 5

Scheme 5 comprises a partial extended saline lake (8 ha) with increased tidal flushing and new freshwater lakes (6.5 ha in total); supported by additional ponds or wetlands as needed (total area of pons draining to the lakes is 4.7 ha). The Developed Conditions Pond models of the freshwater Lakes and a separate linked model of the partially extended saline lake were run with inputs calculated using the MUSIC model. Four scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake;
(ii) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands;
(iii) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake; and
(iv) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands.

The results of the assessment of the original Scheme 5 are compared with the previous results reported in 2004 in **Table E.3**. The original Scheme 5 was based on widening the existing outlet channel by 80% and lowering the outlet channel uniformly by 0.09 m.

However concerns expressed by several stakeholders regarding any modification of the existing outlet channel within the SEPP 14 wetland zone meant that consideration was given to a different outlet arrangement. Under this outlet configuration the existing outlet channel remains unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel. The second outlet channel would be constructed without disturbing the SEPP 14 wetland. It would connect to a second existing drain located within the SEPP 14 wetland zone.

These two channels were represented as the existing channel width increased by 100% and the channel invert levels uniformly lowered by 0.05 m.

For comparison the impact on water quality in the saline lake of retaining the existing outlet channel unchanged without a second outlet channel was also assessed.

The results of the assessment of the retaining the existing outlet channel unchanged with and without a second outlet channel are compared with the original Scheme 5 results in **Table E.4**.

Table E.2
Estimated Lake Water Quality under Scheme 3 Developed Conditions

Percentile	Scheme 3				
	2004 Study	This Study RWT + Lake	This Study RWT + Lake + Ponds	This Study No RWT + Lake + Ponds	ANZECC, 2000 Trigger Value / Ranges
Salinity (g/L)					
5%	3.4	3.8	3.8	3.7	3-20 g/L
20%	8.2	7.9	8.0	7.7	
50%	13.7	14.0	14.4	13.7	
80%	21.6	22.6	23.3	22.0	
95%	26.7	28.1	28.8	27.7	
DO Bottom (mg/L)					
5%	2.8	2.0	3.0	2.6	
20%	5.8	5.7	6.1	5.9	
50%	7.1	6.9	7.2	7.1	
80%	8.2	7.9	8.2	8.1	
95%	9.1	8.8	9.0	9.0	
DO Saturation (%)					
5%	32%	22%	33%	30%	80%-100%
20%	69%	66%	73%	70%	
50%	86%	84%	87%	86%	
80%	94%	93%	95%	94%	
95%	99.3%	98.1%	99.6%	99.2%	
TP (mg/L)					
5%	0.0023	0.0028	0.0019	0.0020	0.03
20%	0.0051	0.0057	0.0038	0.0043	
50%	0.0103	0.0130	0.0077	0.0085	
80%	0.0240	0.0310	0.0175	0.0179	
95%	0.0527	0.0579	0.0362	0.0373	
TN (mg/L)					
5%	0.27	0.23	0.18	0.21	0.3
20%	0.34	0.30	0.24	0.27	
50%	0.45	0.41	0.33	0.36	
80%	0.59	0.63	0.50	0.52	
95%	0.91	0.91	0.76	0.78	
Algal Biomass (mg/L)					
50%	0.0011	0.0011	0.0011	0.0011	0.004
70%	0.0012	0.0012	0.0012	0.0012	
90%	0.0016	0.0018	0.0018	0.0019	
95%	0.0023	0.0035	0.0031	0.0034	
100%	0.0191	0.0305	0.0282	0.0253	

Table E.3
Estimated Lake Water Quality under Original Scheme 5 Developed Conditions

Percentile	Scheme 5									ANZECC, 2000 Trigger Value / Ranges
	2004 Study		This Study							
	Saline Lake	Fresh Lake(s)	RWTs only		RWTs + Ponds		No RWTs		No RWT + Ponds	
			Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	
Salinity (g/L)											
5%	3.3		1.4		3.5		1.4		3.4		3-20 g/L
20%	8.2		5.9		7.9		5.6		7.6		
50%	14.1		12.5		15.2		11.5		14.3		
80%	22.8		22.1		25.1		20.2		23.7		
95%	28.9		30.4		32.2		27.9		30.4		
DO Bottom (mg/L)											
5%	2.7	5.9	1.5	3.1	3.6	4.8	1.4	2.7	3.6	4.4	
20%	4.6	7.9	4.4	6.9	4.7	7.6	4.3	6.6	4.8	7.4	
50%	6.0	8.6	5.9	8.1	6.2	8.6	5.9	7.9	6.2	8.5	
80%	7.4	9.4	7.2	8.8	7.5	9.2	7.1	8.8	7.6	9.1	
95%	8.4	10.1	8.2	9.4	8.5	9.8	8.1	9.4	8.5	9.8	
DO Saturation (%)											
5%	35%	62%	19%	33%	51%	52%	15%	29%	50%	46%	80%-100%
20%	65%	85%	61%	71%	72%	80%	57%	69%	71%	78%	
50%	80%	94%	79%	86%	82%	93%	77%	84%	82%	92%	
80%	88%	100%	87%	99%	89%	100%	86%	98%	89%	100%	
95%	93.0%	100.0%	92.8%	100.0%	93.8%	100.0%	92.5%	100.0%	93.5%	100.0%	
TP (mg/L)											
5%	0.0041	0.0007	0.0037	0.0007	0.0028	0.0007	0.0039	0.0007	0.0029	0.0007	0.03
20%	0.0065	0.0015	0.0066	0.0011	0.0049	0.0007	0.0073	0.0012	0.0052	0.0007	
50%	0.0098	0.0055	0.0126	0.0097	0.0081	0.0019	0.0140	0.0115	0.0086	0.0024	
80%	0.0174	0.0206	0.0247	0.0467	0.0142	0.0150	0.0261	0.0486	0.0147	0.0164	
95%	0.0332	0.0572	0.0490	0.0821	0.0251	0.0332	0.0506	0.0849	0.0258	0.0354	
TN (mg/L)											
5%	0.24	0.87	0.22	0.75	0.18	0.53	0.25	0.76	0.20	0.56	0.3
20%	0.30	0.92	0.29	0.81	0.23	0.56	0.32	0.81	0.24	0.58	
50%	0.39	0.98	0.42	0.92	0.30	0.62	0.45	0.92	0.32	0.63	
80%	0.52	1.08	0.64	1.19	0.43	0.75	0.66	1.19	0.45	0.77	
95%	0.77	1.30	0.94	1.39	0.63	0.97	0.96	1.40	0.65	0.99	
Algal Biomass (mg/L)											
50%	0.0012	0.0010	0.0012	0.0010	0.0011	0.0010	0.0013	0.0010	0.0012	0.0010	0.004
70%	0.0013	0.0010	0.0014	0.0010	0.0013	0.0010	0.0015	0.0011	0.0013	0.0010	
90%	0.0017	0.0013	0.0020	0.0016	0.0016	0.0014	0.0021	0.0016	0.0017	0.0015	
95%	0.0021	0.0017	0.0027	0.0026	0.0019	0.0018	0.0028	0.0027	0.0019	0.0022	
100%	0.0105	0.0304	0.0323	0.1397	0.0052	0.0592	0.0344	0.1860	0.0065	0.0912	

Table E.4
Estimated Lake Water Quality under Final Scheme 5 Developed Conditions

	Original Scheme 5		Existing Outlet Only		Final Scheme 5	
Channel Widening Factor	1.8		1.0		2.0	
Ave Lowering of Channel (m)	0.09		0.0		0.05	
Percentile						
Salinity	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.5	3.4	1.3	1.2	3.0	2.9
20%	7.9	7.6	3.1	2.8	6.9	6.6
50%	15.2	14.3	6.9	6.3	13.7	12.8
80%	25.1	23.7	12.2	10.8	23.1	21.6
95%	32.2	30.4	16.7	15.2	30.2	28.2
DO Bottom	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.6	3.6	4.4	4.4	3.7	3.8
20%	4.7	4.8	6.1	6.1	5.0	5.0
50%	6.2	6.2	7.1	7.1	6.3	6.4
80%	7.5	7.6	8.3	8.3	7.7	7.7
95%	8.5	8.5	9.0	9.0	8.6	8.6
DO % Saturation	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	51%	50%	54%	53%	52%	51%
20%	72%	71%	75%	74%	73%	71%
50%	82%	82%	85%	84%	83%	82%
80%	89%	89%	92%	92%	90%	89%
95%	94%	94%	97%	96%	95%	94%
TP	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.0028	0.0029	0.0009	0.0010	0.0022	0.0023
20%	0.0049	0.0052	0.0017	0.0019	0.0039	0.0043
50%	0.0081	0.0086	0.0047	0.0050	0.0074	0.0078
80%	0.0142	0.0147	0.0127	0.0134	0.0139	0.0148
95%	0.0251	0.0258	0.0252	0.0258	0.0256	0.0265
TN	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.18	0.20	0.31	0.33	0.20	0.21
20%	0.23	0.24	0.35	0.37	0.25	0.26
50%	0.30	0.32	0.42	0.44	0.32	0.34
80%	0.43	0.45	0.55	0.56	0.45	0.47
95%	0.63	0.65	0.73	0.75	0.66	0.67
Algal Biomass	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
50%	0.0011	0.0012	0.0010	0.0010	0.0011	0.0011
70%	0.0013	0.0013	0.0011	0.0011	0.0012	0.0013
90%	0.0016	0.0017	0.0014	0.0014	0.0016	0.0016
95%	0.0019	0.0019	0.0017	0.0018	0.0018	0.0019
100%	0.0052	0.0065	0.0049	0.0060	0.0053	0.0066

WSUD 1 Scheme with RWTs + Ponds
WSUD 2 Scheme without RWTs + Ponds

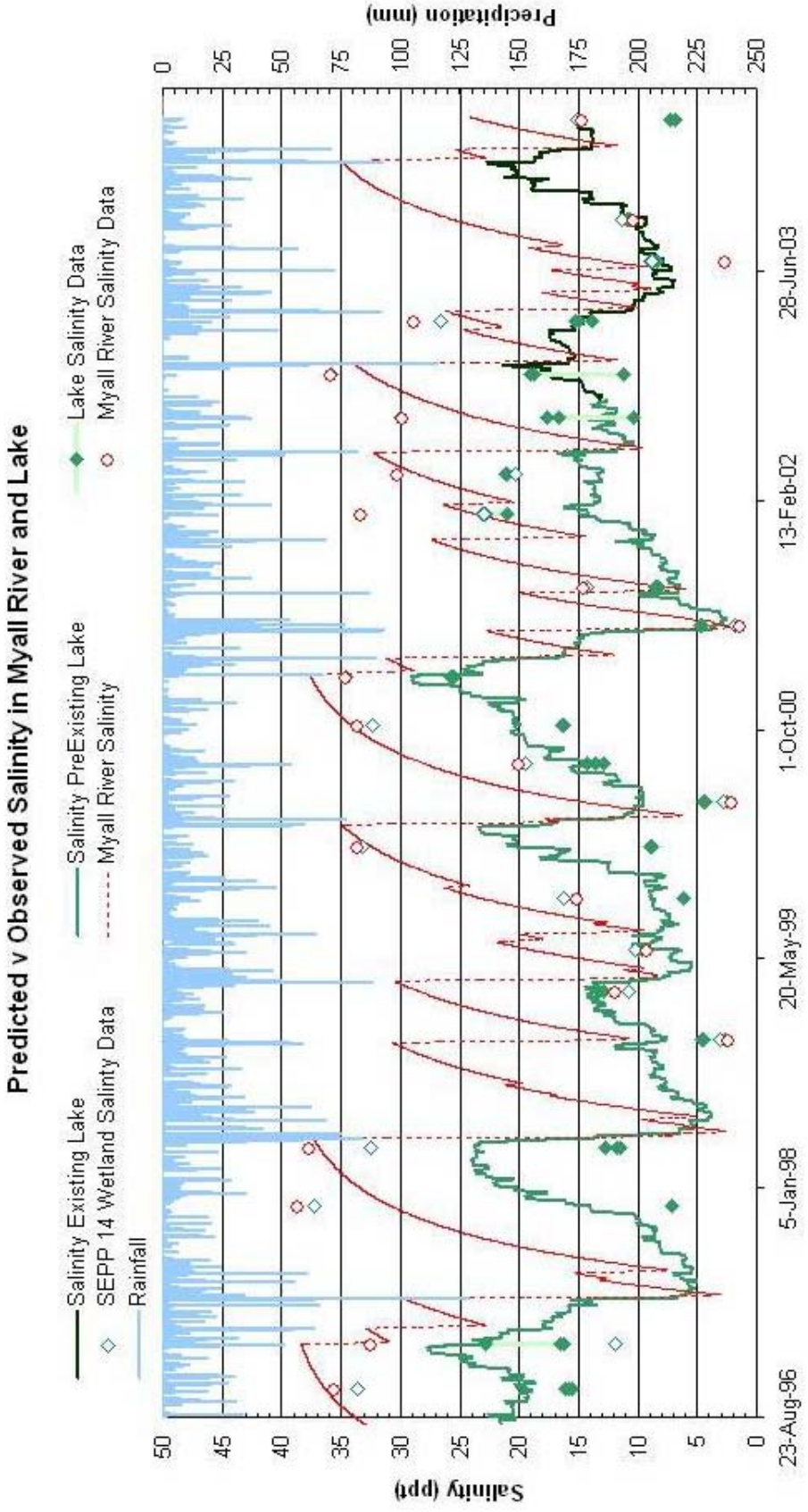


Figure E.1
Comparison of Predicted and Observed Salinity in the Myall River and Existing Lake

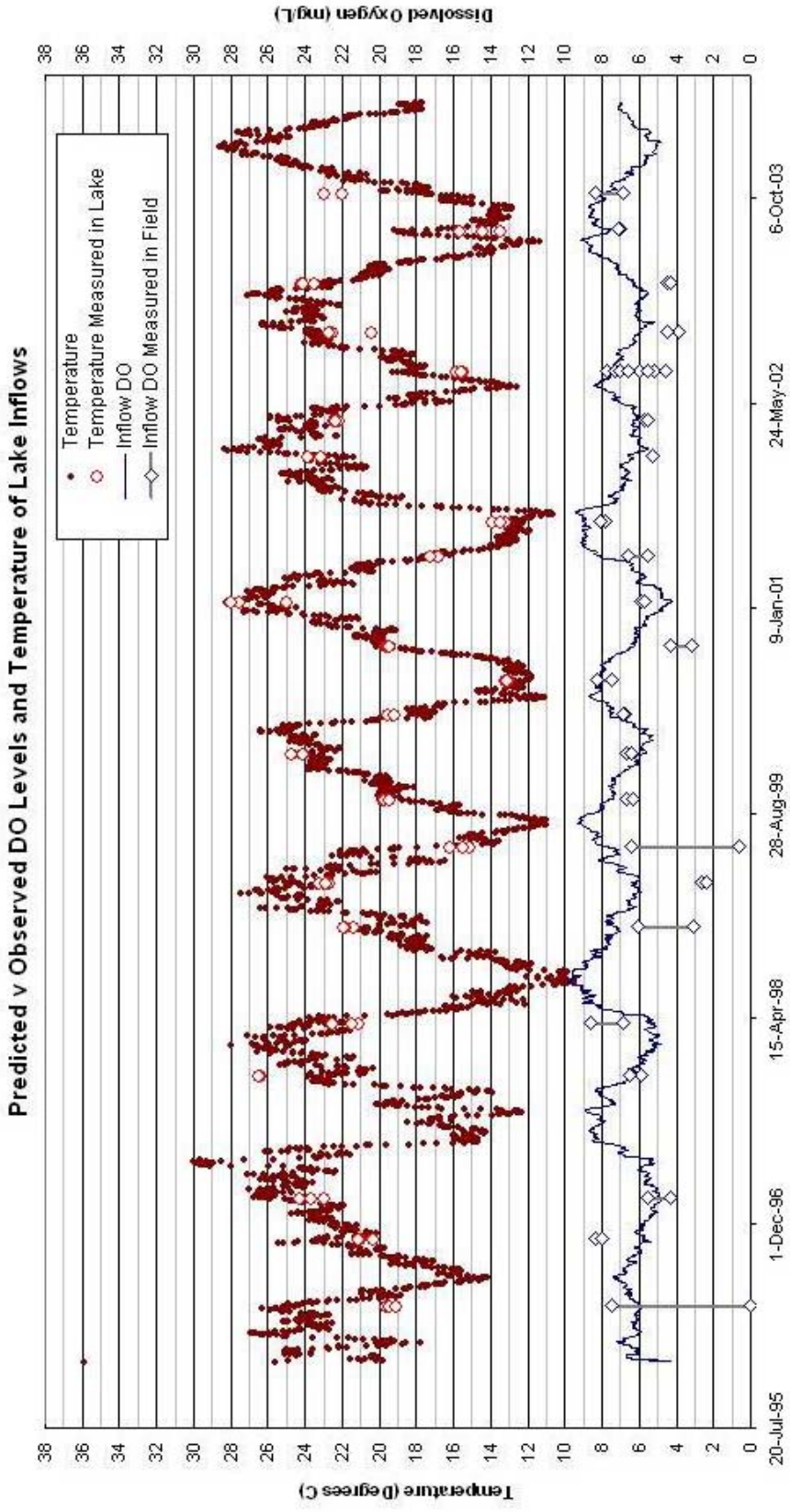


Figure E.2
Comparison of Predicted and Observed Dissolved Oxygen and Temperature of Lake Inflows

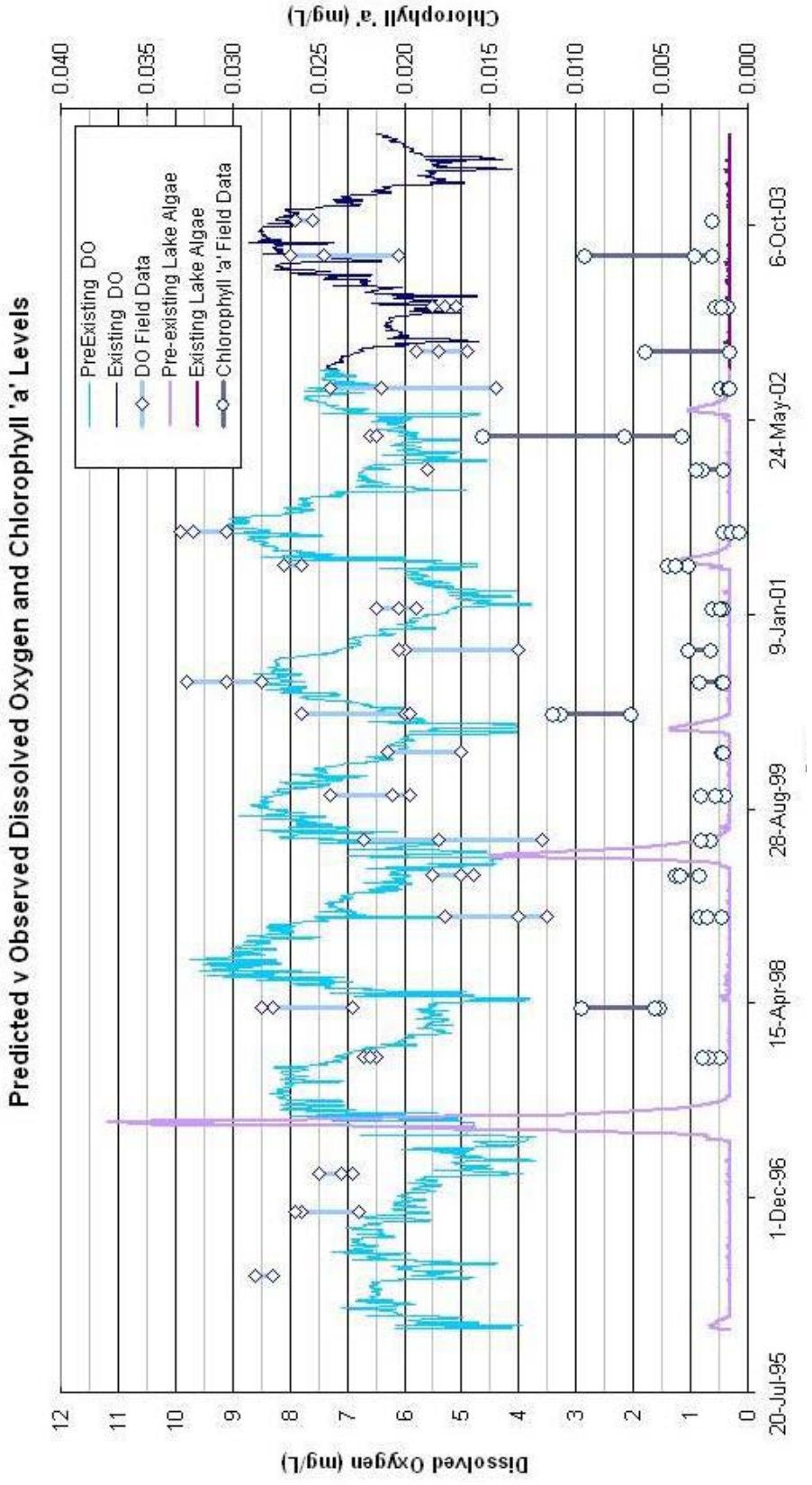
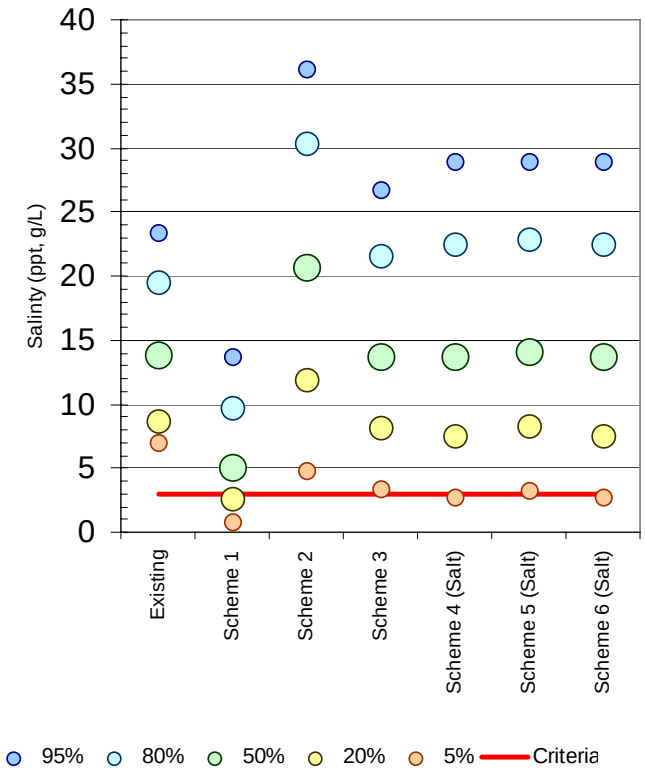


Figure E.3
Comparison of Predicted and Observed Dissolved Oxygen and Algae in the Existing Lake



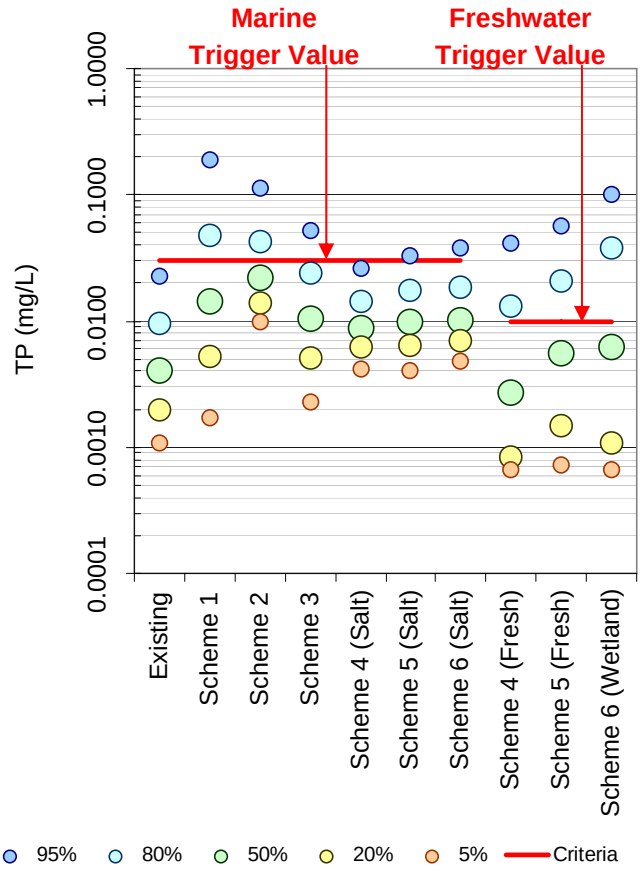


Figure E.4
2004 Comparison of Predicted Salinity and TP Concentrations for Various Management Options

APPENDIX F

ASSESSMENT OF WATER MANAGEMENT OPTIONS
SEPTEMBER 2004

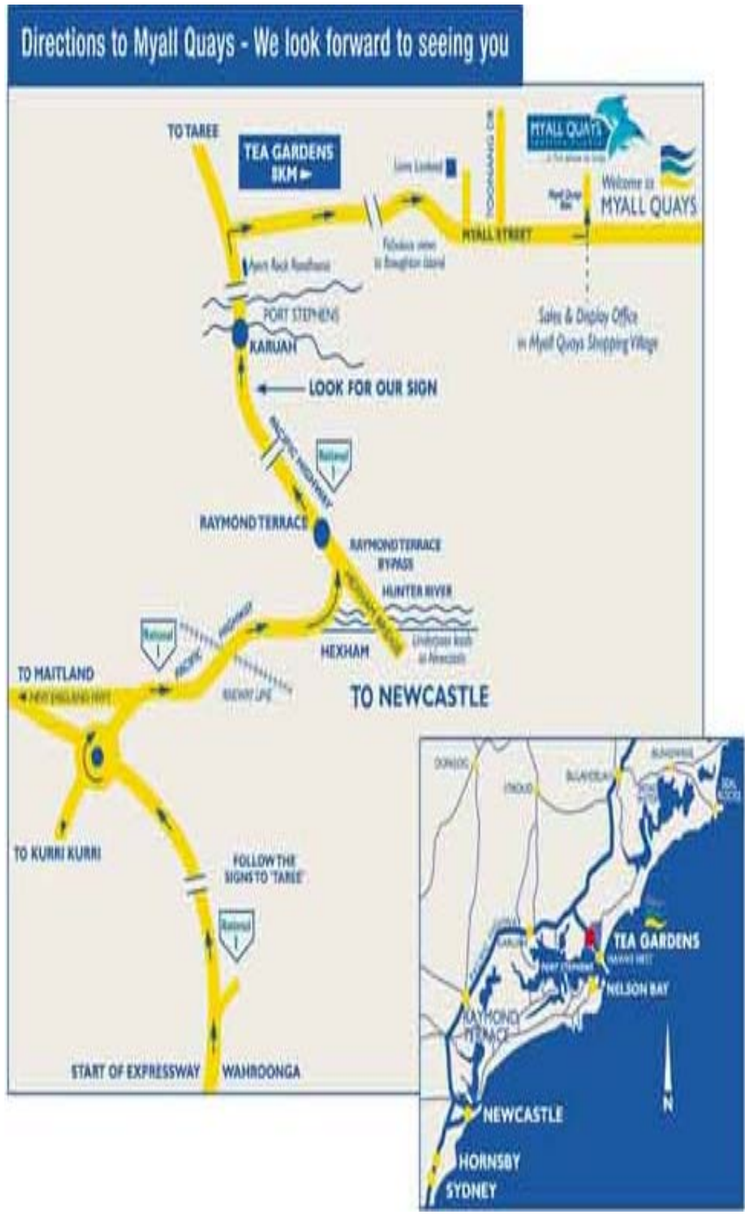
Myall Quays Development

Tea Gardens

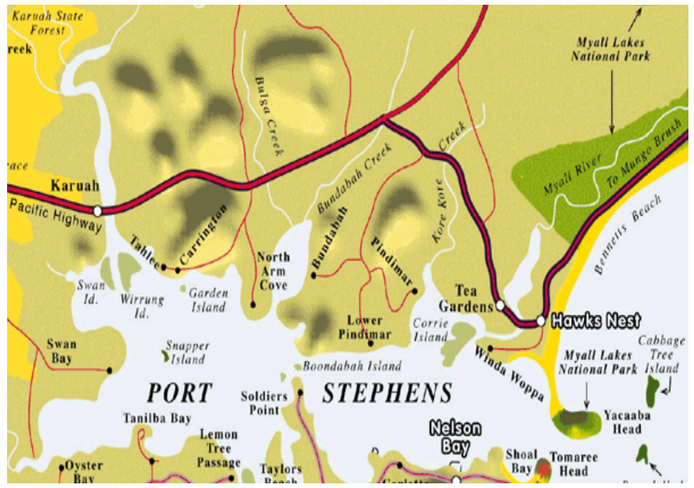
Assessment of Water Management Options

September 2004

Background



Location of Myall Quays relative to Sydney and Port Stephens



Location map of Port Stephens. Tea Gardens can be seen on the North Shore adjacent to Hawks Nest on the beachfront.

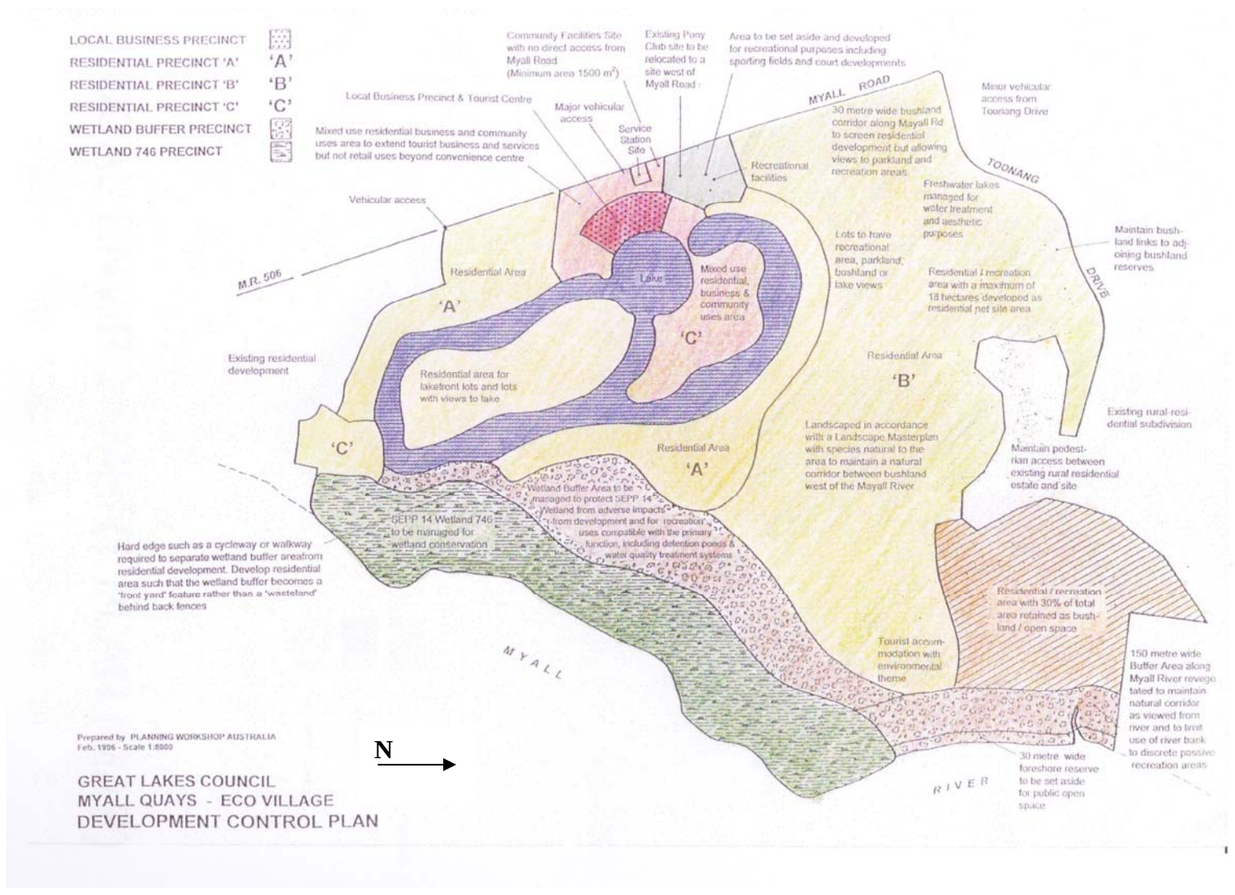
Aerial view of Tea Gardens depicting the development till 2000 of Myall Quays and its vicinity.

Site Location – Myall Quays

Myall Quays is located within the township of Tea Gardens. It is situated on the Mid North Coast of NSW, approximately 230 km north of Sydney. The Myall Lakes and Port Stephens catchment has an area of 370 km^2. Tea Gardens is located on the mouth of Myall River of Port Stephens just west of the popular holiday destination of Hawks Nest.

Myall Quays lies within the coastal zone adjacent to Myall River. It is bounded by various residential and other developments to all sides except to the east where the site is bounded by Myall River and SEPP 14 wetlands This site is approximately 230 ha and has a 2 km frontage to the Myall River / SEPP 14 wetland. The existing Myall Quays development features a 6 ha man-made tidally influenced detention lake. The SEPP 14 wetland is protected within a 7(a) Wetlands and Littoral Rainforest zone, which in turn is separated from the developable area of the site by a 7(b) Conservation Buffer zone.

Myall Quays is accessed from the main approach route to Tea Gardens / Hawks Nest, ie. Myall Road (approximately 9 km to the Pacific Highway). Much of the site was historically used as a major pine plantation, leaving a significant portion of the site currently cleared of vegetation. The site is very flat falling gently southward towards the existing detention lake.



History of the Site

In 1991 Crighton Properties Pty Ltd acquired the 230 ha site currently known as Myall Quays. A Local Environmental Study (LES) had been commissioned to consider the rezoning of the land for recreational, commercial, tourist and residential uses.

An adjoining 30 ha parcel of land, part of the 1991 purchase, was already zoned for residential development (Zone 2(a)). Since the purchase Crighton Properties have developed 220 high quality home sites.

The development of Myall Quays included the construction of a major detention lake that also helped to improve the quality of stormwater discharged to the Myall River. The water quality purposes were part of the 2(a) zoned development. The approval for the lake was obtained before the NSW Government's SEPP 50 (Canal Estates) was introduced.

A rezoning of the 230 ha rural land was gazetted in June 2000, pursuant to the LES. The majority of this land was zoned 2(f) accommodating a mix of residential, commercial and recreational uses. Under the Development Control Plan for the Myall Quays it was also proposed to extend the existing detention lake to create a 22 ha lake.

The previous use of this land was as a pine plantation. The majority of subject land cleared of vegetation was to allow the silviculture to proceed.

The Myall Quays – Eco Village – Development Control Plan opposite depicts the various land uses for this area. The Local Environmental Plan map shows the zoning of the site gazetted in 2000.

Current Development Proposal

The proposed project is for an extension of the Myall Quays development. It is proposed to construct additional housing, commercial, sporting and tourist facilities on the remaining 179 ha of the site. This is to include increasing the current lake to (refer schemes) as part of an integrated approach to stormwater management that both detains and treats stormwater on the site. The strategy includes a number of additional stormwater ponds and rainwater tanks to harvest rainwater and support its reuse on approximately 600 new residential lots as well as a nine hole golf course.

Regional and Area Development

(Tea Gardens, Hawks Nest and other Crighton Developments)

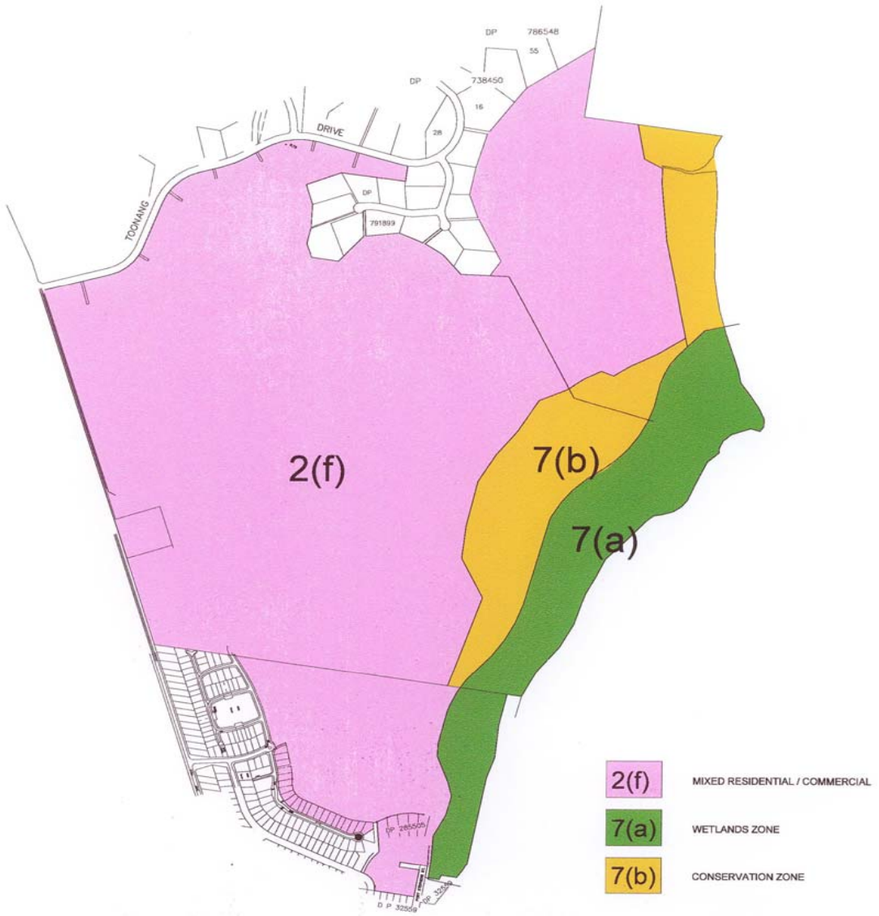
The dwindling opportunities for coastal development on the southern shores of Port Stephens, the creation of Myall Lakes National Park and the reduced travel times to Sydney have created a demand for land in the Tea Gardens and Hawks Nest area on the northern shore of Port Stephens. This area is growing quickly and is a popular holiday / retirement destination due to its close proximity to Sydney.

Both Tea Gardens and Hawks Nest are significantly developed areas providing a wide range of land uses and amenities including residential areas, commercial uses, recreational facilities, public amenities, holiday attractions, administration offices and related infrastructure. The Myall Quays site is bounded by Tea Gardens to the south, rural residential development to the north, residential / industrial development to the west and Myall River / Wetlands to the east.

A number of planning studies have been carried out in the Tea Gardens / Hawks Nest area in response to the need to protect its special character and the character of the surrounding area. The Tea Gardens and Hawks Nest urban areas at the time of the study (LES 1991) had the capacity to accommodate about 600 and 1,300 new residential lots respectively. The proposed project site could accommodate about 1,000 dwellings together with tourist developments, which would represent a significant development element in the local context. The development of Myall River Downs Estate and Tea Gardens Grange Lifestyle Resort are also providing greater residential capacity in the Great Lakes local government area.

There are various developments taking place in the Great Lakes local government area. Myall Quays is just one of several residential / commercial developments creating new estates to provide lifestyle properties in a sustainable environment.

Upgrades to major roads (Pacific Highway) are being undertaken providing efficient and convenient access to these destinations.



LOCAL ENVIRONMENT PLAN (MAP)

MYALL QUAYS

Local Environmental Plan

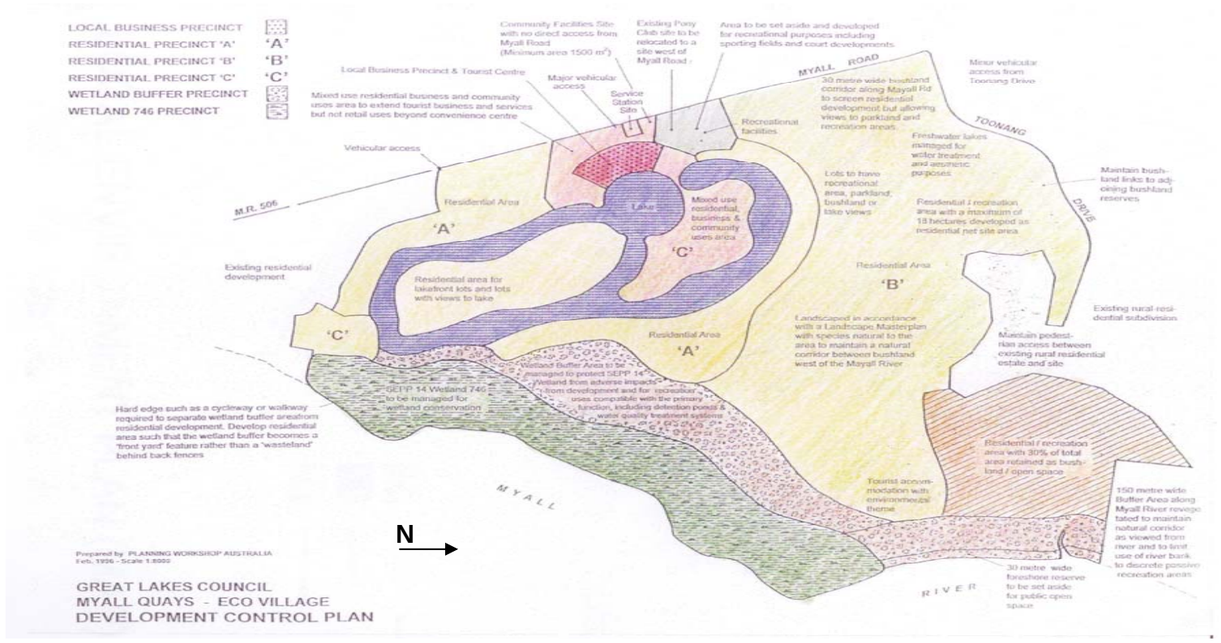
The current Local Environmental Plan (map) shows the different zoning of the proposed project site.

- The pink area 2(f) is zoned for mixed residential / commercial / recreational;
- The yellow area is 7(b) conservation zone; while
- The green area 7(a) wetland is the SEPP 14 wetlands fringing the Myall River.

Aerial view of Tea Gardens facing south east (2000)

View of existing lake and residences in background (2000)

Aerial view of Myall River facing south (2000)



Development Control Plan

The DCP gazetted in 2000 identifies the following precincts:

Local Business Precinct

- Local business precinct and tourist centre.

Residential Precinct A

- Residential Area

Residential Precinct B

- 30m wide bushland corridor along Myall Road to screen residential development but allowing views to parkland and recreation areas.
- Freshwater lakes managed for water treatment and aesthetic purposes.
- Lots to have recreational area, parkland, bushland or lake views.
- Residential / recreation area with a maximum of 18ha developed as residential net site area.
- Landscaped in accordance with a landscape masterplan with endemic species to maintain a natural corridor between bushland west of the Myall River.
- To provide a 100 m wide east / west wildlife movement corridor.

Residential Precinct C

- Mixed residential, business and community uses area to extend tourist business and services but not retail uses beyond convenience centre.
- Community facilities site with no direct access from Myall Road (minimum area 1,500 m^2).
- Major vehicular access.
- Service station site.
- Existing pony club to be relocated to a site west of Myall Road, with this area to be set aside and developed for recreational purposes including sporting fields and court development.
- Minor vehicular access from Toonang Drive.
- Maintain bushland links to adjoining bushland reserves.
- Maintain pedestrian access between existing rural residential estate and project site.
- Tourist accomodation with environmental theme.

Wetland Buffer Precinct

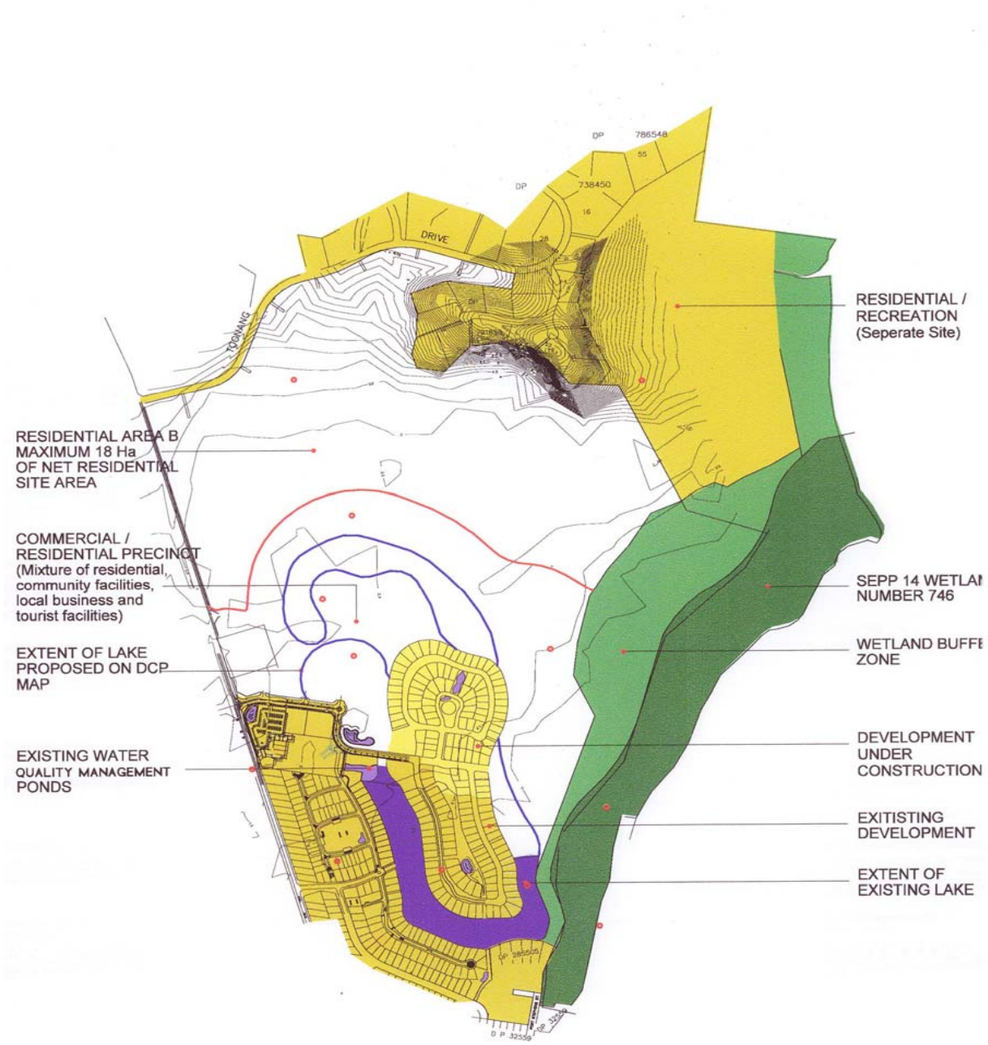
- Wetland buffer area managed to protect the SEPP 14 wetland from adverse impacts from development and for recreation uses compatible with the primary function, including detention ponds and water quality treatment systems.
- 30m wide foreshore reserve to be set aside for public open space.
- Cycleway or walkway to separate buffer from residential area.

Wetland 746 Precinct

- SEPP 14 wetland 746 to be managed for wetland conservation.

The two DCP maps opposite depict the project location and a comparison of the lastest and original can be made.

ZONING CONSTRAINTS



ZONING CONSTRAINTS
(BASED ON CURRENT DEVELOPEMENT AND APPROVED DCP)

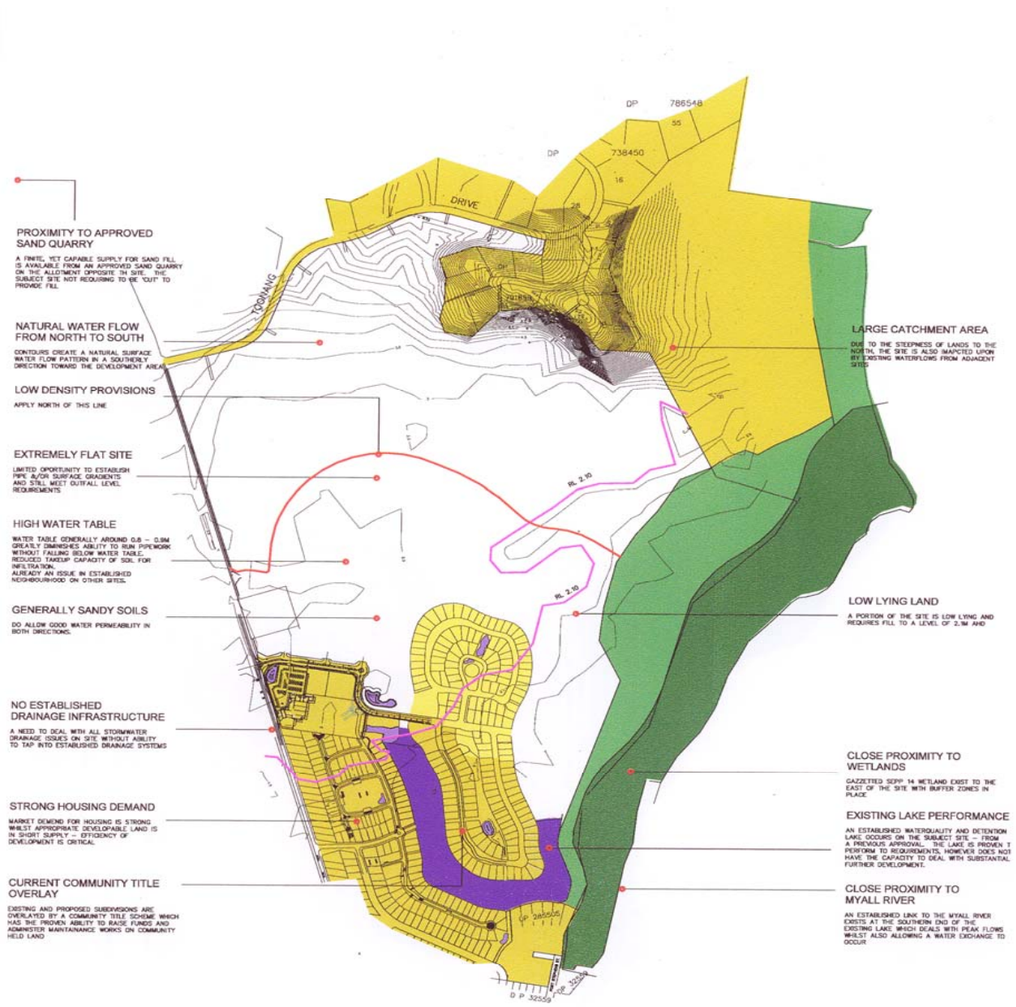
MYALL QUAYS

Zoning Constraints

The current zoning constraints include:

- Residential area B – a maximum 18 ha of net residential site area.
- Commercial / residential precinct – mixture of residential, community facilities and tourist facilities.
- Extent of lake proposed on DCP Map.
- Existing water quality management ponds / wetlands.
- Residential / recreation (separate site).
- SEPP 14 wetland number 746.
- Wetland buffer zone.
- Development under construction.
- Existing development.
- Extent of existing lake.
- Land set aside for water management, under Community Title.

ENVIRONMENTAL AND DEVELOPMENT CONSTRAINTS



DEVELOPMENT CONSTRAINTS
POSED BY SITE CONDITIONS AND SITUATIONAL ISSUES

MYALL QUAYS

ENVIRONMENTAL CONSTRAINTS

The environmental constraints include:

State Environmental Planning Policies

The following are the State Environmental Planning Policies (SEPP) which are presently identified as having influence on the Proposal:

SEPP 50 Canal Estates **-relevant due to detention lake**

This policy prohibits new 'canal estate' developments. The proposed extension of the present detention lake and associated waterbodies, however, are in accordance with the requirements of SEPP 50 because the lake extension is the minimum required to meet necessary drainage and water quality requirements. (refer clause 3 SEPP 50.

SEPP 71 Coastal Protection **-relevant as in coastal zone**

This policy aims to protect and manage the natural, cultural, recreational and economic attributes of the New South Wales Coast. This policy is relevant due to the proximity of the proposed development in relation to the coast.

SEPP 14 Coastal Wetlands **-relevant as designated SEPP 14 wetlands (7(a) zone) exists in the area**

This policy affects the proposed development, as there is a SEPP 14 wetland adjoining the eastern edge of the proposed development.

Local Planning Instruments

The two local planning instruments directly influence the proposal include the:

- Great Lakes Shire LEP 1996, and
- Myall Quays DCP No 22

Other constraints on the proposed project at Myall Quays include:

Floodplain – the site is low lying land and in part is flood prone. This constraints minimum ground and floor levels.

DEVELOPMENT CONSTRAINTS

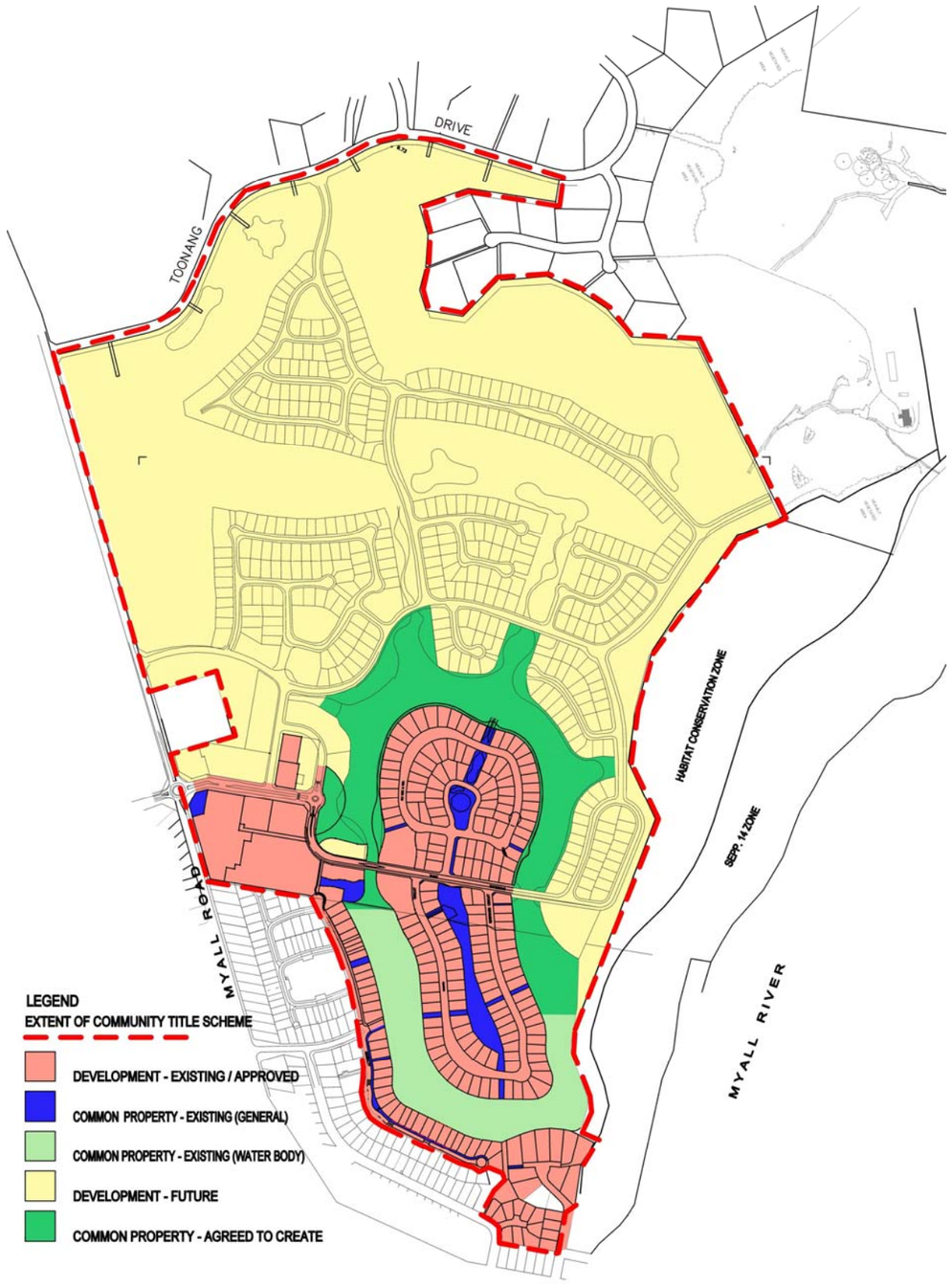
The development constraints include:

- Natural water flow from north to south.
- Extremely flat site.
- Shallow water table that varies in response to rainfall.
- Generally sandy soils.
- Established drainage infrastructure in developed areas.
- External catchment area drains into the site.
- Low lying land that in part is subject to flood inundation.
- Designated conservation zone to protect existing SEPP 14 wetlands.
- Stormwater discharges through the wetlands to reach the Myall River.

CRIGHTON PROPERTIES

Cardno

Community Constraints



MYALL QUAYS COMMUNITY TITLE

Community Constraints

Lands
Existing and proposed subdivisions are overlayed by a community title scheme, which has the proven ability to raise funds and administer maintenance works on community held land.

Title
The Community Titles Legislation in New South Wales provides for owners in a conventional land subdivision to share and manage a range of community facilities. The title to land incorporating these options is called 'Community Title'. The development will continue to be carried out as a Community Title subdivision. The community is 'collectively' responsible for the maintenance and well being of all commonly held property (including the water quality ponds and detention lake).

Existing Financial Model
The community contributes approximately $340 / year / household to the community association.

Budget
The total administration budget for this financial year based on the current number of members is $18,140, with $6,000 being allocated for water quality testing.

Extent
The community title currently applies to the entirety of the land hatched on the diagram, land cannot be added to the community title. Land cannot be subtracted from or reallocated a boundary without unanimous resolution from the community. The extent of community land (common property boundary) has already been agreed to and formalised by the community with information provided at the point of sale. This cannot be altered without unanimous resolution.

Issues
Community members have agreed to the allocation of common property in consideration of balancing the need for water quality and want of accessible open space against the cost of maintaining this space.

Water Quality Assessment

Water Quality Parameters

Salinity

What is salinity?
Salinity is a measure of salt content in water, for instance the salinity of seawater is 35 g/L (parts per thousand (ppt)). Typically salinity levels range from fresh at <1g/L to almost oceanic at >30g/L within an estuary. A value of 3g/L is taken as the salinity dividing fresh from saline waters.

Processes in estuaries – fresh water & salt water
The salinity distribution within coastal waterways reflects the relative magnitudes of fresh water, e.g. inflows from storms in comparison with the exchange of tidal waters. Salinity levels in an estuary fluctuate with tidal flows and with mixing of fresh water and marine water by wind and currents. Fresh water flows into coastal waterways are mainly episodic and are largely controlled by conditions in the catchment as well as rainfall patterns. Entrance size and sea level dictate the levels of exchange of marine water, and the level to which salinity can build up within a coastal waterway.

A decrease in fresh water flows will lead to elevated salinity whereas large influxes of freshwater will lower salinity levels.

Importance of salt regimes
Salinity varies in ranges from < 3 g/L (classified as freshwater), 3-20 g/L (hyposaline), 20-50 g/L (mesosaline) and 50 g/L (hypersaline). An increase of salinity above 3g/L is associated with a transition from freshwater species to saltwater species.It is important for salinity to remain between certain limits, to provide a suitable habitat for aquatic organisms to thrive (e.g. reproduce, feed, lifecycle).

The majority of aquatic organisms function optimally within a narrow range of salinity. When salinity varies above or below the optimum range an organism may lose the ability to regulate its internal ion concentration causing it to become susceptible to biotic pressures such as predation, competition, disease or parasitism. Shifting salinity distributions can affect the distributions of macro benthos as well as rooted vegetation (seagrasses) and sessile organisms. Salinity is also an important factor in the successful recruitment of larval and juvenile fish. Salinity factors influencing the proposal include

- **Salinities between 3 g/L and 20 g/L seem to exhibit greater species diversity and richness; and**
- **Increasing salinity levels above 20 g/L decreases both species richness and diversity.**

Salinity has more impact as a community determinant only where salinities approach those of freshwater.

Optimum range is between 3 g/L and 20 g/L

Dissolved Oxygen

What is Dissolved Oxygen?
Dissolved Oxygen (DO) is the measure of the amount of oxygen contained in water. **Oxygen has limited solubility in water usually ranging from 6 mg/L to 14 mg/L**. **ANZECC guidelines set default trigger at a range of 80 –110 % oxygen saturation for slightly disturbed estuarine environments**. Levels of 6 mg/L will fall within the recommended guidelines.

DO concentrations reflect the equilibrium between oxygen producing processes (eg photosynthesis) and oxygen consuming processes (eg decomposition of organic matter).

Processes in estuaries
DO concentrations can change as oxygen solubility varies with salinity, water temperature and atmospheric and hydrostatic pressure. The amount of plant and algal biomass, light intensity and water temperature influence DO consumption, and are subject to seasonal and diurnal (day/night) variations.

DO concentrations naturally vary over a twenty-four hour period due to tidal exchange and oxygen production by plants and algae during daylight (photosynthesis).

Nutrient enrichment enhances plant and algal growth often resulting in a mass influx of particulate organic matter. This can in turn result in masses of decomposing organic matter that consume oxygen particularly in bottom waters.

Tidal exchange can replenish coastal waterways with oxygen.

Significance of Dissolved Oxygen
Most aquatic organisms require DO to be within defined levels to support respiration and to support an efficient metabolism. Even short-lived anoxic (zero oxygen) or hypoxic (low oxygen) events can cause major 'kills' of aquatic organisms. Exposure to low oxygen concentrations can depress the immune system of a fish that elevates their susceptibility to diseases for several years.

The toxicity of a number of pollutants can double when DO is reduced from 10 mg/L to 5 mg/L. The death of sessile organisms and avoidance of low oxygen conditions by mobile organisms can also cause changes in the structure of biological communities. The depletion of oxygen in bottom waters or sediments can give rise to the release of nutrients and other pollutants into the water column and can initiate and sustain algal blooms.

Optimum range is between 80 % and 110 % oxygen saturation

Chlorophyll *a*

What is Chlorophyll *a*
Chlorophyll *a* is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll *a* concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. High levels often indicate poor water quality and low levels often suggest good conditions. Elevated Chlorophyll *a* concentrations are not necessarily bad, however if they persist for long periods, the potential for algal blooms increases.

Processes in Estuaries
Chlorophyll *a* levels fluctuate naturally over time, with concentrations often being higher after rainfall due to the flushing of nutrients into waterways. Higher concentrations of Chlorophyll *a* are common during summer months when water temperatures and light levels are high.

Coastal lagoons, enclosed bays and microtidal waterways (mean tidal range < 2m) with limited flushing are susceptible to eutrophication (ie. high Chlorophyll *a* concentrations).

Tidal mixing is important in controlling algal biomass and lowering Chlorophyll *a* concentrations due to the reduced time algae undergoes photosynthesis. Changes to systems that decrease or increase flushing rates influence concentrations as flushing dilutes the nutrients available to plants. Slow moving or stagnant waters can concentrate nutrients and cause cell numbers to grow.

Significance of Elevated Chlorophyll *a* Concentrations
Elevated Chlorophyll *a* concentrations can indicate an increase in nutrients and increasing trends can indicate eutrophication of aquatic ecosystems.

The most pervasive system change which can lead to problems with constructed shallow lakes is the excessive influx of inorganic nutrients, either in soluble form or associated with organic matter, that lead to excessive algal growth.

Optimum levels less than 0.004 µg/ L for estuarine ecosystems and 0.005 µg/ L for fresh ecosystems

Nitrogen

What is Nitrogen?
Nitrogen (N) is a chemical element that is an essential building block for plant and animal growth. Nitrogen exists in water in inorganic and organic forms, and in dissolved and particulate states. Total nitrogen (TN) is a measure of all forms of dissolved and particulate nitrogen present in a water sample.

Enclosed bays, shallow coastal lagoons and other microtidal systems (mean tidal range < 2m) with limited freshwater inflows cannot readily flush nutrients and are particularly susceptible to nutrient build up and internal recycling.

Optimum levels less than 0.3 mg/ L for estuarine ecosystems and 0.35 mg/ L for fresh ecosystems

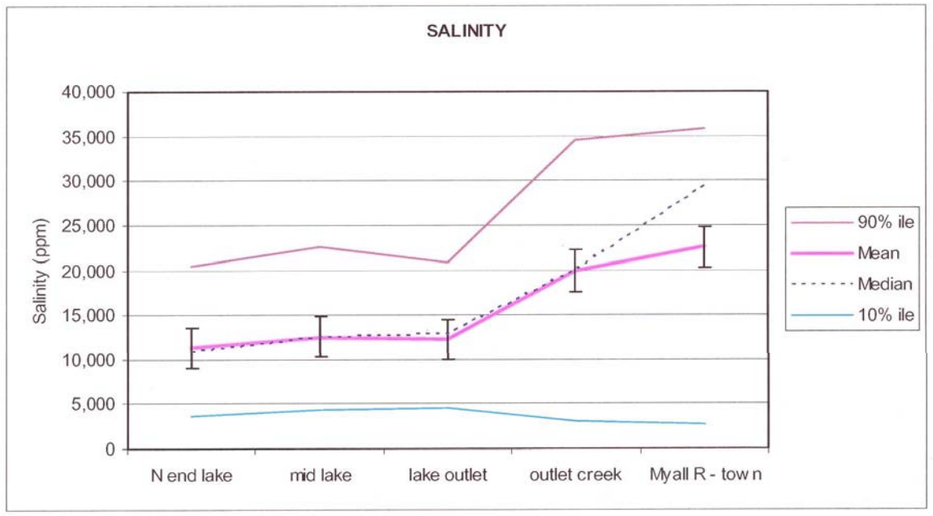
Phosphorous

What is Phosphorus?
Phosphorus (P) is a chemical element that is an essential building block for plant and animal growth. Phosphorus is found in waterbodies in dissolved and particulate forms. Total phosphorus (TP) is a measure of all the various forms of phosphorus (dissolved and particulate) found in water.

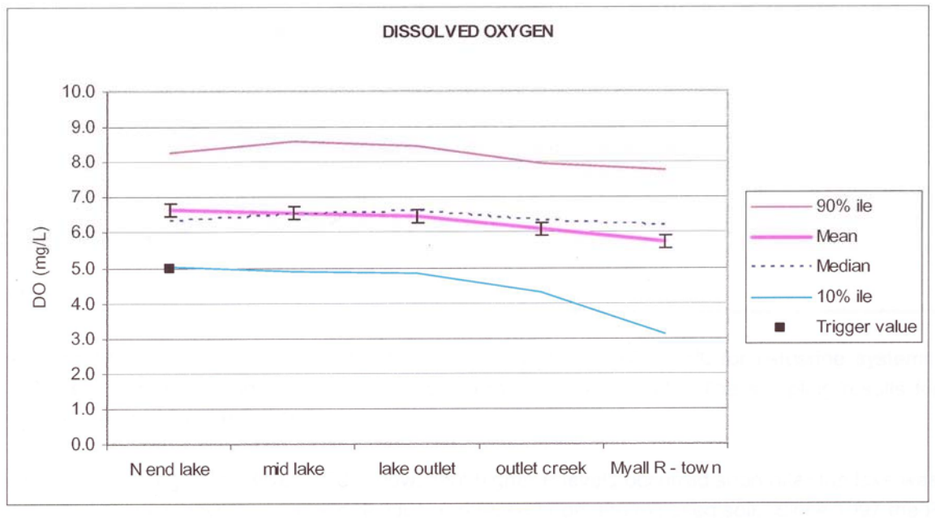
Enclosed bays, shallow coastal lagoons and other microtidal systems (mean tidal range < 2m) with limited freshwater inputs cannot readily flush nutrients and are particularly susceptible to nutrient build up and internal recycling.

Optimum levels less than 0.03 mg/ L for estuarine ecosystems and 0.01 mg/ L for fresh ecosystems

These graphs represent the various levels of salinity, dissolved oxygen and phosphate at the 5 sample locations.



Salinity Levels



Dissolved Oxygen Levels

Existing Conditions

The catchment under consideration is located on the eastern side of Myall Street and extends from Myall River northwards to high ground near Viney Creek Road. The total area of the catchment is approximately 272 ha.

Surface water drains partly toward the existing lake and partly toward the SEPP 14 wetlands on the eastern boundary of the site. The site is subject to both local and river flooding. Local flooding has been observed by the land owners and Council staff. This local flooding reflects the flat ground slopes and absence of natural drainage channels.

The impact of the existing development on flood flows was mitigated by constructing a detention lake to temporarily store floodwaters and to release it at a rate similar to pre-development conditions. A number of small retarding basins have also been build within the existing development to meet retardation requirements.

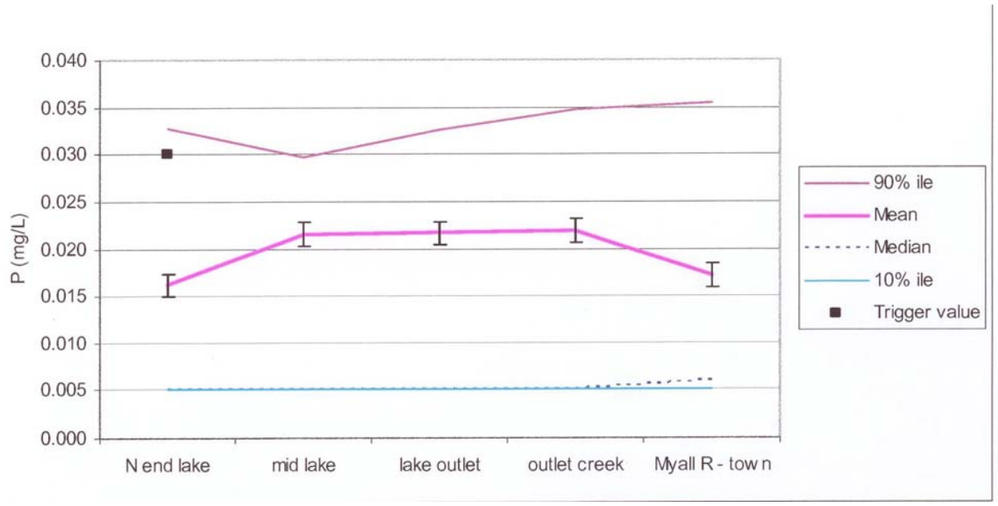
Water Quality Management

The primary aim for the existing management of water quality is to protect the SEPP 14 wetland by directing the runoff from the catchment to a tidally flushed lake. This is also supported by a number of smaller ponds and wetlands located within the residential areas.

Water quality impacts on the lake at Myall Quays are due to event-driven loads from runoff, decay of in-lake algae and releases from sediments. Tidal inflows can also impact on water quality. The stormwater runoff impacts can be expected to increase with urban development in the northern part of the project site unless remedial measures are provided and / or the lake is increased in size.

The Water Quality Objectives include:

- The lake and ponds meet microbiological standards for bacterial content and pathogens.
- The lake and ponds be free of nuisance organisms such as algal scums and odours, midges and aquatic worms.
- Visual clarity and colour, physical appearance of lake / pond and discharged water to be clear and colourless.
- pH within range 5.0-9.0.
- Toxic chemicals meet standard for untreated drinking water.
- Surface films such as oil and petrochemicals should not be visually noticeable nor detected by odour.
- Sustain a healthy ecosystem.
- Free of trash and debris.
- Free of mosquito related health risks and irritants.
- Free of nuisance macro aquatic plants.



Phosphorous Levels

Comparison of monitored DO levels in Myall Lake and Myall River

Water Quality Monitoring

A water quality monitoring programme was established in 1996 firstly by the developer, and more recently taken over by the Myall Quays Community Association. Hunter Water Laboratories is contracted to collect and analyse samples at 5 locations every 3 months.

Salinity

The sampling indicates that the lake water is brackish, consisting of a mean salinity of 12 g/L, which is approximately one third of the salinity of seawater. There is variability in the salinity concentration due to both catchment (freshwater) runoff as well as the influence of tides and varying salinity in the Myall.

Dissolved Oxygen (DO)

The mean DO level within the lake for the sampling period is 6.6 mg/L, with a 10th percentile level of 4.9 mg/L. The 4.9 mg/L level is just below the recommended ANZECC trigger value of 5.0 mg/L for freshwater fish.

Nutrients

The adopted ANZECC 2000 trigger value for Phosphorus (P) is 0.03 mg/L for estuarine systems. Most of the samples have been below the recommended value, with a mean of 0.02 mg/L. Higher P levels occurred soon after the lake was constructed, possibly due residual P released from exposed soil.

The ANZECC 2000 trigger value for Nitrogen (N) is 0.3 mg/L for estuarine systems. The samples measured have generally been low, contributing to the overall good water quality in the existing lake.

Most chemical indicators are below the ANZECC 2000 trigger values. There is 90% of the catchment that is undeveloped, with the existing treatment measures in the southern part of the catchment seemingly assisting with maintenance of good water quality with the existing lake.

Water Quality of Lake in Comparison with the Myall River

The DO levels measured within the Myall Quays Lake and the Myall River have been compared. The Hunter Water Laboratories data shows the ANZECC high quality guidelines for DO are not currently met at all times, in either the lake or river (Copeland Ave Wharf). This data shows the DO levels in the existing lake are often better that in the Myall River.

Water Quality and Retardation Summary Table

Scheme	Water Quality Summary								Retardation Summary				
									Additional Detention Basin(s)*				
			Saline Lake		Freshwater Lake / Wetland		Outlet Channel to Myall River		Included**		Additional Required***		Total Additional Detention (ha) [a+b]
	BASIX	Additional Neighbourhood Ponds	Area (ha)	Ave Depth (m)	Area (ha)	Ave Depth (m)	Times existing width	Deepening of existing connection to river (m)	Area (ha) [a]	Ponding Level (mAHD)	Area (ha) [b]	Ponding Depth (m)	
0			6	2.06			x 1	0.00					
1	√		6	2.06			x 1	0.00					
2	√	√	6	2.06			x 4	0.30			12	0.72	12
3	√	√	13.5	1.8			x 2	0.10	7.5	0.92	3	1.22	10.5
4	√		6	2.06	12	1.5	x 1.6	0.09	12	0.74			12
5	√		8	2.06	6.5	1.65	x 1.8	0.09	6.5	1.22			6.5
6	√		6	2.06	16	0.25	x 1.6	0.09	16	0.37			16

* Additional basin(s) required over and above existing detention lake (6ha) to limit post-development Local peak 100 yr ARI outlet to existing peak outflow.
** Retardation achieved through Water Quality management initiatives
*** Additional basin(s) required over and above the retardation achieved through the Water Quality management initiatives

Myall Quays Water Management Schemes

0. Existing conditions.

1. Do nothing – keep the current waterbody as it is without increasing the size (but with BASIX implemented).

2. Existing lake with **increased tidal flushing** and additional dry basins.

3. Extended tidally flushed lake.

4. Existing lake (saline) **and new freshwater lake(s)** incl. Basin.

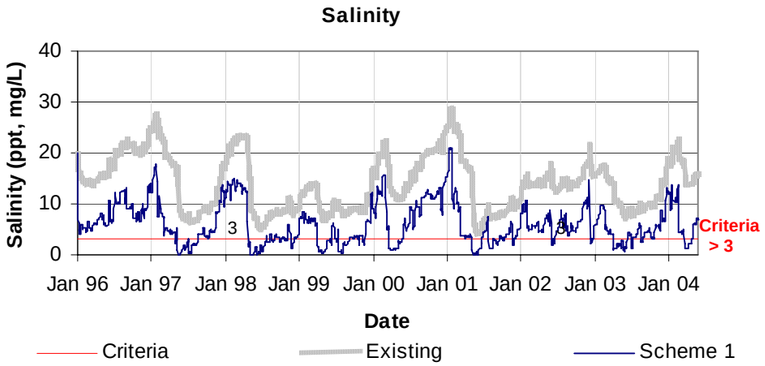
5. Partially extended saline lake and new freshwater lake.

6. Existing lake and **new wetlands**.

7. Existing lake and **dry swales**.

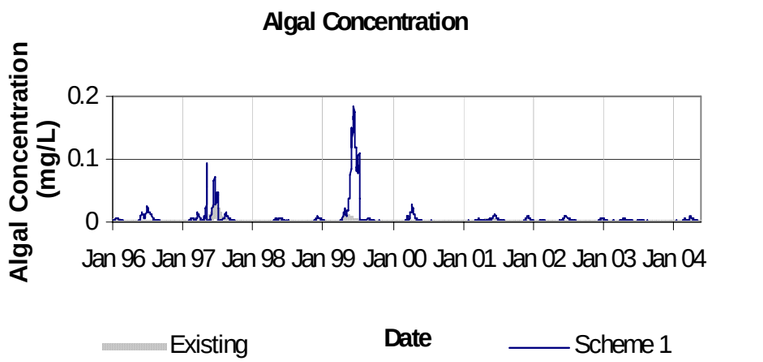
Notes:

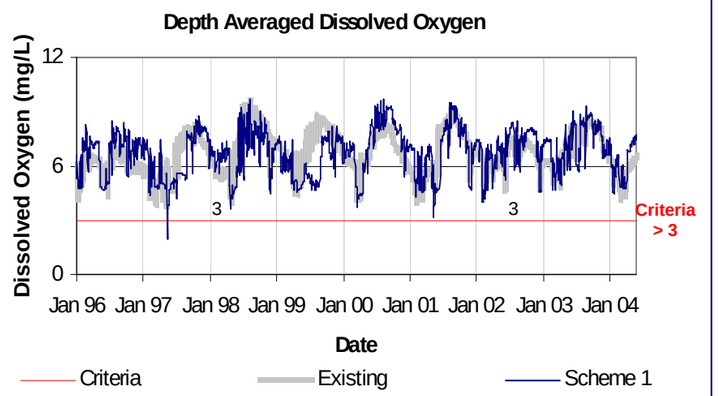
i. BASIX included in all new developments in schemes 1 - 6.
ii. All schemes aim to maintain the water quality regime in the existing lake and to not increase the local 100yr ARI peak outflow to the Myall River.

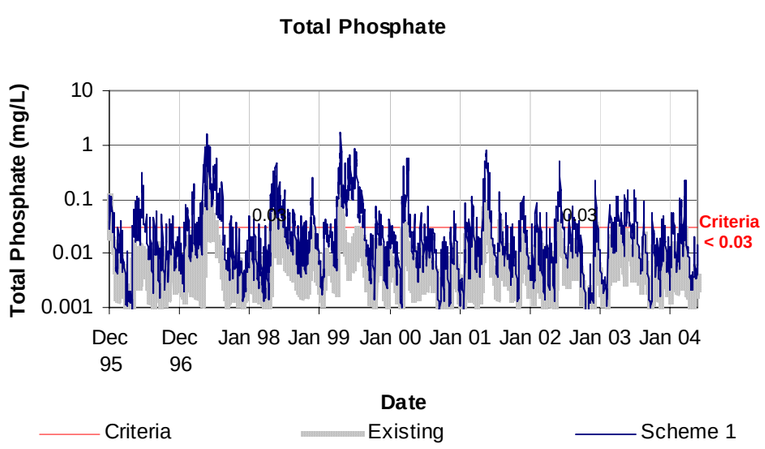


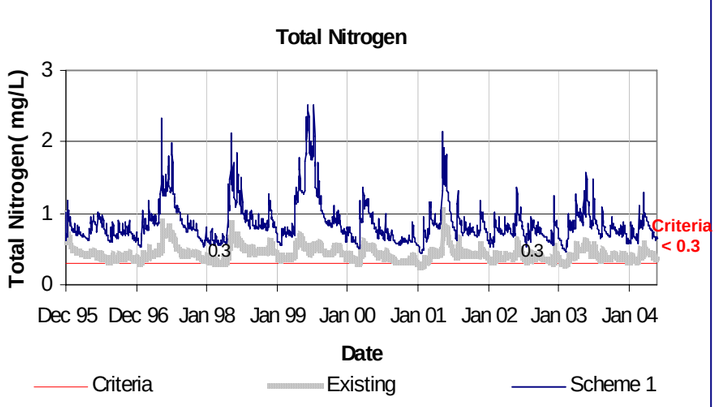
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	0
Total WQ Area [a]	6 ha
Outlet Channel Details	
Outlet Width	x 1
Outlet Depth	-
Retardation Details	
Total Available [=a]	6 ha
Additional Required	
Total	









Scheme 1

This scheme represents the implementation of the proposed development without any additional work to manage stormwater quantity or quality except the installation of measures to meet the requirements of BASIX for all new residential properties. This is the "Do Nothing" scheme. All stormwater flows to be piped into existing lake or discharged directly to wetland.

Strengths

- Least cost

Weaknesses

- No measures to mitigate the impact of the proposed development with respect to stormwater quantity or quality.
- Greatest potential impact on existing detention lake water quality and ecosystems ceases to function satisfactorily.
- Greatest potential impact on SEPP 14 wetlands.
- Does not meet the requirements of the Great Lakes Councils Stormwater Quality DCP.
- Highly likely to result in algal blooms, scour and discharge of pollutants.
- Inability to provide pipe gradients and surface water flow paths without importing vast quantities of fill and raising land some 1 – 1.5 m.

CRIGHTON PROPERTIES

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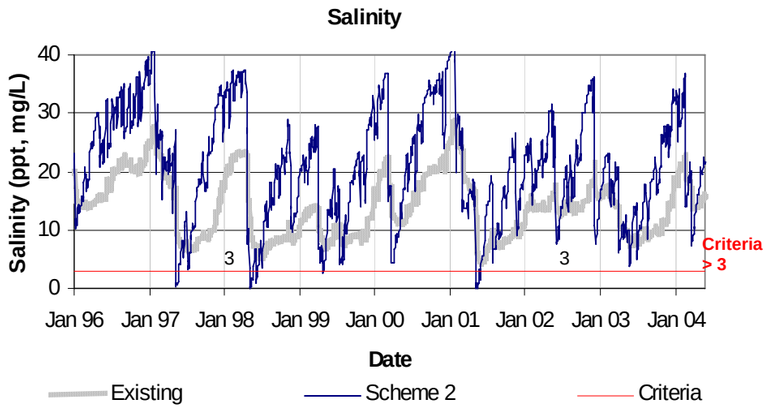
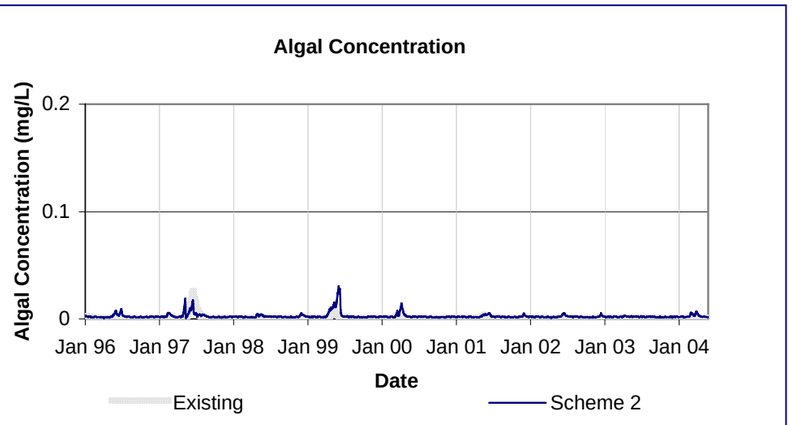
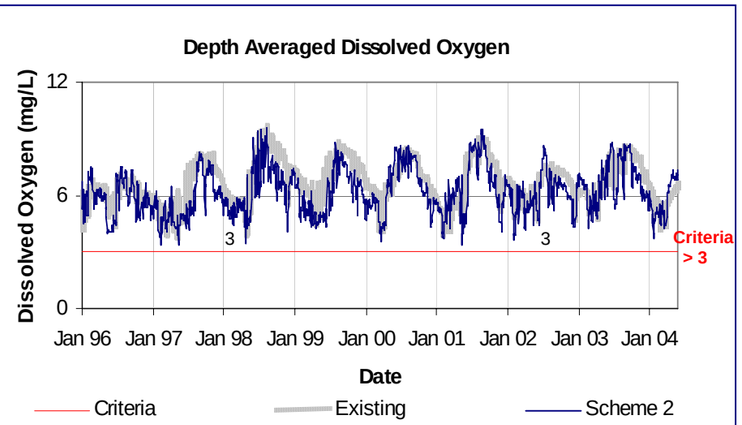
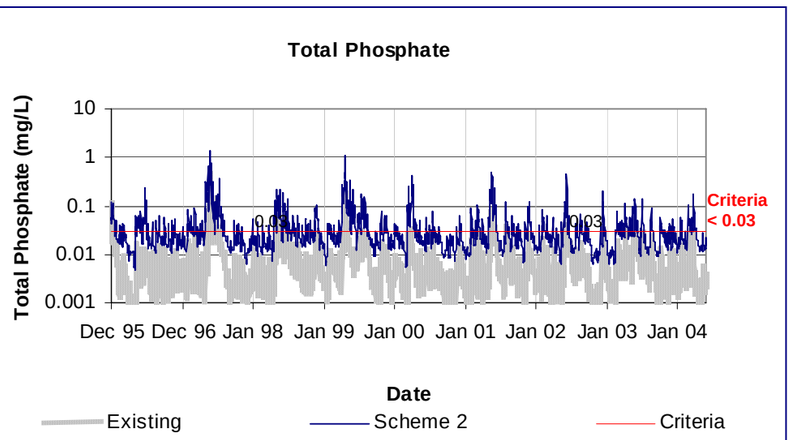


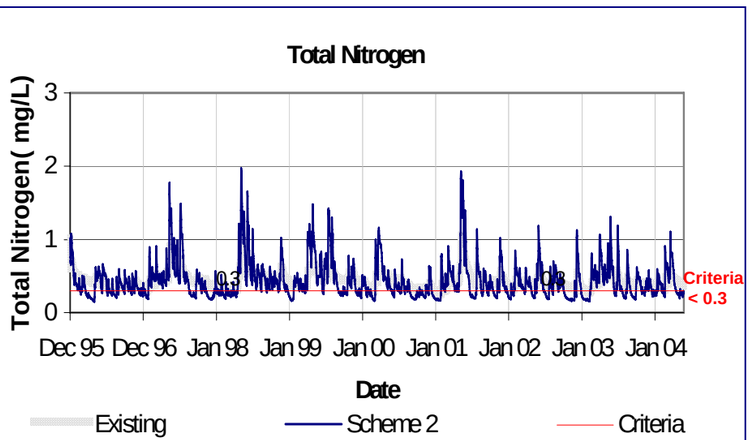
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	0
Total WQ Area [a]	6ha
Outlet Channel Details	
Outlet Width	x 4
Outlet Depth	0.3 m
Retardation Details	
Total Available [=a]	
Additional Required	0
Total	12 ha









Scheme 2

This scheme attempts to mitigate the adverse impacts of scheme 1 by increasing tidal flushing to combat water quality impacts and the provision of dry basins to help address detention and nutrient control.

Strengths

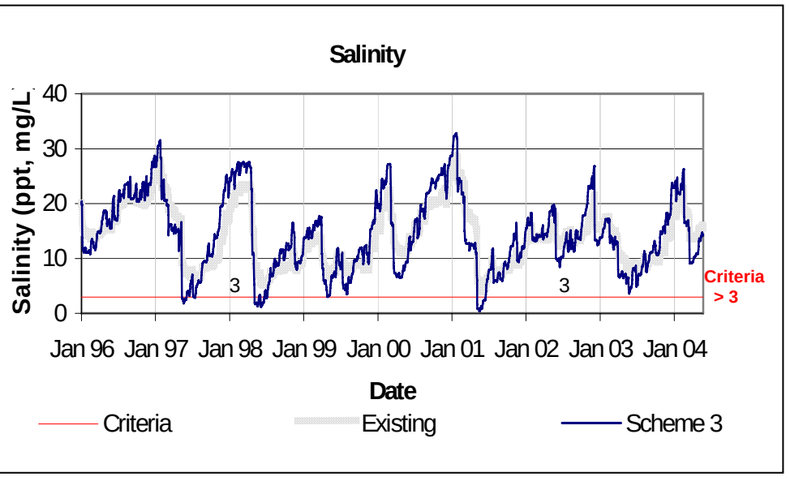
- Low cost.

Weaknesses

- Greatest change in the salinity regime in the existing lake.
- Greatest vulnerability to poorer water quality in the Myall River.
- Channel works have greatest impact on SEPP 14 wetland and conservation zone (massive increase in flows).
- Overall lake level significantly lowered
- Impact on the aesthetics of the existing lake.
- Additional dry retarding basins need to be above wet rainfall year groundwater levels.
- Even minimum grades on swales and basins lead to significant additional filling of new lots (1 – 1.5 m).

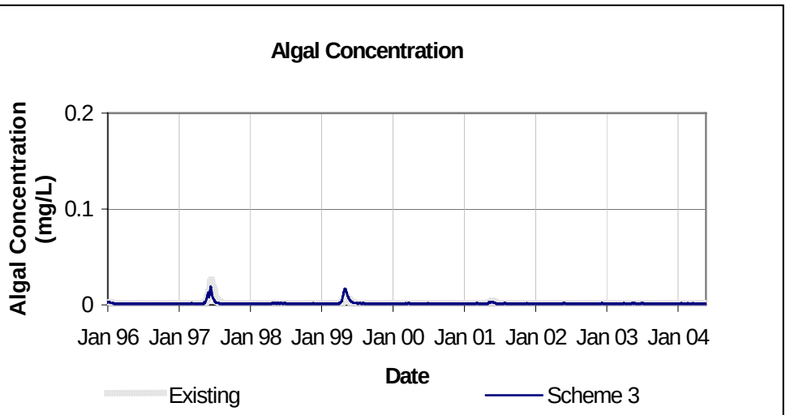
CRIGHTON PROPERTIES

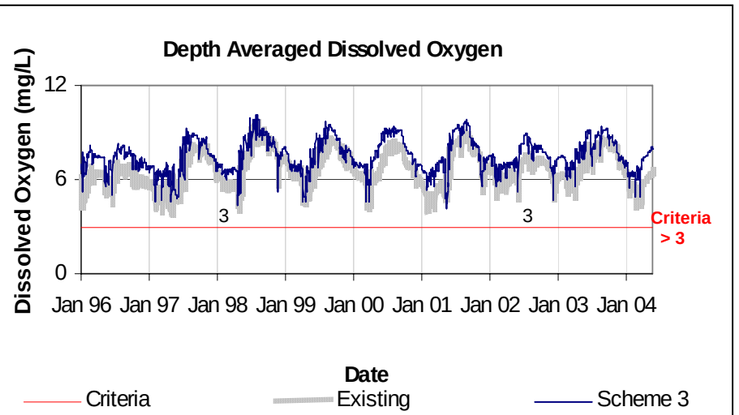
Cardno

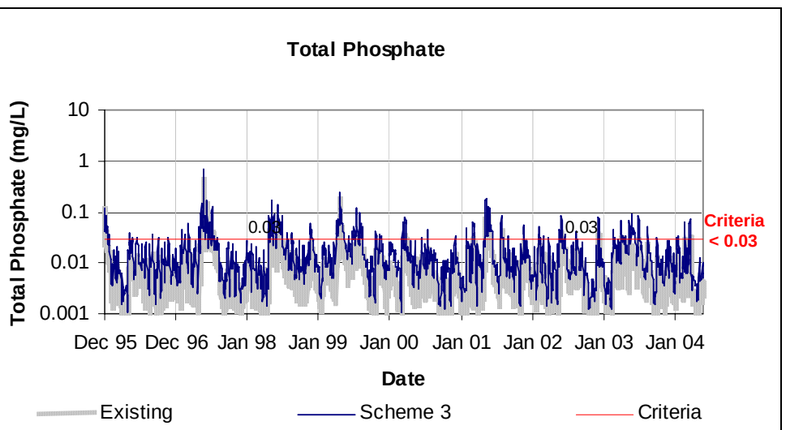


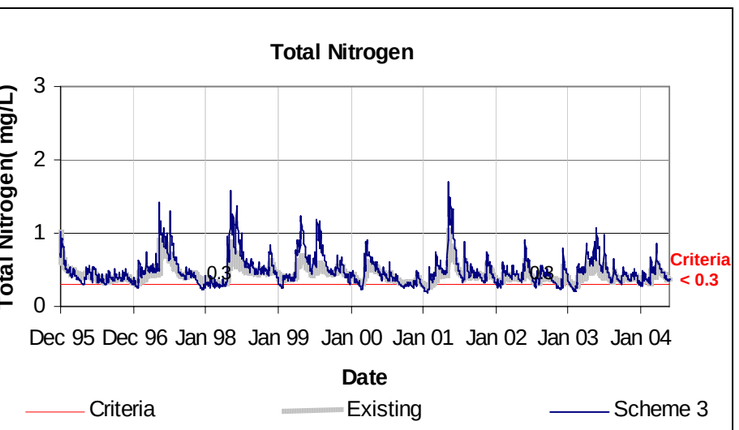
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	7.5 ha
Additional Freshwater Area	0
Total WQ Area [a]	13.5 ha
Outlet Channel Details	
Outlet Width	x 2
Outlet Depth	0.10 m
Retardation Details	
Total Available [=a]	
Additional Required	3 ha
Total	16.5 ha









Scheme 3

This involves the extension (by 7.5 ha) of the existing lake to give a tidally flushed lake with water quality comparable to existing conditions. The extended lake would also partially meet the requirements for additional active detention storage.

Strengths

- Tidal flushing assists water quality throughout the system.
- Expansion of established ecosystem (fish habitat etc)
- Benefits to existing lake quality due to final shape (improved circulation)
- Allows greater area to be serviced at water level (not requiring pipe gradients or fill).
- Aesthetic benefits.
- Most efficient land use with respect to site density.
- Extracted material could be used for shaping golf course and public areas.
- Minimum fill required over site generally (close to natural levels).
- Established proven Community Title arrangements to ensure on-going maintenance.
- Facilitates the drainage of the new developments with minimal fill.
- Desensitises water body to quality fluctuations.
- Lower long term maintenance costs.

Weaknesses

- Higher capital cost.
- Potential local impact on SEPP 14 wetland and conservation zone due to channel works.
- Single water body, reduces degree of security from contamination.
- Still requires additional detention.

CRIGHTON PROPERTIES

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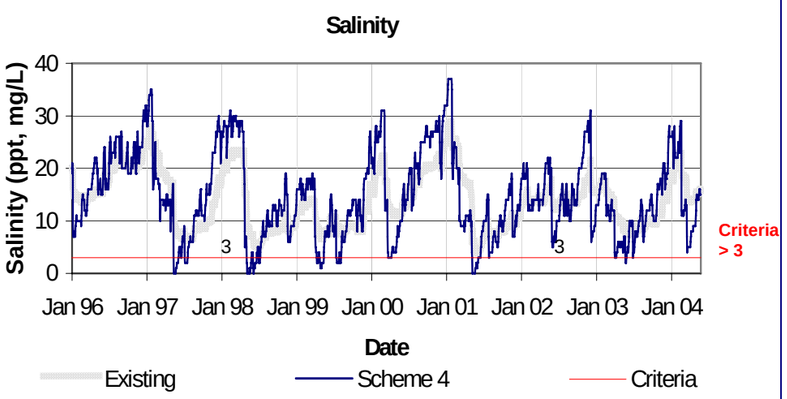
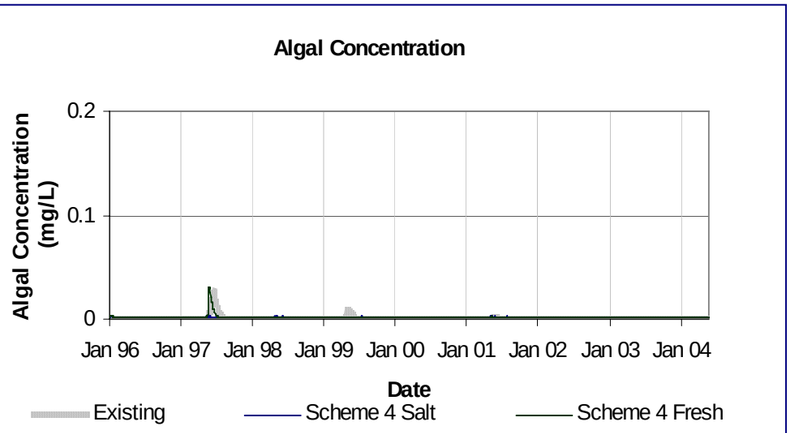
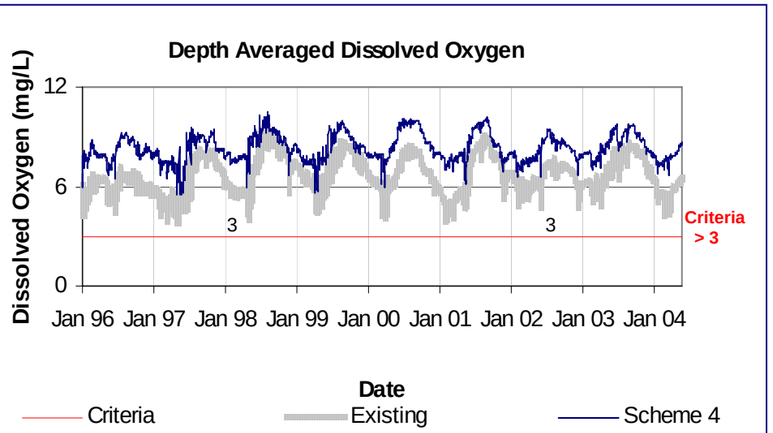
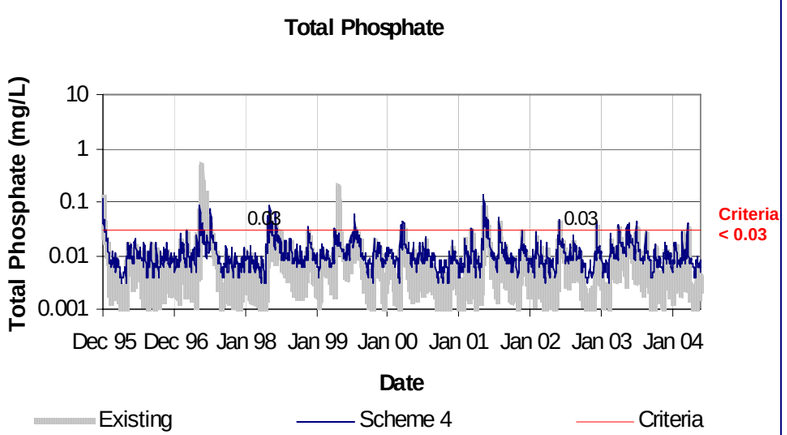


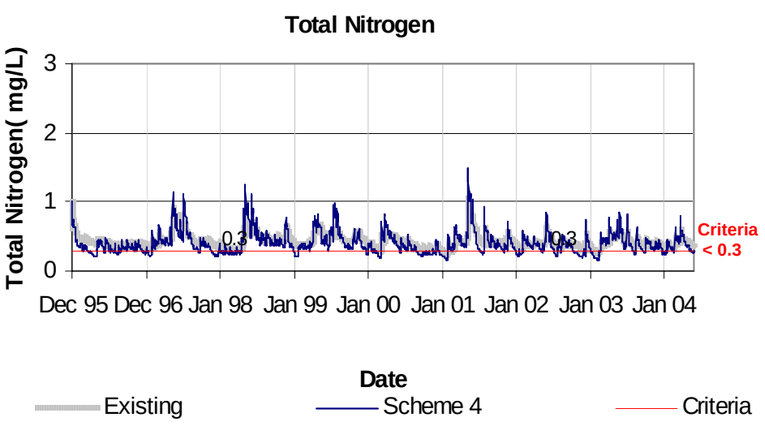
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	12 ha
Total WQ Area [a]	18 ha
Outlet Channel Details	
Outlet Width	x 1.6
Outlet Depth	0.09 m
Retardation Details	
Total Available [=a]	
Additional Required	0
Total	18 ha









Scheme 4

Under this scheme a separate freshwater lake (12 ha) and / or equivalent area of water bodies would be constructed to treat stormwater from the new development prior to its discharge into the existing detention lake. This lake would be a window lake with an expected average water level slightly higher than the existing tidally flushed lake. The additional lake / pond(s) would also include active storage to partially meet the retardation requirements.

Strengths

- Ponds could be constructed sequentially.
- Ponds could be located where required (when required).
- Dual role of water quality and partial detention.

Weaknesses

- No tidal flushing provided to limit potential of algal blooms.
- The size of a freshwater lake / pond greater than a tidally flushed lake (i.e. not as space efficient).
- The raised water levels in a freshwater lake / pond, impacts on the hydraulics of drainage swales (slight loss of fall potential).
- A number of different ponds to service and maintain.
- Higher overall land take in comparison with other schemes.
- No assistance to the established brackish ecosystem.
- Inherent circulation issues in ponds.

CRIGHTON PROPERTIES

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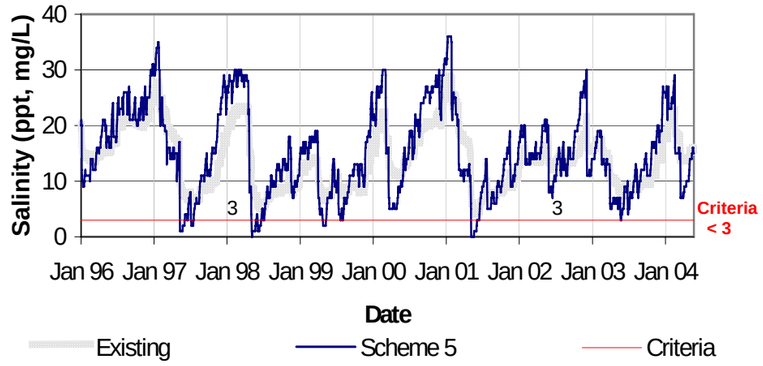
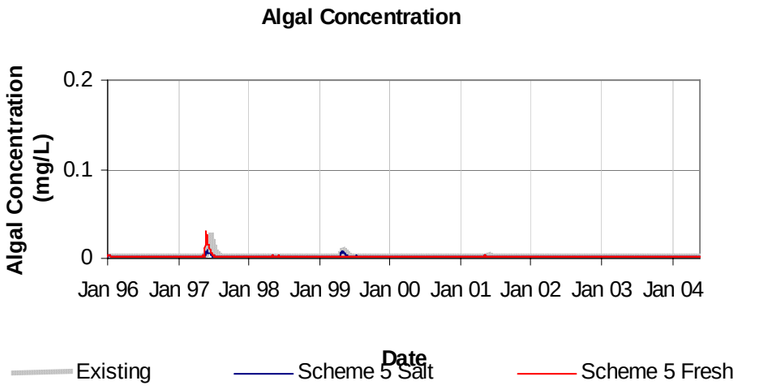
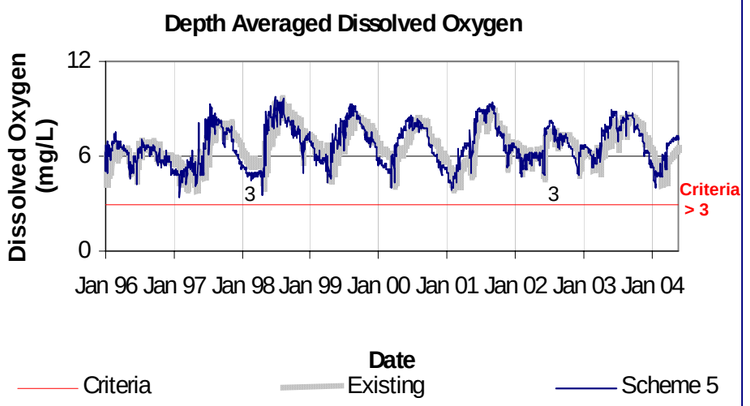
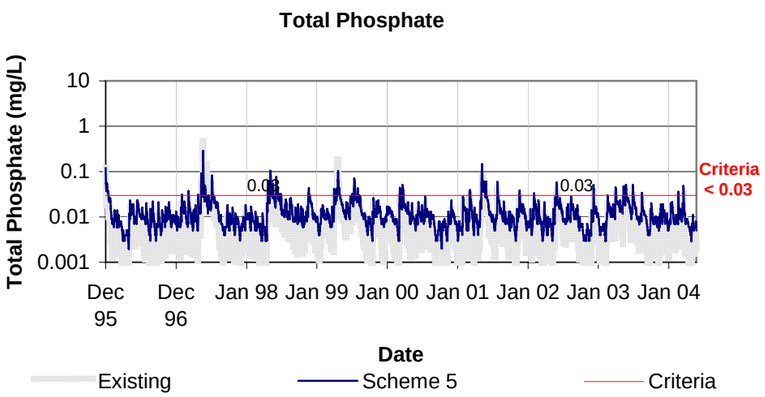


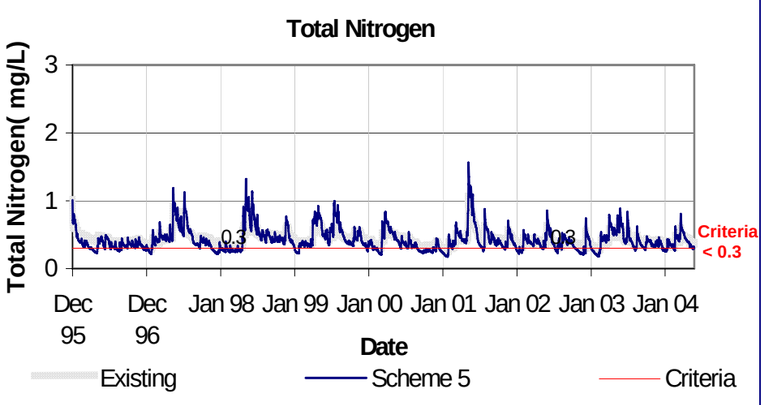
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	2 ha
Additional Freshwater Area	6.5
Total WQ Area [a]	14.5 ha
Outlet Channel Details	
Outlet Width	x 1.8
Outlet Depth	0.09 m
Retardation Details	
Total Available [=a]	
Additional Required	0
Total	14.5 ha









Scheme 5

This scheme is a combination of schemes 3 and 4. It would comprise the extension of the western arm of the existing tidally flushed lake as well as the construction of an additional freshwater lake or chain of ponds (total extension).

Strengths

- The extended tidally flushed lake is able to reduce the size of the separate freshwater lake / ponds.
- Ponds could be constructed sequentially.
- Land take is less than other "split lake" schemes.
- Potential to integrate with open space strategy.
- Moderately increased tidal flushing.
- Better protection is afforded by discharging commercial runoff to brackish catchment.

Weaknesses

- The raised water levels in a freshwater lake / pond(s) impact on the hydraulics of the drainage swales.
- Need to maintain multiple water bodies.
- Local impact on SEPP 14 wetlands and conservation zone due to outlet channel works.

CRIGHTON PROPERTIES

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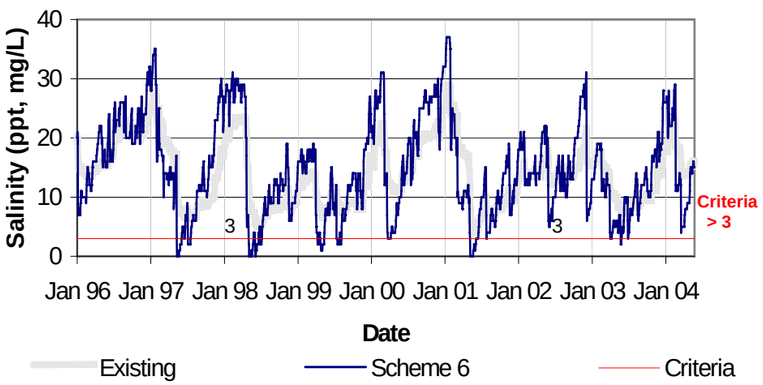
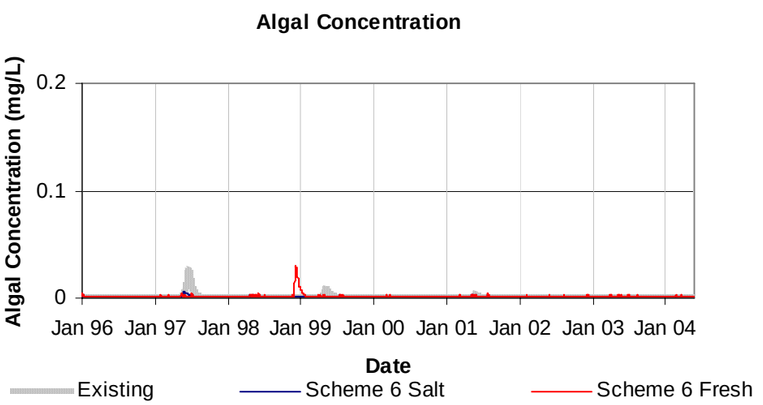
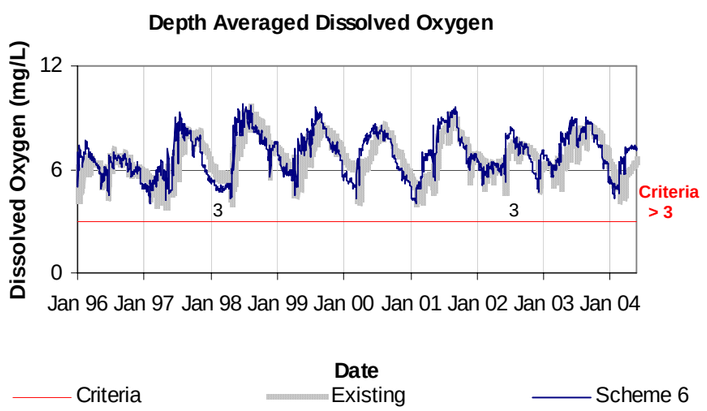
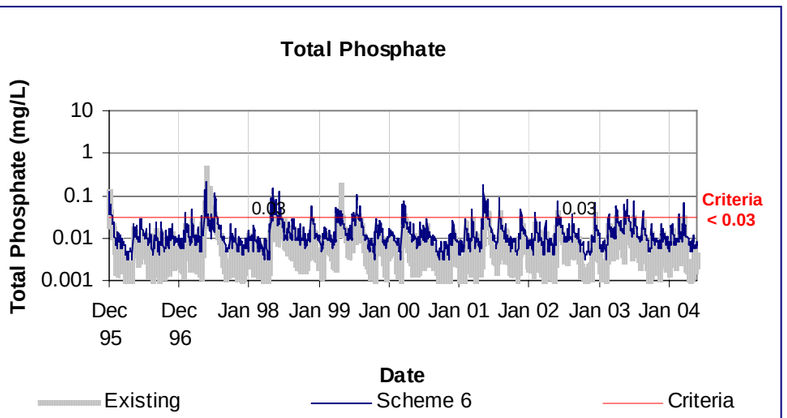


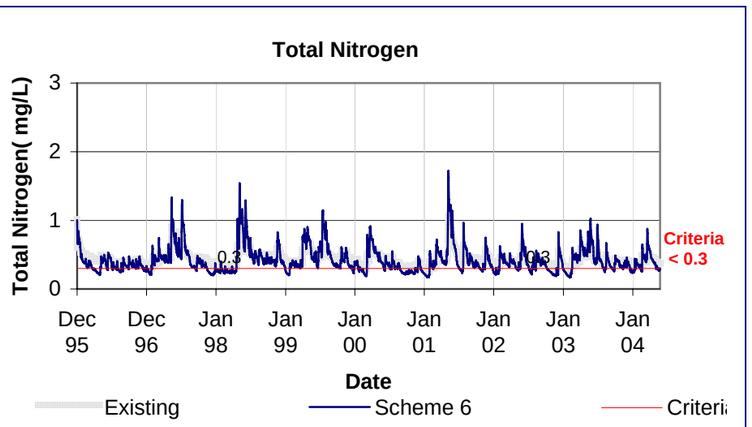
Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	16 ha
Total WQ Area [a]	22 ha
Outlet Channel Details	
Outlet Width	x 1.6
Outlet Depth	0.09 m
Retardation Details	
Total Available [=a]	
Additional Required	16 ha
Total	22 ha









Scheme 6

This is also a variation on Scheme 4. Instead of an additional shallow lake / pond(s) additional shallow lined wetlands would be constructed.

Strengths

- Wetlands could be constructed where required (when required).
- Dual role of water quality and detention.
- Moderate increase in tidal flushing.

Weaknesses

- Wetland would need to be lined to maintain water within the wetlands.
- Large area of wetlands may pose a health risk to residents through increased potential for mosquito breeding.
- Land take is greater than other schemes.
- The level of the wetlands likely to impact on the hydraulics of drainage swales
- Need to incorporate open water zones within the wetlands to assist predation on mosquitoes
- Aesthetic impacts.
- Local impact.
- Lined wetlands susceptible to drying out.
- Increased fire risk (see the Map below with the APZ required – in red).

CRIGHTON PROPERTIES

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SWALES

What is a Swale?
Swales are linear broad shallow channels that provide for stormwater collection and conveyance. Swales may be grass-lined or densely vegetated and / or landscaped. While swales provide for stormwater transportation, they also contribute to the removal of gross pollutants, such as litter and coarse sediment, from stormwater runoff.

In urban areas, swales may be used as an alternative to the conventional street naturestrip or in central median strips of roads, through to runoff collection points in car park areas. Hydraulically swales can reduce run-off volumes and peak flows. Current designs involve the use of grass or other vegetation (such as rushes) to carry out this function. Examples of their current use are in road medians and verges, car park run-off areas, parks and recreation areas.

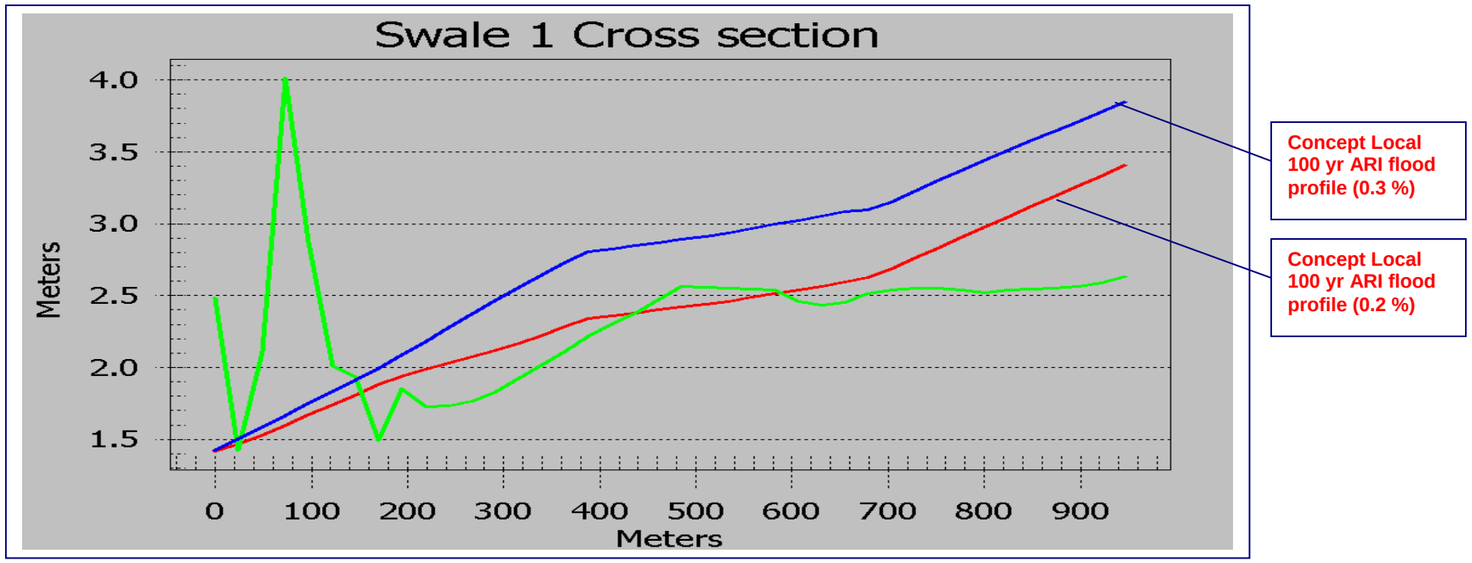
Swales initially immobilise pollutants, by binding them to organic matter and soil particles. Settling, filtration and infiltration into the subsoil achieve ultimate pollutant removal. Certain pollutants, such as hydrocarbons, may be digested and processed by the soil microorganisms in the filter strip. Consequently, adequate contact time between the run-off and the vegetation and soil surface is required to optimise pollutant removal.

Swale design for Myall Quays
Swales design purpose is to carry varying flows. The design for Myall Quays development is to incorporate grassed swales, approximately 6 m wide. Minimum gradient 0.2%

Vital Statistics

Lake Details	
Existing Lake Area (Saline)	6 ha
Additional Saline Lake Area	0
Additional Freshwater Area	0
Total WQ Area [a]	6ha
Outlet Channel Details	
Outlet Width	x 4
Outlet Depth	0.3 m
Retardation Details	
Total Available [=a]	
Additional Required	swales
Total	

Swale Cut and Fill Cross Section



Concept Local 100 yr ARI flood profile (0.3 %)

Concept Local 100 yr ARI flood profile (0.2 %)

Scheme 7

This scheme is effectively scheme 2 with the benefit of swales. This scheme attempts to mitigate the adverse impacts of scheme 1 by increasing tidal flushing to combat water quality impacts and the provision of dry basins to help address detention and nutrient control.

Strengths

- Can reduce and delay storm run-off,
- Retains particulate pollutants close to source,
- More aesthetically appealing than kerb and gutter, and
- Relatively inexpensive to construct.

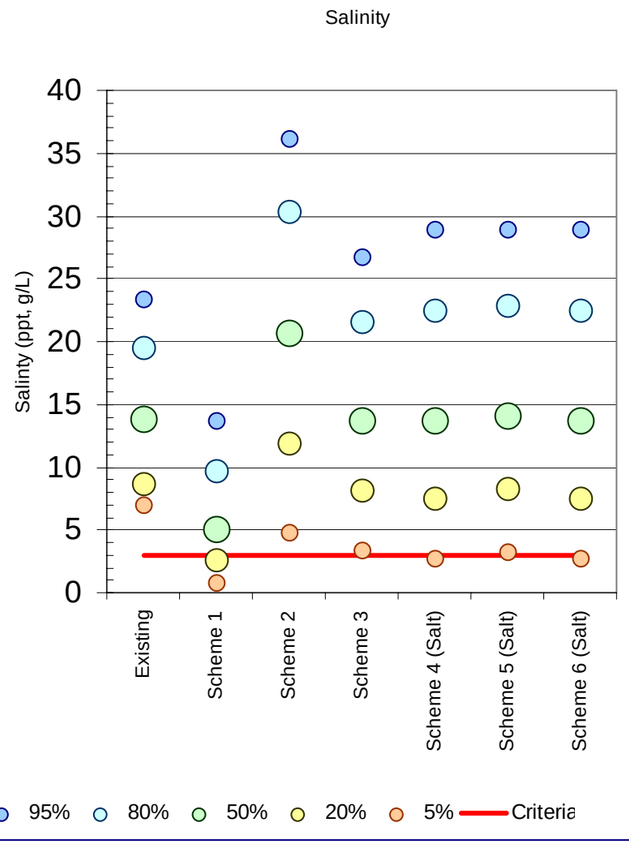
Weaknesses

- Limited removal of fine sediment and dissolved pollutants,
- Requires larger land area that kerb and gutter, with certain activities restricted (i.e. car parking),
- Sunny aspect is required for plant growth, limiting its application in shaded areas,
- Regular inspections are required; and
- Even at minimum gradient (0.2%) swales result in massive fill required at upper end of catchment.

Salinity

The plot of salinity compares modelled existing conditions (calibrated using recorded data) with the various schemes considered for the Myall Quays development. The values (5%, 20%, 50%, 80% and 95% percentile) for the probability of exceedence of the salinity in a tidally flushed lake (either existing or extended) is depicted for pre-existing conditions, existing conditions as well as Schemes 1 – 6. Schemes 3 to 6 have salinity levels (within hyposaline range) to support a more diverse ecosystem compared to that of scheme 2. Scheme 2 has levels with the 80%ile reaching relatively high salinity levels, which limits the species diversity and richness. Scheme 0 is similar to schemes 3 to 6. Scheme 1 is modelled depicting relatively low salinity levels.

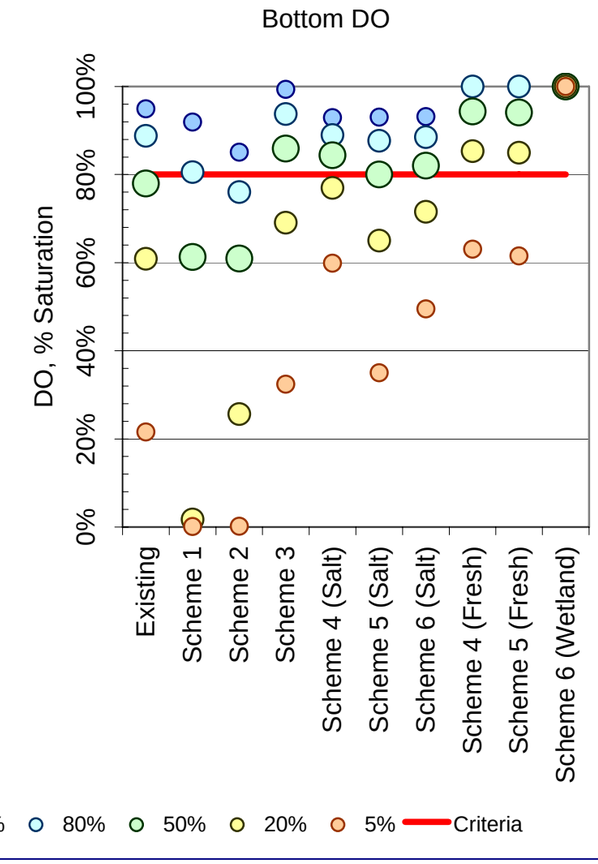
Rank	Scheme
1	0
7	1
6	2
2	3
3	4
3	5
3	6



Dissolved Oxygen

The DO concentrations measured in the existing lake include readings of both bottom and surface waters. The levels in bottom waters tend to be lower dissolved oxygen. Scheme 3, 4 and 5 have a high percentage of DO levels in the optimal range (80% to 110%) to support a healthy ecosystem than other schemes.

Rank	Scheme
5	0
7	1
6	2
4	3
2	4
3	5
1	6



Chlorophyll *a*

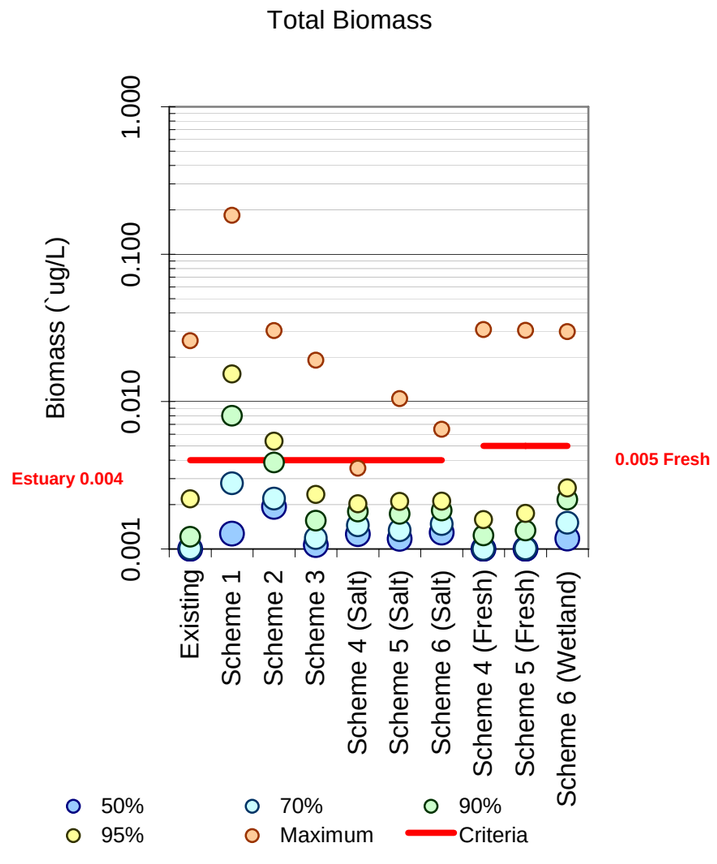
The Chlorophyll *a* concentrations in Myall Quays detention lake vary at certain times of the year. Modelling of the different options for the proposed development are represented, with certain schemes showing less dramatic variations.

ANZECC (2000) Trigger Values for Chlorophyll *a*

	Chlorophyll *a*
Fresh	5 µg/L
Marine	1 µg/L
Estuary	4 µg/L

Scheme Ranking for Chlorophyll *a*

Rank	Scheme
4	0
7	1
6	2
5	3
1	4
3	5
2	6



Nitrogen

The ANZECC(2000) trigger values for TN are shown in the table below.

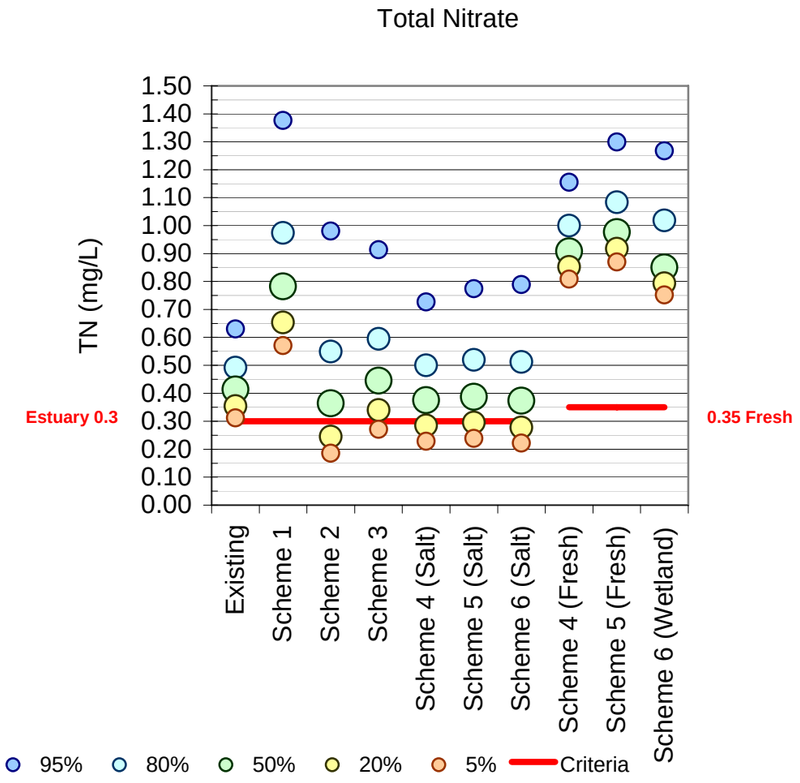
ANZECC (2000) Trigger Values for Nitrogen

	Total Nitrogen (TN)
Fresh	0.35mg/L
Marine	0.12mg/L
Estuary	0.3mg/L

Scheme Ranking for Nitrogen

Rank	Scheme
2	0
4	1
3	2
1	3
5	4
7	5
6	6

Implementation of new management measures and the appropriation of a higher site specific target monitored using community funding means water quality in the existing and proposed lake / pond(s) will meet the recommended ANZECC (2000) guidelines. The higher standard is desirable as the nutrient status of water quality would not encourage algal blooms, phytoplankton blooms and midge outbreaks etc that occur in eutrophic or high nutrient waters. The observed levels in the existing lake have generally been low. This appears to be contributing to the overall good water quality.



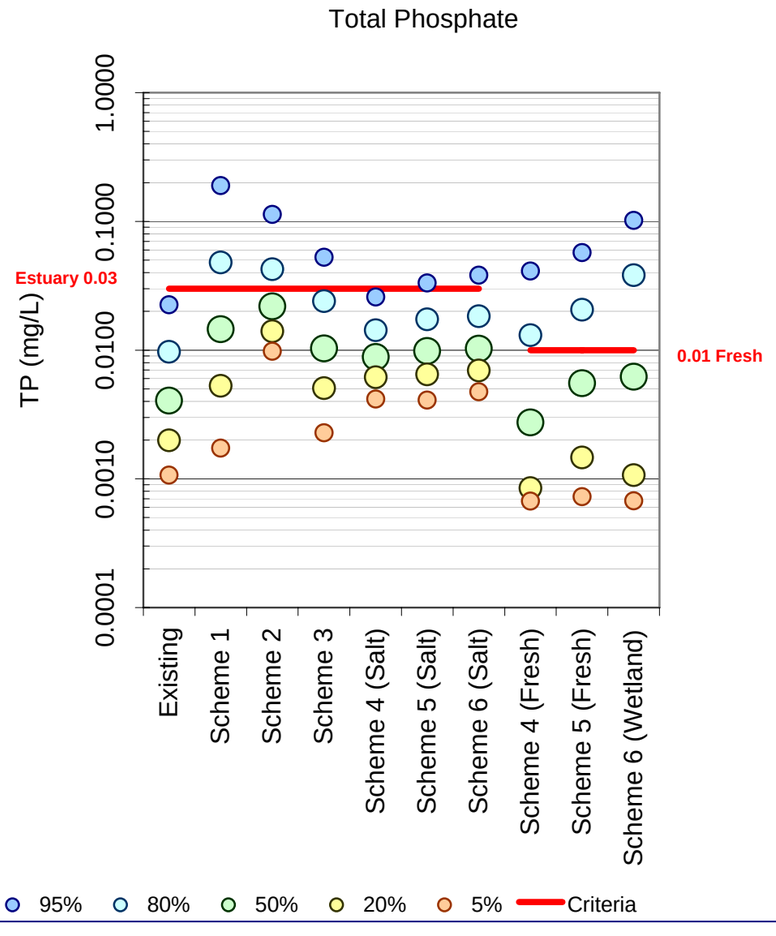
Phosphorus

The ANZECC(2000) trigger values for (80%ile) TP are shown in the table below.

	Total Phosphorus (TP)
Fresh	0.01 mg/L
Marine	0.025 mg/L
Estuary	0.03 mg/L

Rank	Scheme
1	0
7	1
6	2
2	3
3	4
4	5
5	6

The TP levels in the lake at Myall Quays are generally low. The mean value for the existing lake is 0.02 mg/L. The phosphorous concentrations have declined since 1997 to consistently low values, contributing to the overall very good water quality.



CRIGHTON PROPERTIES

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Water Quantiity Assessment

Retardation

Why is retardation required?
It is necessary to consider and implement retardation management strategies. Retardation is required to minimise the impacts of flooding during major storm events. Retardation modelling has been undertaken for Schemes 2 – 6.

The modelling of the various Schemes has been conducted to maintain, as close as possible, the existing (estimated) 100 year outflow (14.63 m^3/s) to Myall River. Various options, in terms of total volume of retardation required and engineering interventions possible, have been considered for each of the Schemes to achieve the existing outflow.

Retardation Options
The various options considered under each Scheme are as follows:

Option 2 All discharges into existing lake only.
Option 2A Existing lake and future dry detention area (12 ha) with 4 x of 0.6 m diameter pipes 30m long at 0.3% slope (n = 0.012), 6 m weir spillway 0.5 m above basin invert.
Option 2B Existing lake and future dry detention area (12 ha) with 4 x of 0.6 m diameter pipes 30m long at 0.3% slope (n = 0.012), 20 m weir spillway 0.5 m basin invert.
Option 2C Existing lake and future dry detention area (12 ha) with 4 x of 0.6 m diameter pipes 30m long at 0.3% slope (n = 0.012), 36 m weir spillway 0.35 m basin invert.

Option 3 Extending the existing lake to 13.5 ha. Spill level at RL 0.9, 240 m wide.
Option 3.1 Extending the existing lake to 13.5 ha. Spill level at RL 1.00, 240m wide.
Option 3A Extending the existing lake to 13.5 ha. Spill level at RL 0.9, 240 m wide. Additional basin area of 6 ha, 10 m weir spillway 0.5 m from basin invert.
Option 3B Extending the existing lake to 13.5 ha. Spill level at RL 0.9, 240 m wide. Additional basin area of 4 ha, 10 m weir spillway 0.5 m from basin invert.
Option 3C Extending the existing lake to 13.5 ha. Spill level at RL 0.9, 240 m wide. Additional basin area of 6 ha, 12 m weir spillway 0.5 m from basin invert.
Option 3D Extending the existing lake to 13.5 ha. Spill level at RL 0.9, 240 m wide. Additional basin area of 6 ha, 10 m weir spillway 0.4 m from basin invert.
Option 3E Extending the existing lake to 13.5 ha. Spill level at RL 1.0, 240 m wide. Additional basin area of 3 ha, 10 m weir spillway 0.3 m from basin invert.

Option 4 Existing lake and future freshwater lake (12 ha) with 12 m wide spillway 0.5 m basin invert.
Option 4A Existing lake and future freshwater lake (12 ha) with 30 m wide spillway 0.3 m basin invert.

Option 5 Existing lake increased to 8 ha and future freshwater lake (6.5 ha). 12 m wide spillway 0.5 m basin invert.
Option 5A Existing lake increased to 8 ha and future freshwater lake (6.5 ha). 14 m wide spillway 0.5 m basin invert.

Option 6 Existing lake and future wetland (16 ha) with 12 m wide spillway 0.5 m basin invert.
Option 6A Existing lake and future wetland (16 ha) with 20 m wide spillway 0.5 m basin invert.
Option 6B Existing lake and future wetland (16 ha) with split spillways 38 m wide at basin invert.

Retardation Analysis

Myall Quays Lake Retention Analysis – 1 % AEP Flood								
Conditions	Existing Basin / Lake		Future Pond[1]		Additional Pond[2]		Large Lake	
	Level (mAHD)	Outflow (m3/s)	Depth (m)	Outflow (m3/s)	Depth (m)	Outflow (m3/s)	Level (mAHD)	Outflow (m3/s)
Existing	0.99	14.63						
Option 2	0.99	29.53						
Option 2A	0.80	7.14	1.09	6.46				
Option 2B	0.87	10.98	0.92	10.28				
Option 2C	0.92	14.46	0.72	13.72				
Option 3							0.99	18.90
Option 3.1							1.05	17.21
Option 3A					1.26	9.98	0.96	12.00
Option 3B					1.37	12.18	0.97	14.47
Option 3C					1.29	12.64	0.97	14.93
Option 3D					1.27	12.23	0.97	14.67
Option 3E					1.22	13.21	1.03	14.43
Option 4	0.95	8.77	1.07	7.81				
Option 4A	0.98	14.38	0.74	13.04				
Option 5	0.98	14.09	1.27	12.18				
Option 5A	0.98	14.69	1.22	12.74				
Option 6	0.93	6.30	0.96	5.70				
Option 6A	0.94	7.87	0.88	7.05				
Option 6B	0.98	14.43	0.37	13.05				

Notes
1 Future Pond – Future pond/lake/basin/wetland included as part of the Water Quality Assessment
2 Additional Pond – Additional pond/lake/basin/wetland required over and above what is included as per the Water Quality Assessment
3 Preferred options are highlighted under each scheme

Impacts of Retardation Requirements on Site Topography

The various schemes considered are constrained by minimum basin invert levels and minimum gradients to ensure drainage of swales and basin (typically a minimum 0.2% longitudinal grade). These constraints can have differing impacts on the fill required to ensure floor levels are no lower than the local 100 yr ARI flood level or river 100 yr ARI flood level (which ever is higher of 2.1 m AHD). The following illustrations show the the existing lake level and the levels required to achieve the minimum gradient under each Scheme.

Scheme 2

The local 100 yr ARI flood levels vary from 0.98 m AHD at the existing lake to up to 3.1 m AHD at farthest end of the detention basin (also see the illustration in the box showing the 'stepped' retardation that would be required to maintain the minimum longitudinal gradient of 0.2% along the detention basin)

Scheme 3

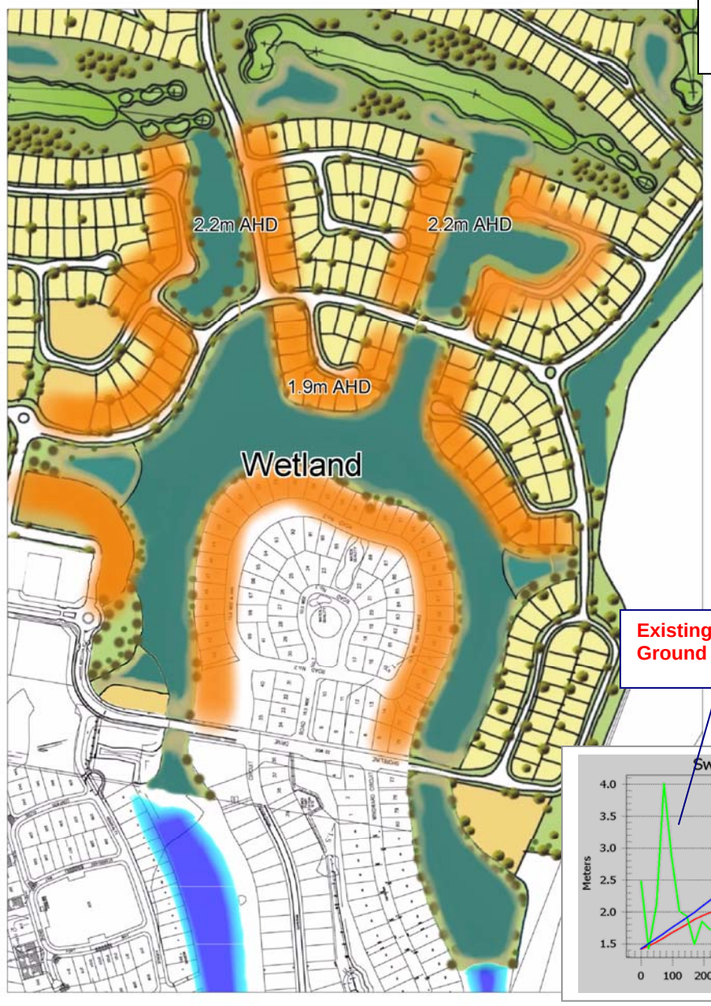
The local 100 yr ARI flood levels in the extended lake vary between 0.97 m AHD and 1.03 m AHD

Scheme 4

The local 100 yr ARI flood levels vary between 0.98 m AHD in the existing lake and 1.54-1.64 m AHD at the freshwater lake

Scheme 5

The local 100 yr ARI flood levels vary between 0.98 m AHD at the partially extended lake and 2.0-2.1 m AHD in the additional freshwater lake



Scheme 6

The local 100 yr ARI flood levels vary between 0.98 m AHD in the existing lake and up to 2.2 m AHD at the farthest end of the wetland

Scheme 7

The local 100 yr ARI flood levels vary between 0.98 m AHD at the existing lake and up to 3.5 m AHD at the farthest end of the swale. See the graphs shown for each line of swales considered (in purple line on the map)

CRIGHTON PROPERTIES

Cardno

Summary

Summary of Qualitative Assessment of Schemes

Criteria	Weight	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5	Scheme 6	Scheme 7
Water Quality								
Salinity	0.2	2	4	3	2	3	3	2
Dissolved Oxygen	0.2	1	1	4	4	4	4	3
Algae	0.2	1	3	4	4	4	4	3
Total Nitrogen	0.2	1	4	4	1	1	1	3
Total Phosphorous	0.2	2	2	3	3	3	3	3
Environmental Impacts								
Impact on existing water body	0.4	1	2	4	4	4	4	4
Impact on SEPP 14 wetlands	0.3	2	3	4	4	4	4	4
Impact on Myall River	0.1	2	3	4	4	4	4	4
Impact on Ground Water	0.2	2	2	3	3	3	4	1
Viability								
Loss of potential lots	0.3	3	4	5	3	3	1	1
Aesthetic/Health	0.1	2	2	4	4	4	1	1
Landtake for Basins	0.2	1	4	5	4	4	4	2
Landtake for Ponds / Wetlands	0.2	1	4	5	4	4	4	2
Filling	0.2	5	4	5	3	4	2	1
Weighted Total Score		5.50	9.00	12.30	10.10	10.50	9.40	7.60
Rank		7	5	1	3	2	4	6

Criteria / Score	1	2	3	4	5
Salinity	Extremely Low	Low	Meets the Criteria	Good	Extremely Good
Dissolved Oxygen	Extremely Low	Low	Meets the Criteria	Exceeds Criteria	Extremely Good
Algae	Highly Elevated	Elevated	Meets the Criteria	Lower than Criteria	Extremely Good
Nutrients	Highly Elevated	Elevated	Meets the Criteria	Lower than Criteria	Extremely Good
Impact on existing water body	Negative Impact	Some Negative Impact	No Impact / No Change	Some Improvement	Positive Impact
Impact on SEPP 14 wetland	Significant Negative Impact	Some Negative Impact	Slight Negative Impact	Minimal Impact	No Impact / No Change
Impact on Myall River	Significant Negative Impact	Some Negative Impact	Slight Negative Impact	Minimal Impact	No Impact / No Change
Impact on Ground Water	Significant Negative Impact	Some Negative Impact	Slight Negative Impact	Minimal Impact	No Impact / No Change
Loss of potential lots	Significant loss of lots	Loss of lots	Slight loss of lots	Minimal loss of lots	No net loss of lots
Aesthetic/Health	Significant Negative Impact	Negative Impact	No Impact / No Change	Positive Impact	Significant Positive
Landtake for Basins	Greatest landtake	Additional landtake	Some landtake	Contained within public open space	Excellent
Additional Water Area	Greatest landtake	Additional landtake	Some landtake	Contained within public open space	No additional area required
Filling	Most volume of fill required	Additional fill required	Some additional fill	Minimal additional fill	No Impact / No Change

APPENDIX G

GROUNDWATER ASSESSMENT
OCTOBER 2007

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GROUNDWATER ASSESSMENT

Crighton Properties
Riverside Development, Tea Gardens

GEOTLCOV23225AA-AD
26 October 2007

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
8/12 Mars Road Lane Cove West NSW 2066 Australia

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

26 October 2007

Crighton Properties
PO BOX 3369 Tuggerah
NSW 2259

Attention: Mr Peter Childs

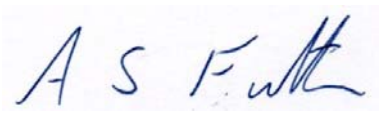
Dear Sir

RE: Groundwater Assessment, Riverside Development, Tea Gardens.

Coffey Geotechnics is pleased to present our groundwater study for the Riverside Development, Myall Quays.

We trust that our report meets your requirements. If you have any questions regarding the report, please do not hesitate to contact the undersigned or either Jessica Northey and Andy Fulton.

For and on behalf of Coffey Geotechnics Pty Ltd



Andrew Fulton

Senior Hydrogeologist

Distribution: Original held by Coffey Geotechnics Pty Ltd
1 copy to Cardno Willing Pty Ltd
1 copy to Tattersall Surveyors Pty Ltd
1 copy by Coffey Geotechnics Pty Ltd

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Executive Summary

A groundwater study and modelling program was undertaken to assess the groundwater aspects of concept layout for the proposed Riverside development. The development includes housing and a man made lake which has been constructed to provide a storm water detention structure and to aid water quality management.

The site is located to the west of the Myall River and is bounded to the west by Myall Road and Toonang Road. The ground surface generally slopes down gently south-east towards the river with ground levels typically below 3mAHD. A series of sand ridges trending roughly north-south are present across the site. An elevated bedrock outcrop, rising to about 25mAHD, is present at the northern end of the site. Elevated bedrock levels are also present at the north-western limit of the site.

The sandy aquifer local to the development is contained within a discrete area and groundwater users further a field are not likely to be affected by activities at the Riverside development site. The shallow rock levels to the north of the site provide a barrier to groundwater inflow. The sand aquifer is expected to extend to the south and west of the site and be in hydraulic contact with the waters of the Myall River to the south, Wobbegong Bay and Pindimar Bay (Port Stephens) to the south-west and Kore Kore Creek to the west.

Losses from the groundwater system occur due to seepage to the Myall River and evapotranspiration from areas of shallow water table. Rainfall infiltration forms the main groundwater recharge mechanism and previous monitoring results from the bores over the site show marked groundwater level response to rainfall events. Lower groundwater levels recorded recently are likely to be the result of lower than average rainfall which has occurred on the Mid North Coast of NSW in recent years.

Groundwater modelling that was conducted in an earlier investigation phase was built upon and used to simulate the expected impacts from the proposed development. The modelling indicated that the extension of the lake and the introduction of a series of stepped freshwater lakes will cause localised drawdown on the north-western most extremity of the extended lake by up to 0.75 m. There was negligible impact indicated from the modelling on the wetland area fringing the Myall River.

Groundwater quality monitoring indicates that quality has remained relatively stable when recent results were compared to earlier testing periods. Groundwater quality is generally below the key criteria for protection of species in marine water with the exception of some metal concentrations. Groundwater from monitoring bores closer to the Myall River tends to be characterised by higher EC and a similar anion to cation ratio to seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.

Groundwater quality was compared to the Australian Drinking Water Guidelines (NHMRC, 2004) and is not potable due to concentrations of a range of analytes exceeding the drinking water guidelines. Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and outside the lower criterion for drinking water of pH 6.5. Groundwater near the Myall River has elevated levels of electro-conductivity, anions and cations that do not meet the criteria for drinking water. Elevated ammonia concentration found in some bores also renders groundwater unsuitable for potable use due to the exceeding of ANZECC guidelines. Groundwater away from the Myall River may be considered for irrigation purposes, however high concentrations of phosphorus have the potential to result in bio-clogging of irrigation equipment.

An assessment of potential acid sulfate soils was undertaken at the site (Coffey 2007 GEOTSGTE20248AA-AE) which indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area. The lake extension will cause groundwater level reductions on the north-western tip of the lake extension to fall slightly below levels interpreted to have acid soil producing potential. However, the area affected and the exceedance of criteria is considered to be limited for the predicted resulting groundwater levels.

The groundwater results from the current monitoring round suggest that the reclaimed water from treatment facilities in the area may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of the reclaimed water with water of higher quality.

The results of this study as presented has show that groundwater levels within are not significantly affected by the proposed development proposed . Groundwater quality results indicate that the groundwater form the aquifer at Riverside is not suitable for potable use although it is possible that reclaimed water can be used for irrigation purposes provided appropriate treatment is undertaken. Groundwater quality results also indicate that the groundwater is generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations.

1 INTRODUCTION

This report presents the results of a groundwater study and modelling program undertaken to assess the latest concept layout for the proposed Riverside development (the Site) at Tea Gardens (Figure 1) on local groundwater movements. Coffey Geotechnics Pty Ltd (Coffey) was commissioned to

undertake the project by Crighton Properties to address the issues noted in the amended Director-General's Environmental Assessment Requirements (Ref.: MP 06_0010, dated 29 December 2006) for the site, in particular:

- Analysis of groundwater quality of the site;
- Interception and use of groundwater;
- Potential for impact on existing groundwater with respect to the latest concept layout for the development;
- Beneficial uses of groundwater; and
- The potential impact of reuse of reclaimed water and the quality required to minimise impact on groundwater.

Mr Peter Childs of Crighton Properties commissioned the works in March 2007 in response to a Coffey proposal (Ref: GEOTLCCOV22325AA, 6 March 2007). Cardno Willing (Cardno) are consultants to Crighton Properties and they have provided information in relation to the proposed development.

2 PROPOSED DEVELOPMENT

It is understood that Crighton Properties has commenced development at the site in accordance with the current Local Environment Plan (LEP) zonings – mixed residential/commercial 2(f), wetlands 7(a) and a conservation zone 7(b). The development is approximately 230ha in size and comprises residential areas, a commercial area, open space recreational areas, wildlife corridors and buffer zones and the lake.

The development features a large lake partially encircling an existing residential development. Development approval has been granted for a portion of the development at the south of the site including housing and a man made lake (about 6.5ha in area) which has been constructed to provide a storm water detention structure and as a water quality management measure.

The proposed development will involve extending the existing lake and construction of housing and open space recreational areas. This is the latest concept layout for the proposed Riverside development considered in this report. Along the eastern boundary of the development, a natural wetland area separates the site from the Myall River. This wetland is recognised under State Environment Planning Policy No. 14 (SEPP 14) as Wetland No. 746 and consists of seagrass tidal mud flats containing fringing mangroves along the river bank.

3 PREVIOUS INVESTIGATIONS AT THE SITE

Coffey has previously undertaken a groundwater assessment of the site in 2004 (Ref: E12752/3-AF) to assess the impact of an earlier development proposal at the site. The report included groundwater level and groundwater quality monitoring, acid sulfate soil testing and the development of a numerical groundwater model.

The groundwater assessment reported on the results from a network of fourteen monitoring bores, four of which were installed by Coffey in the vicinity of the lake (Bores 21 to 24). Rainfall was assessed to be the main groundwater recharge mechanism and groundwater level was found to respond rapidly to rainfall events. During periods of low rainfall, groundwater levels gradually fall as seepage towards the Myall River and the lake occurs.

Previous monitoring of groundwater level indicated the area is underlain by a shallow watertable, particularly in the eastern part of the site in the vicinity of the wetlands and the Myall River. The watertable was found to be slightly deeper (0.5 to 1m) in the northern and western parts of the site.

Groundwater quality monitoring, undertaken in 2004, indicated that there had been little change in groundwater quality between the 1995 and 2004 monitoring rounds. Groundwater in the vicinity of the Myall River is characterised by higher salinity, with decreasing salinity as distance to the river increases. Groundwater quality was assessed to be unsuitable for drinking purposes but was considered to be potentially suitable for irrigation purposes.

An assessment of potential acid sulfate soils was also undertaken at the site (Coffey 2007 GEOTSGTE20248AA-AE). The laboratory results indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area.

A steady state groundwater model was established for the site to predict groundwater level conditions for the proposed development. It was assessed that groundwater level would decrease slightly to the north of the lake and that groundwater direction in the area would change slightly, with groundwater discharging to the constructed lake.

4 GEOLOGICAL AND HYDROLOGICAL CONDITIONS

The geological and hydrological conditions at the site were presented in Coffey's earlier report (Ref.: 12752/3-AF, dated 23 December 2004) and are summarised below.

4.1 Topography and Geology

The site is located to the west of the Myall River and is bounded to the west by Myall Road and Toonang Road. The ground surface generally slopes gently south-east towards the river with ground levels below 3mAHD. A series of sand ridges trending roughly north-south are present across the site. An elevated bedrock outcrop, rising to about 25mAHD, is present at the northern end of the site. Elevated bedrock levels are also present at the north-western limit of the site.

Soils in low lying areas are generally silty sand and topsoil overlying fine to medium grained sand containing cemented layers (coffee rock) and peaty bands. Basement rock occurs at a depth of 10m to 20m over much of the site, rising steeply at the northern end of the site forming an outcrop. A surface clay layer of 1m to 2.5m thickness exists at the north-west of the site accompanied by an underlying layer of peat.

The sand aquifer is underlain by basement sandstone at a depth of up to approximately 20m. Sand thickness varies from 0m in the elevated areas in the north of the site to about 20m at the southern limit of the proposed development.

4.2 Surface Water Conditions

The catchment of the site is limited to the north by a ridge outcrop, and to the south-west by Myall Road. The catchment is largely contained within the site area except for a comparatively small area to the north and north-west. With the exception of the portion at the south of the site that has already been developed, there is little natural development of surface drainage features and the sandy surface soils generally result in a high level of rainfall infiltration to the groundwater system. As a result, significant surface runoff is unlikely except during periods of high rainfall when groundwater levels rise to near the ground surface and recharge is rejected.

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. Runoff from the eastern margin of the site tends to flow to the east towards the SEPP 14 wetlands and the Myall River.

Much of the site runoff including runoff from the contributing catchment north of Toonang Road flows to the lake at the south of the site before discharging through the drain to the Myall River. The invert level of this drain is at approximately 0.64 mAHD. During high tide, saline water from the Myall River flows through the drain and the adjacent low lying area to the detention lake. The water in the lake is therefore brackish.

4.3 Groundwater Conditions

The subsurface sands form an aquifer characterised by moderate to high transmissivity, previously estimated at 200m^2/day, which is present over much of the development site and over the SEPP 14 wetland area. Previous groundwater levels indicated shallow water tables are present over the site. generally within 1m of the surface and at the western limit of the SEPP 14 wetlands and Myall River, groundwater levels are within 0.5m of the ground surface. Groundwater flow is south-east toward the Myall River and groundwater is relatively fresh in the main body of the sand aquifer. There is a secure town water supply well to the north of the area and currently groundwater is not used except for minor home irrigation.

The shallow rock levels to the north of the site provide a barrier to groundwater inflow from that direction. The sand aquifer is expected to extend to the south and west of the site and be in hydraulic contact with the waters of the Myall River to the south, Wobbegong Bay and Pindimar Bay (Port Stephens) to the south-west and Kore Kore Creek to the west.

During periods of low rainfall, losses from the groundwater system will occur due to seepage to the Myall River and evapotranspiration from areas of shallow water table. Evapotranspiration losses from the water table reduce with increasing depth of the water table in a non-linear fashion (Coffey Partners International, 1996).

Rainfall infiltration forms the main groundwater recharge mechanism. Previous monitoring results from the bores over the site show marked groundwater level response to rainfall events.

The aquifer is in contact with saline water in the Myall River and also in contact with the brackish water in the lake in the south of the site. This results in the development of an interface between high quality fresh groundwater and saline water. The depth of the fresh/salt water interface is a function of the density difference between fresh and salt water and the height of the groundwater surface. For seawater, this depth can be estimated using the Ghyben-Herzberg approximation to be about 40 times the height of the groundwater table above average sea water surface (Fetter 2001).

The proposed development involves the extension of the existing lakes on the western side and a series of stepped freshwater lakes on the eastern side. Evaporation from these lake extensions would be greater than evapotranspiration losses from the water table over a similar area. These increased evaporative losses are expected to be balanced in part by the reduced evapotranspiration losses that would accompany covering part of the ground surface for residential development.

4.4 Climate – Rainfall and Evaporation

Historical rainfall and evaporation was obtained from the Bureau of Meteorology. Daily rainfall measurements recorded at the Bureau of Meteorology weather station No#61054 at Nelson Bay along

with summary statistics of monthly data. The climate data is included in Appendix A of Coffey's earlier report (Ref.: E12752/3-AF, dated 23 December 2004).

5 FIELD INVESTIGATIONS

5.1 Previous Investigation

Field investigations were previously undertaken by Coffey in April 2004. The field work included extending the bore network by adding four groundwater bores, monitoring of groundwater levels and the collection of soil and groundwater samples for laboratory testing.

5.2 Current Investigation

Field work for the current investigation was undertaken on 29 and 30 March, 2007. The field work included:

- Monitoring groundwater levels in accessible bores (bore 3 and Bore 7 could not be accessed);
- Groundwater samples were collected from a selection of the monitoring bores, in accordance with the following protocols:
    - Prior to purging, the groundwater levels were measured in each bore;
    - Purging of the bores prior to sampling using a plastic bailer, until pH and electrical conductivity (EC) readings stabilised (minimum of 3 well volumes purged);
    - Samples were collected using a plastic bailer;
    - Samples were poured into appropriately preserved laboratory-supplied containers and placed in a cooler box filled with ice immediately after collection.

The samples were then dispatched to ALS, a NATA accredited laboratory under chain of custody conditions.

The groundwater samples were analysed for a range of parameters including pH, EC, total dissolved solids (TDS), total hardness, total alkalinity as $CaCO_3$, major cations and anions (including sodium, calcium, magnesium, potassium, chloride and sulfate), ammonia, nitrate, nitrite, total Kjeldahl nitrogen (TKN), heavy metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury), biological oxygen demand (BOD) and total organic carbon (TOC).

The locations and levels of the groundwater bores were surveyed by Tattersall Surveyors.

6 RESULTS

6.1 Groundwater Level Monitoring

A network of twelve groundwater monitoring bores (Bore 1 to Bore 12) was installed by DJ Douglas & Partners in 1994 and four monitoring bores (Bore 21 to Bore 24) were installed by Coffey in 2006. Four of the bores (Bore 1, Bore 2, Bore 3 and Bore 7) had been destroyed or lost between the current and previous monitoring rounds. The remaining available bores formed a network for Coffey's 2007 monitoring program.

One round of groundwater level monitoring was undertaken from the existing monitoring network using a dip meter. Table 1 presents a summary of groundwater monitoring data from the previous and current monitoring rounds.

The depth to groundwater at the site has decreased since April 2004 at all locations with the exception of Bore 21. Groundwater level ranges from 0.5m to 1.7m below ground surface and tends to be shallower in the vicinity of the Myall River and the lake (Bores 4, 10, 21, 22, 23 and 24) and deeper further from the river (Bores 5, 8, 9, 11 and 12). The shallow groundwater conditions at the site will limit the capacity of the groundwater system to accept rainfall recharge.

Previous groundwater level data collected by automatic loggers indicates that the measured groundwater levels respond to rainfall events. Groundwater levels measured in March 2007 are typically 0.3 m lower than corresponding levels measured in April 2004. The largest reductions were recorded for Bore 11 (reduction of 0.87 m) and Bore 12 (reductions of 1.1 m). These monitoring bores are in elevated ground and are the two bores most distant from the existing lake of the bores for which comparisons could be made.

As groundwater levels respond to prevailing climatic conditions that a decrease in groundwater levels would be experienced during periods of lower than average rainfall. Lower than average rainfall has been experienced on the mid central coast of NSW in recent years. It is most likely that this is the cause of groundwater level decreases observed.

TABLE 1: GROUNDWATER LEVEL MONITORING

Location	Bore Depth Below Ground (m)	Screened Depth Interval (m)	Elevation of TOC* (mAHD)	Water Depth (m) below TOC	**Water Level (mAHD)**	Water Depth (m) below TOC	**Water Level (mAHD)**	Water Depth (m) below TOC	**Water Level (mAHD)**
				7 April 2004		11 May 2004		29 March 2007	
Bore 2	5.0	2.5 – 4.5	~2.300	Destroyed		Destroyed		Destroyed	
Bore 3	5.0	2.5 – 4.5	0.842	0.544	0.298	0.610	0.232	Bore not found	-
Bore 4	10.0	7.5 – 9.5	2.663	1.519	1.144	1.735	0.928	1.84	0.823
Bore 5	5.0	2.5 – 4.5	3.038	0.995	2.043	1.587	1.451	1.735	1.303
Bore 6	5.0	2.5 – 4.5	1.463	0.695	0.768	-		Bore not found	-
Bore 7	5.0	2.5 – 4.5	3.841	1.025	2.816	1.760	2.081	Bore not found	-
Bore 8	5.0	2.5 – 4.5	2.584	0.270	2.314	0.810	1.774	1.05	1.534
Bore 9	6.0	3.5 – 5.5	3.512	1.401	2.111	1.632	1.880	1.855	1.657
Bore 10	5.0	2.5 – 4.5	1.851	0.750	1.101	1.015	0.836	1.31	0.541
Bore 11	5.0	2.5 – 4.5	4.074	1.512	2.562	2.135	1.939	2.385	1.689
Bore 12	5.0	2.5 – 4.5	3.835	1.127	2.708	1.715	2.120	2.18	1.655
Bore 21	3.0	1.0 – 3.0	2.213	-	-	1.435	0.778	1.4	0.813
Bore 22	3.0	1.0 – 3.0	2.276	-	-	1.400	0.876	1.45	0.826
Bore 23	3.1	1.1 – 3.1	2.370	-	-	1.440	0.930	1.61	0.760
Bore 24	3.0	1.0 – 3.0	2.068	-	-	1.387	0.681	1.44	0.628

** Measured from the top of the casing (TOC) including extension pipes where added*

6.2 Groundwater Quality

6.2.1 Current Monitoring Round

Laboratory results from the groundwater bores selected for analysis are presented in Table LR1 in Appendix A. The laboratory reports are included in Appendix B. A summary of the results are presented below in Table 2.

TABLE 2: SUMMARY OF LABORATORY RESULTS (mg/l unless otherwise stated)

SAMPLE ID	**ANZECC Marine (slightly to moderately disturbed system)**		NHMRC Human Health Guidelines		**ANZECC Irrigation and General Use (moderately sensitive crops)**		Bore 4	Bore 9	Bore 12	Bore 21
SAMPLE DATE							29/03/07	30/03/07	29/03/07	29/03/07
GENERAL PARAMETERS										
pH (pH Unit)			6.5-8.5	7			5.32	3.99	5.02	5.62
EC (µS/cm)							202	178	268	15500
Total Dissolved Solids			500	7			155	200	1210	11500
Total Hardness			200	7			23	14	29	2040
MAJOR ANIONS										
Sulfate as SO_4^{2-}							10	13	22	702
Chloride			250	7	175-350	3	50.4	34.4	64.6	5300
Bicarbonate Alkalinity							14	26	6	92
Total Alkalinity							14	26	6	92
MAJOR CATIONS										
Calcium							2	<1	2	126
Magnesium							4	3	6	420
Sodium			180	7	115-230	3	29	15	39	2650
Potassium							<1	4	4	65
HEAVY METALS										
Arsenic	0.0023	2	0.007	6	0.1	4	<0.001	<0.001	<0.001	0.002
Cadmium	0.014	1	0.002	6	0.01	4	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.0486	1	0.05	6	0.1	4	<0.001	<0.001	<0.001	0.002
Copper	0.003	1	2.0	6	0.2	4	<0.001	<0.001	<0.001	0.001
Lead	0.0066	1	0.01	6	2.0	4	<0.001	<0.001	<0.001	<0.001
Nickel	0.2	1	0.02	6	0.2	4	<0.001	<0.001	<0.001	<0.001
Zinc	0.023	1	3.0	7	2.0	4	0.085	0.017	0.009	<0.005
Mercury	0.0007	1	0.001	6	0.002	4	<0.0001	<0.0001	<0.0001	<0.0001
NUTRIENTS										
Ammonia as N			0.5	7			0.212	0.545	0.303	0.934
Nitrite as N			3	6			<0.010	0.028	0.027	<0.010
Nitrate as N			50	6			0.034	<0.010	0.039	0.027
Nitrite + Nitrate as N							0.034	0.034	0.066	0.027
TKN					5.0	4	0.9	2.5	3	12.1
Total Phosphorus					0.05	5	0.14	1	0.76	1.38
Reactive Phosphorus							0.017	0.799	0.036	0.035

Concentration exceeds the respective ANZECC (2000) Marine Water Guideline for slightly to moderately disturbed systems

Concentration exceeds the respective human health guideline NHMRC (2004) for drinking water

5 Concentration exceeds the respective ANZECC (2000) Irrigation Water Guideline for moderately sensitive crops/long term use

1 ANZECC (2000) Marine Water Guidelines for protection of 90% of species in slightly to moderately disturbed systems

2 Low reliability trigger level

3 ANZECC (2000) Guidelines for irrigation - moderately sensitive crops

4 ANZECC (2000) Guidelines for irrigation - long-term trigger value

5 To minimise bioclogging of irrigation equipment only

6 Human Health Guidelines (NHMRC, 2004)

7 Aesthetic Guidelines (NHMRC, 2004)

- Not Analysed

TABLE 2 (CONT): SUMMARY OF LABORATORY RESULTS (mg/l unless otherwise stated)

SAMPLE ID	**ANZECC Marine (slightly to moderately disturbed system)**		**NHMRC Human Health Guidelines**		**ANZECC Irrigation and General Use (moderately sensitive crops)**		BORE 22	BORE 23	BORE 24	Lake
SAMPLE DATE							29/03/07	29/03/07	29/03/07	30/03/07
GENERAL PARAMETERS										
pH (pH Unit)			6.5-8.5	7			6.05	5.6	5.46	5.83
EC (µS/cm)							1610	234	2730	182
Total Dissolved Solids			500	7			1350	212	2250	129
Total Hardness			200	7			123	39	300	33
MAJOR ANIONS										
Sulfate as SO_4^{2-}							39	6	344	12
Chloride			250	7	175-350	3	430	58.7	800	37.4
Bicarbonate Alkalinity as $CaCO_3$							102	28	26	23
Total Alkalinity as $CaCO_3$							102	28	26	23
MAJOR CATIONS										
Calcium							11	3	31	8
Magnesium							23	7	54	3
Sodium			180	7	115-230	3	283	31	551	22
Potassium							7	1	24	2
HEAVY METALS										
Arsenic	0.0023	2	0.007	6	0.1	4	0.001	<0.001	0.006	<0.001
Cadmium	0.014	1	0.002	6	0.01	4	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.0486	1	0.05	6	0.1	4	0.007	<0.001	0.005	<0.001
Copper	0.003	1	2.0	6	0.2	4	<0.001	<0.001	0.001	0.005
Lead	0.0066	1	0.01	6	2.0	4	<0.001	<0.001	<0.001	<0.001
Nickel	0.2	1	0.02	6	0.2	4	<0.001	<0.001	0.003	0.001
Zinc	0.023	1	3.0	7	2.0	4	<0.005	0.008	0.016	0.029
Mercury	0.0007	1	0.001	6	0.002	4	<0.0001	<0.0001	<0.0001	<0.0001
NUTRIENTS										
Ammonia as N			0.5	7			0.655	0.179	0.893	<0.010
Nitrite as N			3	6			0.087	<0.010	0.013	<0.010
Nitrate as N			50	6			<0.010	0.013	0.013	0.02
Nitrite + Nitrate as N							0.037	0.013	0.026	0.02
TKN					5.0	4	7.2	2.5	9.3	0.7
Total Phosphorus					0.05	5	0.79	0.32	1.12	0.08
Reactive Phosphorus							0.095	-	0.062	<0.010

Concentration exceeds the respective ANZECC (2000) Marine Water Guideline for slightly to moderately disturbed systems

Concentration exceeds the respective human health guideline NHMRC (2004) for drinking water

5 Concentration exceeds the respective ANZECC (2000) Irrigation Water Guideline for moderately sensitive crops/long term use

1 ANZECC (2000) Marine Water Guidelines for protection of 90% of species in slightly to moderately disturbed systems

2 Low reliability trigger level

3 ANZECC (2000) Guidelines for irrigation - moderately sensitive crops

4 ANZECC (2000) Guidelines for irrigation - long-term trigger value

5 To minimise bioclogging of irrigation equipment only

6 Human Health Guidelines (NHMRC, 2004)

7 Aesthetic Guidelines (NHMRC, 2004)

- Not Analysed

The results indicate that:

- Groundwater chemistry has not changed significantly since the previous monitoring round in 2004 (Ref: E12752/3-AF). The 2004 report indicated that groundwater chemistry had not changed significantly since the groundwater quality monitoring undertaken in 1994/1995. A comparison table showing the 2004 and 2007 results is presented Table LR2 in Appendix A.
- The results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations.
- Evidence of significant heavy metal contamination in the groundwater samples was not observed however the concentrations of zinc, chromium and copper slightly exceed the guidelines in some samples.
- Groundwater from monitoring bores closer to the Myall River tend to be characterised by higher EC and a similar anion to cation ratio as seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.
- Groundwater quality was compared to the Australian Drinking Water Guidelines (NHMRC, 2004) and is not potable due to concentrations of a range of analytes exceeding the drinking water guidelines. Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) that do not meet the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC guidelines.
- Groundwater away from the Myall River may be considered for irrigation purposes, however high concentrations of phosphorus have the potential to result in bioclogging of irrigation equipment (ANZECC 2000).

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

Major cation and anion analytical results for the groundwater samples were plotted on a Piper Trilinear Diagram (Figure 3). The Piper diagram provides a visual method of assessing the relative proportion of the major ions in the groundwater. The positions of the sample points in the diamond field facilitate interpretation of water types relative to one another.

The Piper Diagram indicates that all the groundwater samples are characterised by sodium chloride type waters with lesser concentrations of magnesium and alkalinity. There is little variability in the relative proportion of the major ions, indicating a similar source of groundwater across the site. The water from the lake shows a slightly higher concentration of calcium and alkalinity than the groundwater at the site.

Figure 4 shows the sodium/chloride ratio in the groundwater and pond water samples relative to the seawater dilution line. All samples generally plot along the seawater dilution line indicating an atmospheric source of salt in locations further away from the Myall River and interaction with seawater as the source of salt in the bores closer to the River.

A Wilcox Diagram can be used to classify water for its suitability for irrigation by plotting the sodium adsorption ratio (SAR) of samples against their EC value. Figure 5 shows a Wilcox Diagram for groundwater at the site. Groundwater in the majority of bores away from the Myall River (Bores 4A, 12 and 23) show low salinity and sodicity hazard, suggesting these waters are suitable for irrigation purposes. However, it should be noted that the water in the lake is influenced by the tide and salinity will vary with time depending on the amount of rainfall recharge to the lake both directly as rainfall and via groundwater discharge into the lake. Bore 9, to the north of the detention basin, shows a high salinity hazard but a low sodicity hazard. This water may suitable under specific conditions including salt tolerance of the vegetation and permeability and drainage of the soil. Groundwater from bores close to the Myall River (Bores 22 and 24) show a high salinity hazard and high sodicity hazard, indicating water from these locations would be unsuitable for irrigation.

Table 3 shows the various potential uses of groundwater in each bore. The results indicate that it is generally select parameters, namely pH, ammonia and salinity (or TDS) that are limiting the potential use of the groundwater rather than a wide range of parameters. Consequently, some treatment of groundwater with respect to these parameters is likely to increase the number of potential uses of the groundwater across the Site. It is also noted that groundwater away from the Myall River tends to have greater potential usability, primarily due to lower salinity (or TDS) and lower concentrations of sodium and chloride.

TABLE 3: POTENITAL USES OF GROUNDWATER

	Bore 4A	**Bore 9**	**Bore 12**	**Bore 21**	**Bore 22**	**Bore 23**	**Bore 24**	**Pond**	**Comments**
Maintenance of Ecosystem	× due to zinc	✓	✓	✓	✓	✓	× due to arsenic	× due to copper and zinc	
Drinking water supply	×	×	×	×	×	×	×	×	Due to low pH and high concentrations of TDS, Na, Cl and / or NH_3
Irrigation, parks, gardens	✓	✓	✓	× due to NO_3, Na and Cl	× due to Na and Cl	✓	× due to NO_3, Na and Cl	× variable quality	Bioclogging of irrigation equipment due to high P may occur
Stock watering	✓	✓	✓	× due to TDS	✓	✓	× due to TDS	✓	
Primary* recreation contact	× due to NH_3	× due to pH and NH_3	× due to NH_3	× due to NH_3 and hardness	× due to NH_3	× due to NH_3	× due to NH_3	✓	

NO_3: nitrate; Na: sodium; Cl: chloride; NH_3: ammonia; TDS: total dissolved solids; P: phosphorus

** Concentrations of Na and Cl were detected above the water quality guidelines for recreational purposes, however these concentrations are due to groundwater interaction with seawater and are not considered to limit the use of groundwater for recreational purposes.*

Based on the assessment described above and set out in Table 3, the highest beneficial uses for groundwater in some locations are for irrigation and ecosystem maintenance.

7 ASSESSMENT OF THE POTENTIAL FOR USING RECLAIMED WATER FOR IRRIGATION

It is understood that there is the potential to use reclaimed water from a nearby water treatment plant to irrigate open spaces (parks, gardens, lawns etc) at the site. Many water needs can be satisfied using reclaimed recycled water as long as it is adequately treated to ensure water quality is appropriate for the proposed use (NSW DEC, 2004).

For the purposes of this report, effluent is considered to be wastewater from the collection or treatment systems associated with sewerage works, processing industries (livestock, wood, paper or food), intensive livestock, aquaculture or agricultural industries.

In assessing the suitability of waters for irrigation use, water quality characteristics that affect the catchment condition and downstream water quality must be considered. The water quality guidelines recommended for irrigation purposes are listed in the *Environmental Guidelines: Use of Effluent by Irrigation* (NSW DEC, 2004) and ANZECC (2000). A summary table of relevant water quality characteristics is presented as part of Table LR1 in Appendix A. Environmental performance objectives that apply to the use of reclaimed water by irrigation include the protection of surface waters, groundwater and lands and public health risk.

Nutrients

Nutrients in effluent such as nitrogen, phosphorus and sulfur are generally beneficial to plant growth and may reduce the need for fertiliser application. Nitrogen, phosphorus and sulfur need not be removed from effluent where it can be shown that the land management system effectively uses these nutrients both in the short and long term.

Nitrogen

Nitrogen (N) can be present in organic and mineral forms, including ammonia (NH_3) ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-). The relative amount of each of these forms depends on the original constitution of the wastewater, and the treatment and stabilisation processes used.

Mineral forms of nitrogen are readily transformed into other mineral forms. Some mineral forms such as nitrate, nitrite and ammonia can be taken up by plants. Nitrate is also readily leached to groundwater. High concentrations of nitrate can nourish unwanted plants and algae.

Phosphorus

Phosphorus (P) concentrations in municipal sewage plants are between 0.5 and 10 mg/L depending on the extent of P removal processes used. Phosphorus contained in effluent exists in many forms but is normally expressed as total P.

The major P removal mechanisms in effluent irrigation systems are uptake by vegetation, and soil sorption by chemical precipitation and adsorption to soil particles. Soil sorption of P (P sorption capacity) is an immobilisation reaction that renders phosphorus unavailable for plant uptake and varies widely from low levels in sandy soils to high levels in strongly weathered clay soils. Soil sorption capacity can be taken into account when developing a nutrient budget for soils irrigated with reclaimed water.

Most Australian soils have the capacity to immobilise phosphorus (P) in soil thereby making it unavailable for plant growth, however this capacity can vary with depth. In general, sandy soils have a very low sorption capacity. If the effluent has a higher P content than can be absorbed by the growing plant, then it will be necessary to estimate the P sorption capacity of the soil to determine the risk of P leaving the irrigated site during the life of the irrigation scheme thereby potentially contaminating ground and surface waters. The form of P in the effluent and the pH of the soil may also affect the mobility of P in soil.

Table 4 shows the range of potential P sorption capacities measured from sandy Sydney Basin soils and coastal soils. Table 4 indicates that sandy soils from coastal dune systems have a low capacity for P adsorption, suggesting that there may be more P applied during irrigation with reclaimed water than can be removed by soil adsorption and crop uptake. In this situation, assessments of P sorption capacity should be made. If application of P exceeds this threshold, both runoff and leaching of phosphorus to surface and groundwater may occur.

TABLE 4: PHOSPHORUS ADSORPTION POTENTIAL OF NSW SOILS (1M DEPTH)

Location	Soil parent material	Soil classification	Total P sorption capacity(kg/ha)	P sorption capacity (critical) (kg/ha)
Sydney Basin	Hawkesbury sandstone	Soloth	5,440	2,700
Sydney Basin	Hawkesbury sandstone	yellow earth	13,600	4,600
Coastal	Sand dune	Siliceous sand	25-130	25-36

7.1 Groundwater

When using reclaimed water to irrigate open spaces, the quality of the underlying groundwater must not be downgraded to the extent that the resource is not able to support its most sensitive beneficial use (NSW DEC, 2004). With regard to the groundwater results from the current monitoring round, the most sensitive beneficial use of the groundwater is for irrigation purposes and maintenance of ecosystems in selected locations (see Table 3).

Where supporting technical advice has not been obtained, effluent should not be applied to land where the depth to groundwater table is considered to be less than 10 metres or where the irrigation area is located less than 1000 metres from a town water supply bore. Water quality objectives for the groundwater (i.e. water quality needed to protect beneficial uses of groundwater) should also be considered (NSW DEC, 2004). It is noted that groundwater was shallower than 10m across the site during the previous and current monitoring rounds.

7.2 Surface water

The quality of streams and rivers in the catchment of an effluent irrigation scheme must not be downgraded (i.e. relevant water quality objectives need to be taken into account). There is a risk that surface waters may be degraded by poorly designed or managed effluent irrigation schemes, particularly where effluent with high quantities of nutrients, salt, pathogens or other contaminants is being irrigated. Potential impacts on current and future downstream water users and resources need to be considered, for example, wetlands that may be located downstream (NSW DEC, 2004).

7.3 Reclaimed Water Quality

A sample of the reclaimed water was not available to undertake testing of the soil, however, Mid Coast Water provided Coffey with data showing average water quality of treated water from a treatment plant. Coffey understands that the water quality information provided is indicative of the reclaimed water that may be used for irrigation of open spaces and gardens in the Riverside development. Table 5 shows an indicative concentration of the reclaimed water that may be used for irrigation purposes compared to the ANZECC Guidelines for irrigation and the protection of marine ecosystems.

TABLE 5: WATER QUALITY OF RECLAIMED WATER

Parameter	Indicative Concentration (mg/L)	ANZECC Guidelines for Irrigation (long term use) (mg/L)	ANZECC Guidelines for marine ecosystems (90% protection) (mg/L)
pH	6.8	4.5-9.0	-
Total Phosphorus	2.2	0.05*	-
Nitrogen (Ammonia)	1	-	1,200
Nitrogen (Nitrate)	5	-	0.7^
Total Nitrogen	6.4	5	-

* for bio-clogging of irrigation equipment only
^ low reliability trigger value
- no guidelines available

Indicative ammonia concentration in the reclaimed water is 1mg/L, well within the ANZECC guidelines for the protection of marine ecosystems. There are no guidelines for ammonia concentrations in irrigation water. The concentration of ammonia in groundwater is generally low as it adsorbs to soil particles and is not readily leached from soils. Consequently, the concentrations of ammonia in the reclaimed water are unlikely to pose any constraints on using the water for irrigation purposes.

The indicative concentration of nitrate in reclaimed water is 5mg/L and total nitrogen 6.4mg/L (Table 6). Nitrate, the dominant form of nitrate in the reclaimed water, is soluble in water and can move freely through the soil to the water table in recharge derived from irrigation water. The concentration of nitrogen marginally exceeds the ANZECC Guidelines for long-term irrigation (up to 100 years), however is significantly lower than the nitrogen concentrations for short term use (up to 20 years) of 25-125mg/L. It should be noted that a site assessment should be undertaken before using the guidelines for short-term irrigation.

The indicative concentration of total phosphorus in the reclaimed water is 2.2mg/L. Compared with nitrate, phosphate is less mobile in soil-water and groundwater and tends to bind to soil particles. However, if the soil becomes saturated with phosphate there is a chance of phosphate reaching groundwater. As the soils at the site are highly sandy, the phosphorus adsorption capacity is likely to be low, in the range of 25-36kg/ha (see Table 4). The ANZECC guidelines for irrigation indicate a trigger value of 0.05mg/L for phosphorus, however this is with respect to bio-clogging of irrigation equipment. The ANZECC guidelines (2000) recommend total phosphorus concentrations for freshwater lakes and reservoirs to be below 0.01mg/L and 0.025mg/L for NSW east flowing coastal rivers. It is recognised that the lake is likely to show tidal influence, so that criteria for coastal rivers is considered more appropriate. Indicative phosphorus concentration recorded in testing of groundwater quality sampled from the bores in April 2007 range from 0.14 mg/L to 1.38mg/L. There are no guidelines for phosphorus for the protection of marine ecosystems.

A NATA-accredited laboratory was commissioned to develop a water sample with similar concentrations of nitrate, phosphorus and pH to those anticipated for reclaimed water from treatment facilities in the area. This water was then used as a leaching agent for three soil samples collected from the site. Leachate tests were undertaken in accordance with the Australian Standard Leaching Procedure (ASLP) method, using the laboratory- produced reclaimed water as the leaching agent. Table 6 shows the concentrations of the lab-produced reclaimed water and the concentrations of anaytes in the leachate water.

TABLE 6: LEACHATE WATER QUALITY USING MANUFACTURED RECLAIMED WATER

Parameter	Manufactured reclaimed water	HA01 Topsoil 0-0.1m	HA01 Subsoil 0.4-0.5m	HA02 Topsoil 0-0.1m	HA02 Subsoil 0.4-0.5m	HA03 Topsoil - 0.1m	HA03 Subsoil 0.4-0.5m
pH	6.6	5.4	5.3	4.9	5.6	5.3	5.0
Total Phosphorus (mg/L)	2.5	ND	0.8	ND	0.5	ND	ND
Nitrate (mg/L)	4.7	5.0	4.8	5.3	5.0	4.6	4.6

ND: Not detected, detection limit 0.1mg/L

The concentration of nitrate in the leachate water from all samples is similar or greater than the concentration of nitrate in the lab-produced reclaimed water (4.7mg/L). This indicates that the potential for nitrate adsorption on the soil is low and the travel time of nitrate through the soil is likely to be similar to the rate of water through the soil.

The concentration of phosphorus in the leachate water is consistently significantly below the concentration of phosphorus in the lab-produced reclaimed water. Phosphorus was not detected in any of the topsoil samples and one of the subsoil samples after the leaching procedure and at low concentrations in the remaining two of the subsoil samples. These results indicate the soil at the site has the capacity to adsorb phosphorus present in reclaimed water and that the travel time of phosphorus through the soil is very slow. These initial results show that with respect to phosphorus, reclaimed water may be used for irrigation purposes. However, Coffey recommend further testing when samples of reclaimed water proposed for irrigation use are available.

The groundwater results suggest that the reclaimed water may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of reclaimed water with water of higher quality.

The concentration of pathogens is also an important effluent quality consideration in terms of public health, which affects the way effluent should be reused and managed on-site. Treatment would need to occur as required to meet relevant health standards.

8 NUMERICAL MODELLING OF GROUNDWATER IMPACTS

The Riverside development lies in an area with a shallow groundwater table that has the potential to be impacted by the proposed changes to the development. A groundwater model was established using MODFLOW, a finite difference groundwater simulation program, during the 2004 monitoring period, based on the level of understanding of the hydrogeological conditions in the vicinity of the site at that time. Following calibration against measured groundwater levels, the model was used to predict groundwater level conditions for the proposed development to assist in the assessment of potential groundwater impacts of the proposed development.

The model was adapted to incorporate changes to the development and was carried out under steady state conditions with a view to assessment of groundwater levels under typical rainfall conditions.

8.1 Model Establishment

The groundwater model was set up using MODFLOW, a finite difference groundwater simulation program. The MODFLOW program was developed by the US Geological Survey and is widely used for groundwater analysis. A steady state model was prepared to represent average conditions across the site.

A finite difference grid was set up to model groundwater behaviour in the Riverside area leading out to Myall River. The following assumptions and modelling choices were made in establishing the model:

- The base grid size of 50m x 50m was maintained. This was considered sufficiently fine to provide a reasonable representation of the site and the layout of the proposed development. The lake areas within the development were refined to a grid size of 25m x 50m. The extent of the model domain is presented in Figure 9.
- Constant head conditions were adopted along the eastern, southern and western boundaries (representing Myall River, Pindimar Bay and Kore Kore Creek, respectively). The constant head boundaries were set to be 0.045mAHD, consistent with the average water level in the Myall River adjacent to the development. A no flow boundary following a surface water divide was adopted along the northern boundary of the model.
- The model was established in one layer, from surface levels to bedrock.
- Given the consistent surface conditions across the site, a uniform net rate of groundwater infiltration from rainfall was adopted over more of the site. The exception to this is a small area in the north western corner of the site where bedrock outcrops. As rainfall recharge will be very limited in this area, the rate of groundwater infiltration from rainfall was much reduced.
- A uniform net rate of evapotranspiration was adopted across the site – This was considered reasonable given the proximity of the water table to the ground surface. Evaporation was assumed to occur when the water table approaches the ground surface and was assumed to reduce with depth to zero at a depth of 2m. This assumption was based on a study which assessed the change in the rate of groundwater decline with depth to the water table during periods of low rainfall from the monitoring data from Bore 4 (Coffey, 1996).
- Sand aquifer conditions were considered uniform within the model domain. The depth to bedrock varies across the site from outcrops of rock at the ground surface to depths of approximately 17m below ground surface. Previous field investigations have been undertaken

across the site down to bedrock levels. The assumed bedrock contours and depths to rock are adopted are shown on Figure 10.

- Ground surface levels were based on the Port Stephens 1:25000 topographic map and survey data from Tattersals, and are shown in Figure 11.
- The aquifer was modelled as having a specific storage of 0.00001m^{-1}, a specific yield of 0.1, an effective porosity of 0.2 and a total porosity of 0.35 – These values are considered to be typical values for a sandy aquifer.
- The water level at the lake was set at 0.64mAHD, as advised by Cardno. The lake was modelled as a highly permeable layer, with a permeability of 200000m/day to represent uniform head levels within the lake.
- Changes to original model include extension of constant head cells in north-western extent of model to enable a more effective contouring of groundwater levels in this area.

8.2 Model Calibration

The groundwater model was previously calibrated during the 2004 monitoring round by testing a range of values of permeability, evapotranspiration rate and infiltration (recharge) rate. These parameters are considered to have the highest level of uncertainty. The calibration of the model is discussed in Coffey's previous report (Ref: E12752/3-AF). Details of calibration results are provided in Appendix C.

During the calibration trials, a steady state calibration in reasonable agreement with measured groundwater levels was obtained (predevelopment conditions). The groundwater level contours for modelled conditions under present conditions are shown in Figure 12. Table 7 presents a comparison of groundwater levels obtained for the calibration analysis compared with the range of measured groundwater levels at the observation wells.

Minor disagreements with recent monitored groundwater levels and modelled results were present in observation wells (Bores 9, 11 and 12) in the northern parts of the site, with the largest disagreement of about 0.5m between the calibrated level and the measured level at Bore 9. It is considered that these minor disagreements may be contributed to localised (shallow rock) or seasonal conditions and/or limitations of the model. Given that the modelled groundwater levels agreed with the measured levels at the key locations (Bores 5, 10, 11), it is considered that, overall the model has been successfully calibrated for the development area.

TABLE 7 – COMPARISON OF CALIBRATED GROUNDWATER LEVELS WITH OBSERVATIONS

Observation Well	Measured Range of Groundwater Levels (mAHD) – April/May 2004	Calibrated Groundwater Level (mAHD)	Average Groundwater Levels (mAHD) – April/May 2004	Groundwater Levels (mAHD) – April 2007	Comments on the Calibrated Level vs Measured Range
BORE 3	0.18 to 0.29	0.34	0.23	Bore not found	NA
BORE 4	0.66 to 0.87	0.97	0.76	0.823	Slightly lower, but within ±0.5m
BORE 5	1.55 to 2.14	1.81	1.85	1.303	Slightly lower, but within ±0.5m
BORE 6	0.34	0.42	~0.30	Bore not found	NA
BORE 7	2.03 to 2.77	2.91	2.40	Bore not found	NA
BORE 8	1.79 to 2.33	1.61	2.06	1.534	Slightly lower, but within ±0.5m
BORE 9	1.78 to 2.01	1.21	1.89	1.657	Slightly higher, but within ±0.5m
BORE 10	0.78 to 1.04	0.87	0.91	0.541	Slightly lower, but within ±0.5m
BORE 11	1.94 to 2.57	1.94	2.25	1.689	Slightly lower, but within ±0.5m
BORE 12	2.08 to 2.66	1.85	2.37	1.655	Slightly lower, but within ±0.5m

The modelled groundwater level contours show that groundwater flows across the site in a south-easterly direction towards Myall River. In general, groundwater levels from recent monitoring round were lower than those used to calibrate the groundwater model. However, water levels from recent monitoring are all within 0.5 m of calibrated values and the model is estimated to be representative of the groundwater system. The adopted model parameters following calibration trials are summarised in Table 8.

TABLE 8 – ADOPTED MODEL PARAMETERS – CALIBRATED MODEL

Parameter	Adopted Value	Source / Comment
Aquifer permeability	Horizontal permeability = 8m/day Vertical Permeability = 8m/day	Consistent with results reported by DJ Douglas & Partners (1994b). Typical value for relatively clean sand.
Rainfall infiltration (recharge) rate for general sandy area	2.0mm/day	Consistent with the calibrated value of the previous model established by Coffey Partners International (1996), i.e. approximate 60% of average rainfall. Consistent with sandy soil in an undeveloped environment.
Rainfall infiltration (recharge) rate for the clayey area in the north-western part of site	0.5mm/day	Typical permeability and recharge value for clayey soil. Comparable with the value adopted (0.2mm/day) in the Coffey Partners International (1996) model. Groundwater level contours are not sensitive to the value adopted.
Evapotranspiration rate	2.5mm/day	Approximately 50% of the pan evaporation rates from Williamtown weather station.

Site groundwater recharge may contain a proportion of hillslope runoff on the northern boundary of the model domain where exposed bedrock forms the model boundary however insufficient data were available to reliably assess the amount contributed from that source. For the purposes of this assessment, groundwater recharge from infiltration was taken as being uniformly distributed. Impacts calculated from predictive modelling will be conservatively high because any contribution from hillslope runoff was distributed over the model domain rather than application of this runoff at the northern extremities of the sand aquifer (and therefore comprised to minimal extent by development).

8.3 Assessment of Groundwater Levels of Post Development

Following the calibration, groundwater modelling was carried out to assess the impacts of the proposed development on the groundwater system. Typical conditions were modelled using steady state analysis.

A total of seven schemes were initially investigated in the Riverside Master plan for the proposed development. The current development is a development of Scheme 5. Scheme 5 involves a partial extension of the existing lake to 8 ha and a series of freshwater lakes covering approximately 6.5 ha. The extended lake would be approximately double the size of the existing lake, covering approximately 14.5ha. The proposed development would also include construction of a series of single dwelling residential housing and open space recreational areas (including some isolated small ponds).

Under post development conditions for the current proposal the following assumptions were made for the modelling:

- The water level of the extended lake will remain the same at 0.64mAHD;

- Rainfall infiltration (and recharge) and evapotranspiration rates will remain the same, including the proposed housing and open space recreational area;
- Small ponds of the open space recreational areas are considered insignificant to the overall hydrogeological impacts; and
- General ground surface levels will not be dramatically altered.

Figure 13 presents modelled post-development (extended lake) groundwater levels for typical conditions. Figure 14 shows the modelled reduction in groundwater level associated with the extended lake only proposed development. The modelled results are summarised as follows:

- Under typical conditions, modelled post-development groundwater levels in the northern, eastern and southern parts of the site are similar to those for pre-development (Figure 12).
- Groundwater levels to the north of the existing lake will be lowered by up to about 0.75 m due to the extension of the lake. The effects of the lake are especially visible within the area surrounding the North West extension of the lake.
- Groundwater flow will be induced towards the lake extension due to a change in groundwater gradients in the vicinity of the lake extension.
- Groundwater levels along the SEPP 14 wetlands are assessed to be similar to the existing levels, with a small decrease in groundwater level (approximately less than 0.1m drawdown) on the western edge of the SEPP 14 wetland area.
- Groundwater generally flows in a south easterly direction. However groundwater to the west and north of the extended lake will tend to flow towards the extended lake. As a result, general groundwater flow directions in the area will change slightly and a higher volume of groundwater will be discharged into the lake.

The modelled results are generally comparable with the modelled results presented in Coffey Partners International (1996).

8.4 Flow Budgets

Flow budgets were conducted for the areas representing the proposed subdivision to the north of the lake and the area which encompasses the existing and extend lake. This enabled mass balance calculations to be conducted for the purpose of estimating return of nutrients of potential irrigation of treated water. Table 9 lists the flow budgets for the zones as indicated in Figure 15. The flow budget was calculated with errors of less than 0.01%.

Zone 1 (Z1) encompasses the majority of the model domain with Zone 2 (Z2) occupying the area in which additional development is planned to occur. Zone 3 (Z3) represents the area of the existing lake and the planned lake extension.

TABLE 9: FLOW BUDGETS FOR THE STEADY STATE MODEL

Budget Component	**Average Daily Flow Rate (ML/day)**	
	IN	**OUT**

Ponds			
	Rainfall Recharge	1.31	
	Evapotranspiration		0.66
Z1 to Z3	Baseflow In	0.62	
Z2 to Z3	Baseflow In	0.23	
Z3 to Z1	Baseflow Out		0.55
New Development Area (irrigated)			
Z1 to Z2	Baseflow In	0.08	
Z2 to Z1	Baseflow Out		0.06
Z2 to Z3	Baseflow Out	0.23	
	Rainfall Recharge	0.52	
	Evapotranspiration		0.30
Rest of Model Domain			
	Baseflow In	17.93	
	Baseflow Out		17.93
	Rainfall Recharge	17.2	
	Evapotranspiration		15.55

8.5 Geometry of the Freshwater / Saline Water Mixing Zone

As part of the proposed development, the existing lake is to be extended on the western side and there is also the introduction of a series of stepped freshwater lakes on the eastern side. Much of the site runoff will flow to this lake. The lake is hydraulically linked to the Myall River by a drain. The invert level of this drain is at approximately 0.64 mAHD. During high tide (tidal water levels above 0.64 mAHD), saline water from the Myall River flows through the drain and the adjacent low lying area to the lake. At other times, the lake either discharges by surface flow back through the drain (while lake water levels are above 0.64mAHD) or by groundwater flow generally towards the river. Cardno have previously advised that the water level in the lake generally fluctuates around an average elevation of approximately 0.64 mAHD.

The lake accepts groundwater flow from up gradient parts of the aquifer, and also accepts surface water runoff and saline water from the river. The 50 percentile concentration of total dissolved solids for lake water is 12,800 mg/L (Cardno 2007) and given the input of river water, is brackish. A concentration of 20,000 mg/L was used in this analysis. The periodic tidal action will create a fluctuating water table

at the lake edge which will create a typical saltwater / freshwater mixing zone observed in coastal systems.

To assess the geometry of the saltwater / freshwater interface that will be created by the presence of the lake, a simple species transport simulation was conducted for a cross-section through the lake representing the general hydrogeological conditions to the west of the lake. The simulation assumes the following:

- Long-term steady state hydrogeological conditions immediately west of the lake;
- No groundwater extraction;
- Average concentration of total dissolved solids (TDS) for lake water is 20,000mg/L (about 60% of the average TDS of seawater, to incorporate mixing with water from fresher water sources). This concentration was chosen to provide a conservative basis for assessment. Measured lake water quality is typically of much lower salinity;
- Average TDS concentration in groundwater is 240mg/L (average of results for seven groundwater samples analysed in 2004);
- Average TDS concentration in rainwater is 10mg/L;
- Instantaneous and complete mixing of fresh and salt water in the lake;
- Maximum tidal height of 0.8mAHD, based on the average tidal range at Fort Denison in Sydney;
- Calibrated aquifer parameters, with a rainfall recharge rate of 1mm/day;
- Dispersivity of 0.001m for TDS over a time period of 6 hours.

Results of the simulation are shown in Figure 18. The concentration contours are a general indicator of typical conditions which may arise based on the above assumptions. The contours also incorporate a simple Ghyben-Herzberg analysis (Ghyben, 1889; Herzberg, 1901) (assuming a TDS concentration of 20,000mg/L for the lake) to account for density-driven flow. The interpreted contours are therefore an assessment of the potential geometry of the long-term saltwater/freshwater interface that may be created by the lake. The contours assume no groundwater abstraction.

Interpreted contours indicate that pre-development aquifer conditions are probably maintained at a distance of 100m from the lake edge. If groundwater abstraction takes place, this will draw the contours away from the lake edge. As this assessment has used a high salinity concentration (20,000 mg/L), the actual scenario is expected to be more conservative.

8.6 Acid Sulfate Soil

An assessment of potential acid sulfate soils was undertaken at the site (Coffey 2007 GEOTSGTE20248AA-AE). The laboratory results indicated elevated levels of total potential sulfidic acidity and peroxide oxidisable sulfur were present in the samples tested. It was considered that the potential acid sulfate soils were likely to be present in the area.

Groundwater modelling indicates that the lake extension will cause groundwater level reductions by approximately up to 0.75. To date there is no indication of the potential for sulfate production in the area but a number of bores were drilled within close proximity of the lake extension. Several test holes were

drilled and the soils tested for the potential to produce acid sulfate soils. BH37 is located in the area where the maximum drawdown has been predicted and the results of SPOCAS analysis indicate that from 2 m below surface, samples tested exceed the Acid Sulfate Soil Management Advisory Committee (ASSMAC) action criteria. The potential to produce acid soils increased with depth with the interval 2.0 – 2.5 m just exceeding the criteria.

Groundwater levels in this area are approximately 1.5 m below surface and a 0.75 m groundwater level decline will lower groundwater levels into this zone however, the area affected would be restricted to the 0.75 m drawdown contour indicated in Figure 14.

A comparison of pH from previous investigations conducted in April 2004 with recent results collected in March 2007 indicates that there has been no discernable change in groundwater pH. This suggests that even with the groundwater level reductions assessed to be affected by lower than average rainfalls in the last few years, there has been no additional increase in acid production resulting from the drying of acid producing soils.

9 DISCUSSION

9.1 Groundwater Levels and Flow Directions

The results from the current monitoring round indicate groundwater levels have decreased across the majority of the site since 2004, when development at the site commenced. The decrease in groundwater levels has been in the order of 0.1mAHD to 0.2mAHD in the majority of wells and a maximum of 0.47mAHD. Groundwater levels respond to prevailing climatic conditions and the decrease in groundwater levels experienced are likely to be the result from lower than average rainfall which has occurred on the mid central coast of NSW in recent years.

Groundwater modelling indicates that groundwater level contours are altered in the vicinity of the lake extension with the greatest impact at the north-western most point of the proposed lake extension. This will induce groundwater flow towards the lake within the vicinity of the lake which will act to prevent the intrusion of saline water into the aquifer from Myall River and brackish water from the lake.

The enclosed nature of the groundwater system within the localised riverside area limits the potential impacts on other groundwater users further afield.

9.2 Groundwater Quality

Laboratory results from the groundwater bores selected for analysis indicate that groundwater quality has not changed significantly since the last monitoring round in 2004. The results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC guidelines, with the exception of some metal concentrations. Groundwater from monitoring bores closer to the Myall River tend to be characterised by higher EC and a similar anion to cation ratio as seawater, suggesting the dilution of seawater is occurring as a result of rainfall recharge from the catchment.

All groundwater samples are characterised by sodium chloride type waters with lesser concentrations of magnesium and alkalinity. There is little variability in the relative proportion of the major ions, indicating a similar source of groundwater across the site.

9.3 Groundwater Modelling

Groundwater modelling of post-development with an extended lake indicates that groundwater levels for typical conditions in the northern, eastern and southern parts of the site are similar to those for pre-development. Groundwater levels to the north of the existing lake will be lowered by up to about 0.75 m due to the extension of the lake. The effects of the lake are especially visible within the area surrounding the North West extension of the lake. Groundwater to the west and north of the extended lake will tend to flow towards the extended lake. As a result, general groundwater flow directions in the area will change slightly and a higher volume of groundwater will be discharged into the lake.

Groundwater levels along the SEPP 14 wetlands are assessed to be similar to the existing levels, with a marginal decrease in groundwater levels (less than 0.1m drawdown) on the western edge of the SEPP 14 wetland area.

9.4 Geometry of the Freshwater / Saline Water Interface

Interpreted contours indicate that pre-development aquifer conditions are probably maintained at a distance of less than 100m from the lake edge which is well within the riverside concept plan and project site. If groundwater abstraction takes place, this would draw the contours away from the lake edge.

10 CONCLUSIONS

10.1 Groundwater Levels

Influence of the Lake Extension

The results of the groundwater modelling study for the proposed Riverside development site are presented. The results indicate that there will be negligible impacts to the wet land area and groundwater decline will be limited to a fall of approximately 0.75 m in the vicinity of the lake extension.

The lake extension will cause groundwater level to fall slightly below levels interpreted to have acid soil producing potential. However, the area affected is considered to be limited and the exceedance of criteria of ASSMAC slight for the predicted resulting groundwater levels.

On the basis of these results, Coffey does not consider that the proposed extension of the lake would adversely affect site groundwater outside the proposed lake extension.

10.2 Groundwater Quality and Impact of Development on Potential Future Use as a Potable Water Source

Groundwater quality is not considered to be potable due to concentrations of a range of analytes exceeding the drinking water guidelines (ANZECC 2000). Groundwater in all bores and the surface water in the lake are acidic to slightly acidic and below the criteria for drinking water of pH 6.5. Groundwater near the Myall River (including Bores 21, 22, 24) has elevated levels of EC, anions and cations (due to the interaction of groundwater with seawater in this area) above the criteria for drinking water. Groundwater in Bores 9, 21, 22 and 24 are not potable due to the concentration of ammonia exceeding the ANZECC (2000) guidelines.

The groundwater results indicate that it is generally select parameters, namely pH, ammonia and salinity (or TDS) that are limiting the potential use of the groundwater rather than a wide range of

parameters. Consequently, some treatment of groundwater with respect to these parameters is likely to increase the potential uses of the groundwater across the Site. It is also noted that groundwater away from the Myall River tends to have greater potential usability, primarily due to lower salinity (or TDS) and lower concentrations of sodium and chloride.

Groundwater quality is such that treatment would be required to allow potable use given the limited extent of the aquifer and the constraints on usage rates which would need to be imposed to avoid saltwater intrusion and the impacts on wetland areas. Consequently, Coffey consider the groundwater resource unsuitable for development as a significant potable supply.

10.3 Groundwater Quality and Impact of Development on Adjacent Ecosystems

Groundwater quality results are generally below the key criteria for protection of species in marine water (90% protection) presented in the ANZECC (2000) guidelines, with the exception of some metal concentrations. Groundwater quality modelling indicates that the salt water interface would not be significantly affected by the development and groundwater level modelling indicates that there will be little impact within the wetland area. Groundwater level changes resulting from the proposed development are assessed to be below 0.25 m beyond 300 m from the development and 0.1 m within the wetland area. Changes of this magnitude would be within the existing groundwater level variability and are therefore considered unlikely to adversely affect adjacent ecosystems.

10.4 Re-use of reclaimed water

A laboratory developed a water sample with similar concentrations of nitrate, phosphorus and pH to the reclaimed water data supplied by Mid Coast Water. This water was used as a leaching agent for three soil samples collected from the site.

The concentration of nitrate in the leachate water was similar or greater than the concentration of nitrate in the lab-produced reclaimed water. This indicates that the potential for nitrate adsorption on the soil is low and the travel time of nitrate through the soil is likely to be similar to the rate of water through the soil.

The concentration of phosphorus in the leachate water was consistently significantly below the concentration of phosphorus in the lab-produced reclaimed water. These results indicate the soil at the site has the capacity to adsorb the phosphorus present in the reclaimed water and that the travel time of phosphorus through the soil is very slow.

These initial results show that with respect to phosphorus, the reclaimed water may be used for irrigation purposes. However, Coffey recommend further testing when a sample of reclaimed water from Mid-Coast Water is available. Table 10 provides groundwater quality and indicative concentration parameters for key chemical constituents.

The groundwater results from the current monitoring round suggest that the reclaimed water may be suitable for irrigation of open spaces and gardens within the development area subject to a small reduction in total nitrogen concentrations. This reduction may be achieved through a combination of treatment and dilution of the reclaimed water with water of higher quality.

TABLE 10: GROUNDWATER QUALITY AND INDICATIVE CONCENTRATION FOR KEY CHEMICAL CONSTITUENTS

Parameter	Average in Groundwater (mg/L)	ANZECC guidelines (mg/L)	Indicative conc. from STP (mg/L)
Nitrate	0.02	0.7	5
Ammonia	0.53	1200	1
Total Phosphorus	0.79	0.05	2.2

Based on the signature of key chemical constituents present above, three re-use options are presented as possible scenarios for the use of re-used water for the purposes of irrigation:

1. Treatment of the reclaimed water to meet health standards including pathogens. The reclaimed water may be used for irrigation if 10% of the reclaimed water is mixed with 90% of fresh water.
2. Treatment of the reclaimed water to limit NO_3 to an average concentration of 0.7mg/L. If this level of treatment is obtained on an average basis, 100% of the reclaimed water may be used for irrigation purposes, assuming partial uptake of nutrients by vegetation.
3. Treatment of the reclaimed water to limit NO_3 to an average concentration of 1.4mg/L. If this level of treatment is obtained on an average basis, a mixture of 50% of reclaimed water and 50% of fresh water may be used for irrigation.

Calculations of the average time required for the groundwater to migrate from the development area to the lake or river indicated that the groundwater moves at a rate of approximately 10 m/year. This is based on an assumed hydraulic conductivity of 8 m/day, a porosity of 35 % and a groundwater gradient of 0.12 %. The leaching tests indicate that nitrate will move at a similar rate to the groundwater and that phosphorus will move at a significantly slower rate.

Given this low rate of groundwater movement, Coffey consider that the irrigation impacts can be considered on a time averaged basis. With respect to use of reclaimed water for irrigation purposes, it is considered that irrigation of parks and open spaces within the development is unlikely to adversely impact groundwater or the water in the lake if one of the above treatment options is employed. Appropriate monitoring of irrigated areas should however be employed to ensure key indicators remain within relevant guidelines.

11 RECOMMENDATIONS

Monitoring of the groundwater system is recommended to confirm the findings of this report following development and initiation of any proposed water re-use program. Coffey recommend that a monitoring plan be developed to check performance of the groundwater system. This would include:

- Monitoring of irrigation water and groundwater quality;
- Irrigation water application rates and timing; and
- Soil testing

12 LIMITATIONS

The findings contained within this report are the result of discrete/specific sampling methodologies used in accordance with normal practices. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points.

13 REFERENCES

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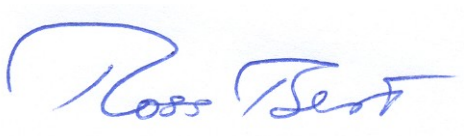
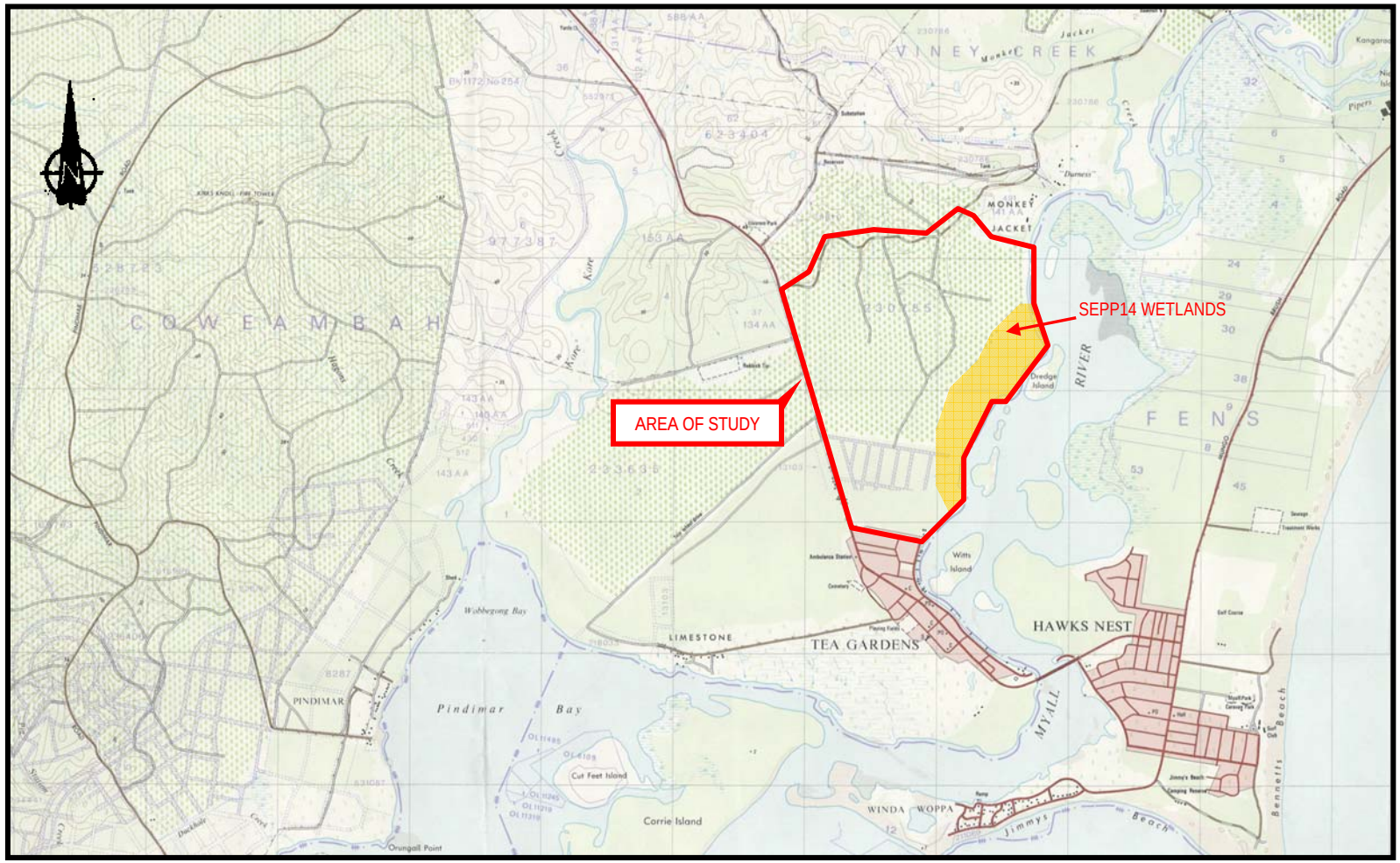
For and on behalf of Coffey Geotechnics Pty Ltd



Ross Best

Senior Principal

Figures



REFERENCE:
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9332-IV-S First Edition 1:25000 Series

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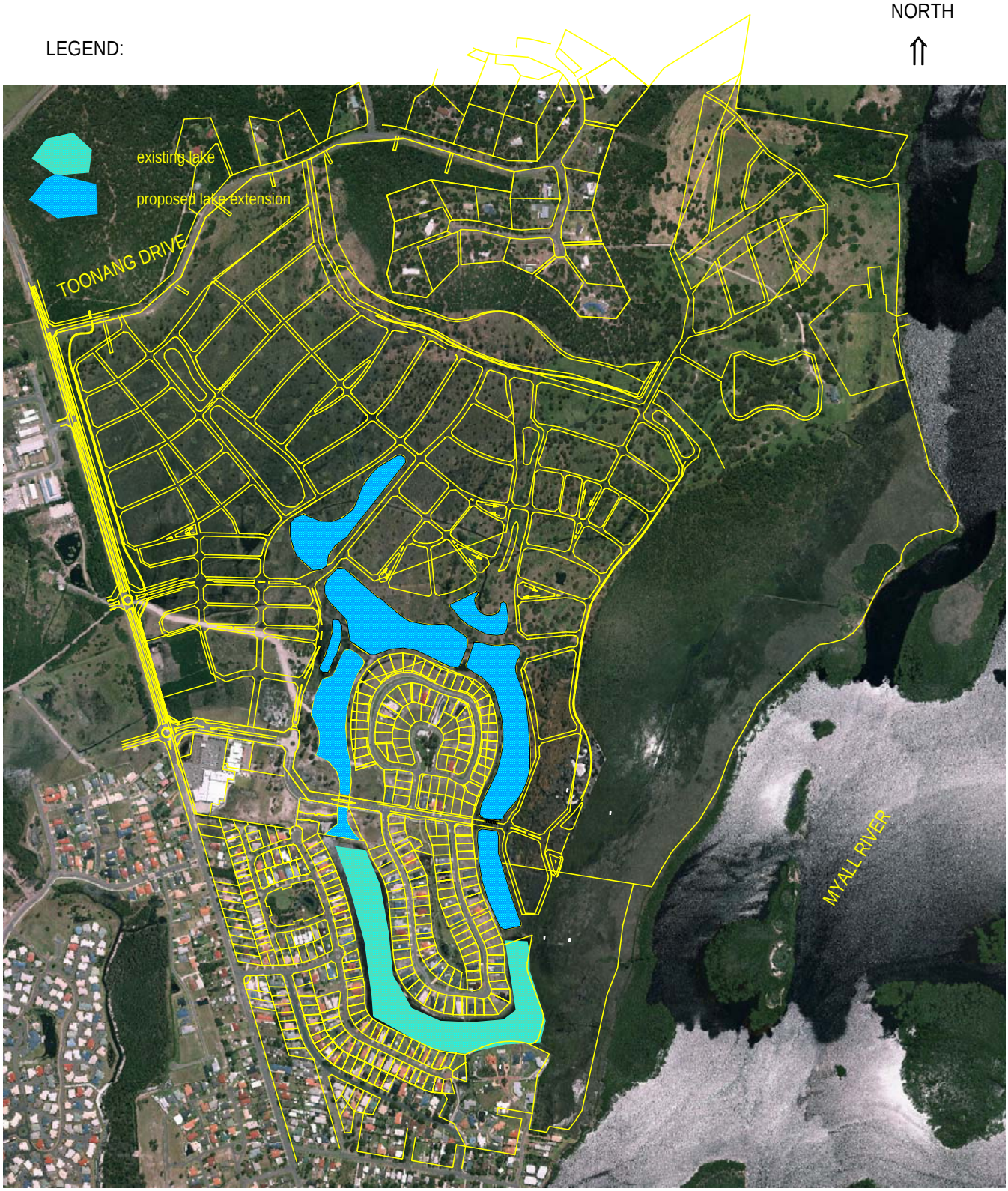
Approved	RJB		
Date	23/04/07		
Scale	1:500,000		Job no: GEOTLCOV23225

LEGEND:

NORTH



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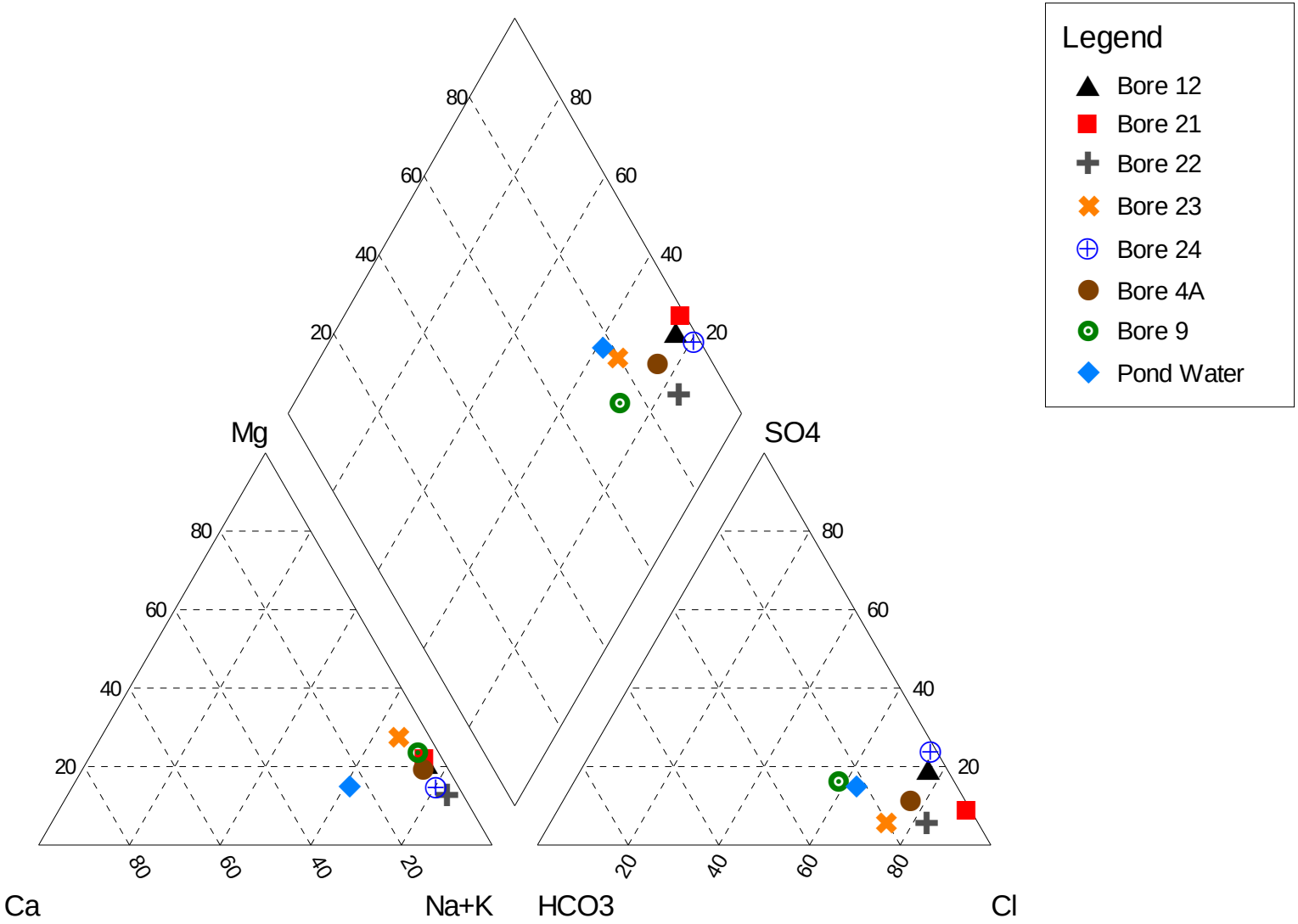
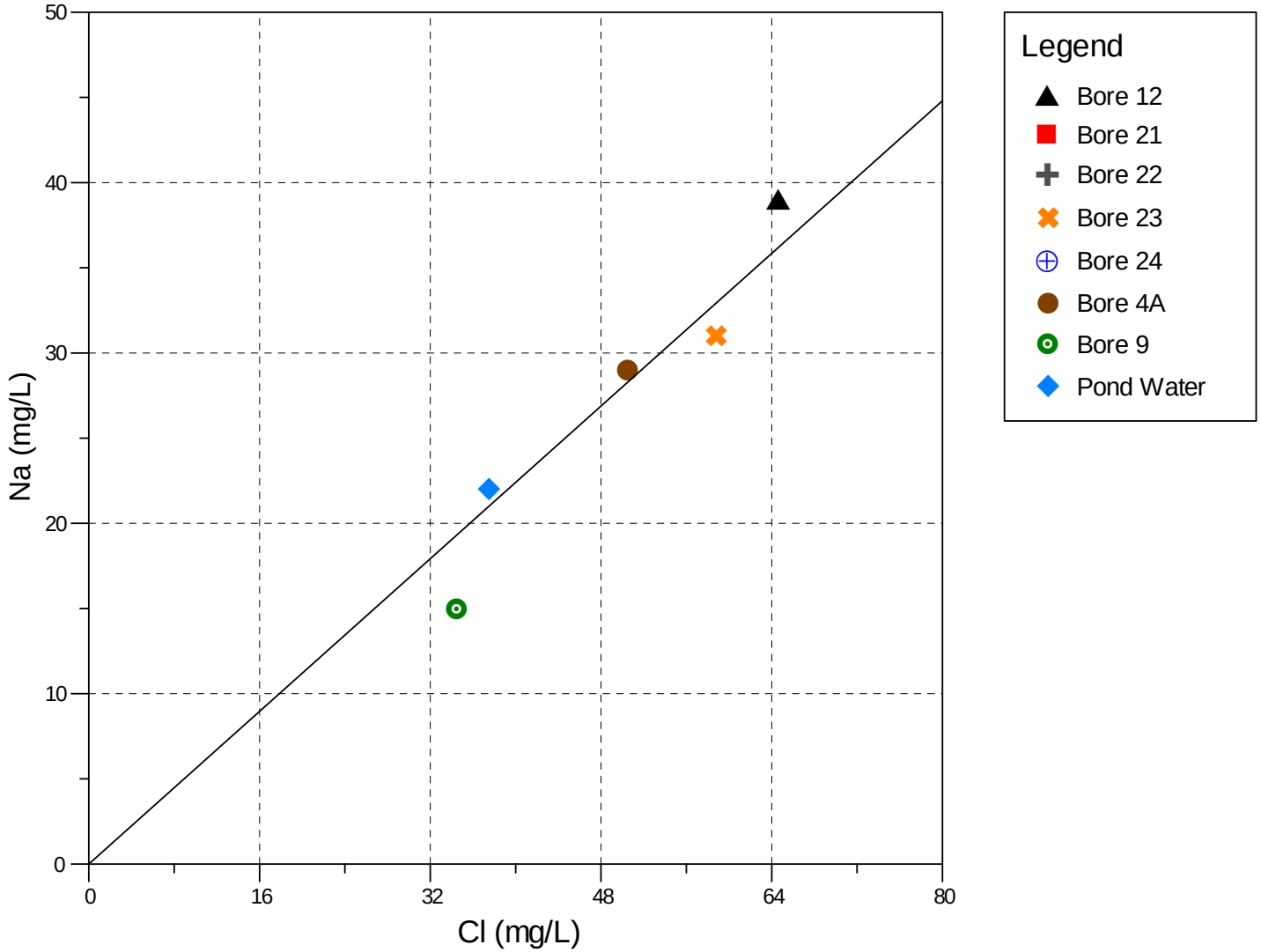
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	23/04/2007	MYALL QUAYS DEVELOPMENTS	
Scale	NTS	PROPOSED DEVELOPMENT	Job No: GEOTLCOV23255

Piper Plot - Surface and Groundwater Samples



drawn	JN	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	CARDNO WILLING
approved			project:	GROUNDWATER ASSESSMENT RIVERSIDE DEVELOPMENT TEA GARDENS
date	20/04/07		title:	Piper Diagram – Groundwater and Surface Water Samples
scale	NTS		project no: GEOTLCOV23225AA	figure no: FIGURE 3
original size	A4			

Seawater Dilution Ratio Na: Cl



drawn	**JN**
approved	
date	**20/04/07**
scale	**NTS**
original size	**A4**

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client: **CARDNO WILLING**

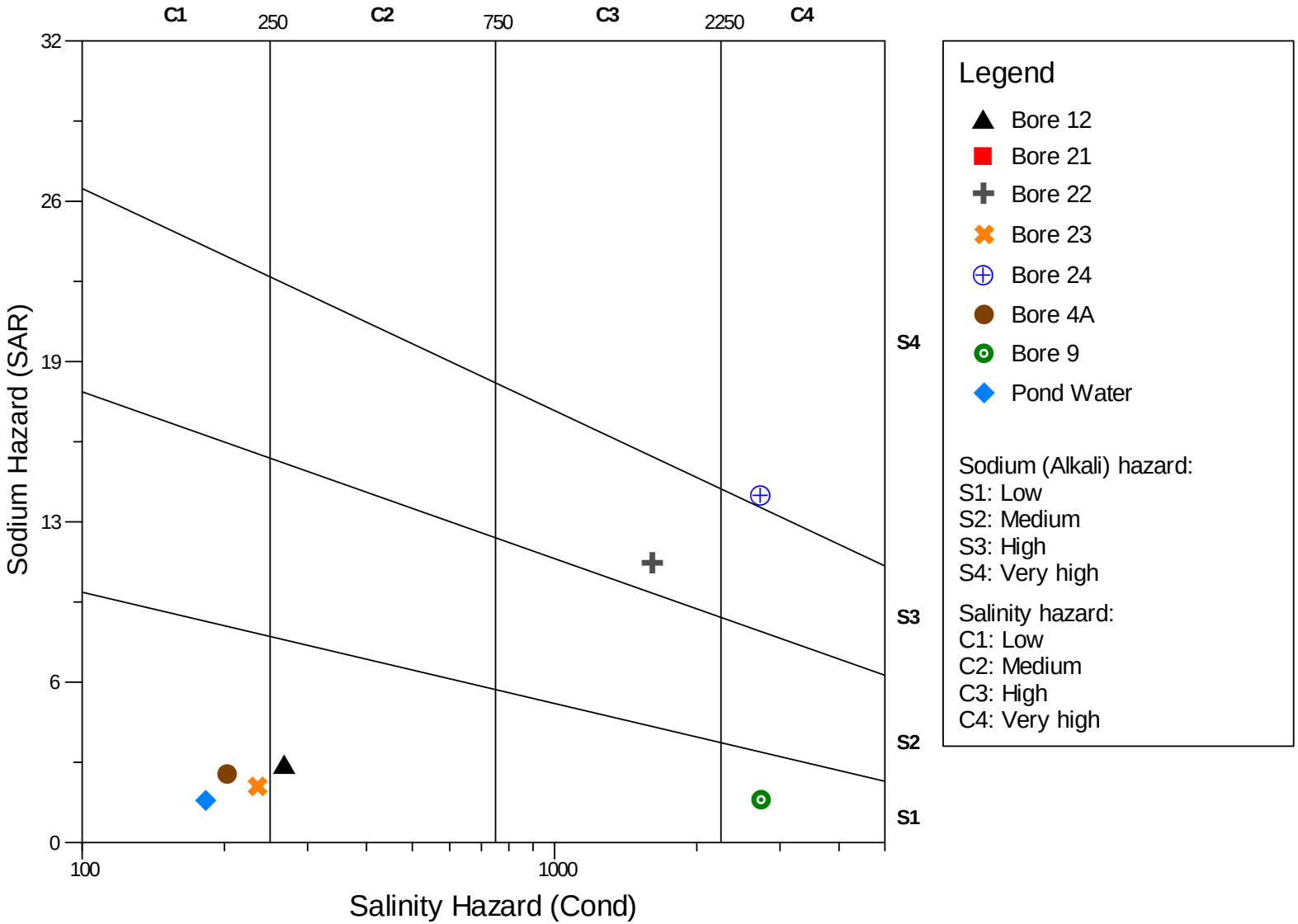
project: **GROUNDWATER ASSESSMENT RIVERSIDE DEVELOPMENT TEA GARDENS**

title: **Seawater Dilution Ratio Na:Cl for selected samples**

project no: **GEOTLCOV23225AA**

figure no: **FIGURE 4**

Wilcox Diagram - Groundwater and Surface Water Samples



drawn	**JN**
approved	
date	**20/04/07**
scale	**NTS**
original size	**A4**

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SPECIALISTS MANAGING THE EARTH

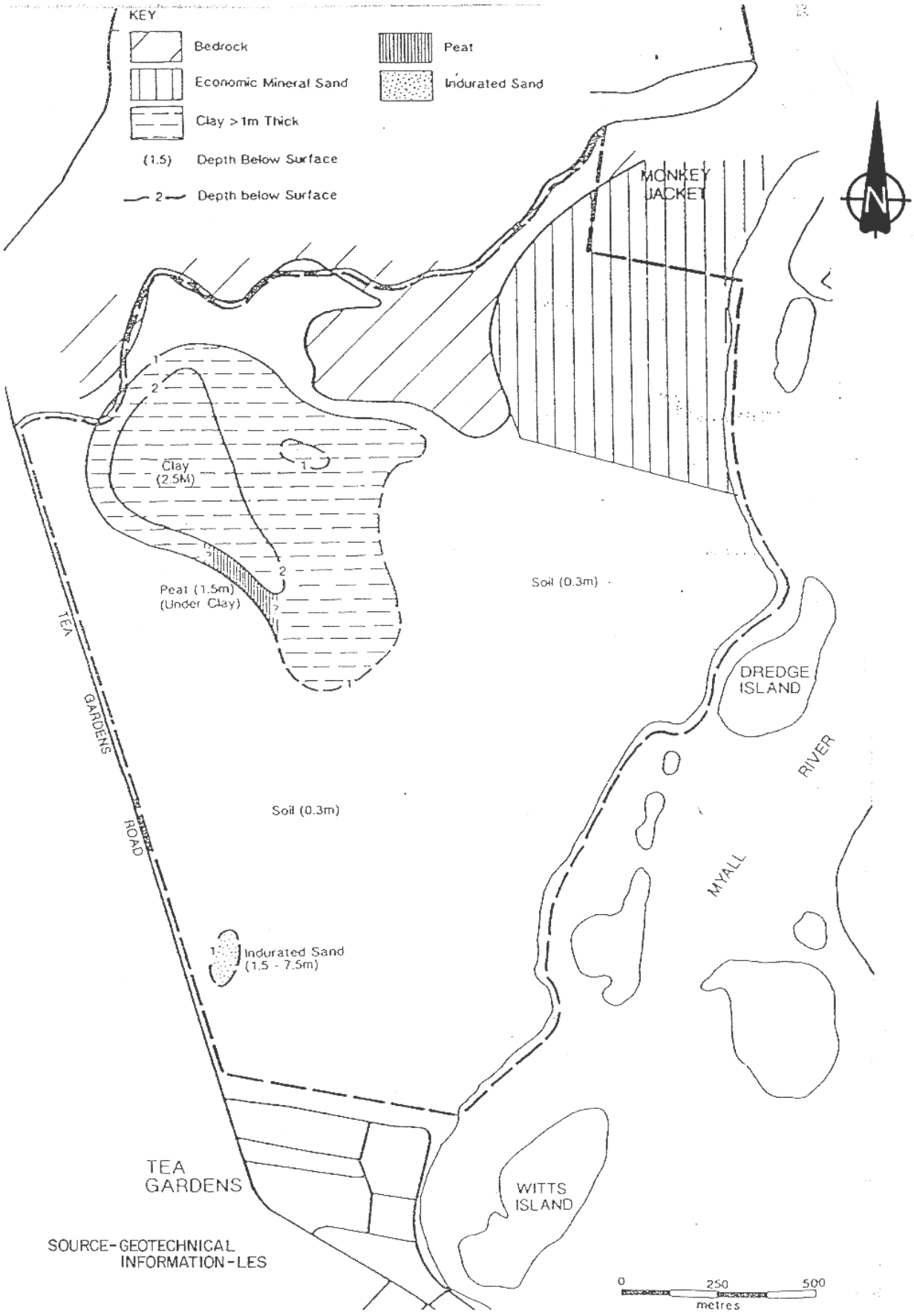
client: **CARDNO WILLING**

project: **GROUNDWATER ASSESSMENT RIVERSIDE DEVELOPMENT TEA GARDENS**

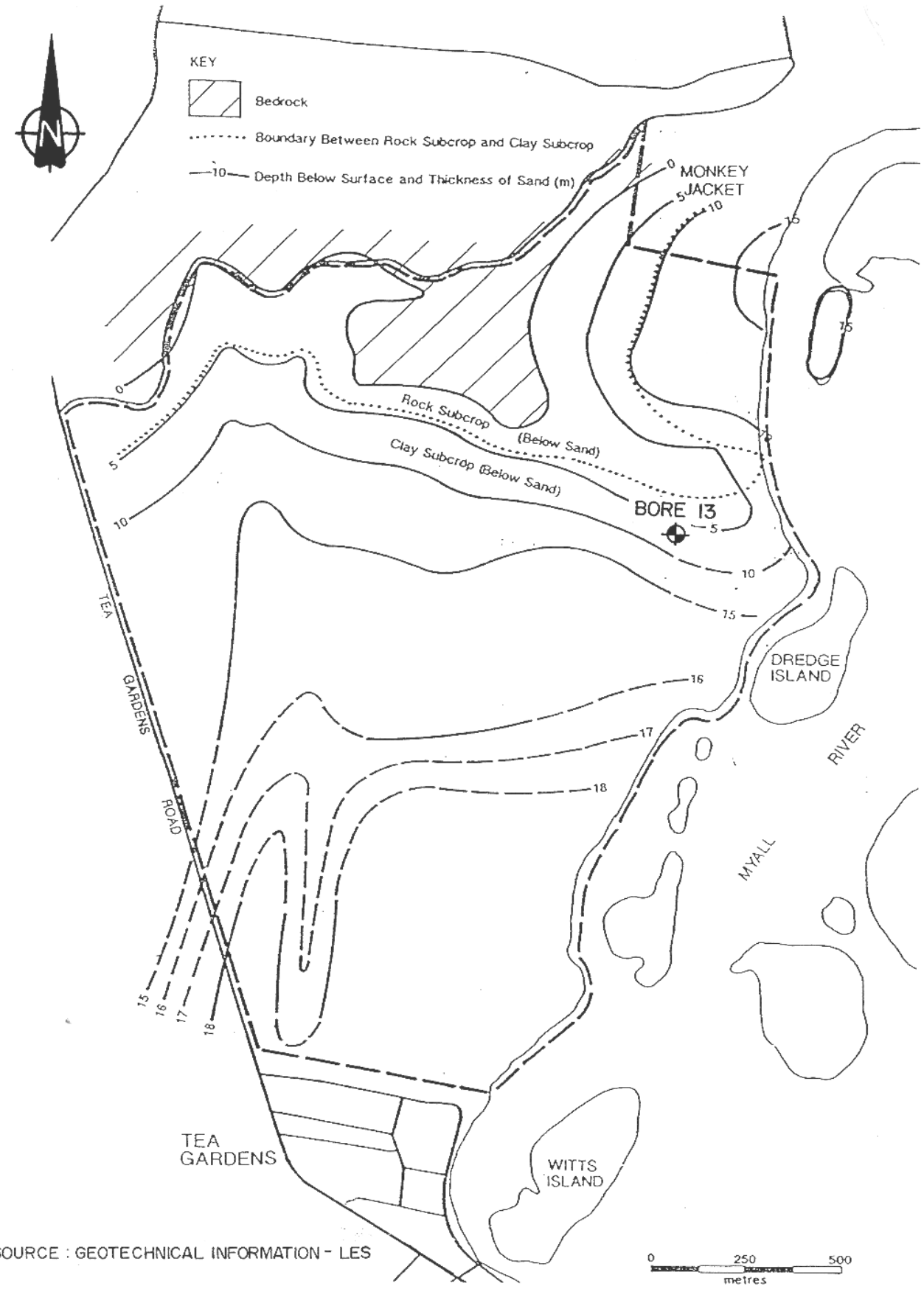
title: **Wilcox Diagram – Groundwater and Surface Water Samples**

project no: **GEOTLCOV23225AA**

figure no: **FIGURE 5**



Coffey Geotechnics Pty Ltd		Geotechnical **I Resources I** Environmental **I Technical I** Project Management	
Drawn	EW/RJB	CRIGHTON PROPERTIES GROUNDWATER ASSESSMENT MYALL QUAYS DEVELOPMENT EXTENT OF SURFACE CLAY	Drawing no: FIGURE 6
Approved	RJB		
Date	23/04/07		
Scale	As Shown		Job no: GEOTLCO23225



Coffey Geotechnics Pty Ltd ACN 056 335 516		Geotechnical **I Resources I** Environmental **I Technical I** Project Management	
Drawn	EW/RJB	CRIGHTON PROPERTIES GROUNDWATER ASSESSMENT MYALL QUAYS DEVELOPMENT SAND THICKNESS	Drawing no: FIGURE 7
Approved	RJB		
Date	23/04/07		
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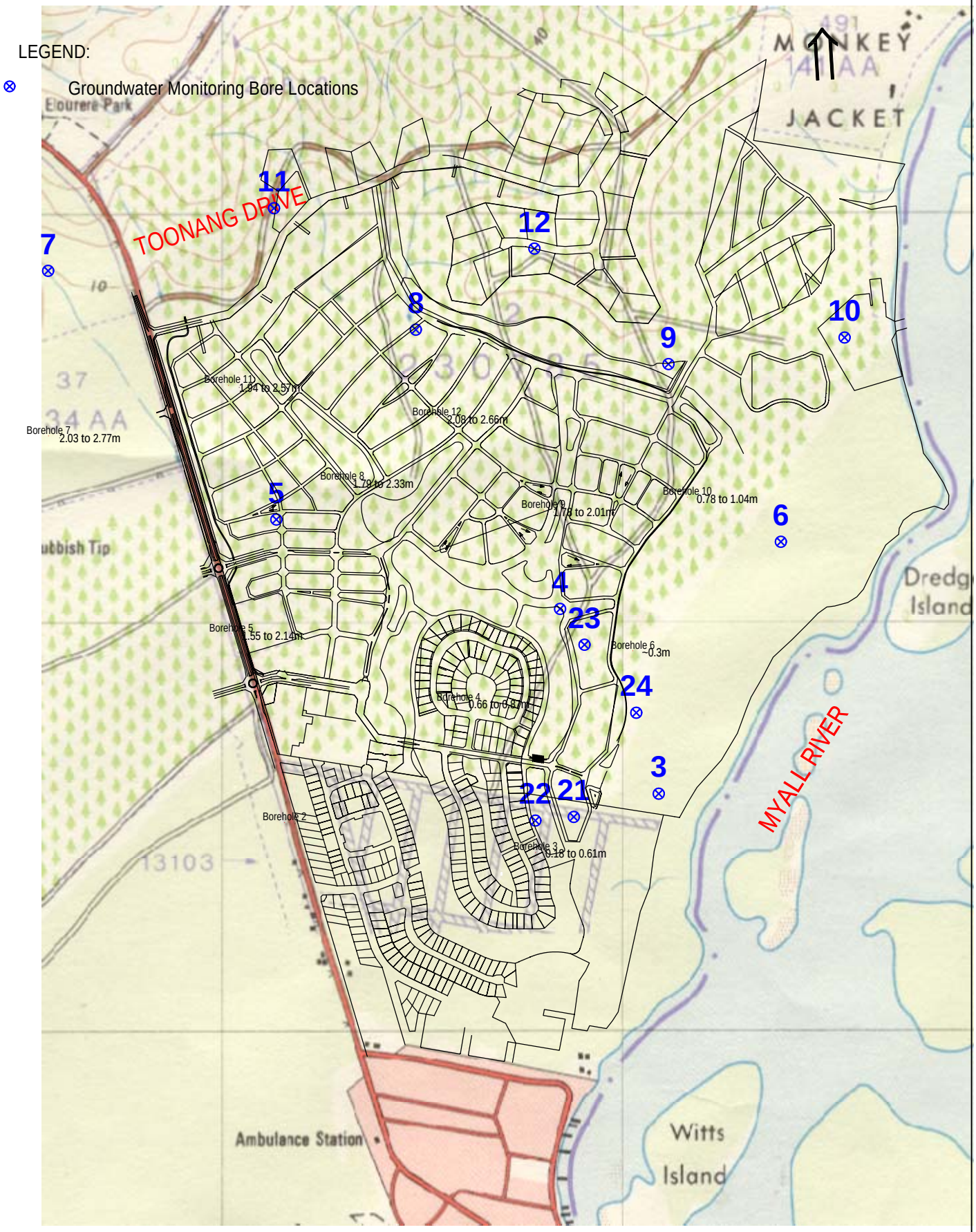

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Drawn	EW	CRIGHTON PROPERTIES	FIGURE 8
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	23/04/2007	MYALL QUAYS DEVELOPMENTS	
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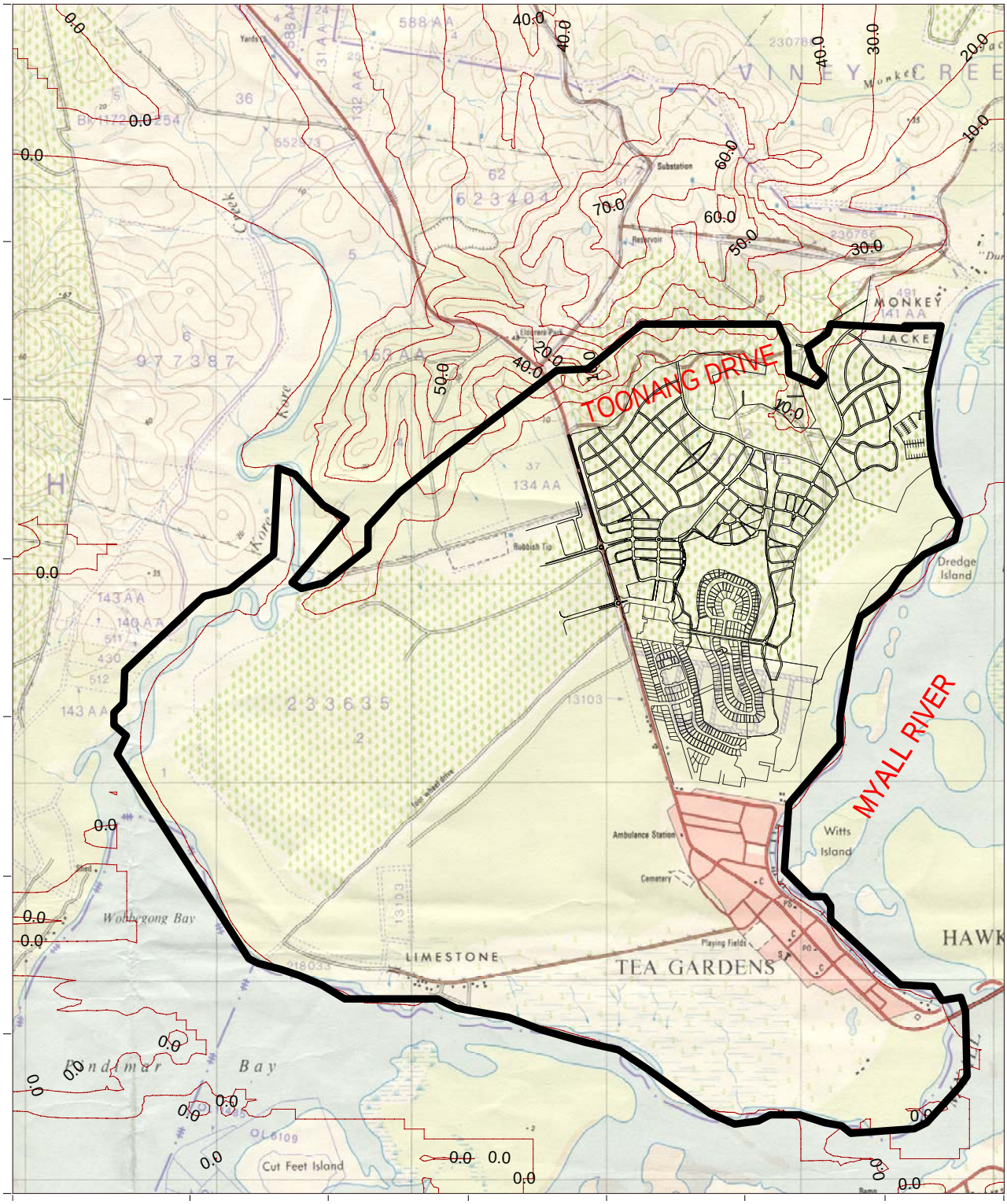
NORTH

LEGEND:

Extent of the Modflow Model



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Drawn	EW	CRIGHTON PROPERTIES	FIGURE 9
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Date	23/04/2007	MYALL QUAYS DEVELOPMENTS	
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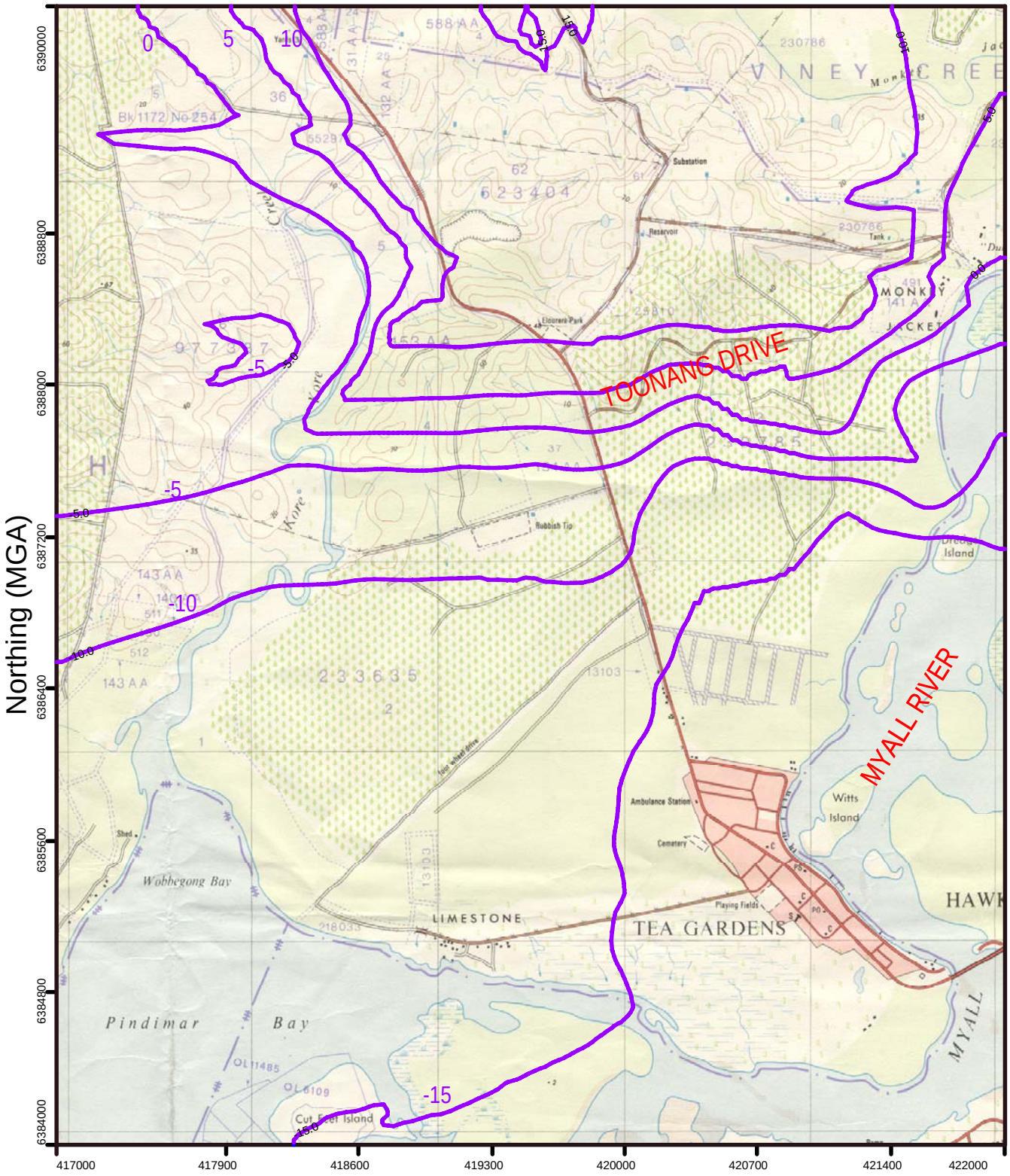
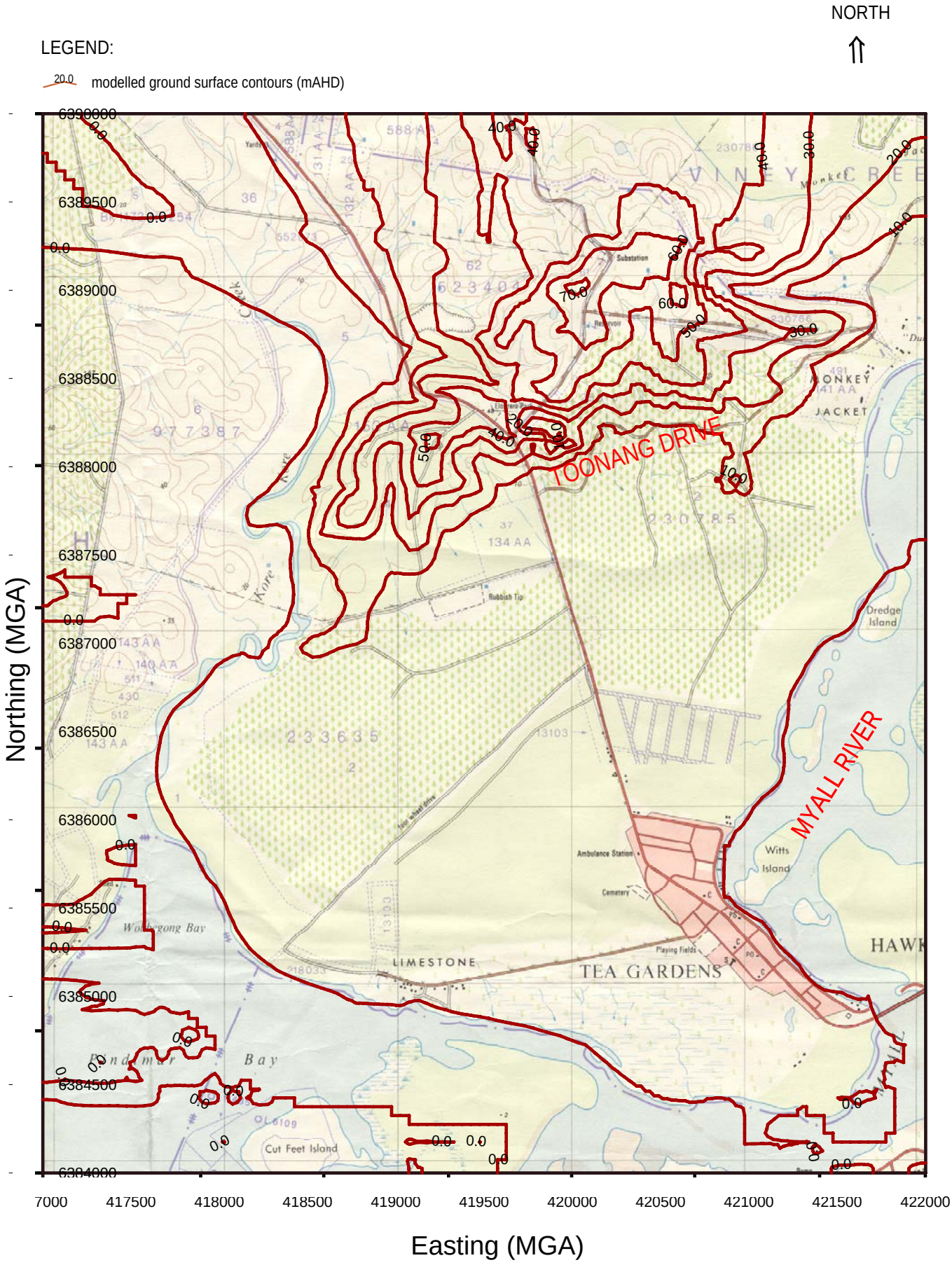
NORTH

LEGEND:

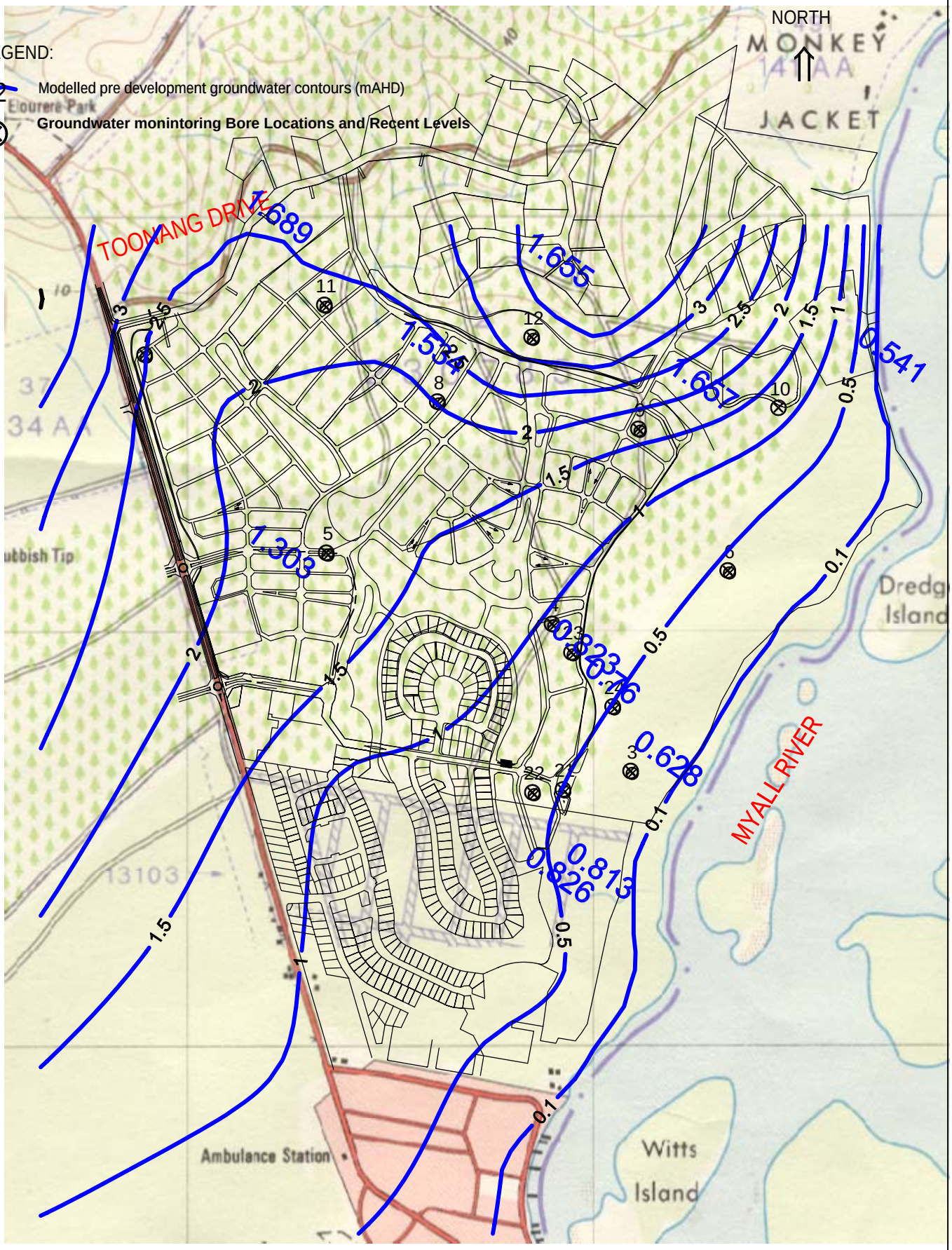
modelled top of rock level contours (mAHD)



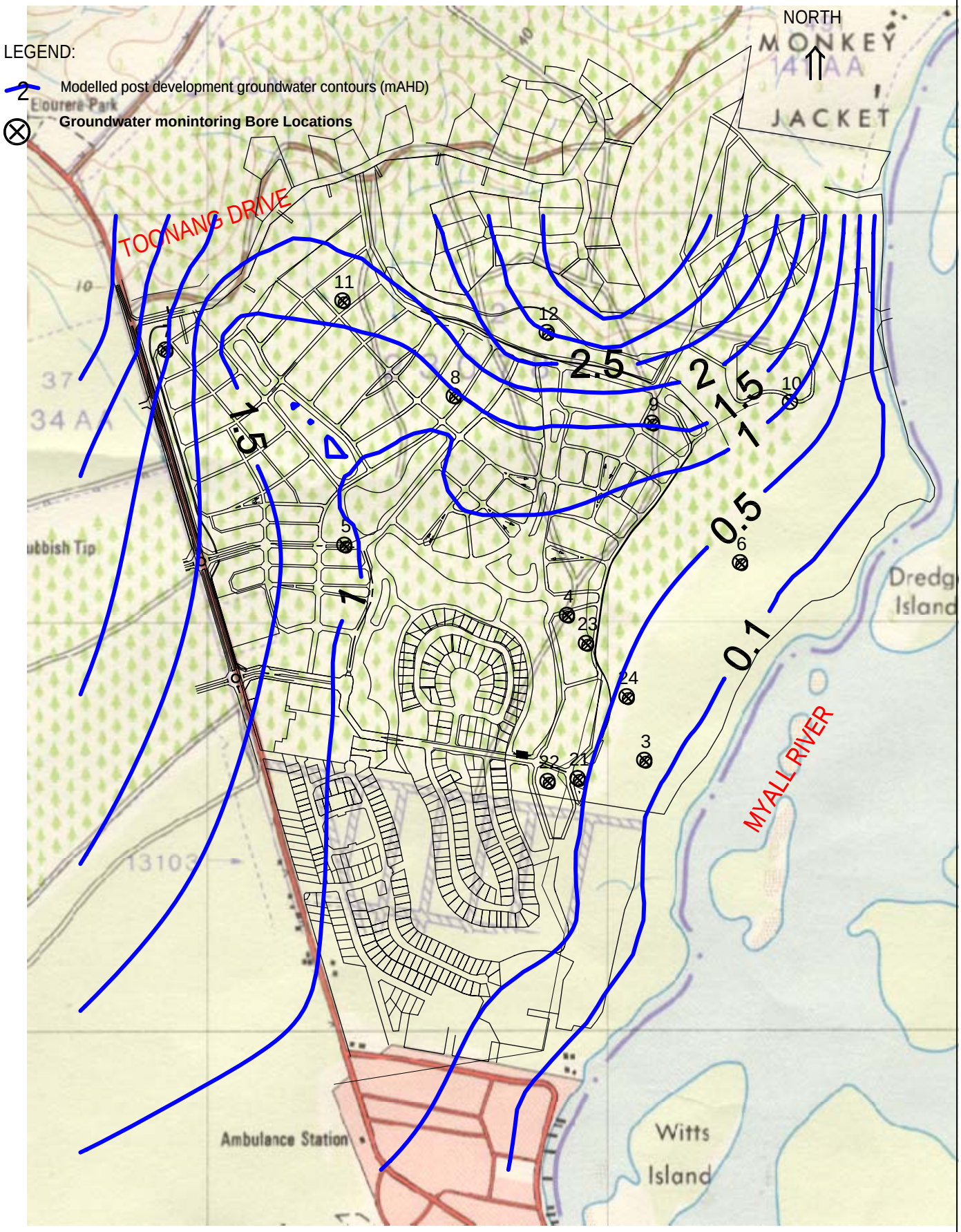
Coffey Geotechnics Pty Ltd		Geotechnical I Resources I Environmental I Technical I Project Management	
Drawn	EW	CRIGHTON PROPERTIES	FIGURE 10
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	23/04/2007	MYALL QUAYS DEVELOPMENTS	
Scale	1:30000	MODELLED ROCK LEVEL CONTOURS	Job No: GEOTLCOV23225



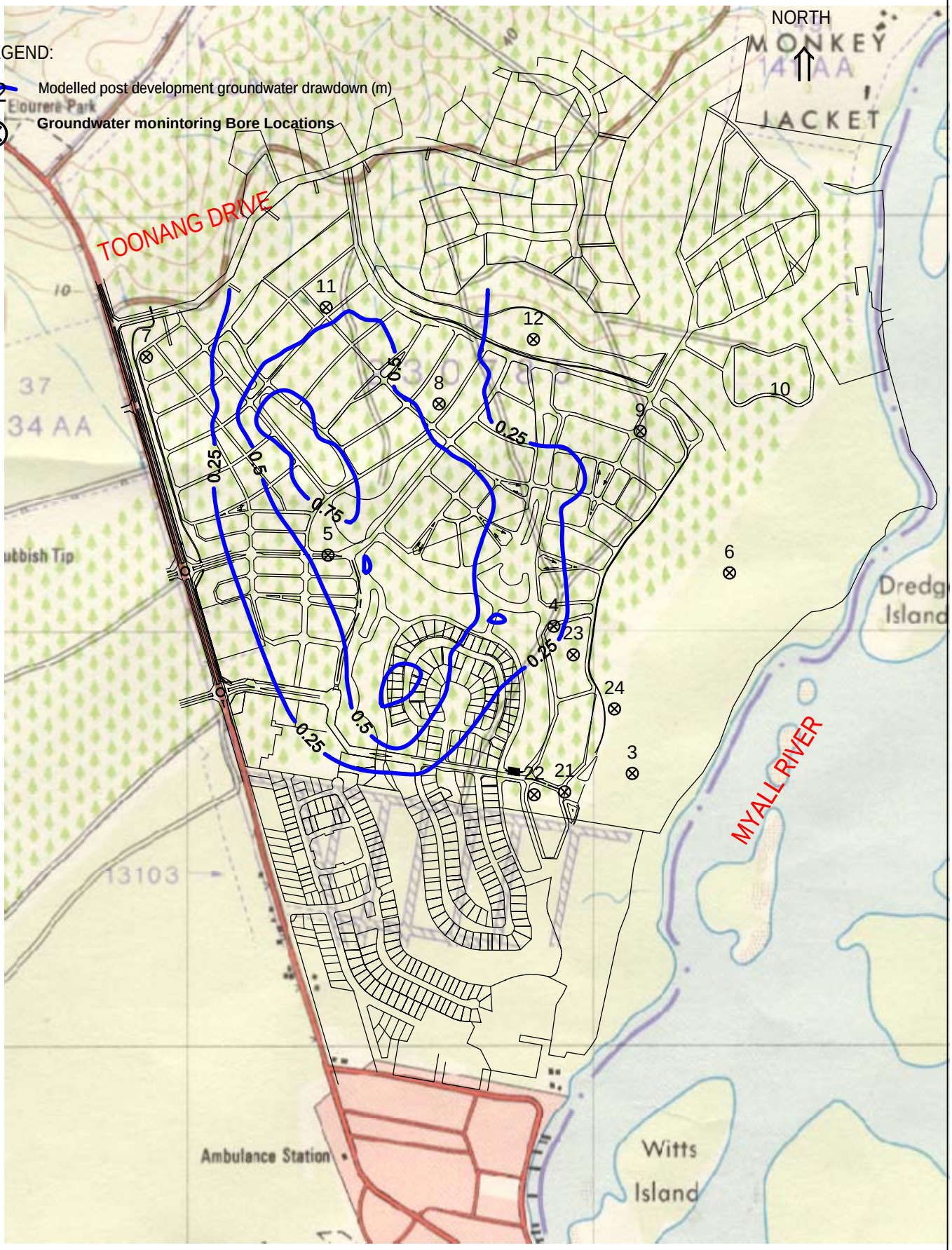
Coffey Geotechnics Pty Ltd		Geotechnical I Resources I Environmental I Technical I Project Management	
Drawn	EW	CRIGHTON PROPERTIES	FIGURE 11
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	23/04/2007	MYALL QUAYS DEVELOPMENTS	
Scale	1:30000	MODELLED GROUND SURFACE CONTOURS	Job No: GEOTLCOV23225



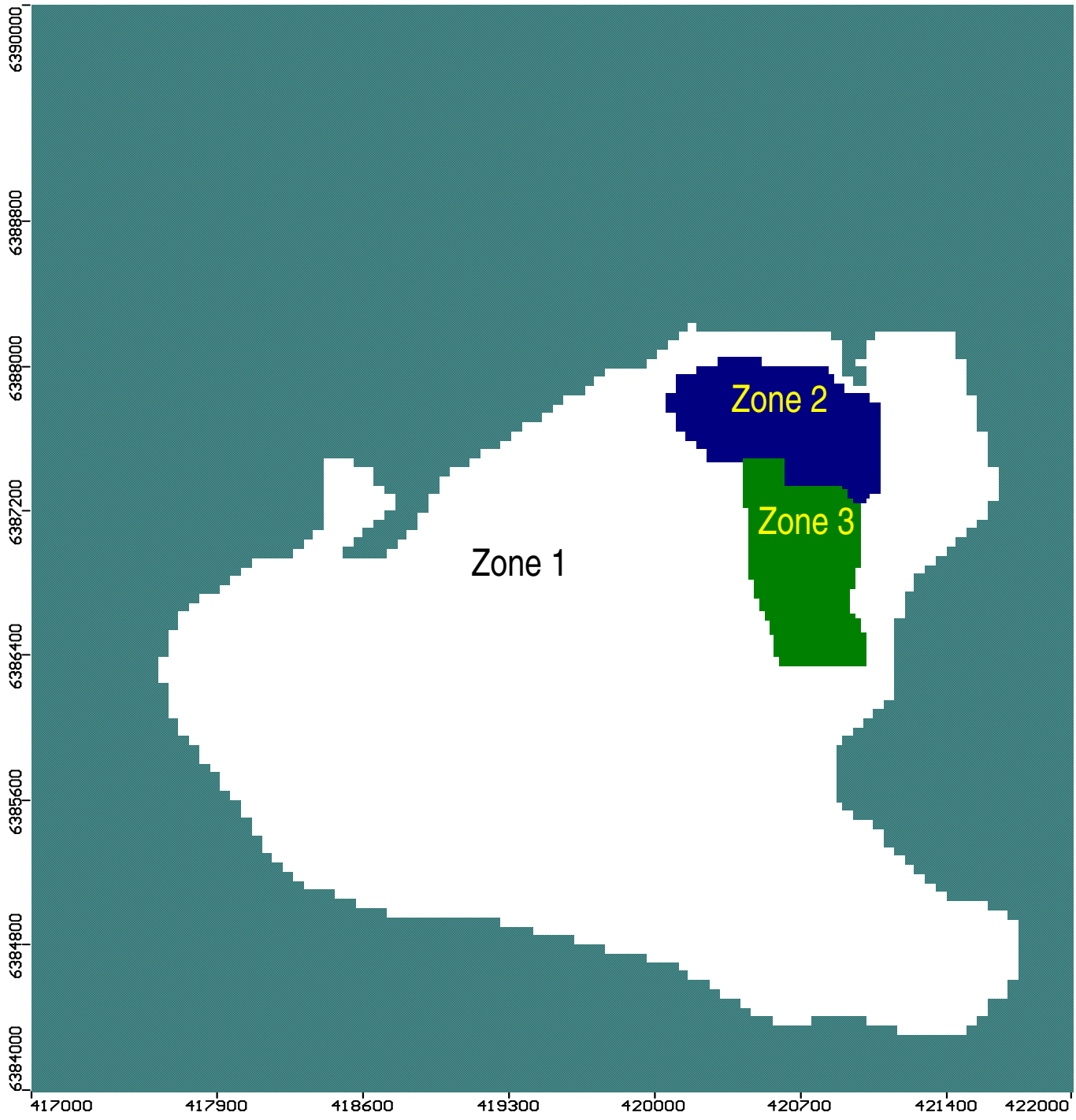
Coffey Geotechnics Pty Ltd		Geotechnical I Resources I Environmental I Technical I	
Drawn	AF	CRIGHTON PROPERTIES	FIGURE 12
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	23/04/2007	MYALL QUAYS DEVELOPMENTS	
Scale	1:12500	MODELLED PRE DEVELOPMENT GROUNDWATER CONTOURS	Job No: GEOTLCOV23225



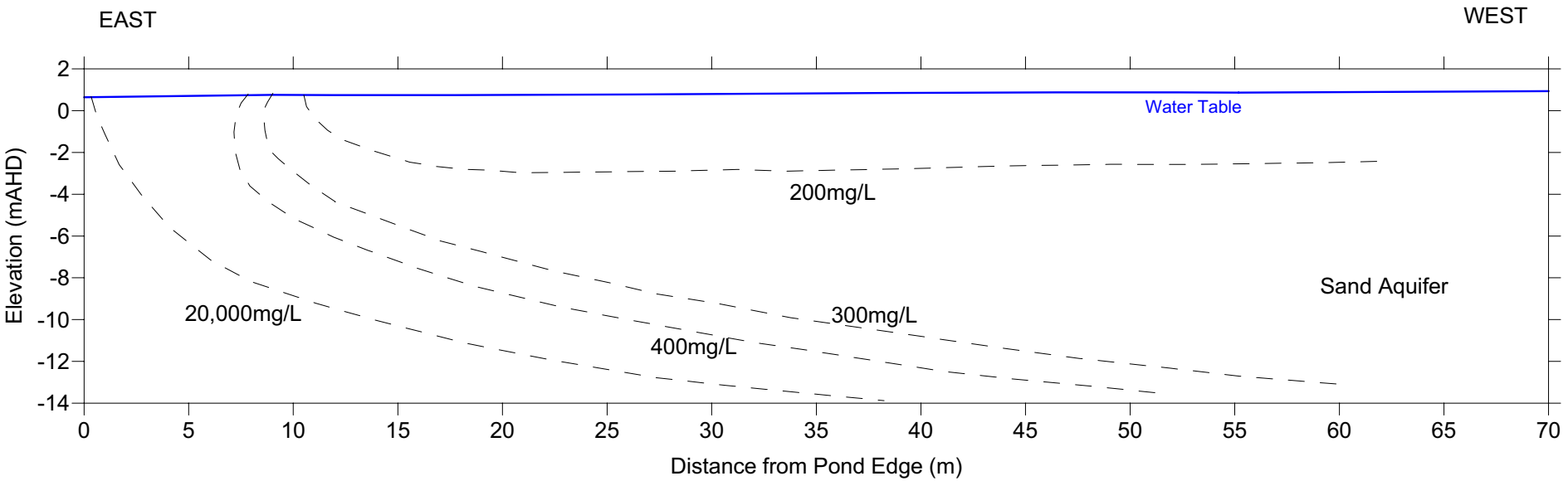
Coffey Geotechnics Pty Ltd		Geotechnical I Resources I Environmental I Technical I	
Drawn	AF	CRIGHTON PROPERTIES	FIGURE 13
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	26/10/2007	MYALL QUAYS DEVELOPMENTS	
Scale	1:12500	MODELLED POST DEVELOPMENT GROUNDWATER CONTOURS	Job No: GEOTLCOV23225



Coffey Geotechnics Pty Ltd		Geotechnical I Resources I Environmental I Technical I	
Drawn	AF	CRIGHTON PROPERTIES	FIGURE 14
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	26/10/2007	MYALL QUAYS DEVELOPMENTS	
Scale	1:12500	MODELLED POST DEVELOPMENT GROUNDWATER DRAWDOWN	Job No: GEOTLCOV23225



drawn	AF	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	Crighton Properties
approved	RJB		project:	Myall Quays Development
date	4/04/2007			Myall Quays
scale	AS SHOWN		title:	Mass Balance Budget Zones
original size	A4		project no: GEOTLCOV 23225	figure no: FIGURE 15



— — Interpreted concetration contour for total dissolved solids

drawn	PT
approved	RJB
date	Apr 2007
scale	1:300
original size	A4

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client: Cardno Willing

project: Groundwater Assessment
Riverside Development
Tea Gardens, NSW

title: **INTERPRETED TYPICAL SALINITY CONTOURS**

project no: GEOTLCOV23225AA

figure no: **FIGURE 16**

Appendix A

TABLE LR1

SUMMARY OF RESULTS

GROUNDWATER

All results in mg/L unless stated

SAMPLE ID	ANZECC Marine (slightly to moderately disturbed system)		NHMRC Human Health Guidelines		ANZECC Irrigation and General Use (moderately sensitive crops)		4A	9	12	21
MATRIX							WATER	WATER	WATER	WATER
SAMPLE DATE							29/03/2007	30/03/2007	29/03/2007	29/03/2007
GENERAL PARAMETERS										
pH (pH Unit)			6.5-8.5	[7]			5.32	3.99	5.02	5.62
Electrical Conductivity (µS/cm)							202	178	268	15500
Total Dissolved Solids			500	[7]			155	200	1210	11500
Total Hardness as $CaCO_3$			200	[7]			23	14	29	2040
SAR							19.3	15	19.5	19.4
MAJOR ANIONS										
Sulphate as SO_4^{2-}							10	13	22	702
Chloride			250	[7]	175-350	[3]	50.4	34.4	64.6	**5300**
Bicarbonate Alkalinity as $CaCO_3$							14	26	6	92
Total Alkalinity as $CaCO_3$							14	26	6	92
MAJOR CATIONS										
Calcium							2	<1	2	126
Magnesium							4	3	6	420
Sodium			180	[7]	115-230	[3]	29	15	39	**2650**
Potassium							<1	4	4	65
HEAVY METALS										
Arsenic	0.0023	[2]	0.007	[6]	0.1	[4]	<0.001	<0.001	<0.001	0.002
Cadmium	0.014	[1]	0.002	[6]	0.01	[4]	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.0486	[1]	0.05	[6]	0.1	[4]	<0.001	<0.001	<0.001	0.002
Copper	0.003	[1]	2.0	[6]	0.2	[4]	<0.001	<0.001	<0.001	0.001
Lead	0.0066	[1]	0.01	[6]	2.0	[4]	<0.001	<0.001	<0.001	<0.001
Nickel	0.2	[1]	0.02	[6]	0.2	[4]	<0.001	<0.001	<0.001	<0.001
Zinc	0.023	[1]	3.0	[7]	2.0	[4]	0.085	0.017	0.009	<0.005
Mercury	0.0007	[1]	0.001	[6]	0.002	[4]	<0.0001	<0.0001	<0.0001	<0.0001
NUTRIENTS										
Ammonia as N			0.5	[7]			0.212	0.545	0.303	0.934
Nitrite as N			3	[6]			<0.010	0.028	0.027	<0.010
Nitrate as N			50	[6]			0.034	<0.010	0.039	0.027
Nitrite + Nitrate as N							0.034	0.034	0.066	0.027
Total Kjeldahl Nitrogen as N					5.0	[4]	0.9	2.5	3	**12.1**
Total Phosphorus as P					0.05	[4, 5]	**0.14**	**1**	**0.76**	**1.38**
Reactive Phosphorus as P							0.017	0.799	0.036	0.035
TOC / BOD										
Total Organic Carbon							16	-	22	109
Biochemical Oxygen Demand							9	-	<2	<2

Concentration exceeds the respective ANZECC (2000) Marine Water Guideline for slightly to moderately disturbed systems

Concentration exceeds the respective human health guideline NHMRC (2004) for drinking water

5 Concentration exceeds the respective ANZECC (2000) Irrigation Water Guideline for moderately sensitive crops / long term use

[1] ANZECC (2000) Marine Water Guidelines for protection of 90% of species in slightly to moderately disturbed systems

[2] Low reliability trigger level

[3] ANZECC (2000) Guidelines for irrigation and general use - moderately sensitive crops

[4] ANZECC (2000) Guidelines for irrigation and general use - long-term trigger value

[5] To minimise bioclogging of irrigation equipment only

[6] Human Health Guidelines (NHMRC, 2004)

[7] Aesthetic Guidelines (NHMRC, 2004)

- Not Analysed

TABLE LR2

RESULTS 2004 and

SAMPLE RANGE OF RESULTS 2004-2007

All results in mg/L unless stated

SAMPLE ID	ANZECC Marine (slightly to moderately disturbed system)		NHMRC Human Health Guidelines		ANZECC Irrigation and General Use (moderately sensitive crops)		BORE 4A	BORE 9	BORE 12
							2007 results	2007 results	2007 results
SAMPLE DATE							(range 2004-1007)	(range 2004-1007)	(range 2004-1007)
GENERAL PARAMETERS									
pH (pH Unit)			6.5-8.5	[7]			5.32 (5.24-6.26)	3.99 (3.99-4.43)	5.02 (5.02-6.12)
Electrical Conductivity (µS/cm)							202 (159-239)	178 (141-178)	268 (254-290)
Total Dissolved Solids			500	[7]			155 (106-185)	200 (162-200)	1210 (197-1210)
Total Hardness as $CaCO_3$			200	[7]			23 (17-23)	14 (12-14)	29 (21-29)
MAJOR ANIONS									
Sulphate as SO_4^{2-}							10 (4-15)	13 (6-34)	22 (15-22)
Chloride			250	[7]	175-350	[3]	50.4 (40-51)	34.4 (25-37)	64.6 (57-65)
Total Alkalinity as $CaCO_3$							14 (7-14)	26 (<1-26)	6 (6-8)
MAJOR CATIONS									
Calcium							2 (<1-2)	<1 (<1)	2 (1)
Magnesium							4 (4)	3 (3-4)	6 (5)
Sodium			180	[7]	115-230	[3]	29 (19-36)	15 (14-19)	39 (38-43)
Potassium							<1 (<1)	4 (<1-4)	4 (2)
HEAVY METALS									
Arsenic	0.0023	[2]	0.007	[6]	0.1	[4]	<0.001 (<0.001-0.002)	<0.001	<0.001 (<0.001-0.002)
Cadmium	0.014	[1]	0.002	[6]	0.01	[4]	<0.0001 (<0.0001-<0.001)	<0.0001 (<0.0001-<0.001)	<0.0001 (<0.0001-<0.001)
Chromium	0.0486	[1]	0.05	[6]	0.1	[4]	<0.001 (<0.001-0.002)	<0.001 (<0.001-0.004)	<0.001 (<0.001-0.001)
Copper	0.003	[1]	2.0	[6]	0.2	[4]	<0.001 (<0.001-0.235)	<0.001 (<0.001-0.008)	<0.001
Lead	0.0066	[1]	0.01	[6]	2.0	[4]	<0.001 (<0.001-0.026)	<0.001 (<0.001-0.006)	<0.001 (<0.001-0.017)
Zinc	0.023	[1]	3.0	[7]	2.0	[4]	0.085 (0.047-0.140)	0.017 (0.006-0.017)	0.009 (0.009-0.026)
NUTRIENTS									
Ammonia as N			0.5	[7]			0.212 (0.07-0.21)	0.545 (0.37-0.55)	0.303 (0.17-0.3)
Nitrite + Nitrate as N							0.034 (0.02-0.034)	0.034 (0.02-0.07)	0.066 (0.01-0.07)
Total Kjeldahl Nitrogen as N					5.0	[4]	0.9 (0.5-1)	2.5 (1.6-3.6)	3 (1.2-3)
Total Phosphorus as P					0.05	[4, 5]	0.14 (<0.01-0.14)	1 (0.46-1.08)	0.76 (0.13-0.76)
TOC / BOD									
Total Organic Carbon							16 (6-10)	42-51	22 (20-47)
Biochemical Oxygen Demand							9 (<2-9)	<2-2	<2 (<2)

TABLE LR1

SUMMARY OF RESULTS

GROUNDWATER

All results in mg/L unless stated

SAMPLE ID	ANZECC Marine (slightly to moderately disturbed system)		NHMRC Human Health Guidelines		ANZECC Irrigation and General Use (moderately sensitive crops)		22	23	24	POND
MATRIX							WATER	WATER	WATER	WATER
SAMPLE DATE							29/03/2007	29/03/2007	29/03/2007	30/03/2007
GENERAL PARAMETERS										
pH (pH Unit)			6.5-8.5	7			6.05	5.6	5.46	5.83
Electrical Conductivity (µS/cm)							1610	234	2730	182
Total Dissolved Solids			500	7			1350	212	2250	129
Total Hardness as $CaCO_3$			200	7			123	39	300	33
SAR							33.3	12.4	25.9	8.0
MAJOR ANIONS										
Sulphate as SO_4^{2-}							39	6	344	12
Chloride			250	7	175-350	3	**430**	58.7	**800**	37.4
Bicarbonate Alkalinity as $CaCO_3$							102	28	26	23
Total Alkalinity as $CaCO_3$							102	28	26	23
MAJOR CATIONS										
Calcium							11	3	31	8
Magnesium							23	7	54	3
Sodium			180	7	115-230	3	**283**	31	**551**	22
Potassium							7	1	24	2
HEAVY METALS										
Arsenic	0.0023	2	0.007	6	0.1	4	0.001	<0.001	0.006	<0.001
Cadmium	0.014	1	0.002	6	0.01	4	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.0486	1	0.05	6	0.1	4	0.007	<0.001	0.005	<0.001
Copper	0.003	1	2.0	6	0.2	4	<0.001	<0.001	0.001	0.005
Lead	0.0066	1	0.01	6	2.0	4	<0.001	<0.001	<0.001	<0.001
Nickel	0.2	1	0.02	6	0.2	4	<0.001	<0.001	0.003	0.001
Zinc	0.023	1	3.0	7	2.0	4	<0.005	0.008	0.016	0.029
Mercury	0.0007	1	0.001	6	0.002	4	<0.0001	<0.0001	<0.0001	<0.0001
NUTRIENTS										
Ammonia as N			0.5	7			0.655	0.179	0.893	<0.010
Nitrite as N			3	6			0.087	<0.010	0.013	<0.010
Nitrate as N			50	6			<0.010	0.013	0.013	0.02
Nitrite + Nitrate as N							0.037	0.013	0.026	0.02
Total Kjeldahl Nitrogen as N					5.0	4	7.2	2.5	**9.3**	0.7
Total Phosphorus as P					0.05	4, 5	**0.79**	**0.32**	**1.12**	**0.08**
Reactive Phosphorus as P							0.095	-	0.062	<0.010
TOC / BOD										
Total Organic Carbon							189	56	94	-
Biochemical Oxygen Demand							<2	9	<2	5

Concentration exceeds the respective ANZECC (2000) Marine Water Guideline for slightly to moderately disturbed systems

Concentration exceeds the respective human health guideline NHMRC (2004) for drinking water

5 Concentration exceeds the respective ANZECC (2000) Irrigation Water Guideline for moderately sensitive crops / long term use

[1] ANZECC (2000) Marine Water Guidelines for protection of 90% of species in slightly to moderately disturbed systems

[2] Low reliability trigger level

[3] ANZECC (2000) Guidelines for irrigation and general use - moderately sensitive crops

[4] ANZECC (2000) Guidelines for irrigation and general use - long-term trigger value

[5] To minimise bioclogging of irrigation equipment only

[6] Human Health Guidelines (NHMRC, 2004)

[7] Aesthetic Guidelines (NHMRC, 2004)

- Not Analysed

TABLE LR2

RESULTS 2004 and

SAMPLE RANGE OF RESULTS 2004-2007

All results in mg/L unless stated

SAMPLE ID	ANZECC Marine (slightly to moderately disturbed system)		NHMRC Human Health Guidelines		ANZECC Irrigation and General Use (moderately sensitive crops)		BORE 22	BORE 23	BORE 24
							2007 results	2007 results	2007 results
SAMPLE DATE							(range 2004-1007)	(range 2004-1007)	(range 2004-1007)
GENERAL PARAMETERS									
pH (pH Unit)			6.5-8.5	[7]			6.05 (5.88)	5.6 (5.92)	5.46 (5.45)
Electrical Conductivity (µS/cm)							1610 (7410)	234 (317)	2730 (6060)
Total Dissolved Solids			500	[7]			1350 (4390)	212 (192)	2250 (4580)
Total Hardness as $CaCO_3$			200	[7]			123 (1310)	39 (26)	300 (791)
MAJOR ANIONS									
Sulphate as SO_4^{2-}							39 (299)	6 (7)	344 (300)
Chloride			250	[7]	175-350	[3]	430 (2240)	58.7 (39)	800 (2580)
Total Alkalinity as $CaCO_3$							102 (44)	28 (24)	26 (96)
MAJOR CATIONS									
Calcium							11	3	31
Magnesium							23	7	54
Sodium			180	[7]	115-230	[3]	283 (982)	31 (28)	551 (1390)
Potassium							7	1	24
HEAVY METALS									
Arsenic	0.0023	[2]	0.007	[6]	0.1	[4]	0.001 (<0.001)	<0.001 (0.002)	0.006 (3)
Cadmium	0.014	[1]	0.002	[6]	0.01	[4]	<0.0001	<0.0001	<0.0001 (0.1)
Chromium	0.0486	[1]	0.05	[6]	0.1	[4]	0.007 (0.004)	<0.001 (0.012)	0.005 (7)
Copper	0.003	[1]	2.0	[6]	0.2	[4]	<0.001 (0.003)	<0.001 (0.003)	0.001 (2)
Lead	0.0066	[1]	0.01	[6]	2.0	[4]	<0.001 (0.002)	<0.001 (0.004)	<0.001 (2)
Zinc	0.023	[1]	3.0	[7]	2.0	[4]	<0.005 (0.008)	0.008 (0.005)	0.016 (7)
NUTRIENTS									
Ammonia as N			0.5	[7]			0.655 (0.51)	0.179 (0.14)	0.893 (1.1)
Nitrite + Nitrate as N							0.037 (0.04)	0.013 (0.01)	0.026 (0.02)
Total Kjeldahl Nitrogen as N					5.0	[4]	7.2 (5.9)	2.5 (2.1)	9.3 (6.4)
Total Phosphorus as P					0.05	[4, 5]	0.79 (<0.01)	0.32 (0.15)	1.12 (0.08)
TOC / BOD									
Total Organic Carbon							189 (29)	56	94 (53)
Biochemical Oxygen Demand							<2 (6)	9 (<2)	<2 (11)

Appendix B

ALS 5 Rosegum Close, Warabrook, NSW 2304. Phone (02) 4968 9433; Facsimile (02 4968 0349. Email Samples.Newcastle@alsenviro.com

CHAIN OF CUSTODY DOCUMENTATION

Australian Laboratory Services Pty Ltd

CLIENT: Coffey Geosciences	SAMPLER: JJT
ADDRESS / OFFICE: Sandgate	MOBILE: 0421 763 913
PROJECT MANAGER (PM): Andrew Fulton	PHONE
PROJECT ID: Myall Quays	EMAIL REPORT TO: andrew_fulton@coffey.com.au
SITE: P.O. NO.:	EMAIL INVOICE TO: (if different to report)
RESULTS REQUIRED (**Date**): standard QUOTE NO.:	**ANALYSIS REQUIRED including SUITES** (note - suite codes must be listed to attract suite prices)

FOR LABORATORY USE ONLY
COOLER SEAL (circle appropriate)
Intact: (Yes) No N/A
SAMPLE TEMPERATURE 3.9°C
CHILLED: (Yes) No

COMMENTS / SPECIAL HANDLING / STORAGE OR DIPOSAL:

Notes: e.g. Highly contaminated samples
e.g. "High PAHs expected".
Extra volume for QC or trace LORs etc.

****Please see note below****

ALS ID	SAMPLE ID	MATRIX	DATE	Time	Type / Code	Total bottles	8 Metals	Ca,Mg, Na, K, Chloride, Sulphate	Total Alkalinity, Total Hardness	Nitrite, Nitrate, Ammonia, TKN	Total Phosphorus	pH, Ec, TDS	TOC	BOD
1	22	H20	29/03/2007				x	x	x	x	x	x	x	x
2	21		29/03/2007				x	x	x	x	x	x	x	x
3	24		29/03/2007				x	x	x	x	x	x	x	x
4	23		29/03/2007				x	x	x	x	x	x	x	x
5	4A		29/03/2007				x	x	x	x	x	x	x	x
6	8		29/03/2007				x	x	x	x	x	x	x	x
7	DUP1		29/03/2007				x	x	x	x	x	x	x	x
	10						Sample not received							
	11						Sample not received							
	5						Sample not received							
8	?1		30/03/2007				x	x	x	x	x	x		
	8#						Sample not received							
	D1						Sample not received							
9	D2		30/03/2007				x	x	x	x	x	x		x
10	POND		30/03/2007				x	x	x			x		x
	Split	▼	30/03/2007				x	x	x	x		x		x

Environmental Division
Sydney
Work Order
ES0704246

Telephone : 61-2-8784 8555

Send to SGS Acknowledged FF

RELINQUISHED BY:		RECEIVED BY		METHOD OF SHIPMENT
Name: Jon Tonks	Date:30/3/07	Name: Ken Reid	Date: 30/3/07	Con' Note No:
Of: Coffeys	Time: 5:52pm	Of: ALS Newcastle	Time: 5:55 pm	
Name: Kate Kelly	Date: 2/4/07	Name: Frank Ferraro	Date: 03/04/07	Transport Co:
Of: ALS Newcastle	Time: 4pm	Of: ALS Sydney	Time: 08:30	

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserveed Plastic; AG = Amber Glass Unpreserved; V = VOA Vial HCl Preserved; VS = VOA Vial Sulphuric Preserved; SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bad for Acid Sulphate Soils; B = Unpreserved Bag.

AUSTRALIAN LABORATORY SERVICES P/L

*** **Please Note:-Modifications made, as per Ross Best (Coffey). 2/4/07, 11:15am. Both verbally and as per attached email. ***

ALS Environmental

CERTIFICATE OF ANALYSIS

Client	: **COFFEY GEOTECHNICS**	*Laboratory*	: **Environmental Division Sydney**	*Page*	: **1 of 7**
Contact	: **MR ANDREW FULTON**	*Contact*	: **Victor Kedicioglu**	*Work Order*	: **ES0704246**
Address	: **13 MANGROVE ROAD SANDGATE NSW AUSTRALIA 2304**	*Address*	: **277-289 Woodpark Road Smithfield NSW Australia 2164**		
E-mail	: **andrew_fulton@coffey.com.au**	*E-mail*	: **Victor.Kedicioglu@alsenviro.com**		
Telephone	: **49676377**	*Telephone*	: **61-2-8784 8555**		
Facsimile	: **49675402**	*Facsimile*	: **61-2-8784 8500**		
Project	: **MYALL QUAYS**	*Quote number*	: **EN/007/07**	*Date received*	: **2 Apr 2007**
Order number	: **- Not provided -**			*Date issued*	: **12 Apr 2007**
C-O-C number	: **- Not provided -**			*No. of samples*	- *Received* : **10**
Site	: **- Not provided -**				*Analysed* : **10**

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This document is issued in accordance with NATA's accreditation requirements.

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This document has been electronically signed by those names that appear on this report and are the authorised signatories. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatory	*Position*	*Department*
Ankit Joshi		**Inorganics - NATA 825 (10911 - Sydney)**
Phyu Phyu Lwin	**Spectroscopist**	**Inorganics - NATA 825 (10911 - Sydney)**

ALS Environmental

Comments

This report for the ALSE reference ES0704246 supersedes any previous reports with this reference. Results apply to the samples as submitted. All pages of this report have been checked and approved for release.

This report contains the following information:

- **Analytical Results for Samples Submitted**
- **Surrogate Recovery Data**

The analytical procedures used by ALS Environmental have been developed from established internationally-recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported herein. Reference methods from which ALSE methods are based are provided in parenthesis.

When moisture determination has been performed, results are reported on a dry weight basis. When a reported 'less than' result is higher than the LOR, this may be due to primary sample extracts/digestion dilution and/or insuffient sample amount for analysis. Surrogate Recovery Limits are static and based on USEPA SW846 or ALS-QWI/EN38 (in the absence of specified USEPA limits). Where LOR of reported result differ from standard LOR, this may be due to high moisture, reduced sample amount or matrix interference. When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for process purposes. Abbreviations: CAS number = Chemical Abstract Services number, LOR = Limit of Reporting. * Indicates failed Surrogate Recoveries.

Specific comments for Work Order **ES0704246**

It has been noted that RP is greater than TP (sample ID D2), however this difference is within the limits of experimental variation.
TDS by method EA-015 may bias high on various sample due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
EK059G: It has been noted that Nitrite is greater than NOx on sample ID (22), however this difference is within the limits of experimental variation.

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Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: 22	21	24	23	4A
Sample Matrix Type / Description:				WATER	WATER	WATER	WATER	WATER
Sample Date / Time:				29 Mar 2007 15:00	29 Mar 2007 15:00	29 Mar 2007 15:00	29 Mar 2007 15:00	29 Mar 2007 15:00
Laboratory Sample ID:				ES0704246-001	ES0704246-002	ES0704246-003	ES0704246-004	ES0704246-005
EA005: pH								
pH Value		0.01	pH Unit	6.05	5.62	5.46	5.60	5.32
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C		1	µS/cm	1610	15500	2730	234	202
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	1350	11500	2250	212	155
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3		1	mg/L	123	2040	300	39	23
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	102	92	26	28	14
Total Alkalinity as CaCO3		1	mg/L	102	92	26	28	14
ED040F: Dissolved Major Anions								
Sulphate as SO4 2-	14808-79-8	1	mg/L	39	702	344	6	10
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1.0	mg/L	430	5300	800	58.7	50.4
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	11	126	31	3	2
Magnesium	7439-95-4	1	mg/L	23	420	54	7	4
Sodium	7440-23-5	1	mg/L	283	2650	551	31	29
Potassium	7440-09-7	1	mg/L	7	65	24	1	<1
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	0.001	0.002	0.006	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	0.007	0.002	0.005	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	0.001	0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	0.003	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.016	0.008	0.085
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.010	mg/L	0.655	0.934	0.893	0.179	0.212
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N		0.010	mg/L	0.087	<0.010	0.013	<0.010	<0.010

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Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: 22	21	24	23	4A
Sample Matrix Type / Description:				WATER	WATER	WATER	WATER	WATER
Sample Date / Time:				29 Mar 2007 15:00	29 Mar 2007 15:00	29 Mar 2007 15:00	29 Mar 2007 15:00	29 Mar 2007 15:00
Laboratory Sample ID:				ES0704246-001	ES0704246-002	ES0704246-003	ES0704246-004	ES0704246-005
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.010	mg/L	<0.010	0.027	0.013	0.013	0.034
EK059G: NOX as N by Discrete Analyser								
Nitrite + Nitrate as N		0.010	mg/L	0.037	0.027	0.026	0.013	0.034
EK061: Total Kjeldahl Nitrogen (TKN)								
Total Kjeldahl Nitrogen as N		0.1	mg/L	7.2	12.1	9.3	2.5	0.9
EK067G: Total Phosphorous-As P by Discrete Analyser								
Total Phosphorus as P		0.01	mg/L	0.79	1.38	1.12	0.32	0.14
EK071G: Reactive Phosphorous as P by discrete analyser								
Reactive Phosphorus as P		0.010	mg/L	0.095	0.035	0.062	----	0.017
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon		1	mg/L	189	109	94	56	16
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand		2	mg/L	<2	<2	<2	9	9

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Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: 8 Sample Matrix Type / Description: WATER Sample Date / Time: 29 Mar 2007 15:00 Laboratory Sample ID: ES0704246-006	DUP1 WATER 29 Mar 2007 15:00 ES0704246-007	?1 WATER 30 Mar 2007 15:00 ES0704246-008	D2 WATER 30 Mar 2007 15:00 ES0704246-009	POND WATER 30 Mar 2007 15:00 ES0704246-010
EA005: pH								
pH Value		0.01	pH Unit	5.02	5.53	3.99	3.86	5.83
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C		1	µS/cm	268	15500	2730	169	182
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	1	mg/L	1210	9700	200	195	129
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3		1	mg/L	29	2070	14	13	33
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	6	96	26	<1	23
Total Alkalinity as CaCO3		1	mg/L	6	96	26	<1	23
ED040F: Dissolved Major Anions								
Sulphate as SO4 2-	14808-79-8	1	mg/L	22	701	13	10	12
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1.0	mg/L	64.6	5180	34.4	33.7	37.4
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	2	127	<1	<1	8
Magnesium	7439-95-4	1	mg/L	6	427	3	3	3
Sodium	7440-23-5	1	mg/L	39	2670	15	14	22
Potassium	7440-09-7	1	mg/L	4	66	4	4	2
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	0.002	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	0.001	<0.001	0.001	0.005
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.001
Zinc	7440-66-6	0.005	mg/L	0.009	<0.005	0.017	0.032	0.029
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.010	mg/L	0.303	1.14	0.545	0.541	<0.010
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N		0.010	mg/L	0.027	<0.010	0.028	0.027	<0.010

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Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: 8	DUP1	?1	D2	POND
Sample Matrix Type / Description				WATER	WATER	WATER	WATER	WATER
Sample Date / Time				29 Mar 2007 15:00	29 Mar 2007 15:00	30 Mar 2007 15:00	30 Mar 2007 15:00	30 Mar 2007 15:00
Laboratory Sample ID				ES0704246-006	ES0704246-007	ES0704246-008	ES0704246-009	ES0704246-010
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.010	mg/L	0.039	0.011	<0.010	0.013	0.020
EK059G: NOX as N by Discrete Analyser								
Nitrite + Nitrate as N		0.010	mg/L	0.066	0.011	0.034	0.040	0.020
EK061: Total Kjeldahl Nitrogen (TKN)								
Total Kjeldahl Nitrogen as N		0.1	mg/L	3.0	11.2	2.5	3.8	0.7
EK067G: Total Phosphorous-As P by Discrete Analyser								
Total Phosphorus as P		0.01	mg/L	0.76	1.33	1.00	1.10	0.08
EK071G: Reactive Phosphorous as P by discrete analyser								
Reactive Phosphorus as P		0.010	mg/L	0.036	0.016	0.799	1.12	<0.010
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon		1	mg/L	22	110	----	----	----
EP030: Biochemical Oxygen Demand (BOD)								
Biochemical Oxygen Demand		2	mg/L	<2	<2	----	6	5

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Surrogate Control Limits

- **No surrogates present on this report.**

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QUALITY CONTROL REPORT

Client	:	**COFFEY GEOTECHNICS**	**Laboratory**	: Environmental Division Sydney	**Page**	:	**1 of 11**
Contact	:	MR ANDREW FULTON	**Contact**	: Victor Kedicioglu			
Address	:	13 MANGROVE ROAD SANDGATE NSW AUSTRALIA 2304	**Address**	: 277-289 Woodpark Road Smithfield NSW Australia 2164	**Work order**	:	**ES0704246**
					Amendment No.	:	
Project	:	MYALL QUAYS	**Quote number**	: EN/007/07	**Date received**	:	**2 Apr 2007**
Order number	:	- Not provided -			**Date issued**	:	**12 Apr 2007**
C-O-C number	:	- Not provided -					
Site	:	- Not provided -					
E-mail	:	andrew_fulton@coffey.com.au	**E-mail**	: Victor.Kedicioglu@alsenviro.com	**No. of samples**		
Telephone	:	49676377	**Telephone**	: 61-2-8784 8555	**Received**	:	10
Facsimile	:	49675402	**Facsimile**	: 61-2-8784 8500	**Analysed**	:	10

This final report for the ALSE work order reference ES0704246 supersedes any previous reports with this reference.

Results apply to the samples as submitted. All pages of this report have been checked and approved for release.

This report contains the following information:

- Laboratory Duplicates (DUP); Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Samples (LCS); Recovery and Acceptance Limits
- Matrix Spikes (MS); Recovery and Acceptance Limits

Work order specific comments

TDS by method EA-015 may bias high on various sample due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
EK059G: It has been noted that Nitrite is greater than NOx on sample ID (22), however this difference is within the limits of experimental variation.
It has been noted that RP is greater than TP (sample ID D2), however this difference is within the limits of experimental variation.

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Accredited for compliance with ISO/IED 17025

This document has been electronically signed by those names that appear on this report and are the authorised signatories. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatory	Department
Ankit Joshi	Inorganics - NATA 825 (10911 - Sydney)
Phyu Phyu Lwin	Inorganics - NATA 825 (10911 - Sydney)

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Quality Control Report - Laboratory Duplicates (DUP)

The quality control term **Laboratory Duplicate** refers to an intralaboratory split sample randomly selected from the sample batch. Laboratory duplicates provide information on method precision and sample heterogeneity.
- Anonymous - Client Sample IDs refer to samples which are not specifically part of this work order but formed part of the QC process lot. *Abbreviations:* ***LOR*** = *Limit of Reporting,* ***RPD*** = *Relative Percent Difference.*
* Indicates failed QC. The permitted ranges for the RPD of Laboratory Duplicates (relative percent deviation) are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting:- Result < 10 times LOR, no limit - Result between 10 and 20 times LOR, 0% - 50% - Result > 20 times LOR, 0% - 20%

Matrix Type: WATER ***Laboratory Duplicates (DUP) Report***

Laboratory Sample ID	*Client Sample ID*	*Analyte name*	*LOR*	*Original Result*	*Duplicate Result*	*RPD*
EA005: pH						
EA005: pH - (QC Lot: 385626)				**pH Unit**	**pH Unit**	**%**
ES0704246-001	22	pH Value	0.01 pH Unit	6.05	6.05	0.0
ES0704246-010	POND	pH Value	0.01 pH Unit	5.83	5.86	0.5
EA010P: Conductivity by PC Titrator						
EA010P: Conductivity by PC Titrator - (QC Lot: 385345)				**µS/cm**	**µS/cm**	**%**
ES0704246-001	22	Electrical Conductivity @ 25°C	1 µS/cm	1610	1580	2.0
ES0704252-001	Anonymous	Electrical Conductivity @ 25°C	1 µS/cm	22400	22300	0.4
EA015: Total Dissolved Solids						
EA015: Total Dissolved Solids - (QC Lot: 385565)				**mg/L**	**mg/L**	**%**
ES0704217-001	Anonymous	Total Dissolved Solids @180°C	1 mg/L	7890	7720	2.2
ES0704229-006	Anonymous	Total Dissolved Solids @180°C	1 mg/L	500	508	1.6
ED037P: Alkalinity by PC Titrator						
ED037P: Alkalinity by PC Titrator - (QC Lot: 385344)				**mg/L**	**mg/L**	**%**
ES0704246-001	22	Hydroxide Alkalinity as CaCO3	1 mg/L	<1	<1	0.0
		Carbonate Alkalinity as CaCO3	1 mg/L	<1	<1	0.0
		Bicarbonate Alkalinity as CaCO3	1 mg/L	102	102	0.0
		Total Alkalinity as CaCO3	1 mg/L	102	102	0.0
ES0704252-001	Anonymous	Hydroxide Alkalinity as CaCO3	1 mg/L	<1	<1	0.0
		Carbonate Alkalinity as CaCO3	1 mg/L	<1	<1	0.0
		Bicarbonate Alkalinity as CaCO3	1 mg/L	<1	<1	0.0
		Total Alkalinity as CaCO3	1 mg/L	<1	<1	0.0
ED040F: Dissolved Major Anions						
ED040F: Dissolved Major Anions - (QC Lot: 386020)				**mg/L**	**mg/L**	**%**
ES0704246-001	22	Sulphate as SO4 2-	1 mg/L	39	40	0.0
ED045G: Chloride Discrete analyser						
ED045G: Chloride Discrete analyser - (QC Lot: 386094)				**mg/L**	**mg/L**	**%**

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Matrix Type: WATER

Laboratory Duplicates (DUP) Report

Laboratory Sample ID	Client Sample ID	Analyte name	LOR	Original Result	Duplicate Result	RPD
ED045G: Chloride Discrete analyser - continued						
ED045G: Chloride Discrete analyser - (QC Lot: 386094) - continued				mg/L	mg/L	%
ES0704246-001	22	Chloride	1.0 mg/L	430	436	1.4
ES0704246-008	?1	Chloride	1.0 mg/L	34.4	33.9	1.5
ED093F: Dissolved Major Cations						
ED093F: Dissolved Major Cations - (QC Lot: 386021)				mg/L	mg/L	%
ES0704246-001	22	Calcium	1 mg/L	11	11	0.0
		Magnesium	1 mg/L	23	24	0.0
		Sodium	1 mg/L	283	285	0.6
		Potassium	1 mg/L	7	7	0.0
ES0704314-001	Anonymous	Calcium	1 mg/L	3	3	0.0
		Magnesium	1 mg/L	62	63	2.3
		Sodium	1 mg/L	779	746	4.3
		Potassium	1 mg/L	<1	<1	0.0
EG020F: Dissolved Metals by ICP-MS						
EG020F: Dissolved Metals by ICP-MS - (QC Lot: 385229)				mg/L	mg/L	%
ES0704242-001	Anonymous	Arsenic	0.001 mg/L	<0.001	<0.001	0.0
		Cadmium	0.0001 mg/L	<0.0001	<0.0001	0.0
		Chromium	0.001 mg/L	<0.001	<0.001	0.0
		Copper	0.001 mg/L	0.001	<0.001	0.0
		Lead	0.001 mg/L	<0.001	<0.001	0.0
		Nickel	0.001 mg/L	<0.001	<0.001	0.0
		Zinc	0.005 mg/L	0.014	0.014	0.0
ES0704246-002	21	Arsenic	0.001 mg/L	0.002	<0.001	0.0
		Cadmium	0.0001 mg/L	<0.0001	<0.0001	0.0
		Chromium	0.001 mg/L	0.002	0.002	0.0
		Copper	0.001 mg/L	0.001	0.001	0.0
		Lead	0.001 mg/L	<0.001	<0.001	0.0
		Nickel	0.001 mg/L	<0.001	<0.001	0.0
		Zinc	0.005 mg/L	<0.005	<0.005	0.0
EG035F: Dissolved Mercury by FIMS						

Matrix Type: WATER

Laboratory Duplicates (DUP) Report

Laboratory Sample ID	Client Sample ID	Analyte name	LOR	Original Result	Duplicate Result	RPD
EG035F: Dissolved Mercury by FIMS - continued						
EG035F: Dissolved Mercury by FIMS - (QC Lot: 385598)				mg/L	mg/L	%
ES0704246-001	22	Mercury	0.0001 mg/L	<0.0001	<0.0001	0.0
ES0704289-004	Anonymous	Mercury	0.0001 mg/L	<0.0001	<0.0001	0.0
EK055G: Ammonia as N by Discrete Analyser						
EK055G: Ammonia as N by Discrete Analyser - (QC Lot: 386879)				mg/L	mg/L	%
ES0704246-001	22	Ammonia as N	0.010 mg/L	0.655	0.670	2.3
ES0704246-010	POND	Ammonia as N	0.010 mg/L	<0.010	<0.010	0.0
EK057G: Nitrite as N by Discrete Analyser						
EK057G: Nitrite as N by Discrete Analyser - (QC Lot: 385367)				mg/L	mg/L	%
ES0704246-002	21	Nitrite as N	0.010 mg/L	<0.010	<0.010	0.0
ES0704246-010	POND	Nitrite as N	0.010 mg/L	<0.010	<0.010	0.0
EK059G: NOX as N by Discrete Analyser						
EK059G: NOX as N by Discrete Analyser - (QC Lot: 386091)				mg/L	mg/L	%
ES0704246-001	22	Nitrite + Nitrate as N	0.010 mg/L	0.037	0.036	2.7
ES0704246-010	POND	Nitrite + Nitrate as N	0.010 mg/L	0.020	0.019	5.1
EK061: Total Kjeldahl Nitrogen (TKN)						
EK061: Total Kjeldahl Nitrogen (TKN) - (QC Lot: 387458)				mg/L	mg/L	%
ES0704246-001	22	Total Kjeldahl Nitrogen as N	0.1 mg/L	7.2	6.4	11.7
ES0704246-010	POND	Total Kjeldahl Nitrogen as N	0.1 mg/L	0.7	0.7	0.0
EK067G: Total Phosphorous-As P by Discrete Analyser						
EK067G: Total Phosphorous-As P by Discrete Analyser - (QC Lot: 387459)				mg/L	mg/L	%
ES0704246-001	22	Total Phosphorus as P	0.01 mg/L	0.79	0.76	3.9
ES0704246-010	POND	Total Phosphorus as P	0.01 mg/L	0.08	0.03	85.7
EK071G: Reactive Phosphorous as P by discrete analyser						
EK071G: Reactive Phosphorous as P by discrete analyser - (QC Lot: 385204)				mg/L	mg/L	%
ES0704246-001	22	Reactive Phosphorus as P	0.010 mg/L	0.095	0.111	15.5
EP005: Total Organic Carbon (TOC)						
EP005: Total Organic Carbon (TOC) - (QC Lot: 385545)				mg/L	mg/L	%
ES0704203-004	Anonymous	Total Organic Carbon	1 mg/L	20	20	0.0
ES0704252-001	Anonymous	Total Organic Carbon	1 mg/L	4	3	0.0

Matrix Type: WATER

Laboratory Duplicates (DUP) Report

Laboratory Sample ID	*Client Sample ID*	*Analyte name*	*LOR*	*Original Result*	*Duplicate Result*	*RPD*
EP030: Biochemical Oxygen Demand (BOD)						
EP030: Biochemical Oxygen Demand (BOD) - (QC Lot: 385733)				**mg/L**	**mg/L**	**%**
EB0703652-001	Anonymous	Biochemical Oxygen Demand	2 mg/L	6	6	0.0
EB0703660-015	Anonymous	Biochemical Oxygen Demand	2 mg/L	23	19	19.0
EP030: Biochemical Oxygen Demand (BOD) - (QC Lot: 385734)				**mg/L**	**mg/L**	**%**
EB0703640-001	Anonymous	Biochemical Oxygen Demand	2 mg/L	3850	3640	5.5
ES0704278-001	Anonymous	Biochemical Oxygen Demand	2 mg/L	1740	1840	5.8

ALS Environmental

Quality Control Report - Method Blank (MB) and Laboratory Control Samples (LCS)

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC type is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a known, interference free matrix spiked with target analytes or certified reference material. The purpose of this QC type is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of actual laboratory data. Flagged outliers on control limits for inorganics tests may be within the NEPM specified data quality objective of recoveries in the range of 70 to 130%. Where this occurs, no corrective action is taken. Abbreviations: LOR = Limit of reporting.

Matrix Type: WATER

Method Blank (MB) and Laboratory Control Samples (LCS) Report

Analyte name	*LOR*	*Method blank result*	*Actual Results*		*Recovery Limits*	
			Spike concentration	*Spike Recovery*	*Dynamic Recovery Limits*	
				LCS	*Low*	*High*
EA010P: Conductivity by PC Titrator						
EA010P: Conductivity by PC Titrator - (QC Lot: 385345)		µS/cm	µS/cm	%	%	%
Electrical Conductivity @ 25°C	1 µS/cm	----	2000	101	86.3	112
	1 µS/cm	<1	----	----	----	----
EA015: Total Dissolved Solids						
EA015: Total Dissolved Solids - (QC Lot: 385565)		mg/L	mg/L	%	%	%
Total Dissolved Solids @180°C	1 mg/L	----	293	107	77.9	122
	1 mg/L	<1	----	----	----	----
ED037P: Alkalinity by PC Titrator						
ED037P: Alkalinity by PC Titrator - (QC Lot: 385344)		mg/L	mg/L	%	%	%
Total Alkalinity as CaCO3	1 mg/L	----	200	91.6	80.2	108
ED040F: Dissolved Major Anions						
ED040F: Dissolved Major Anions - (QC Lot: 386020)		mg/L	mg/L	%	%	%
Sulphate as SO4 2-	1 mg/L	<1	1	----	----	----
	1 mg/L	----	150	93.4	82.9	114
ED045G: Chloride Discrete analyser						
ED045G: Chloride Discrete analyser - (QC Lot: 386094)		mg/L	mg/L	%	%	%
Chloride	1 mg/L	----	50	104	83.7	124
	1 mg/L	----	250	96.0	83.7	124
	1.0 mg/L	<1.0	----	----	----	----
ED093F: Dissolved Major Cations						
ED093F: Dissolved Major Cations - (QC Lot: 386021)		mg/L	mg/L	%	%	%
Calcium	1 mg/L	<1	----	----	----	----
	1 mg/L	----	50	92.9	82.9	121

Matrix Type: WATER

Method Blank (MB) and Laboratory Control Samples (LCS) Report

Analyte name	*LOR*	*Method blank result*	*Actual Results*		*Recovery Limits*	
			Spike concentration	*Spike Recovery*	*Dynamic Recovery Limits*	
				LCS	*Low*	*High*
ED093F: Dissolved Major Cations - continued						
ED093F: Dissolved Major Cations - (QC Lot: 386021) - continued		mg/L	mg/L	%	%	%
Magnesium	1 mg/L	----	50	96.1	82.7	114
	1 mg/L	<1	----	----	----	----
Potassium	1 mg/L	----	50	94.5	84.3	118
	1 mg/L	<1	----	----	----	----
Sodium	1 mg/L	<1	----	----	----	----
	1 mg/L	----	50	92.1	77.4	113
EG020F: Dissolved Metals by ICP-MS						
EG020F: Dissolved Metals by ICP-MS - (QC Lot: 385229)		mg/L	mg/L	%	%	%
Arsenic	0.001 mg/L	<0.001	----	----	----	----
	0.001 mg/L	----	0.1	94.6	70	130
Cadmium	0.0001 mg/L	----	0.1	92.3	70	130
	0.0001 mg/L	<0.0001	----	----	----	----
Chromium	0.001 mg/L	----	0.1	96.4	70	130
	0.001 mg/L	<0.001	----	----	----	----
Copper	0.001 mg/L	----	0.1	91.7	70	130
	0.001 mg/L	<0.001	----	----	----	----
Lead	0.001 mg/L	<0.001	----	----	----	----
	0.001 mg/L	----	0.1	94.3	70	130
Nickel	0.001 mg/L	----	0.1	91.9	70	130
	0.001 mg/L	<0.001	----	----	----	----
Zinc	0.005 mg/L	----	0.1	101	70	130
	0.005 mg/L	<0.005	----	----	----	----
EG035F: Dissolved Mercury by FIMS						
EG035F: Dissolved Mercury by FIMS - (QC Lot: 385598)		mg/L	mg/L	%	%	%
Mercury	0.0001 mg/L	<0.0001	----	----	----	----
	0.0001 mg/L	----	0.010	115	80.5	117
EK055G: Ammonia as N by Discrete Analyser						
EK055G: Ammonia as N by Discrete Analyser - (QC Lot: 386879)		mg/L	mg/L	%	%	%

ALS Environmental

Matrix Type: WATER

Method Blank (MB) and Laboratory Control Samples (LCS) Report

Analyte name	LOR	Method blank result	Actual Results: Spike concentration	Actual Results: Spike Recovery LCS	Recovery Limits: Dynamic Recovery Limits Low	Recovery Limits: Dynamic Recovery Limits High
EK055G: Ammonia as N by Discrete Analyser - continued						
EK055G: Ammonia as N by Discrete Analyser - (QC Lot: 386879) - continued		mg/L	mg/L	%	%	%
Ammonia as N	0.01 mg/L	----	1.00	105	75.6	128
	0.010 mg/L	<0.010	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser						
EK057G: Nitrite as N by Discrete Analyser - (QC Lot: 385367)		mg/L	mg/L	%	%	%
Nitrite as N	0.010 mg/L	<0.010	----	----	----	----
	0.01 mg/L	----	0.96	102	66.6	131
EK059G: NOX as N by Discrete Analyser						
EK059G: NOX as N by Discrete Analyser - (QC Lot: 386091)		mg/L	mg/L	%	%	%
Nitrite + Nitrate as N	0.010 mg/L	<0.010	----	----	----	----
	0.01 mg/L	----	0.96	94.3	76.9	122
EK061: Total Kjeldahl Nitrogen (TKN)						
EK061: Total Kjeldahl Nitrogen (TKN) - (QC Lot: 387458)		mg/L	mg/L	%	%	%
Total Kjeldahl Nitrogen as N	0.1 mg/L	----	10	98.2	62.4	140
	0.1 mg/L	<0.1	----	----	----	----
EK067G: Total Phosphorous-As P by Discrete Analyser						
EK067G: Total Phosphorous-As P by Discrete Analyser - (QC Lot: 387459)		mg/L	mg/L	%	%	%
Total Phosphorus as P	0.01 mg/L	<0.01	----	----	----	----
	0.01 mg/L	----	4.42	90.3	64.3	120
EK071G: Reactive Phosphorous as P by discrete analyser						
EK071G: Reactive Phosphorous as P by discrete analyser - (QC Lot: 385204)		mg/L	mg/L	%	%	%
Reactive Phosphorus as P	0.010 mg/L	<0.010	----	----	----	----
	0.01 mg/L	----	0.50	102	83.8	122
EP005: Total Organic Carbon (TOC)						
EP005: Total Organic Carbon (TOC) - (QC Lot: 385545)		mg/L	mg/L	%	%	%
Total Organic Carbon	1 mg/L	----	10	92.2	86.9	125
	1 mg/L	<1	----	----	----	----
EP030: Biochemical Oxygen Demand (BOD)						

Matrix Type: WATER

Method Blank (MB) and Laboratory Control Samples (LCS) Report

Analyte name	*LOR*	*Method blank result*	*Actual Results*		*Recovery Limits*	
			Spike concentration	*Spike Recovery*	*Dynamic Recovery Limits*	
				LCS	*Low*	*High*
EP030: Biochemical Oxygen Demand (BOD) - continued						
EP030: Biochemical Oxygen Demand (BOD) - (QC Lot: 385733)		mg/L	mg/L	%	%	%
Biochemical Oxygen Demand	2 mg/L	<2	----	----	----	----
	2 mg/L	----	200	99.5	66.8	112
EP030: Biochemical Oxygen Demand (BOD) - (QC Lot: 385734)		mg/L	mg/L	%	%	%
Biochemical Oxygen Demand	2 mg/L	<2	----	----	----	----
	2 mg/L	----	200	96.0	66.8	112

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Quality Control Report - Matrix Spikes (MS)

The quality control term **Matrix Spike (MS)** refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC type is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQO's). 'Ideal' recovery ranges stated may be waived in the event of sample matrix interferences. - Anonymous - Client Sample IDs refer to samples which are not specifically part of this work order but formed part of the QC process lot. *Abbreviations:* ***LOR*** *= Limit of Reporting,* ***RPD*** *= Relative Percent Difference.*

* Indicates failed QC

Matrix Type: WATER

Matrix Spike (MS) Report

					Actual Results		*Recovery Limits*	
					Sample Result	*Spike Recovery*	*Static Limits*	
Analyte name	*Laboratory Sample ID*	*Client Sample ID*	*LOR*	*Spike Concentration*		*MS*	*Low*	*High*
ED045G: Chloride Discrete analyser								
ED045G: Chloride Discrete analyser - (QC Lot: 386094)				mg/L	mg/L	%	%	%
Chloride	ES0704246-001	22	1 mg/L	250	430	125	70	130
EG020F: Dissolved Metals by ICP-MS								
EG020F: Dissolved Metals by ICP-MS - (QC Lot: 385229)				mg/L	mg/L	%	%	%
Arsenic	ES0704242-001	Anonymous	0.001 mg/L	0.2	<0.001	98.1	70	130
Cadmium			0.0001 mg/L	0.05	<0.0001	98.4	70	130
Chromium			0.001 mg/L	0.2	<0.001	94.9	70	130
Copper			0.001 mg/L	0.2	0.001	95.4	70	130
Lead			0.001 mg/L	0.2	<0.001	100	70	130
Nickel			0.001 mg/L	0.2	<0.001	96.8	70	130
Zinc			0.005 mg/L	0.2	0.014	104	70	130
EG035F: Dissolved Mercury by FIMS								
EG035F: Dissolved Mercury by FIMS - (QC Lot: 385598)				mg/L	mg/L	%	%	%
Mercury	ES0704246-001	22	0.0001 mg/L	0.0100	<0.0001	116	70	130
EK055G: Ammonia as N by Discrete Analyser								
EK055G: Ammonia as N by Discrete Analyser - (QC Lot: 386879)				mg/L	mg/L	%	%	%
Ammonia as N	ES0704246-001	22	0.01 mg/L	1.00	0.655	93.3	70	130
EK057G: Nitrite as N by Discrete Analyser								
EK057G: Nitrite as N by Discrete Analyser - (QC Lot: 385367)				mg/L	mg/L	%	%	%
Nitrite as N	ES0704246-002	21	0.01 mg/L	0.60	<0.010	102	70	130
EK059G: NOX as N by Discrete Analyser								
EK059G: NOX as N by Discrete Analyser - (QC Lot: 386091)				mg/L	mg/L	%	%	%
Nitrite + Nitrate as N	ES0704246-001	22	0.01 mg/L	0.60	0.037	92.3	70	130
EK061: Total Kjeldahl Nitrogen (TKN)								

ALS Environmental

Matrix Type: WATER

Matrix Spike (MS) Report

					Actual Results		Recovery Limits	
					Sample Result	Spike Recovery	Static Limits	
Analyte name	*Laboratory Sample ID*	*Client Sample ID*	*LOR*	*Spike Concentration*		*MS*	*Low*	*High*
EK061: Total Kjeldahl Nitrogen (TKN) - continued								
EK061: Total Kjeldahl Nitrogen (TKN) - (QC Lot: 387458)				mg/L	mg/L	%	%	%
Total Kjeldahl Nitrogen as N	ES0704246-001	22	0.1 mg/L	25	7.2	100	70	130
EK067G: Total Phosphorous-As P by Discrete Analyser								
EK067G: Total Phosphorous-As P by Discrete Analyser - (QC Lot: 387459)				mg/L	mg/L	%	%	%
Total Phosphorus as P	ES0704246-001	22	0.01 mg/L	5	0.79	75.3	70	130
EK071G: Reactive Phosphorous as P by discrete analyser								
EK071G: Reactive Phosphorous as P by discrete analyser - (QC Lot: 385204)				mg/L	mg/L	%	%	%
Reactive Phosphorus as P	ES0704246-001	22	0.01 mg/L	0.50	0.095	101	70	130
EP005: Total Organic Carbon (TOC)								
EP005: Total Organic Carbon (TOC) - (QC Lot: 385545)				mg/L	mg/L	%	%	%
Total Organic Carbon	ES0704203-004	Anonymous	1 mg/L	100	20	94.9	70	130

17 May 2007 **TEST REPORT**

Coffey Environments Pty Ltd
8/12 Mars Road
LANE COVE WEST
NSW 2066

Your Reference: GEOTLCOV23225AA
Report Number: 52430

Attention: Jessica Northey

Dear Jessica
The following samples were received from you on the date indicated.

Samples: Qty.	6 Soils, 1 Water
Date of Receipt of Samples:	08/05/07
Date of Receipt of Instructions:	08/05/07
Date Preliminary Report Emailed:	Not Issued

These samples were analysed in accordance with your written instructions.
A copy of the instructions is attached with the analytical report.

The results and associated quality control are contained in the following pages of this report. Unless otherwise stated, solid samples are expressed on a dry weight basis (moisture has been supplied for your information only), air and liquid samples as received.

Should you have any queries regarding this report please contact the undersigned.

Yours faithfully
SGS ENVIRONMENTAL SERVICES

Ly Kim Ha
Senior Organic Chemist

Edward Ibrahim
Laboratory Services Manager

Alexandra Stenta
Key Account Representative

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SGS Australia Pty Ltd
ABN 44 000 964 278
Environmental Services Unit 16, 33 Maddox Street, Alexandria Australia
t (02) 8594 0400 f (02) 8594 0499
www.au.sgs.com
Member of the SGS Group

Inorganics Our Reference: Your Reference Sample Type Depth Date Sampled	UNITS ---------- ----------	52430-7 NUTRIENT WATER Water -
pH	pH Units	6.6
Nitrate as N	mg/L	4.7
Total Phosphorus as P	mg/L	2.5

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ASLP by client requested water						
Our Reference:	UNITS	52430-1	52430-2	52430-3	52430-4	52430-5
Your Reference	----------	HA1	HA1	HA2	HA2	HA3
Sample Type	----------	Soil	Soil	Soil	Soil	Soil
Depth		0.0-0.1	0.4-0.5	0.0-0.1	0.4-0.5	0.0-0.1
Date Sampled		30/03/2007	30/03/2007	30/03/2007	30/03/2007	30/03/2007
pH of final Leachate	pH units	5.40	5.30	4.90	5.60	5.30
Nitrate as N (in leachate)	mg/L	5.0	4.8	5.3	5.0	4.6
Total Phosphorus as P (in leachate)	mg/L	<0.10	0.80	<0.10	0.50	<0.10

ASLP by client requested water		
Our Reference:	UNITS	52430-6
Your Reference	----------	HA3
Sample Type	----------	Soil
Depth		0.4-0.5
Date Sampled		30/03/2007
pH of final Leachate	pH units	5.00
Nitrate as N (in leachate)	mg/L	4.6
Total Phosphorus as P (in leachate)	mg/L	<0.10

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Method ID	Methodology Summary
AN101	pH - Measured using pH meter and electrode in accordance with APHA 20th ED, 4500-H+.
SEI-038	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA 20th ED, 4110-B.
SEI-067	Total Phosphorus - Jirka modification, followed by colorimetric determination using an Ascorbic Acid method, in accordance with APHA 20th ED, 4500-P-F. Analysis is carried out by SGS Environmental Services Welshpool.
SEP-003	Toxicity Characteristic Leaching Procedure (TCLP) and AS Bottle leach procedure.

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QUALITY CONTROL Inorganics	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
pH	pH Units		AN101	[NT]	[NT]	[NT]	[NR]	[NR]
Nitrate as N	mg/L	0.05	SEI-038	<0.05	[NT]	[NT]	LCS	101 || [N/T]
Total Phosphorus as P	mg/L	0.1	SEI-067	<0.10	[NT]	[NT]	LCS	94 || [N/T]
QUALITY CONTROL ASLP by client requested water	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
pH of final Leachate	pH units		SEP-003	[NT]	52430-1	5.40 || 5.30 || RPD: 2	[NR]	[NR]
Nitrate as N (in leachate)	mg/L	0.05	SEI-038	<0.05	52430-1	5.0 || 5.0 || RPD: 0	LCS	101 || [N/T]
Total Phosphorus as P (in leachate)	mg/L	0.1	SEI-067	<0.10	52430-1	<0.10 || [N/T]	LCS	94 || [N/T]

QUALITY CONTROL ASLP by client requested water	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
pH of final Leachate	pH units	[NT]	[NT]	[NR]	[NR]
Nitrate as N (in leachate)	mg/L	[NT]	[NT]	52430-2	99 || [N/T]
Total Phosphorus as P (in leachate)	mg/L	[NT]	[NT]	[NR]	[NR]

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Result Codes

[INS]	:	Insufficient Sample for this test	[HBG]	:	Results not Reported due to High Background Interference
[NR]	:	Not Requested	*	:	Not part of NATA Accreditation
[NT]	:	Not tested	[N/A]	:	Not Applicable

Result Comments

Date Organics extraction commenced: N/A
NATA Corporate Accreditation No. 2562, Site No 4354
Note: Test results are not corrected for recovery (excluding Dioxins/Furans* and PAH in XAD and PUF).
This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

Quality Control Protocol

Reagent Blank: Sample free reagents carried through the preparation/extraction/digestion procedure and analysed at the beginning of every sample batch analysis. For larger projects, a reagent blank is prepared and analysed with every 20 samples.
Duplicate: A separate portion of a sample being analysed which is treated the same as the other samples in the batch. A duplicate is prepared at least every 10 samples.
Matrix Spike Duplicates: Sample replicates spiked with identical concentrations of target analyte(s). The spiking occurs during the sample preparation and prior to the extraction/digestion procedure. They are used to document the precision and bias of a method in a given sample matrix. Where there is not enough sample available to prepare a spiked sample, another known soil/sand or water (or Milli-Q water) may be used. A duplicate spiked sample is prepared at least every 20 samples.
Surrogate Spike: Added to all samples requiring analysis for organics (where relevant) prior to extraction. Used to determine the extraction efficiency. They are organic compounds which are similar to the target analyte(s) in chemical composition and behaviour in the analytical process, but which are not normally found in environmental samples.
Internal Standard: Added to all samples requiring analysis for organics (where relevant) after the extraction process; the compounds serve to give a standard of retention time and response, which is invariant from run-to-run with the instruments.
Control Standards: Prepared from a source independent of the calibration standards. At least one control standard is included in each run to confirm calibration validity.
Additional QC Samples: A calibration standard and blank are run after every 20 samples of an instrumental analysis run to assess analytical drift.

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coffey

Chain of Custody

No: 0225

Laboratory Quotation / Order No: 0225

Job No: GEOTLCOV23225AA Sheet 1 of 1

Dispatch to: SGS ENVIRONMENTAL SERVICES (Address & Phone No.) 16/33 Maddox St Alexandria 2015 ph 8594 0400	Sampled by: Jonathan Parks	Consigning Officer: LANE COVE WEST Date Dispatched: ph 9911 1099
Attention: Alex Steele	Project Manager: (report results to) JESSICA NORTHEY / ANDREW FULTON	Courier Service: Consignment Note No:

Relinquished by:	Date:	Time:	Received by:	Date:	Time:
K Ramsay	8/5/07	8.45am	X Jan Robson #112	8/5/07	8.45am

Comments	Sample Matrix	Container Type and Preservative	Sample No.	Date Sampled	Analyses Required: PAHs	TPHs	MAHs = BTEX	Metals:	ASLP with nutrient water	+NO3, pH, total phosphorus	pH	NO3	Total P	Sample Condition on Receipt
	SOIL	250ml glass jar 1	HA1 0.0-0.1	30/3/07					X					
		2	HA1 0.4-0.5						X					
		3	HA2 0.0-0.1						X					
		4	HA2 0.4-0.5						X					
		5	HA3 0.0-0.1						X					
		6	HA3 0.4-0.5						X					
	WATER	N/A 7	NUTRIENT WATER	N/A							X	X	X	

SGS
Received 8/5/07
By Cheryl
Time 10:55 am/pm
Sample Intact yes/no
Ice/Cooler Pack yes/no
Comments 52430

Special Laboratory Instructions: Please do ASLP with nutrient water (manufactured by SGS) & analyse nutrient water + leachate for pH, NO_3 & total P.

Detection Limits: P: 0.1 mg/L, others STANDARD

Turnaround Required: STANDARD - 7 days

JOB NUMBER **MUST** BE REFERENCED ON ALL SUBSEQUENT PAGES

64220/9-06

Copies: **WHITE:** Sign on release. **YELLOW:** If dispatched to interstate Lab, Lab to sign on receipt and fax back to Coffey. **BLUE:** To be returned with results.

Appendix C

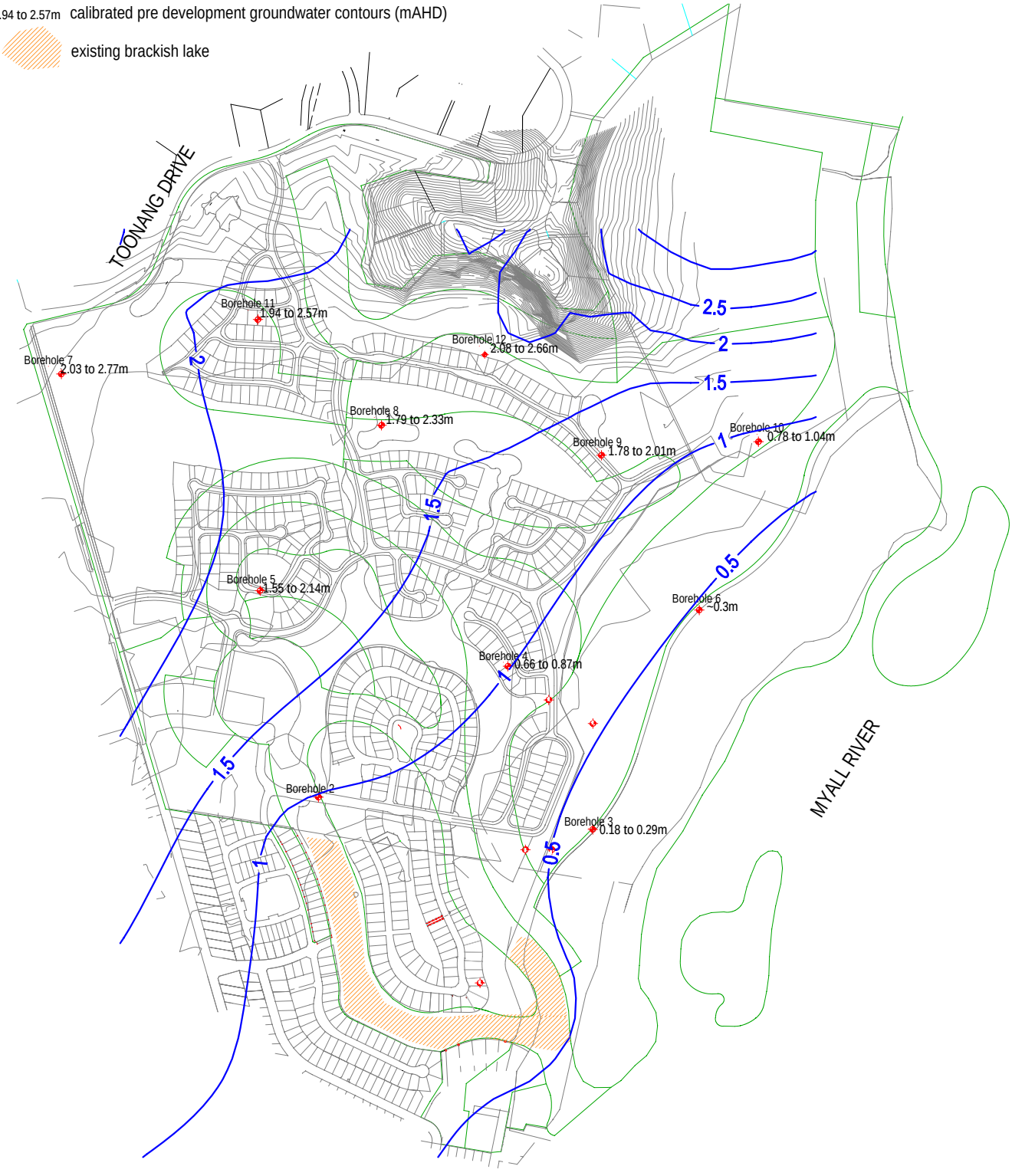
NORTH

LEGEND:

2 calibrated pre development groundwater contours (mAHD)

1.94 to 2.57m calibrated pre development groundwater contours (mAHD)

existing brackish lake



Coffey Geotechnics Pty Ltd		Geotechnical I Resources I Environmental I Technical I Project Management	
Drawn	EW	CRIGHTON PROPERTIES	Appendix D
Approved	RJB	GROUNDWATER ASSESSMENT	
Date	23/12/2004	MYALL QUAYS DEVELOPMENTS	
Scale	1:12500	CALIBRATED GROUNDWATER CONTOURS VS EXPECTED LEVELS	Job No: GEOTLCOV23225

APPENDIX H

FISH COMMUNITY SURVEY
APRIL 2007

Harris Research

Pty Ltd

Dr John H Harris
'Rifflerun'
568 Bootawa Road
Tinonee NSW 2430
Australia

Telephone 02 6553 1806
Mobile 0409 952 528
Facsimile 02 6553 1836
Email john.h.harris@bigpond.com
ABN 36 091 610 490

Fish Community Survey of the 'Riverside' Lake, April 2007

Summary Report & Overview for Crighton Properties Pty Ltd

Executive Summary

The fish community of the Riverside lake (previously Myall Quays) was surveyed in April 2007 as part of a series of biological studies to record the aquatic ecological development of the lake. Seine netting and gill netting captured numbers of both individual fish and fish species that were well in excess of previous surveys. Substantially larger-bodied fish and some fisheries species were caught including yellow-fin bream, striped mullet, sand mullet and silver biddies. The distribution patterns and occurrence of aquatic plants in the lake were similar to those recorded in 2002.

Increased biological diversity and abundance of the fish community show that the Riverside lake is continuing its development towards the ecological condition of the surrounding Myall River estuary and supports casual observations of recreational fishing in the lake. Habitat conditions, water quality and the food web are continuing to develop, supporting fish recruitment and productivity. Fish recruitment and growth in the lake are contributing to biological values in the estuary as a whole and this should increase as ecological processes mature further.

It is recommended that previous recommendations for enhancing the amount and quality of aquatic habitats remain relevant and should be pursued in the design of any extension of the existing lake system, particularly with respect to increasing the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds. It is also important to continue development and maintenance of runoff management systems to sustain high and stable water-quality values. Completion of the planned circular enlargement of the lake would increase tidal ventilation and reduce water-quality variability as well as improving the availability of habitats and food for aquatic and water-associated plants and animals. Additionally, some consideration could be given to augmenting the existing lake (where possible) with additional submerged structure such as sunken logs, rock mounds and artificial reefs to enhance the amount and quality of aquatic habitat.

These development initiatives will ensure the Riverside lake system continues to contribute increasingly to environmental assets of the Tea Gardens area.

Introduction

The third survey in an ongoing series of biological studies in the Riverside lake was completed by The Ecology Lab in April 2007. Previous surveys by the Australian Museum, including water quality, plants, macroinvertebrates and fish, were completed in 1998 (Appendix 1) and 2002 (Appendix 2) (Australian Museum 2002). The broad objective of these surveys is to monitor aquatic ecological and fisheries conditions in the lake and to record its ecological development from a constructed drainage basin to a functional component of the Myall River ecosystem. The general conclusion from the earlier surveys was that ecological conditions in the lake were still maturing, with an aquatic diversity of plants and animals that had not yet approached that of the surrounding waters of the Myall River estuary and with a salinity regime that varied substantially following rainfall runoff.

Ecological principles and options for the Riverside development were considered in a background paper (Harris 2002) (Appendix 3), which noted that the lake's dynamic ecology is driven by tidal and saline regimes together with rainfall runoff events. The paper listed options for ecological management and described ways in which aquatic habitat values could be enhanced, as well as reviewing fish population-dynamics processes that control the fish community.

Fish community analysis was chosen to represent the ecological condition of the lake for the current study because of the role of fish as indicators of the condition of the food web, water quality and other habitat conditions in aquatic systems (MDBC 2004; Harris 1995).

Methods

Fish were surveyed by a fieldwork team from The Ecology Lab on 26 and 27 April 2007 (Appendix 4). Aquatic plant distribution at sampling sites was also noted. Sampling sites in the lake are shown in a map (Appendix 5).

Seine netting

Seine netting was conducted along the shoreline at 8 locations (Appendix 1). GPS coordinates for sampling locations at given in Table 1. The seine used measured 25 m long x 2 m deep, with a mesh size of 5mm. The net was run out from the shore in a U-shape using a boat and then hauled up on to the bank. Fish were collected in the cod end and placed in a tub with water, in order to minimise handling and stress. Identification, measurements and enumeration were done and all native fish were then released. Those species not readily recognisable were preserved in formalin and returned to the laboratory for identification checks.

Gill netting

This technique was used to capture fish in deeper areas of the water body. Nets were made of a rectangular panel measuring 30m (50mm mesh x 0.25mm diameter) x 1.8m deep. Four gill nets were deployed along the middle of the lake with GPS points taken at the start and end of each panel. GPS coordinates for gill-net sampling locations are given in Table 2 and shown in Appendix 5. Gill nets were placed either perpendicular or horizontal to the shore. Deployment times were 90 minutes, with times deployed listed in Table 2. Captured fish were identified to species, measured

and released. Those fish species not readily identifiable in the field were preserved in 10% formalin and checked in the laboratory.

Aquatic plants

Aquatic plants and algae were identified at fish sampling sites using a visual assessment of percentage cover.

Table 1 . Field sampling locations and time of each seine net shot. Datum: WGS84 - Zone 56H.

Sample	Easting	Northing	Date	Time
SEINE 1	420583	6155610	26/04/07	13:15
SEINE 2	420571	6386708	26/04/07	13:45
SEINE 3	420978	6386366	26/04/07	14:50
SEINE 4	421001	6386403	26/04/07	15:15
SEINE 5	420599	6386606	27/04/07	8:40
SEINE 6	420793	6386419	27/04/07	9:10
SEINE 7	420969	6386597	27/04/07	9:40
SEINE 8	420678	6386536	27/04/07	10:15

Table 2. Field sampling locations, depths and time for the start and end of each gill net set. Datum: WGS84 - Zone 56H.

	Start				
Sample	Date	Time	Easting	Northing	Depth (m)
GILL 1	26/04/07	12:55	420973	6386428	3.4
GILL 2	26/04/07	13:05	420829	6386389	3.5
GILL 3	27/04/07	8:15	420586	6386780	2.1
GILL 4	27/04/07	8:18	420642	6386597	3.1
	End				
Sample	Time		Easting	Northing	Depth (m)
GILL 1	14:25		420970	6386399	3.3
GILL 2	14:35		420814	6386373	3.4
GILL 3	9:45		420563	6386763	3
GILL 4	9:48		420629	6386572	3.5

Results

In fish samples there was a total of 11 or 12 species of finfish (the two flathead gudgeon species were not positively identified), listed in Table 3, and the palaemonid estuary shrimp. A total of 840 fish was caught. The catch was dominated by flathead gudgeons, striped ('sea') mullet, exquisite sand gobies, Pacific blue-eyes and silver biddies, with the other species in smaller numbers. Only one alien species (i.e. originating outside Australia) was recorded, the eastern gambusia, only four individuals were caught.

While small-bodied and juvenile fish dominated the catch, some larger fish were either caught or observed. They included striped mullet up to 420mm, sand mullet to 290mm and yellow-fin bream to 329mm.

Table 3. Fish species collected in combined netting samples from Riverside lake, 26-27 April 2007.

Species	**Common name**
Gambusia holbrooki	Eastern gambusia
Psuedomugil signifer	Pacific blue-eye
Mugil cephalus	Striped (or 'sea') mullet
Myxus elongatus	Sand mullet
Acanthopagrus australis	Yellow-finned Bream
Gerres subfasciatus	Silver Biddy
*Philypnodon grandiceps/*sp.	Flathead gudgeon/Dwarf flathead gudgeon
Psueudogobius sp.	Blue spot goby
Afurcagobius tamarensis	Tamar River goby
Amoya bifrenatus	Bridled goby
Favonigobius exquisitus	Exquisite sand goby

Aquatic plants that were identified included green algae *Cladophora* sp*., Spirogyra* sp. and *Rhizoclonium* sp.*;* unidentified filamentous Blue-Green/Red algae*;* the seagrasses *Zostera capricorni* and *Ruppia polycarpa;* the hornwort *Ceratophyllum demersu;* the emergent saltmarsh *Sarcocornia quinqueflora;* and emergent macrophytes including *Juncus* sp*., Triglochin striata and Phragmites australis.*

Conclusions

It is difficult to make direct comparisons of the fish communities represented in the three surveys, as the seasonality, amount of effort and sampling methods varied among the surveys. The current survey sampled less intensively than earlier ones. Nevertheless, previous samples of the Riverside lake's fish community in 1998 and 2002 recorded fewer species – nine in 1998 and seven in 2002 - compared to the 11 or 12 species captured in the current survey.

A much greater size range of fish is also present in 2007, up to 420mm, whereas all fish caught in the 2002 survey were less than 50mm long. And 304 individual fish were collected in the more-extensive sampling in 2002, compared with 840 caught in the current survey's sampling. Fishes that were collected in the current survey but not present in 2002 samples included sand mullet, yellowfin bream, the Tamar River goby, exquisite sand goby, bridled goby and silver biddy. The silver biddy and three gobies were recorded in the lake in 1998. A single common jollytail, *Galaxias maculatus*, was found in 2002 but none were detected in 2007 samples.

The distribution patterns and occurrence of aquatic plants in the lake were not examined in detail in the current survey, but the species listed were similar to those recorded in 2002.

The increased biological diversity and abundance of the fish community shows that the Riverside lake is continuing its development towards the ecological condition of the surrounding Myall River estuary. This result supports casual observations of increasing levels of recreational fishing activity in the lake. Habitat conditions, water quality and the food web are continuing to develop, supporting improved fish recruitment and productivity. Fish recruitment and growth in the lake are contributing to biological values in the estuary as a whole and this should increase as ecological processes mature further.

Recommendations

Previous recommendations (Harris 2002) (Appendix 3) for enhancing the amount and quality of aquatic habitats remain relevant and should be pursued, particularly with respect to increasing the extent, complexity and quality of near-shore habitats for fish, invertebrates and birds. These recommendations for optimising the quality of aquatic habitats, which are incorporated in current proposals to extend the lake area, include:

- Influencing the water-quality regime to increase habitat diversity and stability.
- Continuing effective management of the series of runoff-treatment ponds.
- Increasing variability of depth profiles by introducing physical structures such as submerged logs, rockwork or other artificial reefs
- Experimentally introducing indigenous submerged and emergent aquatic plants and planting littoral trees, shrubs and grasses and
- Introducing shoreline complexity in newly created waterway areas.

It is important to continue development and maintenance of runoff management systems to sustain high and stable water-quality values, especially through the system of treatment ponds.

Completion of the planned circular enlargement of the lake and incorporation of these recommendations would increase tidal ventilation and reduce water-quality variability as well as improving the availability of habitats and food for aquatic and water-associated plants and animals.

These development initiatives will ensure the Riverside lake system continues to contribute increasingly to environmental assets of the Tea Gardens area.

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Appendix 1.

AMBS CONSULTING

Biological Study of Myall Quays Lake

Crighton Properties/Myall Quay Estate

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Printed - 1 July, 1998

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Summary

This study evaluated the health of the Myall Quays Lake by comparing the water quality with the ANZECC guidelines and by investigating the flora and fauna found in the lake. AMBS specifically looked at fishes, macro-invertebrate epifauna, seagrass and algal communities in the lake. Community structure was compared to water quality data, to evaluate whether salinity and nutrient levels influence the distribution of species in the lake.

Myall Quays Lake (32 30.40'S, 152 09.11'E) is contained within the Myall Quays development which is located near Tea Gardens, north of Newcastle. It was constructed as a detention basin to serve the needs of the adjoining residential development. The lake is approximately 4.8 hectares in surface area and varies in depth up to 4m. It has five freshwater inlets and is also tidal on certain spring tides (ie. ≥1.6m) through an established drain located in the easternmost corner of the lake.

The ecosystem within the lake is only two years old and communities within it may still be maturing. Currently, a total of eleven plants, nine fishes and one confirmed macro-invertebrate species are found in the lake, with a relatively uniform band of vegetation found in the shallow margin of the lake. The species are predominantly marine/estuarine species, although a few freshwater/brackish species are also found. As the lake was not horizontally stratified, the distribution of species and communities did not appear to be influenced by salinity and nutrient levels. Based on oxygen and the nutrient levels (total phosphorus and nitrogen) Myall Quays Lake has good surface water quality, with conditions within the guidelines recommended for lakes and reservoirs by ANZECC (1992).

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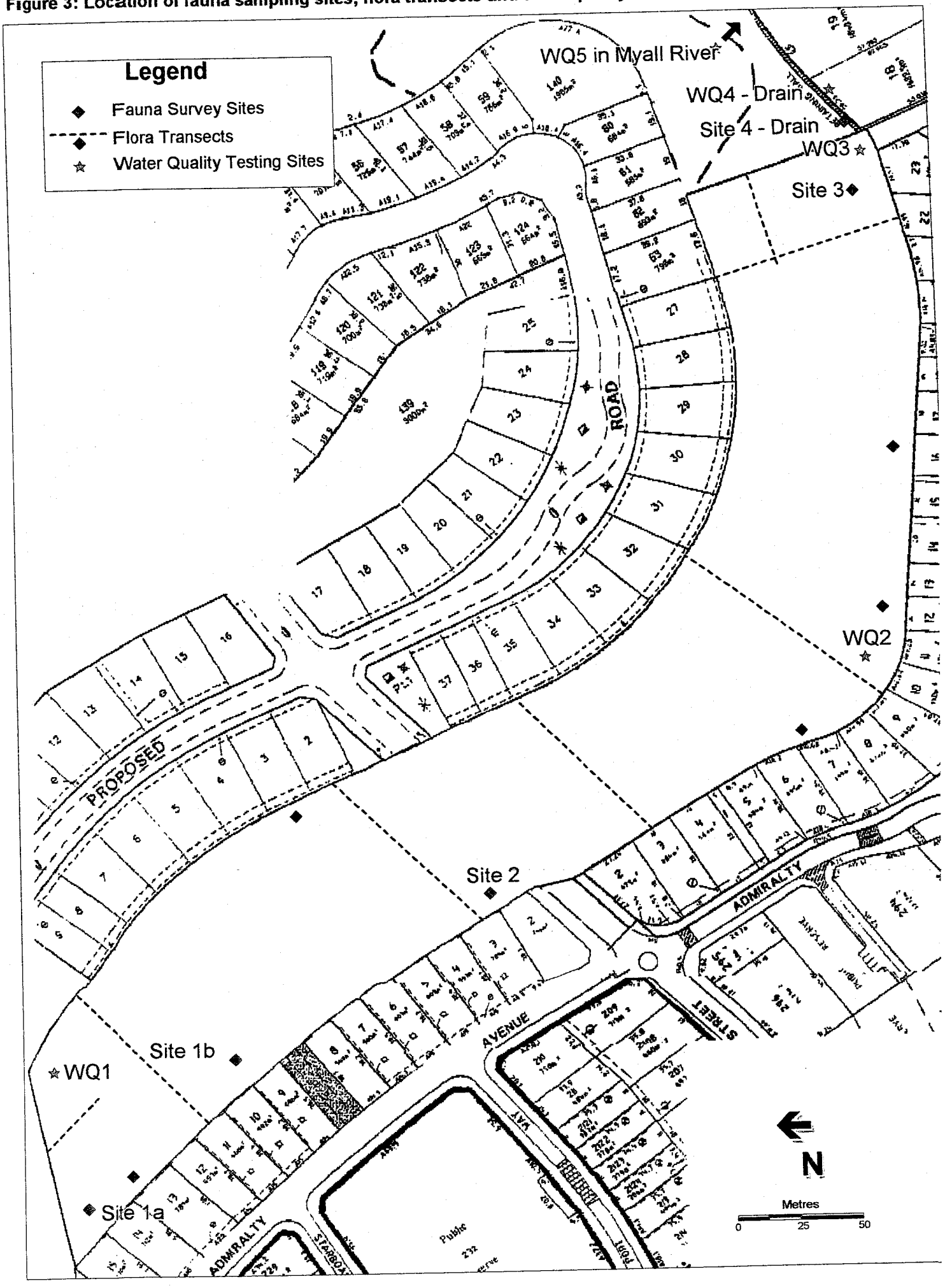
Figure 3: Location of fauna sampling sites, flora transects and water quality testing sites



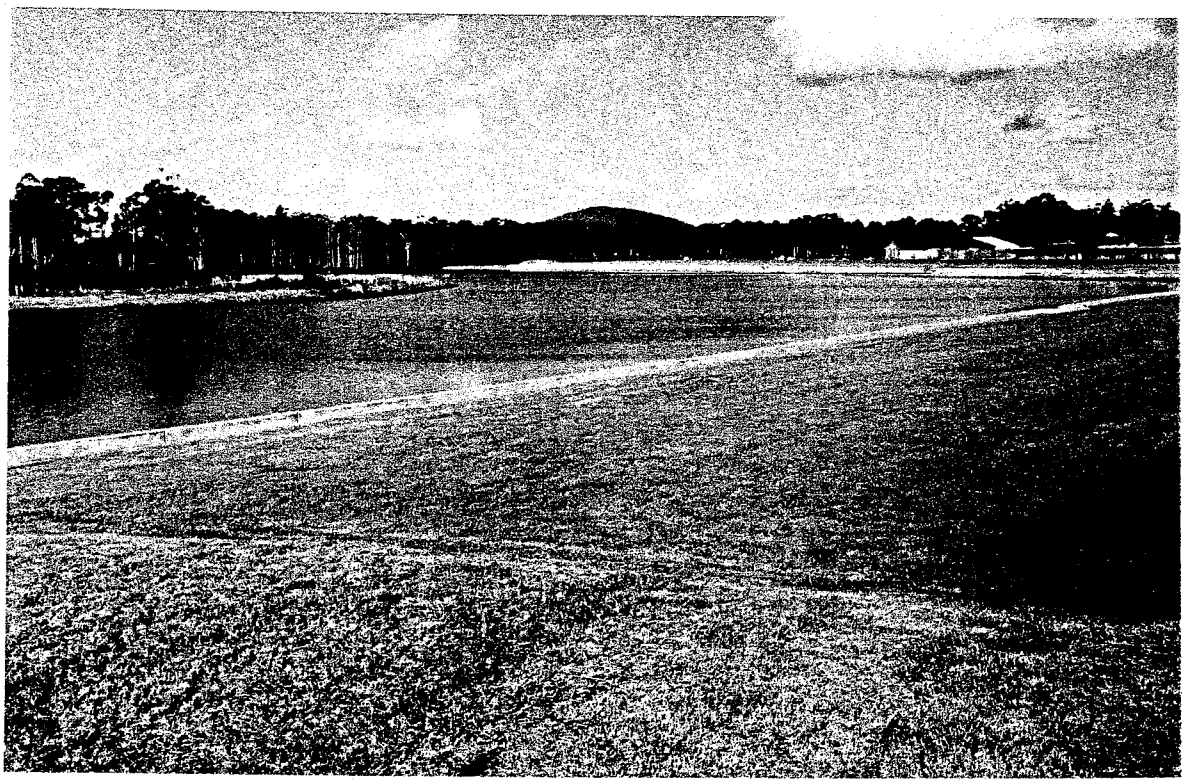
Biological Study of Myall Quays Lake

1. Introduction

Australian Museum Business Services (AMBS) was requested by Crighton Properties to undertake a biological survey of Myall Quays Lake (32 30.40'S, 152 09.11'E) The lake is contained within the Myall Quays development which is located near Tea Gardens, north of Newcastle. Myall Quays Lake was constructed as a detention basin to serve the needs of the adjoining residential development and has the capacity to detain 17,000 m^{-3} of stormwater (Figure 1). The lake is approximately 4.8 hectares in surface area and varies in depth up to 4m, with shallow edges (1:9 slope for 15-20m) sloping (1:4) into deeper water. It has five freshwater inlets and is also tidal on certain spring tides (ie. ≥1.6m) through an established drain located in the easternmost corner of the lake.

AMBS evaluated the health of the lake was evaluated by comparing the water quality with the ANZECC guidelines and by investigating the flora and fauna found in the lake. AMBS will specifically look at fishes, macro-invertebrate epifauna, seagrass and algal communities in the lake were specifically surveyed, their abundance estimated from various areas of the lake, including near the northwestern freshwater inlet and the eastern tidal mouth (drain) of the lake. Community structure is compared to water quality data, to evaluate whether salinity and nutrient levels influence the distribution of species in the lake.

Figure 1: Myall Quays Lake



2. Methods

2.1 Review of Available Water Quality Data

Hunter Water has been taking regular water samples from the lake at varying intervals from 3-10 months since February 1996. The Australian Museum assessed these data to determine the lake's nutrient status and its horizontal stratification. Horizontal stratification of the lake would influence the sampling design used during the fieldwork component of the project. As only single water samples were taken at each site, no data were available to determine the vertical stratification of the lake or the variation between replicate water samples.

Sampling times for water samples were compared to tide and rainfall data, as both factors should influence, at least, the salinity values. Tidal heights are taken from the tide tables for Australia, East Coast - Newcastle, for the years 1996 and 1997. At high tides of 1.6m and greater, there is an inflow of saline water from the lower Myall River into the lake (R. Wraight, pers. comm. 23/1/98). The rainfall figures are daily amounts in mm taken at the Myall Quays development site.

2.2 Field Work

Field work was conducted on 22 January 1998 by three members of the AMBS team, aided by personnel from Myall Quays Estate. Fish and macroinvertebrate epifauna were collected using seine nets (0.5cm mesh) at three sites within the lake and from the drain (Figure 2) leading into the lake from the wetlands adjoining the Myall River (Figure 3). Sites in the lake were located at either end of the lake and in the middle, so that variation in community structure could be determined.

Figure 2: Myall Quays Lake showing mouth of drain leading into the lake from the wetlands

The sampling site locations are:

Site 1a: Northwestern end of lake - bulrushes and algae growing near edge;

Site 1b: Northwest from office - 25m northwest from stormwater drainage inlet in front of freshwater lake;

Site 2: In front of Office;

Site 3: Eastern end of lake near drain entrance; and

Site 4: In drain.

In deeper areas of the lake a 25m long beach seine was used in conjunction with a rowboat; the seine was overweighted so it pulled along the bottom in deeper water. Both a 5m seine and small Japanese seine were used in shallower areas. The various fish collections retained were qualitative rather than quantitative. The majority of the mullet were returned to the lake and the largest specimens of mullet escaped by jumping over the seine. Larger numbers of the smaller species were retained because precise field identification is not possible for these. Fishes were identified primarily using Kuiter (1993) and McDowall (1996), and both sources were used for information on biology and distribution.

Observations on the extent, pattern of cover and species composition of aquatic angiosperms and macroalgae were made by the use of transects normal to the shoreline to determine the composition and distribution of plant communities (Figure 3). The transects extended until the limit of vegetation was reached. Observations were made by snorkelling and whilst wading. The abundance of the vegetation and their distribution patterns were recorded according to the abundance/sociability scale described in Table 1 (King and Barclay 1986). Sainty and Jacobs (1981), Moore (1986) and Womersley (1984, 1987) were the primary sources for identification of and information on the aquatic plants.

From these observations, a vegetation map was drawn up showing the distribution and abundance of the vegetation using the key outlined in Table 1. Specimens collected were identified by Australian Museum scientists.

Table 1: Abundance/sociability scale from King and Barclay (1986)

Abundance	Sociability		
	a Individual strands or clumps	b Patches	c Beds of relatively even distribution
1 Sparse growth (< 15%)	5%	10%	15%
2 Moderate growth (15-50%)	15%	25%	35%
3 Abundant growth (> 50%)	-	60%	65%

3. Results

3.1 Water Quality

The water quality data were limited to single samples taken at five sites over a period from January 1996 to November 1997. As no replicates were taken or samples from different depth (readings taken from within 1m of the surface), AMBS was unable to assess variability in readings at each site or whether the lake was vertically stratified. Vertical stratification, especially saline or dissolved oxygen levels, can significantly affect the composition and distribution of flora and fauna communities.

3.1.1 Salinity

After construction of the lake in January 1996, it was filled by stormwater following heavy rain during the first week. During the month of January 1996 the tide reached 1.8-2.0 m on 11 days. The salinity of Myall Quays Lake gradually increased from approximately 3.5ppt (February 1996) to 16.1-22.8ppt in January 1997. The salinity fluctuated from 7-12ppt between November 1997 and January 1998 (Figure 4). Water samples taken during the present survey indicated that the salinity of the lake was between 10-12ppt (Table 2), with the northwestern portion of the lake slightly lower than the middle and eastern portions of the lake. Water samples taken by Hunter Water show that there is little horizontal stratification within the lake, with minor variations in salinity between sites 1-3 at anyone point in time. However, in January 1997 the southern corner in the middle of the lake had a salinity of 22.8ppt, in contrast to 16.1-16.5ppt at either end of the lake, and only 11.9ppt in the drain.

Variations in salinity within the lake may occur as a result of:

- Freshwater influxes;
- Runoff;
- tidal influx;
- groundwater input; and,
- vertical stratification of salt and fresh water after heavy rainfall.

As the lake is fed by stormwater and saline river water during high tides (> 1.6m), it may be expected that the salinity of the lake would fluctuate during the month depending on the amount of rainfall and the number of tidal flows into the lake. However, care needs to be taken when comparing the water quality data with tide and rainfall data because of the time lag between rainfall and freshwater influx, and the timing of water testing compared to tidal influx.

Figure 4: Salinity of Myall Quays Lake 1996-1997

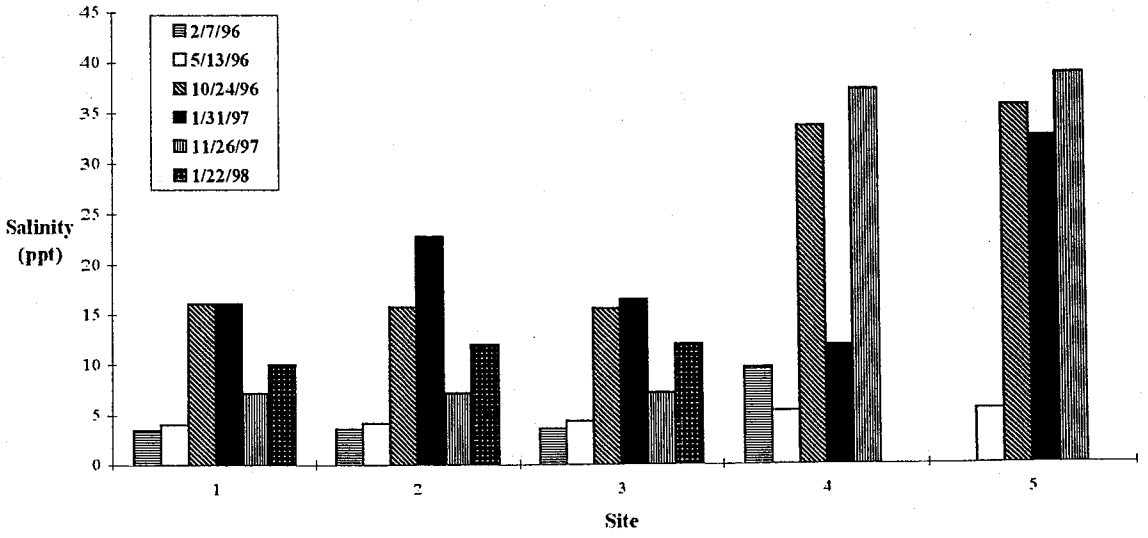
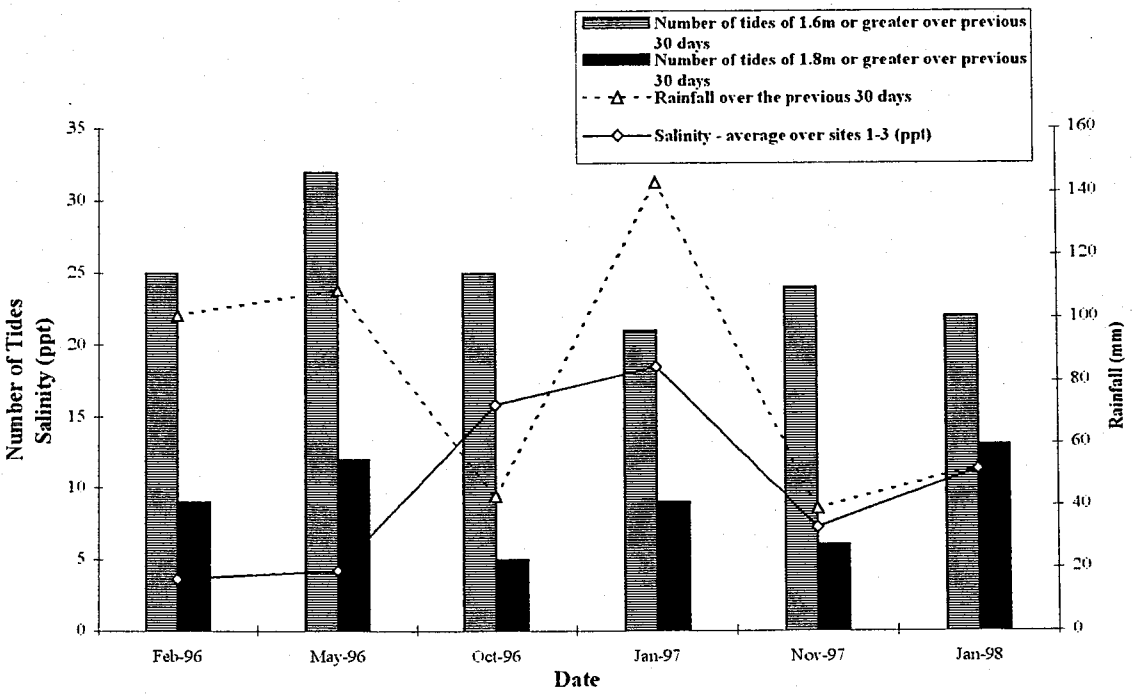


Table 2: Salinity reading recorded during January 1998

Site	Salinity (ppt)
1	10
2	12
3	12

When all three variables (salinity, tide and rainfall) are plotted (Figure 5), it can be seen that for the three samples of 1996, rainfall and salinity were highly correlated. When rainfall was high (100 or more mm in the preceding 30 days), salinity was low (less than 5ppt) and when rainfall was low (less than 50 mm in the preceding month) salinity was high (15+ppt). However, in January 1997, 143mm rain preceded a salinity of 15+ppt, and in November 1997, 39mm of rain preceded salinity of 7ppt. The addition of tidal information neither accounts for the breakdown of the rainfall/salinity relationship in 1997, nor improves the predictability of the model. Whether examining the number of tides 1.6m or greater in the preceding month, 1.8m or greater in the month, or the number of tides 1.6m or greater in the preceding week, the tides are not correlated with salinity variations.

Figure 5: Salinity, rainfall and high tide variations in Myall Quays Lake

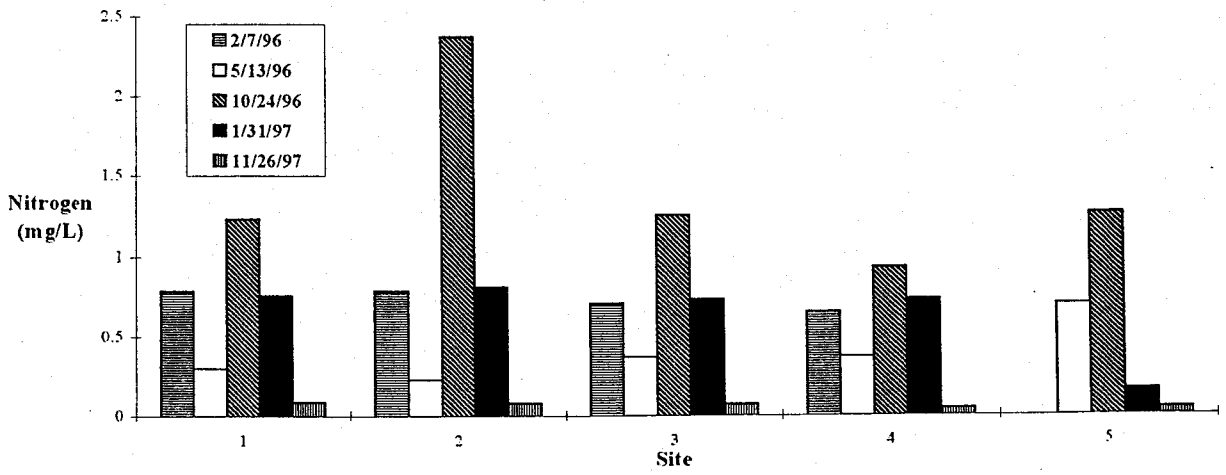


It is not clear from the tide and rainfall data what is causing the variation in salinity in the lake and drain in 1997. In January 1997 the salinity in the drain was 11.9ppt, about 25% lower than anywhere else in the lake and only about 1/3 of the salinity in the Myall River (Figure 4). Yet 21 tidal cycles in the previous 30 days had been 1.6 m or higher, and 9 of these had been 1.8 m or higher. In May 1996, the salinity in Myall River was only 5.5 ppt, compared with other river values in excess of 30 ppt. In January 1997 rainfall was more than 30% higher without significantly affecting river salinity. Thus, it is clear that salinity variations cannot be explained by simple variation in rainfall and tidal heights and that the lake and drain are part of a complex hydrological system that is influenced by other factors such as groundwater and vertical stratification.

3.1.2 Nutrients

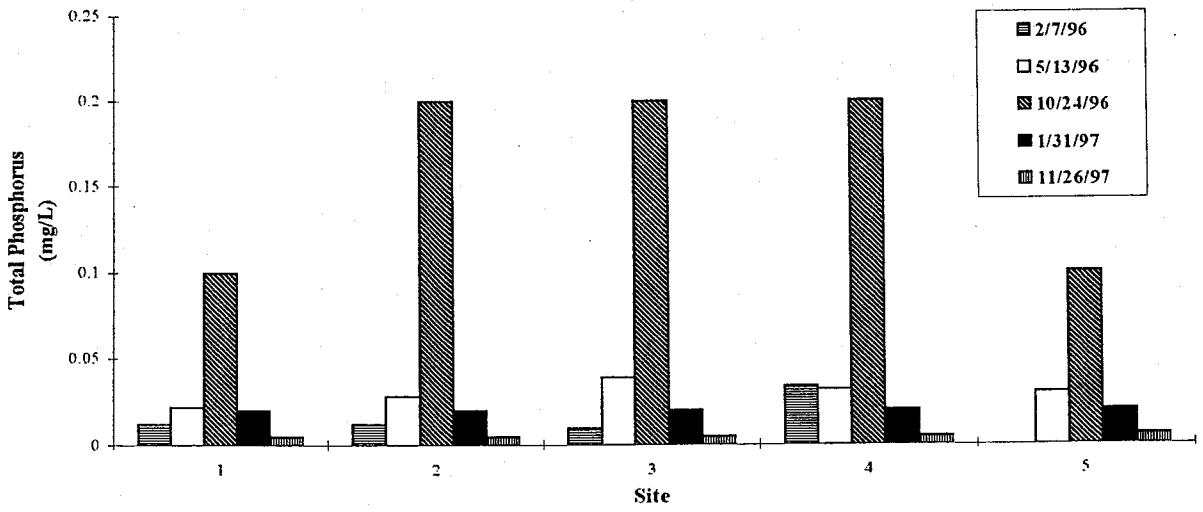
As for salinity, the nutrient levels (nitrogen and phosphorus) increased in the lake during 1996, with levels peaking in October 1996 (Figure 6 and Figure 7). During 1997, both total nitrogen and total phosphorus levels decreased in the lake. The variations in nitrogen and phosphorus levels are not correlated with rainfall, and may be a natural evolution of the lake as it matures. The low levels in 1997, particularly in November, match those in the Myall River. However, the phosphate values for November 1997 are for ortho-phosphate only and are not comparable to the total phosphate values given in all previous measurements. Total phosphate also includes the amount of condensed phosphates and organically bound phosphates as well as ortho-phosphate.

Figure 6: Total nitrogen in Myall Quays Lake 1996-1997



NB. February 1996 - January 1997 sum of Total Oxidised Nitrogen and Total Kjeldahl Nitrogen, November 1997 sum of Total Oxidised Nitrogen and Free Ammonia (no data available on Organic Nitrogen)

Figure 7: Total phosphorus in Myall Quays Lake 1996-1997



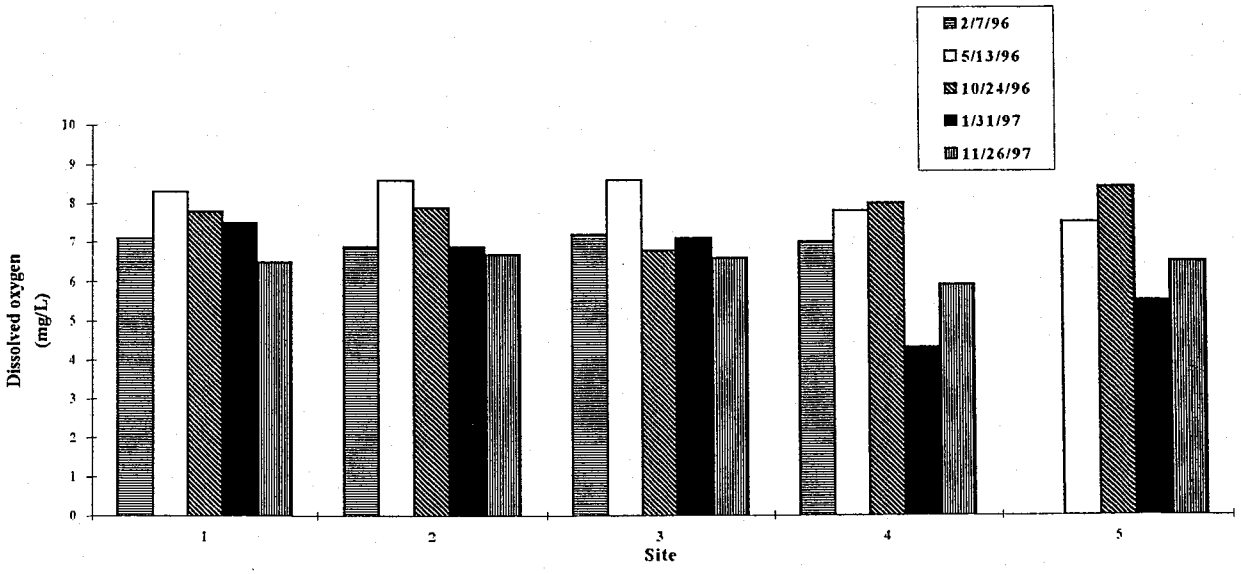
NB. February 1996 - January 1997 Total Phosphorus measured, November 1997 Ortho-Phosphate measured (no data available on condensed phosphates and organically bound phosphates)

3.1.3 Dissolved Oxygen

Dissolved oxygen levels, although increasing initially (from February 1996 to May 1996), have declined gradually but slightly over time (Figure 8). The variation in the drain has been greater, more closely approximating the variation in the Myall River. The amount of dissolved oxygen is inversely proportional to water temperature, with colder water able to hold more oxygen. Therefore, percent oxygen saturation is often calculated. Lake levels have varied between 80-96% saturation, while the Myall River has fluctuated between 76-100% saturation. Due

to the limitations of the available water quality data, it is unknown whether the lake is vertical stratificatied in terms of dissolved oxygen levels.

Figure 8: Dissolved oxygen levels in Myall Quays Lake 1996-1997



3.2 Flora

3.2.1 Flora Species Present in Myall Quays Lake

The aquatic angiosperms and macroalgae recorded in Myall Quays Lake are:

Seagrass

Ruppia polycarpa (Sea Tassel)

Grows in coastal lakes and lagoons at similar or lower salinities than seawater. *Ruppia polycarpa* is the second most dominant species in Myall Quays Lake.

Aquatic angiosperms

Triglochin striata (Streaked Arrow Grass)

Grows in tidal and freshwater swamps. Found growing in shallow areas around the lake.

Elatine gratioloides (Waterwort)

Usually found in or on the margins of stationary or slowly flowing freshwater to about 40 cm. Isolated patches were found growing in the northwestern portion of the lake.

Juncus spp. (Rushes)

Most species of *Juncus*. occur in periodically damp areas but vary greatly in their tolerance to the intervening dry periods. Some species (eg. *J. acutus* and *J. usitatus*) prefer areas with damp subsurface moisture, while other species are able to survive permanent or periodic inundation (eg. *J. aridicola*, *J. prismatocarpus*).

The species found around Myall Quays Lake is most likely *J. krausii* (grows in saline or brackish conditions) or the commonly occurring freshwater species *J. acutus* or *J. usitatus*. However, specimens were not collected for identification as the species was growing around the lake rather than in the lake.

Other

Isolate plants of two unidentified aquatic angiosperms were observed growing in the northwestern/middle section of the lake.

Macroalgae

Charophytes (Stoneworts)

Lamprothamnium papulosum

Dominant vegetation in Myall Quays Lake. Studies have shown that *L. papulosum* has an optimal salinity range between 24-28 ppt, with a minimum salinity tolerance around 8 ppt. However, *L. papulosum* is able to withstand salinities up to and including 104ppt, although it does not grow satisfactorily in salinities over 60ppt (Womersley 1984). *Lamprothamnium papulosum* is reported to be a food source for water fowl (Delroy 1974 cited in Womersley 1984).

Nitella subtilissima

Usually found in still or flowing freshwater. Occasionally found in brackish water. Only one other record of its occurrence in NSW.

Chlorophyta (Green Algae)

Cladophora sp.

Member of the Chlorophyta which grow in freshwater and saline conditions. Usually found attached to rocks, hard substrates, plants and algae in eutrophic and alkaline streams and lakes.

Rhizoclonium sp.

Member of the Chlorophyta which is often found entangled with other filamentous algae in slow flowing water. Generally found in alkaline and/or saline streams and common in estuarine areas.

Spirogyra sp.

Member of the Chlorophyta which is found floating or attached in flowing or still freshwater.

Phaeophyta (Brown Algae)

Family Chordariaceae

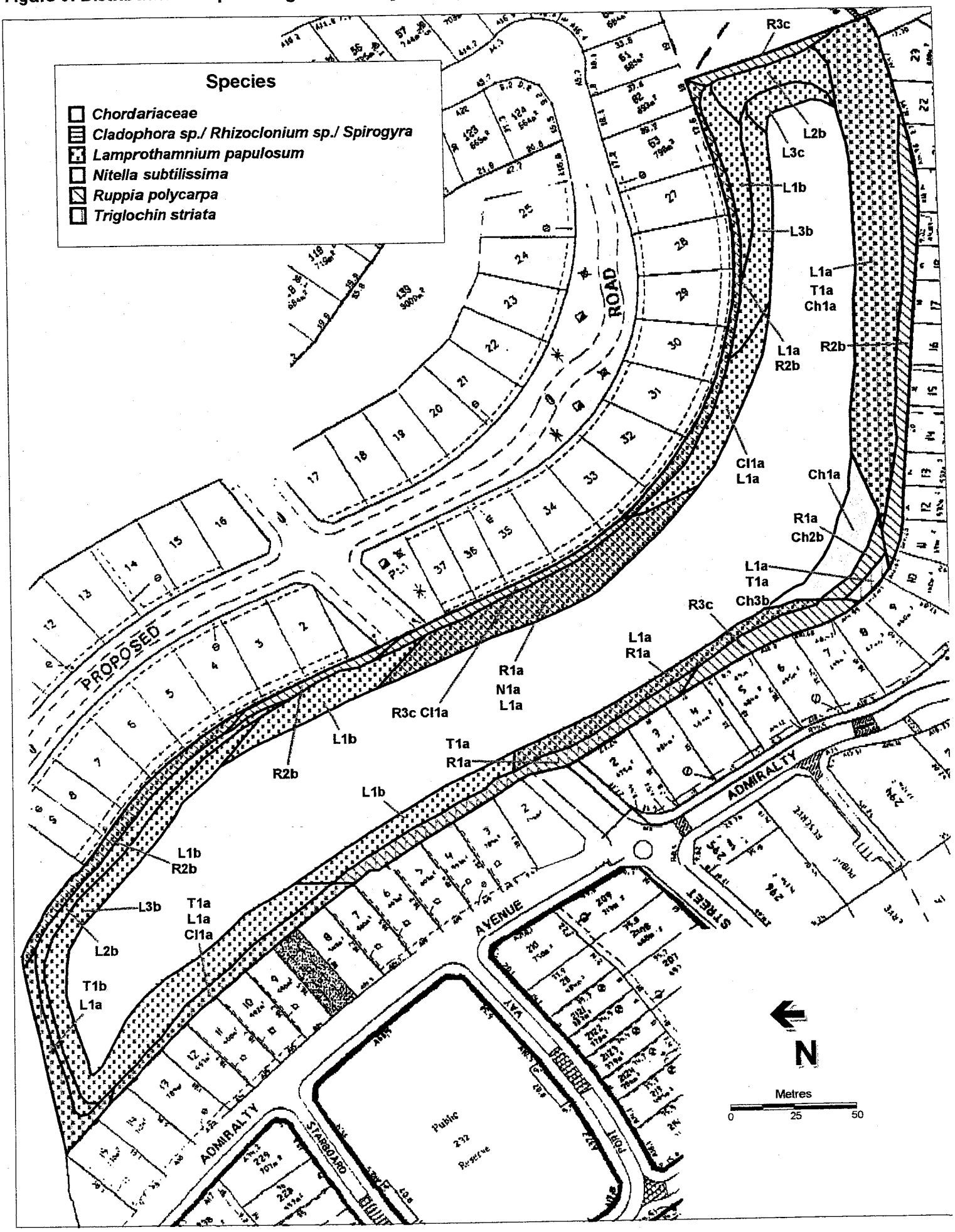
Members of this family are usually common in the lower intertidal and upper sublittoral and are also usually seasonal (in summer) in the occurrence of the macrosporophytes (macroscopic form of alga).

3.2.2 Distribution

The distribution of these aquatic angiosperms and macroalgae is presented in Figure 9, with a relatively uniform band of vegetation (approximately 20-25m in width) found around the margin of the lake. The vegetation of Myall Quays Lake was dominated by *Lamprothamnium papulosum* (a stonewort). In the deeper water (approximately 4m to 25m from the shore), *L. papulosum* was usually the only species present, with large clumps (up to approximately 50-75cm diameter and 50cm high) covering the bottom sediment. *Ruppia polycarpa* was dominant in shallow areas of the lake (less than 0.5m), where smaller clumps of *L. papulosum* were also found. These two species comprised approximately 80-90% of the total plant biomass of the lake. A brown alga of the family Chordariaceae was also abundant in the middle portion of the lake, where it formed a dense, free floating blanket over the bottom sediment. This patch was located near a stormwater outlet. Only isolated individuals of the other dominant species were found growing amongst the brown alga.

Several other species were also recorded, but they were usually found in isolated patches. In the northwestern portion of the lake, the number of species present appeared to be greater (including *Elatine gratioloides* and two unidentified aquatic angiosperms) than in the middle (southern) and eastern areas. However, further studies would be needed to verify this.

Figure 9: Distribution of aquatic vegetation in Myall Quays Lake



3.3 Fauna

3.3.1 Fauna Species Present in Myall Quays Lake

Fish and macroinvertebrates recorded in Myall Quays Lake are:

Fish

Family Poeciliidae

Gambusia holbrooki (Mosquito Fish)

Mosquito fish is an exotic species, introduced into Australia from the USA in the 1920s. It is widespread and abundant throughout NSW, SA and Victoria in both inland and coastal drainages, and coastal Queensland. Mosquito fish tolerates a wide range of salinities, from pure freshwater to full marine salinities. It is most abundant in warm and gently flowing or still waters, mostly around margins and along the edges of aquatic vegetation beds. This species feeds on a wide range of both terrestrial and aquatic organisms ie. it is an adaptable generalist predator, that may be a threat to other small fish species into whose habitat it has been introduced or spread. Recently it has been implicated in the reduction of green and golden bell frog distribution, presumably by feeding on the tadpoles.

Family Pseudomugilidae

Pseudomugil signifer (Southern Blue-eye)

Southern blue-eye is widespread throughout eastern drainages, from northern Queensland to Narooma, NSW (South-East Drainage). It is abundant in fresh or brackish coastal waters, but does not penetrate far inland.

Family Gerreidae

Gerres subfasciatus (Common Silver Belly)

Common silver belly is found in the northern half of Australia, south to Wollongong on the east coast. It occurs in estuaries and harbours out to fairly deep water along the shore.

Family Mugilidae

Mugil cephalus (Sea Mullet)

Sea mullet occurs along the entire Australian coast in estuaries; large schools migrate along ocean beaches. It spawns offshore and small schools of juveniles enter rivers, as do adults occasionally. The species can survive more than one year in freshwater. It is an important commercial species.

Family Gobiidae

Favonigobius exquisitus (Exquisite Sand Goby)

Exquisite sand goby occurs in NSW coastal bays and sandy estuaries, sometimes in seagrass.

Gobiopterus semivestitus (Glass Goby)

Glass goby occurs from southern Queensland to SA, in quiet coastal estuaries. It enters freshwater and is usually found in small to large schools.

Mugilogobius paludis (Mangrove Goby)

Mangrove goby is known from southern Queensland to SA. Its intertidal in mangroves and also enters lower reaches of freshwater streams.

Pseudogobius sp. (Blue-Spot Goby)

An undescribed species, but is not uncommon. It is found from southern Queensland to Victoria and occurs in coastal estuaries, usually in muddy upper reaches with rocks or seagrasses.

Philypnodon sp. (Dwarf Flathead Gudgeon)

Dwarf flathead gudgeon is another undescribed species, occurring in coastal streams of southern Queensland, NSW, Victoria and SA. It is found in brackish waters in estuaries, to altitudes of a few hundred metres and is common in coastal northern areas of range. This species prefers relatively calm waters and lives over mud or rocks, or in weedy areas.

Family Anguillidae

Anguilla reinhardtii (Long Finned Freshwater Eel)

Long finned freshwater eel occurs from Cape York to Tasmania, in all coastal rivers, streams and lakes, as well as in brackish waters. It migrates out to sea to breed after up to ten years in freshwater and is commercially important. Previously it was observed by Myall Quays staff, but it was not collected in January 1998.

Macroinvertebrates

Crustacea: Infraorder Caridea

Family Palaemonidae

These shrimps are commonly found in estuaries and feed on algae and detritus. The commonest species of estuary shrimps do not exceed 45 mm in length and

are of no commercial importance.

Crustacea: Infraorder Brachyura

Family Portunidae

Portunus pelagicus (Blue Swimmer Crab)

Blue swimmer crab is found Australia-wide, in bays and estuaries as well as offshore. A large crab of commercial importance. Previously it was observed by Myall Quays staff, but was not collected in January 1998.

3.3.2 Distribution

The number of fish/macroinvertebrates captured is presented in Table 3. The fauna of Myall Quays Lake was dominated in numbers by *Favonigobius exquisitus* (Exquisite sand goby) and *Pseudomugil signifer* (Southern blue-eye). *Mugil cephalus* (Sea mullet) was the largest fish recorded in Myall Quays Lake, and dominant in biomass. No accurate count of numbers of this species was obtained, as most of the mullet were released. Several other fish species were also recorded with *Gobiopterus semivestitus* (Glass goby) the next most common species (based on numbers caught). Only one species of macroinvertebrates, an estuary shrimp of the family Palaemonidae, was caught during the sampling period.

Table 3: Fish numbers from Myall Quays Estate, Tea Gardens

Species		Site					Total
		1a	1b	2	3	4	
FISHES							
Gambusia holbrooki	Mosquito fish	-	-	6	-	16	**22**
Pseudomugil signifer	Southern blue-eye	132	26	1	40	75	**274**
Gerres subfasciatus	Common silver belly	-	-	-	6	-	**6**
Mugil cephalus	Sea mullet	-	2	11	3	2	**18**
Favonigobius exquisitus	Exquisite sand goby	32	52	19	174	-	**277**
Gobiopterus semivestitus	Glass goby	79	12	-	60	2	**153**
Mugilogobius paludis	Mangrove goby	-	-	-	-	1	**1**
***Pseudogobius* sp.**	Blue spot goby	5	9	1	10	-	**25**
***Philypnodon* sp.**	Dwarf flathead gudgeon	18	32	-	13	-	**63**
MACROINVERTEBRATES							
Palaemonidae		4	-	-	-	14	**18**
	Total	**270**	**133**	**38**	**306**	**110**	**839**

Most of the fish species appear to occur in all parts of the lake. The exception seems to be the mosquito fish *Gambusia*, with largest numbers in the drain and few in the lake proper. The same is also true of the estuary shrimp, with most in

the drain and low numbers only in the northwest corner of the lake. The two rarest fishes, the Mangrove goby and Common silver belly, were both found only in the drain or eastern end of the lake near the drain entrance. All other fish species were taken in at least 3 of the 4 lake sites, but four fish species, including the commonest Exquisite sand goby, were absent from the drain.

4. Discussion

4.1 Water Quality

Indicative concentrations (preferred upper limits) of total nitrogen and phosphate for lakes and reservoirs (as recommended by ANZECC 1992) are shown in Table 4. They were not able to recommend a single set of nitrogen and phosphorus concentrations, as this would require a site-specific study. However, these ranges provide an indication of levels at or above which problems (such as phytoplankton blooms) have been known to occur (depending on a range of other factors eg. temperature, turbidity).

Table 4: Indicative concentration range of total nitrogen and phosphate for lakes and reservoirs (as recommended by ANZECC 1992)

Nutrient	Indicative Concentration Range
Total Phosphorus	5-50μg/L (0.005-.05mg/L)
Total Nitrogen	100-500μg/L (0.1-0.5mg/L)

With the exception of October 1996, total phosphorus in Myall Quays Lake has always been 0.04mg/L or less. All of the January 1997 values were less than 0.02mg/L (the November 1997 values were for ortho-phosphate and are not comparable).

With the exception of October 1996, where total nitrogen values of 1-2+mg/L were attained, all measurements of total nitrogen within the lake have been only slightly over or under the recommended value of 0.5mg/L. From the peak of October 1996 the nitrogen values have been steadily decreasing, with the values of November 1997 exceptionally low at >0.1mg/L. These values are indicative of very good water quality.

The figures given above are for freshwater; Australian estuarine studies are very limited and ANZECC (1992) recommended figures for estuarine waters, based on one study in Western Australia, are not presented in either total nitrogen or total phosphate and thus are not comparable to our data. Variation in nutrient levels within the lake may be a result of runoff from the catchment, either wastewater discharge or diffuse runoff. They may also be a result of metabolic decomposition,

which may be seasonal resulting in a timelag in nutrient levels within the lake. In terms of potential algal blooms, one of the important factors is the ratio of total nitrogen/total phosphorus. With both nutrients being below the maximum recommended values, algal blooms should not be a problem if the present range of values are maintained.

The ANZECC (1992) guidelines also recommended that dissolved oxygen levels normally should not be permitted to fall below 6mg/L or 80-90% saturation. None of Myall Quays Lake surface (top 1m) values ever fell below these recommended minima. However, it is not known whether dissolved oxygen levels at the bottom of the lake comply with ANZECC guidelines. Dissolved oxygen varies significantly during a 24 hour period, depending on temperature, salinity, and biological activity (ie. whether the aquatic plants are photosynthesising during the day and producing oxygen or respiring at night and using oxygen). Therefore, oxygen levels should be determined over at least one circadian cycle. Water samples should also be taken at more than one depth including from near the bottom to determine if the lake is vertically stratified. Dissolved oxygen levels in bottom waters may be significantly different (lower) that surface waters due bacterial decomposition of organic matter. This can result in the death of organisms which are unable to escape from the zone of oxygen depletion (Scanes and Scanes 1995). Reduction in dissolved oxygen concentrations in water can also reduce the physiological efficiency of fishes and non-airbreathing invertebrates, with levels below 5mg/L stressful to many species (Koehn and O'Connor 1990). During both sampling times in 1997, oxygen saturation in the drain was less than 80% and in January 1997 the oxygen was only 4.3 mg/L, thus placing the fishes in the drain under stress. One feature of fishes is their ability which to move to higher quality water in times of stress, and they may have moved into the lake during January 1997.

Overall, on the basis of both oxygen levels and the nutrient levels of total phosphorus and nitrogen as recommended in the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 1992), Myall Quays Lake has good surface water quality.

4.2 Flora

The vegetation of Myall Quays Lake was dominated by the Charophyte *L. papulosum*. The seagrass, *Ruppia polycarpa*, was also prominent in shallow areas of the lake. These two species made up 80-90% of the plant biomass of the lake. Charophyte beds are ecologically important as they have a high biomass, accumulate large concentrations of nutrients and have a large surface area which is readily colonised by micro-organisms which can support a large invertebrate population (Moore 1986). The large clumps of *L. papulosum* would most likely provide shelter and food for fishes.

Aquatic macrophytes usually grow best in lakes and rivers in areas of fine sediment and low current velocity (Wright and McDonnell 1986). These condition

are met in Myall Quays Lakes, where the sediment is composed of fine sand and there is frequently little or no water flow. Macrophyte and algal growth in Myall Quays Lake is thought to be primarily limited by turbidity, with only *Lamprothamnium papulosum* found growing in the deeper, turbid waters of the lake. In the deepest areas of the lake no vegetation was found growing.

Charophytes, such as *L. papulosum* and *Nitella subtilissima,* usually prefer calcium rich waters which are low in phosphate, with phosphate levels above 20µg/L often inhibiting their growth (Moore 1986). Water quality testing of Myall Quays Lake has shown that total phosphate levels vary. However, total phosphate levels in January 1997 were less than 20µg/L (total phosphate was not recorded in November 1997). Thus the current physical environment within the lake appears to be suitable for Charophyte growth. A permanent increase in nutrient levels could affect the growth of Charophytes and result in a change in the vegetation communities found in the lake.

Highly fluctuating salinity levels may limit the survival of some aquatic plants. Many species, although able to withstand saline conditions, are unable to cope with rapidly fluctuating salinities. If the level of salinity change seen in the lake between January and November 1997 (from 23 to 7 ppt at site 2) occurred over a short period, some species probably would not survive.

4.3 Fauna

A total of nine species of fishes and one shrimp species were collected. The two dominant fish species in the lake in terms of numbers are the exquisite sand goby, *Favonigobius exquisitus,* and the southern blue eye, *Pseudomugil signifer.* The sea mullet, *Mugil cephalus,* is by far the largest in terms of biomass, making up all the large fish in the lake. Based on our sampling, the school of fish that comes to feed on the bread every day consists entirely of sea mullet.

All of the nine fish species are tolerant to relatively wide salinity ranges. However, if the salinity continue to vary over a wide range, the number of additional species to colonise the lake may be limited. Many species cannot tolerate such a wide range of salinities, particularly if the changes occur over a short period of time. It may be that these fluctuating salinities are a natural feature of this lake, due to its function as a stormwater reservoir, and therefore there will never be a rich fauna of resident fishes and macroinvertebrates.

4.4 Ecology of Myall Quays Lake

As the lake is only two years old, the communities within the lake are probably still maturing and may change in composition, abundance and distribution over time. Although the lake is currently dominated by the plants *Lamprothamnium papulosum* and *Nitella subtilissima,* and the fishes *Mugil cephalus, Favonigobius exquisitus,* and *Pseudomugil signifer*, the dominant species present could

significantly change if nutrient concentrations or salinity were to change dramatically. Currently the species present in the lake are adapted to a changing physical environment, with fluctuations in salinity, nutrients and dissolved oxygen occurring as a complex result of freshwater influxes (stormwater), tidal flows, and other causes.

If nutrient levels within the lake increased significantly, this could also significantly affect the vegetation community currently found in the lake. Growth of the dominant species, *L. papulosum*, may be affected by high phosphate levels, which could result in decline of the species. Other species such as cyanobacteria and *Cladophora* sp. prefer high nutrient conditions, and if conditions changed in the lake such that nutrient levels increased, this may result in excessive growth of such species. Although not all species are toxic, excessive growth may affect other species by smothering or shading. The positioning of the brown alga currently found in the lake (family Chordariaceae), near a stormwater outlet suggests that biomass of this alga may increase in high nutrient conditions. An increase in cyanobacteria in the lake may result in blooms when suitable conditions (high temperature, stable water column, nutrients) occur. Cyanobacteria blooms are known to be toxic. Thus, although the species composition of the lake may not change due to increasing nutrient levels, the dominant species may. Changes in the vegetation community of the lake would affect faunal species that rely on the plants for food and shelter.

Presently the lower Myall River and wetlands serve as the main source for species found in the lake. The species composition of the lake may be expected to increase as the community becomes more complex with age. New plants may also be introduced into the lake by animals such as birds, while many freshwater invertebrates have aerial adult stages. There is a reasonable likelihood of achieving a healthy ecosystem with good water quality if a natural source of species is present. Many artificial lakes require considerable management, including the monitoring of water quality, to ensure that they do not become eutrophic (promoting the incidence of toxic cyanobacteria blooms) or deficient in dissolved oxygen.

The drain allows Myall River water to flow back into the lake during the highest tides of each month, benefiting water quality. During previous heavy rain in March 1997, the mullet population was washed out of the lake into the river. The present mullet, some of which exceed 20 cm length, are presumably juveniles that entered after that flood and have grown to their present size in the intervening year. Thus the lake can act as a supplementary growing area for populations of Myall River species.

4.5 Conclusion

The ecosystem within the lake is only two years old and communities within it are probably still maturing and may change in composition, abundance and distribution over time. Currently, a total of eleven plants (excluding *Juncus* sp.), nine fishes and one confirmed macroinvertebrate species are found in the lake, with a relatively uniform band of vegetation found in the shallow margin of the lake. The species are predominantly marine/estuarine species, although a few freshwater/brackish species (eg. *Nitella* sp., *Triglochin striata, Elatine gratioloides*) are also found. As the lake was not horizontally stratified, the distribution of species and communities did not appear to be influenced by salinity and nutrient levels. Based on oxygen and the nutrient levels (total phosphorus and nitrogen) Myall Quays Lake has good surface water quality, with conditions within the guidelines recommended for lakes and reservoirs by ANZECC (1992).

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Appendix 2.

AMBS CONSULTING

Biological Study of Myall Quays Lake

Crighton Properties Pty Ltd

Draft Report

2002009

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September 2002

Document Information

Date:	2/10/2002
Issue:	Draft Report (fish and water quality)
Recipient:	Crighton Properties
Copies:	
Reviewed:	
Approved:	
Printed:	8/10/02 3:02 PM
Last Saved By:	Jemma Sargent
File Name and Path:	Document4
Project Manager:	Jemma Sargent
Client Name:	Crighton Properties Pty Ltd
Name of Document:	Biological Survey of Myall Quays Lake

Project Team

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Executive Summary

AMBS carried out an ecological survey of the Myall Quays Lake to assess the aquatic habitats present and determine changes to the assemblages since the baseline survey in 1998. An evaluation of the health of the lake was carried out by comparing historical water quality parameters with those recommended in the ANZECC Guidelines with relevance to the seagrass, macroalgae, fish and macroinvertebrates present.

Myall Quays Lake is contained within the Myall Quays development which is located near Tea Gardens, north of New Castle. It was constructed as a detention basin to serve the needs of adjoining residential development.

Generally the ecological assemblages within the lake can still be considered to be maturing. The lake appears to be influenced more strongly by rainfall events than tidal inundation and as a result the salinity concentration within the large are variable. It can be concluded that the variable water parameters are influencing the species able to inhabit the lake and conditions are more favourable to those able to with stand extreme fluctuations in salinity levels. While some water quality parameters such as dissolved oxygen and faecal coliforms are not within the recommended guidelines further monitoring is required to determine the effects of these variations.

During the study seven species of fish were collected. The lake appears to be supporting a small number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye.

The aquatic flora of the lake is maturing and has become more widespread throughout the lake. Four species of aquatic plants (excluding riparian plants) were present in the lake during this survey, the dominant seagrass *Ruppia polycarpa* and three macroalagae; *Lamprothamnion papulosum*, *Chara spp* and *Ulvaria oxysperm.*

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1 Introduction

Australian Museum Business Services (AMBS Consulting) carried out a baseline biological survey of the Myall Quays Lake for Crighton Properties in 1998. This survey of the ecological assemblages of the lake was conducted in September 2002 to determine changes to the lake environment that may have occurred since the baseline study. The Myall Quays Lake is located within the Myall Quays development near Tea Gardens, north of Newcastle. The lake was constructed as a detention basin to serve the needs of the surrounding residential development.

The scope of the study was an ecological survey of the lake to assess the current habitats present and determine changes to the assemblages since the previous survey. An evaluation of the health of the lake was carried out by comparing historical water quality parameters with those recommended in the ANZECC Guidelines.

2 Project objectives

This study aimed to;

- Survey the existing fish, seagrass, macrophyte, macroalgae and macroinvertebrates present in the Lakes;
- Compare current ecological assemblages with those present during the baseline survey;
- Map current lake vegetation;
- Analyse historical water quality data with relation to rainfall and tidal influence;
- Discuss water quality parameters with relevance to community assemblages and
- Provide advice for future lake management decisions.

3 Background Information

The baseline survey was conducted in 1998 when the lake was two years old and the communities within it were maturing. Previously 11 plants, nine fishes and one macroinvertebrate species were collected from the lake. The species were predominantly marine/estuarine species. The distribution of the species did not appear to be influenced by water quality parameters. The water quality of the lake was within the recommended ANZECC Guidelines.

4 Methodology

4.1 Review of Available Water Quality Data

Hunter Water Laboratories have collected water quality parameters from the lake since 1996 and the most recent available data was sampled in April 2002. AMBS reviewed and analysed the data collected since the previous report (02.04.98-11.4.02) and compared the results with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC Guidelines) and the previous water quality analyses. As only single water quality samples were taken at each site, no data was available to determine the vertical stratification of the lake or variation between replicate water samples.

Rainfall data for the lake was provided by Crighton Properties and was compared with the water quality results to determine any existing relationship between the two. Tidal information was sourced from the Department of Defence Australian National Tide Tables for Newcastle and was compared with the water quality results to determine any existing relationship between the two.

4.2 Site Locations

Sampling was undertaken at the sites previously surveyed. A map of the locations is included in Appendix A and site photographs are included in Appendix B;
Site 1a: North western end of lake
Site 1b: North western from the office
Site 2: In front of the office
Site 3: Eastern end of the lake near the drain entrance
Site 4: Near the drain

4.3 Seagrass and Macroalgae

4.3.1 Field

AMBS staff mapped five previously surveyed representative transects in the lake to determine the extent, pattern of cover and species composition of the seagrass, macrophyte and macroalgae communities. The abundance and distribution patterns of the vegetation were determined using the abundance/sociability scale (King and Barclay 1987) below, used previously to allow comparisons to be carried out. The plants were identified in the field and some macroalgae samples were transported to experts at the Royal Botanical Gardens for confirmation.

Table 1. Seagrass Abundance and Sociability Scale (based on King and Barclay 1986)

		Sociability	
Abundance	A	B	C
	Individuals	Patches	Beds relatively even distribution
1			
Sparse Growth (<15%)	A1	B1	C1
2			
Moderate Growth (15-50%)	A2	B2	C2
3			
Abundant Growth (>50%)	A3	B3	C3

4.3.2 Mapping

The seagrass beds were mapped using MapInfo.

4.4 Fishes

4.4.1 Field

AMBS staff used a variety of techniques to sample fish from the five sites. Based on habitat characteristics of the sites the techniques used included electrofishing, a 10m seine, Japanese seine and a fine mesh seine. These techniques are described below;

- **Electrofishing** was undertaken using a Model 12-A POW Smith Root Backpack
- **A 10 metre seine** was operated by two people walking towards the shore from about 1m depth, each holding a pole at either end of the net. This net was also operated using a row boat which allowed a greater water depth to be sampled.
- **A Japanese seine** is a small one-person collecting device which consists of two poles separated by a fine-meshed scooped net. The operator can effectively collect small fishes from stream banks and many areas that larger seines are ineffective.
- **A Fine mesh seine** is a two-person mesh net of about 2-3m in length and about 1m in height. This seine has very fine mesh and is therefore useful for collecting small fishes which may escape through the mesh of larger seines.

The fishes that were collected were identified in the field where possible and returned to the water. Any specimens unable to be identified in the field were preserved in 10% formalin and returned to the laboratory for identification. The fishes were transferred from 10% formalin to 70% alcohol after about one week.

4.4.2 Laboratory

Fishes collected that were less than 5cm could not be accurately identification in the field to species level. These were returned to the museum for identification under microscopes.

5 Results

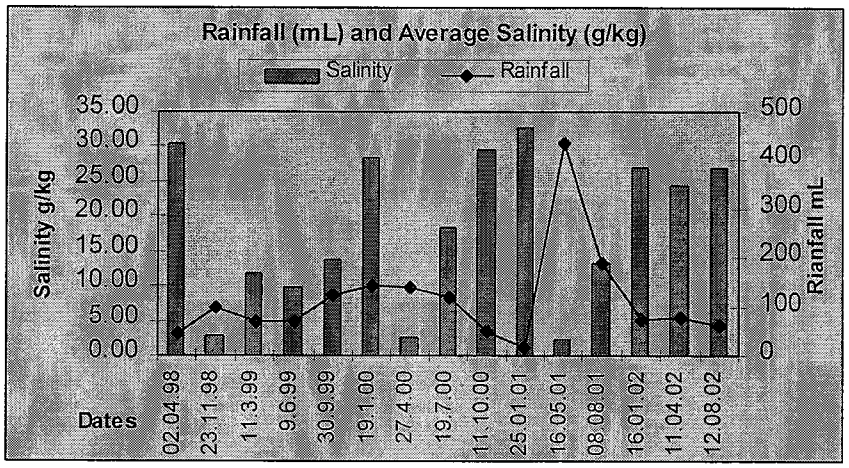
5.1 Water Quality

5.1.1 Salinity

The average salinity in the lake ranged from 2.22 to 32.81. On average salinity levels have remained similar to the previous survey, however, fluctuations and periods of low salinity have increasingly occurred.

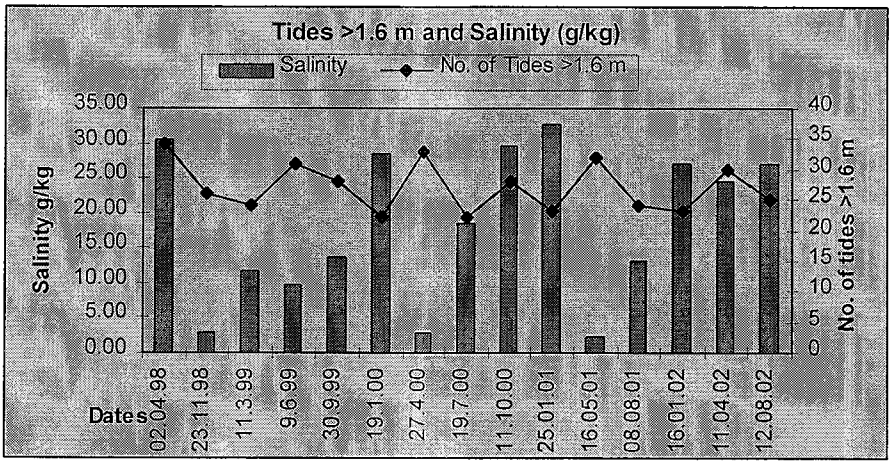
The salinity data was compared with rainfall totals for the month preceding the sampling to determine whether rainfall was influencing salinity levels in the lake. The lowest level of salinity occurred in 2001 following a period of high rainfall and the most saline sample was collected following a month of low rainfall. There would appear from the data to be a relationship between rainfall and salinity levels.

Figure 1 Salinity and Average Rainfall



The salinity data was compared with tidal influence by calculating salinity levels with the number of tides > than or equal to 1.6 metres in the month preceding the sampling event. There did not appear to be a relationship between the number of high tides and levels of salinity in the lake.

Figure 2 Tidal Influence and Salinity

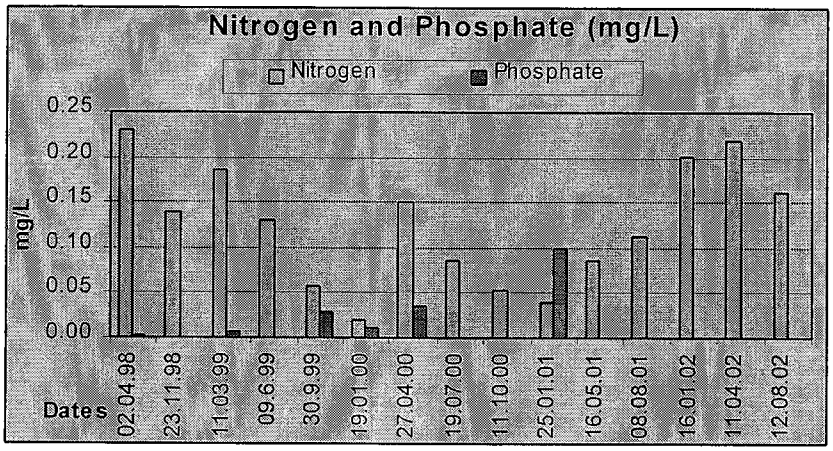


5.1.2 Nutrients

Nutrients in the environment are composed of phosphorus (P) and nitrogen (N). Levels of phosphorus and nitrogen in a water column are useful measures of the potential for nuisance plants to grow. Since the baseline survey phosphorus was measured as mg/L and the most bioavailable form of phosphorus, orthosphosphate was not analysed. Phosphate levels cannot be compared to the ANZECC Guidelines as the samples were filtered and do not include orthophosphate. Similarly, the oxidised nitrogen mg/L was measured without kjeldahl nitrogen so comparisons with the ANZECC Guidelines cannot be made.

General indications of trends relating to nutrient levels have been calculated using oxidised nitrogen, ammonia, and nitrates and phosphate (levels below .005 were considered as zero for nitrates and .01 for phosphate). On average levels of phosphate were low. The nitrogen levels on average reduced during 2000 but began increasing in 2001.

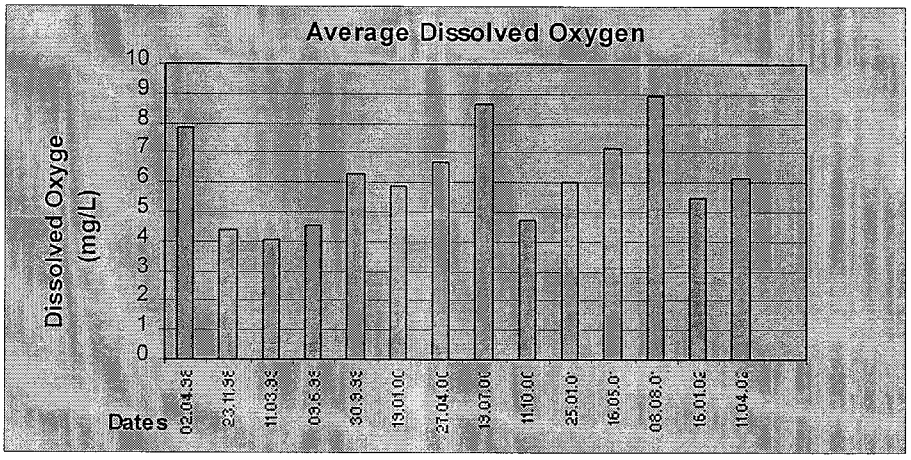
Figure 3 Average Nutrient Levels



5.1.3 Dissolved Oxygen

Average dissolved oxygen levels in the lake ranged from 4.4 -8.92 mg/L during the sampling period. The ANZECC Guidelines have set a default trigger range of 80-110% saturation levels for slightly disturbed estuarine environments. Levels of 6 mg/L and above will fall within the recommended guidelines. On average during half of the sampling events DO levels fell below the recommended guidelines. During the baseline survey all samples of DO fell within the recommended guidelines.

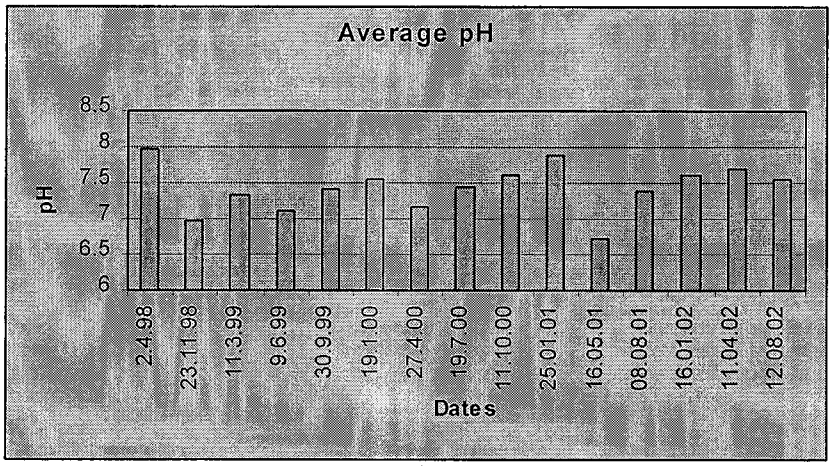
Figure 4 Average Dissolved Oxygen



5.1.4 pH

pH is the measure of the acidity or alkalinity of water on a scale of 0 (extremely acidic) to 7 neutral to 14 (extremely alkaline). The pH of natural fresh waters range from 6.5-8.0 and marine waters are commonly closer to 8.2. The average pH in the lake ranged from 6.72 -7.98, and values remained fairly consistent over the sampling period. On average the pH values of the lake were within the recommended guidelines for pH levels in estuarine environments.

Figure 5 Average pH Levels



5.1.5 Faecal Coliforms

Based on the ANZECC Guidelines for recreational water quality for primary contact the median bacterial content of fresh or marine waters should not exceed 150 faecal coliform organisms/100mL and 1000 organisms for secondary contact. Generally the levels were within the recommended guidelines but during five sampling events the faecal coliforms exceeded levels considered safe for primary contact such as swimming (Figure 6). It appears that the spikes in faecal coliform levels in the lake followed periods of rainfall. On average the lake did not exceed the recommended guidelines. Site 2 most commonly had the highest levels of coliforms. (Figure 7)

Figure 6 Faecal Coliforms

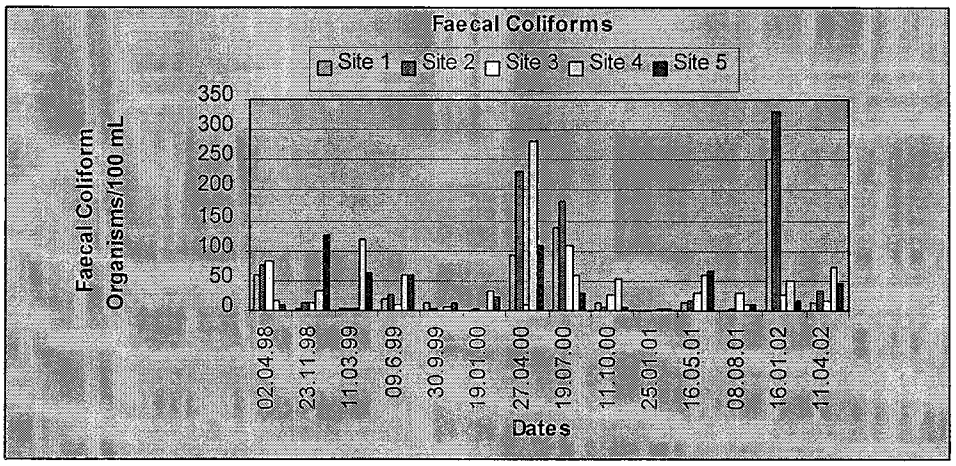
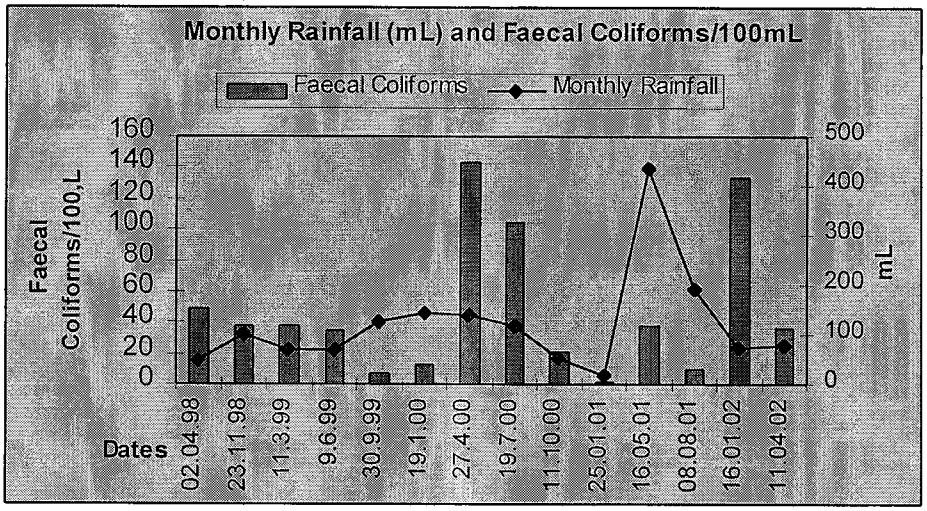


Figure 7 Monthly Rainfall and Faecal Coliforms



5.2 Seagrass and Macroalgae

The following aquatic flora were present in the lake:

5.2.1 Seagrass

Ruppia polycarpia (Sea Tassel)
Commonly grows in coastal lakes and lagoons at similar or lower salinities than seawater. *Ruppia polycarpa* is the most dominant species in Myall Quays Lake.

5.2.2 Aquatic Angiosperms

Triglochlin striata (Streaked Arrow Grass)
This is a useful stabilising species growing in tidal and freshwater swamps (Sainty & Jacobs, 1994). *Triglochlin striata* was found growing around the banks of the lake particularly in the north western end of the lake.

Family Caryophyllaceae
Paronychia brasiliana
Polycarpon tetraphyllum (Four leaved Allseed)
These plants were considered riparian and will not be discussed. *P. tetraphyllum* is a native to Europe.

Juncus spp. (Rushes)
These rushes surround the lake along the shoreline. They were not identified further as they were not growing in the lake.

5.2.3 Macroalgae

Chlorophyta (Green Alagae)
Ulvaria oxysperma

No information regarding this species could be sourced from the Royal Botanic Gardens. *U. oxysperma* was present in the shallows along the north western shoreline of the lake.

Charophytes (Stoneworts)
Chara spp
Is a native algae is found in lakes or slow moving water where calcium levels are high. *Chara* spp is present from the middle of the lake to the eastern end.

Lamprothamnion papulosum (Foxtail stonewort)
This stonewort is commonly associated with saline lakes in Australia in conditions ranging from relatively fresh to brine salt water salinities. This species is noted for its tolerance to salt water. *L. papulosum* was present only in the north western end of the lake in the shallows.

5.2.4 Distribution

A map of the distribution of the aquatic flora is presented in Appendix C. The vegetation of Myall Quays Lake was dominated by the seagrass *Ruppia polycarpa* in beds that included the charophytes; *Lamprothamnion papulosum* in the west and *Chara* spp in the middle and eastern ends of the lake. The beds were almost continuous across most of the lake thinning to the lake edges towards the eastern end of the lake. At the western end *Ulvaria oxysperma* was present in a shallow band around the lakes edge. The *L. papulosum* at the western end of the lake was present as sparse individual plants in the *R. polycarpa* bed extending to 25 metres from shore. The rest of the lake was dominated by *Chara* spp and *R. polycarpa* that formed beds covering the width of the lake. The seagrass beds were generally continuous ranging in densities from individual plants to very thick beds. Towards the eastern end of the lake the beds gradually became closer to shore. These eastern beds were dominated by gradually thinning *R. polycarpa.*

5.3 Fishes and Invertebrates

Fishes were collected at each of the five sites (1a, 1b, 2, 5 and 6). No fishes were returned to the water as all fishes were less than 5 cm and could not be accurately identified in the field to species level. The techniques carried out included electrofishing (no fishes caught), 10m seine (few gudgeons caught), Japanese seine (few gudgeons and gobies caught) and a fine mesh seine (most fishes were collected using this net). A small school of mullet (family Mugilidae) was seen, but not collected at site 6. All specimens are registered in the Australian Museum Fish Collection, under the station numbers, I. 41538 - I. 41542
Seven species of fishes representing six families were recorded from the lake. A total of 304 fishes were collected. The dominant fish species in the lake in terms of numbers collected was the blue-spot goby *Pseudogobius* sp., with 203 specimens collected (approx. two-thirds of all fish collected). The blue-spot goby was present at all sites. The next most dominant fish species in terms of numbers collected were the dwarf flathead gudgeon *Philypnodon* sp. (39 specimens from 4 sites), southern blue-eye *Pseudomugil signifer* (30 specimens from 3 sites) and flathead gudgeon *Philypnodon grandiceps* (24 specimens from 4 sites). The two other fish species

collected (Mosquitofish *Gambusia holbrooki* and Common jollytail *Galaxias maculatus*) were represented by 4 or less specimens and were only present at one site each.
The following fishes were collected from the lake;

Family Galaxiidae (Galaxiids)
Galaxias maculatus (Common jollytail)
Site 2: 1 specimen 33mm standard length
The common jollytail is very common in the coastal drainages of mainland south-eastern Australia (southern Qld to Adelaide, SA), Tasmania and southern WA (Denmark to Esperance). It is also known from Lord Howe Island, the Chatham Island, New Zealand, Argentina, Chile and the Falkland Islands. It is found in a variety of habitats, but most commonly occurs in still or gently flowing water of streams, rivers and lakes at low elevations. It has a high salinity tolerance and can live in fresh or seawater. This species is an important component of whitebait fisheries throughout the Southern Hemisphere. Adults typically migrate downstream into estuaries during high spring tides in autumn to spawn on fringing vegetation.

Family Poeciliidae (Livebearers)
Gambusia holbrooki (Mosquito Fish)
Site 6: 4 specimens: size range 19-22mm standard length
The mosquito fish is an exotic species, introduced into Australia from the USA in the 1920's. It is widespread and abundant throughout NSW, SA and Vic. in both inland and coastal drainages, and coastal Qld. It is also known from parts of WA. Mosquito fish tolerate a wide range of salinities from pure fresh water to full marine salinities. It is most abundant in warm and gently flowing or still waters, mainly around margins and along the edges of aquatic vegetation beds. It feeds on a wide array of both terrestrial and aquatic organisms. It is an adaptable generalist predator that may be a threat to other small fish species into whose habitat it has been introduced or spread. It has also been implicated in the reduction of green and golden bell frogs, presumably by feeding on the tadpoles.

Family Pseudomugilidae (Blue eyes)
Pseudomugil signifer (Southern Blue eye)
Site 2: 7 specimens: size range 12-25mm standard length
Site 5: 2 specimens: size range 24mm standard length (both specimens)
Site 6: 21 specimens: size range 12-17mm standard length
The southern blue-eye is widespread throughout eastern drainages, from Cooktown (northern Qld) southwards to Narooma, NSW. It is abundant in fresh or brackish coastal waters, but does not penetrate far inland and is usually found within 15-20km of the sea. It has been found in water temperatures of 15-28°C and pH values of 5.5-7.8.

Family Mugilidae (Mullets)
Mugil cephalus (Sea Mullet)
Site 2: 4 specimens: size range 19-28mm standard length
Sea mullet occur worldwide in tropical and temperate seas. It occurs along the entire Australian mainland coastline and northern Tasmania. It is primarily a coastal marine fish but frequently enters the lower reaches of large rivers. Large schools migrate along ocean beaches, leaving the estuaries to spawn offshore. Small schools of

juveniles enter rivers, as do adults occasionally. The species can survive for more than one year in freshwater. It is an important commercial species.

Family Gobiidae (Gobies)
Pseudogobius sp. (Blue spot goby)
Site 1a: 47 specimens: size range 9-22mm standard length
Site 1b: 31 specimens: size range 13-19mm standard length
Site 2: 58 specimens: size range 12-28mm standard length
Site 5: 28 specimens: size range 16-28mm standard length
Site 6: 39 specimens: size range 13-37mm standard length
Although this species is undescribed it is not uncommon. It is distributed from Bundaberg (southern Qld) southwards to the Victoria/SA border and is also in northern Tasmania. It occurs in coastal estuaries, coastal lagoons and swamps near the sea and usually inhabits aquatic vegetation over sand or mud.

Family Eleotrididae (Gudgeons)
Philypnodon grandiceps (Flathead gudgeon)
Site 1b: 2 specimens: size range 22-33mm standard length
Site 2: 3 specimens: size range 17-48mm standard length
Site 5: 11 specimens: size range 21-40mm standard length
Site 6: 8 specimens: size range 18-31mm standard length
The flathead gudgeon is widespread and common in the Southeast Coast Drainage Division between the Burdekin R. (Qld) and the Murray River mouth (SA), extending inland throughout the Murray Darling system. It is also found at Kangaroo Island (SA) and occasionally on Tasmania's northern coast. Adults feed on small fishes, crustaceans, insects and tadpoles. It attains a maximum size of 12cm and commonly occurs to 8cm.

Philypnodon sp. (Dwarf flathead gudgeon)
Site 1b: 5 specimens: size range 14-23mm standard length
Site 2: 4 specimens: size range 20-30mm standard length
Site 5: 24 specimens: size range 14-27mm standard length
Site 6: 6 specimens: size range 17-22mm standard length
This species is undescribed, but has been known to scientists for many years. It occurs in coastal streams of southern Qld, NSW, Victoria and SA. It is found in brackish waters in estuaries to altitudes of a few hundred metres and is common in coastal northern areas of its range. It prefers relatively calm waters and lives over mud, rocks, woody debris or in weedy areas. This species is carnivorous, feeding on a wide variety of insects, larvae and micro-crustaceans. It attains a maximum size of about 5cm and commonly occurs to 3.5-4 cm.

PHYLUM MOLLUSCA

Family Amphibolidae
site 1a: 14 specimens collected by fine mesh seine
site 6: 3 specimens collected by fine mesh seine
Salinator fragilis is a small snail (maximum size of about 1cm)
Salinator fragilis is a small snail restricted to estuaries and coastal lagoons. It has a thin, fragile shell with a narrow band around the edge and is an air-breather. It is often abundant on sand and mudflats and occurs in all Australian states (Ponder et al. 2000).

Family Hydrobiidae
site 1b: 1 specimen collected by fine mesh seine
site 2: 1 specimen collected by fine mesh seine
site 6: 16 specimens collected by fine mesh seine
Tatea rufilabrus is a small gastropod shell (maximum size about 5mm) that is restricted to estuaries and coastal lagoons, being found in association with algae and other plants, in leaf litter, under logs and rocks. It has a tall spire with many whorls. It is distributed from southern Qld to southern WA and Tasmania (Ponder et al. 2000).

6 Conclusions

Myall Quays Lake is now six years old and changes to the water quality parameters, ecological communities and habitats have occurred as it has matured.

6.1 Water Quality

Water quality parameters have been sampled from five sites within the lake since 1996. As previously, the lack of replication at each sampling site makes it difficult to assess variability at each site or vertical stratification of the lake environment. Vertical stratification, especially saline or dissolved oxygen levels, can significantly affect the composition and distribution of the biological assemblages.

The salinity levels of the lake are similar to those collected during the baseline survey and are typical of an estuarine environment. The salinity levels fluctuate more widely than previously and the lake experiences periods of almost freshwater conditions. The lake is influenced by runoff, groundwater, stormwater, saline river water inputs and vertical stratification of salt and freshwater after heavy rainfall. It would appear from the data analyses that rainfall levels have a greater influence on levels of salinity in the lake than tidal influences. It is unknown wether the low levels of salinity during certain sampling events are a result of flushing by rainfall events or increased stratification of the water column. The fluctuations in saline concentrations of the lake would effect the ecological assemblages of the lake by making the environment favourable only to species adapted to survive in highly variable saline conditions.

The nutrient samples collected could not be compared to the baseline survey or the ANZECC Guidelines due to the omission of certain components necessary for comparisons. Nitrogen levels deceased during 2000 but started increasing towards 2002. Generally it is known that nitrogen is the nutrient that limits plant growth in marine environments and sometimes in estuarine environments where salinity is low or variable.

Dissolved oxygen levels in the lake are considered depressed when compared with the baseline survey and the recommended Guidelines for estuarine environments. During the baseline survey dissolved oxygen levels were within the recommended guidelines but levels collected during subsequent sampling events were below the recommended levels and generally the dissolved oxygen levels have decreased over time. Dissolved oxygen concentrations measured in the lake reflect the equilibrium between the oxygen consuming processes (respiration) and oxygen-releasing process (eg. photosynthesis). The dissolved oxygen levels sampled indicate that there is a

disturbance to these processes. Dissolved oxygen levels are highly dependent on temperature, salinity, biological activity and rate of transfer with the atmosphere. It is common in highly productive systems such as estuaries to have periods of oxygen depletion particularly where stratification occurs. Dissolved oxygen levels are highly influenced by diurnal variety particularly where significant levels of nutrient enrichment occurs. Low levels of dissolved oxygen have the potential to adversely effect fishes. While DO levels are depressed on average in the lake, this could be caused by a variety of reasons such as nutrient enrichment of the lake, stratification, atmospheric absorption and diurnal variation relating to sampling timing. Generally average DO levels are below those recommended in the ANZECC guidelines.

The pH levels in the lake on average fell within the recommended guidelines for marine and aquatic assemblages.

Levels of faecal coliforms present in the lake were above the recommended guidelines for recreation and primary contact on a number of occasions during water quality sampling. A number of reasons for the high levels of coliforms present in the lake were suggested by NSW Health including; rainfall events, septic tank seepage into the environment, stormwater input and urban runoff. Rainfall did appear to influence the average levels of coliforms present in samples. Levels were highest at site 2 near the office while site 1 near the stormwater drain did not experience levels as consistently high. So conclusions as to the exact entry of coliforms into the lake could not be established.

NSW Health indicated that levels such as those recorded are not unusual and are common following rainfall events. It is recommended that following rainfall events primary contact with lake water is avoided for 48 hours. (pers comm NSW Health). The commonly high levels of coliforms in the lake have the potential to increase nutrient levels in the water column and result in blooms of nuisance algae species.

6.2 Seagrasses and Macroalgae

Four species of aquatic plants (excluding riparian plants) were present in the lake during this survey, the seagrass *Ruppia polycarpa* and three macroalagae; *Lamprothamnion papulosum*, *Chara spp* and *Ulvaria oxysperm*. The baseline survey identified seven aquatic species (excluding riparian plants) present including *R. polycarpa and L. papulosum*. The number and type of species present and their distribution and densities have changed since the baseline survey. The seagrass *R. polycarpa* is the dominant plant throughout the lake forming continuos beds across the lake. The previously dominant *L. papulosum* has become restricted to sparse beds in the western end of the lake and has been replaced by the similar charophyte, *Chara spp* in the middle and eastern end of the lake. During the baseline survey the beds were restricted to the shallows along the shoreline but now plants are present throughout much of the lake only narrowing to the lake edges in the eastern end.

The increased colonisation of *R. polycarpa* may be related to the salinty fluctuations experienced within the lake. This seagrass is adapted to wide ranges in freshwater and saline conditions enabling it to thrive in variable saline conditions.

The Charophytes, *L. papulosum* and *Chara spp* prefer nutrient poor, calcium rich environments and are highly sensitive to nutrient enrichment. While *Nitella subtilissima* is no longer present in the lake *Chara spp* appears to be flourishing. Charophytes are now present throughout the lake and their increased colonisation may be the best indication that faecal coliforms influxes have not significantly increased nutrient levels in the lake. Likewise, no blooms of nuisance macroalgae species such as *Cladophora sp* have occurred that would indicate nutrient enrichment, rather this species is no longer present in the lake.

6.3 Fishes and Invertebrates

Seven species representing 6 families were recorded from the lake as compared to nine species during the baseline study. A total of 304 fishes were collected compared to 839 during the baseline study. This difference could be partly related to the use of slightly differing sampling techniques or differing abundances of fish species in different seasons (the baseline survey was completed in January and this survey was undertaken in September). As was outlined in the baseline survey, the lake is still young and changes in the faunal composition of the lake are not surprising. The physical (eg habitat) and chemical (eg salinity, pH) variables controlling fish occurrences and abundances appear to be still changing in the lake.

Two species collected in the most recent survey that were not collected in the baseline survey were the flathead gudgeon *Philypnodon grandiceps* and the saline tolerant common jollytail *Galaxias maculatus.* Three species of goby and the common silver belly were collected during the baseline survey but were not collected during the most recent survey. The wide range of salinities recorded in the lake would favour estuarine species that can tolerate such changing conditions. It is expected that if fish sampling were undertaken on a more regular basis, more species would be recorded than have been on the previous two occasions. It is likely that some fishes are not permanent residents of the lake and only enter it when conditions are favourable to their needs.

The Myall Quays Estate Lake appears to be supporting a small number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye. Sea mullet may only be present in considerable numbers at specific times of the year and probably migrate out of the lake to spawn at sea.

6.4 Summary

The ecosystem within the lake is now six years old and the water quality and ecological communities within it have changed in composition, abundance and distribution over time. The species present in the lake are adapted to a changing physical environment, with fluctuations in salinity, nutrients and dissolved oxygen occurring as a complex result of freshwater influxes (rainfall and stormwater), tidal flows and other causes.

The physical characteristics of the lake appear to have changed since the baseline survey. The lake appears to be less effected by tidal influence and increasingly by rainfall events. While salinity levels within the lake have remained similar in general

to the baseline survey, the lake experiences extreme fluctuations in concentrations following rainfall events. At times the lake experiences conditions of almost freshwater ranges. This will effect the species able to live in the lake. pH levels fall within the recommended ANZECC Guidelines, however the dissolved oxygen levels appear to be becoming depressed over time. On average levels of faecal coliforms within the lake have been within the guidelines, however on a number of occasions during sampling events total levels have been above those recommended for primary contact.

During the study seven species of fish were collected. The lake appears to be supporting a small number of resident fishes that are probably present year round and breed within the lake. These fishes include the flathead gudgeon, dwarf flathead gudgeon, blue-spot goby and southern blue-eye.

The aquatic flora of the lake is maturing and has become more widespread throughout the lake. Four species of aquatic plants (excluding riparian plants) were present in the lake during this survey, the dominant seagrass *Ruppia polycarpa* and three macroalagae; *Lamprothamnion papulosum*, *Chara spp* and *Ulvaria oxysperm.*

7 Recommendations

AMBS suggest that water quality sampling of the lake continue and that future samples be replicated within the sites to allow more stringent statistical analysis. The sampling should include orthophosphate and kjeldahl nitrogen so that nutrient levels can be compared to the ANZECC guidelines. The monitoring of nutrient levels could prove important in the future to monitor the effects of runoff of faecal coliforms into the lake.

Based on the ANZECC guidelines for recreational water quality on a number of occasions in the last few years the faecal coliform levels in the lake were above the recommended levels for primary contact (swimming). These guidelines direct that a minimum of five samples are taken at regular intervals not exceeding a month and four out the five samples must contain less than 600 organisms/100mL. AMBS suggest that Crighton Properties regularly monitoring the lake for faecal coliforms following rainfall events following the sampling frequency above.

AMBS suggest that monitoring of the ecological assemblages of the lake continue to be carried every few years. Assessments of fish habitat in the lake and inflowing waters may help to provide information on the suitability of any necessary habitat changes.

Further fish surveys at more regular intervals would confirm or deny whether the above mentioned fishes are permanent residents. As the lake currently only has a small number of habitats (i.e. mainly sand, mud, algae), the introduction of new habitat such as growing mangroves at the seaward end may encourage more fishes into the lake. There is currently little protection for larger fishes (ie over 10cm) within the lake from bird predation. The introduction of additional native aquatic vegetation (eg. mangroves) or artificial habitat (eg woody debris or artificial structures) may encourage the growth and survival of fishes by providing shelter and food.

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Appendix A Site Locations

Appendix B Site Photograph

Appendix C Maps of Aquatic Vegetation

Appendix 3.

Appendix 3.

HARRIS RESEARCH Pty Ltd

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Freshwater ecology and fisheries

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10 August 2002

ECOLOGICAL PRINCIPLES AND DEVELOPMENT OPTIONS FOR THE MYALL QUAYS WATERWAY

Background

The success of the Myall Quays development will be judged by the natural values that it supports and these values can be optimised by integrating environmental, social and commercial principles. Planning for the development should be based on an understanding of the principles that govern the ecology of comparable brackish lagoon systems, as well as the engineering, town planning and other considerations. The following notes aim to outline the aquatic ecological principles that should be considered and planning options that may be available. They are underpinned by the assumption that water is the key resource to be managed for best usage, rather than a waste product of development or a problem to be dealt with. Key objectives include biological diversity, fisheries-based recreational opportunities and environmental amenity for residents.

The tidal and saline regimes will drive ecology

The most basic planning issue for the aquatic system relates to the levels of salinity and tidal flushing, and their variations. Clearly, these attributes will be dynamic and result from the interaction of freshwater runoff, groundwater and incursions from the Myall River estuary via the small connecting drains from the lake.

The tidal and saline regimes will drive the waterway's ecology, determining the types of plants and animals that can be supported, and their patterns of diversity and abundance. If it were possible to create full tidal ventilation, the system would come to mimic that seen in the adjacent estuary. At the other extreme, if tidal incursion were prevented, a freshwater system similar to the existing runoff detention ponds would result. For several reasons, a saline regime intermediate between these two extremes seems desirable. Other regional brackish systems such as Smiths Lake or the Mall Lakes provide potential models. It is important to recognise that, in practice, the

saline regime will vary substantially as the various controlling inputs change with the weather and tides. Reflecting this variation, the waterway's ecology will also be dynamic, with only a limited range of plant and animal species able to cope with these fluctuating conditions.

Towards the saline end of the water-quality spectrum, those fish that are 'euryhaline' – meaning they can tolerate changing salinities - will dominate the wetlands fish community. Typically they might include two or three mullet species, estuarine herring, two eels, bream, silver biddies, blue-eyes, gobies and perhaps flathead and a few other infrequent species. Alternatively, a predominantly freshwater system would occasionally support some of these species plus two or three gudgeons, smelt, eels and Australian bass. The level and stability of the saline regime would similarly determine the composition of aquatic vegetation and the invertebrate fauna.

A desirable management objective would be to represent a variety of aquatic systems. This could be achieved by maintaining tidal, saline conditions in the lagoon while promoting a freshwater 'riverine' regime in the in-flowing tributary sections. Such a combination would enhance biological diversity, visual amenity and recreational opportunities for Myall Quays residents.

Options for managing saline and tidal regimes

Each of the key inputs – runoff, groundwater and tidal incursion – are more or less amenable to planned manipulation to achieve an optimal outcome. Runoff can potentially be detained or diverted to some degree, groundwater could (in theory at least) be raised or lowered, and tidal incursion through the drains can be restricted or enhanced. These possibilities suggest some useful management and design options.

1. Tidal control

It appears highly desirable to install facilities to control the extent of tidal incursion through the lagoon's drains. This would allow the lagoon's water levels and water quality to be manipulated. If it were appropriate, salinity could be regulated closer to that of the adjacent Myall River. Potential problems such as nuisance blooms of algae or low dissolved oxygen could be managed directly by tidal flushing should they occur.

A simple 'drop-log' control structure would be needed to control tidal incursion. These are simple concrete 'U'-shaped structures, slotted to carry timber or concrete drop-logs, and sized to conform to the drain. Manually adding or removing drop-logs can either increase or reduce the amount of tidal incursion. The maximum height needed would be the median high-tide level, so that visual impact would be slight. It might be desirable to control both the main drains from the lagoon.

To optimise control over water quality, it would be desirable to deepen the drains slightly so that greater tidal flow can be available if needed. Deepening by 300mm – 400mm would probably be sufficient.

2. Limiting upstream salinity

To produce stable freshwater conditions in the tributary riverine reaches of the waterway it will be necessary both to design appropriately sized channels and also to control saline inputs to these upstream areas. The number and surface area of these riverine areas may need to be modelled in order to balance them against the frequency and volume of runoff events and to maintain water quality by continued through-flow. But it seems clear that only a small number (one, two or three) should be created, perhaps with a long, sinuous path to enhance their individual area. A uniform, low gradient is needed to ensure outflow, and this could resemble the upper Myall River reaches above Bulahdelah.

In the diverse, freshwater/brackish waterway system suggested, salt intrusion into the riverine areas from the lagoon would need to be prevented. This would arise from gravity-driven saline stratification in the lagoon, and could be prevented by creating a shallow sill at the junction of each riverine tributary with the lagoon. A narrow rocky sill across the stream, perhaps built with rip-rap material over a clay core, should limit depth to about 300mm at this point. This would prevent deep saline layers from intruding upstream and help maintain freshwater conditions. Similar sills might also be desirable upstream to retain stable freshwater pools.

Aquatic habitats should be optimised

The diversity of aquatic habitats will determine the biological diversity that can be supported by the waterway. Similarly, the quantity of habitat will control the abundance, diversity and resilience of biological populations. Of course, both these quantity and quality relationships depend on the assumption that water quality will be maintained at suitable levels of dissolved oxygen, pH, nutrients, toxicants and salinity and these conditions should be encouraged by enhancing tidal flushing of the lagoon. Continuing effective operation of the small runoff-treatment ponds is also clearly important.

In the suggested freshwater/brackish system, habitat quality can be predicted from several key attributes: depth, physical structure (including macrophyte growth), the nature of substrates, and the extent of the littoral zone (i.e. the near-shore areas where the land and water meet). Flow velocity is unlikely to be a significant factor except in and adjacent to the drains or during extreme-runoff periods. Creating diversity should be a guiding principle in planning the design of the key attributes.

Options for enhancing the amount and quality of habitat

Depth profiles should be varied as much as practicable while bearing in mind the need to ensure adequate flows and mixing. The littoral zone is a critical area for food-web production, mainly based on the growth of algae and macrophytes, so that extensive areas with low-gradient batters are valuable within the upper one metre of the water column.

Physical structure is a critical aspect of habitat and can be derived from several sources. Submerged logs and mounds of rockwork would both provide valuable structure, especially when distributed in the upper two metres of the water column. Within practical limits, the more structure, the better.

Beds of macrophytes and algae can also contribute greatly as structural habitat and food-web source areas. Their growth will be determined by the stability of water quality and other factors. In creating the waterway it would be important to introduce desirable aquatic plants early in the process to pre-empt weed growth. Desirable plants in the brackish zone could include Ruppia and Zostera, with Phragmites and Vallisneria in freshwater areas. Emergent littoral rushes and reeds should also be experimentally planted. It could be productive to engage a botanical consultant to provide detailed advice on these aspects.

Options to incorporate diverse substrates seem limited, given the sandy character of the area, other than for the rockwork mounds suggested earlier. But this aspect deserves consideration in any underwater structural works such as culverts. Rip-rap and other rock-based construction methods will contribute far more habitat value than formed concrete.

The size of the littoral zone can be increased in the lagoon by creating a complex, strongly curved shoreline, with many small bays and inlets. A sinuous stream path would have the same effect in the riverine section. These simple options can produce substantial habitat benefits and will also enhance visual amenity.

Fringing terrestrial native plants, including trees, shrubs, rushes and grasses, contribute to food resources for many fish. They also reduce temperature fluctuations, control excessive wind effects and contribute greatly to amenity. Landscaping options should be investigated, using local native plant communities as a guide.

The network of small runoff-treatment ponds also has potential habitat value. Enabling fish passage over their small control weirs could activate this. A suitable device would be a small-scale rock-ramp fishway on a slope of 1:20.

Recruitment processes control fish populations

Recruitment involves the addition of new individuals to the populations. These counteract population losses from emigration and mortality. Three sources of recruitment are possible in the Myall Quays development.

1. Immigration from the Myall River

Estuarine fish species will enter and leave the waterway via the drains. Fish of many species will enter as juveniles, grow for a period in the lagoon, and then emigrate, often to spawn elsewhere. Mullets, bream, eels and herring are examples.

2. Local spawning

Some species, especially the smaller ones like gobies, smelt and gudgeons, are likely to spawn and recruit within the waterway. The extent of this local recruitment will depend on availability of suitable habitat, especially plant beds and rocky substrates, together with an appropriate water quality.

3. Fish stocking

Some success has already been reported with the stocking of hatchery-propagated Australian bass, and this is a way of maintaining numbers of this popular species. Wild bass may colonise the waterway naturally, but local populations are in severe decline and it would be useful to boost numbers artificially. Bass will tend to move towards the freshwater habitats.

Options for enhancing recruitment

An extra benefit from deepening the drains as suggested earlier would be the enhancement of fish recruitment from the Myall estuary. Increasing depth and flow through the drains should result in significantly greater fish immigration.

The various options suggested for enhancing habitat attributes could all be expected to aid local recruitment of fish through increased spawning and nursery areas, as well as a stronger, more diverse food web.

The bass-stocking option is worthwhile. Hatcheries should be asked to provide juvenile fish bred from local broodstock. It may be best to stock small numbers annually.

Continuing growth of knowledge is critical

The ecology of aquatic systems such as the Myall Quays waterway is dynamic and it is not possible to predict the composition of biological communities with certainty. Furthermore, such communities undergo substantial fluctuations driven by weather, conditions in the estuary and other poorly predictable influences. And, in addition, it must be expected that an artificially created waterway will go through a long process of ecological development, with large trends in its physical, water-quality and biological attributes over a period of years or decades.

Options to improve knowledge

To manage such a dynamic system effectively and minimise the various inherent risks, it is essential that knowledge of the system should be as comprehensive and thorough as possible. This shows the need to utilise existing knowledge about comparable systems, such as that gathered at the University of New South Wales' Smiths Lake field station.

It is also necessary to have effective ongoing monitoring to understand how the hydrological, water-quality, physical and biological components of the system are responding through time. Various consultancy reports already achieve some of these objectives. It seems desirable to complement this process through an association with a suitable university, and an ongoing

series of student scholarships would be an effective means of achieving this at relatively low cost. It should be stressed that the value of such knowledge would increase exponentially through time, regular observations over a long period are far more valuable for most of the important topics. A sequence of student projects on the waterway's biology, hydrology, water quality and ecological processes would be an extremely useful tool for management.

Appendix 4.

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MEMORANDUM

3 May 2007

John Harris [John.h.harris@bigpond.com]

Peter Childs [peter@crighton.com.au]

To: Dr John Harris, Peter Childs

From: Dr Peggy O'Donnell

Re: Results of Fish Survey, Myall Quay Lakes

John and Peter,

Sampling in Myall Quay Lake was completed as requested on 26 and 27 April, 2007.

Methodology used was as described in our proposal of 24 April 2007, and subsequent conversation with John Harris regarding recording information on the relative abundance of aquatic macrophytes. Data are attached as an Excel file with 3 worksheets, and a pdf file containing site photographs. Additional sampling details are provided below:

Seine netting

Seine netting was conducted along the shoreline at 8 locations. GPS coordinates for sampling locations at given in Table 1 (Excel spreadsheet attached). The seine used measured 25 m long x 2 m deep, with a mesh size of 5mm. The net was run out from the shore in a U-shape using a boat and then hauled up on to the bank. Fish were collected in the cod end and placed in a tub with water, in order to minimise handling and stress. Identification, measurements and enumeration were done and all native fish were then released. Those species not readily recognisable were preserved in formalin and returned to the laboratory for identification checks.

Gill netting

This technique was used to capture fish in deeper areas of the water body. Nets were made of a rectangular panel measuring 30m (50mm mesh x 0.25mm diameter) x 1.8m deep. Four gill nets were deployed along the middle of the lake with GPS points taken at the start and end of each panel. GPS coordinates for sampling locations at given in Table 2 (Excel spreadsheet attached). Gill nets were placed either perpendicular or horizontal to the shore. Deployment times were 90 minutes, with times deployed listed in Table 2. Captured fish were identified to species, measured and released. Those fish species not readily identifiable in the field were preserved in 10% formalin and checked in the laboratory.

Macrophytes

Aquatic plants and algae were identified using a visual assessment of percentage cover based on King and Barclay (1986):

1 – present - low density (< 15% cover),

2 – common - medium density (15% - 50% cover), or

3 – abundant - high density (> 50% cover).

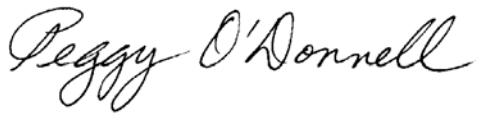
Macrophytes present in the sampling area along the bank were inspected and ranked using this classification. Algae and seagrass were inspected along the shoreline, and were also categorised based on species and amounts collected in the seine and gill nets. The seagrass *Ruppia* spp. was recorded at only one of the sampling sites.

Additional Information

Photos of several of the sampling sites were taken, including macrophytes. These are found in the attached pdf file. Note that photographs of algae and seagrass were limited due to poor instream visibility.

I would be happy to provide any further detail you may require.

Regards,



Dr Peggy O'Donnell

Senior Environmental Scientist, Manager

Table 1 - Field sampling locations and time of each seine net shot. Datum: WGS84 - Zone 56H.

Sample	Easting	Northing	Date	Time
SEINE 1	420583	6155610	26/04/2007	13:15
SEINE 2	420571	6386708	26/04/2007	13:45
SEINE 3	420978	6386366	26/04/2007	14:50
SEINE 4	421001	6386403	26/04/2007	15:15
SEINE 5	420599	6386606	27/04/2007	8:40
SEINE 6	420793	6386419	27/04/2007	9:10
SEINE 7	420969	6386597	27/04/2007	9:40
SEINE 8	420678	6386536	27/04/2007	10:15

Table 2 - Field sampling locations, depths and time for the start and end of each gill net set. Datum: WGS84 - Zone 56H.

	Start					End			
Sample	Date	Time	Easting	Northing	Depth (m)	Time	Easting	Northing	Depth (m)
GILL 1	26/04/2007	12:55	420973	6386428	3.4	14:25	420970	6386399	3.3
GILL 2	26/04/2007	13:05	420829	6386389	3.5	14:35	420814	6386373	3.4
GILL 3	27/04/2007	8:15	420586	6386780	2.1	9:45	420563	6386763	3
GILL 4	27/04/2007	8:18	420642	6386597	3.1	9:48	420629	6386572	3.5

Data entered by:HLS 30/04/2007
Data checked by:HLS & MP 02/05/2007
Data corrections entered by:MP 02/05/2007

Table 3 - Survey data for seine and gill net fish samples. Caudal fin legth was measured for up to 10 individuals of larger species. # denotes an exotic species.

			Seine shot 1		Seine shot 2		Seine shot 3		Seine shot 4		Seine shot 5		Seine shot 6		Seine shot 7		Seine sh
Family Name	**Species Name**	**Common Name**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**	**No. Individuals**	**Caudal Fin Lengths (mm)**
FISH																	
Poeciliidae	*Gambusia holbrooki*	Mosquito fish#								3				1			
Psuedomugilidae	*Psuedomugil signifer*	Pacific blue-eye								9				2			
Mugilidae	*Mugil cephalus*	Sea mullet		40	1				115	1	65, 80, 80, 75, 60, 70, 50, 65, 70, 70	65	125, 155, 80, 50, 50, 70, 50, 45, 45.	9			50, 50, 50, 60, 50, 40, 60, 45, 50, 80
Mugilidae	*Myxus elongatus*	Sand mullet															
Sparidae	*Acanthopagrus australis*	Yellow-finned Bream	329	1	130	1							150	1			
Gerreidae	*Gerres subfasciatus*	Silver Biddy	105, 110, 140, 130, 155, 120, 135, 110.	8	165, 138, 125, 125, 85, 110.	6	130	1	170	1	125, 140.	2	130, 120, 120.	3	145	1	
Gobiidae	*Philypnodon grandiceps/* sp.	Flathead gudgeon/Dwarf flathead gudgeon		90		83		3		78		95		130		18	
Gobiidae	*Psueudogobius sp.*	Blue spot goby		1										8		1	
Gobiidae	*Afurcagobius tamarensis*	Tamar River goby				10		4				1				2	
Gobiidae	*Amoya bifrenatus*	Bridled goby												2			
Gobiidae	*Favonigobius exquisitus*	Exquisite sand goby		6		3		17		1		4		7		1	
MACROINVERTEBRATES																	
Palaemonidae		Estuary Shrimp						2				2		11			
Gastropoda	Unidentified species																
Notes			2 large mullet observed jumped out of net.														
Data entered by:HLS																	
Date data entered:30/04/2007																	
Data checked by:HLS & MP																	
Date data checked:02/05/2007																	
Data corrections entered by:MP																	
Date corrections entered:02/05/2007																	

Myall Quays Lake Fish Study 2007

Table 3 - Survey data for seine and gill net fish samples. Caudal fin legth was measured for up to 10 individu

Family Name	Species Name	Common Name	ot 8	Gill Net rep 1		Gill Net rep 2		Gill Net rep 3		Gill Net rep 4	
			No. Individuals	Caudal Fin Lengths (mm)	No. Individuals	Caudal Fin Lengths (mm)	No. Individuals	Caudal Fin Lengths (mm)	No. Individuals	Caudal Fin Lengths (mm)	No. Individuals
FISH											
Poeciliidae	*Gambusia holbrooki*	Mosquito fish#									
Psuedomugilidae	*Psuedomugil signifer*	Pacific blue-eye	20								
Mugilidae	*Mugil cephalus*	Sea mullet	22			420	1				
Mugilidae	*Myxus elongatus*	Sand mullet		290	1	290	1				
Sparidae	*Acanthopagrus australis*	Yellow-finned Bream									
Gerreidae	*Gerres subfasciatus*	Silver Biddy									
Gobiidae	*Philypnodon grandiceps*/ sp.	Flathead gudgeon/Dwarf flathead gudgeon	112								
Gobiidae	*Psueudogobius sp.*	Blue spot goby	1								
Gobiidae	*Afurcagobius tamarensis*	Tamar River goby									
Gobiidae	*Amoya bifrenatus*	Bridled goby									
Gobiidae	*Favonigobius exquisitus*	Exquisite sand goby	4								
MACROINVERTEBRATES											
Palaemonidae		Estuary Shrimp	1								
Gastropoda	Unidentified species		1								
Notes								No fish found		No fish found	
Data entered by:HLS											
Date data entered:30/04/2007											
Data checked by:HLS & MP											
Date data checked:02/05/2007											
Data corrections entered by:MP											
Date corrections entered:02/05/2007											

Table 4 - Relative abundance of macrophytes recorded at each sampling site in Myall Quays Lake. 1 = Present; 2 = Common; 3 = Abundant. Blank cells indicate absence from sampling site. Growth forms: 1 = Floating attached; 2 = Submerged; 3 = Emergent.

Type	Scientific name	Common name	Growth Form	Seine shot 1	Seine shot 2	Seine shot 3	Seine shot 4	Seine shot 5	Seine shot 6	Seine shot 7	Seine shot 8	Gill net rep 1	Gill net rep 2	Gill net rep 3	Gill net rep 4
Algae															
Chlorophyta (Green Algae)															
	Cladophora sp., *Spirogyra* sp., *Rhizoclonium* sp.		2		3		1	2	2	1	3				
Cyanobacteria/Rhodophyta															
	Unid. filamentous Blue-Green/Red algae														1
Seagrass															
	Zostera capricorni	Eel grass	2	1		1	2			1	1				
	Ruppia polycarpa	Sea tassel	2								2				
Saltmarsh															
	Sarcocornia quinqueflora		2							2					
Macrophyte															
	Juncus sp.	Common rush	3	2	3	3	2	3	3	1					
	Triglochin striata	Streaked arrow-grass	3						1		1				
	Ceratophyllum demersum	Hornwort	2	1			2								
	Phragmites australis	Common reed					1								
Bed description				Mostly bare muddy sands	bare sands with silt/muds	Mostly bare sand with silt detritus			Sand and mud with fine detritus	Muddy sands					Black algae sample taken

Data entered by:HLS 30/04/2007
Data checked by:HLS & MP 02/05/2007
Data corrections entered by:MP 02/05/2007

Plate 1. Upper: tidal inlet.

Plate 1. Lower: looking North with tidal inlet near right.

Plate 2. Upper: sand mullet from seine net shot 4.

Plate 2. Lower: Seine net shot at site 5. Photo looking North, away from tidal inlet.

Plate 3. Upper: seine net shot Site 7 including *Juncus* sp. and *Sarcocornia quinqueflora.*

Plate 3. Lower: *Sarcocornia quinqueflora* at seine Site 8.

Plate 4. Upper: Medium density *Juncus* sp. on embankment located at seine net shot 1.

Plate 4. Lower: High density *Juncus* sp. instream and on embankment at seine net shot 6.

Plate 5. Upper: Setting gill net from boat.

Plate 5. Lower: Seine net shot 8 site looking towards tidal inlet. *Ruppia* spp. growing on shallow sand sandbars around the enclosures.

Appendix 5.

Map of sampling sites in Myall Quays Lake, 26 and 27 April 2007. S = Seine shot, G = gill net set.

APPENDIX I

PRACTICAL CONSIDERATION OF CLIMATE CHANGE
MAY 2008

Cardno Willing

Shaping the Future

Riverside at Tea Gardens

Practical Consideration of Climate Change

CRIGHTON PROPERTIES

MAY 2008

JOB NO. W4332-7

CRIGHTON PROPERTIES

Riverside at Tea Gardens
Practical Consideration of Climate Change

Final Report
May 2008

Client	Crighton Properties			
Document	Riverside at Tea Gardens Climate Change Assessment			
Status	Preliminary	☐	**Author**	Dr Brett C Phillips, Stephen Yu
	Draft	☐	**Signature**	Brett C. Phillips
	Draft Final	☐	**Date**	23 May 2008
	Final	■	**Reviewer**	Dr Brett C Phillips
	Superseded	☐	**Signature**	Brett C. Phillips
	Other Specify	☐	**Date**	29 May 2008

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[1] McLuckie, D., Lord, D. and Gibbs, J. (2006) "Climate Change – The Future is Uncertain, Practical Consideration of Climate Change in Flood Risk Management in NSW", proceedings, 46th NSW FMA Conference, Lismore, March.

SUMMARY

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment. Sensitivity assessments of climate change were undertaken for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change". These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

It was concluded from the results of the sensitivity runs for the Myall River that:

- The current adopted 100 yr ARI level of 2.1 m AHD could accommodate up to a 30% increase in rainfall under conditions where there is no increase in sea level;
- The increase in 100 yr ARI levels in the Myall River in the vicinity of Riverside due to increases in rainfall reduce as the sea level rise increases ie. a 30% increase in rainfall increases 100 yr ARI levels in the Myall River by
  - 0.06 m to 0.07 m under a sea level rise of 0.18 m
  - 0.04 m to 0.06 m under a sea level rise of 0.55 m
  - 0.03 m to 0.04 m under a sea level rise of 0.91 m
- Under the +0.18 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is around 0.43 to 0.25 m depending on the adopted increase in rainfall intensity
- Under the +0.55 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is only around 0.02 to 0.07 m depending on the adopted increase in rainfall intensity
- Under the +0.91 m sea level rise scenario Council's Flood Planning Level of 2.6 m AHD is exceeded by 0.26 m to 0.3 m depending on the adopted increase in rainfall intensity
- It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios.

It was concluded from the river flooding inundation plots that:

- River flooding under either a low or a medium climate change scenario would not inundate any unimproved lots;
- River flooding under a high climate change scenario would partially inundate around 180-220 unimproved lots (but not over floors) to a maximum depth of 0.3 m;
- Under a low climate change scenario there would be minimal inundation of planned roads;
- Under a medium climate change scenario there would be inundation of a number of planned roads by up to 0.5 m (which would be Low Hazard due to the expected very low velocity of the fringes of the river flooding through the development);
- Under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading.

It was concluded from the results of the sensitivity runs for the local catchment that:

- In areas where the estimated 100 yr ARI flood level is greater than 2.1 m AHD the 1.5 hour storm burst gives higher local 100 yr ARI flood levels than the 9 hour storm burst
- The East Branch and North Branch Flood Planning Levels are controlled by the Myall River under a +0.18 m or greater sea level rise;
- The Flood Planning Levels adjacent to the West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The Flood Planning Levels adjacent to the lower reaches of the East West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The greatest increase in the 100 yr ARI flood level in the East West Branch in the reach unaffected by sea level rise is 0.28 m;

It is noted that the Riverside proposal has an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD for all homes in Riverside will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

Elsewhere in the development consideration a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

While under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading. Even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

It was also noted from the 1980 flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

1. BACKGROUND

In October 2007 the NSW Department of Environment and Climate Change (DECC) released a guideline titled “Practical Consideration of Climate Change”.

As discussed in the guideline, climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations.

Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 m to 0.91 m by between 2090 and 2100.

In addition, climate change impacts on flood producing rainfall events show a trend for larger scale storms (rainfall totals for the 40 year average recurrence interval (ARI) 1 day storm events) tend to increase by 2030 and 2070. **Figure 1** shows the potential impacts of changes in current design ARIs due to increases in rainfall. CSIRO is currently undertaking further work in the area of shorter duration rainfall events which is expected to lead to further advice in this area in the future.

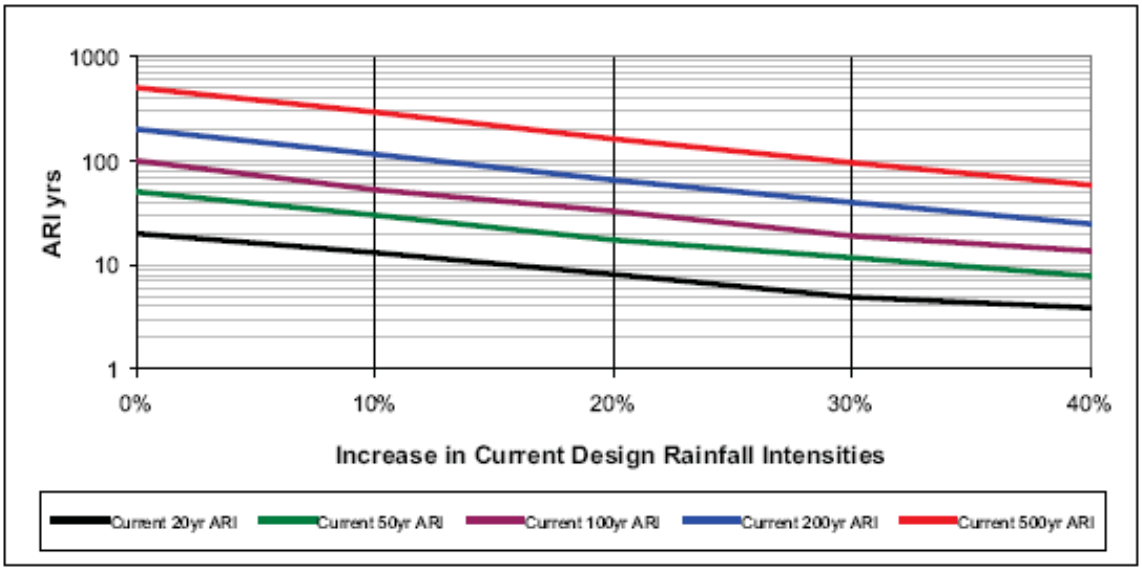

Figure 1
Indicative Change in Design ARI as Rainfall Intensities Increase
(after McLuckie et al, 2005)[2]

[2] McLuckie, D., Lord, D. and Gibbs, J. (2006) “Climate Change – The Future is Uncertain, Practical Consideration of Climate Change in Flood Risk Management in NSW”, proceedings, 46th NSW FMA Conference, Lismore, March.

DECC, 2007 recommends that the following sensitivity analyses are undertaken:

- Sea level where relevant to a study area:
  - 0.18m (Low Level Ocean Impacts
  - 0.55m (Mid Range Ocean Impacts
  - 0.91m (High Level Ocean Impacts

- Rainfall intensities. Increases of:
  - 10% in peak rainfall and storm volume
  - 20% in peak rainfall and storm volume
  - 30% in peak rainfall and storm volume

  until more work is completed in relation to the climate change impacts on rainfall intensities

2. PREVIOUS STUDIES

Department of Public Works, NSW (1980) "Lower Myall River Flood Analysis, 32 pp.

Flood behaviour in the Myall River was studied in the Lower Myall River Flood Analysis (Department of Public Works, 1980). The study used mathematically modelled, synthesised floods of various frequencies to illustrate the range of expected flood flows in Myall Lakes and the River. Unfortunately there was little hydrological and water level data for the catchment, Lake and River available at the time, so the model could not be fully calibrated.

Peak lake heights were derived by running the model for a number of predetermined hydrological conditions and applying them for various durations.

A sensitivity analysis was also performed with the model. This involved changing various factors within the model such as rainfall intensities, losses, storage functions, initial levels in the Myall Lakes, Manning's "n" values and the lake outflow rating. The report found that flowrates and lake levels were maximised with higher rainfall intensities (3.6 mm/hr to 4 mm/hr), a reduced Manning's "n" on the overbanks (0.1 to 0.06) and a lake outflow rating raised by 25%.

The study used the HEC-2 backwater analysis program to compute water levels in the Myall River. Long-section profiles for the river showing water levels for low, mean and high tides and under a surge situation were plotted. The plot states (Figure 7, 1980), "these profiles are based on steady-state analyses at each tide and hence only represent real water levels upstream from about cross section 10 where the profiles nearly coincide". A peak surge level at Paddy Marrs Bar of 2 m AHD was used for the surge situation based on estimates supplied by the Coastal Branch of PWD. The derivation of the peak surge level was probably based on mean sea level including storm surge plus some allowance for wind and wave set-up.

The report recognised that its major shortcoming was the non-modelling of the tidal cycle in the lower river up to 10 km from the river mouth. Downstream of this point flood levels gradually change from river to ocean conditions however there was no information available at the time to determine accurate levels. The report does note however that the difference between the 100 Year ARI flood and a high tide at Tea Gardens is less than 100 mm although the actual levels were not given.

Public Works Department, NSW, Manly Hydraulics Laboratory (1993a), Lower Myall River Compilation of Data, Report MHL622.

The report is a summary of existing data, both published and unpublished, on estuarine processes in the Lower Myall River. The report notes that most of the information is more than 10 to 15 years old, however little work of specific relevance has been collected since. Physical characteristics of the river are outlined including information on climate, ecology, geology, geomorphology, sediments and shoaling. Previous investigations into flooding, hydraulic conditions, hydrographic changes, numerical modelling, sediment transport and water quality are also presented.

Section 7 of the report deals with flooding. It mentions that historical records of flood levels in the Myall Lake System and the Lower Myall River are very limited, with most data only available from local observations. These data do not provide precise accounts of the events and given levels are difficult to relate to any specific datum. A brief description of the 1980 PWD flood study is also included.

Section 10 of the report provides an overview of model investigations into the lower Myall River. Of particular interest is a one dimensional numerical estuarine model set up by PWD in 1980. The report provides a reasonably detailed description of the model and provides results and discussion of the effects of flooding, tidal action and shoaling on sediment transport and water levels.

Willing & Partners (1995) "Hawks Nest North Local Environment Study, Flood Impact Assessment", prepared for ERM Mitchell McCotter, September, 27 pp.

Willing and Partners were commissioned to review the 100 Year ARI flood behaviour and the impact of floodplain filling for the Lower Myall River as part of a Local Environmental Study. The area of land under consideration is north of the existing Hawks Nest township at Port Stephens, between the coast and the Myall River.

A review of available data was undertaken including an overview of three reports by NSW Public Works. These reports provided much of the initial input for the hydraulic model, such as tailwater levels in Port Stephens and peak flow rates for the Myall River. Cross-section data was obtained from PWD hydrosurveys and 1:4000 orthophotomaps.

EXTRAN-XP was used for hydraulic modelling of the Lower Myall. Peak flows derived in the 1980 PWD flood study and tailwater levels discussed in the 1993 Port Stephens Flood Study were used as input to the model. A sensitivity analysis was performed by varying these tailwater and flow conditions. This provided upper and lower bounds for flood levels at the site under a range of scenarios.

Final adopted flood levels ranged from 2.01 m at Hawks Nest Bridge to 2.25 m at the northern end of the study area. This was based on a conservative tailwater level of 1.89 m and a peak flow of 341 m^3/s.

A line of ecological significance identified at the site by ERM Mitchell McCotter was set as the maximum westward limit of filling into the floodplain. The effect of filling was modelled by narrowing the appropriate cross-sections. The resulting levels showed little or no change from existing conditions.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 1, Analysis and Review of Existing Information, Report MHL623, Great Lakes Council and Port Stephens Council.

The Port Stephens Flood Study represents the first stage of the management process identified under the State Government's Flood Policy. It was prepared for Port Stephens Council and Great Lakes Council to provide a preliminary assessment of flood behaviour under present day conditions. The report provides a description of the catchment, an overview of data available and an analysis of past studies. It also examines the joint probability of

freshwater floods and peak ocean water levels and gives a discussion of previous study findings and preliminary design flood levels.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 2, Design Water level and Wave Climate, Report MHL759, prepared for Great Lakes Council and Port Stephens Council.

This part of the study considered the tide behaviour, ocean storm conditions, catchment rainfall-runoff and local wind setup to estimate design water levels around the foreshore of Port Stephens and Tilligerry Creek. In addition, the local wind wave climate and the ocean wave climate (i.e. wave height and wave period) were estimated at selected locations around the Port Stephens foreshore.

Water level, tidal, rainfall, wind and wave data in the NSW coastal regions has in the past been collected and collated by the Department of Public Works and Services (DPWS). This data collection program then became the responsibility of the former Department of Land and Water Conservation (DLWC). This report refers to data collected in the past by DPWS and current data collection stations as being operated by the former DLWC.

The water levels for Port Stephens vary around the foreshore of Port Stephens and in Tilligerry Creek depending on the combination of flood conditions. bathymetry, wind direction and the impact of rainfall-runoff. As a result of potential development pressure, 42 locations were selected around the foreshore of Port Stephens (in consultation with Great Lakes and Port Stephens Councils) for flood assessment (refer **Figure 2**). Results were estimated at these 42 sites plus locations in Tilligerry Creek.

There was insufficient data available to decide which combination of rainfall, tides wind and ocean conditions would result in the worst flooding. Sensitivity analysis was carried out using the numerical models to check the results by assuming a particular combination of ocean level, wind, rainfall-runoff and wave climate. The sensitivity study identified the following important points that contribute to flooding in Port Stephens:

- elevated ocean levels control the water levels in Port Stephens;
- wind setup on top of Port Stephens water level has a significant impact on the final water level which can vary by as much as 0.3 m depending on the direction of the wind;
- the combination of rainfall-runoff and Port Stephens water levels controls flood levels in Tilligerry Creek;
- the occurrence of wind waves and ocean waves in Port Stephens has the potential to significantly impact on inundation levels around the foreshore;
- the analysis showed that water levels in Port Stephens could vary by as much as 0.3 m and the levels in Tilligerry Creek by as much as 0.1 m depending on the combination of factors selected.

Webb, McKeown & Associates (2002) "Port Stephens Foreshore (Floodplain) Management Study, Final report, prepared for Port Stephens and Great Lakes Councils, April.

Elevated water levels occur in Port Stephens mainly as a result of:

- ocean influences -tides and storm surges,
- wind and wave activity within the estuary,
- rainfall from the local catchment (this factor provides the least influence on levels).

This study was initiated by Port Stephens and Great Lakes Councils to help manage the flood problem. The primary objectives of the Study were to define the nature and extent of the hazard; to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development; and to make allowance for flood compatible future development.

The study builds on the Port Stephens Flood Study (Stages 1 to 3) which defines design flood levels for the foreshore area.

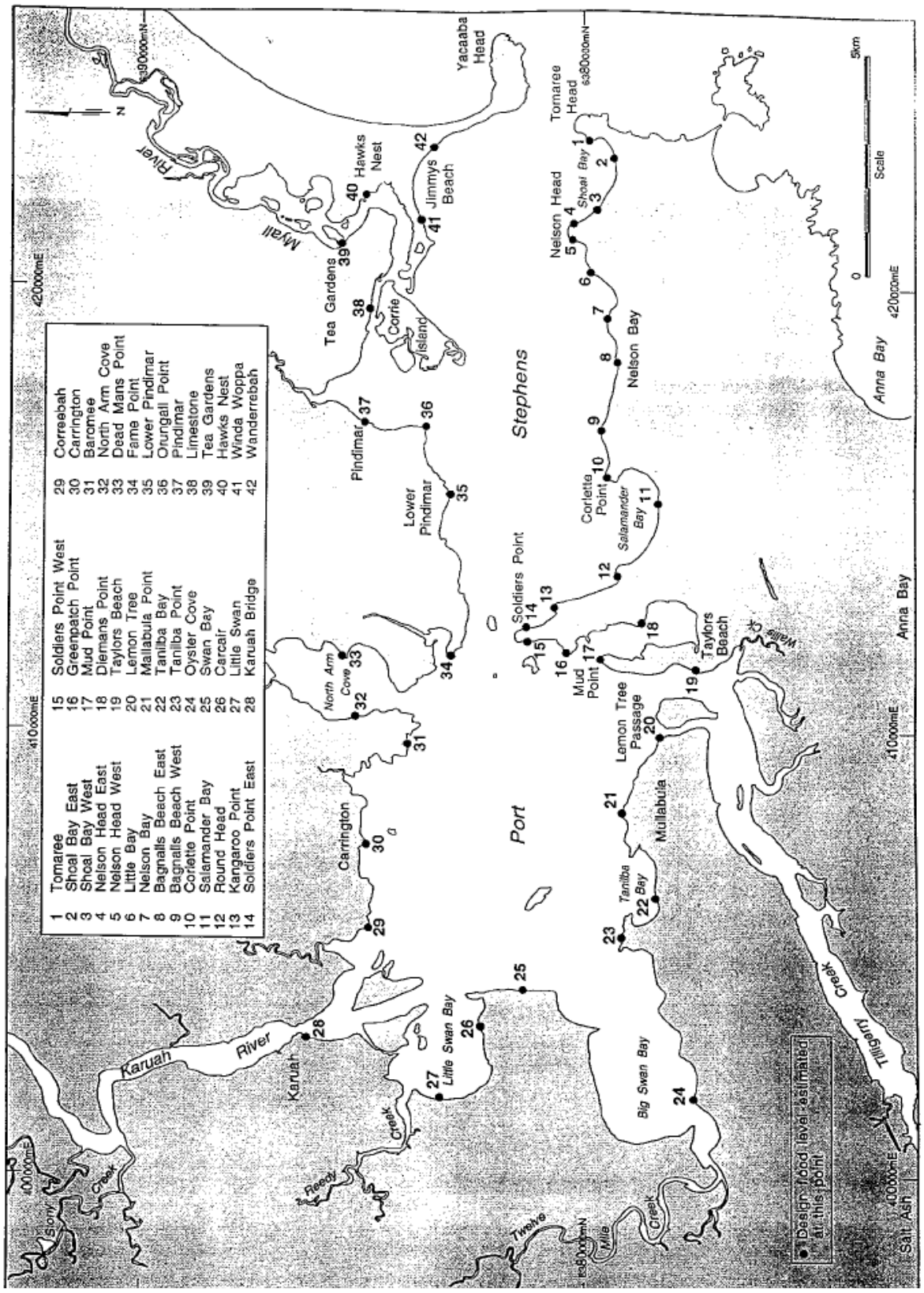

Figure 2 Location of Estimated Design water levels (after MHL, 1996)

3. ASSESSMENT APPROACH

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment.

3.1 Myall River Flooding

Great Lakes first adopted a flood policy in December 1985 and adopted the 100 yr ARI event as the flood standard. A 100 yr ARI level of 2.1 m AHD for the foreshore area has been adopted for over 15 years. The exact source of the level is unknown (Webb, McKeown & Associates, 2002).

The foreshore area includes the Myall River. Consequently the 100 yr ARI level in the lower lying areas of the Riverside site is controlled by the 100 yr ARI level in the Myall River ie. 2.1 m AHD.

Prior to formulating an assessment approach the 1995 quasi-2D model of the lower Myall River was de-archived, uploaded into **xpswmm** and re-run to confirm it gives similar answer to the results reported in 1995.

The approach to assess climate change scenarios on 100 yr ARI flood levels in the Myall River was as follows:

- Adopt the 1995 **xpswmm** model of the Myall River for estimation of river flood levels;
- Calculate downstream boundary conditions that equate to sea level rises of: 0 m, 0.18 m, 0.55 m and 0.91 m
- Run the model for the following increases in the adopted peak outflow from the Myall Lakes: 0%, 10%, 20% and 30%
- Tabulate the estimated 100 yr ARI flood levels at two nodes that broadly correspond to the lower end and upper end of the Riverside site.

3.2 Local Flood Levels

The 100 yr ARI level in areas of Riverside where the land is higher than 2.1 m AHD is controlled by runoff from the local catchment. Assessments of local flooding and drainage have been previously undertaken and are described in the 2007 Riverside at Tea Gardens Integrated Water Management Report.

Estimates of runoff from the Riverside at Tea Gardens catchment during design storms were obtained using the **xprafts** rainfall/runoff model.

Estimates of flood levels in the Riverside at Tea Gardens site were obtained using the **xpswmm** model.

The approach to assess climate change scenarios on 100 yr ARI flood levels in the Riverside site was as follows:

- Run the existing **xpswmm** model for the following increases in the 1.5 hr and 9 hr 100 yr ARI rainfall intensities: 0%, 10%, 20% and 30%
- It was assumed that the existing/extended lake will be swamped by the Myall River flooding so the 100 yr ARI flood levels within the drainage corridors are of primary interest
- Local runoff in combination with sea level rise in the Myall River was not modelled because the flood levels in the Myall River control in the lower lying areas of the site.

4. MYALL RIVER FLOODING

4.1 Hydraulic Model

The 1995 hydraulic model was initially based on the 1980 Flood Study hydraulic model. This was modified to include branches and the flow paths which short circuit meanders in the river. Levels were taken from the 1:4000 orthophotomaps and the 1978 hydrosurvey. The final model layout in **Figure 3**. A schematic representation of the model as overlaid on the 1:25000 topographical map of the area is given in **Figure 4**. This shows the approximate location of the nodes and cross sections.

In many cases the cross section locations from the 1980 PWD flood study were chosen again, although the levels were altered. Most of the original cross sections were considered representative of the reach on which they were located. Where they were not considered representative extra cross sections were provided so that the entire Lower Myall River was satisfactorily defined. Looped flow was also introduced to more accurately define flow paths and flood levels in cases where overbank flow was possible (usually flow diverted from the main channel) or where there were large obstructions (such as islands) in the main channel.

4.2 Peak Flow

The 1980 PWD flood study undertook a sensitivity analysis. The results of this analysis for the 100 Year ARI event of seven days duration are given in **Table 1**.

Table 1 Results of 1980 Sensitivity Analysis

	Adopted	Maximum from Sensitivity Analysis
Peak Lake Level (m AHD)	3.00	3.22
Peak Lake Outflow (m^3/s)	289	341

Based on the adopted 100 yr ARI peak flow of 289 m^3/s (0% rainfall increase) it was assumed conservatively that increases in rainfall would equate to equal increases in the peak lake outflow. Consequently the adopted peak flows under climate change scenarios were 318 m^3/s (10% increase), 347 m^3/s (20% increase) and 376 m^3/s (30% increase).

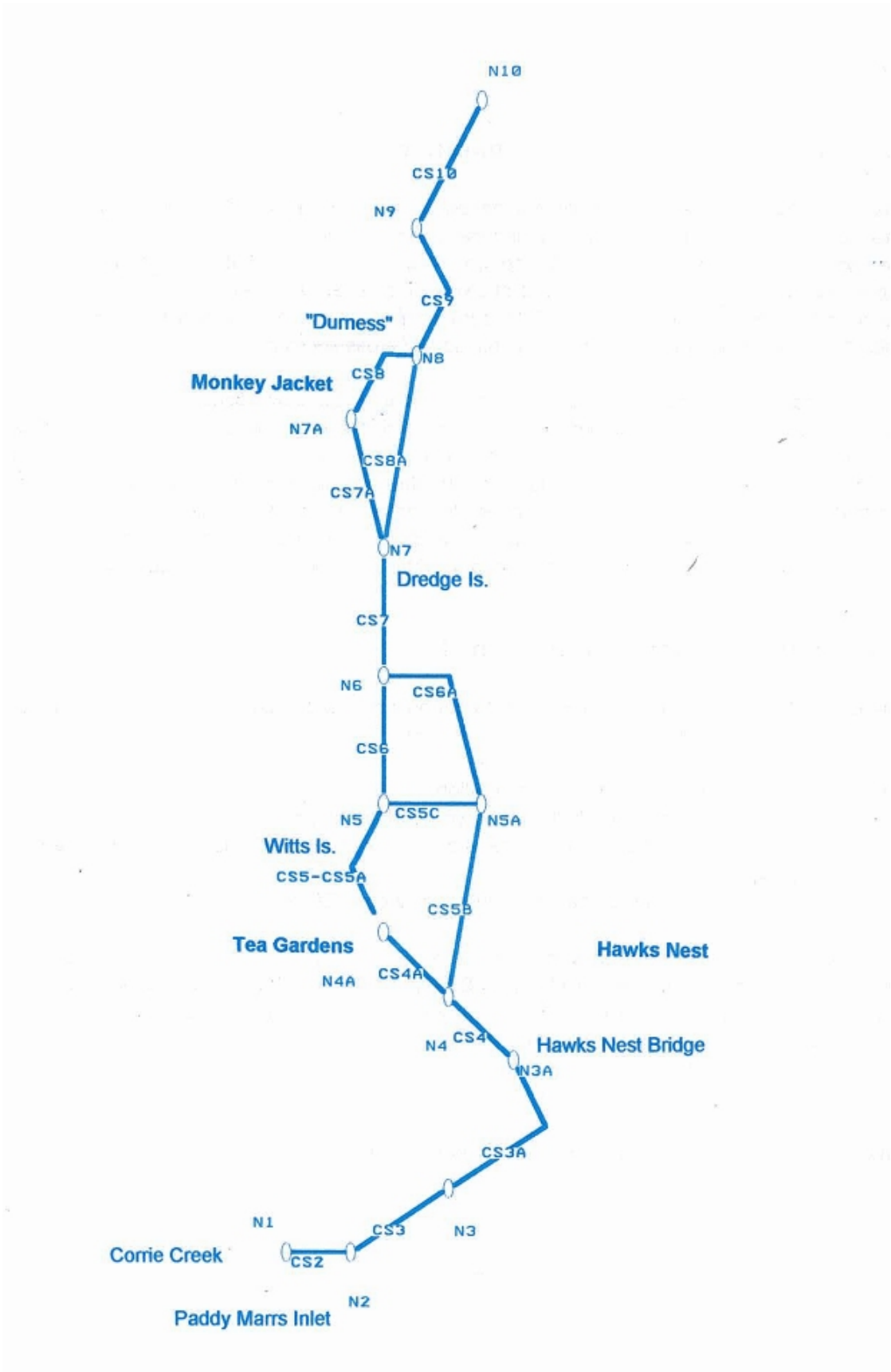

Figure 3 xpswmm Model Layout for Lower Myall River (after Willing & Partners, 1995)

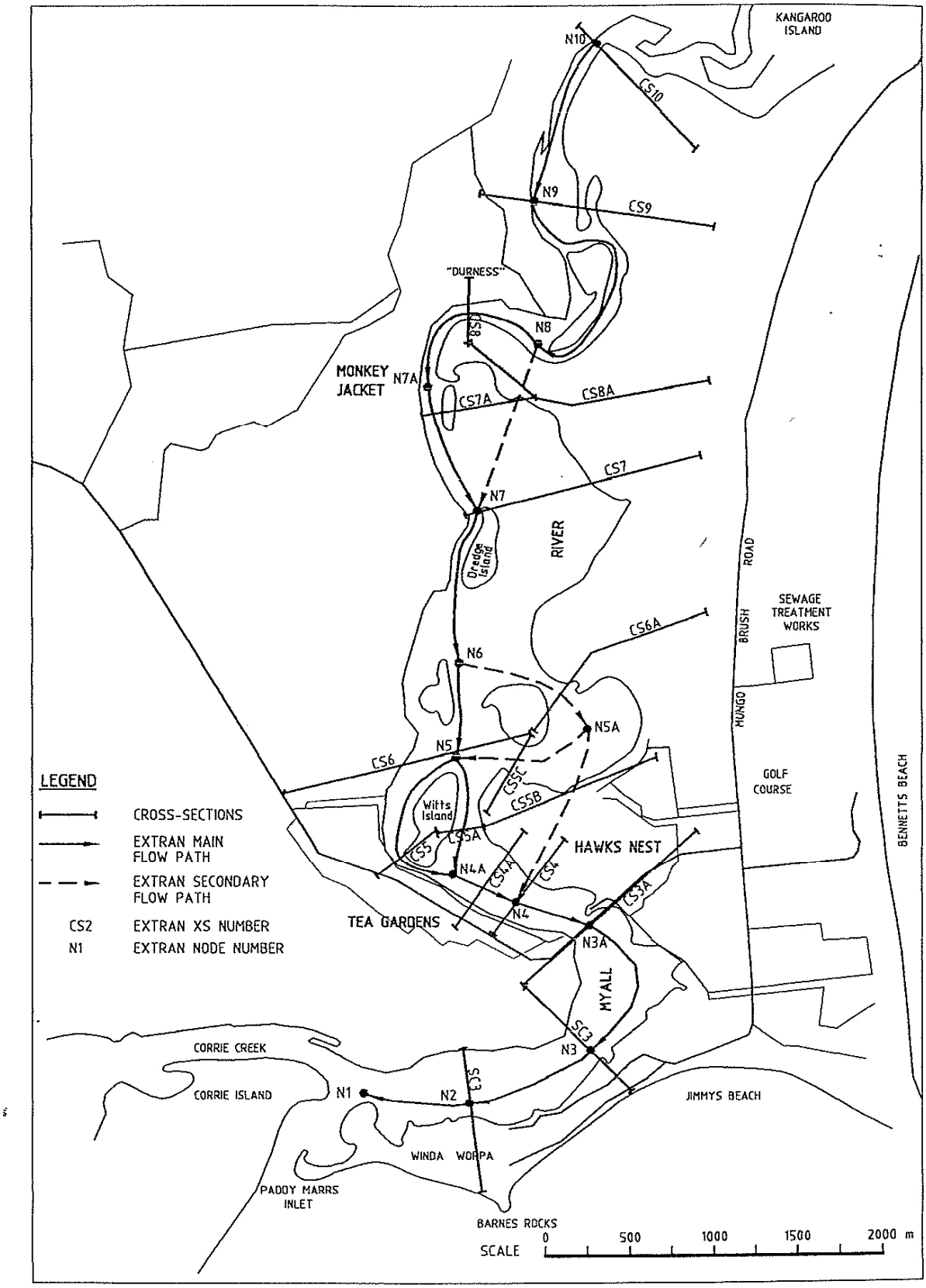

Figure 4 Schematic xpswmm Model Layout (after Willing & Partners, 1995)

4.3 Downstream Boundary Condition

For the purpose of the 1995 study, the tailwater level was determined in the lower reaches of the river somewhere between Tea Gardens and Corrie Island. The river ends at Corrie Island where it bifurcates into Corrie Creek and Paddy Marrs Inlet. This is a relatively sheltered location. Hydrosurvey information is available and it is the location of the last cross section in the 1980 PWD hydraulic model. On this basis the tailwater was positioned at Node 1 on the **xpswmm** layout (refer **Figure 4**).

Based on the approach adopted in the 1995 study the downstream boundary levels summarised in **Table 2** were adopted for the sensitivity testing under sea level rise scenarios.

Table 2 Adopted 100 yr ARI Downstream Boundary Levels with Sea Level Rise

Site Condition	Water Level Rise (m AHD)			
Mean Sea Level (MSL)	0	0	0	0
High Tide	1.0	1.0	1.0	1.0
Barometric Set-up	0.3	0.3	0.3	0.3
Wind Set-up	0.2	0.2	0.2	0.2
Local Wind & Wave Set-up	0.3	0.3	0.3	0.3
Flood Surcharge	0.2	0.2	0.2	0.2
Sea Level Rise	0	0.18	0.55	0.91
Tidal gradient	-0.11	-0.11	-0.11	-0.11
Total Level (m AHD)	1.89	2.07	2.44	2.80

4.4 Results

Sixteen sensitivity runs were undertaken.

The estimated 100 yr ARI flood levels at two nodes that broadly correspond to the lower end (Node N5) and upper end (Node N7)of the Riverside site are summarised in **Table 3**.

Table 3 Estimated 100 yr ARI Flood levels in the Myall River under Climate Change Scenarios

	Sea Level Rise (mAHD)							
Sea Level Rise	0 m		+ 0.18m		+ 0.55m		+ 0.91m	
100 yr ARI Boundary Level	1.89 mAHD		2.07 mAHD		2.44 mAHD		2.80 mAHD	
Node	**N5**	**N7**	**N5**	**N7**	**N5**	**N7**	**N5**	**N7**
Q_{peak} = 289 m^3/s	2.00	2.02	2.17	2.18	2.52	2.52	2.86	2.86
Q_{peak} = 318 m^3/s (+10%)	2.02	2.04	2.19	2.20	2.53	2.54	2.87	2.87
Q_{peak} = 347 m^3/s (+20%)	2.04	2.06	2.21	2.23	2.54	2.56	2.88	2.89
Q_{peak} = 376 m^3/s (+30%)	2.07	2.09	2.23	2.25	2.56	2.58	2.89	2.90

It was concluded from the results of the sensitivity runs for the Myall River that:

- The current adopted 100 yr ARI level of 2.1 m AHD could accommodate up to a 30% increase in rainfall under conditions where there is no increase in sea level;
- The increase in 100 yr ARI levels in the Myall River in the vicinity of Riverside due to increases in rainfall reduce as the sea level rise increases ie. a 30% increase in rainfall increases 100 yr ARI levels in the Myall River by
  - 0.06 m to 0.07 m under a sea level rise of 0.18 m
  - 0.04 m to 0.06 m under a sea level rise of 0.55 m
  - 0.03 m to 0.04 m under a sea level rise of 0.91 m
- Under the +0.18 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is around 0.43 to 0.25 m depending on the adopted increase in rainfall intensity
- Under the +0.55 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is only around 0.02 to 0.07 m depending on the adopted increase in rainfall intensity
- Under the +0.91 m sea level rise scenario Council's Flood Planning Level of 2.6 m AHD is exceeded by 0.26 m to 0.3 m depending on the adopted increase in rainfall intensity
- It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios.

The extent of incremental inundation of Riverside was also plotted for four cases as follows:

- No Climate Change Scenario (Existing Conditions) – 2.02 m AHD river flood level (see **Figure 5**);
- Low Climate Change Scenario – 2.2 m AHD river flood level which equates to a 0.18 m sea level rise + 10% increase in rainfall intensity (see **Figure 6**);
- Medium Climate Change Scenario – 2.55 m AHD river flood level which equates to a 0.55 m sea level rise + 20% increase in rainfall intensity (see **Figure 7**);
- High Climate Change Scenario – 2.90 m AHD river flood level which equates to a 0.91 m sea level rise + 30% increase in rainfall intensity (see **Figure 8**).

It was concluded from the river flooding inundation plots that:

- River flooding under either a low or a medium climate change scenario would not inundate any unimproved lots;
- River flooding under a high climate change scenario would partially inundate around 180-220 unimproved lots (but not over floors) to a maximum depth of 0.3 m;
- Under a low climate change scenario there would be minimal inundation of planned roads;
- Under a medium climate change scenario there would be inundation of a number of planned roads by up to 0.5 m (which would be Low Hazard due to the expected very low velocity of the fringes of the river flooding through the development);

- Under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading.

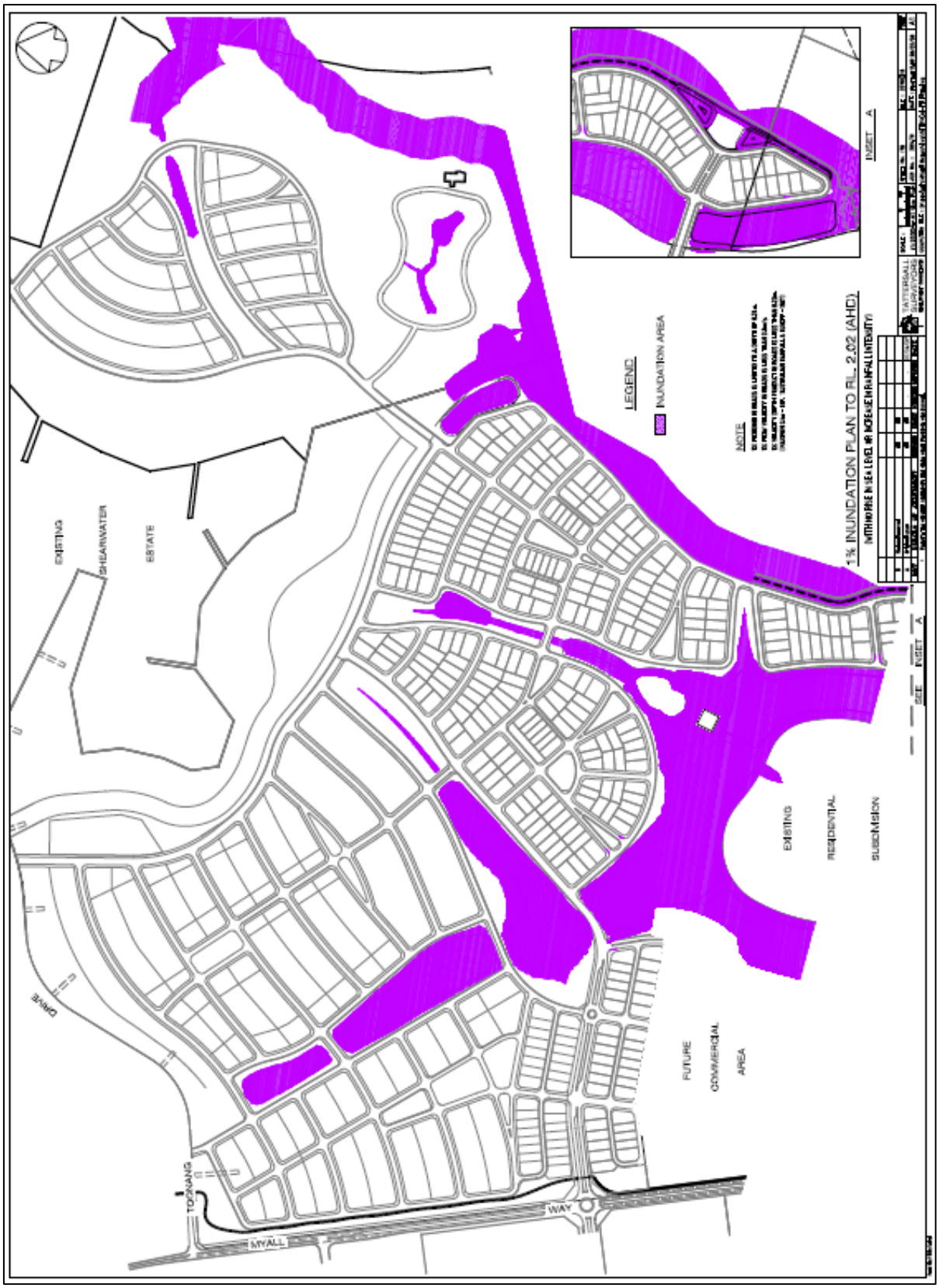

Figure 5 100 yr Inundation (0 m Sea Level Rise + 0% Rainfall Increase)

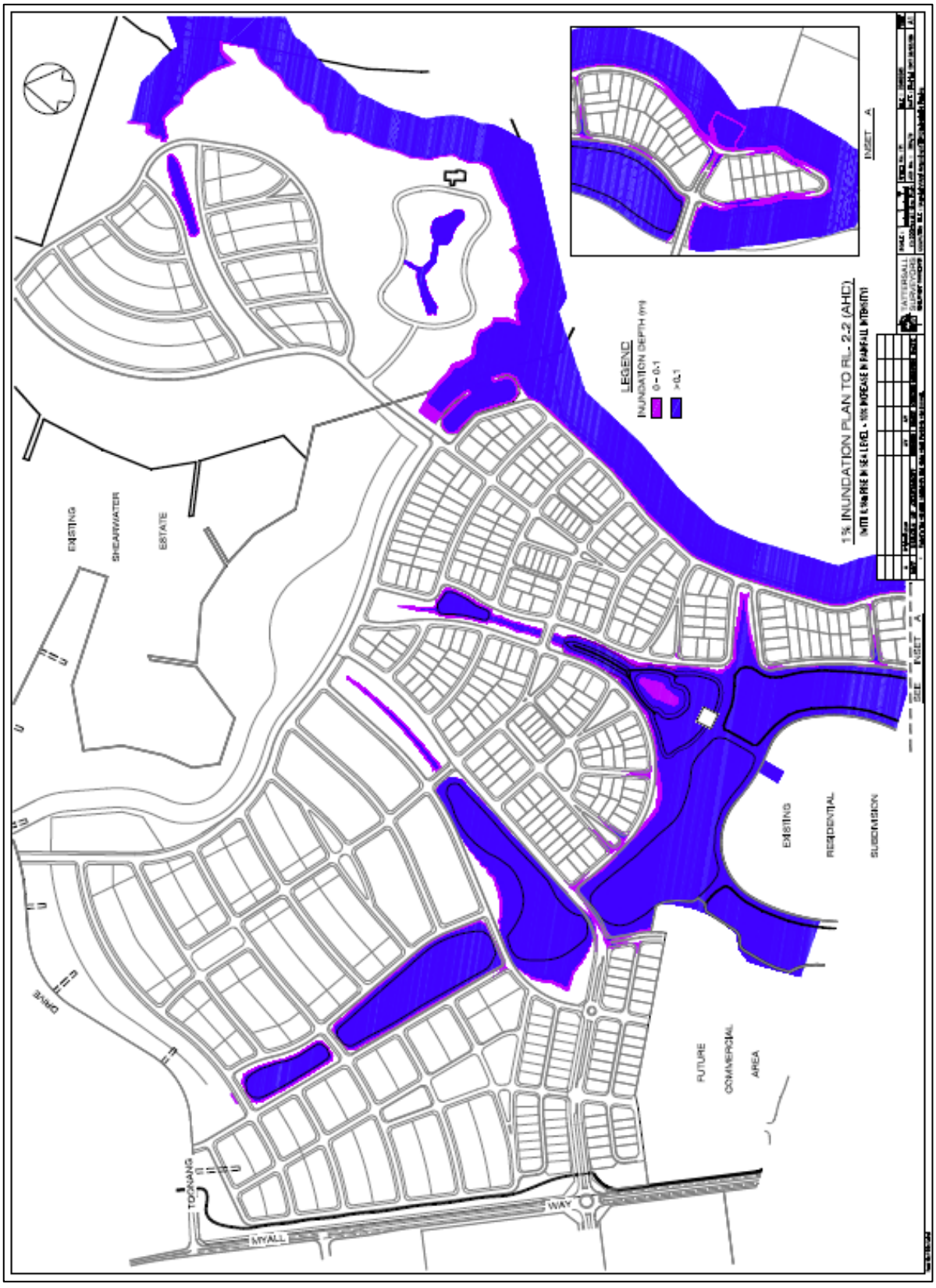

Figure 6 100 yr Inundation (0.18 m Sea Level Rise + 10% Rainfall Increase)

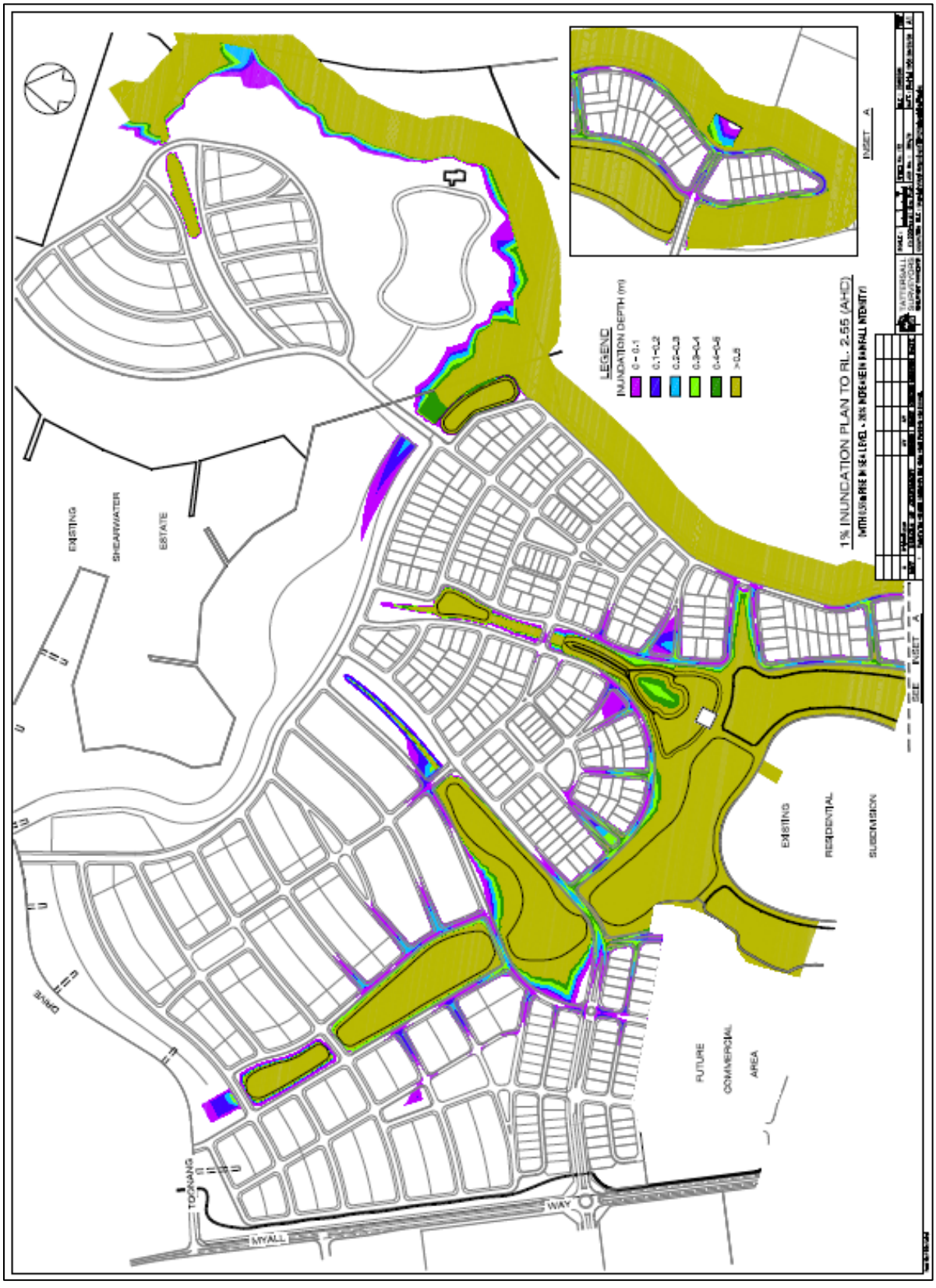

Figure 7 100 yr Inundation (0.55 m Sea Level Rise + 20% Rainfall Increase)

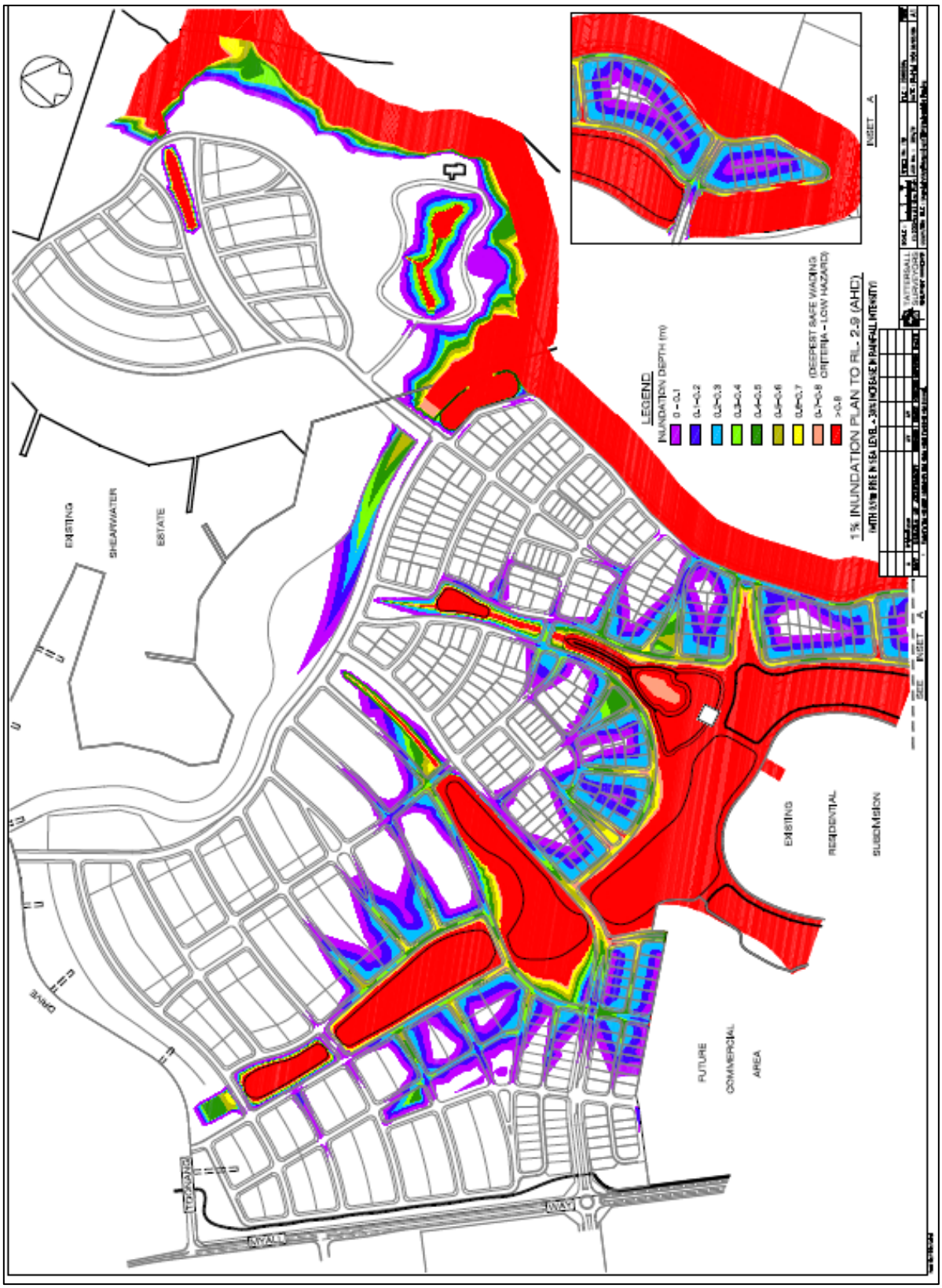

Figure 8 100 yr Inundation (0.91 m Sea Level Rise + 30% Rainfall Increase)

5. LOCAL FLOODING AND DRAINAGE

5.1 Hydraulic Model

The hydraulic model used for the assessments of local flooding and drainage is described in the 2007 Riverside at Tea Gardens Integrated Water Management Report (see **Figure 15**).

5.2 Inflow Hydrographs

It was assumed conservatively that increases in rainfall would equate to equal increases in the catchment runoff and inflow hydrographs. Consequently all inflow hydrographs were increased by 10%, 20% and 30% under the climate change scenarios.

5.3 Downstream Boundary Condition

The adopted downstream boundary condition from the 2007 assessments was adopted for these assessments. Sea level rise in the Myall River was not included in the downstream boundary condition because the flood levels in the Myall River control in the lower lying areas of the site.

5.4 Results

Six sensitivity runs were undertaken. The 100 yr ARI flood levels within the drainage corridors under the 1.5 hour and 9 hour duration storm burst are presented in **Figures 9** to **14** and are summarised in **Tables 4** and **5**.

Locations where the local 100 yr ARI is exceeded by the estimated Myall River 100 yr levels are colour coded as follows:

	Locations where the Myall River 100 yr Level with +0.0 m sea level rise exceeds the local 100 yr ARI flood level (2.02 m AHD)
	Additional locations where the Myall River 100 yr Level with +0.18 m sea level rise exceeds the local 100 yr ARI flood level (2.2 m AHD)
	Additional locations where the Myall River 100 yr Level with +0.55 m sea level rise exceeds the local 100 yr ARI flood level (2.55 m AHD)
	Additional locations where the Myall River 100 yr Level with +0.91 m sea level rise exceeds the local 100 yr ARI flood level (2.9 m AHD)

Table 4 Estimated 100 yr ARI Peak Flood Levels for 1.5 hour Storm Burst

Node	1% 1.5hr	1% 1.5hr +10%	*diff.*	1% 1.5hr +20%	*diff.*	1% 1.5hr +30%	*diff.*
	(a) (mAHD)	(b) (mAHD)	*(b)-(a) (cm)*	(c) (mAHD)	*(b)-(a) (cm)*	(d) (mAHD)	*(b)-(a) (cm)*
West Branch							
WB1	2.93	2.95	*3*	2.98	*6*	3.02	*9*
WB2	2.75	2.79	*4*	2.84	*9*	2.88	*13*
N89	2.16	2.20	*4*	2.25	*9*	2.32	*16*
WB3	2.16	2.20	*4*	2.25	*9*	2.31	*15*
WB4	2.16	2.20	*4*	2.25	*9*	2.31	*15*
N70	1.77	1.82	*5*	1.87	*11*	1.95	*18*
WB5	1.77	1.82	*5*	1.87	*11*	1.95	*18*
WB6	1.77	1.82	*5*	1.87	*11*	1.95	*18*
N71	1.68	1.73	*5*	1.78	*11*	1.83	*15*
WB7	1.68	1.73	*5*	1.78	*11*	1.83	*15*
WB8	1.61	1.63	*2*	1.66	*5*	1.68	*7*
East Branch							
EB1	2.58	2.59	*1*	2.61	*2*	2.62	*3*
EB2	1.74	1.75	*1*	1.76	*2*	1.77	*3*
N68	1.74	1.75	*1*	1.76	*2*	1.76	*3*
EB3	1.56	1.58	*2*	1.60	*4*	1.62	*6*
EB4	1.50	1.51	*1*	1.54	*4*	1.56	*6*
EB5	1.48	1.51	*3*	1.54	*6*	1.56	*8*
EB6	1.48	1.51	*3*	1.54	*6*	1.56	*8*
EB7_1	1.48	1.51	*3*	1.54	*6*	1.56	*8*
EB7_2	1.48	1.51	*3*	1.54	*6*	1.56	*8*
N73	1.48	1.51	*3*	1.54	*6*	1.56	*8*
North Branch							
NB1	2.19	2.20	*1*	2.20	*1*	2.21	*2*
NB2	1.98	2.00	*2*	2.02	*4*	2.04	*7*
NB3	1.97	1.99	*2*	2.01	*5*	2.04	*7*
NB4	1.68	1.73	*5*	1.78	*11*	1.83	*15*
NB5	1.68	1.73	*5*	1.78	*11*	1.83	*15*
NB6	1.68	1.73	*5*	1.78	*11*	1.83	*15*
East-West Branch							
EW1	8.69	8.70	*1*	8.72	*3*	8.74	*5*
EW1_1	4.71	4.72	*1*	4.74	*3*	4.76	*5*
EW2	3.85	3.90	*5*	3.98	*13*	4.05	*20*
EW3	3.79	3.88	*9*	3.96	*17*	4.04	*24*
EW4	2.93	2.94	*1*	2.96	*3*	3.00	*7*
EW5	2.81	2.83	*2*	2.85	*5*	2.90	*10*
EW6	2.48	2.49	*1*	2.50	*2*	2.51	*3*
N43	2.16	2.18	*2*	2.19	*3*	2.21	*5*
EW7	1.97	1.97	*1*	1.98	*2*	1.99	*3*
EW8	1.87	1.87	*0*	1.87	*1*	1.87	*1*

Table 5 Estimated 100 yr ARI Peak Flood Levels for 9 hour Storm Burst

Node	1% 9hr (a) (mAHD)	1% 9hr +10% (b) (mAHD)	*diff. (b)-(a) (cm)*	1% 9hr +20% (c) (mAHD)	*diff. (c)-(a) (cm)*	1% 9hr +30% (d) (mAHD)	*diff. (d)-(a) (cm)*
West Branch							
WB1	2.81	2.81	*0*	2.84	*3*	2.85	*4*
WB2	2.56	2.56	*0*	2.61	*5*	2.63	*7*
N89	1.97	1.99	*2*	2.07	*10*	2.13	*16*
WB3	1.97	1.99	*2*	2.07	*10*	2.13	*16*
WB4	1.97	1.99	*2*	2.07	*10*	2.13	*16*
N70	1.85	1.88	*3*	1.97	*12*	2.03	*18*
WB5	1.85	1.88	*3*	1.97	*12*	2.03	*18*
WB6	1.85	1.88	*3*	1.97	*12*	2.03	*18*
N71	1.78	1.80	*2*	1.85	*7*	1.90	*12*
WB7	1.78	1.80	*2*	1.85	*7*	1.89	*11*
WB8	1.67	1.68	*1*	1.70	*4*	1.72	*5*
East Branch							
EB1	2.50	2.50	*1*	2.51	*1*	2.52	*2*
EB2	1.71	1.71	*0*	1.72	*1*	1.73	*2*
N68	1.71	1.71	*0*	1.72	*1*	1.73	*2*
EB3	1.60	1.62	*2*	1.65	*5*	1.67	*7*
EB4	1.60	1.61	*1*	1.63	*3*	1.65	*5*
EB5	1.60	1.61	*1*	1.63	*3*	1.65	*5*
EB6	1.59	1.61	*2*	1.63	*4*	1.65	*6*
EB7_1	1.59	1.61	*2*	1.63	*4*	1.65	*6*
EB7_2	1.59	1.61	*2*	1.63	*4*	1.65	*6*
N73	1.59	1.61	*2*	1.63	*4*	1.65	*6*
North Branch							
NB1	2.14	2.15	*0*	2.15	*1*	2.15	*1*
NB2	1.90	1.91	*2*	1.94	*4*	1.97	*7*
NB3	1.87	1.90	*3*	1.93	*6*	1.97	*10*
NB4	1.78	1.80	*2*	1.85	*7*	1.89	*11*
NB5	1.78	1.80	*2*	1.85	*7*	1.89	*11*
NB6	1.78	1.80	*2*	1.85	*7*	1.89	*11*
East-West Branch							
EW1	8.61	8.61	*0*	8.63	*2*	8.65	*4*
EW1_1	4.63	4.63	*0*	4.66	*3*	4.67	*4*
EW2	3.84	3.84	*0*	4.01	*17*	4.08	*24*
EW3	3.79	3.80	*1*	4.00	*20*	4.07	*28*
EW4	2.93	2.93	*0*	2.97	*4*	3.08	*16*
EW5	2.81	2.81	*1*	2.86	*5*	3.02	*21*
EW6	2.48	2.48	*0*	2.50	*2*	2.53	*4*
N43	2.08	2.09	*1*	2.11	*3*	2.12	*4*
EW7	1.98	1.98	*0*	2.00	*2*	2.01	*3*
EW8	1.87	1.87	*0*	1.87	*1*	1.88	*1*

It was concluded from the results of the sensitivity runs that:

- In areas where the estimated 100 yr ARI flood level is greater than 2.1 m AHD the 1.5 hour storm burst gives higher local 100 yr ARI flood levels than the 9 hour storm burst
- The East Branch and North Branch Flood Planning Levels are controlled by the Myall River under a +0.18 m or greater sea level rise;
- The Flood Planning Levels adjacent to the West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The Flood Planning Levels adjacent to the lower reaches of the East West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The greatest increase in the 100 yr ARI flood level in the East West Branch in the reach unaffected by sea level rise is 0.28 m.

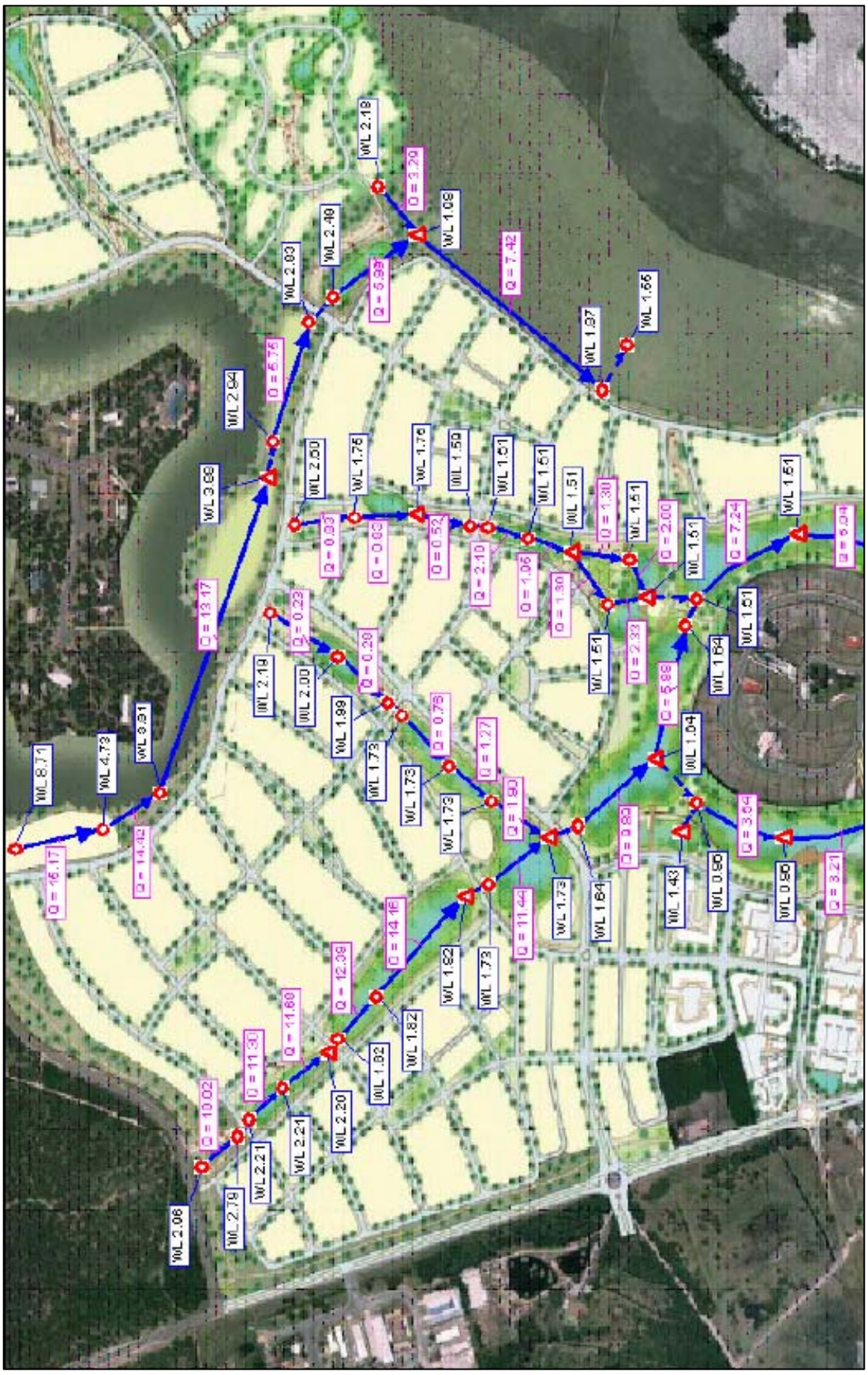

Figure 9 100 yr ARI Flood Levels under 1.5 Storm Burst + 10% Increase

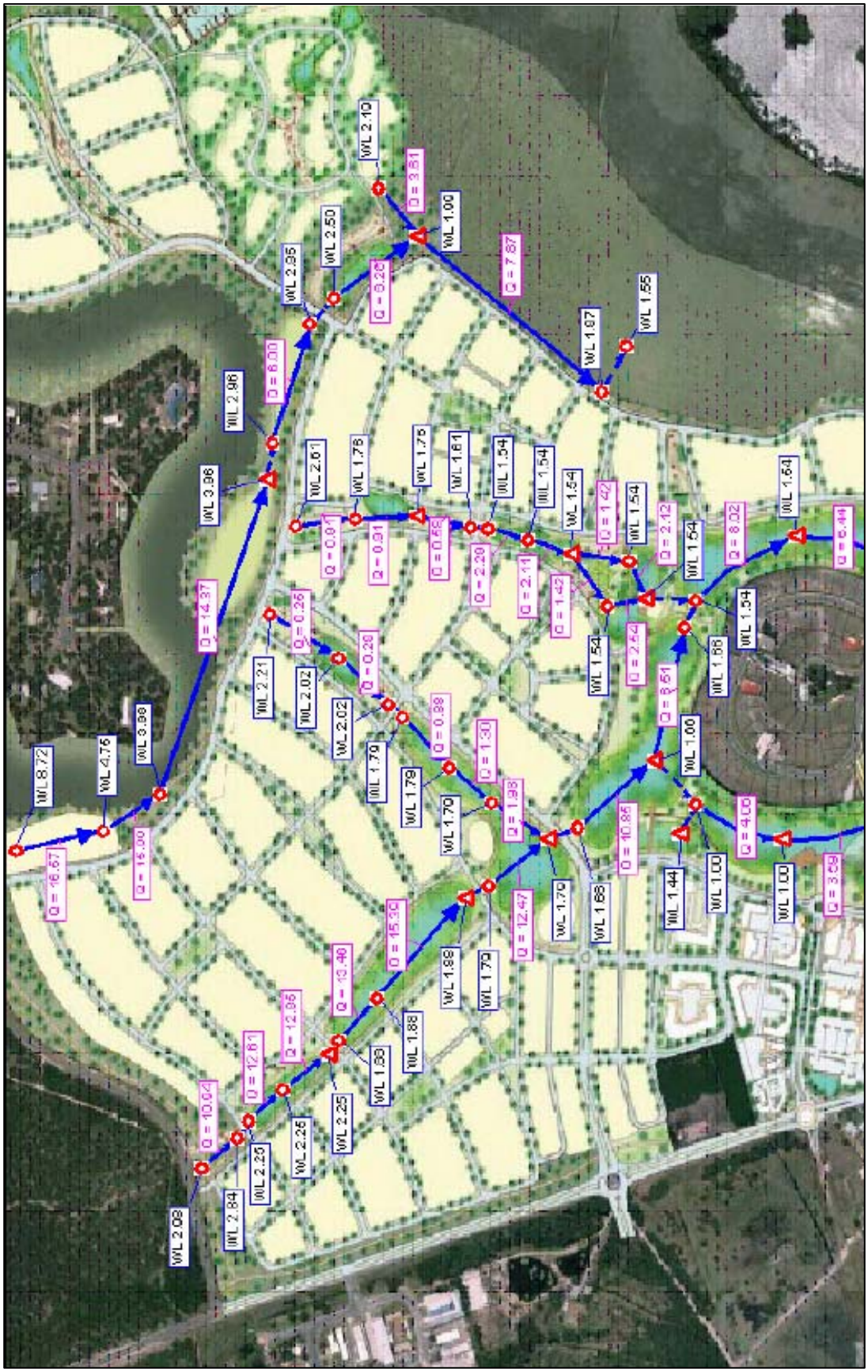

Figure 10 100 yr ARI Flood Levels under 1.5 Storm Burst + 20% Increase

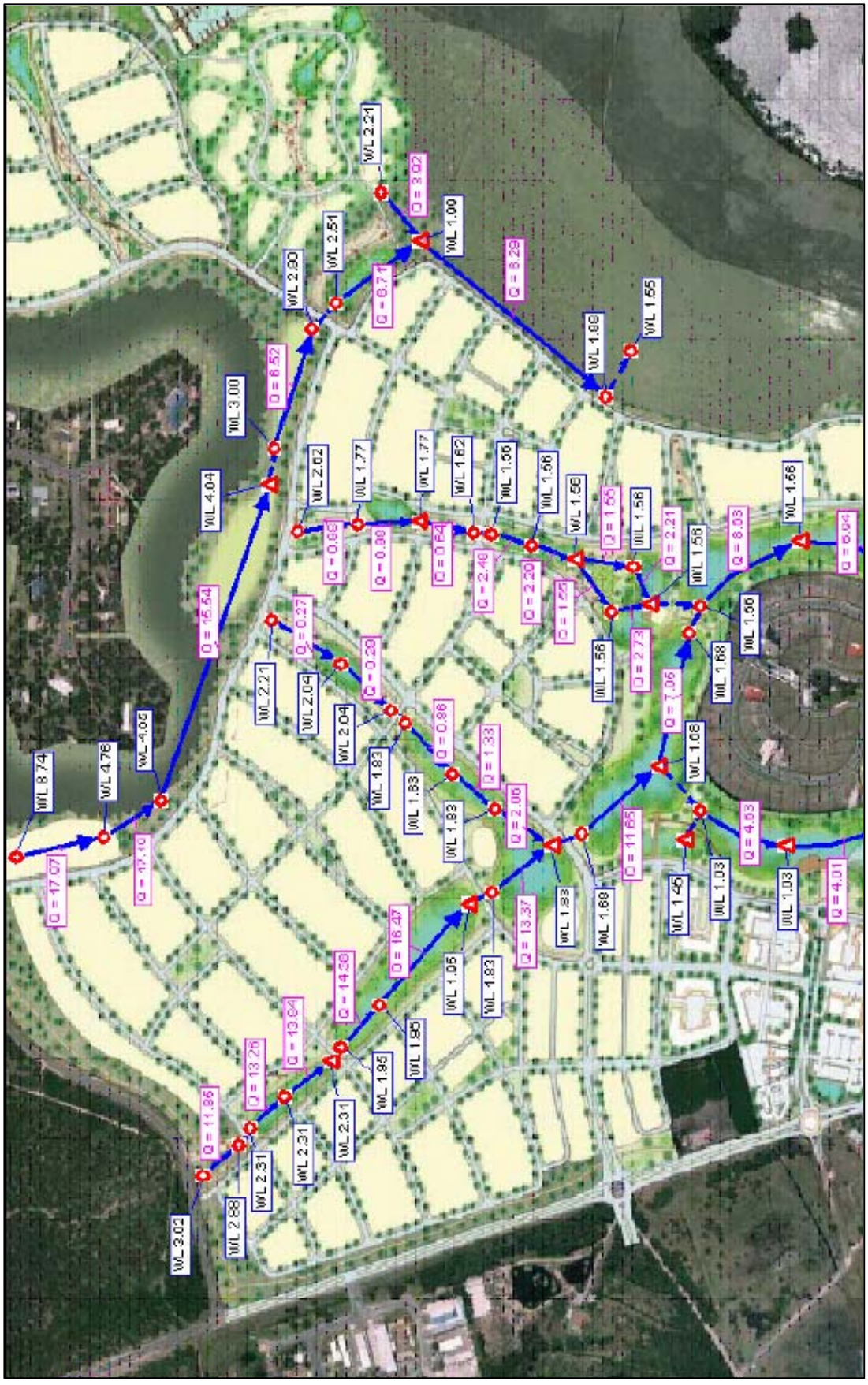

Figure 11 100 yr ARI Flood Levels under 1.5 Storm Burst + 30% Increase

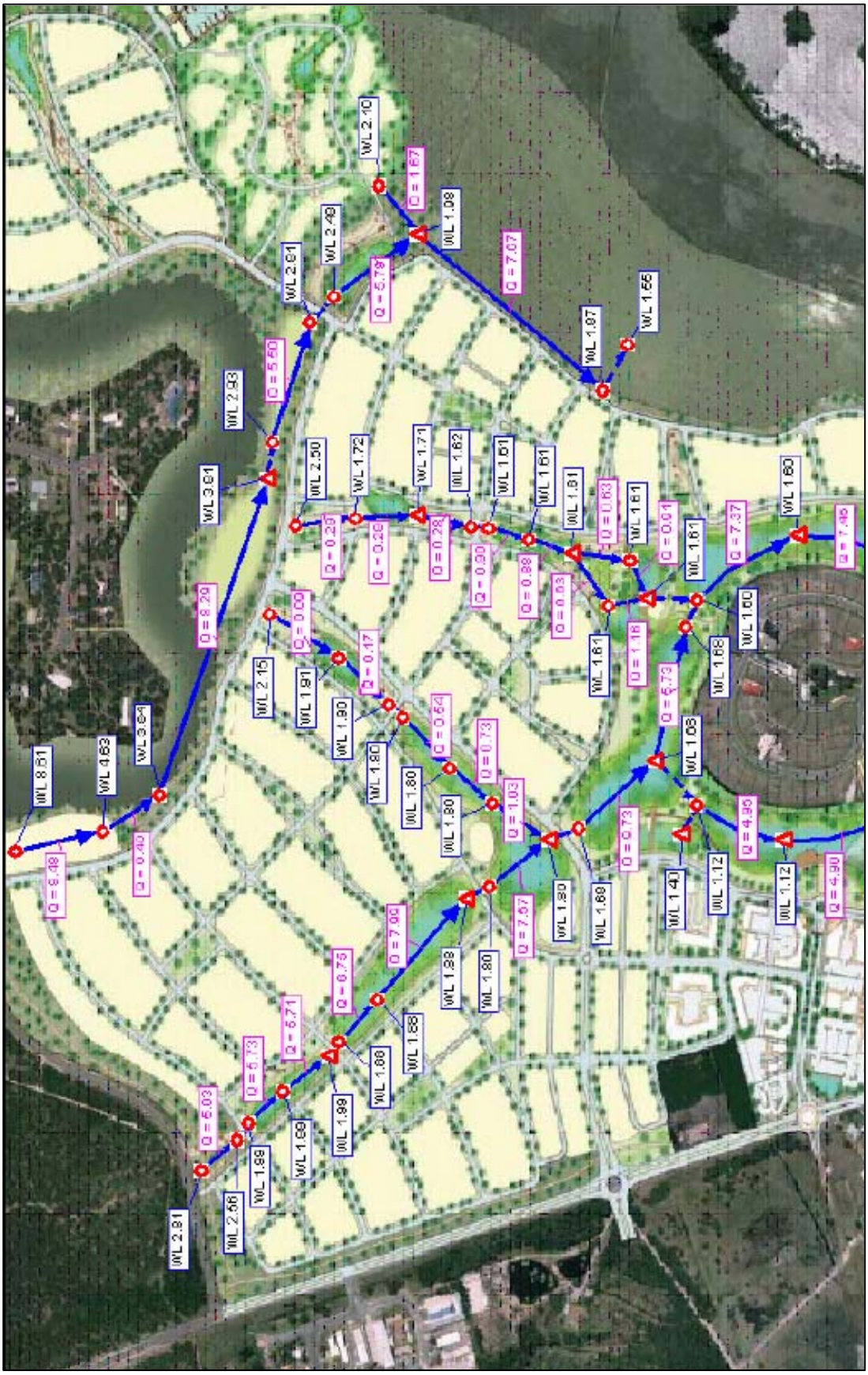

Figure 12 100 yr ARI Flood Levels under 9 Storm Burst + 10% Increase

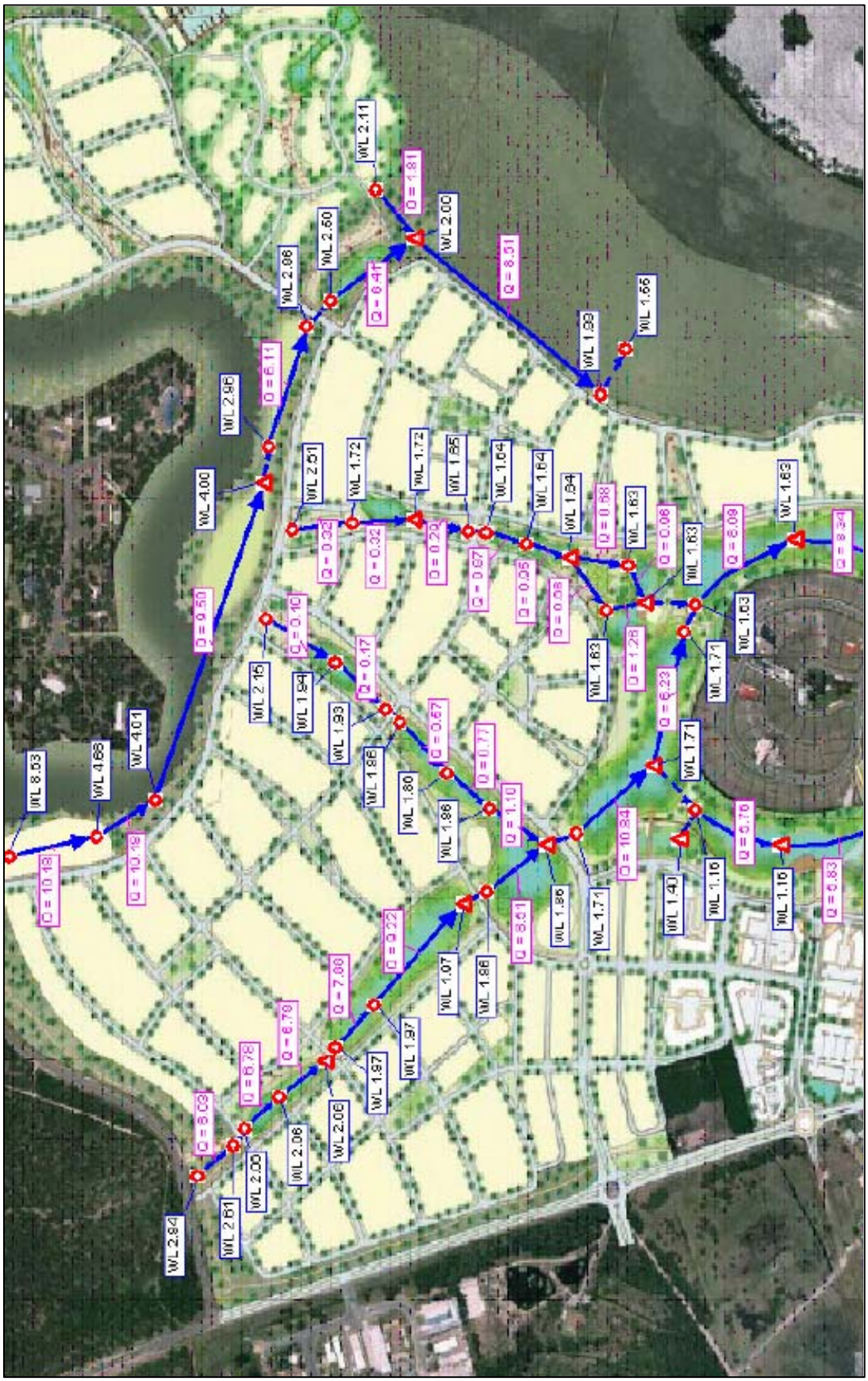

Figure 13 100 yr ARI Flood Levels under 9 Storm Burst + 20% Increase

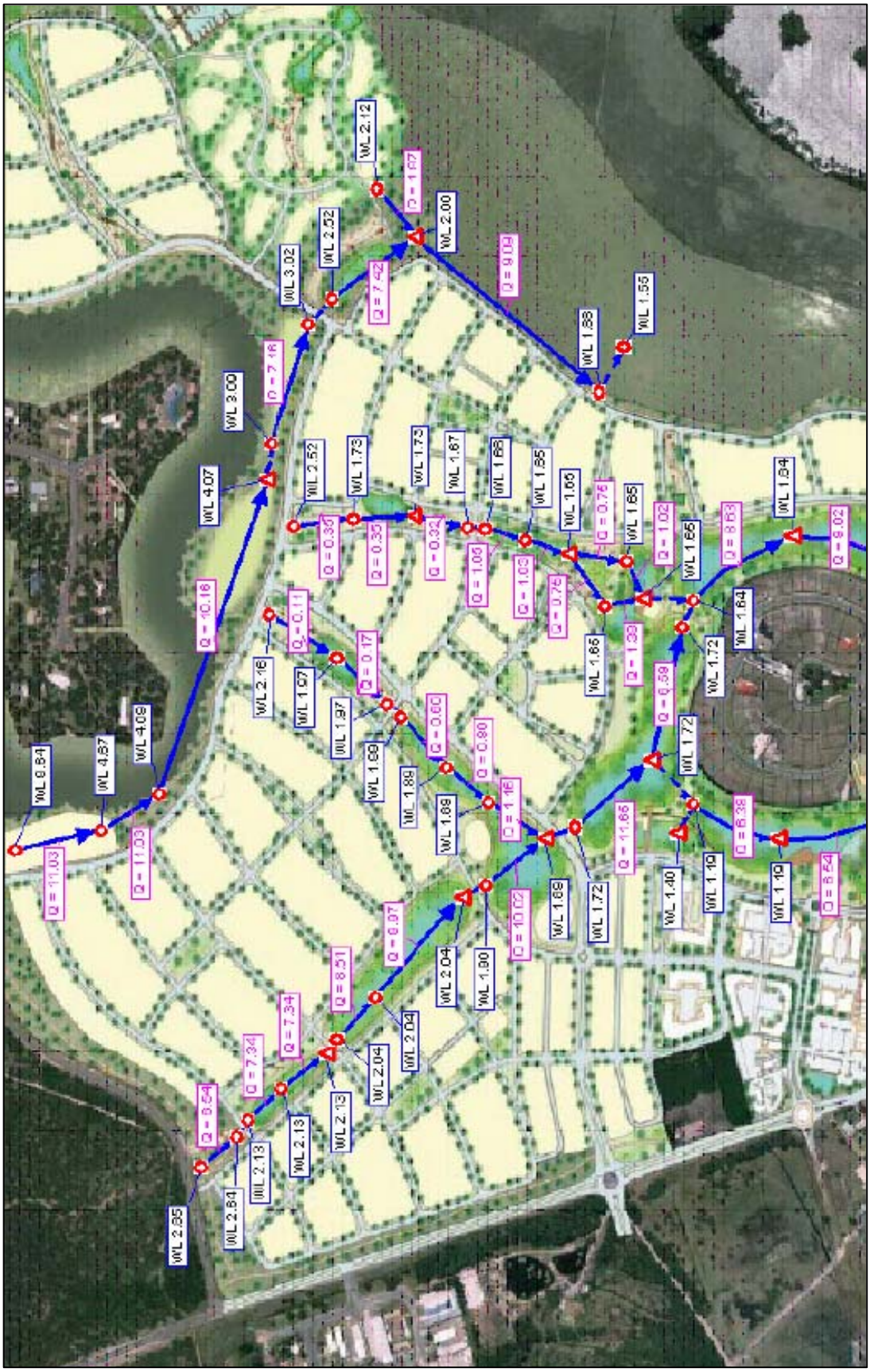

Figure 14 100 yr ARI Flood Levels under 9 Storm Burst + 30% Increase

Figure 15 Model Layout

6. OTHER CONSIDERATIONS

6.1 Floor Levels

It is noted that the Riverside proposal has an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD for all homes in Riverside will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

Elsewhere in the development consideration a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

6.2 Flood Evacuation

While under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading. As indicated in **Figure 8**, even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

It was also noted from the 1980 flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

7. REFERENCES

Department of Environment and Climate Change (2007) “Practical Consideration of Climate Change, Floodplain Risk Management Guidelines, Version No. 1,14 pp.

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NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 1, Analysis and Review of Existing Information, Report MHL623, Great Lakes Council and Port Stephens Council.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 2, Design Water level and Wave Climate, Report MHL759, prepared for Great Lakes Council and Port Stephens Council.

Public Works Department, NSW, Manly Hydraulics Laboratory (1993a), Lower Myall River Compilation of Data, Report MHL622.

Webb, McKeown & Associates (2002) “Port Stephens Foreshore (Floodplain) Management Study, Final report, prepared for Port Stephens and Great Lakes Councils, April.

Willing & Partners (1995) “Hawks Nest North Local Environment Study, Flood Impact Assessment”, prepared for ERM Mitchell McCotter, September, 27 pp.

Volume 3A: Probable Maximum Flood Assessment

Cardno Willing

Shaping the Future

Riverside at Tea Gardens

Probable Maximum Flood

CRIGHTON PROPERTIES

NOVEMBER 2008 JOB NO. W4332-7

CRIGHTON PROPERTIES

Riverside at Tea Gardens
Probable Maximum Flood

Final Report
November 2008

Client	Crighton Properties			
Document	Riverside at Tea Gardens Probable Maximum Flood			
Status	Preliminary	☐	**Author**	Dr Brett C Phillips, Stephen Yu
	Draft	☐	**Signature**	Brett C. Phillips
	Draft Final	☐	**Date**	September 2008
	Final	■	**Reviewer**	Dr Brett C Phillips
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	Other Specify	☐	**Date**	10 November 2008

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SUMMARY

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment.

The sensitivity of river and local flood levels to climate change was assessed recently for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change" (Cardno Willing, 2008a). These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

An assessment of the PMF levels under river and local flooding (without climate change) at the request of the NSW Department of Planning and is reported herein.

The estimated PMF levels in the Myall River in the vicinity of Riverside are summarised as follows:

Event	Description	Estimated Flood Level (m AHD)
PMF	The PMF level under existing conditions with a 100 yr ARI downstream boundary level in the lower reach of the Myall River of RL 1.89 m.	2.82 – 2.89 m
PMF	The PMF level under existing conditions with an extreme downstream boundary level in the lower reach of the Myall River of RL 2.0 m	2.86 – 2.93 m

It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adopted minimum floor level of 2.9 m is comparable to the estimated PMF level in the Myall River.

The hydraulic model used for the assessments of local flooding and drainage up to 100 yr ARI events was used to also estimate PMF levels due to local runoff.

The estimated local PMF levels are summarised in **Table 2**.

It was noted that in almost all locations the 1 hour PMP storm gave the highest flood level except for the upper reach of the West Branch where the 30 minute PMP storm gave the highest estimated flood levels. In most locations it was estimated that the PMF level is between 0.9 m to 1.45 m higher than the local 100 yr ARI level.

It should be noted that the local PMF levels are based on floodwaters confined to the drainage corridors and as such these are conservative estimates. During a PMF event local runoff would spill from the drainage corridors into the residential areas which would result in lower PMF levels than summarised in Table 2.

1. BACKGROUND

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment.

The sensitivity of river and local flood levels to climate change was assessed recently for the scenarios given in the 2007 DECC Guideline titled “Practical Consideration of Climate Change” (Cardno Willing, 2008a). These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

An assessment of the PMF levels under river and local flooding (without climate change) at the request of the NSW Department of Planning and is reported herein.

2. PREVIOUS STUDIES

A number of flooding investigations of the Myall River and Port Stephens have been previously undertaken and reported as follows:

Department of Public Works, NSW (1980) “Lower Myall River Flood Analysis, 32 pp.

Public Works Department, NSW, Manly Hydraulics Laboratory (1993), Lower Myall River Compilation of Data, Report MHL622.

NSW Public Works, Manly Hydraulics Laboratory (1993a), Port Stephens Flood Study Stage 1, Analysis and Review of Existing Information, Report MHL623, Great Lakes Council and Port Stephens Council.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 2, Design Water level and Wave Climate, Report MHL759, prepared for Great Lakes Council and Port Stephens Council.

Willing & Partners (1995) “Hawks Nest North Local Environment Study, Flood Impact Assessment”, prepared for ERM Mitchell McCotter, September, 27 pp.

Webb, McKeown & Associates (2002) “Port Stephens Foreshore (Floodplain) Management Study, Final report, prepared for Port Stephens and Great Lakes Councils, April.

Cardno Willing (2008) “Riverside at Tea Gardens, Practical Consideration of Climate Change”, prepared for Crighton Properties, May.

Several of these sties are outlined as follows.

Department of Public Works, NSW (1980) “Lower Myall River Flood Analysis, 32 pp.

Flood behaviour in the Myall River was studied in the Lower Myall River Flood Analysis (Department of Public Works, 1980). The study used mathematically modelled, synthesised floods of various frequencies to illustrate the range of expected flood flows in Myall Lakes and the River. Unfortunately there was little hydrological and water level data for the catchment, Lake and River available at the time, so the model could not be fully calibrated.

Peak lake heights were derived by running the model for a number of predetermined hydrological conditions and applying them for various durations.

A sensitivity analysis was also performed with the model. This involved changing various factors within the model such as rainfall intensities, losses, storage functions, initial levels in the Myall Lakes, Manning's "n" values and the lake outflow rating. The report found that flowrates and lake levels were maximised with higher rainfall intensities (3.6 mm/hr to 4 mm/hr), a reduced Manning's "n" on the overbanks (0.1 to 0.06) and a lake outflow rating raised by 25%.

The study used the HEC-2 backwater analysis program to compute water levels in the Myall River. Long-section profiles for the river showing water levels for low, mean and high tides and under a surge situation were plotted. The plot states (Figure 7, 1980), "these profiles are based on steady-state analyses at each tide and hence only represent real water levels upstream from about cross section 10 where the profiles nearly coincide". A peak surge level at Paddy Marrs Bar of 2 m AHD was used for the surge situation based on estimates supplied by the Coastal Branch of PWD. The derivation of the peak surge level was probably based on mean sea level including storm surge plus some allowance for wind and wave set-up.

The report recognised that its major shortcoming was the non-modelling of the tidal cycle in the lower river up to 10 km from the river mouth. Downstream of this point flood levels gradually change from river to ocean conditions however there was no information available at the time to determine accurate levels. The report does note however that the difference between the 100 Year ARI flood and a high tide at Tea Gardens is less than 100 mm although the actual levels were not given.

The 1980 PWD flood study also reported an indicative estimate of the PMF outflow from the Myall Lakes of around 1,000 m^3/s (ie. 3.46 times the 100 yr ARI peak outflow from the Myall Lakes).

Public Works Department, NSW, Manly Hydraulics Laboratory (1993a), Lower Myall River Compilation of Data, Report MHL622.

The report is a summary of existing data, both published and unpublished, on estuarine processes in the Lower Myall River. The report notes that most of the information is more than 10 to 15 years old, however little work of specific relevance has been collected since. Physical characteristics of the river are outlined including information on climate, ecology, geology, geomorphology, sediments and shoaling. Previous investigations into flooding, hydraulic conditions, hydrographic changes, numerical modelling, sediment transport and water quality are also presented.

Section 7 of the report deals with flooding. It mentions that historical records of flood levels in the Myall Lake System and the Lower Myall River are very limited, with most data only available from local observations. These data do not provide precise accounts of the events and given levels are difficult to relate to any specific datum. A brief description of the 1980 PWD flood study is also included.

Section 10 of the report provides an overview of model investigations into the lower Myall River. Of particular interest is a one dimensional numerical estuarine model set up by PWD in 1980. The report provides a reasonably detailed description of the model and provides results and discussion of the effects of flooding, tidal action and shoaling on sediment transport and water levels.

Willing & Partners (1995) "Hawks Nest North Local Environment Study, Flood Impact Assessment", prepared for ERM Mitchell McCotter, September, 27 pp.

Willing and Partners were commissioned to review the 100 Year ARI flood behaviour and the impact of floodplain filling for the Lower Myall River as part of a Local Environmental Study. The area of land under consideration is north of the existing Hawks Nest township at Port Stephens, between the coast and the Myall River.

A review of available data was undertaken including an overview of three reports by NSW Public Works. These reports provided much of the initial input for the hydraulic model, such as tailwater levels in Port Stephens and peak flow rates for the Myall River. Cross-section data was obtained from PWD hydrosurveys and 1:4000 orthophotomaps.

EXTRAN-XP was used for hydraulic modelling of the Lower Myall. Peak flows derived in the 1980 PWD flood study and tailwater levels discussed in the 1993 Port Stephens Flood Study were used as input to the model. A sensitivity analysis was performed by varying these tailwater and flow conditions. This provided upper and lower bounds for flood levels at the site under a range of scenarios.

Final adopted flood levels ranged from 2.01 m at Hawks Nest Bridge to 2.25 m at the northern end of the study area. This was based on a conservative tailwater level of 1.89 m and a peak flow of 341 m^3/s.

A line of ecological significance identified at the site by ERM Mitchell McCotter was set as the maximum westward limit of filling into the floodplain. The effect of filling was modelled by narrowing the appropriate cross-sections. The resulting levels showed little or no change from existing conditions.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 1, Analysis and Review of Existing Information, Report MHL623, Great Lakes Council and Port Stephens Council.

The Port Stephens Flood Study represents the first stage of the management process identified under the State Government's Flood Policy. It was prepared for Port Stephens Council and Great Lakes Council to provide a preliminary assessment of flood behaviour under present day conditions. The report provides a description of the catchment, an overview of data available and an analysis of past studies. It also examines the joint probability of freshwater floods and peak ocean water levels and gives a discussion of previous study findings and preliminary design flood levels.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 2, Design Water level and Wave Climate, Report MHL759, prepared for Great Lakes Council and Port Stephens Council.

This part of the study considered the tide behaviour, ocean storm conditions, catchment rainfall-runoff and local wind setup to estimate design water levels around the foreshore of Port Stephens and Tilligerry Creek. In addition, the local wind wave climate and the ocean wave climate (i.e. wave height and wave period) were estimated at selected locations around the Port Stephens foreshore.

Water level, tidal, rainfall, wind and wave data in the NSW coastal regions has in the past been collected and collated by the Department of Public Works and Services (DPWS). This data collection program then became the responsibility of the former Department of Land and Water Conservation (DLWC). This report refers to data collected in the past by DPWS and current data collection stations as being operated by the former DLWC.

The water levels for Port Stephens vary around the foreshore of Port Stephens and in Tilligerry Creek depending on the combination of flood conditions. bathymetry, wind direction and the impact of rainfall-runoff. As a result of potential development pressure, 42 locations were selected around the foreshore of Port Stephens (in consultation with Great Lakes and Port Stephens Councils) for flood assessment (refer **Figure 1**). Results were estimated at these 42 sites plus locations in Tilligerry Creek.

There was insufficient data available to decide which combination of rainfall, tides wind and ocean conditions would result in the worst flooding. Sensitivity analysis was carried out using the numerical models to check the results by assuming a particular combination of ocean level, wind, rainfall-runoff and wave climate. The sensitivity study identified the following important points that contribute to flooding in Port Stephens:

- elevated ocean levels control the water levels in Port Stephens;
- wind setup on top of Port Stephens water level has a significant impact on the final water level which can vary by as much as 0.3 m depending on the direction of the wind;
- the combination of rainfall-runoff and Port Stephens water levels controls flood levels in Tilligerry Creek;
- the occurrence of wind waves and ocean waves in Port Stephens has the potential to significantly impact on inundation levels around the foreshore;
- the analysis showed that water levels in Port Stephens could vary by as much as 0.3 m and the levels in Tilligerry Creek by as much as 0.1 m depending on the combination of factors selected.

Webb, McKeown & Associates (2002) "Port Stephens Foreshore (Floodplain) Management Study, Final report, prepared for Port Stephens and Great Lakes Councils, April.

Elevated water levels occur in Port Stephens mainly as a result of:

- ocean influences -tides and storm surges,
- wind and wave activity within the estuary,
- rainfall from the local catchment (this factor provides the least influence on levels).

This study was initiated by Port Stephens and Great Lakes Councils to help manage the flood problem. The primary objectives of the Study were to define the nature and extent of the hazard; to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development; and to make allowance for flood compatible future development.

The study builds on the Port Stephens Flood Study (Stages 1 to 3) which defines design flood levels for the foreshore area.

Cardno Willing (2008) "Riverside at Tea Gardens, Practical Consideration of Climate Change", prepared for Crighton Properties, May.

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment. Sensitivity assessments of climate change were undertaken for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change". These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

It was concluded from the results of the sensitivity runs for the Myall River that:

- The current adopted 100 yr ARI level of 2.1 m AHD could accommodate up to a 30% increase in rainfall under conditions where there is no increase in sea level;
- The increase in 100 yr ARI levels in the Myall River in the vicinity of Riverside due to increases in rainfall reduce as the sea level rise increases ie. a 30% increase in rainfall increases 100 yr ARI levels in the Myall River by
  - 0.06 m to 0.07 m under a sea level rise of 0.18 m
  - 0.04 m to 0.06 m under a sea level rise of 0.55 m
  - 0.03 m to 0.04 m under a sea level rise of 0.91 m
- Under the +0.18 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is around 0.43 to 0.25 m depending on the adopted increase in rainfall intensity
- Under the +0.55 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is only around 0.02 to 0.07 m depending on the adopted increase in rainfall intensity
- Under the +0.91 m sea level rise scenario Council's Flood Planning Level of 2.6 m AHD is exceeded by 0.26 m to 0.3 m depending on the adopted increase in rainfall intensity

- It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios.

It was concluded from the river flooding inundation plots that:

- River flooding under either a low or a medium climate change scenario would not inundate any unimproved lots;
- River flooding under a high climate change scenario would partially inundate around 180-220 unimproved lots (but not over floors) to a maximum depth of 0.3 m;
- Under a low climate change scenario there would be minimal inundation of planned roads;
- Under a medium climate change scenario there would be inundation of a number of planned roads by up to 0.5 m (which would be Low Hazard due to the expected very low velocity of the fringes of the river flooding through the development);
- Under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading.

It was concluded from the results of the sensitivity runs for the local catchment that:

- In areas where the estimated 100 yr ARI flood level is greater than 2.1 m AHD the 1.5 hour storm burst gives higher local 100 yr ARI flood levels than the 9 hour storm burst
- The East Branch and North Branch Flood Planning Levels are controlled by the Myall River under a +0.18 m or greater sea level rise;
- The Flood Planning Levels adjacent to the West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The Flood Planning Levels adjacent to the lower reaches of the East West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The greatest increase in the 100 yr ARI flood level in the East West Branch in the reach unaffected by sea level rise is 0.28 m;

It is noted that the Riverside proposal has an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD for all homes in Riverside will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

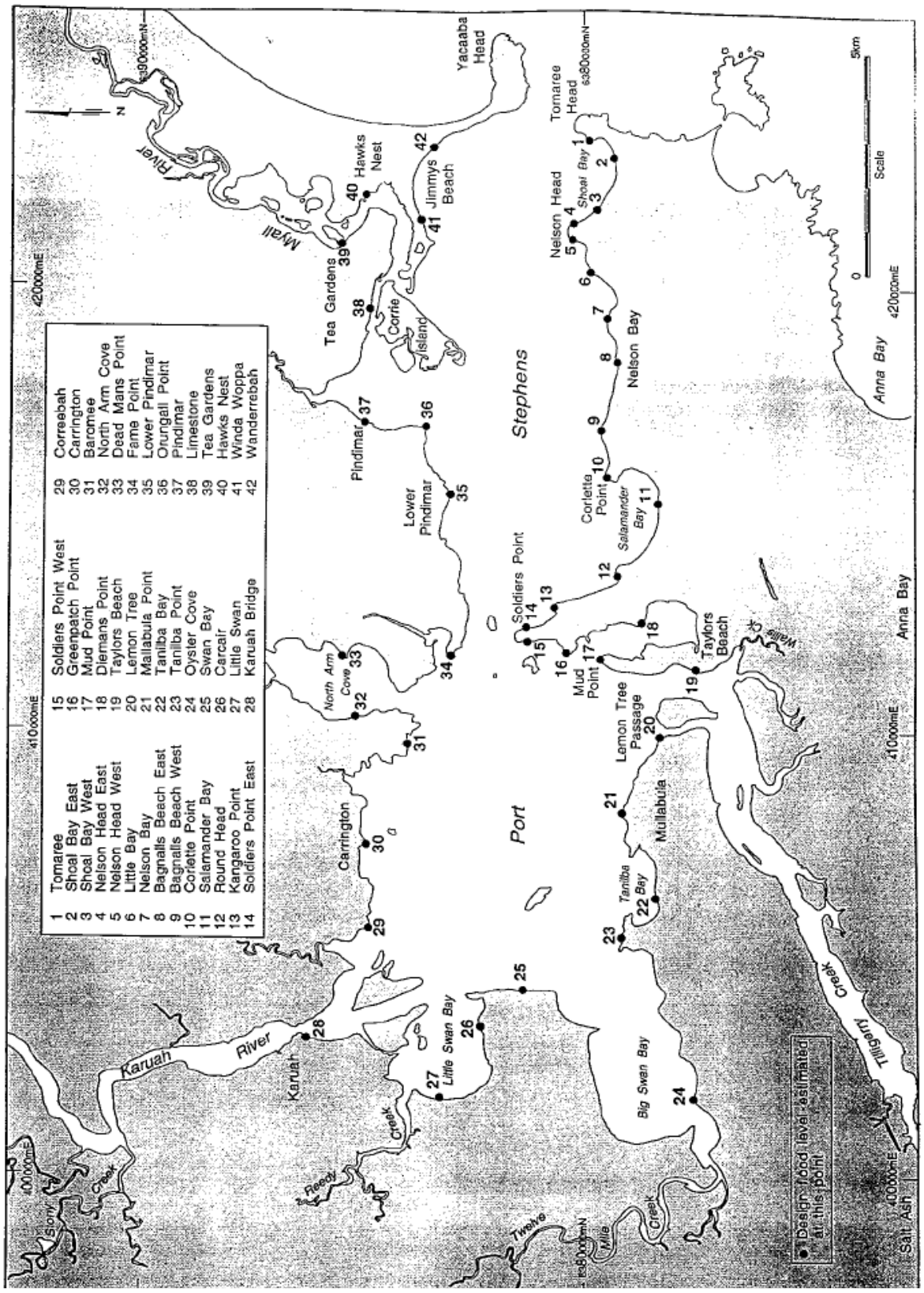

Figure 1 Location of Estimated Design water levels (after MHL, 1996)

3. ASSESSMENT APPROACH

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment.

3.1 Myall River Flooding

The approach to assess the PMF levels in the Myall River was as follows:

- Adopt of modified version of the 1995 **xpswmm** model of the Myall River that was amended by Cardno Willing, 2008 by:
  - Updating the levels of Kingfisher Avenue in the vicinity of the site based on supplied survey spot levels (Cross Section CS3A);
  - Adding a new cross section was added to the model that was in part based on representative ground levels through the centre of the site immediately downstream of Kingfisher Avenue (New Cross Section CS3B);
  - Add a further cross section to the model to represent the Myall River and overbank levels downstream of the site (new Cross Section CS3C);
- Run the modified model and estimate:
  - Indicative PMF levels for Riverside with a 100 yr ARI downstream boundary level and an Extreme downstream boundary level without any allowance for climate change.

3.2 Local Flood Levels

The 100 yr ARI flood level in areas of Riverside where the land is higher than 2.1 m AHD is controlled by runoff from the local catchment. Assessments of local flooding and drainage have been previously undertaken and are described in the 2007 Riverside at Tea Gardens Integrated Water Management Report and the 2008 report titled Riverside at Tea Gardens, Practical Consideration of Climate Change.

Estimates of runoff from the Riverside at Tea Gardens catchment during design storms were obtained using the **xprafts** rainfall/runoff model.

Estimates of flood levels in the Riverside at Tea Gardens site were obtained using the **xpswmm** model.

The approach to assess climate change scenarios on PMF flood levels in the Riverside site was as follows:

- Estimate the 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP rainfall intensities using Bulletin 53 released by the Bureau of Meteorology;
- Run the existing **xprafts** model for the 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP rainfall intensities;
- Import the PMF hydrographs and run the existing **xpswmm** model for the following increases in the 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP storms;

- It was assumed that the existing/extended lake will be swamped by the Myall River flooding during a PMF event. The assumed downstream flood level was equal to the 100 yr ARI flood level of 2.1 m AHD.

4. MYALL RIVER FLOODING

4.1 Hydraulic Model

The 1995 hydraulic model was initially based on the 1980 Flood Study hydraulic model. This was modified to include branches and the flow paths which short circuit meanders in the river. Levels were taken from the 1:4000 orthophotomaps and the 1978 hydrosurvey.

In many cases the cross section locations from the 1980 PWD flood study were chosen again, although the levels were altered. Most of the original cross sections were considered representative of the reach on which they were located. Where they were not considered representative extra cross sections were provided so that the entire Lower Myall River was satisfactorily defined. Looped flow was also introduced to more accurately define flow paths and flood levels in cases where overbank flow was possible (usually flow diverted from the main channel) or where there were large obstructions (such as islands) in the main channel.

- Adopt of modified version of the 1995 **xpswmm** model of the Myall River that was amended by Cardno Willing, 2008c by:
  - Updating the levels of Kingfisher Avenue in the vicinity of the site based on supplied survey spot levels (Cross Section CS3A);
  - Adding a new cross section was added to the model that was in part based on representative ground levels through the centre of the site immediately downstream of Kingfisher Avenue (New Cross Section CS3B);
  - Add a further cross section to the model to represent the Myall River and overbank levels downstream of the site (new Cross Section CS3C);

The amended model layout in **Figure 3**.

A schematic representation of the model as overlaid on the 1:25000 topographical map of the area is given in **Figure 4**. This shows the approximate location of the nodes and cross sections.

4.2 Peak Flow

The 1980 PWD flood study reported an indicative estimate of the PMF outflow from the Myall Lakes of around 1,000 m^3/s (ie. 3.46 times the 100 yr ARI peak outflow from the Myall Lakes).

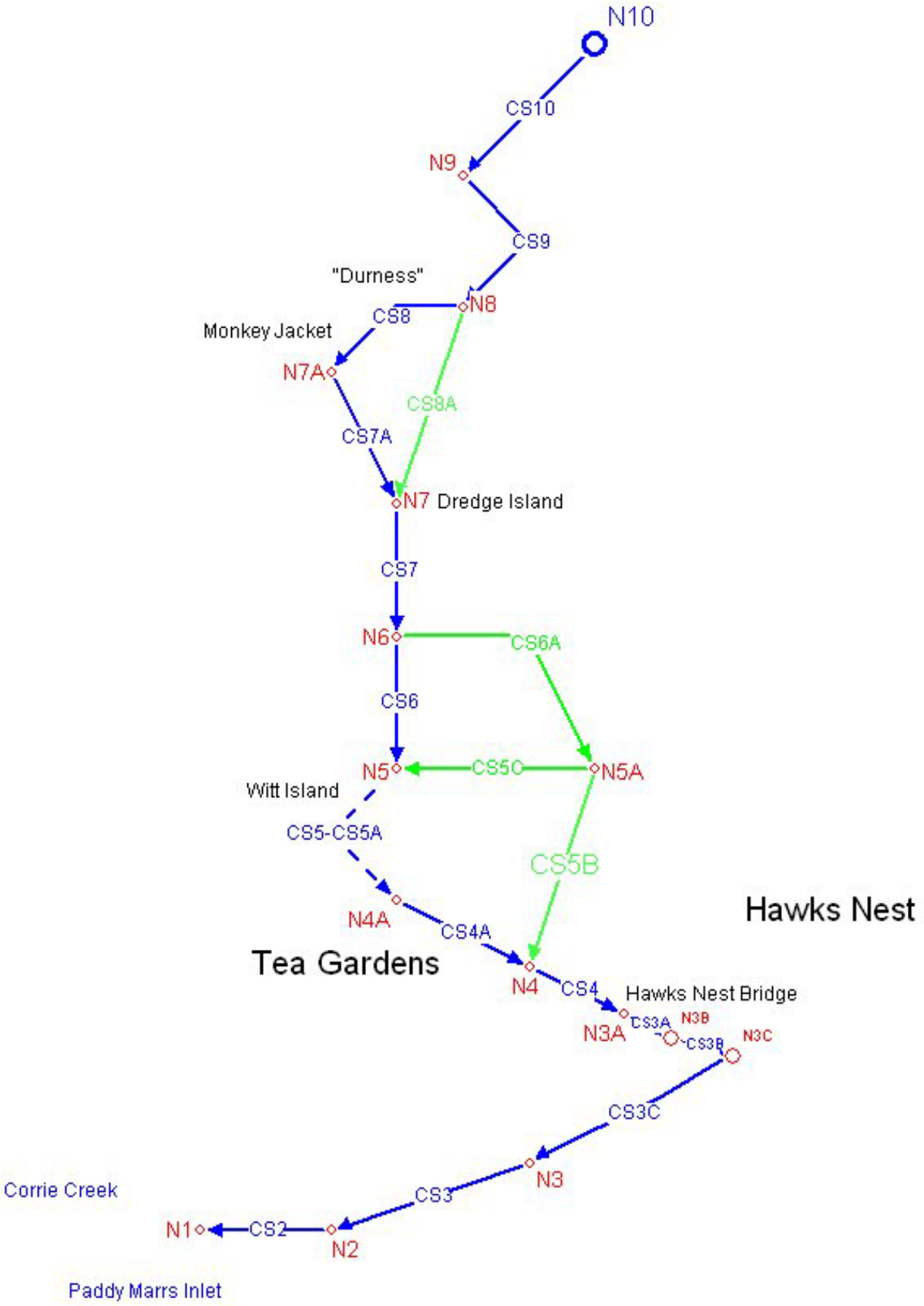

Figure 2 Amended xpswmm Model Layout for Lower Myall River (after Cardno Willing, 2008c)

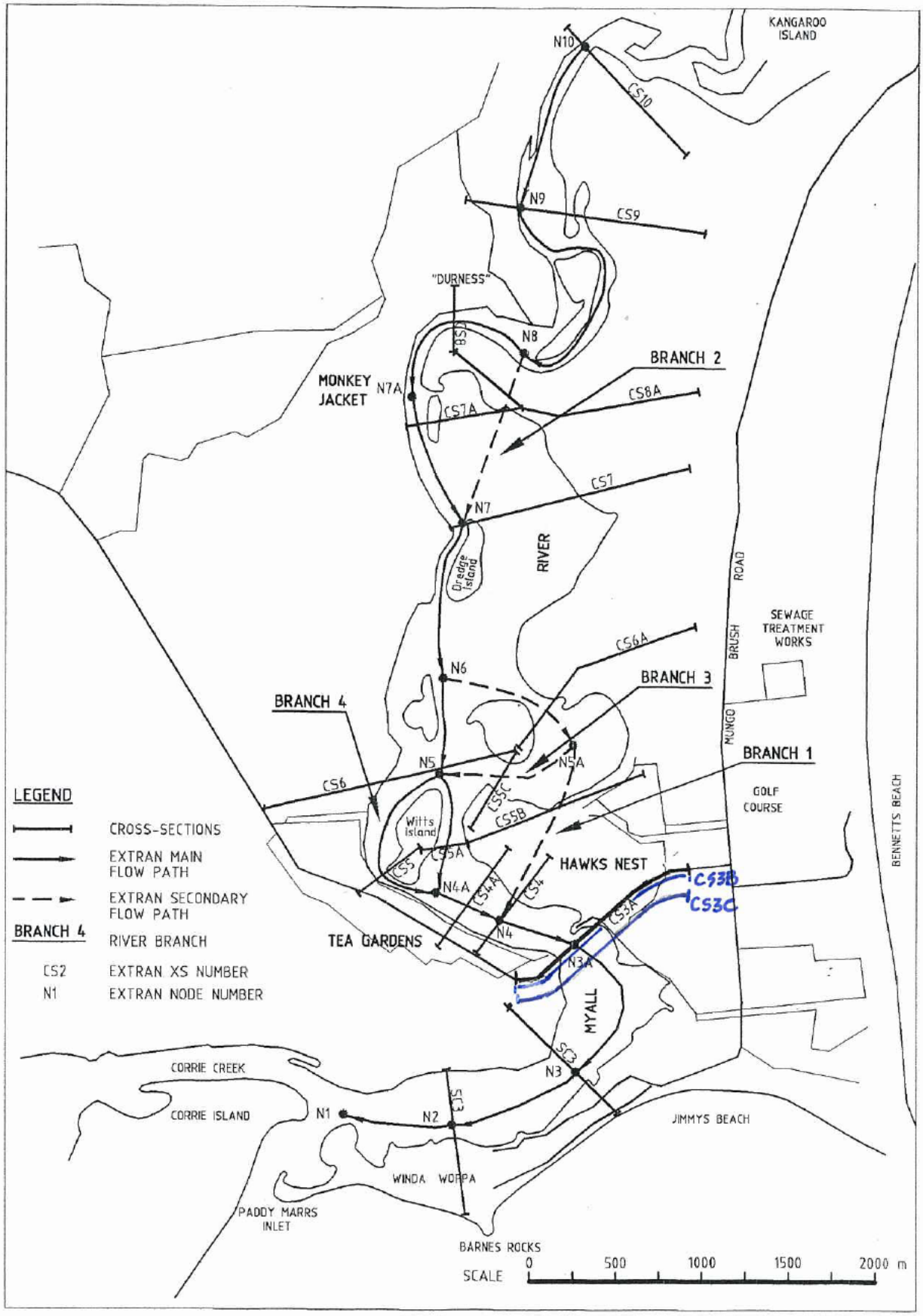

Figure 3 Amended Schematic xpswmm Model Layout (after Cardno Willing, 2008c)

4.3 Downstream Boundary Condition

For the purpose of the 1995 study, the tailwater level was determined in the lower reaches of the river somewhere between Tea Gardens and Corrie Island. The river ends at Corrie Island where it bifurcates into Corrie Creek and Paddy Marrs Inlet. This is a relatively sheltered location. Hydrosurvey information is available and it is the location of the last cross section in the 1980 PWD hydraulic model. On this basis the tailwater was positioned at Node 1 on the **xpswmm** layout (refer **Figure 3**).

Based on the approach adopted in the 1995 study and reported in Cardno Willing, 2008a the downstream 100 yr ARI boundary level of 1.89 m AHD was adopted.

The 2002 Port Stephen Foreshore (Floodplain) Management Study (Webb, McKeown & Associates, 2002) reported an Extreme Stillwater level of 2.0 m AHD (refer Table 2, page 7 of the report).

4.4 Results

The hydraulic model was run for two scenarios and estimated the following PMF levels on the site (refer **Table 1**):

Table 1
Estimated Peak Flood Levels (m AHD) at Riverside

Event	Description	Estimated Flood Level (m AHD)
PMF	The PMF level under existing conditions with a 100 yr ARI downstream boundary level in the lower reach of the Myall River of RL 1.89 m.	2.82 – 2.89 m
PMF	The PMF level under existing conditions with an extreme downstream boundary level in the lower reach of the Myall River of RL 2.0 m	2.86 – 2.93 m

5. LOCAL FLOODING AND DRAINAGE

5.1 Hydraulic Model

The hydraulic model used for the assessments of local flooding and drainage is described in the 2008 Riverside at Tea Gardens Integrated Water Management Report (see **Figure 4**).

5.2 Inflow Hydrographs

The 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP rainfall intensities were estimated using Bulletin 53 released by the Bureau of Meteorology. These rainfall intensities were input into the existing **xprafts** model that was then run to estimate 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP hydrographs.

5.3 Downstream Boundary Condition

It was assumed that the existing/extended lake will be swamped by the Myall River flooding during a PMF event. The assumed downstream flood level was equal to the 100 yr ARI flood level of 2.1 m AHD.

5.4 Results

The 100 yr ARI flood levels and PMF levels within the drainage corridors are summarised in **Table 4**.

The PMF levels within the drainage corridors under the 30 minute and 1 hour PMP storms are presented in **Figures 5** and **6**.

It should be noted that the PMF levels are based on floodwaters confined to the drainage corridors and as such these are conservative estimates. During a PMF event local runoff would spill from the drainage corridors into the residential areas which would result in lower PMF levels than summarised in **Table 2.**

It was noted that in almost all locations the 1 hour PMP storm gave the highest flood level except for the upper reach of the West Branch where the 30 minute PMP storm gave the highest estimated flood levels.

In most locations it was estimated that the PMF level is between 0.9 m to 1.45 m higher than the local 100 yr ARI level.

Table 2 Estimated 100 yr ARI and PMF Peak Flood Levels

Node	1% 1.5hr	1% 9hr	PMF 15min	PMF 30min	PMF 1hr		PMF - 1% AEP
	(mAHD)	(mAHD)	(mAHD)	(mAHD)	(mAHD)		(cm)
West Branch							
WB1	2.93	2.81	4.02	4.11	4.02		118
WB2	2.75	2.56	4.00	4.09	3.99		133
N69	2.16	1.97	3.51	3.62	3.55		146
WB3	2.16	1.97	3.51	3.62	3.55		146
WB4	2.16	1.97	3.51	3.62	3.55		146
N70	1.77	1.85	3.08	3.24	3.20		139
WB5	1.77	1.85	3.09	3.24	3.21		139
WB6	1.77	1.85	3.08	3.24	3.20		139
N71	1.68	1.78	2.80	2.96	2.97		119
WB7	1.68	1.78	2.80	2.96	2.97		119
WB8	1.61	1.67	2.47	2.61	2.68		101
East Branch							
EB1	2.58	2.50	2.82	2.77	2.79		23
EB2	1.74	1.71	2.51	2.60	2.66		92
N68	1.74	1.71	2.51	2.60	2.66		92
EB3	1.56	1.60	2.52	2.60	2.66		106
EB4	1.50	1.60	2.39	2.55	2.64		104
EB5	1.48	1.60	2.39	2.55	2.64		104
EB6	1.48	1.59	2.39	2.55	2.64		105
EB7_1	1.48	1.59	2.39	2.54	2.63		104
EB7_2	1.48	1.59	2.39	2.54	2.63		104
N73	1.48	1.59	2.39	2.54	2.63		104
North Branch							
NB1	2.19	2.14	3.08	3.20	3.21		103
NB2	1.98	1.90	3.07	3.19	3.21		124
NB3	1.97	1.87	3.07	3.19	3.21		125
NB4	1.68	1.78	2.80	2.96	2.97		119
NB5	1.68	1.78	2.80	2.96	2.97		119
NB6	1.68	1.78	2.80	2.96	2.97		119
East-West Branch							
EW1	8.69	8.61	9.09	9.21	9.23		54
EW1_1	4.71	4.63	5.14	5.29	5.40		69
EW2	3.85	3.84	4.51	4.88	5.14		129
EW3	3.79	3.79	4.49	4.84	5.09		130
EW4	2.93	2.93	3.50	3.79	3.99		106
EW5	2.81	2.81	3.42	3.67	3.84		103
EW6	2.48	2.48	2.83	3.10	3.29		81
N43	2.16	2.08	2.31	2.50	2.68		52
EW7	1.97	1.98	2.31	2.51	2.68		70
EW8	1.87	1.87	2.11	2.14	2.18		31
Lakes							
LakeA	1.61	1.67	2.47	2.61	2.68		101
LakeB	1.48	1.59	2.39	2.54	2.62		103
LakeC	1.46	1.56	2.31	2.40	2.44		88
Salt_Ext	0.91	1.09	2.41	2.54	2.60		151
ExtLake	0.89	1.03	2.10	2.10	2.10		107

Figure 4 Model Layout

Figure 5 PMF Levels under a 30 Minute PMP Storm

Figure 6 PMF Levels under a 1 Hour PMP Storm

6. REFERENCES

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Volume 3A: Geotechnical and Acid Sulphate Soil Assessment

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PROPOSED SUBDIVISION - RIVERSIDE ESTATE PROJECT APPLICATION AND MASTER PLAN AREA, TEA GARDENS

Tattersall Surveyors Pty Ltd

GEOTSGTE20248AA-AF
4 July 2008

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
19 Warabrook Boulevard Warabrook NSW 2304 Australia

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

4 July 2008

Tattersall Surveyors Pty Ltd
PO Box 54
RAYMOND TERRACE NSW 2324

Attention: Bob Lander

Dear Bob

RE: PROPOSED SUBDIVISION

RIVERSIDE ESTATE PROJECT APPLICATION AND MASTER PLAN AREA, TEA GARDENS

GEOTECHNICAL AND ACID SULFATE SOILS ASSESSMENT

Please find enclosed a report describing geotechnical studies carried out on the above site.

The purpose of the assessment was to provide comments and recommendations on acid sulfate soils within the proposed development area. A generic Acid Sulfate Soils (ASS) Management Plan has been provided for the Riverside Estate Project Application and subsequent stages.

The assessment also provides preliminary geotechnical information for the design and construction of road pavements and residential footings. On site soils have been assessed and preliminary site classifications in accordance with AS2870-1996 are provided.

Further advice on the uses and limitations of this report is presented in the attached document, *'Important Information about your Coffey Report'.*

If you have any questions regarding this matter please contact Robert Pearce or the undersigned.

For and on behalf of Coffey Geotechnics Pty Ltd.

Arthur Love

Principal Geotechnical Engineer

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Appendix A: Results of Field Investigations

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1 INTRODUCTION

This report presents the results of a geotechnical assessment carried out by Coffey Geotechnics Pty Ltd (Coffey) on behalf of Tattersall Surveyors Pty Ltd for the proposed Riverside Estate Project Application and Master Plan area, Tea Gardens.

The work was commissioned by Bob Lander of Tattersall Surveyors Pty Ltd on behalf of Crighton Properties Pty Ltd by way of two faxed Authorisation to Proceed forms dated 16 March and 5 April 2007. A master plan of the proposed subdivision was provided by the client.

The proposed Riverside Estate Project Application is understood to involve the subdivision of the site into a total of 390 dwellings, including dual occupancy dwellings and small lot / medium density development and construction of associated subdivision roads. The proposed Riverside Estate Master Plan area is located to the north and north east of the Riverside Estate Project Application and is understood to involve the subdivision of the site.

The scope of work for the geotechnical assessment included providing recommendations on:

- Site preparation;
- Excavation conditions;
- The suitability of the site soils for use as fill and on fill construction procedures;
- Acid sulfate soil conditions and requirements for an acid sulfate soils management plan;
- Preliminary site classification to AS2870–1996;
- Preliminary pavement design and construction;
- Special requirements for construction procedures and or site drainage.

The following report presents the results of field investigations and laboratory testing and provides discussion and recommendations relevant to the above scope of work.

2 FIELD WORK

Field work was carried out between from 4 April to 5 June 2007 and consisted of:

- Excavation of 40 test pits (TP1 to TP34 and TP39 to TP44) across the site using a rubber tyred backhoe to depths of up to 2.5m. Disturbed samples of representative materials were taken for acid sulfate soils testing;
- Drilling of six boreholes (BH35 to BH38 and BH45 and BH46) at the site using a 4WD mounted drilling rig to depths of up to 10.45m;
- Site observations and mapping of relevant site features.

All field work was carried out in the full time presence of an Engineering Geologist who located the test pits and boreholes, carried out the sampling and testing and produced engineering logs of the test pits and boreholes. Engineering logs of the test pits and boreholes are presented in Appendix A, together with explanation sheets defining the terms and symbols used in their preparation.

The test pit and borehole locations were pegged by the client prior to the investigation. Test pit and borehole locations are shown on Figure 1.

3 SITE CONDITIONS

3.1 Surface Conditions

The site is bounded by Toonang Drive and an existing residential subdivision to the north, Myall Street to the west, undeveloped low lying land adjoining the Myall River to the east and the recently constructed Myall Quays Estate to the south.

Topographically the site is located within an area of low lying coastal sand plains. The site is flat to slightly sloping and is subject to prolonged water logging during periods of wet weather.

Surface elevations across the site range from about RL0.75m AHD in the south eastern corner of the site, to between about RL5m across the north eastern portion.

The majority of the site has been cleared, with vegetation comprising an established cover of medium to tall grasses and scattered medium sized eucalypts.

3.2 Subsurface Conditions

With reference to the Newcastle 1:250,000 Geological Series Sheet SI 56-2, the site is judged to be underlain by Quaternary aged deposits comprising gravel, sand, silt and clay.

The typical soil types encountered at test pit and borehole locations during the field investigations have been divided into geotechnical units as summarised in Table 1.

TABLE 1 – SUMMARY OF GEOTECHNICAL UNITS AND SOIL TYPES AT TEST LOCATIONS

GEOTECHNICAL UNIT	SOIL TYPE	DESCRIPTION
1	Topsoil	Typically Silty Clayey SAND and Silty SAND, fine to medium grained and Sandy Silty CLAY / Silty Sandy CLAY, dark brown and dark grey, root affected to depths of between 0.15m to 0.45m.
2	Clay	Sandy CLAY and CLAY, medium to high plasticity, dark brown, dark grey and grey brown mottled orange of stiff consistency and Clay SAND, fine to medium grained, typically pale brown, pale grey and grey brown.
3	Sand	SAND, fine to medium grained, pale grey to white, pale grey brown, grey brown and dark brown, moist to wet and medium dense to very dense.
4	Possible Indurated / Indurated Sand	Clayey SAND and Silty SAND, fine to medium grained, dark brown, pale brown and orange brown, dense to very dense, with cemented sand nodules.

Table 2 provides a summary of the distribution of the above geotechnical units at each test location.

TABLE 2 – SUMMARY OF DISTRIBUTION OF GEOTECHNICAL UNITS AT TEST LOCATIONS

TEST LOCATION	UNIT 1	UNIT 2	UNIT 3	UNIT 4	GROUNDWATER INFLOW / WATERTABLE
	DEPTH (m)				
TP 1	0.0 - 0.3	0.3 - 0.6	0.6 - > 1.9	-	1.9
TP 2	0.0 - 0.4	0.4 - 1.5	1.5 - > 1.9	-	1.5
TP 3	0.0 - 0.5	0.5 – 0.8	0.8 - > 1.8	-	1.7
TP 4	0.0 - 0.4	0.4 - 2.0	2.0 - > 2.1	-	2.0
TP 5	0.0 – 0.4	0.4 – 0.75	0.75 - > 1.9	-	1.4
TP6	0.0 - 0.6	-	1.1 - > 2.1	0.6 - > 1.1	2.0
TP7	-	0.0 - > 1.0	-	-	0.9
TP8	-	0.0 - > 0.6	-	-	-
TP9	0.0 - 0.6	-	1.1 - > 2.0	0.6 – 1.1	1.8
TP10	0.0 - 0.45	-	0.8 - > 1.9	0.45 – 0.8	-
TP11	0.0 - 0.2	0.2 – 0.45	1.0 - > 1.9	0.45 – 1.0	1.8
TP12	0.0 - 0.4	0.4 - 1.0	1.0 - > 2.0	-	2.0
TP13	0.0 - 0.6	-	-	0.4 - > 2.0	1.9
TP14	0.0 - 0.4	0.4 - > 1.8	-	-	-
TP15	0.0 – 0.5	-	0.5 - > 1.7	-	-
TP16	0.0 - 0.25	-	0.25 – 1.7	1.7 - > 1.8	1.7
TP17	0.0 – 0.5	-	1.1 - > 2.0	0.5 – 1.1	1.7
TP18	0.0 – 0.4	0.4 – 0.8	0.8 - > 1.9	-	1.3
TP19	0.0 – 0.35	0.35 – 1.2	1.2 - > 1.8	-	1.6

TEST LOCATION	UNIT 1	UNIT 2	UNIT 3	UNIT 4	GROUNDWATER INFLOW / WATERTABLE
	DEPTH (m)				
TP20	0.0 – 0.2	0.2 - > 1.7	-	-	1.7
TP21	0.0 – 0.35	-	0.6 - > 2.0	0.35 – 0.6	1.7
TP22	0.0 – 0.5	0.5 – 0.8	1.2 - > 1.9	0.8 – 1.2	1.8
TP23	0.0 – 0.3	0.3 – 0.8	0.8 - > 2.0	-	-
TP24	0.0 – 0.4	0.4 – 0.7	0.7 - > 2.0	-	1.4
TP25	0.0 – 0.5	-	-	0.5 – > 2.0	1.9
TP26	0.0 – 0.3	-	0.3 - > 1.5	-	1.5
TP27	0.0 – 0.6	-	0.8 - > 1.8	0.6 - 0.8	1.7
TP28	0.0 – 0.6	-	1.2 - > 1.8	0.6 – 1.2	1.7
TP29	0.0 – 0.5	0.5 – 1.4	1.4 - > 1.7	-	1.7
TP30	0.0 – 0.3	-	0.3 - > 1.7	-	0.3
TP31	0.0 – 0.1	0.1 – 1.1	1.1 - > 1.8		0.7 & 1.1
TP32	0.0 – 0.3	0.3 - > 1.7	-	-	0.3 & 0.8
TP33	0.0 – 0.25	0.25 – 1.9	-	1.9 - > 2.0	0.75
TP34	0.0 – 0.25	0.25 – 1.9	1.9 - > 2.0	-	0.55
BH35	-	-	0.0 - > 4.0	-	0.3
BH36	-	-	0.0 - > 4.0	4.0 - > 7.0	0.7
BH37	-	-	0.0 – 3.8	3.8 - > 7.0	0.8
BH38	0.0 – 0.1	0.1 – 2.2	2.2 - > 7.0	-	1.8
TP39	0.0 – 0.15	0.15 – 1.4	1.4 - >1.7	-	1.45
TP40	0.0 – 0.2	0.2 – 1.1	1.1 - >1.7	-	1.5

TEST LOCATION	UNIT 1	UNIT 2	UNIT 3	UNIT 4	GROUNDWATER INFLOW / WATERTABLE
	DEPTH (m)				
TP41	0.0 – 0.3	0.3 – 1.5	1.5 - >2.5	-	2.2
TP42	0.0 – 0.3	0.3 – 1.1	1.1 - >1.7	-	1.7
TP43	0.0 – 0.15	-	0.15 - >1.85	-	1.7
TP44	0.0 – 0.3	-	0.3 - >1.8	-	-
BH45	-	-	0.0 - >10.45	-	2.3
BH46	0.0 – 0.25	-	0.25 - >7.45	-	0.9

4 ACID SULFATE SOILS (ASS) ASSESSMENT

4.1 Formation of Acid Sulfate Soils

Acid Sulfate Soils (ASS) are soils which contain significant concentrations of pyrite which, in the presence of sufficient moisture, oxidises when exposed to oxygen, resulting in the generation of sulfuric acid.

Unoxidised pyritic soils are referred to as potential ASS. When the soils are exposed, the oxidation of pyrite occurs and sulfuric acids are generated, the soils are said to be actual ASS.

Pyritic soils typically form as waterlogged, saline sediments rich in iron and sulfate. Typically, the environments for the formation of these soils include tidal flats, salt marshes and mangrove swamps below about RL 5m AHD. They can also form as bottom sediments in coastal rivers and creeks.

Pyritic soils of concern on low lying NSW and coastal lands have mostly formed in the Holocene period, (ie: 10,000 years ago) predominantly in the 7,000 years since the last rise in sea level. It is generally considered that pyritic soils which formed prior to the Holocene period (ie: >10,000 years ago) would already have oxidised and leached during periods of low sea level during ice ages, which exposed pyritic coastal sediments to oxygen.

4.2 Significance of Acid Sulfate Soils

Disturbance or poorly managed development and use of acid sulfate soils can generate significant amounts of sulfuric acid, which can lower soil and water pH to extreme levels (generally <4) and produce acid salts, resulting in high salinity.

The low pH, high salinity soils can reduce or altogether preclude vegetation growth and can produce aggressive soil conditions which may be detrimental to concrete and steel components of structures, foundations, pipelines and other engineering works.

Generation of the acid conditions often releases aluminium, iron and other naturally occurring elements from the otherwise stable soil matrices. High concentrations of some such elements, coupled with low pH and alterations to salinity can be detrimental to aquatic life. In severe cases, affected waters can have a detrimental effect on aquatic ecosystems.

4.3 Acid Sulfate Soils Risk Map

Reference to the Acid Sulfate Soils Risk Map for Port Stephens indicates that the site is located in an area where there is a low probability of occurrence of acid sulfate soil materials between 1m and 3m below the ground surface. The map also indicates that ASS materials, if present, are sporadic and may be buried by alluvium or windblown sediments.

The map indicates the north eastern portion of the site adjacent to the Myall River is located in an area where there is a low to high probability of acid sulfate soil materials at or near the ground surface.

4.4 Screening Tests

Samples obtained during the field investigation were screened for the presence of actual and potential acid sulfate soils using methods 21Af and 21Bf of the 1998 ASSMAC Guidelines. The results of screening tests are presented in Appendix B and are summarised below:

- pH values in 1:5 soil to distilled water mix ranged from 4.09 to 7.68. A pH of <4 in this test can indicate the presence of actual ASS;
- pH values of soil in 30% H_2O_2 were between 1.43 to 5.77. A pH of <3 in this test can indicate the presence of potential ASS;
- A maximum pH change of 4.99 after oxidation with H_2O_2 was recorded. Significant pH changes (>2) after oxidation with H_2O_2 can indicate potential ASS. pH changes >2 were recorded in 19 of the 105 samples screened for ASS;
- Slight to moderate effervescence was observed in 29 of the 105 samples tested. Vigorous effervescent reactions with oxidation in 30% H_2O_2 can indicate potential ASS;
- An odour was released upon oxidation with H_2O_2 in 18 of the 105 samples tested. A sulphurous odour is often associated with oxidising potential ASS;
- Temperatures of 19.5° to 33° were recorded in all H_2O_2 oxidation screening tests. Generally the oxidation of significant quantities of pyrite in this test will generate temperatures to >60°C.

4.5 Laboratory Analysis

Laboratory test results for samples sent for SPOCAS / SCR Suite analysis are summarised in Table 3.

TABLE 3 – SUMMARY OF ASS TEST RESULTS

LOCATION	SAMPLE DEPTH (m)	SCREENING TEST RESULT		S_{POS} / S_{CR} (%)	TPA / NET ACIDITY (mol H+ / tonne)	LIMING RATE (kg / tonne)
		pH_F	pH_{FOX}			
TP6	2.0 – 2.1	4.94	4.06	0.02	16	-
TP14	0.6 – 0.7	5.20	3.26	**0.14**	**84**	**6**
TP19	0.5 – 0.6	4.96	3.70	0.08	49	4
TP25	1.9 – 2.0	4.36	3.26	**0.12**	**76**	**6**
TP26	1.5 – 1.6	4.71	2.60	< 0.02	< 10	-
TP27	1.1 – 1.2	4.47	3.35	0.03	**21**	**2**
TP28	0.6 – 0.7	4.95	3.55	**0.08**	**53**	**4**
TP30	1.5 – 1.6	5.25	2.81	**0.09**	**58**	**4**
TP32	1.6 – 1.7	6.40	1.43	**0.13**	**84**	**6**
TP33	1.1 – 1.2	6.34	1.45	**0.12**	**77**	**6**
TP34	1.0 – 1.1	6.35	1.36	**0.19**	**117**	**9**
BH36	0.5 – 1.0	5.03	4.24	**0.04**	**26**	**2**
BH36	3.5 – 4.0	5.75	3.26	< 0.02	11	-
BH37	0.5 – 1.0	5.85	4.67	0.02	14	**-**
BH37	2.0 – 2.5	5.55	3.92	**0.07**	**44**	**3**
BH37	5.0 – 5.5	5.83	3.27	**0.15**	**93**	**7**
BH37	6.5 – 7.0	5.73	3.07	**0.17**	**104**	**8**
BH38	0.5 – 1.0	5.19	4.20	**0.24**	**147**	**11**
BH38	6.5 – 7.0	5.63	4.26	< 0.02	11	-
TP39	1.0 – 1.1	6.75	3.86	0.006	**56**	**5**

LOCATION	SAMPLE DEPTH (m)	SCREENING TEST RESULT		S_{POS} / S_{CR} (%)	TPA / NET ACIDITY (mol H+ / tonne)	LIMING RATE (kg / tonne)
		pH_F	pH_{FOX}			
TP40	1.5 – 1.6	5.90	4.73	<0.005	9	1
TP41	0.5 – 0.6	5.20	3.86	<0.005	**39**	**5**
TP42	1.0 – 1.1	5.25	4.19	0.007	**37**	**3**
TP43	1.7 – 1.8	5.83	5.18	<0.005	7	1
BH45	5.5 – 5.9	6.17	4.80	0.011	**22**	**3**
BH46	1.0 – 1.1	6.57	2.28	0.028	**20**	**2**
BH46	2.5 – 3.0	6.70	4.38	0.016	**18**	**2**
BH46	5.5 – 6.0	7.68	5.33	0.013	10	1
ASSMAC Action Criteria	-	-	-	0.1* 0.03**	62* 18**	-
Levels of Concern for Screening Test	-	4	3	-	-	-

NOTE:

** Action criteria shown are those for fine textured soils (ie clays) and management of excavations involving disturbance of less than 1000 tonnes of soil;*

*** Action criteria shown are those for course textured soils (ie sands) and management of excavations involving disturbance of more than 1000 tonnes of soil;*

S_{POS} – Percentage of oxidisable Sulfur;

S_{CR} – Percentage of chromium reducible Sulfur;

TPA – Total Potential Acidity.

Results of SPOCAS and SCR Suite analysis indicate nineteen out of the twenty eight samples tested exceeded the Acid Sulfate Soil Management Advisory Committee (ASSMAC) action criteria. Works involving disturbance of soils that exceed these action criteria must prepare an Acid Sulfate Soils Management Plan.

5 DISCUSSION AND RECOMMENDATIONS

5.1 Acid Sulfate Soils (ASS) Management Plan

The purpose of the plan presented in Appendix C was to provide a generic plan for management of ASS in future earthworks that occur within the Riverside Estate. It is understood that the plan is to be provided as a reference to all lot purchasers and contractors required to work on the site. It has therefore been formatted in a way that will be useable to individual land owners to assist in obtaining DA approvals and in controlling and managing ASS during the development of each lot.

5.2 Site Preparation

Site preparation and earthworks suitable for pavement and structure support should consist of:

- Prior to construction of roads and placement of any fill, the proposed fill areas should be stripped to remove all vegetation and root affected or other potentially deleterious material. Test pit logs indicate Unit 1 (Topsoil) to be present to depths of up to 0.6m, however the root affected zone is generally less than 0.3m, but up to 0.45m depth. Stripping is therefore generally expected to be required to depths of between 0.15m to 0.45m;
- Following stripping, wet areas that remain may require over excavation and backfilling with an approved select material. The exposed subgrade materials should be inspected by a geotechnical authority to assess the need for over excavation or placement of a geofabric beneath the select fill layer. The select material should be placed in a single lift. It is anticipated that this treatment could be wide spread across this site;
- It is understood that site finished levels will be up to 1m above existing surface levels across the site. The first layer of approved fill beneath roads should be placed in a single layer of 500mm loose thickness and should not be heavily compacted. Subsequent layers should not exceed 300mm loose thickness and should be compacted to a minimum density index of 70% for sands or minimum density ratio of 95% Standard Compaction for cohesive soils in accordance with AS1289 5.1.1 or equivalent. Clay subgrade fill should be placed and maintained at 60% to 90% of standard Optimum Moisture Content;
- The impact of road fill on drainage of adjacent lots needs to be considered in lot drainage design as there is a tendency for water to pond on the surface of clay soils. One option would be to provide drainage columns through the clay layer to allow surface water to drain through to the underlying sands;
- The top 300mm of natural subgrade below pavements or the final 300mm of road subgrade replaced should be compacted to a minimum density index of 80% for sands or minimum density ratio of 100% Standard Compaction for cohesive soils within the above stated moisture range;
- Residential site fill beneath structures should be compacted to a minimum density ratio of 95% Standard Compaction within ±2% of OMC;
- All fill should be supported by properly designed and constructed retaining walls or else battered at 1V:2H or flatter and protected against erosion;
- Earthworks should be carried out in accordance with the recommendations outlined in AS3798-1996 *'Guidelines for Earthworks for Commercial and Residential Developments'*.

5.3 Excavation Conditions

Where excavation is required, it is anticipated that all site materials could be excavated by conventional dozer blade or excavator bucket at least to the depths indicated on the appended test pit and borehole logs. The excavator should use a 'gummy' bucket to avoid over-disturbance of the soils below the depth of excavation.

5.4 Reuse of Materials

The following comments are made regarding the suitability of the site materials for reuse in filled areas:

- Where site regrade is proposed vegetation, root affected or other potentially deleterious material should be removed to spoil or stockpiled for reuse as landscaping materials only. Stripping is generally expected to be required to depths of between 0.15m to 0.45m;
- Wet areas that remain after stripping may require over excavation. Unit 2 soils that are over excavated because they are over wet should also be removed to spoil;
- Very stiff to hard Unit 2 soils and Unit 3 and Unit 4 soils should be carefully excavated as necessary and stockpiled for reuse as general site fill;
- The Unit 2 soils are likely to be moderately to highly reactive (susceptible to volume changes with variation in moisture content) and if excavated and reused will need to be placed and compacted close to the specifications outlined to minimise reactive soil movements.

5.5 Preliminary Pavement Design

5.5.1 Design Traffic Loading

Design traffic loadings have been adopted in accordance with Great Lakes Council guidelines. Table 4 presents a summary of design traffic loadings adopted for subdivision roads.

TABLE 4 – DESIGN TRAFFIC LOADINGS

ROAD TYPE	ESA's
Local Access	5×10^5
Collector	1×10^6

5.5.2 Preliminary Design CBR Values

Based on the results of the fieldwork, and previous experience in the adjoining Myall Quays Estate, preliminarily design subgrade California Bearing Ratio (CBR) values as outlined in Table 5 have been adopted.

TABLE 5 – DESIGN CBR VALUES

MATERIAL TYPE	DESIGN CBR
Clay Soils	2 %
Sand Soils	10 %

5.5.3 Preliminary Flexible Pavement Design

Preliminary flexible pavement thickness designs have been prepared with reference to ARRB Special Report No 41, APRG Report No 21 and Austroads - Pavement Design 2004.

The recommended material, construction specification and pavement make-up are presented on the attached Pavement Thickness Design Summary (PTDS) sheet.

It is understood from discussions with Tattersall Surveyors that the design finished level of roads within the subdivision will vary from on-grade to about 1m above. At the time of the field investigation, which followed recent rain, large areas of water were observed to be ponding across the south eastern area of the site.

Subgrade moisture contents of the Unit 2 soils were judged to be generally greater than standard Optimum Moisture Content (OMC). Moisture contents are likely to remain high in these soils. It should therefore be anticipated that drying back of Unit 2 subgrade materials or over excavation and replacement will be necessary prior to the placement of site fill and / or pavement construction. The required time period to prepare the subgrade is likely to be dependant on the prevailing weather conditions at the time of construction.

If over wet subgrade conditions exist at the time of construction, these materials should be over-excavated and replaced with a minimum depth of 500mm (refer to PTDS) of well graded granular select material with a CBR of 15% or greater.

The requirement for, and extent of subgrade replacement should be confirmed by the geotechnical authority at the time of construction.

It is recommended that each construction length be boxed out to the minimum subgrade level required by the relevant pavement thickness design. Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

5.5.4 Drainage

The enclosed preliminary pavement designs assume the provision of adequate surface and subsurface drainage of the pavement and adjacent areas. It is recommended that subsoil drains be installed along both sides of roads where Unit 2 soils are encountered at subgrade level.

5.6 Preliminary Site Classification

On the basis of the soil profiles encountered during the field investigations, results of Dynamic Cone Penetrometer testing and results of laboratory shrink / swell testing carried out in the adjoining Myall Quays Estate, lots within the proposed subdivision are currently classified in accordance with AS2870-1996 '*Residential Slabs and Footings*', as Moderately Reactive, Class 'M'. A characteristic free surface movement of up to 40mm is estimated for the natural soil profiles encountered.

The effects of changes to the soil profile by additional cutting and filling and the effects of past and future trees should be considered in selection of the design value for differential movement. Footings for the proposed development should be designed and constructed in accordance with the requirements of AS2870.

The classification presented above assumes that:

- All footings are founded in controlled fill or in the natural soils below all root affected material and fill under slab panels meets the requirements of AS2870, in particular, the root zone must be removed prior to the placement of fill materials beneath slab floors;
- The performance expectations set out in AS2870 are acceptable;
- Site maintenance complies with the provisions of CSIRO Sheet BTF 18, *Foundation Maintenance and Footing Performance: A Homeowner's Guide*, a copy of which is attached;
- Service trenches backfilled with uncontrolled fill do not extend below a line extending out and down at 45° from the ground surface at the edge of the building;
- The constructional and architectural requirements for reactive clay sites set out in AS2870 are followed.

Where fill is to be placed to raise site levels, the affected allotments will require reclassification once the depth and type of placed fill are known and the level of earthworks control has been established.

6 CONSTRUCTION RISK

The extent of testing associated with this assessment is limited to discrete test pit and borehole locations and variations in ground conditions can occur between and away from such locations. If subsurface conditions encountered during construction differ from those given in this report further advice should be sought without delay.

Further advice on the uses and limitations of this report is presented in the attached document, '*Important Information about your Coffey Report*'.

For and on behalf of Coffey Geotechnics Pty Ltd

Arthur Love

Principal Geotechnical Engineer

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

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pavement thickness design summary

client : ***TATTERSALL SURVEYORS PTY LTD*** job no : ***GEOTSGTE20248AA***

principal : ***CRIGHTON PROPERTIES PTY LTD*** laboratory : ***NEWCASTLE***

project : ***PROPOSED SUBDIVISION*** report date : ***May 09, 2007***

location : ***RIVERSIDE ESTATE, PROJECT APPLICATION, TEA GARDENS*** test report no.: ***MAY09-03/1***

council : ***GREAT LAKES COUNCIL*** designed by : ***RJP*** checked by :

road name or type :		***LOCAL ACCESS***	***LOCAL ACCESS***	***COLLECTOR***	***COLLECTOR***
chainage interval :	(m)	***Clay Subgrade***	***Sand Subgrade***	***Clay Subgrade***	***Sand Subgrade***
design traffic loading:	(ESA)	***5 x 10^5***	***5 x 10^5***	***1 x 10^6***	***1 x 10^6***
wearing course thickness :	(mm)	***40***	***40***	***40***	***40***
basecourse thickness:	(mm)	***150***	***150***	***150****	***150****
sub-base thickness:	(mm)	***150***	***150***	***150****	***150****
select thickness:	(mm)	***500***	***-***	***500***	***-***
total thickness :	(mm)	***840***	***340***	***840***	***340***
CBR used for design :	(%)	***2***	***10***	***2***	***10***

design traffic loading : Design traffic loading is the number of equivalent standard axles (E.S.A.) in the design lane during the design period. For definitions, refer Appendix 1.1 "Pavement Design" AUSTROADS. Refer covering letter/report.

Material Quality

wearing course : ***RTA QA Specification R116***

basecourse : ***Conforming to ARRB Special Report No 41, * RTA QA Specification 3051***

sub-base: ***Conforming to ARRB Special Report No 41, * RTA QA Specification 3051***

select : ***Well graded granular material, maximum particle size 100mm, minimum CBR 15%.***

Note : Recommended material types may vary from those of job specification or statutory authority. Refer covering letter/report.

Compaction Requirements

wearing course : ***RTA QA Specification R116***

basecourse : ***98% MODIFIED***

sub-base : ***95% MODIFIED***

select : ***80% DI, 100% STD***

subgrade : ***80% DI, 100% STD***

fill below : ***70% DI, 95% STD***

Modified: Minimum required dry density ratio, AS1289 5.4.1-1993, calculated using field dry density determined by AS1289 5.3.1-2004 or equivalent, and the maximum dry density obtained using AS1289 5.2.1-2003 or equivalent.

Standard: As above, but maximum dry density obtained using AS1289 5.1.1-2003 or equivalent.

Density Index: Minimum required Density Index AS1289 5.6.1-1998, calculated using field dry density determined by AS1289 5.3.1-2004 or equivalent, and laboratory values of maximum and minimum density obtained by AS1289 5.5.1-1998 or equivalent.

Note: Recommendations for compaction may vary from those of job specification or statutory authority. Refer covering letter/report.

Drainage: The design assumes the provision of adequate surface and subsurface drainage of the pavement and adjacent areas. Refer covering letter/report.

Form Number L2.10RL Version 6.0

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Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction
There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion
All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation
This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil
All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure
This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

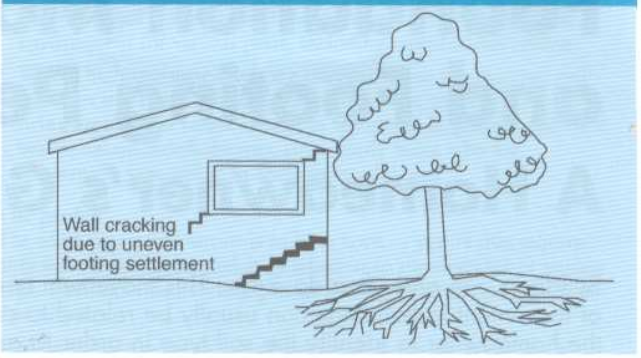
Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

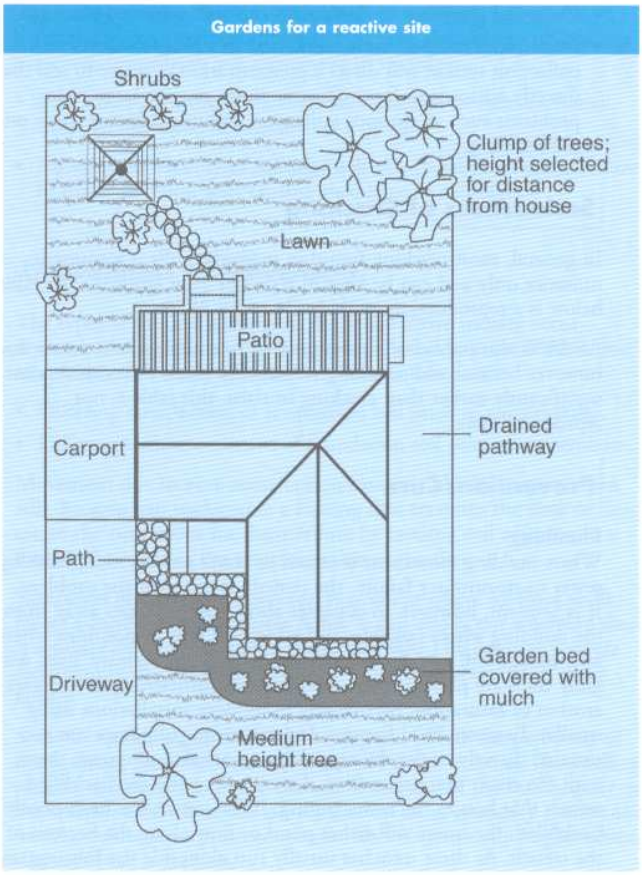
It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

Distributed by

CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia

Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au

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Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

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SPECIALISTS MANAGING THE EARTH

Important information about your **Coffey** Report

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.
Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

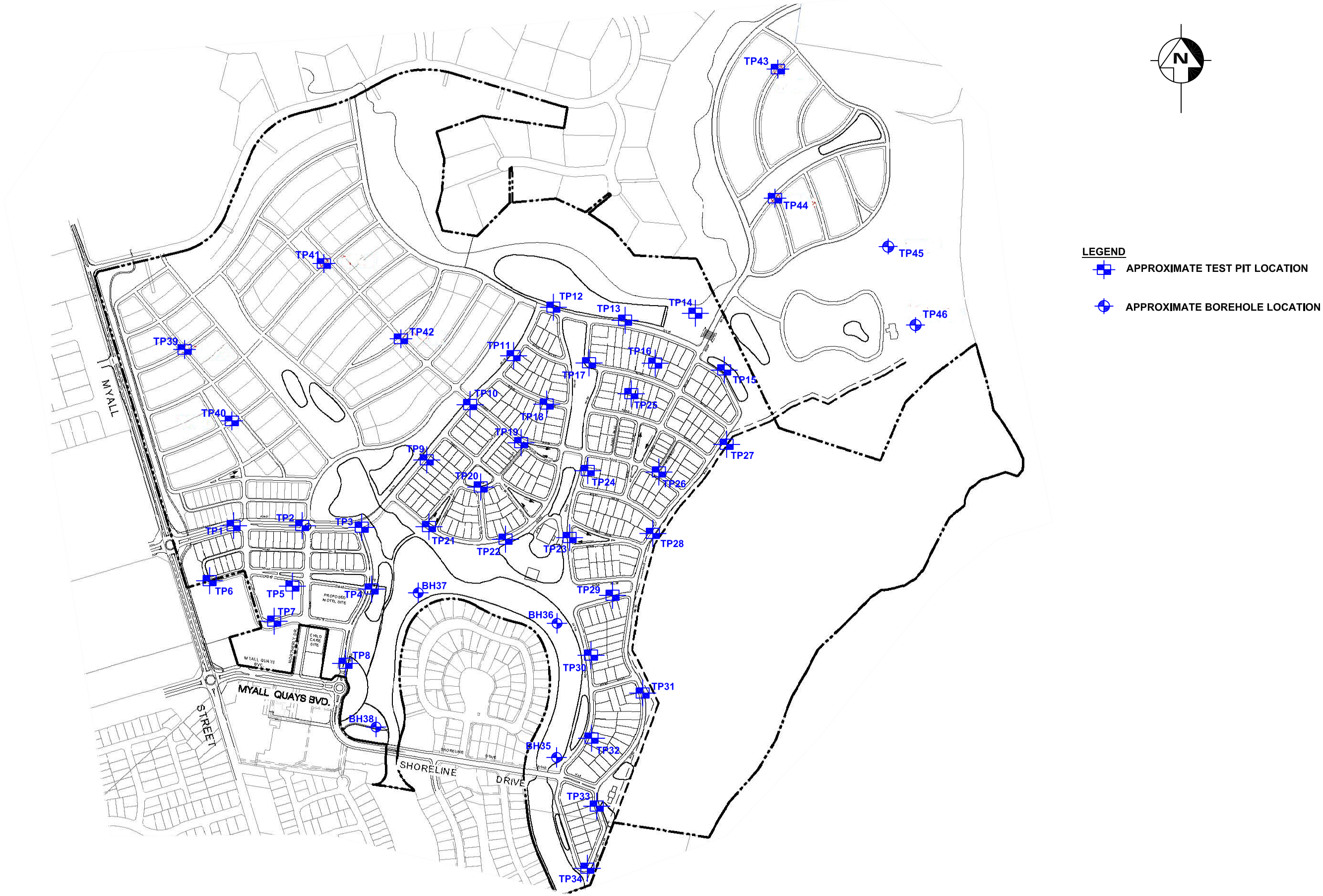
Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Figures



revision	description	drawn	approved	date

0 15 30 60 90

Scale (metres)

drawn	RJP/NLS
approved	
date	24-10-07
scale	1:1500
original size	A3

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client: TATTERSALL SURVEYORS PTY LTD

project: ADDENDUM TO REPORT FOR PROPOSED SUBDIVISION RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS

title: TESTPIT/BOREHOLE LOCATION PLAN

project no: GEOTSGTE20248AA-AE

figure no: FIGURE 1

Appendix A

Results of Field Investigations

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Soil Description Explanation Sheet (1 of 2)

DEFINITION:

In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.

Moist Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.

Wet As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH s_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	–	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: <5% Fine grained soils: <15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 - 12% Fine grained soils: 15 - 30%

SOIL STRUCTURE

ZONING		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

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Soil Description Explanation Sheet (2 of 2)

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)							USC	PRIMARY NAME
COARSE GRAINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.			GW	GRAVEL
				Predominantly one size or a range of sizes with more intermediate sizes missing.			GP	GRAVEL
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			GM	SILTY GRAVEL
				Plastic fines (for identification procedures see CL below)			GC	CLAYEY GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes missing			SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing.			SP	SAND
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).			SM	SILTY SAND
				Plastic fines (for identification procedures see CL below).			SC	CLAYEY SAND
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm			IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.					
		SILTS & CLAYS Liquid limit less than 50	**DRY STRENGTH**	**DILATANCY**	**TOUGHNESS**			
			None to Low	Quick to slow	None		ML	SILT
			Medium to High	None	Medium		CL	CLAY
			Low to medium	Slow to very slow	Low		OL	ORGANIC SILT
		SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium		MH	SILT
			High	None	High		CH	CLAY
			Medium to High	None	Low to medium		OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS			Readily identified by colour, odour, spongy feel and frequently by fibrous texture.				Pt	PEAT

• Low plasticity – Liquid Limit W_L less than 35%. • Modium plasticity – W_L between 35% and 50%.

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	A surface or crack across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	DEFINITION	DIAGRAM
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.	

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Rock Description Explanation Sheet (1 of 2)

The descriptive terms used by Coffey are given below. They are broadly consistent with Australian Standard AS1726-1993.

DEFINITIONS: Rock substance, defect and mass are defined as follows:

Rock Substance	In engineering terms roch substance is any naturally occurring aggregate of minerals and organic material which cannot be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Effectively homogenous material, may be isotropic or anisotropic.
Defect	Discontinuity or break in the continuity of a substance or substances.
Mass	Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

SUBSTANCE DESCRIPTIVE TERMS:

ROCK NAME	Simple rock names are used rather than precise geological classification.
PARTICLE SIZE	Grain size terms for sandstone are:
Coarse grained	Mainly 0.6mm to 2mm
Medium grained	Mainly 0.2mm to 0.6mm
Fine grained	Mainly 0.06mm (just visible) to 0.2mm
FABRIC	Terms for layering of penetrative fabric (eg. bedding, cleavage etc.) are:
Massive	No layering or penetrative fabric.
Indistinct	Layering or fabric just visible. Little effect on properties.
Distinct	Layering or fabric is easily visible. Rock breaks more easily parallel to layering of fabric.

CLASSIFICATION OF WEATHERING PRODUCTS

Term	Abbreviation	Definition
Residual Soil	**RS**	Soil derived from the weathering of rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely Weathered Material	**XW**	Material is weathered to such an extent that it has soil properties, ie, it either disintegrates or can be remoulded in water. Original rock fabric still visible.
Highly Weathered Rock	**HW**	Rock strength is changed by weathering. The whole of the rock substance is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Some minerals are decomposed to clay minerals. Porosity may be increased by leaching or may be decreased due to the deposition of minerals in pores.
Moderately Weathered Rock	**MW**	The whole of the rock substance is discoloured, usually by iron staining or bleaching , to the extent that the colour of the fresh rock is no longer recognisable.
Slightly Weathered Rock	**SW**	Rock substance affected by weathering to the extent that partial staining or partial discolouration of the rock substance (usually by limonite) has taken place. The colour and texture of the fresh rock is recognisable; strength properties are essentially those of the fresh rock substance.
Fresh Rock	**FR**	Rock substance unaffected by weathering.

Notes on Weathering:

1. AS1726 suggests the term "Distinctly Weathered" (DW) to cover the range of substance weathering conditions between XW and SW. For projects where it is not practical to delineate between HW and MW or it is judged that there is no advantage in making such a distinction. DW may be used with the definition given in AS1726.
2. Where physical and chemical changes were caused by hot gasses and liquids associated with igneous rocks, the term "altered" may be substituted for "weathering" to give the abbreviations XA, HA, MA, SA and DA.

ROCK SUBSTANCE STRENGTH TERMS

Term	Abbrev-iation	Point Load Index, I_S50 (MPa)	Field Guide
Very Low	**VL**	Less than 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with a knife; pieces up to 30mm thick can be broken by finger pressure.
Low	**L**	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show with firm bows of a pick point; has a dull sound under hammer. Pieces of core 150mm long by 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium	**M**	0.3 to 1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
High	**H**	1 to 3	A piece of core 150mm long by 50mm can not be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High	**VH**	3 to 10	Hand specimen breaks after more than one blow of a pick; rock rings under hammer.
Extremely High	**EH**	More than 10	Specimen requires many blows with geological pick to break; rock rings under hammer.

Notes on Rock Substance Strength:

1. In anisotropic rocks the field guide to strength applies to the strength perpendicular to the anisotropy. High strength anisotropic rocks may break readily parallel to the planar anisotropy.
2. The term "extremely low" is not used as a rock substance strength term. While the term is used in AS1726-1993, the field guide therein makes it clear that materials in that strength range are soils in engineering terms.
3. The unconfined compressive strength for isotropic rocks (and anisotropic rocks which fall across the planar anisotropy) is typically 10 to 25 times the point load index (Is50). The ratio may vary for different rock types. Lower strength rocks often have lower ratios than higher strength rocks.

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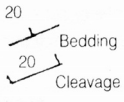
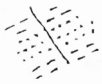
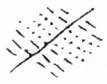
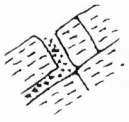
Rock Description Explanation Sheet (2 of 2)

COMMON DEFECTS IN ROCK MASSES

Term	Definition	Diagram	Map Symbol	Graphic Log (Note 1)
Parting	A surface or crack across which the rock has little or no tensile strength. Parallel or sub parallel to layering (eg bedding) or a planar anisotropy in the rock substance (eg, cleavage). May be open or closed.			
Joint	A surface or crack across which the rock has little or no tensile strength. but which is not parallel or sub parallel to layering or planar anisotropy in the rock substance. May be open or closed.			
Sheared Zone (Note 3)	Zone of rock substance with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge shaped blocks.			
Sheared Surface (Note 3)	A near planar, curved or undulating surface which is usually smooth, polished or slickensided.			
Crushed Seam (Note 3)	Seam with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock substance which may be more weathered than the host rock. The seam has soil properties.			
Infilled Seam	Seam of soil substance usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint, infilled seams less than 1mm thick may be described as veneer or coating on joint surface.			
Extremely Weathered Seam	Seam of soil substance, often with gradational boundaries. Formad by weathering of the rock substance in place.			

Notes on Defects:

1. Usually borehole logs show the true dip of defects and face sketches and sections the apparent dip.
2. Partings and joints are not usually shown on the graphic log unless considered significant.
3. Sheared zones, sheared surfaces and crushed seams are faults in geological terms.

DEFECT SHAPE TERMS

Planar	The defect does not vary in orientation
Curved	The defect has a gradual change in orientation
Undulating	The defect has a wavy surface
Stepped	The defect has one or more well defined steps
Irregular	The defect has many sharp changes of orientation

Note: The assessment of defect shape is partly influenced by the scale of the observation.

ROUGHNESS TERMS

Slickensided	Grooved or striated surface, usually polished
Polished	Shiny smooth surface
Smooth	Smooth to touch. Few or no surface irregularities
Rough	Many small surface irregularities (amplitude generally less than 1mm). Feels like fine to coarse sand paper.
Very Rough	Many large surface irregularities (amplitude generally more than 1mm). Feels like, or coarser than very coarse sand paper.

COATING TERMS

Clean	No visible coating
Stained	No visible coating but surfaces are discoloured
Veneer	A visible coating of soil or mineral, too thin to measure; may be patchy
Coating	A visible coating up to 1mm thick. Thicker soil material is usually described using appropriate defect terms (eg, infilled seam). Thicker rock strength material is usually described as a vein.

BLOCK SHAPE TERMS

Blocky	Approximately equidimensional
Tabular	Thickness much less than length or width
Columnar	Height much greate than cross section

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP 1**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.586

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5				**TOPSOIL:** SAND, fine to medium grained, dark brown with approximately 30% low plasticity fines, with 300mm of rootlets.	M			TOPSOIL
				D	2.0	0.5		CI	**Sandy CLAY:** medium plasticity, dark brown-orange, sand fine to medium grained.				
								SP	**SAND:** fine to medium grained, pale grey-white.		VD		
				D	1.5	1.0							
									Becoming pale grey-brown.	W			
				D	1.0	1.5							
			04-04-07 8:54am		0.5	2.0			Test pit TP 1 terminated at 1.9m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP 2**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.433

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N							**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark brown with approximately 30% of low plasticity fines, with approximately 300mm of rootlets.	M			TOPSOIL
				D	2.0	0.5		CI	**Sandy CLAY:** medium plasticity, dark brown-orange, with some sand lenses.	M/W	St	x	
			04-04-07 9:13am	D	1.5	1.0						x	
					1.0	1.5		SP	**SAND:** fine to medium grained, brown-dark grey.	W			
				D									Rapid inflow of groundwater and pit collapsing below 1.7m depth.
					0.5	2.0			Test pit TP 2 terminated at 1.9m				
					0.0	2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

TESTPIT 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

Form GEO 5.2 Issue 3 Rev.2

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Engineering Log - Excavation

Excavation No. TP 3

Sheet 1 of 1

Project No: GEOTSGTE20248AA

Client: TATTERSALL SURVEYORS PTY LTD

Date started: 4.4.2007

Principal:

Date completed: 4.4.2007

Project: RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS

Logged by: CW

Test pit location: REFER TO FIGURE 1

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.571

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5				**TOPSOIL:** Silty Clayey SAND, fine to coarse grained, pale brown-brown, low plasticity fines with some rootlets to 300mm.	M			TOPSOIL
				D	2.0	0.5		SC	**Clayey SAND:** fine to medium grained, orange-brown / pale brown, low plasticity fines.		VD		
						1.0		SP	**SAND:** fine to coarse grained to fine to medium grained, pale grey-white.	M/W			
				D	1.5				Becoming pale brown-white.				
			▼ 04-04-07		1.0	1.5							Rapid inflow of groundwater and pit collapsing below 1.7m depth.
				D					Becoming white.				
					0.5	2.0			Test pit TP 3 terminated at 1.8m				
						2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP 4**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.260

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.0 / 0.5			**TOPSOIL:** Silty CLAY, medium plasticity, dark grey-black, small percentage of sand <10% with some rootlets.	M			TOPSOIL
				D	1.5 / 1.0		CH	**CLAY:** medium to high plasticity, dark grey.	M>Wp	St	x x x	
				D	1.0 / 1.5							
			▼ 05-04-07 12:12pm		0.5 / 2.0						x x x x x x	
				D			SP	**SAND:** fine to coarse grained, pale grey.	W			Rapid inflow of groundwater at 2.0m depth.
					0.0 / 2.5			Test pit TP 4 terminated at 2.1m				

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP 5**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.765

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N	04-04-07 8:35am	D	2.5	0.5			**TOPSOIL:** SAND, fine to medium grained, dark brown, with low plasticity fines, approximately 30% fines with some rootlets to approximately 150mm.	M			TOPSOIL
								CI	**Sandy CLAY:** medium plasticity, orange-brown, sand fine to medium grained.		VSt		
				D	2.0	1.0		SP	**SAND:** fine to medium grained, pale grey-white. Becoming pale grey-brown.		VD		
				D	1.5	1.5							
				D	1.0					W			Rapid groundwater inflow below 1.7m depth.
					0.5	2.0			Test pit TP 5 terminated at 1.9m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP 6**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.846

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5 / 0.5			**TOPSOIL:** Silty SAND, fine to medium grained, dark grey mottled white, with some rootlets and roots to 150mm.	D			TOPSOIL
				D			SM	**Silty SAND:** fine to medium grianed, brown / red cemented sand nodules.	M	VD		INDURATED SAND?
				D	2.0 / 1.0							
			▼ 05-04-07 12:33pm		1.5 / 1.5		SP	**SAND:** fine to medium grained, pale brown-white with some cemented sand nodules.				
					1.0 / 2.0			Becoming pale grey-white.	W			
								Lenses of cemented sand nodules dark brown-red present.				Water visible. Pit collapsing due to groundwater.
					0.5 / 2.5			Test pit TP 6 terminated at 2.1m				

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. TP 7

Sheet 1 of 1

Project No: GEOTSGTE20248AA

Client: TATTERSALL SURVEYORS PTY LTD

Date started: 13.4.2007

Principal:

Date completed: 13.4.2007

Project: RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS

Logged by: JJT

Test pit location: REFER TO FIGURE 1

Checked by:

equipment type and model:

Pit Orientation:

Easting: m

R.L. Surface: 2.388

excavation dimensions: m long m wide

Northing: m

datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HA		N			2.0	0.5		CH	**Sandy CLAY:** high plasticity, dark brown, sand fine to medium grained.	M			
			▼	D									
					1.5			SC	**Clayey SAND:** fine to medium grained, grey.		VD		
				D		1.0				W			
									Hole terminated at 1.0m, hole collapsing because of groundwater. Test pit TP 7 terminated at 1m				
					1.0	1.5							
					0.5	2.0							
					0.0	2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- ▼ water level on date shown
- ► water inflow
- ◄ water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP 8**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **13.4.2007**

Principal:

Date completed: **13.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **JJT**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: | Pit Orientation: | Easting: m | R.L. Surface: 3.184

excavation dimensions: m long m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HA		N	Not Measured	D	3.0	0.5		SP	Clayey SAND: fine to medium grained, black.	M	D		
					2.5	1.0			Hole terminated at 0.6m, sand too dry to retrieve. Test pit TP 8 terminated at 0.6m				
					2.0	1.5							
					1.5	2.0							
					1.0	2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP 9**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.735

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5	0.5			TOPSOIL: Silty Clayey SAND, fine to medium grained, dark grey, low plasticity fines, with some rootlets and thick roots to 100mm.	M			TOPSOIL
				D				SC	Clayey SAND: fine to medium grained, dark brown-black, low plasticity fines with some black cemented sand nodules up to approximately 0.13m diameter.		D/VD		
				D	2.0	1.0		SP	SAND: medium to coarse grained, pale grey-white.				
			▼ 04-04-07 10:41am		1.5	1.5			Becoming pale grey-brown.	W			Groundwater inflow below 1.8m depth.
				D	1.0	2.0							
					0.5	2.5			Test pit TP 9 terminated at 2m				

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP10**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.585

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N	None Observed		2.5 / 0.5			TOPSOIL: Clayey SAND, fine to medium grained, brown, low plasticity fines, with some rootlets and roots (10-30mm thick) to approximately 450mm.	M			TOPSOIL
				D	2.0 / 1.0		SC	Clayey SAND: fine to medium grained, pale brown, with some cemented sand nodules, low plasticity fines.		MD		
							SP	SAND: fine to medium grained, pale grey-white.		D		
				D	1.5 / 1.5					VD		
				D	1.0 / 2.0			One big, 0.7mm dia., cemented sand nodule.	W			No obvious groundwater level or inflow but pit collapsing.
					0.5 / 2.5			Test pit TP10 terminated at 1.9m				

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP11**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: *TATTERSALL SURVEYORS PTY LTD*

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: *RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS*

Logged by: **CW**

Test pit location: *REFER TO FIGURE 1*

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.732

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5	0.5			**TOPSOIL:** Silty SAND, fine to medium grained, grey-brown, low plasticity fines? with some rootlets.	M			TOPSOIL
								SC	**Clayey SAND:** fine to medium grained, pale grey-brown, low plasticity fines.		VD		
				D		0.5		SC	**Clayey SAND:** fine to medium grained, orange-brown, dark brown-black, low plasticity fines, with cemented sand nodules up to approximately 0.13mm dia.				
					2.0								
				D		1.0		SP	**SAND:** fine to coarse grained, pale grey-brown.	W			
					1.5								
						1.5			Colour change.				
				D	1.0								
			04-04-07 11:15am			2.0			Test pit TP11 terminated at 1.9m				
					0.5								
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP12**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: *TATTERSALL SURVEYORS PTY LTD*

Date started: *4.4.2007*

Principal:

Date completed: *4.4.2007*

Project: *RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS*

Logged by: *CW*

Test pit location: *REFER TO FIGURE 1*

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 3.126

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			3.0				**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey, low plasticity fines, with some rootlets to approximately 350mm.	M			TOPSOIL
						0.5		SC	**Clayey SAND / Sandy CLAY:** fine to medium grained, dark grey-brown, medium plasticity fines.		St	x x	
				D	2.5			CL	**Sandy CLAY:** low to medium plasticity, orange-brown, sand fine to medium grained.				
						1.0		SP	**SAND:** fine to coarse grained, pale grey-white.		VD		
				D	2.0								
						1.5			Becoming pale grey-brown.				
				D	1.5								
			04-04-07 11:30am		1.0				Test pit TP12 terminated at 2m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP13**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.825

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5	0.5			**TOPSOIL:** Silty SAND, fine to medium grained, dark grey-black with some rootlets and roots (10-30mm thick).	D/M			TOPSOIL
				D				SM	**Silty SAND:** dark brown-dark red, fine to medium grained, with cemented sand nodules to 0.16mm dia.	M	VD		Bucket scraping on hard layer.
			04-04-07 11:51am	D	2.0	1.0			Becoming brown-pale brown cemented nodules of sand still present.				
				D	1.5	1.5			Becoming dark brown-brown weakly cemented nodules present.	W			
					1.0	2.0			Test pit TP13 terminated at 2m				
					0.5	2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP14**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.760

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information						material substance					
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5 / 0.5			TOPSOIL: Silty CLAY, medium plasticity fines, brown with some rootlets approximately 400mm.				TOPSOIL
				D	2.0 / 1.0		CH	CLAY: high plasticity, brown-dark brown.		VSt		
				D	1.5 / 1.5			Becoming dark grey-black with some mottled orange.				
				D	1.0 / 2.0			Test pit TP14 terminated at 1.8m				
					0.5 / 2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP15**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.355

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.0	0.5			TOPSOIL: Silty (Clayey) SAND, fine to medium grained, dark grey-black, with some roots 10mm and rootlets to approximately 400mm.	M			TOPSOIL
				D				SP	**SAND:** fine to coarse grained, pale grey-brown, small percent of fines <20%.	M/W	D/VD		
					1.5	1.0			Becoming pale grey mottled black and white.				
				D									
					1.0	1.5							Pit collapsing no groundwater observed.
				D									
					0.5	2.0			Pit collapsing. Test pit TP15 terminated at 1.7m				
					0.0	2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP16**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.683

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			2.5				**TOPSOIL:** Silty SAND, fine to medium grained, dark grey-black mottled white, with some rootlets.	D			TOPSOIL
						0.5		SP	**SAND:** fine to medium grained, pale grey-brown.	M	D		
				D	2.0								
						1.0					VD		
				D	1.5					M/W			
			04-04-07 12:54pm			1.5							
				D	1.0			SP	**SAND:** fine to medium grained, dark grey-black, cemented sand nodules, coffee rock.	W			INDURATED SAND
									Pit collapsing.				
						2.0			Test pit TP16 terminated at 1.8m				
					0.5								
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP17**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.635

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			2.5	0.5			**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey-black mottled white, low plasticity fines, with some rootlets.	D			TOPSOIL
				D	2.0			SC	**Silty Clayey SAND:** fine to medium grained, dark brown / red, low to medium plasticity fines, with cemented nodules of SAND.	M	VD		
						1.0		SC	**Clayey SAND:** fine to medium grained, brown-pale brown, low plasticity fines, with weakly cemented nodules of sand.				
				D	1.5			SP	**SAND:** fine to coarse grained, pale grey-pale brown.				
			05-04-07 10:53am			1.5							
					1.0				Becoming grey-brown.	W			Rapid inflow of groundwater below 1.7m depth.
				D		2.0							
					0.5				Pit collapsing. Test pit TP17 terminated at 2m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP18**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.302

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			2.0	0.5			**TOPSOIL:** Sandy CLAY, low to medium plasticity, dark brown-black, sand fine to medium grained, with some rootlets to 100mm.	M			TOPSOIL
				D				CI	**CLAY:** medium plasticity, dark grey mottled orange, with minor sand component approximately 10%.		VSt	x	
					1.5			SC	**Clayey SAND:** fine to medium grained, grey, low plasticity fines.		D		
						1.0		SP	**SAND:** fine to coarse grained, pale grey-white.				
				D					Becoming grey / brown.		VD		
			05-04-07 10:35am		1.0								
						1.5							
				D	0.5				Sand becoming indurated and dark brown / red.	W			
						2.0			Pit collapsing due to inflow of groundwater, collapsing from sides. Test pit TP18 terminated at 1.9m				
					0.0	2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Excavation

Excavation No. **TP19**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.261

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.0	0.5			TOPSOIL: Clayey SAND, fine to medium grained, dark brown-black, low plasticity fines with some rootlets.	D			TOPSOIL
				D				CH	Sandy CLAY: medium to high plasticity, dark brown-black, sand fine to coarse grained.				
					1.5	1.0							
				D					Becoming dark grey-grey.				
			▼ 04-04-07 2:31pm		1.0	1.5		SP	SAND: fine to coarse grained, pale grey-white.	W	VD		
				D	0.5				Becoming pale brown / grey.				
						2.0			Pit collapsing due to groundwater. Test pit TP19 terminated at 1.8m				
					0.0	2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 — no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Excavation

Excavation No. **TP20**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: *TATTERSALL SURVEYORS PTY LTD*

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: *RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS*

Logged by: **CW**

Test pit location: *REFER TO FIGURE 1*

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.255

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			2.0	0.5			**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey-black mottled white, with some rootlets.	D			TOPSOIL
								CL	**Sandy CLAY:** low plasticity, dark brown-red, sand fine to medium grained, trace of rootlets and cemented sand nodules.	M			
								CL	**Sandy CLAY:** low to medium plasticity, pale grey-pale brown mottled orange, sand fine to medium grained.				
				D	1.5	1.0				M/W			
			04-04-07 2:15pm	D	1.0	1.5			Becoming pale brown / grey.				
				D									
					0.5	2.0			Pit collapsing due to groundwater. Test pit TP20 terminated at 1.7m				
					0.0	2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

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Engineering Log - Excavation

Excavation No. **TP21**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.675

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			2.5	0			**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey, low plasticity fines with some rootlets and some thick roots to 300mm.	M			TOPSOIL
				D		0.5		SC	**Clayey SAND:** fine to medium grained, orange-pale brown, low plasticity fines with some cemented red sand nodules.		VD		
					2.0			SP	**SAND:** fine to medium grained, pale grey-white.				
				D	1.5	1.0							
			04-04-07			1.5			Becoming pale brown-pale grey.				
					1.0					W			Rapid groundwater inflow below 1.7m depth.
				D		2.0			Test pit TP21 terminated at 2m				
					0.5								
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

TESTPIT 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

Form GEO 5.2 Issue 3 Rev 2

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Engineering Log - Excavation

Excavation No. **TP22**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.332

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.0	0.5			**TOPSOIL:** Sandy CLAY, low to medium plasticity, dark brown-black, sand fine to medium grained, with some rootlets.	D			TOPSOIL
				D				CI	**CLAY:** medium plasticity, dark brown-black, with some sand component approximately 30%.	M			
					1.5	1.0		SM	**Silty SAND:** fine to medium grained, brown-pale brown, with some cemented sand nodules.		D		
				D							VD		
					1.0	1.5		SP	**SAND:** fine to medium grained, pale grey-white. Becoming pale grey / brown.	M/W			
			04-04-07 2.50m	D	0.5								
					0.0	2.0			Pit collapsing due to groundwtaer inflow. Test pit TP22 terminated at 1.9m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

TESTPIT 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

Form GEO 6.2 Issue 3 Rev.2

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Engineering Log - Excavation

Excavation No. **TP23**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.090

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N	None Observed		2.0 / 0.0			**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey-black, low plasticity fines, with some rootlets to 300mm.	D			TOPSOIL
					0.5		SC	**Clayey SAND:** fine to medium grained, dark grey-black, low to medium plasticity fines.				
					1.5		CL	**Sandy CLAY:** low to medium plasticity, pale brown / orange, sand fine to medium grained.	M			
				D			SC	**Clayey SAND:** fine to medium grained, pale grey / pale brown, low plasticity fines.		VD		
					1.0		SP	**SAND:** fine to coarse grained, pale grey-white.				
				D	1.0 / 0.5							
					1.5			Becoming grey / brown.	W			No visible water, but pit collapsing below 1.7m depth.
				D	2.0							
					0.0 / 2.5			Test pit TP23 terminated at 2m				

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

TESTPIT 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

Form GEO 5.2 Issue 3 Rev.2

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Engineering Log - Excavation

Excavation No. **TP24**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.177

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.0				TOPSOIL: Sandy CLAY, low to medium plasticity, sand fine to medium grained, with some rootlets to 100mm.	M		x x x	TOPSOIL
				D		0.5		CL	**Sandy CLAY:** low to medium plasticity, orange, sand fine to coarse grained.				
					1.5			SP	**SAND:** fine to medium grained, pale grey-white mottled orange.		D		
				D		1.0					VD		
			05-04-07 11:44am		1.0								
						1.5							
					0.5								
				D		2.0			Lenses of colour change to pale grey / brown, with some clay lenses.	W			
					0.0				Pit collapsing from groundwater table. Test pit TP24 terminated at 2m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

TESTPIT 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

Form GEO 5.2 Issue 3 Rev.2

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Engineering Log - Excavation

Excavation No. **TP25**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.611

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5 / 0.5			**TOPSOIL:** Silty SAND, fine to medium grained, dark grey mottled white with some rootlets and roots (10mm) to 150mm.	D			TOPSOIL
				D	2.0 / 1.0			**Silty SAND:** fine to medium grained, dark grey-black, cemented nodules of SAND.	M	D / VD		INDURATED SAND
			05-04-07 11:08am	D	1.5 / 1.5			100mm band of pale grey-pale brown and then becoming grey-brown weakly cemented sand nodules.	W			
				D	1.0 / 2.0			Becoming dark brown / red weakly sand nodules.				Rapid inflow of groundwater below 1.9m depth.
					0.5 / 2.5			Test pit TP25 terminated at 2m				

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP26**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 1.709

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			1.5	0.5			**TOPSOIL:** Silty Sandy CLAY, medium plasticity, dark grey-black, sand fine to medium grained, with some rootlets to 100mm.	M			TOPSOIL
				D	1.0	1.0		SP	**SAND:** fine to coarse grained, pale grey-white.		D		
				D	0.5				Becoming pale brown / grey.				
				D	0.0	1.5			Pit collapsing due to groundwater. Test pit TP26 terminated at 1.5m				
					-0.5	2.0							
						2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP27**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 1.536

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N				0.5			**TOPSOIL:** Silty (Clayey) SAND, fine to medium grained, dark grey-black, with some rootlets to 200mm.	D			TOPSOIL
				D	1.0			SM	**Silty SAND:** fine to medium grained, dark brown, with some cemented sand nodules.	M	VD		
						1.0		SP	**SAND:** fine to coarse grained, brown / grey, with small percent of fines approximately 20-30% possibly clay lenses or nodules.				
			04-04-07 3:46pm	D	0.5								
						1.5			Becoming pale grey-white.	M/W			
				D	0.0				Becoming pale grey / brown.				
					-0.5	2.0			Pit collapsing due to groundwater inflow. Test pit TP27 terminated at 1.8m				
						2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP28**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **4.4.2007**

Principal:

Date completed: **4.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.012

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N				0.5			**TOPSOIL:** Silty SAND, fine to medium grained, dark grey-black, with some rootlets.	D			TOPSOIL
				D	1.5			SM	**Silty SAND:** fine to medium grained, dark brown-black / red, cemented sand nodules.	M	D		
				D	1.0	1.0							
			04-04-07 3:31pm					SP	**SAND:** fine to coarse grained, pale brown / grey.	W			
				D	0.5	1.5			Becoming brown / grey mottled orange.				
					0.0	2.0			Test pit TP28 terminated at 1.8m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP29**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.170

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.0				**TOPSOIL:** Silty SAND, fine to medium grained, dark brown-black, with some rootlets.	D			TOPSOIL
				D		0.5			**Silty SAND:** fine to medium grianed, pale grey / pale brown.		D		
					1.5			SC	**Clayey SAND:** fine to medium grained, pale brown, low plasticity fines.	M			
				D	1.0	1.0							
						1.5		SP	**SAND:** fine to medium grained, pale grey-white.	W			
				D	0.5								
			05-04-07 3:12pm						Pit collapsing. Test pit TP29 terminated at 1.7m				
					0.0	2.0							
						2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP30**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: *TATTERSALL SURVEYORS PTY LTD*

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: *RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS*

Logged by: **CW**

Test pit location: *REFER TO FIGURE 1*

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 1.159

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			1.0				TOPSOIL: Silty Clayey SAND, fine to medium grained, dark grey-black mottled white, low plasticity fines, some rootlets 300mm and roots to 300mm.	D			TOPSOIL
			05-04-07 ▼			0.5		SP	SAND: fine to coarse grained, pale grey-white.	W	MD		Some inflow of groundwater to pit at 0.3m, 8:05am, pit slowly collapsing from sides, organic odour.
				D	0.5						D		
						1.0			Becoming pale brown-grey.				
				D	0.0								
						1.5			Becoming dark brown-red, with some cemented sand nodules.				
				D	-0.5								
					-1.0	2.0			Pit collapsing. Test pit TP30 terminated at 1.7m				
						2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP31**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 0.732

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type; plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N		D	0.5	0.5		SC	**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey-black mottled white, low to medium plasticity fines, with layer of mulch and rootlets to 100mm.	D			TOPSOIL (swampy area) organic odour.
									Clayey SAND: fine to medium grained, pale grey / pale brown, low plasticity fines.	M	MD		
				D	0.0	1.0			Becoming grey / brown.	W	D		Very slow inflow of groundwater.
			05-04-07 8:29am	D	-0.5	1.5		SP	**SAND:** fine to medium grained, dark brown-red, indurated cemented sand nodules.				Rapid inflow of groundwater.
				D	-1.0				**Silty Gravelly SAND:** fine to coarse grained, dark grey-black, gravel fine to medium grained, rounded-subrounded.				
					-1.5	2.0			Pit collapsing due to inflow of groundwater. Test pit TP31 terminated at 1.8m				
						2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP32**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 0.994

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N							TOPSOIL: Silty Clayey SAND, fine to medium grained, dark grey-black mottled white, low plasticity fines, with some rootlets and roots (10mm).	D			TOPSOIL (swampy area)
								SC	**Clayey SAND:** fine to coarse grained, pale grey-pale brown, low plasticity fines maybe low percentage of fines approximately 30-40%.	M	D		Some inflow of water.
			05-04-07 8:47am ▼	D	0.5	0.5							
				D	0.0	1.0			Becoming grey-brown, some presence of cemented sand nodules.	W			Moderate inflow of groundwater 8:47am.
					-0.5	1.5							
				D					Becoming grey mottled brown / orange and presence of subrounded to rounded gravel (fine to medium grained) less than 10mm size.				
					-1.0	2.0			Pit continually collapsed due to water table. Test pit TP32 terminated at 1.7m				
					-1.5	2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP33**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 0.923

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
BH		N			0.5	0.5			**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey-black mottled white, low plasticity fines, with some rootlets to 250mm.	D/M			TOPSOIL (swampy area)
								SC	**Clayey SAND:** fine to coarse grained, pale grey-pale brown.	M	D		
			05-04-07 8:56am ▶	D	0.0	1.0			Becoming grey / brown.	W			Very slow inflow of groundwater 8:56am, organic odour.
				D	-0.5	1.5							
				D	-1.0	2.0		SP	**SAND:** fine to medium grained, dark brown-black, some cemented nodules of sand.				
					-1.5	2.5			Pit collapsing due to water table. Test pit TP33 terminated at 2m				

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

TESTPIT 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

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Engineering Log - Excavation

Excavation No. **TP34**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **5.4.2007**

Principal:

Date completed: **5.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **CW**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 0.893

excavation dimensions: 1.5m long 0.4m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			0.5 / 0.5			**TOPSOIL:** Silty Clayey SAND, fine to medium grained, dark grey-black mottled white, low to medium plasticity fines.	M			TOPSOIL
							SC	**Clayey SAND:** fine to coarse grained, pale grey-white, low plasticity fines. Becoming pale grey-pale brown.		D		
			05-04-07 9:13am ▼	D	0.0 / 1.0		SP	**SAND:** with some clayey lenses, fine to medium grained, low plasticity fines.	M/W			Very slow inflow of water, 9:13am.
				D	-0.5 / 1.5		SC	**Clayey SAND:** fine to coarse grained, grey / brown, low to medium plasticity fines. Pit slowly collapsing due to water table.	W	MD L MD		
					-1.0 / 2.0		SM	**Silty SAND:** fine to medium grained, dark brown / red.				
					-1.5 / 2.5			Pit collapsing due to groundwater. Test pit TP34 terminated at 2m				

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 — no resistance ranging to refusal

water
▼ water level on date shown
► water inflow
◄ water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

coffey geotechnics

Engineering Log - Borehole

Borehole No. **BH35**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **11.4.2007**

Principal:

Date completed: **11.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **JJT**

Borehole Location: **REFER TO FIGURE 1**

Checked by:

drill model and mounting: MD20 | Easting: | slope: -90° | R.L. Surface: 1.006

hole diameter: 100 mm | Northing | bearing: | datum: AHD

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HF		C	▼	SPT 2,2,3 N*=5	0	1		SP	**SAND:** fine to medium grained, grey.	M	MD		
										W			
				SPT 2,3,11 N*=14	-1	2					D		
					-2	3							
				SPT 6,4,12 N*=16	-3	4							
									Borehole BH35 terminated at 4m				
					-4	5							
					-5	6							
					-6	7							
						8							

method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit
*bit shown by suffix e.g.	ADT

support

M mud N nil

C casing

penetration 1 2 3 4 — no resistance ranging to refusal

water

▼ 10/1/98 water level on date shown

water inflow

water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Borehole

Borehole No.	**BH36**
Sheet	1 of 1
Project No:	**GEOTSGTE20248AA**
Client:	**TATTERSALL SURVEYORS PTY LTD**
Date started:	**11.4.2007**
Principal:	
Date completed:	**11.4.2007**
Project:	**RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**
Logged by:	**JJT**
Borehole Location:	**REFER TO FIGURE 1**
Checked by:	

drill model and mounting: MD20 | Easting: | slope: -90° | R.L. Surface: 2.361

hole diameter: 100 mm | Northing | bearing: | datum: AHD

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HF		C	▼		2			SC	**Clayey SAND:** fine to medium grained, black, clay low plasticity.	M			
				SPT 4,4,5 N*=9		1		SP	**SAND:** fine grained, white.	W	D		
					1			SP	**SAND:** fine to medium grained, black (coffee rock).				
						2		SP	**SAND:** fine grained, white.				
				SPT 2,9,11 N*=20	0				Becoming grey.				
						3					VD		
				SPT 6,13,24 N*=37	-1								
						4		SP	**SAND:** fine to medium grained, black (coffee rock).				
					-2				Becoming softer.				
				SPT 6,9,23 N*=32	-3	5							
						6							
				SPT 8,16,14 N*=30	-4	7							
					-5				Borehole BH36 terminated at 7m				
						8							

BOREHOLE 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

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method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit
*bit shown by suffix e.g.	ADT

support

M mud N nil
C casing

penetration 1 2 3 4 — no resistance ranging to refusal

water

▼ 10/1/98 water level on date shown
water inflow
water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Borehole

Borehole No.	BH37
Sheet	1 of 1
Project No:	GEOTSGTE20248AA
Client:	TATTERSALL SURVEYORS PTY LTD
Date started:	11.4.2007
Principal:	
Date completed:	11.4.2007
Project:	RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS
Logged by:	JJT
Borehole Location:	REFER TO FIGURE 1
Checked by:	

drill model and mounting:	MD20	Easting:	slope:	-90°	R.L. Surface:	Not Measured	
hole diameter:	100 mm	Northing	bearing:		datum:	AHD	

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa (100 200 300 400)	structure and additional observations
HF		C						SC	**Clayey SAND:** fine to medium grained, black, clay low plasticity.	M			
								SP	**SAND:** fine to medium grained, white.		D		
			▼	SPT 4,6,10 N*=16		1				W			
									Becoming dark brown, with some organic material.				
				SPT 1,7,8 N*=15		2							
						3							
				SPT 6,18,R N*=R		4		SP	**SAND:** fine to medium grained, black (coffee rock).		VD		INDURATED SAND
						5			Becoming brown.				
				SPT 5,7,R N*=R		6							
				SPT 6,7,R N*=R		7							
									Borehole BH37 terminated at 7m				
						8							

method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit
*bit shown by suffix e.g.	ADT

support

M mud N nil
C casing

penetration

1 2 3 4 — no resistance ranging to refusal

water

▼ 10/1/98 water level on date shown
water inflow
water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

BOREHOLE 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

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Engineering Log - Borehole

Borehole No. **BH38**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **11.4.2007**

Principal:

Date completed: **11.4.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **JJT**

Borehole Location: **REFER TO FIGURE 1**

Checked by:

drill model and mounting: MD20 | Easting: | slope: -90° | R.L. Surface: 2.303

hole diameter: 100 mm | Northing | bearing: | datum: AHD

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HF		C							TOPSOIL: Clayey SAND, fine grained, dark grey, clay low plasticity.	M			TOPSOIL
					2			CL	**Sandy CLAY**: medium to high plasticity, grey, sand fine grained.	>Wp			
				SPT 2,2,3 N*=5		1							
					1			CL	**Sandy CLAY**: low to medium plasticity, dark brown, sand fine grained.				
			▼			2				W			
				SPT 4,5,5 N*=10	0			SW	**SAND**: fine to medium grained, grey.		D		
						3							
					-1				Becoming black.				
				SPT 12,18,23 N*=41		4							
					-2								
						5							
				SPT 4,8,11 N*=19	-3								
						6					MD		
					-4								
				SPT 4,8,8 N*=16		7							
					-5				Borehole BH38 terminated at 7m				
						8							

method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit
*bit shown by suffix e.g.	ADT

support

M mud N nil

C casing

penetration 1 2 3 4 — no resistance ranging to refusal

water

▼ 10/1/98 water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP39**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **1.6.2007**

Principal:

Date completed: **1.6.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **RJP**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.77

excavation dimensions: 2m long 0.45m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N							**TOPSOIL:** Sandy Silty CLAY, medium plasticity, dark grey, sand fine to medium grained.	M			TOPSOIL Root affected.
					2.5	0.5		CH	**CLAY:** high plasticity, grey-brown and orange mottled, some sand.	>Wp	St		
				D								x	
					2.0	1.0		CH	**CLAY:** high plasticity, grey-grey-brown, some orange mottled with a trace of sand fine to medium grained.			x	
				D									
					1.5	1.5		SP	**SAND:** fine to medium grained, white / light grey-brown.	W			Pit collapsing below 1.4m, organic odour.
				D									
					1.0	2.0			Moderate groundwater inflow below 1.4m. Test pit TP39 terminated at 1.7m				
					0.5	2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP40**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **1.6.2007**

Principal:

Date completed: **1.6.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **RJP**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.59

excavation dimensions: 2m long 0.45m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5 / 0.5			**TOPSOIL:** Silty Sandy CLAY, medium plasticity, dark grey, sand fine to medium grained.	>Wp			TOPSOIL Root affected.
				D	2.0 / 1.0		CI	**Sandy CLAY:** medium plasticity, grey-brown and orange mottled, sand fine to medium grained. Becoming grey-brown and sand content increasing to Sandy CLAY / Clayey SAND.		St	x	
				D	1.5 / 1.5		SP	**SAND:** fine to medium grained, grey-brown with some clay.	W		x	
			►	D	1.0 / 2.0		SP	**SAND:** fine to medium grained, light grey-brown.				Rapid groundwater inflow below 1.4m. Organic odour.
					0.5 / 2.5			Pit collapsing below 1.1m. Test pit TP40 terminated at 1.7m				

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

TESTPIT 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

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Engineering Log - Excavation

Excavation No. **TP41**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **1.6.2007**

Principal:

Date completed: **1.6.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **RJP**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 3.63

excavation dimensions: 2m long 0.45m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			3.5 / 0.0			**TOPSOIL:** Sandy CLAY, medium plasticity, grey-brown, sand fine to medium grained.	M			TOPSOIL Root affected.
				D	3.0 / 0.5		Cl	**Sandy CLAY:** medium plasticity, light grey-brown and orange mottled, sand fine to medium grained.	>Wp	St	X	
								Becoming light grey-light grey-brown and orange mottled.				
				D	2.5 / 1.0			Sand content increasing light grey-brown and orange mottled.			X	
				D	2.0 / 1.5		SP	**SAND:** fine to medium grained, light grey-brown some orange mottled, cemented.	M			
			▶	D	1.5 / 2.0		SP	**SAND:** fine to medium grained, white-light grey-brown.	W			Slow groundwater inflow below 2.2m. Organic odour.
					2.5			Test pit TP41 terminated at 2.5m				

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP42**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **1.6.2007**

Principal:

Date completed: **1.6.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **RJP**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 2.82

excavation dimensions: 2m long 0.45m wide | Northing: m | datum: AHD

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			2.5	0.5			**TOPSOIL:** Silty Sandy CLAY, low to medium plasticity, sand fine to medium grained, dark grey-brown.	M			TOPSOIL Root affected.
				D				CI	**Sandy CLAY:** medium plasticity, grey-brown and orange mottled, sand fine to medium grained.	>Wp	St	×	
					2.0	1.0		CI	**Sandy CLAY:** medium plasticity, grey-grey-brown some orange mottled, sand fine to medium grained, sand content increasing.			×	
			►	D				SP	**SAND:** fine to medium grained, white.	W			Very slow water inflow below 1.1m.
					1.5	1.5			Becoming grey-grey-brown, with a trace to some clay.				
				D									
					1.0	2.0			Test pit TP42 terminated at 1.7m				
					0.5	2.5							

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Engineering Log - Excavation

Excavation No. **TP43**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: **TATTERSALL SURVEYORS PTY LTD**

Date started: **1.6.2007**

Principal:

Date completed: **1.6.2007**

Project: **RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS**

Logged by: **RJP**

Test pit location: **REFER TO FIGURE 1**

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 4.75

excavation dimensions: 2m long 0.45m wide | Northing: m | datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N			4.5	0.5		SP	**SAND:** fine to medium grained, grey-brown.	M			AEOLIAN Root affected to 0.15m.
				D					Becoming light grey-brown.				
					4.0	1.0		SP	**SAND:** fine to medium grained, grey-brown and orange mottled, trace to some clay.				
				D									
					3.5	1.5		SP	**SAND:** fine to medium grained, light grey-brown, some weakly cemented nodules, grey-brown.				
			►	D	3.0					W			Very slow water inflow below 1.7m.
						2.0			Test pit TP43 terminated at 1.85m				
					2.5	2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **TP44**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: ***TATTERSALL SURVEYORS PTY LTD***

Date started: ***1.6.2007***

Principal:

Date completed: ***1.6.2007***

Project: ***RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS***

Logged by: ***RJP***

Test pit location: ***REFER TO FIGURE 1***

Checked by:

equipment type and model: 4WD Backhoe | Pit Orientation: | Easting: m | R.L. Surface: 4.46

excavation dimensions: 2m long 0.45m wide | Northing: m | datum: AHD

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL / depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
BH		N	None Observed	D	4.0 / 0.5		SP	**SAND:** fine to medium grained, dark grey-brown.	M			AEOLIAN Root affected to 0.3m.
								Becoming light grey-brown.				
				D	3.5 / 1.0		SP	**SAND:** fine to medium grained, dark brown, some silt / Silty SAND.				INDURATED SAND
				D	3.0 / 1.5			Becoming cleaner and less cemented, brown.				
					2.5 / 2.0			Test pit TP44 terminated at 1.8m				
					2.0 / 2.5							

Sketch

method
- N natural exposure
- X existing excavation
- BH backhoe bucket
- B bulldozer blade
- R ripper
- E excavator

support
- S shoring
- N nil

penetration 1 2 3 4 — no resistance ranging to refusal

water
- water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- V vane shear (kPa)
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Borehole

Borehole No.	BH45
Sheet	1 of 2
Project No:	GEOTSGTE20248AA
Client:	TATTERSALL SURVEYORS PTY LTD
Date started:	5.6.2007
Principal:	
Date completed:	5.6.2007
Project:	RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS
Logged by:	RJP
Borehole Location:	REFER TO FIGURE 1
Checked by:	

drill model and mounting: | Easting: | slope: -90° | R.L. Surface: 3.20

hole diameter: mm | Northing | bearing: | datum: AHD

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HF		C			3			SP	**SAND:** fine to medium grained, grey-brown.	M	D		AEOLIAN SAND
						1							
				SPT 2,5,7 N*=12	2				Becoming light grey-brown.				
					1	2							
			▼	SPT 5,6,8 N*=14						W			
					0	3			Becoming dark grey-brown.				
				SPT 3,15,21 N*=36	-1	4		SP	**SAND:** fine to coarse grained, dark brown, trace of gravel fine grained and silt.		VD		
					-2	5			With a trace fine grained gravel.				20 blows for 100mm penetration.
				SPT 9,21,20 N*=41		6							
					-3								
				SPT 8,18,21 N*=39	-4	7			Becoming fine to medium grained, light brown and brown.				21 blows for 100mm penetration.
						8							

method
AS auger screwing*
AD auger drilling*
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
B blank bit
V V bit
T TC bit
*bit shown by suffix
e.g. ADT

support
M mud N nil
C casing

penetration 1 2 3 4 — no resistance ranging to refusal

water
▼ 10/1/98 water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear (kPa)
P pressuremeter
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

BOREHOLE 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

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Engineering Log - Borehole

Borehole No.	BH45
Sheet	2 of 2
Project No:	GEOTSGTE20248AA
Client:	TATTERSALL SURVEYORS PTY LTD
Date started:	5.6.2007
Principal:	
Date completed:	5.6.2007
Project:	RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS
Logged by:	RJP
Borehole Location:	REFER TO FIGURE 1
Checked by:	

drill model and mounting: | Easting: | slope: -90° | R.L. Surface: 3.20

hole diameter: mm | Northing | bearing: | datum: AHD

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HF		C			-5	9		SP	SAND: fine to coarse grained, dark brown, trace of gravel fine grained and silt. *(continued)*	W	D		
				SPT 5,13,17 N*=30									
					-6	10							
				SPT 1,6,15 N*=21	-7								
			▼ Collapsed back to 2.3m		-8	11			Borehole BH45 terminated at 10.45m				
					-9	12							
					-10	13							
					-11	14							
					-12	15							
						16							

method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix e.g. ADT

support

M mud N nil

C casing

penetration 1 2 3 4 — no resistance ranging to refusal

water

▼ 10/1/98 water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Borehole

Borehole No. **BH46**

Sheet 1 of 1

Project No: **GEOTSGTE20248AA**

Client: *TATTERSALL SURVEYORS PTY LTD*

Date started: **6.6.2007**

Principal:

Date completed: **6.6.2007**

Project: *RIVERSIDE ESTATE PROJECT APPLICATION, TEA GARDENS*

Logged by: **RJP**

Borehole Location: *REFER TO FIGURE 1*

Checked by:

drill model and mounting: | Easting: | slope: -90° | R.L. Surface: 1.07

hole diameter: mm | Northing | bearing: | datum: AHD

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
HF		C	▼						TOPSOIL: Sandy CLAY / Clayey SAND, low plasticity, dark grey, sand fine to medium grained, some silt.	M			TOPSOIL
								SP	SAND: fine to medium grained, grey-brown.		MD		
				SPT 3,2,2 N*=4	0	1			Becoming light grey-brown.	W			
					-1	2							
				SPT 7,12,14 N*=26	-2	3		SP	SAND: fine to medium grained, dark brown, trace silt.		VD		
				SPT 5,16,23 N*=39	-3	4		SP	SAND: fine to medium grained, some clay, brown and dark brown, trace fine grained gravel.				
					-4	5							
				SPT 2,9,18 N*=27	-5	6		SP	SAND: fine to medium grained, light brown.				
				SPT 3,10,18 N*=28	-6	7			Becoming fine to coarse grained, trace fine grained gravel, light grey-brown.				
						8			Borehole BH46 terminated at 7.45m				

method
AS auger screwing*
AD auger drilling*
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
B blank bit
V V bit
T TC bit
*bit shown by suffix
e.g. ADT

support
M mud N nil
C casing

penetration 1 2 3 4
no resistance ranging to refusal

water
10/1/98 water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear (kPa)
P pressuremeter
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

BOREHOLE 20248AA LOGS.GPJ COFFEY.GDT 23.10.07

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Appendix B

Results of Laboratory Testing

ALS Environmental

CERTIFICATE OF ANALYSIS

Client	: COFFEY GEOTECHNICS	*Laboratory*	: Environmental Division Brisbane	*Page*	: 1 of 10
Contact	: MR ROB PEARCE	*Contact*	: Tim Kilmister	*Work Order*	: EB0704186
Address	: 13 MANGROVE ROAD SANDGATE NSW AUSTRALIA 2304	*Address*	: 32 Shand Street Stafford QLD Australia 4053		
E-mail	: robert_pearce@coffey.com.au	*E-mail*	: Services.Brisbane@alsenviro.com		
Telephone	: 49676377	*Telephone*	: 61-7-3243 7222		
Facsimile	: 49675402	*Facsimile*	: 61-7-3243 7259		
Project	: GEOTSGTE 20248AA	*Quote number*	: EN/007/07	*Date received*	: 17 Apr 2007
Order number	: 2524			*Date issued*	: 8 May 2007
C-O-C number	: 0361-0362			*No. of samples*	- *Received* : 19
Site	: - Not provided -				*Analysed* : 19

ALSE - Excellence in Analytical Testing

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This document has been electronically signed by those names that appear on this report and are the authorised signatories. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatory	*Position*	*Department*
Lea-Ellen Catt	Laboratory Technician - Acid Sulphate Soils	Inorganics - NATA 825 (818 - Brisbane)

ALS Environmental

Comments

This report for the ALSE reference EB0704186 supersedes any previous reports with this reference. Results apply to the samples as submitted. All pages of this report have been checked and approved for release.

This report contains the following information:

- **Analytical Results for Samples Submitted**
- **Surrogate Recovery Data**

The analytical procedures used by ALS Environmental have been developed from established internationally-recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported herein. Reference methods from which ALSE methods are based are provided in parenthesis.

When moisture determination has been performed, results are reported on a dry weight basis. When a reported 'less than' result is higher than the LOR, this may be due to primary sample extracts/digestion dilution and/or insuffient sample amount for analysis. Surrogate Recovery Limits are static and based on USEPA SW846 or ALS-QWI/EN38 (in the absence of specified USEPA limits). Where LOR of reported result differ from standard LOR, this may be due to high moisture, reduced sample amount or matrix interference. When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for process purposes. Abbreviations: CAS number = Chemical Abstract Services number, LOR = Limit of Reporting. * Indicates failed Surrogate Recoveries.

Specific comments for Work Order **EB0704186**

Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. Conversion to liming rate in kg/m3 = kg/t x wet bulk density in t/m3.
Excess ANC not required because pH OX less than 6.5.

ALS Environmental

Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: BH36 0.5-1.0	BH36 3.5-4.0	BH37 5.0-5.5	BH37 6.5-7.0	BH38 0.5-1.0
Sample Matrix Type / Description:				SOIL	SOIL	SOIL	SOIL	SOIL
Sample Date / Time:				11 Apr 2007 15:00	11 Apr 2007 15:00	11 Apr 2007 15:00	11 Apr 2007 15:00	11 Apr 2007 15:00
Laboratory Sample ID:				EB0704186-001	EB0704186-002	EB0704186-003	EB0704186-004	EB0704186-005
EA029-A: pH Measurements								
pH KCl (23A)		0.1	pH Unit	4.6	5.2	4.5	4.6	4.2
pH OX (23B)		0.1	pH Unit	4.2	3.8	2.7	2.7	4.1
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)		2	mole H+ / t	26	11	37	41	108
Titratable Peroxide Acidity (23G)		2	mole H+ / t	28	19	120	118	137
Titratable Sulfidic Acidity (23H)		2	mole H+ / t	<2	8	83	77	29
sulfidic - Titratable Actual Acidity (s-23F)		0.02	% pyrite S	0.04	<0.02	0.06	0.06	0.17
sulfidic - Titratable Peroxide Acidity (s-23G)		0.02	% pyrite S	0.04	0.03	0.19	0.19	0.22
sulfidic - Titratable Sulfidic Acidity (s-23H)		0.02	% pyrite S	<0.02	<0.02	0.13	0.12	0.05
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)		0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Peroxide Sulfur (23De)		0.02	% S	<0.02	<0.02	0.09	0.10	0.04
Peroxide Oxidisable Sulfur (23E)		0.02	% S	<0.02	<0.02	0.09	0.10	0.04
acidity - Peroxide Oxidisable Sulfur (a-23E)		10	mole H+ / t	<10	<10	56	63	25
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)		0.02	% Ca	0.02	<0.02	<0.02	<0.02	<0.02
Peroxide Calcium (23Wh)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
Acid Reacted Calcium (23X)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Acid Reacted Calcium (a-23X)		10	mole H+ / t	<10	<10	<10	<10	<10
sulfidic - Acid Reacted Calcium (s-23X)		0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)		0.02	% Mg	0.02	<0.02	<0.02	<0.02	0.04
Peroxide Magnesium (23Tm)		0.02	% Mg	<0.02	<0.02	<0.02	<0.02	0.04
Acid Reacted Magnesium (23U)		0.02	% Mg	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Acid Reacted Magnesium (a-23U)		10	mole H+ / t	<10	<10	<10	<10	<10
sulfidic - Acid Reacted Magnesium (s-23U)		0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
EA029-G: Retained Acidity								
Net Acid Soluble Sulfur (20Je)		0.02	% S	—	—	—	—	0.03
acidity - Net Acid Soluble Sulfur (a-20J)		10	mole H+ / t	—	—	—	—	14
sulfidic - Net Acid Soluble Sulfur (s-20J)		0.02	% pyrite S	—	—	—	—	0.02
HCl Extractable Sulfur (20Be)		0.02	% S	—	—	—	—	0.03

ALS Environmental

Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: BH36 0.5-1.0	BH36 3.5-4.0	BH37 5.0-5.5	BH37 6.5-7.0	BH38 0.5-1.0
Sample Matrix Type / Description:				SOIL	SOIL	SOIL	SOIL	SOIL
Sample Date / Time:				11 Apr 2007 15:00	11 Apr 2007 15:00	11 Apr 2007 15:00	11 Apr 2007 15:00	11 Apr 2007 15:00
Laboratory Sample ID:				EB0704186-001	EB0704186-002	EB0704186-003	EB0704186-004	EB0704186-005
EA029-H: Acid Base Accounting								
ANC Fineness Factor		0.5		1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)		0.02	% S	0.04	<0.02	0.15	0.17	0.24
Net Acidity (acidity units)		10	mole H+ / t	26	11	93	104	147
Liming Rate		1	kg CaCO3/t	2	<1	7	8	11

ALS Environmental

Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: BH38 6.5-7.0 / Sample Matrix Type / Description: SOIL / Sample Date / Time: 11 Apr 2007 15:00 / Laboratory Sample ID: EB0704186-006	Client Sample ID: TP34 1.0-1.1 / Sample Matrix Type / Description: SOIL / Sample Date / Time: 5 Apr 2007 15:00 / Laboratory Sample ID: EB0704186-007	Client Sample ID: TP33 1.1-1.2 / Sample Matrix Type / Description: SOIL / Sample Date / Time: 5 Apr 2007 15:00 / Laboratory Sample ID: EB0704186-008	Client Sample ID: TP32 1.6-1.7 / Sample Matrix Type / Description: SOIL / Sample Date / Time: 5 Apr 2007 15:00 / Laboratory Sample ID: EB0704186-009	Client Sample ID: TP30 1.5-1.6 / Sample Matrix Type / Description: SOIL / Sample Date / Time: 5 Apr 2007 15:00 / Laboratory Sample ID: EB0704186-010
EA029-A: pH Measurements								
pH KCl (23A)		0.1	pH Unit	5.2	4.9	5.7	5.0	5.0
pH OX (23B)		0.1	pH Unit	4.2	2.8	3.0	2.8	3.5
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)		2	mole H+ / t	11	15	2	7	11
Titratable Peroxide Acidity (23G)		2	mole H+ / t	17	99	42	55	56
Titratable Sulfidic Acidity (23H)		2	mole H+ / t	6	84	40	47	45
sulfidic - Titratable Actual Acidity (s-23F)		0.02	% pyrite S	<0.02	0.02	<0.02	<0.02	<0.02
sulfidic - Titratable Peroxide Acidity (s-23G)		0.02	% pyrite S	0.03	0.16	0.07	0.09	0.09
sulfidic - Titratable Sulfidic Acidity (s-23H)		0.02	% pyrite S	<0.02	0.13	0.06	0.08	0.07
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)		0.02	% S	<0.02	0.04	<0.02	<0.02	<0.02
Peroxide Sulfur (23De)		0.02	% S	<0.02	0.21	0.12	0.12	0.08
Peroxide Oxidisable Sulfur (23E)		0.02	% S	<0.02	0.16	0.12	0.12	0.08
acidity - Peroxide Oxidisable Sulfur (a-23E)		10	mole H+ / t	<10	102	75	76	47
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
Peroxide Calcium (23Wh)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
Acid Reacted Calcium (23X)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Acid Reacted Calcium (a-23X)		10	mole H+ / t	<10	<10	<10	<10	<10
sulfidic - Acid Reacted Calcium (s-23X)		0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)		0.02	% Mg	<0.02	0.03	<0.02	<0.02	<0.02
Peroxide Magnesium (23Tm)		0.02	% Mg	<0.02	0.03	0.02	<0.02	<0.02
Acid Reacted Magnesium (23U)		0.02	% Mg	<0.02	<0.02	0.02	<0.02	<0.02
acidity - Acid Reacted Magnesium (a-23U)		10	mole H+ / t	<10	<10	18	<10	<10
sulfidic - Acid Reacted Magnesium (s-23U)		0.02	% S	<0.02	<0.02	0.03	<0.02	<0.02
EA029-H: Acid Base Accounting								
ANC Fineness Factor		0.5		1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)		0.02	% S	<0.02	0.19	0.12	0.13	0.09
Net Acidity (acidity units)		10	mole H+ / t	11	117	77	84	58
Liming Rate		1	kg CaCO3/t	<1	9	6	6	4

ALS Environmental

Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: TP28 0.6-0.7	TP27 1.1-1.2	TP26 1.5-1.6	TP25 1.9-2.0	TP19 0.5-0.6
Sample Matrix Type / Description:				SOIL	SOIL	SOIL	SOIL	SOIL
Sample Date / Time:				5 Apr 2007 15:00	5 Apr 2007 15:00	5 Apr 2007 15:00	5 Apr 2007 15:00	5 Apr 2007 15:00
Laboratory Sample ID:				EB0704186-011	EB0704186-012	EB0704186-013	EB0704186-014	EB0704186-015
EA029-A: pH Measurements								
pH KCl (23A)		0.1	pH Unit	4.4	5.0	5.4	4.3	4.5
pH OX (23B)		0.1	pH Unit	3.1	2.8	3.3	2.2	3.6
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)		2	mole H+ / t	53	21	7	46	36
Titratable Peroxide Acidity (23G)		2	mole H+ / t	94	33	197	53	95
Titratable Sulfidic Acidity (23H)		2	mole H+ / t	40	12	189	8	59
sulfidic - Titratable Actual Acidity (s-23F)		0.02	% pyrite S	0.08	0.03	<0.02	0.07	0.06
sulfidic - Titratable Peroxide Acidity (s-23G)		0.02	% pyrite S	0.15	0.05	0.32	0.08	0.15
sulfidic - Titratable Sulfidic Acidity (s-23H)		0.02	% pyrite S	0.06	<0.02	0.30	<0.02	0.09
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)		0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Peroxide Sulfur (23De)		0.02	% S	<0.02	<0.02	<0.02	0.05	0.02
Peroxide Oxidisable Sulfur (23E)		0.02	% S	<0.02	<0.02	<0.02	0.05	0.02
acidity - Peroxide Oxidisable Sulfur (a-23E)		10	mole H+ / t	<10	<10	<10	30	13
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
Peroxide Calcium (23Wh)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
Acid Reacted Calcium (23X)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Acid Reacted Calcium (a-23X)		10	mole H+ / t	<10	<10	<10	<10	<10
sulfidic - Acid Reacted Calcium (s-23X)		0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)		0.02	% Mg	<0.02	<0.02	<0.02	<0.02	0.02
Peroxide Magnesium (23Tm)		0.02	% Mg	<0.02	<0.02	<0.02	<0.02	0.02
Acid Reacted Magnesium (23U)		0.02	% Mg	<0.02	<0.02	<0.02	<0.02	<0.02
acidity - Acid Reacted Magnesium (a-23U)		10	mole H+ / t	<10	<10	<10	<10	<10
sulfidic - Acid Reacted Magnesium (s-23U)		0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
EA029-G: Retained Acidity								
Net Acid Soluble Sulfur (20Je)		0.02	% S	<0.02	—	—	<0.02	—
acidity - Net Acid Soluble Sulfur (a-20J)		10	mole H+ / t	<10	—	—	<10	—
sulfidic - Net Acid Soluble Sulfur (s-20J)		0.02	% pyrite S	<0.02	—	—	<0.02	—
HCl Extractable Sulfur (20Be)		0.02	% S	<0.02	—	—	<0.02	—

ALS Environmental

Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: TP28 0.6-0.7 Sample Matrix Type / Description: SOIL Sample Date / Time: 5 Apr 2007 15:00 Laboratory Sample ID: EB0704186-011	Client Sample ID: TP27 1.1-1.2 Sample Matrix Type / Description: SOIL Sample Date / Time: 5 Apr 2007 15:00 Laboratory Sample ID: EB0704186-012	Client Sample ID: TP26 1.5-1.6 Sample Matrix Type / Description: SOIL Sample Date / Time: 5 Apr 2007 15:00 Laboratory Sample ID: EB0704186-013	Client Sample ID: TP25 1.9-2.0 Sample Matrix Type / Description: SOIL Sample Date / Time: 5 Apr 2007 15:00 Laboratory Sample ID: EB0704186-014	Client Sample ID: TP19 0.5-0.6 Sample Matrix Type / Description: SOIL Sample Date / Time: 5 Apr 2007 15:00 Laboratory Sample ID: EB0704186-015
EA029-H: Acid Base Accounting								
ANC Fineness Factor		0.5		1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)		0.02	% S	0.08	0.03	<0.02	0.12	0.08
Net Acidity (acidity units)		10	mole H+ / t	53	21	<10	76	49
Liming Rate		1	kg CaCO3/t	4	2	<1	6	4

ALS Environmental

Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: TP14 0.6-0.7 / Sample Matrix Type / Description: SOIL / Sample Date / Time: 5 Apr 2007 15:00 / Laboratory Sample ID: EB0704186-016	TP6 2.0-2.1 / SOIL / 5 Apr 2007 15:00 / EB0704186-017	BH37 0.5-1.0 / SOIL / (5 Apr 2007) (15:00) / EB0704186-018	BH37 2.0-2.5 / SOIL / (5 Apr 2007) (15:00) / EB0704186-019	
EA029-A: pH Measurements								
pH KCl (23A)		0.1	pH Unit	4.1	4.9	5.1	5.0	
pH OX (23B)		0.1	pH Unit	4.1	3.9	4.1	3.2	
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)		2	mole H+ / t	70	16	14	24	
Titratable Peroxide Acidity (23G)		2	mole H+ / t	22	15	102	102	
Titratable Sulfidic Acidity (23H)		2	mole H+ / t	<2	<2	88	78	
sulfidic - Titratable Actual Acidity (s-23F)		0.02	% pyrite S	0.11	0.02	0.02	0.04	
sulfidic - Titratable Peroxide Acidity (s-23G)		0.02	% pyrite S	0.04	0.02	0.16	0.16	
sulfidic - Titratable Sulfidic Acidity (s-23H)		0.02	% pyrite S	<0.02	<0.02	0.14	0.12	
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)		0.02	% S	0.04	<0.02	<0.02	<0.02	
Peroxide Sulfur (23De)		0.02	% S	0.06	<0.02	<0.02	0.03	
Peroxide Oxidisable Sulfur (23E)		0.02	% S	<0.02	<0.02	<0.02	0.03	
acidity - Peroxide Oxidisable Sulfur (a-23E)		10	mole H+ / t	10	<10	<10	21	
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	
Peroxide Calcium (23Wh)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	
Acid Reacted Calcium (23X)		0.02	% Ca	<0.02	<0.02	<0.02	<0.02	
acidity - Acid Reacted Calcium (a-23X)		10	mole H+ / t	<10	<10	<10	<10	
sulfidic - Acid Reacted Calcium (s-23X)		0.02	% S	<0.02	<0.02	<0.02	<0.02	
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)		0.02	% Mg	0.08	<0.02	<0.02	<0.02	
Peroxide Magnesium (23Tm)		0.02	% Mg	0.09	<0.02	<0.02	<0.02	
Acid Reacted Magnesium (23U)		0.02	% Mg	<0.02	<0.02	<0.02	<0.02	
acidity - Acid Reacted Magnesium (a-23U)		10	mole H+ / t	12	<10	<10	<10	
sulfidic - Acid Reacted Magnesium (s-23U)		0.02	% S	<0.02	<0.02	<0.02	<0.02	
EA029-G: Retained Acidity								
Net Acid Soluble Sulfur (20Je)		0.02	% S	<0.02	—	—	—	
acidity - Net Acid Soluble Sulfur (a-20J)		10	mole H+ / t	<10	—	—	—	
sulfidic - Net Acid Soluble Sulfur (s-20J)		0.02	% pyrite S	<0.02	—	—	—	
HCl Extractable Sulfur (20Be)		0.02	% S	0.05	—	—	—	

ALS Environmental

Analytical Results

Analyte	CAS number	LOR	Units	Client Sample ID: TP14 0.6-0.7 Sample Matrix Type / Description: SOIL Sample Date / Time: 5 Apr 2007 15:00 Laboratory Sample ID: EB0704186-016	Client Sample ID: TP6 2.0-2.1 Sample Matrix Type / Description: SOIL Sample Date / Time: 5 Apr 2007 15:00 Laboratory Sample ID: EB0704186-017	Client Sample ID: BH37 0.5-1.0 Sample Matrix Type / Description: SOIL Sample Date / Time: (5 Apr 2007) (15:00) Laboratory Sample ID: EB0704186-018	Client Sample ID: BH37 2.0-2.5 Sample Matrix Type / Description: SOIL Sample Date / Time: (5 Apr 2007) (15:00) Laboratory Sample ID: EB0704186-019	
EA029-H: Acid Base Accounting								
ANC Fineness Factor		0.5		1.5	1.5	1.5	1.5	
Net Acidity (sulfur units)		0.02	% S	0.14	0.02	0.02	0.07	
Net Acidity (acidity units)		10	mole H+ / t	84	16	14	44	
Liming Rate		1	kg CaCO3/t	6	1	1	3	

ALS Environmental

Surrogate Control Limits

- No surrogates present on this report.

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
GEOTSGTE20248AA
sheet *1* of *1*

acid sulfate soil screening test

office: Newcastle (LABTSGTE00173AA)

client: ***TATTERSAL SURVEYORS*** date: ***12/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH/GR***

location: ***TEA GARDENS*** checked by:

date samples recovered: pH meter used/serial **Horiba** date of calibration:

hydrogen peroxide pH prior to use: ***5.46*** hydrogen peroxide temperature prior to use: ***22.3***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP3	*1.0-1.1*		*Sand/ Clay*	*5.60*	*10*	*3.85*	25	b	Y	N	1.75	
TP27	*1.1-1.2*		*Sand*	*4.47*	*10*	*3.35*	25	a	N	N	1.12	
TP28	*0.6-0.7*		*Sand / Clay*	*4.95*	*10*	*3.55*	25	b	Y	N	1.4	
TP22	*1.8-1.9*		*Sand*	*5.59*	*10*	*4.68*	25	a	N	N	0.91	
TP6	*1.5-1.6*		*Sand*	*4.71*	*10*	*2.60*	25	a	N	N	2.11	
TP9	*1.9-2.0*		*Sand*	*5.25*	*10*	*4.15*	25	a	N	N	1.1	
TP24	*0.5-0.6*		*Clay / Sand*	*5.03*	*10*	*3.63*	24	a	N	N	1.4	
TP24	*1.0-1.1*		*Sand*	*5.11*	*10*	*3.88*	24	a	N	N	1.23	
TP24	*1.9-2.0*		*Sand*	*5.56*	*10*	*5.24*	24	a	N	N	0.32	

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet *1* of *1*

acid sulfate soil screening test

office: Newcastle

client: ***TATTERSAL SURVEYORS*** date: ***13/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH***

location: ***Tea Gardens*** checked by:

date samples recovered: pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: ***5.46*** hydrogen peroxide temperature prior to use: ***22.3***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP18	*0.6-0.7*		*Sand*	*4.81*	*10*	*4.17*	23	A	N	N	0.64	
TP18	*1.8-1.9*		*Sand*	*5.27*	*10*	*4.45*	23	A	N	N	0.82	
TP6	*0.6-0.7*		*Silty Sand*	*4.76*	*10*	*4.15*	23	A	N	N	0.61	
TP6	*1.0-1.1*		*Sand*	*4.80*	*10*	*4.15*	23	A	N	N	0.65	
TP4	*0.5-0.6*		*Clay*	*5.62*	*10*	*4.13*	23	A	Y	N	1.49	
TP17	*1.1-1.2*		*Sand*	*5.46*	*10*	*5.21*	23	A	N	N	0.25	
TP11	*1.0-1.1*		*Sand*	*5.70*	*10*	*5.37*	24	A	N	N	0.33	
TP22	*0.5-0.6*		*Silty Sand*	*5.83*	*10*	*5.40*	24	b	N	N	0.43	

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet *1* of *1*

acid sulfate soil screening test

office: Newcastle

client: ***TATTERSAL SURVEYORS*** date: ***12/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH***

location: ***TEA GARDENS*** checked by:

date samples recovered: ***10-04-07*** pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: ***5.46*** hydrogen peroxide temperature prior to use: ***22.3***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP12	*0.6-0.7*		*Sand*	*5.99*	*10*	*3.98*	22		N	N	2.01	
TP12	*1.1-1.2*		*Sand*	*5.66*	*10*	*4.13*	22		N	N	1.53	
TP12	*1.9-2.0*		*Sand*	*6.44*	*10*	*4.71*	23		N	N	1.73	
TP13	*1.1-1.2*		*Sand*	*5.30*	*10*	*4.28*	23		N	N	1.02	
TP14	*0.6-0.7*		*Clay*	*5.20*	*10*	*3.26*	23		N	N	1.94	
TP14	*1.7-1.8*		*Clay*	*4.89*	*10*	*3.42*	23		N	N	1.47	
TP15	*1.1-1.2*		*Sand*	*4.84*	*10*	*3.85*	23		N	N	0.99	
TP34	*1.9-2.0*		*Sand*	*6.33*	*10*	*5.45*	23		N	N	0.88	
TP31	*0.6-0.7*		*Sand*	*6.56*	*10*	*4.80*	23		N	N	1.76	
TP30	*0.6-0.7*		*Sand*	*6.00*	*10*	*4.90*	23		N	N	1.1	
TP32	*1.6-1.7*		*Sand*	*6.40*	*10*	*1.43*	30		Y	N	4.97	

NOTES: 1. Observed Reaction: a. No visible effervescenceb. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

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SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet *1* of *1*

acid sulfate soil screening test

office: Newcastle

client: ***TATTERSAL SURVEYORS*** date: ***12/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH***

location: ***TEA GARDENS*** checked by:

date samples recovered: ***10-04-07*** pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: ***5.46*** hydrogen peroxide temperature prior to use: ***22.3***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP31	*1.0 – 1.1*		*Sand*	*6.00*	*10*	*3.63*	24	A	N	N	2.37	
TP34	*0.55 – 0.65*		*Sand*	*6.76*	*10*	*4.51*	25	B	Yes	N	2.25	
TP32	*0.7 – 0.8*		*Sand*	*5.20*	*10*	*3.91*	24	S	N	N	1.29	
TP33	*1.1-1.2*		*Sand*	*6.34*	*10*	*1.45*	30	B	Yes	N	4.89	
TP34	*1.0 – 1.1*		*Sand*	*6.35*		*1.36*	33	B	Yes	Yes	4.99	Lighter in peroxide
TP30	*1.5 – 1.6*		*Sand*	*5.25*	*10*	*2.81*	25	b	Yes	N	2.44	

NOTES: 1. Observed Reaction: a. No visible effervescenceb. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet *1* of *1*

acid sulfate soil screening test

office: Newcastle

client: ***TATTERSAL SURVEYORS*** date: ***13/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH***

location: ***TEA GARDENS*** checked by:

date samples recovered: ***10-04-07*** pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: ***5.49*** hydrogen peroxide temperature prior to use: ***22.0***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP4	*2.0-2.1*		*Sand*	*5.75*	*10*	*1.65*	28	B	Y	Y	4.1	Lighter After Reaction
TP19	*1.1-1.2*		*Clay*	*5.20*	*10*	*3.50*	23	A	N	N	1.7	
TP9	*1.0-1.1*		*Sand*	*4.90*	*10*	*3.60*	23	A	N	N	1.3	
TP25	*0.6-0.7*		*Sand*	*4.55*	*10*	*3.25*	22	A	N	N	1.3	
TP25	*1.9-2.0*		*Clay*	*4.36*	*10*	*3.26*	23	A	N	N	1.1	
TP6	*2.0-2.1*		*Sand*	*4.94*	*10*	*4.06*	22	A	N	N	0.88	

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet *1* of *2*

acid sulfate soil screening test

office: Newcastle

client: ***TATTERSAL SURVEYORS*** date: ***13/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH/GR***

location: ***TEA GARDENS*** checked by:

date samples recovered: pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: ***5.28*** hydrogen peroxide temperature prior to use: ***21.0***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP16	*0.5-0.6*		*Sand*	*4.96*	*10*	*4.72*	21.5	a	N	N	0.24	
TP16	*1.7-1.8*		*Sand*	*4.93*	*10*	*3.83*	21.5	a	N	N	1.1	
TP3	*1.7-1.8*		*Sand*	*5.65*	*10*	*5.42*	21.0	a	N	N	0.23	
TP5	*1.5-1.6*		*Sand*	*5.25*	*10*	*4.50*	21.5	a	N	N	0.75	
TP5	*0.9-1.0*		*Sand*	*5.78*	*10*	*4.98*	21.5	a	N	N	0.8	
TP2	*1.0-11*		*Sand*	*5.53*	*10*	*3.36*	21.5	a	N	N	2.17	
TP10	*0.5-0.6*		*Sand*	*5.25*	*10*	*4.60*	21	a	N	N	0.65	
TP10	*1.8-1.9*		*Sand*	*5.50*	*10*	*4.60*	21	a	N	N	0.9	
TP1	*1.0-1.1*		*Sand*	*5.60*	*10*	*4.79*	21	a	N	N	0.81	
TP262	*0.5-0.6*		*Sand*	*4.90*	*10*	*4.70*	21	a	N	N	0.2	
TP26	*1.0-1.1*		*Sand*	*4.75*	*10*	*4.28*	21	a	N	N	0.47	

NOTES: 1. Observed Reaction: a. No visible effervescenceb. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet 2 of 2

acid sulfate soil screening test

office: Newcastle

client: *TATTERSAL SURVEYORS* date: *13/04/07*

principal: test location: *Newcastle*

project: *RIVERSIDE ESTATE PROJECT APPLICATION* tested by: *NH/GR*

location: *TEA GARDENS* checked by:

date samples recovered: pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: *5.46* hydrogen peroxide temperature prior to use: *22.3*

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP21	*1.1-1.2*		*Sand*	*5.30*	*10*	*5.20*	21	a	N	N	0.1	
TP10	*1.1-1.2*		*Sand*	*5.30*	*10*	*4.80*	22	a	N	N	0.5	
TP20	*0.6-0.7*		*Sand*	*5.03*	*10*	*4.17*	22	a	N	N	0.86	
TP20	*1.6-1.7*		*Sand*	*5.10*	*10*	*5.01*	22	a	N	N	0.09	
TP29	*1.1-1.2*		*Sand*	*5.20*	*10*	*4.03*	22	b	Y	N	1.17	
TP28	*1.7-1.8*		*Sand*	*5.10*	*10*	*4.60*	22	a	N	N	0.5	
TP19	*0.5-0.6*		*Sand*	*4.96*	*10*	*3.70*	22	b	Y	N	1.26	
TP1	*0.5-0.6*		*Sand*	*7.28*	*10*	*5.32*	24	a	N	N	1.96	

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet *1* of *1*

acid sulfate soil screening test

office: Newcastle

client: ***TATTERSAL SURVEYORS*** date: ***12/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH***

location: ***TEA GARDENS*** checked by:

date samples recovered: ***10-04-07*** pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: ***5.46*** hydrogen peroxide temperature prior to use: ***22.3***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP31	*1.0-1.1*		*Sand*	*6.00*	*10*	*3.63*	24	a	N	N	2.37	
TP34	*0.55-0.65*		*Sand*	*6.76*	*10*	*4.51*	25	b	Y	N	2.25	
TP32	*0.7-0.8*		*Sand*	*5.20*	*10*	*3.91*	24	a	N	N	1.29	
TP33	*1.1-1.2*		*Sand*	*6.34*	*10*	*1.45*	30	b	Y	N	4.89	
TP34	*1.0-1.1*		*Sand*	*6.35*	*10*	*1.36*	33	b	Y	Y	4.99	Lighter in Peroxide
TP30	*1.5-1.6*		*Sand*	*5.25*	*10*	*2.81*	25	b	Y	N	2.44	

NOTES: 1. **Observed Reaction:** a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction
2. **Strong Odour:**

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet *1* of *2*

acid sulfate soil screening test

office: Newcastle

client: ***TATTERSAL SURVEYORS*** date: ***13/04/07***

principal: test location: ***Newcastle***

project: ***RIVERSIDE ESTATE PROJECT APPLICATION*** tested by: ***NH/***

location: ***TEA GARDENS*** checked by:

date samples recovered: ***11/04/07*** pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: ***5.47*** hydrogen peroxide temperature prior to use: ***23.0***

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
BH23	*0.5-1.0*		*Sand*	*5.83*	*10*	*5.01*	22	a	N	N	0.82	
BH35	*2.0-2.5*		*Sand*	*6.15*	*10*	*4.30*	23	b	N	N	1.85	
BH35	*3.5-4.0*		*Sand*	*6.45*	*10*	*5.18*	22	a	N	N	1.27	
BH36	*0.5-1.0*		*Sand*	*5.03*	*10*	*4.24*	23	b	Y	N	0.79	
BH36	*2.0-2.5*		*Sand*	*5.26*	*10*	*3.78*	22	a	N	N	1.4	
BH36	*3.5-4.0*		*Sand*	*5.75*	*10*	*3.26*	22	a	N	N	2.49	
BH36	*5.0-5.5*		*Sand*	*6.19*	*10*	*4.22*	23	a	N	N	1.97	
BH37	*0.5-1.0*		*Sand*	*5.85*	*10*	*4.67*	23	b	N	N	1.18	
BH37	*2.0-2.5*		*Sand*	*5.55*	*10*	*3.92*	22	a	N	N	1.63	
BH37	*3.5-4.0*		*Sand*	*5.80*	*10*	*4.25*	22	a	Y	N	1.55	
BH37	*5.0-5.5*		*Sand*	*5.83*	*10*	*3.27*	22	b	N	N	2.56	

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no:
LABTSGTE00173AA
sheet 2 of 2

acid sulfate soil screening test

office: Newcastle

client: *TATTERSAL SURVEYORS* date: *13/04/07*

principal: test location: *Newcastle*

project: *RIVERSIDE ESTATE PROJECT APPLICATION* tested by: *NH/GR*

location: *TEA GARDENS* checked by:

date samples recovered: pH meter used/serial Horiba date of calibration:

hydrogen peroxide pH prior to use: *5.46* hydrogen peroxide temperature prior to use: *22.3*

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
BH37	*6.5-7.0*		*Sand*	*5.73*	*10*	*3.07*	23	b	N	N	2.66	
BH58	*0.5-1.0*		*Sand / Clay*	*5.19*	*10*	*4.20*	22	b	N	N	0.99	
BH38	*2.0-2.5*		*Sand / Clay*	*5.50*	*10*	*4.15*	22	a	Y	N	1.35	
BH38	*3.5-4.0*		*Sand*	*5.53*	*10*	*4.38*	21	a	N	N	1.15	
BH38	*5.0-5.5*		*Sand*	*5.93*	*10*	*4.55*	22	a	N	N	1.38	
BH38	*6.5-7.0*		*Sand*	*5.63*	*10*	*4.26*	22	a	Y	N	1.39	

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction
2. Strong Odour:

RESULTS OF ACID SULFATE SOIL ANALYSIS (Page 1 of 1)

9 samples supplied by Coffey on 14th June, 2007 - Lab. Job No. E7466
Analysis requested by Warabrook. - **Your Project: Proposed subdivision**

Sample Site	Depth (m)	EAL lab code	Texture (note 6)	Moisture Content (% moisture)	Lab. Bulk Density tonne DW/m^3	TAA pH_{KCl}	Titratable Actual Acidity (TAA) mole H^+/tonne (to pH 6.5)	Reduced Inorganic Sulfur (% chromium reducible S) (%Scr) (note 2)	Reduced Inorganic Sulfur (Scr) mole H^+/tonne	NET ACIDITY Chromium Suite mole H^+/tonne (based on %Scrs)	LIME CALCULATION Chromium Suite kg $CaCO_3/m^3$ (includes 1.5 safety Factor)
Method No.						*23A*	*23F*	*22B*	*a- 22B*	*note 5*	*note 5*
TP 39	1.0 - 1.1	*E7466/1*	Fine	24.9	1.2	4.27	52	0.006	4	56	5
TP 40	1.5 -1.6	*E7466/2*	Coarse	15.9	1.3	4.83	9	<0.005	0	9	1
TP 41	0.5 - 0.6	*E7466/3*	Fine	18.0	1.6	4.42	39	<0.005	0	39	5
TP 42	1.0 - 1.1	*E7466/4*	Fine	21.9	1.1	4.63	33	0.007	4	37	3
TP 43	1.7 - 1.8	*E7466/5*	Coarse	11.7	1.4	5.13	7	<0.005	0	7	1
BH 45	5.5 - 5.9	*E7466/6*	Coarse	16.0	1.6	5.04	16	0.011	7	22	3
BH 46	1.0 - 1.1	*E7466/7*	Coarse	18.5	1.3	5.38	3	0.028	17	20	2
BH 46	2.5 - 3.0	*E7466/8*	Coarse	17.8	1.4	5.23	9	0.016	10	18	2
BH 46	5.5 - 6.0	*E7466/9*	Coarse	18.3	1.4	5.91	2	0.013	8	10	1

NOTE:
1 - All analysis is Dry Weight (DW) - samples dried and ground immediately upon arrival (unless supplied dried and ground)
2 - Samples analysed by SPOCAS method 23 (ie Suspension Peroxide Oxidation Combined Acidity & sulfate) and 'Chromium Reducible Sulfur' technique (Scr - Method 22B)
3 - Methods from Ahern, CR, McElnea AE , Sullivan LA (2004). ***Acid Sulfate Soils Laboratory Methods Guidelines.*** QLD DNRME.
4 - Bulk density was determined immediately on arrival to laboratory (insitu bulk density is preferred)
5 - **ABA Equation: Net Acidity = Potential Sulfidic Acidity (ie. Scrs or Sox) + Actual Acidity + Retained Acidity - measured ANC/FF**
6 - For Texture: coarse = sands to loamy sands; medium = sandy loams to light clays; fine = medium to heavy clays and silty clays
7 - .. Denotes not requested or required
8 - CRS, TAA and ANC are NATA certified but other SPOCAS segments are currently not NATA certification
9- Results at or below detection limits are replaced with '0' for calculation purposes.
10 - Projects that disturb >1000 tonnes of soil, the ≥0.03% S classification guideline would apply.

Lab. Accred. No.: 14960

(Classification of potential acid sulfate material if: coarse Scr≥0.03%S or 19mole H+/t; medium Scr≥0.06%S or 37mole H+/t; fine Scr≥0.1%S or 62mole H+/t)

checked: .....

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no: GEOTSGTE20248AA

sheet 1 of 5

acid sulfate soil screening test

office: NEWCASTLE

client: *TATTERSALL SURVEYORS PTY LTD* date: *08-06-07*

principal: test location: *NEWCASTLE*

project: *RIVERSIDE ESTATE PROJECT APPLICATION TEA GARDENS* tested by: *SB*

location: *REFER TO FIGURE 1* checked by:

date samples recovered: *01-04-07* pH meter used/serial HORIBA date of calibration: *08-06-07*

hydrogen peroxide pH prior to use: *5.45* hydrogen peroxide temperature prior to use: *20.4*

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP39	*0.5-0.6*		*Clay*	*7.47*	*20*	*4.38*	*20.6*	*B*	*A*		3.09	
TP39	*1.0-1.1*		*Clay*	*6.75*	*25*	*3.86*	*20.7*	*B*	*A*		2.89	
TP39	*1.5-1.6*		*Sand*	*7.29*	*15*	*5.46*	*20.3*	*A*	*A*		1.83	
BH46	*1.0-1.5*		*Sand*	*6.57*	*22*	*2.28*	*20.3*	*B*	*B*		4.29	
BH46	*2.5-3.0*		*Sand*	*6.70*	*21*	*4.38*	*20.2*	*B*	*A*		2.32	
BH46	*4.0-4.5*		*Sand*	*7.67*	*20*	*4.66*	*20.2*	*A*	*A*		3.01	
BH46	*5.5-6.0*		*Sand*	*7.68*	*19*	*5.33*	*20.0*	*A*	*A*		2.35	
BH46	*7.0-7.5*		*Sand*	*7.25*	*18*	*5.77*	*19.9*	*A*	*A*		1.48	

NOTES: 1. Observed Reaction: a. No visible effervescenceb. Slight to moderate effervescence c. Vigorous effervescent reaction

2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no: GEOTSGTE20248AA

sheet 2 of 5

acid sulfate soil screening test

office: NEWCASTLE

client: *TATTERSALL SURVEYORS PTY LTD* date: *08-06-07*

principal: test location: *NEWCASTLE*

project: *RIVERSIDE ESTATE PROJECT APPLICATION TEA GARDENS* tested by: *SB*

location: *REFER TO FIGURE 1* checked by:

date samples recovered: *01-04-07* pH meter used/serial HORIBA date of calibration: *08-06-07*

hydrogen peroxide pH prior to use: *5.15* hydrogen peroxide temperature prior to use: *20.2*

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP41	*0.5-0.6*		*Clay*	*5.20*	*42*	*3.86*	*20.8*	*B*	*B*		*1.34*	
TP41	*1.0-1.1*		*Sandy Clay*	*5.18*	*43*	*4.06*	*20.8*	*B*	*A*		*1.12*	
TP41	*1.5-1.6*		*Clayey Sand*	*5.02*	*44*	*4.35*	*21.0*	*A*	*A*		*0.67*	
TP41	*2.4-2.5*		*Sand*	*6.02*	*46*	*4.67*	*20.7*	*A*	*A*		*1.35*	
TP40	*0.5-0.6*		*Clay*	*6.17*	*55*	*4.64*	*20.4*	*B*	*A*		*1.53*	
TP40	*1.0-1.1*		*Clay*	*5.65*	*56*	*4.50*	*20.4*	*A*	*A*		*1.15*	
TP40	*1.5-1.6*		*Sand*	*5.90*	*57*	*4.73*	*20.3*	*A*	*A*		*1.17*	

NOTES: 1. Observed Reaction: a. No visible effervescenceb. Slight to moderate effervescence c. Vigorous effervescent reaction

2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no: GEOTSGTE20248AA

sheet 3 of 5

acid sulfate soil screening test

office: NEWCASTLE

client: *TATTERSALL SURVEYORS PTY LTD* date: *08-06-07*

principal: test location: *NEWCASTLE*

project: *RIVERSIDE ESTATE PROJECT APPLICATION TEA GARDENS* tested by: *SB*

location: *REFER TO FIGURE 1* checked by:

date samples recovered: *01-04-07* pH meter used/serial HORIBA date of calibration: *08-06-07*

hydrogen peroxide pH prior to use: *5.55* hydrogen peroxide temperature prior to use: *20.6*

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP43	*0.5-0.6*		*Sand*	*4.09*	*15*	*4.94*	*21.2*	*B*	*A*		-	
TP43	*1.0-1.1*		*Sand*	*5.26*	*16*	*4.90*	*20.9*	*A*	*A*		*0.36*	
TP43	*1.7-1.8*		*Sand*	*5.83*	*18*	*5.18*	*20.7*	*A*	*A*		*0.65*	
TP42	*0.5-0.6*		*Clay*	*5.71*	*30*	*4.24*	*20.7*	*B*	*A*		*1.47*	
TP42	*1.0-1.1*		*Sandy Clay*	*5.25*	*30*	*4.19*		*A*	*A*		*1.06*	
TP42	*1.5-1.6*		*Sand*	*5.44*		*4.15*	*20.8*	*B*	*A*		*1.29*	

NOTES: 1. Observed Reaction: a. No visible effervescenceb. Slight to moderate effervescence c. Vigorous effervescent reaction

2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no: GEOTSGTE20248AA

sheet 4 of 5

acid sulfate soil screening test

office: NEWCASTLE

client: *TATTERSALL SURVEYORS PTY LTD* date: *08-06-07*

principal: test location: *NEWCASTLE*

project: *RIVERSIDE ESTATE PROJECT APPLICATION TEA GARDENS* tested by: *SB*

location: *REFER TO FIGURE 1* checked by:

date samples recovered: *01-04-07* pH meter used/serial HORIBA date of calibration: *07-06-07*

hydrogen peroxide pH prior to use: *5.44* hydrogen peroxide temperature prior to use: *20.9*

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide)							
					time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
TP44	*0.5-0.6*		*Sand*	*4.70*	*28*	*4.57*	*20.4*	*B*	*B*		*0.13*	
TP44	*1.0-1.1*		*Silty Sand*	*4.95*	*30*	*4.75*	*20.4*	*B*	*A*		*0.20*	
TP44	*1.5-1.6*		*Sand*	*5.04*	*31*	*5.07*	*20.5*	*A*	*A*			

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction

2. Strong Odour:

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

job no: GEOTSGTE20248AA

sheet 5 of 5

acid sulfate soil screening test

office: NEWCASTLE

client: *TATTERSALL SURVEYORS PTY LTD* date: *08-06-07*

principal: test location: *NEWCASTLE*

project: *RIVERSIDE ESTATE PROJECT APPLICATION TEA GARDENS* tested by: *SB*

location: *REFER TO FIGURE 1* checked by:

date samples recovered: *01-04-07* pH meter used/serial HORIBA date of calibration: *08-06-07*

hydrogen peroxide pH prior to use: *5.46* hydrogen peroxide temperature prior to use: *20.3*

sample location	depth (m)	RL (mAHD)	soil description	pH_F pH in 1:5 distilled water	pH_{FOX} (oxidation in 30% hydrogen peroxide) time (mins)	pH FOX	temp (°C)	Effervescence (see note below)	Odour	Colour change during reaction	pH Change (ie pH_F-pH_{FOX})	Additional comments
BH45	*1.0-1.5*		*Sand*	*6.35*	*15*	*5.21*	*20.3*	*A*	*A*		*1.14*	
BH45	*2.5-3.0*		*Sand*	*6.84*	*16*	*5.40*	*19.9*	*A*	*A*		*1.44*	
BH45	*4.0-4.5*		*Sand*	*6.16*	*17*	*4.72*	*19.9*	*A*	*A*		*1.44*	
BH45	*4.0-4.5**		*Sand*	*7.10*	*18*	*5.45*	*19.5*	*A*	*A*		*1.65*	
BH45	*5.5-5.9*		*Sand*	*6.17*	*20*	*4.80*	*20.1*	*A*	*A*		*1.37*	
BH45	*7.0-7.4*		*Sand*	*6.49*	*21*	*5.34*	*20.0*	*A*	*A*		*1.15*	
BH45	*8.5-9.0*		*Sand*	*6.68*	*21*	*5.20*	*20.0*	*A*	*A*		*1.48*	
BH45	*10.0-10.5*		*Sand*	*6.95*	*22*	*5.09*	*20.0*	*A*	*A*		*1.85*	

NOTES: 1. Observed Reaction: a. No visible effervescence b. Slight to moderate effervescence c. Vigorous effervescent reaction

2. Strong Odour:

Appendix C

Acid Sulfate Soils Management Plan

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

4 June 2007

Tattersall Surveyors Pty Ltd
PO Box 54
RAYMOND TERRACE NSW 2324

Attention: Bob Lander

Dear Bob

RE: PROPOSED SUBDIVISION

RIVERSIDE ESTATE PROJECT APPLICATION AND SUBSEQUENT STAGES, TEA GARDENS

GENERAL ACID SULFATE SOILS MANAGEMENT PLAN

Please find enclosed a generic Acid Sulfate Soils (ASS) Management Plan for all future developments within the proposed Riverside Estate Project Application and subsequent stages, Tea Gardens. The plan is aimed at being useable by all future service installers, builders or property owners. It presents an overview of acid sulfate conditions at the site, the potential for exposure to ASS and then provides recommendations and procedures for management and monitoring of ASS conditions.

If you have any questions regarding this management plan, please do not hesitate to contact Robert Pearce or the undersigned.

For and on behalf of Coffey Geotechnics Pty Ltd

Arthur Love

Principal Geotechnical Engineer

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1 INTRODUCTION

Coffey Geotechnics Pty Ltd (Coffey) has prepared a generic Acid Sulfate Soils Management Plan for future developments within the proposed Riverside Estate Project Application, Tea Gardens. The work was commissioned by Bob Lander of Tattersall Surveyors, on behalf of Crighton Properties, the developers of the Riverside Estate.

The Riverside Estate area has been subject to numerous previous acid sulfate soil (ASS) assessments and management plans. Previous development of the adjoining Myall Quays estate has been undertaken in accordance with ASS Management Plans prepared specifically for the development earthworks programs.

The purpose of the plan provided in this document was to provide a generic plan for management of ASS in future earthworks that occur within the Riverside Estate. It is understood the plan is to be provided as a reference to all lot purchasers and contractors required to work on the site. It has therefore been formatted in a way that will be useable to individual land owners to assist in obtaining DA approvals and in controlling and managing ASS during the development of each lot.

2 SITE CONDITIONS AND PROPOSED DEVELOPMENT

Topographically, the proposed development area is located within low lying coastal sand plains, with elevations typically of the order of 0.75m to between about 2.5m to 3m AHD. Vegetation generally comprises of tall grasses and scattered medium sized eucalypts.

Geologically the site is located within a region of windblown sand deposits probably of Pleistocene age (ie. greater than 20,000 years old) overlain by alluvial clays and the subsurface profiles encountered during our current investigation at the site and numerous previous investigations at the adjoining Myall Quays site revealed four main natural materials:

- TOPSOIL: Silty Clayey SAND, fine to medium grained, dark brown and dark grey;
- ALLUVIAL CLAY: Sandy CLAY and CLAY, medium to high plasticity and Clayey SAND, fine to medium grained;
- AEOLIAN SAND: fine to medium grained, pale grey / white and pale grey / brown;
- INDURATED SAND: fine to medium grained, dark brown, pale brown and orange / brown.

Groundwater depths generally vary from 0.3m to 2.0m below the surface.

3 WHAT ARE ACID SULFATE SOILS (ASS)?

3.1 Background Information

Acid Sulfate Soils (ASS) are soils which contain significant concentrations of iron sulphide or pyrite which, when exposed to oxygen in the presence of sufficient moisture, oxidises, resulting in the generation of sulfuric acid. Unoxidised pyritic soils are referred to as potential ASS. When the soils are exposed, the oxidation of pyrite occurs and sulphuric acids are generated, the soils are said to be actual ASS.

Pyritic soils typically form in waterlogged, saline sediments rich in iron and sulfate. Typical environments for the formation of these soils include tidal flats, salt marshes and mangrove swamps below about RL 1m AHD. They can also form as bottom sediments in coastal rivers and creeks.

Pyritic soils of concern on low lying NSW and coastal lands have mostly formed in the Holocene period, (ie. 10,000 years ago to present day) predominantly in the 7,000 years since the last rise in sea level. It is generally considered that pyritic soils which formed prior to the Holocene period (ie. >10,000 years ago) would already have oxidised and leached during periods of low sea level which occurred during ice ages, exposing pyritic coastal sediments to oxygen.

3.2 Significance of ASS

Disturbance or poorly managed development and use of acid sulfate soils can generate significant amounts of sulfuric acid, which can lower soil and water pH to extreme levels (generally <4) and produce acid salts, resulting in high salinity.

The low pH, high salinity soils can reduce or altogether preclude vegetation growth and can produce aggressive soil conditions which may be detrimental to concrete and steel components of structures, foundations, pipelines and other engineering works.

Generation of the acid conditions often releases aluminium, iron and other naturally occurring elements from the otherwise stable soil matrices. High concentrations of some such elements, coupled with low pH and alterations to salinity can be detrimental to aquatic life. In severe cases, affected waters flowing off-site into aquatic ecosystems can have a detrimental effect on aquatic ecosystems.

4 ASS AND THE DEVELOPMENT OF RIVERSIDE ESTATE

Prior to development, the area was occupied by low lying sand plains with elevations typically of the order of 0.75m to about 3m AHD.

The development of the adjoining Myall Quays residential estate involved raising the level of the land to achieve a minimum surface level of 2.1m AHD. Fill used to raise land levels was won onsite and from a sand pit located to the west of the site. All fill used in the development was tested in accordance with relevant guidelines and if necessary treated in accordance with the Acid Sulfate Soils Management Plan for the site. Similar fill materials will also be used to raise site levels across part of Riverside Estate Project Application.

5 POTENTIAL FOR OXIDATION OF ACID SULFATE SOILS

Installation of services involves placement of sewer mains to varying depths of up to 8m below final ground surface level. Risers are installed on each lot so the connection to sewer will not be required to extend to a depth of more than 1m. However, there is a requirement to pier structures in the vicinity of the sewer main to below the zone of influence. As this will be below the water table in most cases driven or screw piles are likely to be used and therefore extensive exposure of ASS is not likely.

As the majority of residential developments do not involve excavation below 1m depth, the following scenarios for exposure of ASS are envisaged:

- Swimming pool excavations exceeding 1m deep;

- Bored piers exceeding 1m deep;
- Other excavations that exceed 1m deep or involve dewatering by lowering the water table to depths of more than 1m.

It is assumed that excavations for roads will not be below 1m deep and therefore it is not envisaged that road excavation will encounter ASS or Potential ASS.

For any such proposed excavations, or dewatering projects, an acid sulfate soils assessment should be undertaken, involving sampling and analysis of soils to the proposed depth of excavation.

6 MANAGEMENT OF EXPOSED ACID SULFATE SOILS

6.1 Neutralisation

The preferred method for managing the relatively small quantities of acid sulfate soil likely to be excavated is neutralisation by lime. The required dosing rate should be derived from testing of representative samples of the soil prior to excavation. Soil samples should be obtained at a rate of 1 per 50m³ of soil disturbed. Samples should be taken by a suitably qualified soils technician, engineer, or soil scientist and submitted to a NATA registered laboratory for analysis by POCAS or Chromium Reducible Sulfur methods.

The recommended liming agent is fine agricultural lime with an Effective Neutralising Value (ENV) of 98% or more. Using lime of this type, the required dosing rate can be calculated from the results of the laboratory testing using the following formula:

Lime required (kg lime/tonne soil) = 1.5 x Total Potential Acidity (kg H_2 SO_4/tonne soil)

The lime and soil should be thoroughly mixed, preferably in a bunded area as close as possible to the source, with provision for runoff water to be collected and treated prior to release. Exposed soils in the walls and floors of the excavations should be treated by spreading of lime on the exposed surfaces.

For excavations disturbing less than 1,000 tonnes of soil, liming will be required unless analysis results fall below the following criteria:

SOIL TYPE	ACTION CRITERIA
Sand to loamy sand	0.03% oxidisable sulfur 18 mol H^+/tonne
Sandy loam to light clay	0.06% oxidisable sulfur 36 mol H^+/tonne
Medium to heavy clay or silty clay	0.1% oxidisable sulfur 62 mol H^+/tonne

Where more than 1,000 tonnes of soil is to be disturbed, all soils should be treated unless test results fall below 0.03% oxidisable sulfur or 18 mol H^+/tonne.

Neutralised soils can be used elsewhere on site provided test results on the neutralised soil meet the above criteria.

6.2 Dewatering

To minimise the impacts of dewatering for installation of services or other excavations, the following recommendations apply:

- Where possible, undertake excavations in the wet (ie without dewatering);
- Minimise the depth and extent of dewatering by staging the works and maintaining the groundwater level as close as possible to the working surface or pipe inverts;
- Minimise the time of exposure of potential ASS by staging excavations, immediately installing services or pipes and backfilling excavation as soon as services are installed;
- Excavated groundwater should be pumped to a holding tank, pond or bunded area. The pH of the water should be measured and the water released only if a pH of 6.5 to 9.0 is achieved. If water pH is less than 6.5, lime should be added as a slurry to the water until pH meets the required values. The preferred method of water disposal is by overland discharge at a rate that allows infiltration into the sand subsoils. Direct runoff to surface drainage or waterways should be avoided;
- Larger exposures, such as those on the batters of detention basins should be further limed and the lower parts of the batter should have a lime buffer placed in the form of limed sand bags (10% lime in sand) to allow neutralisation of acid leachate generated from the excavation walls. If required, (as indicated by pH monitoring) additional neutralisation of water should be undertaken.

7 MONITORING

7.1 pH Monitoring

The following monitoring is recommended to gauge neutralisation of excavated potential ASS:

- Daily measurement of soil pH in distilled water and hydrogen peroxide. Additional lime should be added if soil pH <4 (in distilled water) or pH<3 (in hydrogen peroxide) is encountered;
- Laboratory testing by POCAS or CRS methods at a rate of one per 50m^3 (or part thereof) of neutralised soil;
- Monitoring and liming should continue until required levels have been achieved.

7.2 Water Monitoring

Monitoring of pH in water discharged from dewatering operation should be as discussed in Section 7.1.

Surface waters, such as drainage lines, ponds or creeks in the vicinity of excavations or dewatering operation should also be monitored. Discharge to surface water should be avoided if practical, but where necessary, background water quality testing should be undertaken. Discharges should comply with ANZECC 2000 guidelines.

The following criteria are presented for discharge to surface water:

pH INDICATOR	FRESH WATER	MARINE ECOSYSTEM
pH	6.5 – 8.5	<0.2 unit change
Fe (Total)	500µg/L	N/A
Total Dissolved Solids	0-1500mg/L	>1500 mg/L
Aluminium (Total)	5µg/L for pH <6.5 100µg/L for pH >6.5	-

8 CONTINGENCY PLAN

Contingency plans have been discussed in the preceding section but are summarised below. Sufficient lime should be stored on site to allow implementation of the plans.

Soil

Where tests indicate lime neutralisation has not achieved acceptable results, additional lime shall be mixed through the soil until an acceptable result is achieved.

Water

Water not meeting the criteria outlined above should be treated by addition of lime in the form of a slurry. Mixing rates should be judged by monitoring pH during the process and be confirmed by laboratory testing prior to release. Care should be taken to add lime gradually, as '*over-shooting'* can occur rapidly in such operations.

9 CONCLUSIONS

All personnel on sites involved with excavation or dewatering should be made fully aware of the issues associated with exposure of ASS and the requirements of this plan.

The site management procedures should be constantly reviewed to ensure that opportunities for exposure and oxidation of ASS are minimised.

For and on behalf of Coffey Geotechnics Pty Ltd

Arthur Love

Principal Geotechnical Engineer

Volume 3A: Detention Lake Sediment Sampling

coffey environments
SPECIALISTS IN LIVING AND WORKING PLACES

24 October 2007

Tattersall Surveyors Pty Ltd
PO Box 54
RAYMOND TERRACE NSW 2324

Attention: Bob Lander

Dear Bob

RE: Myall Quays Detention Lake Sediment Sampling and Analysis

1 INTRODUCTION

1.1 General

The is letter presents the results of sediment sampling and analysis carried out by Coffey Environments Pty Ltd (Coffey Environments) from Myall Quays, Tea Garden as shown in **Figure 1**.

The work was commissioned by Mr Bob Lander of Tattersall Surveyors Pty Ltd to measure the levels of potential contaminants present in the Myall Quays.

1.2 Objectives and Scope of Work

The objectives of this investigation were to assess the lake sediments with regards to the potential for the lake to become a 'pollutant sink' resulting in the build up of nutrients and persistent chemical pollutants.

The scope of work included:

- Fieldwork including sediment sampling at selected locations on the lake floor;
- Laboratory analysis of a selected number of samples for heavy metals (Sb, As, Cd, Cr, Cu, Pb, Ni, Ag, Sn, Zn, Hg), total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene and xylenes (BTEX), Polynuclear aromatic hydrocarbons (PAH), organochlorine pesticides (OCP), polychlorinated biphenyls (PCB), total phosphorous, total oxidised nitrogen (NOx) and total kjeldahl nitrogen (TKN);
- Data assessment and reporting.

1.3 Regulatory Background and Applicable Guidelines

Sediments are important as both a source and as a sink of dissolved contaminants. As well as influencing surface water quality, sediments represent a source of bioavailable contaminants to benthic biota and hence potentially to the aquatic food chain.

For assessing contamination levels in the sediment the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000), Chapter 3.5 Sediment Quality Guidelines (the guidelines) were used.[1] The recommended guideline values are tabulated as interim sediment quality guideline (ISQG) values and are presented in **Tables LR1-LR4**. The ISQG are presented in a range. The low range trigger values have been adopted as warning levels and the high range trigger values have been adopted as the investigation levels (ILs). Due to the trace level detection limits required for silver, chlordane, dieldrin, endrin and lindane the warning levels were below the reporting limits of the laboratories.

2 FIELD WORK

2.1 Field Investigations

Field work was carried out on 5 October 2007. Twenty one sediment samples were collected at locations shown in **Figure 2**. Sediment sampling was conducted using Coffey's shallow bottom boat manned by a Coffey Environmental Scientist and a technician. Sixteen sediment samples were collected using a core sampler and disposable gloves. Sediment samples were placed into glass jars with Teflon lined lids as supplied by the laboratory and given a unique sample identification number.

2.2 Field Quality Assurance/Quality Control

Environmental sampling activities were generally based on procedures and protocols outlined in Coffey's Environmental standard operating procedures which is based on industry accepted standard practice.

The sampling equipment was decontaminated between sample locations to avoid cross contamination. A clean pair of disposable gloves was used when handling each sample.

One duplicate sample, identified as D1 (duplicate of S1) was tested by the primary laboratory as part of this investigation to assess whether the field sampling procedures provided adequately reproducible results. One triplicate sample, identified as TRIP1 (triplicate of S1) was tested by the secondary laboratory as part of this investigation to assess whether the primary laboratory procedures provided adequately reproducible results.

In addition to field quality control, the laboratory conducted internal quality control using laboratory duplicates, spikes and method blanks. The results are shown with laboratory report sheets in Appendix B. Analytical methods used for the laboratory testing are also indicated on the laboratory report sheets.

2.3 Laboratory Testing

Primary and duplicate sediment samples were dispatched to SGS Australia Pty Ltd (SGS). SGS forwarded sub samples to the National Measurement Institute for ultra trace level OCP/PCB analysis and the triplicate sediment sample was dispatched to Australian Laboratory Services Environmental (ALSE), both of which are a NATA registered laboratory for the analysis undertaken, under chain of custody conditions.

Selected soil samples collected from near the lake inlets were subjected to laboratory analysis, while other samples were held in the laboratory for further analysis, if required.

The analytical suite was selected based on the analytes tabulated in Chapter 3 of the guidelines.

2.4 Contamination Assessment Results

2.4.1 Quality Assurance/Quality Control

Samples were received by SGS, NM1 and ALSE within the recommended holding times and they were chilled when received. Copies of the Chain of Custody documentation are included in **Appendix A.** The samples were extracted within the required holding time. The percentage recovery results of laboratory control sample were acceptable for the analyses requested. The laboratory blank results were below the practical quantitation limit (PQL) for the analyses requested.

A field duplicate (D1) was also submitted for analysis. The relative percentage difference (RPD) of the results between the primary sample (S1) and field duplicate can give an indication of the robustness of the sampling technique and heterogeneity of contamination. RPD are presented in **Tables LR1-LR4** for analytical results greater than 5 times the level of reporting. There were no RPDs <50% which indicates that the contamination is homogeneous and sampling techniques were robust. Triplicate sample, TRIP1, had a concentration of 0.2 mg/kg where as the primary and duplicate sample were below the laboratory reporting limit. Based on the primary and secondary results the triplicate result has been rejected from the data set and judged to be a QA/QC failure on the secondary laboratory's behalf.

The analytical laboratories also conducted internal QA/QC sample analysis including method blanks, laboratory control samples and duplicates. A review of the internal laboratories QA/QC data were within each laboratories acceptance criteria.

Based on the above information the primary laboratory data is judged to be representative and usable for this investigation.

2.4.2 Comparison of Results with Investigation Levels

A summary of the laboratory results is presented in **Tables LR1-LR4**. The laboratory results and chain of custody documentation is presented in **Appendix A**.

Comparison of the laboratory results to the sediment investigation levels (IL) revealed TPH, BTEX, OCP and PCB were not detected above the laboratory reporting limit and thus the adopted ILs.

Heavy metals were not detected above the warning levels in the primary and duplicate samples analysed. .

There are no ILs established for total phosphorous or total nitrogen for this investigation. These results were compared to Sediment Properties of Urban Lakes and Ponds.[2] The total kjeldahl nitrogen concentrations were in the range of 36-690 mg/kg in the samples analysed. These are below typical range of 1,000-3,000 mg/kg. Total phosphorous concentrations were in the range 23-150 mg/kg in the samples analysed. These are below the typical range of 300-900mg/kg.

2.5 Summary and Conclusions

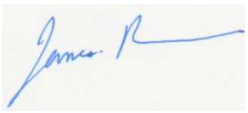
The sediment samples analysed from Myall Quay's Detention Lake show low heavy metals (Cr, Cu, Pb, Hg, Ni and Zn) concentrations which are below the adopted warning levels and may possibly be at background levels.

OCP and PCB were not detected above the laboratory reporting limits. PAH were detected in sample D1 (duplicate of S1) at concentrations below the warning levels for this investigation.

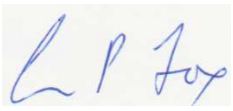
Nutrient concentrations (total nitrogen and total phosphorous) indicate they have not accumulated to levels typical of urban ponds and lakes.

Based on the above investigation it appears that the Myall Quays Detention Lake is not a “pollutant sink” to date. This report has established baseline comparison data for future development and monitoring of the sediments of the detention lake.

For and on behalf of Coffey Environments Pty Ltd



James McMahon
Group Leader Newcastle



Laurie Fox
Associate

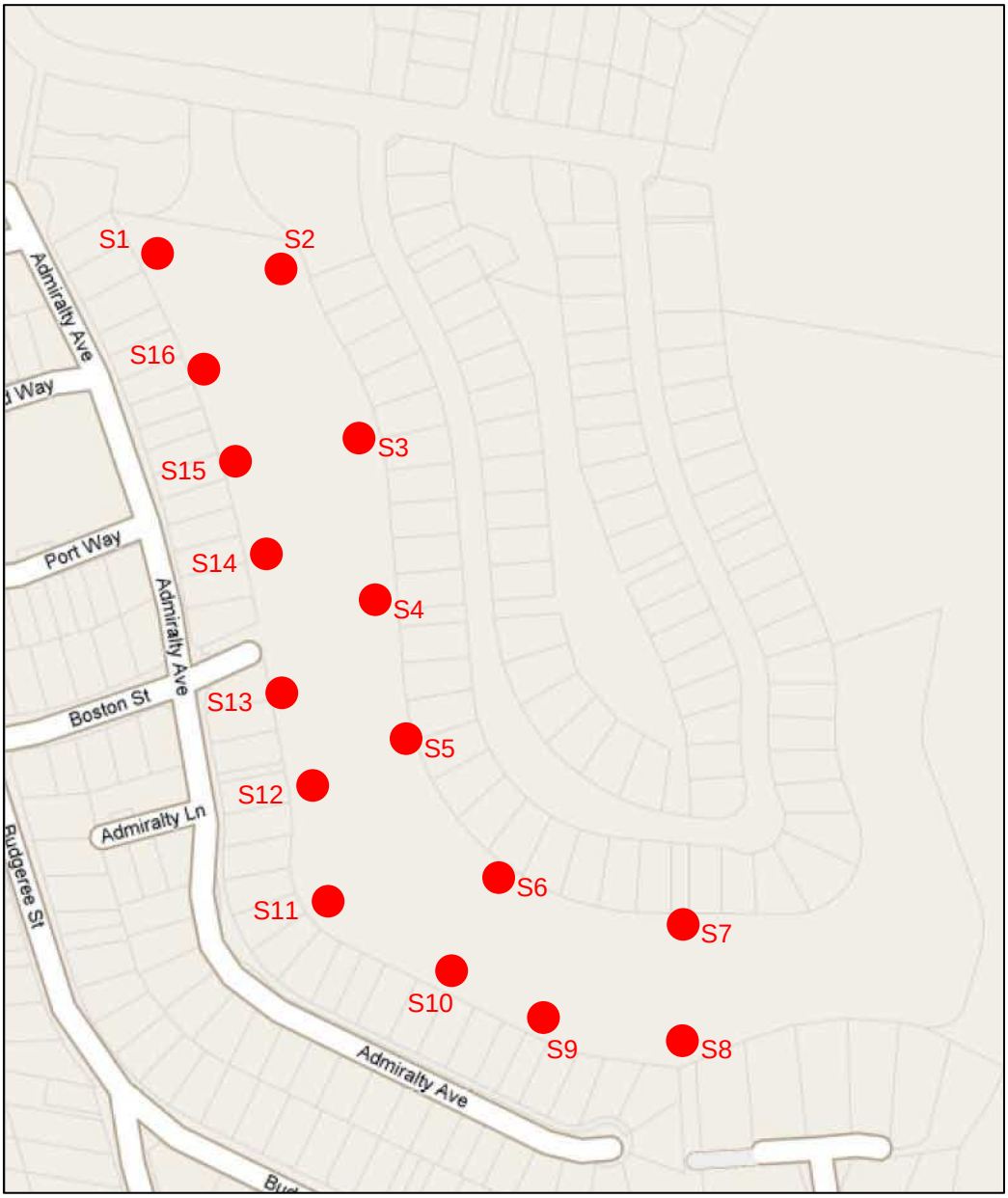
Attachments: Import Information Regarding Your Coffey Environments Report
Figure 1
Figure 2
Table LR1
Table LR2
Table LR3
Table LR4
Laboratory Certificates

---

1 ‘Australian and New Zealand Guidelines for Fresh and Marine Water Quality’, Australian and New Zealand Environment and Conservation Council, 2000.

2 ‘Pond and Wetland Models, Description and Quality Assurances Report’, CRC for Freshwater Ecology, May 2001.

drawn	**NLS**	coffey environments SPECIALISTS IN LIVING AND WORKING PLACES	client:	**TATERSALL SURVEYORS PTY LTD**
approved	JAM		project:	**MYALL QUAYS DETENTION LAKE TEA GARDENS SEDIMENT SAMPLING AND ANALYSIS**
date	**25-10-07**		title:	**SITE LOCALITY PLAN**
scale	**NTS**		project no: **ENVIWARA00137AA**	figure no: **FIGURE 1**
original size	**A4**			



LEGEND

APPROXIMATE SAMPLING LOCATIONS

drawn	**NLS**	coffey environments SPECIALISTS IN LIVING AND WORKING PLACES	client:	**TATERSALL SURVEYORS PTY LTD**
approved	JAM		project:	**MYALL QUAYS DETENTION LAKE TEA GARDENS SEDIMENT SAMPLING AND ANALYSIS**
date	**25-10-07**		title:	**SAMPLING LOCATION PLAN**
scale	**NTS**		project no: **ENVIWARA00137AA**	figure no: **FIGURE 2**
original size	**A4**			

TABLE LR2- RESULTS OF CHEMICAL ANALYSES, SEDIMENT ASSESSMENT

Client:	**Tatersall Surveyors Pty Ltd**											
Project:	**Myall Quays**											
Location:	**Tea Gardens**											
		Polynuclear Aromatic Hydrocarbons µg/kg										
		Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Low Molecular Weight PAHs	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene
ISQG-Low		160	44	16	19	240	85	552	600	665	261	384
ISQG-High		2100	640	500	540	1500	1100	3160	5100	2600	1600	2800
SAMPLE IDENTIFICATION	DEPTH (m)											
S1	0.0-0.05	<10	<10	<10	<10	<10	<10	<50	<10	<10	<10	<10
S7	0.0-0.05	<10	<10	<10	<10	<10	<10	<50	<10	<10	<10	<10
S9	0.0-0.05	<10	<10	<10	<10	<10	<10	<50	<10	<10	<10	<10
S13	0.0-0.05	<10	<10	<10	<10	<10	<10	<50	<10	<10	<10	<10
D1	0.0-0.05	<10	<10	<10	<10	30	<10	<50	80	70	30	30
TRIP1	0.0-0.05	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500

<PQL	Results Below Practical Quantifiable Limit
--	Not Analysed
YELLOW SHADED	Results exceeds ISQG- Low Trigger Value
RED SHADED	Results exceeds ISQG- HighTrigger Value
BLUE SHADED	Laboratory LOR is greater than ISQG-Low trigger value and less than ISQG-High trigger Value
PURPLE SHADED	Laboratory LOR is greater than ISQG-High and results are not able to be interpretted

Criteria from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000), Chapter 3.5 Sediment Quality Guidelines.

Benzo[a]pyrene	Dibenz[a.h]anthracene	High Molecular Weight PAHs
430	63	1700
1600	260	9600
<10	<10	<1000
<10	<10	<1000
<10	<10	<1000
<10	<10	<1000
80	30	<1000
<500	<500	<500

TABLE LR1- RESULTS OF CHEMICAL ANALYSES, SEDIMENT ASSESSMENT

Client:	**Tatersall Surveyors Pty Ltd**								
Project:	**Myall Quays**								
Location:	**Tea Gardens**								
		TPH				BTEX			
		C_6-C_9	C_{10}-C_{14}	C_{15}-C_{28}	C_{29}-C_{36}	Benzene	Toluene	Ethylbenzene	Xylenes
ISQG-Low		NE	NE	NE	NE	NE	NE	NE	NE
ISQG-High		NE	NE	NE	NE	NE	NE	NE	NE
SAMPLE IDENTIFICATION	DEPTH (m)								
S1	0.0-0.05	<20	<20	<50	<50	<0.5	<0.5	<0.5	<0.5
S7	0.0-0.05	<20	<20	<50	<50	<0.5	<0.5	<0.5	<0.5
S9	0.0-0.05	<20	<20	<50	<50	<0.5	<0.5	<0.5	<0.5
S13	0.0-0.05	<20	<20	<50	<50	<0.5	<0.5	<0.5	<0.5
D1	0.0-0.05	<20	<20	<50	<50	<0.5	<0.5	<0.5	<1.5
TRIP1	0.0-0.05	<50	<50	<100	<100	<0.2	<0.5	<0.5	<1.0

<PQL	Results Below Practical Quantifiable Limit
--	Not Analysed
YELLOW SHADED	Results exceeds ISQG- Low Trigger Value
RED SHADED	Results exceeds ISQG- HighTrigger Value
BLUE SHADED	Laboratory LOR is greater than ISQG-Low trigger value and less than ISQG-High trigger Value
PURPLE SHADED	Laboratory LOR is greater than ISQG-High and results are not able to be interpretted

Criteria from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000), Chapter 3.5 Sediment Quality Guidelines.

TABLE LR3- RESULTS OF CHEMICAL ANALYSES, SEDIMENT ASSESSMENT

(concentrations in mg/kg for soil tests and mg/L for TCLP tests)

Client:	**Tatersall Surveyors Pty Ltd**								
Project:	**Myall Quays**								
Location:	**Tea Gardens**								
		Orgonochlorine pesticides/PCBs µg/kg							
		Total DDT	p,p'-DDE	o,p'-+p,p'-DDD	Chlordane	Dieldrin	Endrin	Lindane	Total PCBs
ISQG-Low		1.6	2.2	2	0.5	0.02	0.02	0.32	23
ISQG-High		46	70	20	6	8	8	1	-
SAMPLE IDENTIFICATION	DEPTH (m)								
S1	0.0-0.05	<1	<1	<2	<2	<1	<1	<1	<10
S7	0.0-0.05	<1	<1	<2	<2	<1	<1	<1	<10
S9	0.0-0.05	<1	<1	<2	<2	<1	<1	<1	<10
S13	0.0-0.05	<1	<1	<2	<2	<1	<1	<1	<10
D1	0.0-0.05	<1	<1	<2	<2	<1	<1	<1	<10
TRIP1	0.0-0.05	<50	<50	<50	<50	<50	<50	<50	<100

NOTES:

<PQL	Results Below Practical Quantifiable Limit
--	Not Analysed
YELLOW SHADED	Results exceeds ISQG- Low Trigger Value
RED SHADED	Results exceeds ISQG- HighTrigger Value
BLUE SHADED	Laboratory LOR is greater than ISQG-Low trigger value and less than ISQG-High trigger Value
PURPLE SHADED	Laboratory LOR is greater than ISQG-High and results are not able to be interpretted

CRITERIA:

Criteria from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000), Chapter 3.5 Sediment Quality Guidelines.

TABLE LR4- RESULTS OF CHEMICAL ANALYSES, SEDIMENT ASSESSMENT

Client:	**Tatersall Surveyors Pty Ltd**
Project:	**Myall Quays**
Location:	**Tea Gardens**

		HEAVY METALS/Inorganics mg/kg											Inorganics mg/kg		
		Sb	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Sn	Zn	TP	Nox	TKN
ISQG-Low		2	20	1.5	80	65	50	0.15	21	1	0.005	200	NE	NE	NE
ISQG-High		25	70	10	370	270	220	1	52	3.7	0.07	410	NE	NE	NE
SAMPLE IDENTIFICATION	DEPTH (m)														
S1	0.0-0.05	<3	<3	<0.1	4	1.3	4	<0.05	1.3	<2	<2	14	110	<1.25	320
S2	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S3	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S4	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S5	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S6	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S7	0.0-0.05	<3	3	<0.1	8.4	2.5	4	<0.05	2.7	<2	<2	16	150	<1.25	140
S8	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S9	0.0-0.05	<3	<3	<0.1	3.4	<0.5	2	0.11	1	<2	<2	3.1	23	<1.25	36
S10	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S11	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S12	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S13	0.0-0.05	<3	<3	<0.1	2.4	0.7	2	<0.05	0.91	<2	<2	10	53	<1.25	77
S14	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S15	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
S16	0.0-0.05	NT	NT	NT	NT	NT	NT	<0.05	NT	NT	NT	NT	NT	NT	NT
D1	0.0-0.05	<3	<3	<0.1	3.3	1.4	5	<0.05	1.1	<2	<2	15	77	<1.25	230
TRIP1	0.0-0.05	<5	<5	<1	5	<5	5	0.2	<2	<2	<2	20	76	<0.10	690
%RPD duplicate		NA	NA	NA	19%	7%	22%	NA	17%	NA	NA	7%	35%	NA	33%
%RPD triplicate		NA	NA	NA	22%	NA	22%	NA	NA	NA	NA	35%	37%	NA	73%

<PQL	Results Below Practical Quantifiable Limit
--	Not Analysed
YELLOW SHADED	Results exceeds ISQG- Low Trigger Value
RED SHADED	Results exceeds ISQG- HighTrigger Value
BLUE SHADED	Laboratory LOR is greater than ISQG-Low trigger value and less than ISQG-High trigger Value
PURPLE SHADED	Laboratory LOR is greater than ISQG-High and results are not able to be interpretted

Criteria from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000), Chapter 3.5 Sediment Quality Guidelines.

24 October 2007 **TEST REPORT**

Coffey Environments Pty Ltd
Lot 101, 19 Warabrook Blvd
Warabrook
NSW 2304

Your Reference: ENVIWARA00137AA, (COC#11113)
Report Number: 55703

Attention: James McMahon

Dear James
The following samples were received from you on the date indicated.

Samples: Qty.	21 Soils, 2 Waters
Date of Receipt of Samples:	09/10/07
Date of Receipt of Instructions:	09/10/07
Date Preliminary Report Emailed:	17/10/07

These samples were analysed in accordance with your written instructions.
A copy of the instructions is attached with the analytical report.

The results and associated quality control are contained in the following pages of this report. Unless otherwise stated, solid samples are expressed on a dry weight basis (moisture has been supplied for your information only), air and liquid samples as received.

Should you have any queries regarding this report please contact the undersigned.

Yours faithfully
SGS ENVIRONMENTAL SERVICES

Ly Kim Ha
Senior Organic Chemist

Edward Ibrahim
Laboratory Services Manager

Alexandra Stenta
Key Account Representative

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SGS Australia Pty Ltd
ABN 44 000 964 278
Environmental Services Unit 16, 33 Maddox Street, Alexandria Australia
t (02) 8594 0400 f (02) 8594 0499
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Member of the SGS Group

BTEX in Soil Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Benzene	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
m-Xylene	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
p- Xylene	mg/kg	<0.50	<0.50	<1.0	<0.50	<0.50
o- Xylene	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Total Xylenes	mg/kg	<1.5	<1.5	<1.5	<1.5	<1.5
BTEX Surrogate (%)	%	98	76	76	91	83

BTEX in Soil Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-21 TRIPBLANK Soil 05/10/07	55703-22 TRIPSPIKE Soil 05/10/07
Benzene	mg/kg	<0.5	94%
Toluene	mg/kg	<0.5	98%
Ethylbenzene	mg/kg	<0.5	96%
m-Xylene	mg/kg	<0.5	96%
p- Xylene	mg/kg	<1.0	96%
o- Xylene	mg/kg	<0.50	97%
Total Xylenes	mg/kg	<1.5	97%
BTEX Surrogate (%)	%	122	105%

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TRH in soil with..C6-C9 by P/T Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
TRH C_6 - C_9 P&T	mg/kg	<20	<20	<20	<20	<20
TRH C_{10} - C_{14}	mg/kg	<20	<20	<20	<20	<20
TRH C_{15} - C_{28}	mg/kg	<50	<50	<50	<50	<50
TRH C_{29} - C_{36}	mg/kg	<50	<50	<50	<50	<50

TRH in soil with..C6-C9 by P/T Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-21 TRIPBLANK Soil 05/10/07
TRH C_6 - C_9 P&T	mg/kg	<20
TRH C_{10} - C_{14}	mg/kg	<20
TRH C_{15} - C_{28}	mg/kg	<50
TRH C_{29} - C_{36}	mg/kg	<50

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PAHs in Soil Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Acenaphthene	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthylene	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
2-Methylnaphthanlene	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Anthracene	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorene	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Naphthalene	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Phenanthrene	mg/kg	<0.01	<0.01	<0.01	<0.01	0.03
Benzo[*b*,*k*]fluoranthene	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo[*a*]anthracene	mg/kg	<0.01	<0.01	<0.01	<0.01	0.03
Benzo[*a*]pyrene	mg/kg	<0.01	<0.01	<0.01	<0.01	0.08
Dibenzo[*ah*]anthracene	mg/kg	<0.01	<0.01	<0.01	<0.01	0.01
Chrysene	mg/kg	<0.01	<0.01	<0.01	<0.01	0.03
Fluoranthene	mg/kg	<0.01	<0.01	<0.01	<0.01	0.08
Pyrene	mg/kg	0.01	0.01	<0.01	0.01	0.07
Benzo[*ghi*]perylene	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
p -Terphenyl-*d14*	%	102	102	98	106	106

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OC Pesticides in Soil Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
HCB	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Heptachlor	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Heptachlor Epoxide	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Aldrin	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
gamma-BHC (Lindane)	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
alpha-BHC	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
beta-BHC	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
delta-BHC	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
trans-Chlordane	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
cis-Chlordane	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Oxychlordane	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Dieldrin	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
p,p-DDE	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
p,p-DDD	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
p,p-DDT	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Endrin	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Endrin Aldehyde	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Endrin Ketone	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
alpha-Endosulfan	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
beta-Endosulfan	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Endosulfan Sulphate	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Methoxychlor	mg/kg	<0.001	<0.001	<0.001	<0.001	<0.001
Surrogate	%	78	67	81	82	87

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PCBs in Soil Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Arochlor 1016	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Arochlor 1221	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Arochlor 1232	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Arochlor 1242	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Arochlor 1248	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Arochlor 1254	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Arochlor 1260	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01

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Metals in Soil by ICP-OES Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Antimony	mg/kg	<3	<3	<3	<3	<3
Arsenic	mg/kg	<3	3	<3	<3	<3
Cadmium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	mg/kg	4.0	8.4	3.4	2.4	3.3
Copper	mg/kg	1.3	2.5	<0.5	0.7	1.4
Lead	mg/kg	4	4	2	2	5
Nickel	mg/kg	1.3	2.7	1.0	0.91	1.1
Silver	mg/kg	<2	<2	<2	<2	<2
Tin	mg/kg	<2	<2	<2	<2	<2
Zinc	mg/kg	14	16	3.1	10	15
Phosphorus (Total)	mg/kg	110	150	23	53	77

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Mercury Cold Vapor/Hg Analyser Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Mercury	mg/kg	<0.05	<0.05	0.11	<0.05	<0.05

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Anions in soil Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Nitrite as N 1:5 soil:water	mg/kg	<1	<1	<1	<1	<1
Nitrate as N 1:5 soil:water	mg/kg	<0.25	<0.25	<0.25	<0.25	<0.25

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Inorganics Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Total Kjeldahl Nitrogen *	mg/kg	320	140	36	77	230

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Trace HM (ICP-MS)-Dissolved Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-19 BACKGRO UND Water 05/10/07	55703-20 RINSATE Water 05/10/07
Antimony	µg/L	<1.0	1.8
Arsenic	µg/L	2.0	2.5
Cadmium	µg/L	<0.10	<0.10
Chromium	µg/L	1.3	1.4
Copper	µg/L	3.7	4.7
Lead	µg/L	<1.0	<1.0
Nickel	µg/L	<1.0	<1.0
Silver	µg/L	4.6	1.9
Zinc	µg/L	11	1.9

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Metals in water by ICP-OES			
Our Reference:	UNITS	55703-19	55703-20
Your Reference	----------	BACKGROUND	RINSATE
Sample Type	----------	Water	Water
Date Sampled		05/10/07	05/10/07
Tin (Dissolved)	mg/L	<0.03	<0.03

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Mercury Cold Vapor/Hg Analyser Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-19 BACKGRO UND Water 05/10/07	55703-20 RINSATE Water 05/10/07
Mercury (Dissolved)	mg/L	<0.0005	<0.0005

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Moisture Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-1 S1 Soil 05/10/07	55703-7 S7 Soil 05/10/07	55703-9 S9 Soil 05/10/07	55703-13 S13 Soil 05/10/07	55703-17 D1 Soil 05/10/07
Moisture	%	26	41	24	25	28

Moisture Our Reference: Your Reference Sample Type Date Sampled	UNITS ---------- ----------	55703-21 TRIPBLANK Soil 05/10/07
Moisture	%	<1

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Method ID	Methodology Summary
SEO-018	BTEX - Determination by purge and trap/ Gas Chromatography with MS Detection.
SEO-017	BTEX/TRH C6-C9 - Determination by Purge and Trap Gas Chromatography with Flame Ionisation Detection (FID) and Photo Ionisation Detection (PID). The surrogate spike used is aaa-trifluorotoluene.
SEO-020	TRH - Determination of Total Recoverable Hydrocarbons by gas chromatography following extraction with DCM/Acetone for solids and DCM for liquids.
Ext-003	Analysis subcontracted to SGS Environmental Perth.
SEO-030	PAHs by GC/MS - Determination of Polynuclear Aromatic Hydrocarbons (PAH's) by Gas Chromatography / Mass Spectrometry following extraction with dichloromethane or dichloromethane/acetone. The surrogate spike used is p-Terphenyl-d14.
Ext-048	Subcontracted analysis to Analytical National Measurement Institute, NSW.
SEO-005	OC/OP/PCB - Determination of a suite of Organchlorine Pesticides, Chlorinated Organo-phosphorus Pesticides and Polychlorinated Biphenyls (PCB's) by sonication extraction using dichloromethane for waters or acetone / hexane for soils followed by Gas Chromatographic separation with Electron Capture Detection (GC/ECD). The surrogate spike used is 2,4,5,6-Tetrachloro-m-xylene.
SEM-010	Metals - Determination of various metals by ICP-AES following aqua regia digest.
SEM-005	Mercury - Determination of Mercury by Cold Vapour Generation Atomic Absorption Spectroscopy.
SEI-038	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA 20th ED, 4110-B.
Ext-043	Subcontracted to LabPoint. Nata Accreditation No: 11111
AN318	Determination of elements at trace levels in waters by ICP-MS. Method based on USEPA 6020A
AN320	Metals - Determination of various metals by ICP-OES at trace levels following aqua regia digest.
AN002	Preparation of soils, sediments and sludges undergo analysis by either air drying, compositing, subsampling and 1:5 soil water extraction where required. Moisture content is determined by drying the sample at 105 ± 5°C.

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QUALITY CONTROL BTEX in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Benzene	mg/kg	0.5	SEO-018	<0.5	[NT]	[NT]	LCS	87 || [N/T]
Toluene	mg/kg	0.5	SEO-018	<0.5	[NT]	[NT]	LCS	89 || [N/T]
Ethylbenzene	mg/kg	0.5	SEO-018	<0.5	[NT]	[NT]	LCS	88 || [N/T]
m-Xylene	mg/kg	0.5	SEO-018	<0.5	[NT]	[NT]	LCS	90 || [N/T]
p- Xylene	mg/kg	0.5	SEO-018	<0.50	[NT]	[NT]	LCS	90 || [N/T]
o- Xylene	mg/kg	0.5	SEO-018	<0.50	[NT]	[NT]	LCS	92 || [N/T]
Total Xylenes	mg/kg	1.5	SEO-018	<1.5	[NT]	[NT]	LCS	91 || [N/T]
BTEX Surrogate (%)	%	0	SEO-018	105	[NT]	[NT]	LCS	112 || [N/T]
QUALITY CONTROL TRH in soil with..C6-C9 by P/T	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
TRH C_6 - C_9 P&T	mg/kg	20	SEO-017	<20	[NT]	[NT]	LCS	98 || [N/T]
TRH C_{10} - C_{14}	mg/kg	20	SEO-020	<20	[NT]	[NT]	LCS	100 || [N/T]
TRH C_{15} - C_{28}	mg/kg	50	SEO-020	<50	[NT]	[NT]	LCS	95 || [N/T]
TRH C_{29} - C_{36}	mg/kg	50	SEO-020	<50	[NT]	[NT]	LCS	106 || [N/T]
QUALITY CONTROL PAHs in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Acenaphthene	mg/kg	0.01	Ext-003	<0.01	55703-1	<0.01 || <0.01	[NR]	[NR]
Acenaphthylene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	[NR]	[NR]
2-Methylnaphthanlene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	[NR]	[NR]
Anthracene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	[NR]	[NR]
Fluorene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	55703-1	101 || 91 || RPD: 10
Naphthalene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	55703-1	90 || 80 || RPD: 12
Phenanthrene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	55703-1	97 || 104 || RPD: 7
Benzo[*b,k*]fluoranthene	mg/kg	0.5	Ext-003	[NT]	55703-1	<0.5 || <0.5	[NR]	[NR]
Benzo[*a*]anthracene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || 0.01	55703-1	93 || 109 || RPD: 16
Benzo[*a*]pyrene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || 0.02	55703-1	113 || 132 || RPD: 16
Dibenzo[*ah*]anthracene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	55703-1	111 || 106 || RPD: 5
Chrysene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || <0.01	[NR]	[NR]
Fluoranthene	mg/kg	0.01	SEO-030	<0.01	55703-1	<0.01 || 0.02	[NR]	[NR]
Pyrene	mg/kg	0.01	SEO-030	<0.01	55703-1	0.01 || 0.02 || RPD: 67	55703-1	102 || 126 || RPD: 21
Benzo[*ghi*]perylene	mg/kg	1	Ext-003	[NT]	55703-1	<1.0 || <1.0	[NR]	[NR]
p -Terphenyl-*d* 14	%	0	SEO-030	108	55703-1	102 || 102 || RPD: 0	55703-1	108 || 106 || RPD: 2

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QUALITY CONTROL OC Pesticides in Soil	UNITS	PQL	METHOD	Blank
HCB	mg/kg	0.001	Ext-048	<0.001
Heptachlor	mg/kg	0.001	SEO-005	<0.001
Heptachlor Epoxide	mg/kg	0.001	SEO-005	<0.001
Aldrin	mg/kg	0.001	SEO-005	<0.001
gamma-BHC (Lindane)	mg/kg	0.001	SEO-005	<0.001
alpha-BHC	mg/kg	0.001	SEO-005	<0.001
beta-BHC	mg/kg	0.001	SEO-005	<0.001
delta-BHC	mg/kg	0.001	SEO-005	<0.001
trans-Chlordane	mg/kg	0.001	SEO-005	<0.001
cis-Chlordane	mg/kg	0.001	SEO-005	<0.001
Oxychlordane	mg/kg	0.001	SEO-005	<0.001
Dieldrin	mg/kg	0.001	SEO-005	<0.001
p,p-DDE	mg/kg	0.001	SEO-005	<0.001
p,p-DDD	mg/kg	0.001	SEO-005	<0.001
p,p-DDT	mg/kg	0.001	SEO-005	<0.001
Endrin	mg/kg	0.001	SEO-005	<0.001
Endrin Aldehyde	mg/kg	0.001	SEO-005	<0.001
Endrin Ketone	mg/kg	0.001	SEO-005	<0.001
alpha-Endosulfan	mg/kg	0.001	SEO-005	<0.001
beta-Endosulfan	mg/kg	0.001	SEO-005	<0.001
Endosulfan Sulphate	mg/kg	0.001	SEO-005	<0.001
Methoxychlor	mg/kg	0.001	SEO-005	<0.001
Surrogate	%	0	SEO-005	[NT]

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QUALITY CONTROL PCBs in Soil	UNITS	PQL	METHOD	Blank
Arochlor 1016	mg/kg	0.01	SEO-005	<0.01
Arochlor 1221	mg/kg	0.01	SEO-005	<0.01
Arochlor 1232	mg/kg	0.01	SEO-005	<0.01
Arochlor 1242	mg/kg	0.01	SEO-005	<0.01
Arochlor 1248	mg/kg	0.01	SEO-005	<0.01
Arochlor 1254	mg/kg	0.01	SEO-005	<0.01
Arochlor 1260	mg/kg	0.01	SEO-005	<0.01

QUALITY CONTROL Metals in Soil by ICP-OES	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Antimony	mg/kg	3	SEM-010	<3	[NT]	[NT]	LCS	109 || [N/T]
Arsenic	mg/kg	3	SEM-010	<3	[NT]	[NT]	LCS	104 || [N/T]
Cadmium	mg/kg	0.1	SEM-010	<0.1	[NT]	[NT]	LCS	109 || [N/T]
Chromium	mg/kg	0.3	SEM-010	<0.3	[NT]	[NT]	LCS	103 || [N/T]
Copper	mg/kg	0.5	SEM-010	<0.5	[NT]	[NT]	LCS	107 || [N/T]
Lead	mg/kg	1	SEM-010	<1	[NT]	[NT]	LCS	106 || [N/T]
Nickel	mg/kg	0.5	SEM-010	<0.5	[NT]	[NT]	LCS	107 || [N/T]
Silver	mg/kg	2	SEM-010	<2	[NT]	[NT]	LCS	118 || [N/T]
Tin	mg/kg	2	SEM-010	<2	[NT]	[NT]	LCS	103 || [N/T]
Zinc	mg/kg	0.3	SEM-010	<0.3	[NT]	[NT]	LCS	107 || [N/T]
Phosphorus (Total)	mg/kg	0.1	SEM-010	<0.10	[NT]	[NT]	LCS	100 || [N/T]

QUALITY CONTROL Mercury Cold Vapor/Hg Analyser	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Mercury	mg/kg	0.05	SEM-005	<0.05	[NT]	[NT]	LCS	77 || [N/T]

QUALITY CONTROL Anions in soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Nitrite as N 1:5 soil:water	mg/kg	1	SEI-038	<1	55703-1	<1 || <1	LCS	102 || [N/T]
Nitrate as N 1:5 soil:water	mg/kg	0.25	SEI-038	<0.25	55703-1	<0.25 || <0.25	LCS	104 || [N/T]

QUALITY CONTROL Inorganics	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Total Kjeldahl Nitrogen *	mg/kg	1.0	Ext-043	<1.0	55703-1	320 || [N/T]	55703-1	90 || [N/T]

QUALITY CONTROL Trace HM (ICP-MS)-Dissolved	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Antimony	µg/L	1	AN318	<1.0	[NT]	[NT]	LCS	125 || [N/T]
Arsenic	µg/L	1	AN318	<1.0	[NT]	[NT]	LCS	100 || [N/T]

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QUALITY CONTROL **Trace HM (ICP-MS)-Dissolved**	**UNITS**	**PQL**	**METHOD**	**Blank**	**Duplicate Sm#**	**Duplicate** **Base + Duplicate + %RPD**	**Spike Sm#**	**Matrix Spike % Recovery** **Duplicate + %RPD**
Cadmium	µg/L	0.1	AN318	<0.10	[NT]	[NT]	LCS	101 || [N/T]
Chromium	µg/L	1	AN318	<1.0	[NT]	[NT]	LCS	102 || [N/T]
Copper	µg/L	1	AN318	<1.0	[NT]	[NT]	LCS	106 || [N/T]
Lead	µg/L	1	AN318	<1.0	[NT]	[NT]	LCS	99 || [N/T]
Nickel	µg/L	1	AN318	<1.0	[NT]	[NT]	LCS	96 || [N/T]
Silver	µg/L	1	AN320	<1.0	[NT]	[NT]	LCS	90 || [N/T]
Zinc	µg/L	1	AN318	<1.0	[NT]	[NT]	LCS	102 || [N/T]
QUALITY CONTROL Metals in water by ICP-OES	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Tin (Dissolved)	mg/L	0.03	SEM-010	<0.03	[NT]	[NT]	LCS	97 || [N/T]
QUALITY CONTROL Mercury Cold Vapor/Hg Analyser	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Matrix Spike % Recovery Duplicate + %RPD
Mercury (Dissolved)	mg/L	0.0005	SEM-005	<0.0005	[NT]	[NT]	LCS	97 || [N/T]

QUALITY CONTROL Hold sample-**NO test** required	UNITS	PQL	METHOD	Blank
Sample on HOLD				[NT]
QUALITY CONTROL Moisture	UNITS	PQL	METHOD	Blank
Moisture	%	1	AN002	<1

QUALITY CONTROL Inorganics	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD
Total Kjeldahl Nitrogen *	mg/kg	55703-17	230 || 220 || RPD: 4

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Result Codes

[INS]	:	Insufficient Sample for this test	[HBG]	:	Results not Reported due to High Background Interference
[NR]	:	Not Requested	*	:	Not part of NATA Accreditation
[NT]	:	Not tested	[N/A]	:	Not Applicable

Result Comments

PAH in Soil was analysed by SGS Perth with Report No 13739.

OC/ PCB in Soil were analysed by NMI with Report No SGSA01/071010.

Date Organics extraction commenced: 10/10/07
NATA Corporate Accreditation No. 2562, Site No 4354
Note: Test results are not corrected for recovery (excluding Dioxins/Furans* and PAH in XAD and PUF).
This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

Quality Control Protocol

Reagent Blank: Sample free reagents carried through the preparation/extraction/digestion procedure and analysed at the beginning of every sample batch analysis. For larger projects, a reagent blank is prepared and analysed with every 20 samples.
Duplicate: A separate portion of a sample being analysed which is treated the same as the other samples in the batch. A duplicate is prepared at least every 10 samples.
Matrix Spike Duplicates: Sample replicates spiked with identical concentrations of target analyte(s). The spiking occurs during the sample preparation and prior to the extraction/digestion procedure. They are used to document the precision and bias of a method in a given sample matrix. Where there is not enough sample available to prepare a spiked sample, another known soil/sand or water (or Milli-Q water) may be used. A duplicate spiked sample is prepared at least every 20 samples.
Surrogate Spike: Added to all samples requiring analysis for organics (where relevant) prior to extraction. Used to determine the extraction efficiency. They are organic compounds which are similar to the target analyte(s) in chemical composition and behaviour in the analytical process, but which are not normally found in environmental samples.
Internal Standard: Added to all samples requiring analysis for organics (where relevant) after the extraction process; the compounds serve to give a standard of retention time and response, which is invariant from run-to-run with the instruments.
Control Standards: Prepared from a source independent of the calibration standards. At least one control standard is included in each run to confirm calibration validity.
Additional QC Samples: A calibration standard and blank are run after every 20 samples of an instrumental analysis run to assess analytical drift.

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S151-52 WL25

coffey

Chain of Custody

No: 11113

Laboratory Quotation / Order No: S184-89JJT Job No: ENVIWARA00137AA Sheet 1 of 2

Dispatch to: (Address & Phone No.) SGS Laboratories 16/33 Maddox St Alexandria	Sampled by: Jonathan Tonk	Consigning Officer: / Date Dispatched:
Attention: Login	Project Manager: (report results to) James McMahon.	Courier Service: TNT. / Consignment Note No:

Relinquished by:	Date:	Time:	Received by:	Date:	Time:
			Emily Lin	9/10	3.30

Comments	Sample Matrix	Container Type and Preservative	Sample No.	Date Sampled	PAHs	TPHs	~~VHCs~~ = BTEX	Metals: *	OC/PCB	Nutrients	Sample Condition on Receipt
1	Soil	Soil jars	S1	5/10/07	X	X	X	X	X	X	
2			S2		HOLD						
3			S3		HOLD						
4			S4		HOLD						
5			S5		HOLD						
6			S6		HOLD						
7			S7		X	X	X	X	X	X	
8			S8		HOLD						
9			S9		X	X	X	X	X	X	
10			S10		HOLD						
11			S11		HOLD						
12			S12		HOLD						
13			S13		X	X	X	X	X	X	
14			S14		HOLD						
15			S15		HOLD						
16			S16		HOLD						
17			D1		X	X	X	X	X	X	

SGS Received 9.1.07 By ... Time 9.1.07 @ am/pm Samples Intact ... Yes/no Ice/Cooler Pack ... Yes/no Comments: ESDAT

Special Laboratory Instructions: ALL ANALYSIS to be conducted by ANZECC sediment guidelines detection limit
*Heavy Metals Sb, Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn, As, Sn
Nutrients = Total Phosporow, TKN, Nitrate, Nitrite

Detection Limits:

Turnaround Required:

JOB NUMBER MUST BE REFERENCED ON ALL SUBSEQUENT PAGES

Copies: WHITE: Sign on release. YELLOW: If dispatched to interstate Lab, Lab to sign on receipt and fax back to Coffey. BLUE: To be returned with results.

6422015-06

coffey

Chain of Custody

No: 11114

Laboratory Quotation / Order No: S18489 SJT. Job No: ENVIWARA00137AA Sheet 2 of 2.

Dispatch to: (Address & Phone No.) SGS Labs	Sampled by: Jonathan Tonks	Consigning Officer: / Date Dispatched:
Attention: Login	Project Manager: (report results to) James McMahon.	Courier Service: / Consignment Note No:

Relinquished by:	Date:	Time:	Received by:	Date:	Time:
				9/10	3.00

Comments	Sample Matrix	Container Type and Preservative	Sample No.	Date Sampled	Analyses Required: PAHs	TPHs	~~BTEX~~ BTEX	Metals:	OCP/PCB	Nutrients								Sample Condition on Receipt
18	Soil	Soil jars	TRIP1	5/10/07	X	X	X	X	+	X		FORWARD TO ALS.						
19	Water	Metals Bottle	BACKGROUND					X										
20	Water	Metals Bottle	RINSATE					X										
21 Soil	Water	~~SS~~ Vial	TRIP BLANK		-	X	X											
22 Soil	Water	Vial	TRIPSPIKE				X											
23	Soil	Soil jar	D2.		HOLD													

Special Laboratory Instructions: ALL ANALYSIS to be conducted by ANZECC GUIDELINES (sediment), detection limit & Heavy metals Sb, Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn, As, Sn. Nutrients = Total Phosphorus, TKN, Nitrate, Nitrite

Detection Limits:

Turnaround Required:

JOB NUMBER **MUST** BE REFERENCED ON ALL SUBSEQUENT PAGES

Copies: **WHITE:** Sign on release. **YELLOW:** If dispatched to interstate Lab, Lab to sign on receipt and fax back to Coffey. **BLUE:** To be returned with results.

6422/09-06

coffey environments

PURCHASE ORDER

S 18489 JJT

Coffey Environments Pty Ltd ABN 45 090 522 759

DATE 9/10/07

TO SGS Laboratories
16/33 Maddox St.
Alexandria NSW 2015

SHIP TO 19 Warabrook Boulevard
Warabrook NSW 2304

JOB NAME	PROJECT MANAGER	JOB #	TASK #
Myall Keys	James McMahon	~~S18489 JJT~~ ENVIWARA00137AA	Sampling.

QTY. ORDERED	STOCK NO. / DESCRIPTION	UNIT PRICE	TOTAL

This purchase order is issued in accordance with the Terms & Conditions as listed overleaf.

J Tonkin
P. O. ORIGINATOR

APPROVED BY

PLEASE QUOTE PURCHASE ORDER NO. ON ALL INVOICES

GOWANS & SON PRINTERS (02) 9755 3545

AU.SampleReceipt.Sydney (Sydney)

From: Jonathan Tonks [Jonathan_Tonks@coffey.com]
Sent: Tuesday, 9 October 2007 3:29 PM
To: AU.SampleReceipt.Sydney (Sydney)
Subject: Attention Alex/Angelica
Importance: High
Attachments: 1285_001.pdf

In regard to the fax regarding the samples which arrived without a COC (ENVIRHOD00137AA) there were a couple of things I forgot to mention. The trip blank and spike are soil, not water as per the COC. Also, as we were late back, the samples went into the fridge and we forgot to put the trip blank and spike back in. They will be arriving tomorrow morning with the original paperwork; could you please test that as the same job please?

Thanks again

JONATHAN TONKS
Environmental Scientist

Coffey Environments Pty Ltd
19 Warabrook Boulevard Warabrook NSW 2304 Australia
T (+61) (2) 4016 2300 F (+61) (2) 4016 2380 M 0420 960 040

www.coffey.com

From: COFFEY GEOTECHNICS P/L [mailto:Wara_Scan@coffey.com.au]
Sent: Tuesday, 9 October 2007 2:38 PM
To: Jonathan Tonks
Subject: Attached Image

Company Notice: To reflect our increasing global footprint, we no longer have .au on our web and email addresses.

Please update your databases, address books and bookmarks to:

www.coffey.com
firstname_lastname@coffey.com

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CILDISCL0004

ALS Environmental

CERTIFICATE OF ANALYSIS

Client	: COFFEY ENVIRONMENTS PTY LTD	Laboratory	: Environmental Division Sydney	Page	: 1 of 6
Contact	: MR JAMES MCMAHON	Contact	: Victor Kedicioglu	Work Order	: ES0714015
Address	: 19 WARABRROK BOULEVARD WARABROOK NSW AUSTRALIA 2304	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164		
E-mail	: james_mcmahon@coffey.com	E-mail	: Victor.Kedicioglu@alsenviro.com		
Telephone	: 4016 2300	Telephone	: +61-2-8784 8555		
Facsimile	: 4016 2380	Facsimile	: +61-2-8784 8500		
Project	: ENVIWARA00137AA	Quote number	: EN/007/07	Date received	: 10 Oct 2007
Order number	: S18489			Date issued	: 18 Oct 2007
C-O-C number	: 11114			No. of samples	- Received : 1
Site	: - Not provided -				Analysed : 1

ALSE - Excellence in Analytical Testing

NATA Accredited Laboratory 825

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This document has been electronically signed by those names that appear on this report and are the authorised signatories. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatory	Position	Department
Ankit Joshi	Inorganic Chemist	Inorganics - NATA 825 (10911 - Sydney)
Celine Conceicao	Spectroscopist	Inorganics - NATA 825 (10911 - Sydney)
Hoa Nguyen		Inorganics - NATA 825 (10911 - Sydney)
PHALAK INTHAKESONE	Organics Co-ordinator	Inorganics - NATA 825 (10911 - Sydney)
PHALAK INTHAKESONE	Organics Co-ordinator	Organics - NATA 825 (10911 - Sydney)

Comments

This report for the ALSE reference ES0714015 supersedes any previous reports with this reference. Results apply to the sample as submitted. All pages of this report have been checked and approved for release.

This report contains the following information:

- **Analytical Results for Samples Submitted**
- **Surrogate Recovery Data**

The analytical procedures used by ALS Environmental have been developed from established internationally-recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported herein. Reference methods from which ALSE methods are based are provided in parenthesis.

When moisture determination has been performed, results are reported on a dry weight basis. When a reported 'less than' result is higher than the LOR, this may be due to primary sample extracts/digestion dilution and/or insuffient sample amount for analysis. Surrogate Recovery Limits are static and based on USEPA SW846 or ALS-QWI/EN38 (in the absence of specified USEPA limits). Where LOR of reported result differ from standard LOR, this may be due to high moisture, reduced sample amount or matrix interference. When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for process purposes. Abbreviations: CAS number = Chemical Abstract Services number, LOR = Limit of Reporting. * Indicates failed Surrogate Recoveries.

ALS Environmental

Analytical Results

				Client Sample ID :	TRIP1				
				Sample Matrix Type / Description :	SOIL				
				Sample Date / Time :	5 Oct 2007 15:00				
				Laboratory Sample ID :	ES0714015-001				
Analyte	**CAS number**	**LOR**	**Units**						
EA055: Moisture Content									
Moisture Content (dried @ 103°C)		1.0	%		33.4				
EG005T: Total Metals by ICP-AES									
Antimony	7440-36-0	5	mg/kg		<5				
Arsenic	7440-38-2	5	mg/kg		<5				
Cadmium	7440-43-9	1	mg/kg		<1				
Chromium	7440-47-3	2	mg/kg		5				
Copper	7440-50-8	5	mg/kg		<5				
Lead	7439-92-1	5	mg/kg		5				
Nickel	7440-02-0	2	mg/kg		<2				
Silver	7440-22-4	2	mg/kg		<2				
Tin	7440-31-5	5	mg/kg		<5				
Zinc	7440-66-6	5	mg/kg		20				
EG035T: Total Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		0.2				
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)		0.100	mg/kg		<0.100				
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)		0.100	mg/kg		<0.100				
EK059G: NOX as N by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)		0.100	mg/kg		<0.100				
EK061G: Total Kjeldahl Nitrogen as N									
Total Kjeldahl Nitrogen as N		20	mg/kg		690				
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P		2	mg/kg		76				
EP066: Polychlorinated Biphenyls (PCB)									
Total Polychlorinated biphenyls		0.10	mg/kg		<0.10				
EP068A: Organochlorine Pesticides (OC)									
alpha-BHC	319-84-6	0.05	mg/kg		<0.05				
Hexachlorobenzene (HCB)	118-74-1	0.05	mg/kg		<0.05				
beta-BHC	319-85-7	0.05	mg/kg		<0.05				
gamma-BHC	58-89-9	0.05	mg/kg		<0.05				
delta-BHC	319-86-8	0.05	mg/kg		<0.05				
Heptachlor	76-44-8	0.05	mg/kg		<0.05				
Aldrin	309-00-2	0.05	mg/kg		<0.05				
Heptachlor epoxide	1024-57-3	0.05	mg/kg		<0.05				
trans-Chlordane	5103-74-2	0.05	mg/kg		<0.05				
alpha-Endosulfan	959-98-8	0.05	mg/kg		<0.05				

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Analytical Results

	Client Sample ID :	TRIP1				
	Sample Matrix Type / Description :	SOIL				
	Sample Date / Time :	5 Oct 2007 15:00				
	Laboratory Sample ID :	ES0714015-001				
Analyte	CAS number	LOR	Units			
EP068A: Organochlorine Pesticides (OC)						
cis-Chlordane	5103-71-9	0.05	mg/kg	<0.05		
Dieldrin	60-57-1	0.05	mg/kg	<0.05		
4.4'-DDE	72-55-9	0.05	mg/kg	<0.05		
Endrin	72-20-8	0.05	mg/kg	<0.05		
beta-Endosulfan	33213-65-9	0.05	mg/kg	<0.05		
4.4'-DDD	72-54-8	0.05	mg/kg	<0.05		
Endrin aldehyde	7421-93-4	0.05	mg/kg	<0.05		
Endosulfan sulfate	1031-07-8	0.05	mg/kg	<0.05		
4.4'-DDT	50-29-3	0.2	mg/kg	<0.2		
Endrin ketone	53494-70-5	0.05	mg/kg	<0.05		
Methoxychlor	72-43-5	0.2	mg/kg	<0.2		
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons						
Naphthalene	91-20-3	0.5	mg/kg	<0.5		
Acenaphthylene	208-96-8	0.5	mg/kg	<0.5		
Acenaphthene	83-32-9	0.5	mg/kg	<0.5		
Fluorene	86-73-7	0.5	mg/kg	<0.5		
Phenanthrene	85-01-8	0.5	mg/kg	<0.5		
Anthracene	120-12-7	0.5	mg/kg	<0.5		
Fluoranthene	206-44-0	0.5	mg/kg	<0.5		
Pyrene	129-00-0	0.5	mg/kg	<0.5		
Benz(a)anthracene	56-55-3	0.5	mg/kg	<0.5		
Chrysene	218-01-9	0.5	mg/kg	<0.5		
Benzo(b)fluoranthene	205-99-2	0.5	mg/kg	<0.5		
Benzo(k)fluoranthene	207-08-9	0.5	mg/kg	<0.5		
Benzo(a)pyrene	50-32-8	0.5	mg/kg	<0.5		
Indeno(1.2.3.cd)pyrene	193-39-5	0.5	mg/kg	<0.5		
Dibenz(a.h)anthracene	53-70-3	0.5	mg/kg	<0.5		
Benzo(g.h.i)perylene	191-24-2	0.5	mg/kg	<0.5		
EP080/071: Total Petroleum Hydrocarbons						
C6 - C9 Fraction		10	mg/kg	<10		
C10 - C14 Fraction		50	mg/kg	<50		
C15 - C28 Fraction		100	mg/kg	<100		
C29 - C36 Fraction		100	mg/kg	<100		
EP080: BTEX						
Benzene	71-43-2	0.2	mg/kg	<0.2		
Toluene	108-88-3	0.5	mg/kg	<0.5		
Ethylbenzene	100-41-4	0.5	mg/kg	<0.5		

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Analytical Results

	Client Sample ID :	TRIP1				
	Sample Matrix Type / Description :	SOIL				
	Sample Date / Time :	5 Oct 2007 15:00				
	Laboratory Sample ID :	ES0714015-001				
Analyte	CAS number	LOR	Units			
EP080: BTEX						
meta- & para-Xylene	108-38-3 106-42-3	0.5	mg/kg	<0.5		
ortho-Xylene	95-47-6	0.5	mg/kg	<0.5		
EP066S: PCB Surrogate						
Decachlorobiphenyl	2051-24-3	0.1	%	84.7		
EP068S: Organochlorine Pesticide Surrogate						
Dibromo-DDE	21655-73-2	0.1	%	97.4		
EP068T: Organophosphorus Pesticide Surrogate						
DEF	78-48-8	0.1	%	100		
EP075(SIM)S: Phenolic Compound Surrogates						
Phenol-d6	13127-88-3	0.1	%	103		
2-Chlorophenol-D4	93951-73-6	0.1	%	102		
2.4.6-Tribromophenol	118-79-6	0.1	%	76.7		
EP075(SIM)T: PAH Surrogates						
2-Fluorobiphenyl	321-60-8	0.1	%	104		
Anthracene-d10	1719-06-8	0.1	%	93.7		
4-Terphenyl-d14	1718-51-0	0.1	%	99.0		
EP080S: TPH(V)/BTEX Surrogates						
1.2-Dichloroethane-D4	17060-07-0	0.1	%	94.9		
Toluene-D8	2037-26-5	0.1	%	92.9		
4-Bromofluorobenzene	460-00-4	0.1	%	98.6		

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Surrogate Control Limits

Matrix Type: SOIL - Surrogate Control Limits ***Surrogate Control Limits***

Method name	*Analyte name*	*Lower Limit*	*Upper Limit*
EP066: Polychlorinated Biphenyls (PCB)			
EP066S: PCB Surrogate	Decachlorobiphenyl	10	164
EP068: Pesticides by GCMS			
EP068S: Organochlorine Pesticide Surrogate	Dibromo-DDE	10	136
EP068T: Organophosphorus Pesticide Surrogate	DEF	10	136
EP075(SIM): PAH/Phenols (SIM)			
EP075(SIM)S: Phenolic Compound Surrogates	Phenol-d6	24	113
	2-Chlorophenol-D4	23	134
	2,4,6-Tribromophenol	19	122
EP075(SIM)T: PAH Surrogates	2-Fluorobiphenyl	30	115
	Anthracene-d10	27	133
	4-Terphenyl-d14	18	137
EP080: TPH Volatiles/BTEX			
EP080S: TPH(V)/BTEX Surrogates	1,2-Dichloroethane-D4	80	120
	Toluene-D8	81	117
	4-Bromofluorobenzene	74	121

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Important information about your **Coffey** Environmental Report

Uncertainties as to what lies below the ground on potentially contaminated sites can lead to remediation costs blow outs, reduction in the value of the land and to delays in the redevelopment of land. These uncertainties are an inherent part of dealing with land contamination. The following notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report has been written for a specific purpose

Your report has been developed on the basis of a specific purpose as understood by Coffey and applies only to the site or area investigated. For example, the purpose of your report may be:

- To assess the environmental effects of an on-going operation.
- To provide due diligence on behalf of a property vendor.
- To provide due diligence on behalf of a property purchaser.
- To provide information related to redevelopment of the site due to a proposed change in use, for example, industrial use to a residential use.
- To assess the existing baseline environmental, and sometimes geological and hydrological conditions or constraints of a site prior to an activity which may alter the sites environmental, geological or hydrological condition.

For each purpose, a specific approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible, quantify risks that both recognised and unrecognised contamination pose to the proposed activity. Such risks may be both financial (for example, clean up costs or limitations to the site use) and physical (for example, potential health risks to users of the site or the general public).

Scope of Investigations

The work was conducted, and the report has been prepared, in response to specific instructions from the client to whom this report is addressed, within practical time and budgetary constraints, and in reliance on certain data and information made available to Coffey. The analyses, evaluations, opinions and conclusions presented in this report are based on those instructions, requirements, data or information, and they could change if such instructions etc. are in fact inaccurate or incomplete.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man and may change with time. For example, groundwater levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of the subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project and/or on the property.

Interpretation of factual data

Environmental site assessments identify actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from indirect field measurements and sometimes other reports on the site are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how well qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of Coffey through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other problems encountered on site.

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Important information about your **Coffey** Environmental Report

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered with redevelopment or on-going use of the site. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. In particular, a due diligence report for a property vendor may not be suitable for satisfying the needs of a purchaser. Your report should not be applied for any purpose other than that originally specified at the time the report was issued.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other professionals who are affected by the report. Have Coffey explain the report implications to professionals affected by them and then review plans and specifications produced to see how they have incorporated the report findings.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel), field testing and laboratory evaluation of field samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Contact Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to land development and land use. It is common that not all approaches will be necessarily dealt with in your environmental site assessment report due to concepts proposed at that time. As a project progresses through planning and design toward construction and/or maintenance, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Environmental reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

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