SINCLAIR KNIGHT MERZ

SKM

SYDNEY PORTS

FIRST PORT, FUTURE PORT

Intermodal Logistics Centre at Enfield

ENVIRONMENTAL IMPACT STATEMENT

HYDROLOGY AND HYDRAULICS

- Final
- 30 June 2005

Intermodal Logistics Centre at Enfield

ENVIRONMENTAL IMPACT STATEMENT

HYDROLOGY AND HYDRAULICS

- Final
- 30 June 2005

Sinclair Knight Merz
ABN 37 001 024 095
100 Christie Street
PO Box 164
St Leonards NSW
Australia 1590
Tel: +61 2 9928 2100
Fax: +61 2 9928 2500
Web: www.skmconsulting.com

SKM

Contents

List of Figures

List of Tables

1. Summary

1.1 Description of Proposed Works

Sydney Ports Corporation proposes to develop a large part of the former Enfield Marshalling Yards Site in Enfield. Pacific National now uses only the western section of the site as a marshalling yard, leaving much of the remaining eastern section vacant. The proposal is to develop the large eastern portion of the site into an Intermodal Logistics Centre (ILC), where shipping containers will be transferred from rail to road transport and vice-versa. The area to be developed is approximately 59 ha, which is to be levelled and paved, allowing rail and truck access, and including several warehouses and a large area for container storage and handling. This stage of the project is an assessment of the potential impacts of the proposed development.

The purpose of this Working Paper is to assess the likely stormwater **quantity** impacts of the proposed redevelopment, to provide a conceptual design to mitigate adverse impacts and to provide positive environmental outcomes from the design. The water **quality** impacts of the proposed development are addressed in a separate Stormwater Quality and Soil and Water Management Working Paper.

This report describes the existing environment at the proposed development site and the impact of proposed changes on stormwater runoff. Additionally, proposed impact mitigation features are assessed and discussed.

1.2 Specific Water-Related Project Issues

The project site is located wholly within the Cooks River catchment. A full description of the catchment is given in **Section 3**.

1.2.1 Site layout

The Intermodal Logistics Centre project site currently drains to four individual drains that traverse the site. Each of the four drains conveys stormwater runoff from upstream catchments through the site to discharge into tributaries of Cooks River. Each tributary meets Cooks River several hundred metres downstream of the site.

The proposed project seeks to reshape the site in order to provide a suitable operational area for the Intermodal Logistics Centre. Essentially, the facility requires a large hardstand area on a minimally sloping grade. To achieve this, most of the site area will be reshaped so that it has a gradual slope downwards from north to south. This reshaping has the effect of changing the catchment behaviour. The increase in impervious area requires the provision of detention basins to ensure peak discharge from the site is not increased.

The reshaping provides Sydney Ports Corporation with the opportunity to reduce stormwater flows directed to waterways that are already hydraulically under capacity, particularly the "Central Drain" outlet.

The proposed increase in impervious area (hardstand) is significant. It is estimated that approximately 85% of the internal catchment areas under existing conditions are pervious. The proposed development will increase the quantity of paved area, thus decreasing the pervious area of the internal catchments to approximately 18% of the area. The internal catchments are defined in **Sections 3.7 and 3.8**. These estimations exclude consideration of the area at the southern extremity of the site (south of Coxs Creek), which would remain pervious before and after the project implementation.

1.2.2 Potential Impacts

The proposed redevelopment of the project site into an Intermodal Logistics Centre involves changes to the existing landscape. The proposal involves changes to the landscape form, changes to drainage patterns and an increase in the imperviousness of the project area. To address the issues of additional runoff generated from the increase in imperviousness, detention basins will be incorporated into the design to reduce the post development peak outflow to a level less than or equal to that in the existing case.

Additionally, the redevelopment of the Enfield Intermodal Logistics Centre has the potential to discharge polluted runoff into the downstream environment. Pollutants of concern include petroleum hydrocarbons, oil and grease, heavy metals, other toxicants and suspended solids. It is proposed to provide appropriate water quality treatment for the runoff generated from the redeveloped site to safeguard the downstream environment. A proportion of runoff from the site will be captured, stored and treated prior to discharge off site.

1.2.3 Outline of Proposed Mitigation Works

To manage stormwater flows from the site, it is proposed to take advantage of the proposed site grading and the majority of flows have been directed to the southern end of the site, where increases in discharge will be managed via a detention basin. Coxs Creek (the Southern Channel) is the largest carrier of stormwater through the site, and discharges to this channel will demonstrate the least incremental impact on stormwater flows. Suitable detention is proposed to ensure that any potential impacts are mitigated. Flow rates from the site are addressed in detail in **Section 4.**

The purpose of the hydrologic and hydraulic modelling completed for this report was to:

- Determine the requirement for and to size on-site detention (OSD) basins that will mitigate any increase in the peak discharge value;

- Provide a concept design for the internal drainage system, both pipe flow and overland flowpaths; and
- Check that flood levels in Coxs Creek upstream and downstream of the site, in events up to and including the 100 year ARI, will not rise significantly with the development.

As part of the proposed redevelopment, the potential impacts of water quantity and quality discharged into the downstream environment have to be addressed to ensure that any such impacts are minimised and adequately mitigated.

2. Introduction

2.1 Background

Sydney Ports Corporation (SPC) proposes to develop an Intermodal Logistics Centre (ILC) on part of the former Enfield Marshalling Yards site. Operation of the facility will involve transfer of containerised cargo from Port Botany to the Intermodal Logistics Centre by heavy rail. At the facility, the containers will be marshalled using mobile handling equipment, transferred to truck transports and dispatched to delivery.

A similar operation will occur in reverse, delivering containerised cargo by rail to Sydney Port facilities at Port Botany.

The site also includes areas for empty container storage and distribution; warehousing for the unpacking/packing of containers; light industrial and commercial premises and an area dedicated to community and ecological purposes.

The site for the proposed facility was previously a railway marshalling yard. Marshalling yard activity has been rationalised to an area immediately west of the project site known as "New Enfield Marshalling Yards".

The development requires modification to the existing landscape, resulting in changes to the drainage behaviour of rainfall runoff from the site.

This Working Paper makes an assessment of the likely impacts of the development on the drainage and runoff from the site and more importantly outlines the necessary requirements for mitigation of any negative impacts.

Sinclair Knight Merz (SKM) undertook drainage studies and designs for the redevelopment and rationalisation of the New Enfield Marshalling Yards in 1993. Much of the knowledge and data gathered throughout that project has been utilised in this assessment.

SKM also undertook a hydrology and hydraulics study for a previous proposal at the ILC site in 2001-2002. This study updates that previous study on the basis of the new proposal.

2.2 Requirement of Government Agencies

The Department of Infrastructure, Planning and Natural Resources set out their requirements in the Director General' Requirements dated 1 March 2005. Meetings were also held with Strathfield Council and with Sydney Water, to determine their requirements in relation to the proposed development. The requirements from the above three sources relating to stormwater hydrology and hydraulics can be summarised as follows:

- Describe the hydrology and hydraulics of the catchments,
- Meet the requirements of Strathfield Council's Stormwater Design Manual, 1994,
- Design the underground stormwater pipe system for the 20 year ARI event,
- Describe proposed mitigation measures,
- Limit site stormwater discharge to predevelopment flows by providing Detention Basins,
- Ensure that flood levels, particularly in Coxs Creek, do not rise as a result of the development,
- Groundwater impacts (see Water Quality Working paper).

This report provides details of measures necessary to meet these requirements.

2.3 Previous Reports

A significant amount of reference data was available for consideration in preparing this report, as the site was heavily analysed in preparation for the FreightCorp Marshalling Yard development.

The key reports referred to in this analysis were:

- *Upper Cooks River SWC No. 38 Catchment Management Study* Volumes 1 and 2, Binnie and Partners, 1991;
- *Enfield Freight Terminal Re-Development Stormwater Management Concept*, Sinclair Knight, 1993; and
- *Drainage report for Enfield Marshalling Yard*, Sinclair Knight Merz, 1994.

Data used in this study has been drawn from all of the above reports. Additionally, computer modelling used in this study adopts parameters and concepts developed in the previous work. The relevant sections of the above reports are described briefly below.

2.3.1 Upper Cooks River SWC No. 38 Catchment Management Study

The Upper Cooks River catchment was the subject of a Total Catchment Management (TCM) Study by Binnie and Partners in 1991 for the Water Board (now Sydney Water). This was a comprehensive study into the hydrology, hydraulics and flood damages experienced throughout the Upper Cooks River Catchment.

The Binnie and Partners (1991) report is in two volumes. Volume 1, the main report, investigates the performance of the catchment – hydrologically, hydraulically and in terms of water quality and total catchment management principles. The report investigates and costs upgrade options to reduce flooding within the catchment and makes recommendations for improvements.

The Binnie and Partners (1991) report analysed each of the trunk branches contributing to the Upper Cooks River separately and provides a comprehensive hydrological and hydraulic analysis of each branch in the system. The hydraulic analysis has been drawn on in this study assist in setting up and running the hydraulic model.

Binnie and Partners (1991) recommended some changes to the drainage system including at least one detention basin on the Punchbowl Road branch of Coxs Creek. Sydney Water indicated that the detention basin has not yet been constructed.

Both Strathfield and Bankstown Councils confirmed that, during recent years, there have been no significant works in the Coxs Creek catchment upstream of the site that would have affected flood flows or levels.

2.3.2 Enfield Freight Terminal Redevelopment Stormwater Management Concept

This report (Sinclair Knight, 1993) was a hydrological study for the New Marshalling Yard project. Drainage conditions associated with the New Marshalling Yards site were rigorously examined in this report for the Public Works Department.

The study looked at the flows from catchments upstream of the New Marshalling Yards, and at the capacity of the drainage system (particularly the culvert system under the New Marshalling Yards and SPC site) to convey these flows.

As part of the report, a RAFTS model was developed for the catchments upstream of the New Marshalling Yards, and this RAFTS model was used to develop input hydrographs for the hydraulic assessment undertaken as part of this current study.

The report analysed each of the trunk drain crossings of the New Marshalling Yards in terms of drainage capacity and flooding impact. The report found that generally the trunk stormwater infrastructure was under capacity for events in excess of the 10 year ARI event.

In developing the FreightCorp/Pacific National New Marshalling Yards, care was taken not to exacerbate flooding downstream by discharging peak stormwater flows from the railway yards to already hydraulically stressed downstream channels and significant detention basins were implemented on the western side of the site. For further detail, please refer to the above-mentioned report.

2.3.3 Drainage Report for New Enfield Marshalling Yard

This report (Sinclair Knight Merz, 1994) was prepared for the New Marshalling Yards at Enfield. The report describes improvements to the trunk drainage system undertaken as part of the Marshalling Yards redevelopment.

SKM

3. Existing Drainage and Proposed Changes

3.1 Regional Catchment – Upper Cooks River Catchment

The Enfield Marshalling Yards site is located within the Upper Cooks River Catchment (UCRC). The overall catchment covers an area of approximately 2,200 hectares. The extremities of the catchment extend to the Rookwood cemetery and the Chullora Railway Yards in the north, Potts Hill Reservoir in the west and as far as Roselands commercial district in the south. The entire Cooks River Catchment, including the UCRC, is shown on the map in **Figure 1**. The Upper Cooks River Catchment covers four Local Government Areas (LGA's) being Bankstown, Strathfield, Canterbury and Auburn.

The Upper Cooks River Catchment and trunk branches are illustrated in **Figure 2**. The catchment is drained by several trunk branches, which generally flow in an easterly direction. The trunk branches are:

- Punchbowl Road SWC No. 38ZB;
- Greenacre Park SWC No. 38ZQ; and
- Rookwood Road SWC No. 38ZV.

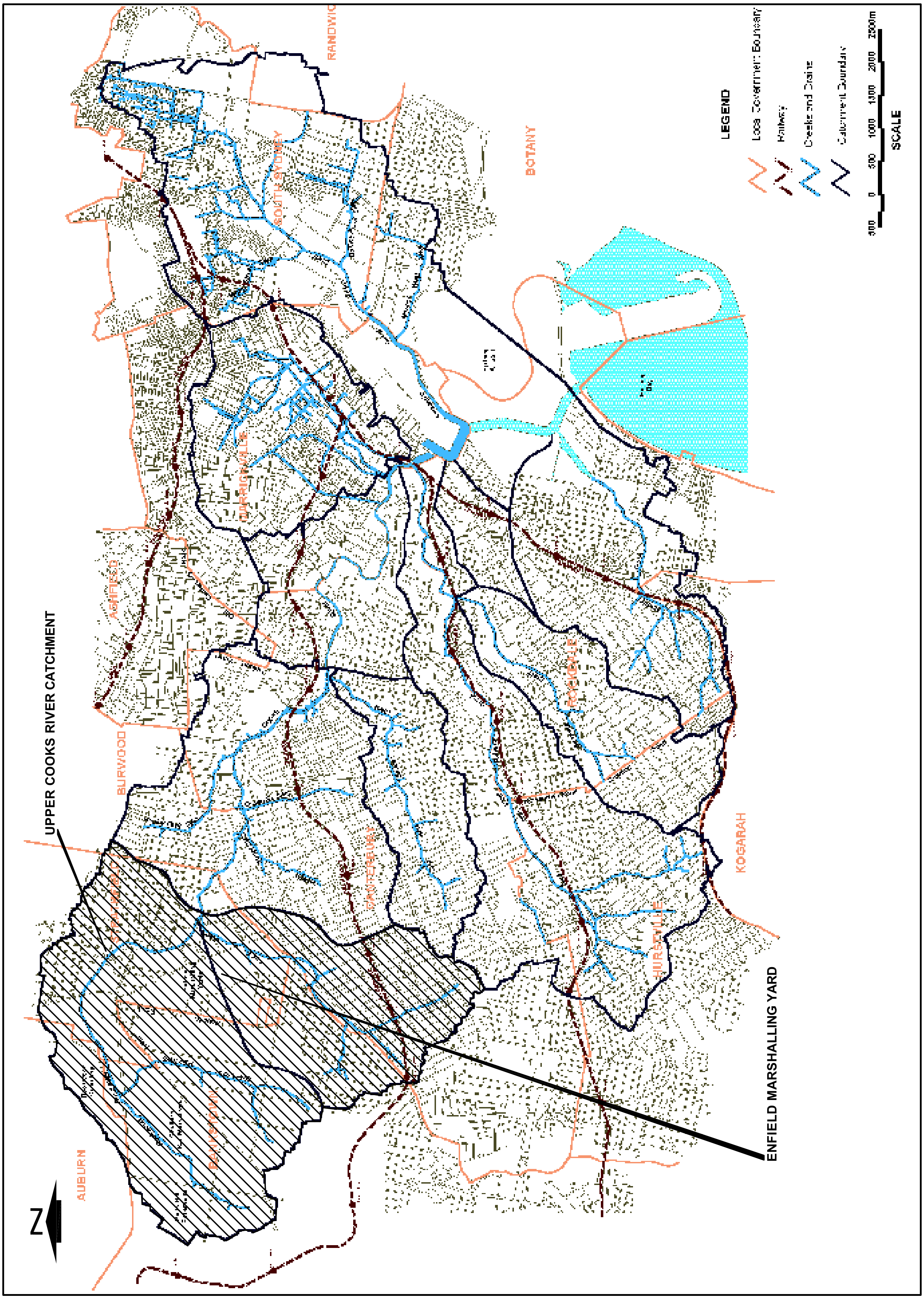
(The reference numbers are the Sydney Water Corporation (SWC) codes).

The Greenacre Park and Rookwood Road branches meet at a confluence at the southern edge of Rookwood Cemetery, to form the Cooks River. The Cooks River flows around to the north and east of the Enfield Marshalling Yards site, and there is a confluence with the Punchbowl Road Branch (Coxs Creek) immediately west of Water Street in Strathfield South. The Cooks River then flows south-east to its receiving waters of Botany Bay adjacent to the Sydney International Airport.

Of the three trunk branches in the UCRC, the Punchbowl Road Branch SWC No. 38ZB is the only branch that flows through the Enfield Marshalling Yards site. The other branches circumvent the site to the north and are not considered further in the context of this project.

Figure 1
COOKS RIVER CATCHMENT
(FROM THE COOKS RIVER STORMWATER MANAGEMENT PLAN,
COOKS RIVER CATCHMENT ASSOCIATION OF COUNCILS 1999)

SINCLAIR KNIGHT MERZ



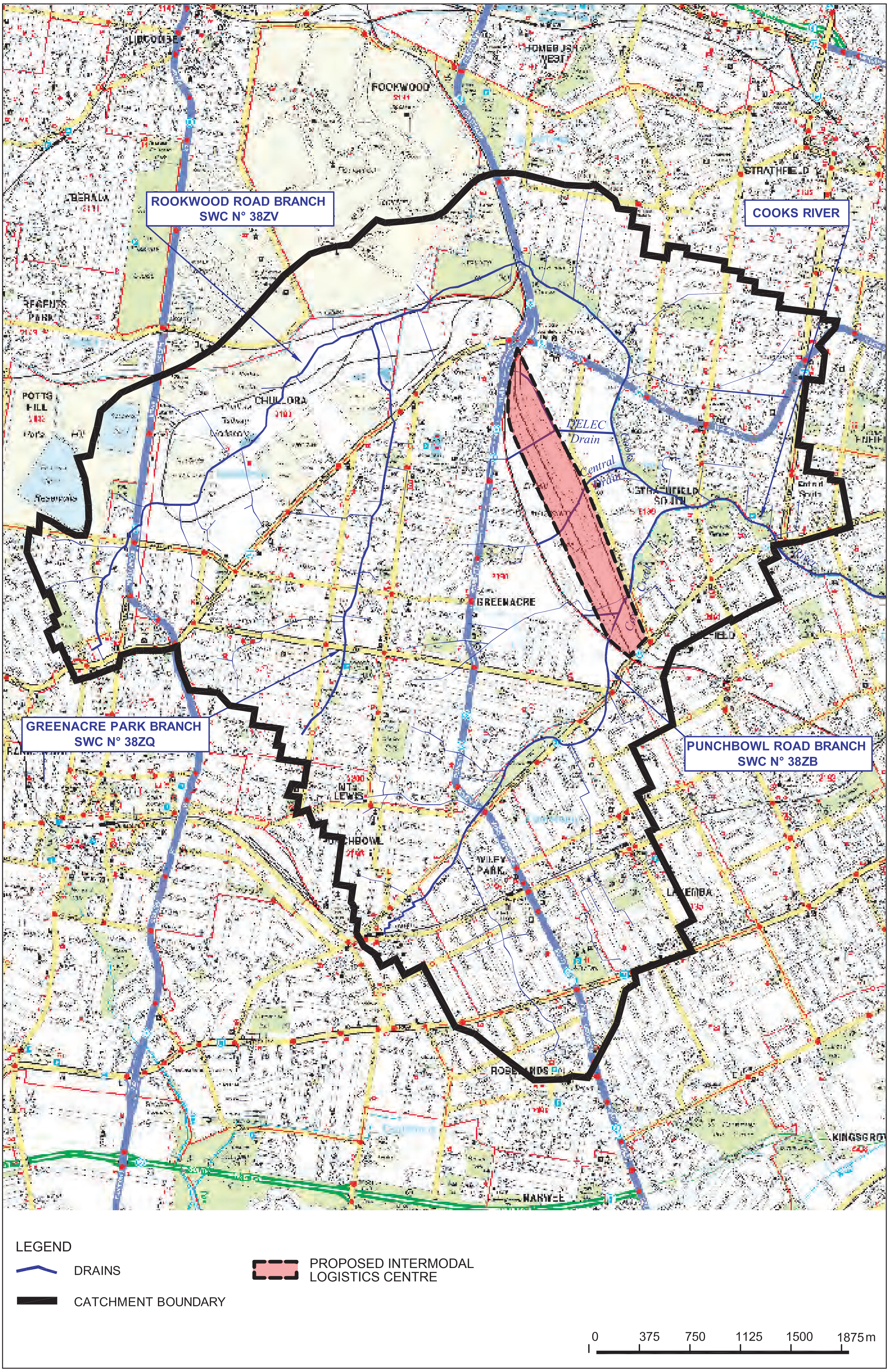


Figure 2
Upper Cooks River Catchment Plan

SKM

3.2 New Enfield Marshalling Yards

The New Enfield Marshalling Yards drain to Coxs Creek upstream of the proposed Intermodal Logistics Centre. The drainage from this area has been designed to incorporate appropriate on-site detention so that the peak flows in Coxs Creek are not increased as a result of the Marshalling Yards development.

SKM's Report titled 'Enfield Freight Terminal Redevelopment Stormwater Management Concept', 1993 identified the need for four detention basins totally some 25,000 cubic metres to ensure that post-development peak stormwater flows were not increased. These basins can be seen in **Figure 10** and have sufficient capacity to take all flow from the critical 100 year ARI storm for Coxs Creek.

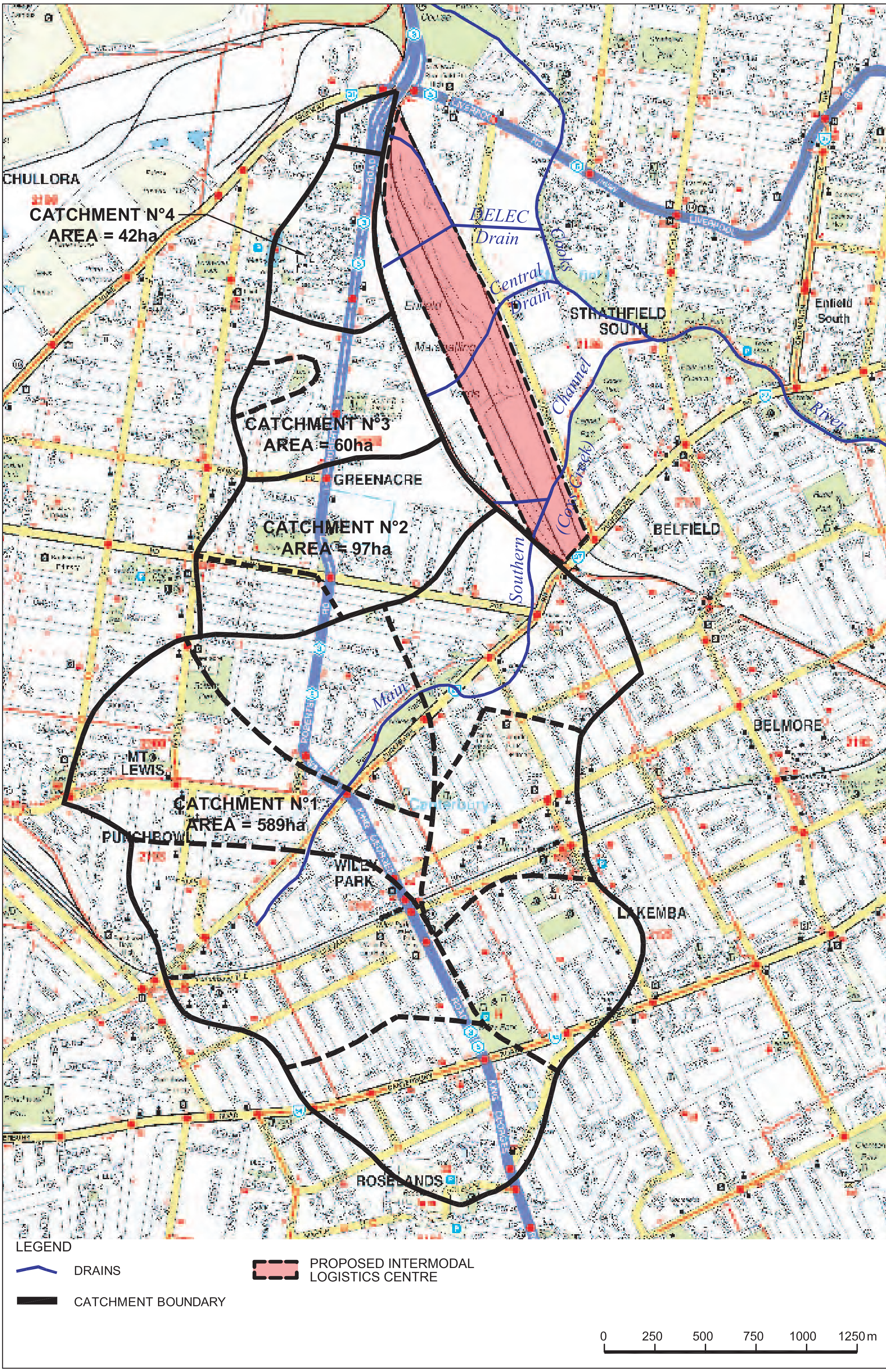
Therefore when considering the flows into Coxs Creek from upstream of the proposed Intermodal Logistics Centre development, derivation of the peak flowrates needs only to consider the inputs from subcatchments 1 and 2 as previously assessed in the Binnie Report (1991) and the SKM report (1994). There is no requirement to add the impacts of the additional runoff due to the increased imperviousness of the New Enfield Marshalling Yards.

3.3 Local Catchment

There are four trunk drainage lines that cross the proposed Intermodal Logistics Centre Site. The four drainage lines drain five subcatchments upstream of the site. In order from south to north, the drainage lines have been termed:

- The Southern Channel, also known as Coxs Creek or the Punchbowl Road Branch, which drains subcatchments 1 and 2;
- The Central drain, which drains subcatchment 3;
- The DELEC drain, which drains subcatchment 4; and
- An unnamed drainage line at the very northern end of the site, which drains a small subcatchment to the north of subcatchment 4. This drainage line joins the DELEC drain just downstream of the site.

The catchment areas 1-4, sub-catchments and the four trunk drainage lines are illustrated in **Figure 3**. It can be seen in **Figure 3** that the Southern Channel, Central Drain and DELEC Drain each join the Cooks River separately.



Intermodal Logistics Centre at Enfield

Figure 3
Catchment Areas Upstream of the Intermodal Logistics Centre site

Details associated with each of the subcatchments are summarised in **Table 1**.

- **Table 1: Local subcatchment details**

Subcatchment name	Area Upstream of Site (ha)	Receiving/Collecting Drain Name
1	589	Coxs Creek
2	97	Coxs Creek
3	60	Central Drain*
4	42	DELEC Drain*

*Note that these are names given to the section of receiving drain of the subcatchment upstream of the Cooks River for the purposes of definition in this report.

The small subcatchment north of subcatchment 4 is immediately to the south of the Hume Highway, and drains a small urban area between Jean Street, Roberts Road and the Hume Highway through the very northern extremity of the New Enfield Marshalling Yards. It joins the DELEC drain near the site boundary. The existence of this drain could not be confirmed during site inspections. However, the proposed project does not impact on either the catchment or the function of the drainage from this catchment and it has been precluded from further consideration. Strathfield Council noted that during the construction of the Liverpool Road – Hume Highway flyover over Roberts Road, the drainage from this area may have been diverted towards the Greenacre/Rookwood Branch of the catchment.

The Southern Channel, Central Drain and DELEC Drain were all included in the Binnie and Partners (1991) report,[1] in their assessment of hydrology, hydraulics and flood damages in the UCRC. These trunk drainage lines were also analysed as part of the hydrology and hydraulics study for the New Marshalling Yards redevelopment in 1993 by Sinclair Knight Consulting Engineers.[2] This report assessed the hydrology and hydraulics of each of the tributaries that flow through the Marshalling Yards site. These two reports have been used as a basis for further analysis and assessment in this report.

Each subcatchment is described in detail in the following sections (**3.3.1** to **3.3.4**)

3.3.1 Subcatchment No. 1 – Coxs Creek

Subcatchment No. 1 is the largest catchment upstream of the proposed Intermodal Logistics Centre at 589 ha. The catchment is characterised by grades ranging from 2.9% to 4.8% and is heavily urbanised.

[1] Binnie and Partners, Upper Cooks River SWC No. 38 Catchment Management Study, 1991.
[2] Sinclair Knight, Enfield Freight Terminal Redevelopment Stormwater Management Concept, October 1993

Upstream of the Marshalling Yards, Coxs Creek closely follows the route of Punchbowl Road in an open concrete channel. At the upstream boundary of the Marshalling Yards, Coxs Creek has been formalised into a trapezoidal concrete channel and culverts which flow beneath existing railway lines.

A three-cell Reinforced Concrete Box Culvert (RCBC) conveys flows beneath the New Marshalling Yards. Each culvert cell is 2.74 m wide and 1.68 m high. The entrance to the RCBC is shown in **Figure 4**.

- **Figure 4: Upstream of Marshalling Yards, entrance to 3-cell RCBC on Coxs Creek (looking downstream)**

At approximately the boundary between the New Enfield Marshalling Yards and the proposed Intermodal Logistics Centre, the three-cell RCBC transforms into a four-cell RCBC with each cell being 2.42 m to 2.82 m wide (varies) and 1.66 m high.

These RCBC discharge into an open concrete lined stormwater channel near Cosgrove Road. **Figure 5** illustrates the culvert exit into the channel. At the culvert/channel junction, the concrete channel is approximately 12.67 m wide and 1.7 m deep with near vertical side walls.

- **Figure 5: Coxs Creek exit from 4-cell RCBC, eastern side of site (looking upstream)**

Approximately 70 metres downstream of the culverts in **Figure 5**, the drainage channel from subcatchment 2 joins the open channel section on the left bank. This junction is shown in **Figure 6**.

- **Figure 6: Subcatchments 1 & 2 confluence in Coxs Creek (looking upstream)**

This channel then flows under a railway viaduct via twin masonry arches, each approximately 4.3 m high and 4.6 m wide. The channel shortly thereafter flows underneath Cosgrove Road via a 3-cell RCBC, each cell 3.05 m wide and 1.93 m high, before opening up into a trapezoidal channel approximately 12.67 m wide and 1.7 m deep with near vertical side walls. The masonry arches and the Cosgrove Road culverts are illustrated in **Figure 7** and **Figure 8** respectively.

- **Figure 7: Masonry arch culverts beneath railway viaduct (looking downstream)**

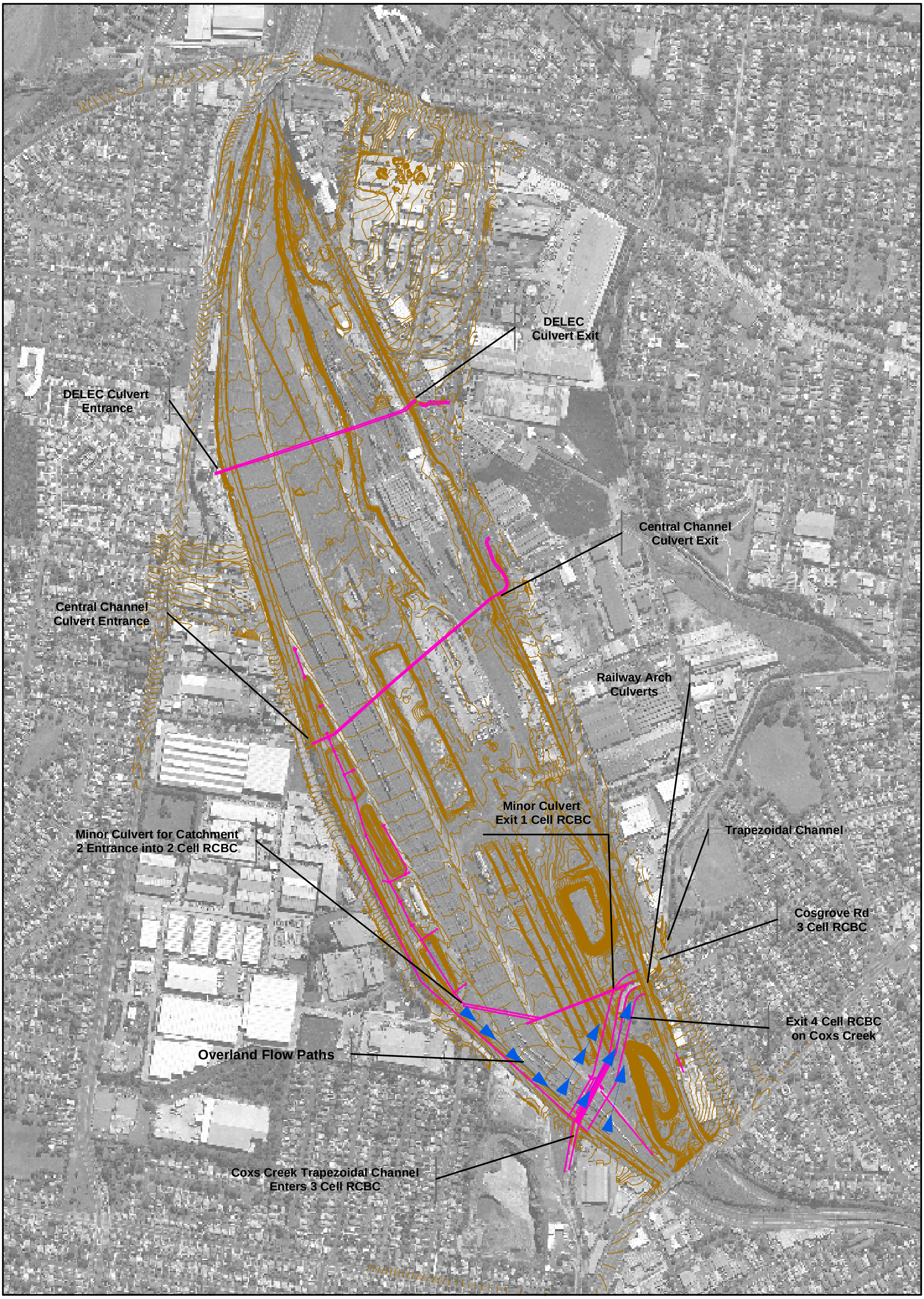
SKM

- **Figure 8: Cosgrove Road culverts (looking downstream)**

The overland flowpath from subcatchment 1 predominantly follows the culvert alignment across the New Marshalling Yards and SPC site. The overland flowpath for Coxs Creek is illustrated on the photograph in **Figure 9** and on the plan in **Figure 10**.

SKM

- **Figure 9: Coxs Creek overland flowpath**



A4 Source: Topographic data supplied by SPC, Air photos BY SKM

File Name:EN01709_Wr_012a.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 12/5/2005
Projection: MGA 56

Figure 10
Drainage Infrastructure and Overland Flow Paths

SKM

3.3.2 Subcatchment No. 2

Subcatchment No. 2 extends upstream of the New Marshalling Yards from the cul-de-sac on Wentworth Street to Waterloo Road in the west, as illustrated in **Figure 3**. The catchment is approximately 97 ha and the natural land grade is between 1.2% and 4.3%.

On the western side of the New Marshalling Yards, the catchment drains to a twin RCBC 2.7 m wide and 1.5 m high, which conveys flows under the Marshalling Yards.

This culvert was installed during the FreightCorp Marshalling Yard upgrading works in 1994/95 and replaced an existing single cell RCBC that was 2.74 m wide by 1.59 m high at its entrance. At the same time the culvert was realigned on a different route. However, one cell of the twin cell arrangement is essentially redundant. Its installation was a provision for any future upgrade/amplification works that may take place downstream of the site to the receiving waters (i.e. Cooks River) to improve overall catchment drainage. To date, no such downstream amplification has occurred.

At the boundary of the Pacific National Marshalling Yard/Intermodal Logistics Centre sites, the upgraded twin cell RCBC connects back into a single cell culvert, which is 3.11 m wide and 1.64 m high at its exit. This essentially makes one cell of the twin RCBC redundant until amplification occurs downstream some time in the future. Amplification downstream would require the upgrading of the whole drainage line to the receiving waters. Amplification of the section under the proposed Intermodal Logistics Centre, without downstream works, would simply exacerbate downstream flooding.

Finally, the single cell culvert emerges into an open channel and converges with the Southern Channel (Coxs Creek) upstream of the railway viaduct arches; see **Figure 6**.

Overland flow unable to enter the culvert at the upstream end adjacent to Wentworth Street, flows in a southerly direction alongside the Marshalling Yards rail tracks to meet Coxs Creek at the upstream side of the Marshalling Yards. The overland flowpaths are illustrated in **Figure 10**.

3.3.3 Subcatchment No. 3

Subcatchment No.3 extends from the western side of the former Enfield Marshalling Yard at Wentworth Street to approximately Waterloo Road in the east, as illustrated in **Figure 3**. The catchment is approximately 60 ha and exhibits grades of approximately 2.3%.

Subcatchment No. 3 also contains a 2,000 m^3 detention basin at Lee Park, which retards flows in storms up to the 10 year ARI event.

The catchment drains to an arched brick culvert approximately 1.2 m high and 1.2 m wide for a length of 10 m and then transitions into 1.5 m x 1.5 m brick arch, which traverses the entire New Marshalling Yard and proposed Intermodal Logistics Centre site. The brick arch discharges into an open earthen lined channel immediately upstream of Cosgrove Road.

Overland flows are generally contained by local landforms. In most flood events, floodwaters would simply build up at the culvert entrance, then dissipate slowly. In severe flood events, some floodwaters probably flow onto the railway lines at the western side of the Marshalling Yards, then south and parallel to the rail lines. Overland flows result in severe localised flooding of Wentworth Street in large storms. This behaviour is discussed further in **Section 3.5**.

3.3.4 Subcatchment No. 4

Subcatchment No. 4 is 42 ha in area. The catchment extends from the former Enfield Marshalling Yard at the downstream end to the Chullora marketplace in the east as the upstream boundary, as illustrated in **Figure 3**.

The catchment drains to a twin 1.2 m diameter concrete pipe culvert that runs beneath the concrete batch plant in Norfolk Road. The twin culverts connect to an arched brick culvert 2.02 m wide and 1.84 m high before running under the New Enfield Marshalling Yard railway tracks adjacent to Roberts Road. The drain continues east under the site beneath the DELEC facility before discharging into an open earthen channel upstream of Cosgrove Road.

This culvert joins with a minor drainage culvert that drains a small area between Jean Street, Roberts Road and the Hume Highway. This culvert connects with the DELEC drain immediately upstream of Cosgrove Road. This minor drain has no real impact on this assessment and is not considered further.

Overland flows from Subcatchment No. 4 are contained by local landforms. Floodwaters can build up at the culvert entrance, but retained floodwaters would gradually flow through the culvert rather than escaping overland.

3.4 Existing Drainage Issues

Both the Binnie and Partners (1991) report and the Sinclair Knight (1993) report extensively discuss issues relating to the capacity of culverts, channels and drains within the catchment.

Of specific relevance to the current project is the capacity of the existing infrastructure, which was assessed in the 1993 report. **Table 2** is a summary of catchment flows and culvert capacities for the drains crossing the Enfield site.

SKM

As part of the Marshalling Yards redevelopment, Sinclair Knight (1993) assessed the peak flows from the catchments upstream of the proposed Intermodal Logistics Centre. **Table 2** has been reproduced from the 1993 report and augmented to include the peak excess flowrates for the 100 year ARI event. It is important to note that the hydrological models used by Binnie & Partners in 1991 were used to develop and derive the flows in the 1993 report, thus there is consistency between the reports.

- **Table 2: Catchment Flows and Drain Capacity**

	Catchment and drain name			
	1 (Southern Channel)	2 (Tributary of Southern Channel)	3 (Central Drain)	4 (DELEC Drain)
Area (ha)	589	97	60	42
10 year ARI Flows (m^3/s)	124	22	16	13
20 year ARI Flows (m^3/s)	142	25	18	14
100 year ARI Flows (m^3/s)	186	33	23	19
Capacity of Culverts (m^3/s)	52	14*	4.3	15
100 year ARI Excess flow (m^3/s)	134	19**	18.7	4

* Understood to indicate the capacity of the old single cell culvert under the Marshalling Yards, rather than the new twin-cell culvert that has replaced it. See Section 3.3.2 for a description of the upgrade.

** Subject to the comment above.

It is evident that the culvert that is critically under capacity is the Coxs Creek channel, which results in 134 m^3/s needing to flow overland through the Enfield Marshalling Yards in the 100 year ARI event. Overland flows from subcatchment 2 would also add to this. Excess flows at the Central and DELEC drains are of a lesser magnitude, however still result in significant flooding at the upstream end of the Central drain, and minor flooding at the upstream end of the DELEC drain. Excess flows from subcatchments 3 and 4 are largely contained by local landforms, and instead of flowing overland, floodwaters tend to build up then dissipate slowly. Flooding is discussed further in **Section 3.6**.

It can be seen from **Table 2** that Coxs Creek receives higher flows than the Central and DELEC Drains. Runoff from the proposed Intermodal Logistics Centre will be conveyed into Coxs Creek, where the increase in volumetric flow will demonstrate a lesser incremental impact than if the runoff were to be conveyed into the Central and/or DELEC outlets.

As discussed in **Section 3.2**, runoff from the New Enfield Marshalling Yards, which joins Coxs Creek and adds to the flows from Subcatchment No. 1, was designed to have no effect on the peak flowrate in the Southern Channel. Therefore the peak flow values presented in **Table 2** above are still valid and represent the peak flowrates at the upstream boundary of the proposed Intermodal Logistics Centre site.

3.5 Structural Condition of Drainage Infrastructure

Sinclair Knight (1993) discussed the condition of the culverts passing underneath the Enfield Marshalling Yards site. This discussion was based on a visual assessment of the culverts. As a result of that report, some opportune remedial works were undertaken during the redevelopment of the Marshalling Yards. The majority of the infrastructure under the SPC site today appears to be consistent with the findings of that report, which are summarised in this section.

3.5.1 Existing Culvert Draining Subcatchment No. 1 (Coxs Creek)

The Sinclair Knight (1993) report found the structural condition of the 3-cell RCBC quite acceptable. However, the inspection identified minor cracking on the masonry walls, minor spalling on the culvert crown and some rusting on the overhead reinforcing rails.

Minor repair work, such as patching and grouting, was recommended to ensure structural integrity be maintained.

The brick arch culverts that pass beneath the railway viaduct at the downstream end of the site were observed as part of the current study and appear to be in very good condition given their age and exposure. The arch does not show any obvious deformation and the brickwork appears firmly fixed and in good line and level.

3.5.2 Existing Culvert Draining Subcatchment No. 2

The structural inspection in 1993 (Sinclair Knight) found this culvert to be in generally sound condition. The inspection identified minor cracking of the masonry walls. Some spalling of concrete from the culvert crown was identified.

Again, minor repair works were advised in order that the integrity of the existing infrastructure is maintained.

In 2005, Sydney Water noted that one of the access lids over this culvert in the SPC site is in need of repair.

3.5.3 Existing Culvert Draining Subcatchment No. 3

The culvert draining Subcatchment No. 3 is a brick arch culvert. The overall condition is reported as good with respect to line, level and integrity, given its apparent age. Some concern was expressed relating to the likely deterioration of the grout/mortar between the bricks. The 1993 inspection advised that the brickwork may need to be reinstated from inside the culvert in the near future.

It should be noted that this culvert traverses both the New Enfield Marshalling Yards site and the proposed Intermodal Logistics Centre site and any remediation works should be conducted across the entire drain.

Additional earth loads on this culvert are to be expected when portions of the project site are filled. This is not expected to be a significant issue as sections of the culvert are already subject to similar earth loads beneath the New Enfield Marshalling Yards site without obvious impacts on the culvert. This should be further investigated at the detailed design stage.

3.5.4 Existing Culvert Draining Subcatchment No. 4

An inspection of the brick arch culvert draining Subcatchment No. 4 was conducted from the Cosgrove Road (downstream) end in 1993 (Sinclair Knight).

The condition of the culvert was reported to be very similar to that draining Subcatchment No. 3, and the comments on this culvert apply here. This is not surprising given that the culverts appear to be of similar design and constructed at approximately the same time.

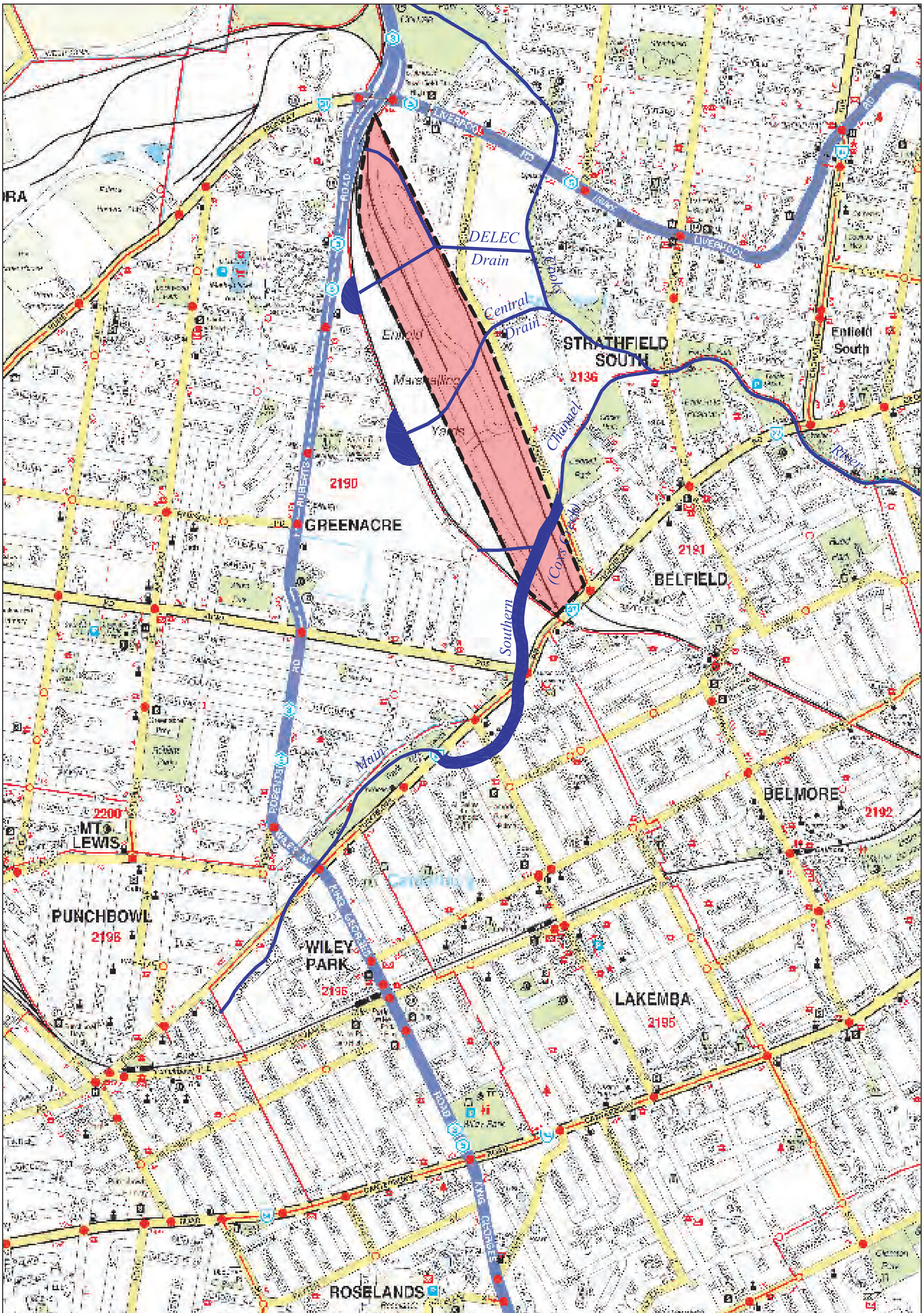
As for the culvert draining Subcatchment No. 3, additional earth loads on this culvert are to be expected when portions of the project site are filled. This is not expected to be a significant issue as sections of the culvert are already subject to similar earth loads beneath the Marshalling Yard site without obvious impacts on the culvert. This should be further investigated at the detailed design stage.

3.6 Existing Flooding Issues

Figure 11 illustrates the areas in the vicinity of the proposed Intermodal Logistics Centre that are subject to flooding.

Coxs Creek is considered under capacity for a significant proportion of its length. **Figure 11** illustrates the areas of Coxs Creek reported as flood prone in the Binnie and Partners (1991) report.

Additionally, the 1993 Sinclair Knight report discussed significant flooding on the upstream side of the former Enfield Marshalling Yards at the points where culverts draining Subcatchments 3 and 4 commence.



LEGEND

DRAINS

AREAS SUBJECT TO FLOODING

PROPOSED INTERMODAL LOGISTICS CENTRE

0 250 500 750 1000 1250m

Intermodal Logistics Centre at Enfield

Figure 11
Identified Areas Subject to Flooding

SKM

3.6.1 Southern Channel

Flooding is experienced at the southern end of the New Enfield Marshalling Yards site in large events, as a result of overland flows from the Southern Channel. The flooding of the Marshalling Yards has little impact on local residents or businesses.

Upstream of the site, there are flooding problems along the Coxs Creek channel, as indicated in **Figure 11**.

Downstream of the site, residents adjacent to Cosgrove Road at Coxs Creek report inundation of their properties in significant rainfall events, which is documented in the Sinclair Knight report (1993). Sydney Water also indicated that there are known flooding problems at Water Street, where Coxs Creek meets the Cooks River.

3.6.2 Central Drain

Flooding is a known issue along Wentworth Street at the Mayvic Street intersection (in the lower reaches of Subcatchment No. 3). Flooding here inundates businesses and disrupts traffic in an event as small as the 1 year ARI event. Flooding was discussed in the Sinclair Knight (1993) report, and some photos were included that indicate the extent of flooding. The report also mentions that the construction of a retarding basin at Lee Park has caused only a minor improvement in the flooding on Wentworth Street, mostly for events up to the 10 year ARI event.

A simple estimation was made of the depth and duration of flooding at the Wentworth St/Mayvic St intersection. It was assumed that all flows from Subcatchment No. 3 would flow away through the Central drain at a maximum flowrate of 4.3 m^3/s (i.e. overland flows were ignored). Results of this analysis are presented in **Table 3**. The flooding durations listed in **Table 3** are upper estimates, and assume that water is not able to escape via overland flowpaths. Local roads would probably be untrafficable for only a portion of the time indicated.

- **Table 3: Flooding at Wentworth St/Mayvic St intersection**

Flood event	Critical duration (mins)	Estimated time of inundation (hours)
1 year ARI	30	0.5
10 year ARI	180	2
20 year ARI	180	3
100 year ARI	270	4

Notwithstanding the above conservative estimates of inundation time, flooding at the Wentworth St/Mayvic St intersection is limited to a depth of about RL 23.5m, or about 0.5 m above the lowest point on Wentworth Street. At this depth, the floodwaters would begin to flow overland into the New Enfield Marshalling Yards and south towards Coxs Creek. This overland flowpath, which may become active in large events, was not illustrated on the plan in **Figure 10** as exact location of the flowpath has not been investigated in detail for this study.

3.6.3 DELEC Drain

Flooding at the western side of the New Enfield Marshalling Yards, at the inlet to the DELEC Drain, is also noted on the map in **Figure 11**. Flooding at this location was not discussed in the Sinclair Knight (1993) report, however the quantum of flooding is likely to be less than at the Wentworth St/Mayvic St intersection, as the upstream catchment area is smaller and the capacity of the culvert is larger (refer **Table 2**). However, until ponding at this location becomes very deep, there is no opportunity for flows to escape via overland flowpaths, and in the case of an extreme flood or a blockage of the main culvert, flooding could become severe.

3.7 Internal Site Drainage

The proposed Intermodal Logistics Centre site is unique in that modifications to the landform over time have resulted in the entire site of the proposed development becoming a subcatchment of its own. Upstream watercourses are diverted underneath the site as discussed in **Section 3.3** of this report.

Internal drainage is captured on site and discharged to one of the three watercourses traversing the site. The proposed development site will drain independently of the upstream catchment and as such, water quality and drainage design need only address the development site, as there is no stormwater contribution to the internal site from the upstream catchments. Thus, in considering the impact of drainage from the proposed development, it is necessary only to consider the impact of proposed changes to the internal drainage system.

This section looks at the existing internal site drainage, in particular the existing catchment areas and peak runoff rates.

3.7.1 Existing Internal Catchments

The existing site can be subdivided into four subcatchments, draining to three separate watercourses. The internal subcatchments are detailed in **Figure 12**. The Southern Channel at the southern end of the site drains Catchments A and D. Two smaller waterways in the central and northern portions of the site (Central and DELEC outlets) drain catchments B and C respectively. The subscripts following the capital letters refer to the subcatchment number and the letter ‘e’ to ‘existing’ sub-catchment. Catchment details are presented in **Table 4.**

Table 4: Pre-development catchment details

Outlet	Contributing Catchment	Impervious area (ha)	Pervious area (ha)	Total Catchment area (ha)
Southern Channel	A	0.5	3.6	4.2
Central channel	B	4.1	6.3	10.4
DELEC outlet	C	2.5	14.6	17.2
Southern Channel	D	0.9	23.0	23.8
TOTALS (1)		**8.1**	**47.5**	**55.5**

Note 1: Minor differences in total due to rounding error

Hydrological modelling was used to assess the existing contribution to the receiving waterways from each catchment. Peak discharges for the 2, 10 and 100 year ARI storms for the existing site were determined using RAFTS, an urban rainfall runoff model. Details of the hydrological modelling methods are presented in **Section 4** of this report. The peak flows derived from this modelling are summarised in **Table 5.**

Table 5: Pre-development catchment runoff from the development areas

ARI (years)	Peak discharges from existing site to each drain (m^3/s)							
	Southern Channel (Catchment A)		Central Channel (Catchment B)		DELEC outlet (Catchment C)		Southern Channel (Catchment D)	
	Critical duration (mins)	Peak flow (m^3/s)	Critical duration (mins)	Peak flow (m^3/s)	Critical duration (mins)	Peak flow (m^3/s)	Critical duration (mins)	Peak flow (m^3/s)
2	720	0.26	90	1.41	720	1.07	540	1.30
10	270	0.46	90	2.26	270	1.90	360	2.18
100	270	0.80	90	3.55	90	3.31	120	3.70

Source: Topographic data supplied by SPC, Air photos BY SKM

Projection: MGA 56
Page Size: A4
File Name:EN01709_Wr_004.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 18/4/2005

N

0 100 200
Metres

Legend

- River
- Stormwater infrastructure
- Exisiting Subcatchment

Figure 12
Existing Internal Subcatchments

SKM

SKM

3.8 Proposed Alterations to Internal Drainage

The Intermodal Logistics Centre development proposes to modify the internal catchment configuration. The operation of an Intermodal Logistics Centre requires that a large essentially level hardstand area be created for the operation of heavy vehicles used in loading/unloading operations. The rearrangement of the existing catchments is discussed further in this section.

Alterations to the internal catchment layout facilitate the operational constraints of the Intermodal Logistics Centre as well as enabling existing drainage issues associated with the local catchment to be addressed.

The development proposes to establish a large impervious area on the site, including container handling and storage areas, rail lines and roads, warehouses and supporting facilities. There will be a substantial increase in the impervious fraction of the site.

The development will also involve re-grading the site so that more of the runoff tends to flow towards the southern end of the site and Coxs Creek. The development of the hardstand area will reduce the catchment areas contributing to the Central and DELEC outlets, both of which are already under capacity, while correspondingly increasing the catchment area discharging to the Southern Channel (Coxs Creek).

In general, the imperviousness of the site will increase and a larger proportion of the flow will be diverted to the main carrier of Coxs Creek via an appropriate detention system. With the use of detention, this can be achieved without increasing peak flows at any of the drainage lines.

The re-arrangements of the internal catchments are presented graphically in **Figure 13**. The subscript letter ‘p’ refers to the proposed site layout.

The post development catchment details are presented in **Table 6**.

- **Table 6: Post-development catchment details**

Outlet	Contributing Catchment	Impervious area* (ha)	Pervious area* (ha)	Total Catchment area (ha)
Southern Channel	A	2.1	0.1	2.3
Central drain	B	2.6	0.1	2.7
DELEC drain	C	4.7	3.5	8.1
Southern channel	D	40.1	2.3	42.4
TOTALS		**49.5**	**6.0**	**55.5**

*For catchments A and B, the light commercial and industrial development areas are assumed to be 95% impervious (this is in accordance with Strathfield Council’s Stormwater Management Code for “large” and “small” commercial and industrial developments, which was consulted for on-site detention requirements).

Source: Topographic data supplied by SPC, Air photos BY SKM

Projection: MGA 56
Page Size: A4
File Name:EN01709_Wr_005.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 18/4/2005

N

0 100 200
Metres

Legend

Proposed Subcatchment

River

Stormwater infrastructure

Figure 13
Post - development Internal Subcatchments

SKM

The proposed development will increase the impervious area of the internal catchment. To address the issues associated with the additional impervious areas, a drainage system incorporating detention and water quality treatment will be introduced.

Section 4 outlines the hydrology in detail, presenting the methodology used and detention requirements derived for each catchment. Presented here in **Table 7** is a summary of the hydrology results, showing the post-development flows.

- **Table 7: Post-development internal catchment runoff for the ILC area**

ARI (years)	Peak discharges from developed site to each drain (m^3/s)							
	Southern Channel (Catchment A)		Central Channel (Catchment B)		DELEC outlet (Catchment C)		Southern Channel (Catchment D)	
	Critical duration (mins)*	Peak flow (m^3/s)	Critical duration (mins)*	Peak flow (m^3/s)	Critical duration (mins)	Peak flow (m^3/s)	Critical duration (mins)	Peak flow (m^3/s)
2	OSD will maintain flows at or below pre-development peak levels*		OSD will maintain flows at or below pre-development peak levels*		720	0.49	540	1.22
10					120	0.84	540	1.62
100					90	3.03	540	3.65

*Light commercial and industrial development is proposed over most of the post-development area of catchments A & B and therefore these areas are subject to Strathfield Council's OSD requirements and were not modelled using RAFTS.

Catchment D increases in both area and in imperviousness. Consequently, a detention basin has been proposed at the southern end of the development to retard discharge from the site to pre-development levels. The configuration and size of the detention basin is discussed in **Section 4.4** of this report.

Catchment C, although it decreases in area, increases in imperviousness and there would be an overall increase in peak flows without detention. A detention basin has been proposed at the eastern edge of the development within subcatchment C. This would retard discharge from the site to pre-development levels. The configuration and size of the detention basin is discussed in **Section 4.5** of this report.

The developed catchments A and B are earmarked for light commercial and industrial development associated with the Intermodal Logistics Centre. At this stage, the details of the nature of the development have not been finalised. However, it is expected that the areas will be developed as individual lots, which will be subject to separate approvals.

In terms of the drainage issues associated with these light commercial and industrial developments, it is proposed that each individual development will address issues associated with drainage detention in accordance with Strathfield Council's On Site Detention (OSD) Policy (Strathfield Council *Stormwater Management Code* 1994). That is to say, each development allotment will develop and maintain an appropriate on site detention system in accordance with Council policy. Hydrological analysis of catchments A and B is discussed further in **Section 4.2**.

It is important to note that flows from the site to the Central channel will be substantially reduced. The rearrangement of the catchments will decrease the contributing catchment to the Central outlet and so reduce the contributing flow to this tributary already hydraulically under capacity. This is of benefit to the local drainage system.

3.9 Changes to the Regional Catchment

3.9.1 Southern Channel (Coxs Creek)

The extension of the hardstand area will encroach into the area currently inundated by overland flows. To assess the impact of lost floodplain storage and any reduction in flood conveyance, a MIKE-11 hydrodynamic model was established.

Details of the hydrodynamic modelling undertaken and the recommended mitigation strategies are given in **Section 5**.

Coxs Creek is under capacity for storm events more frequent than the 10 year ARI event. This was established in the Binnie and Partners report in 1991 and again in the Sinclair Knight report in 1993.

The proposed development involves cut and fill modifications in a section of the floodplain that would normally be inundated during overland flows. The impact and mitigation options relating to this filling have been examined in **Section 5.3** of this report.

3.9.2 Central Channel

The catchment area to the Central Channel is substantially reduced as a result of the development with the diversion of rainfall runoff to Coxs Creek via the detention basins. As a result, the contributing runoff is also reduced to this channel, which was determined in previous reports to be under capacity.

It is proposed to develop the areas adjacent to the Central Channel at the downstream end of the site as light commercial and industrial sites. A key issue is maintenance of the hydraulic capacity of the Central Channel to cater for its existing design flow and assess the impact of future discharges to the channel. The capacity of the central channel is analysed in **Section 5.2.1**.

The developed catchment contributions to this drain will be from the light commercial and industrial development in catchment B. All development will be in accordance with Strathfield Council on-site detention requirements in their Stormwater Management Code. This Code, combined with the reduction in catchment area, will reduce the discharge to these channels and thus benefit the already under capacity system.

This system is therefore deemed to benefit from this development.

3.9.3 DELEC Channel

Similar to the Central Channel, the catchment area to the DELEC channel is substantially reduced. However the impervious fraction would increase as a result of the development and the overall effect is an increase in peak runoff. Therefore some detention is proposed, to bring peak flows back within pre-development levels.

4. Hydrology

4.1 General

To assess the change in rainfall runoff patterns, a rainfall runoff model was established to quantify the changes and develop mitigation options. Ostensibly, the proposed development has two main impacts in terms of hydrology, an increase in peak discharge and an overall increase in runoff volume.

A hydrological model was set up to investigate and quantify the impacts and to further test the mitigation options.

4.2 Methodology

To simulate the rainfall-runoff behaviour of the development, a RAFTS rainfall runoff model was established. RAFTS is the industry standard tool for the assessment of urban rainfall runoff. As the proposed development site is basically an independent catchment, the model developed deals mainly with the internal catchment.

Storms for each of the recurrence intervals, 2, 10 and 100 years, were assessed for a range of durations from 45 minutes to 1080 minutes in length, to determine the critical storms and peak discharges for the pre and post development conditions.

Modelling determined the critical storm and associated peak discharge at the downstream discharge points for the Intermodal Logistics Centre site for both the pre-development and the post-development case. The requirement for and characteristics of any detention basin(s) were then determined.

Two stormwater detention basins are proposed:

- One at the downstream end of catchment D, located at the southern end of the hardstand area; and
- One at the downstream end of catchment C, located on the eastern edge of the site.

Each basin was optimally sized, ensuring that for each recurrence interval assessed, the peak discharges from the site were not increased as a result of the development, and where possible retardation of flows to flowrates less than pre-development conditions could be achieved.

The requirements for water quality “first flush” storage and treatment and requirements for water storage for reuse purposes were considered separately to the detention basins. The first flush and reuse water storage volumes are discussed in the Stormwater Quality and Soil and Water Management Working Paper.

4.2.1 Existing Site Imperviousness and Absorptiveness

A key element of the drainage design is the assessment of existing and proposed pervious and impervious areas. Furthermore, special consideration has been given to the absorptive capacity of the site over the pervious areas, given the history of site use.

The proposed development site was historically a railway marshalling yard. Previous works have consolidated the marshalling activity to the west of the site. However, the redundant marshalling yard under consideration for this development is likely to exhibit some characteristics related to its previous use.

In the past, the site of the proposed ILC was covered with railway lines. The lines and ballast have been removed, however the ballast would have been underlain with a "capping" layer of clay material, which was not completely removed. It is considered that the presence of this capping layer, be it in a semi-disturbed state since decommissioning of the railway yard, will reduce the absorptiveness and infiltration capacity of the site. This is reflected in the continuing rainfall loss parameter adopted for pervious areas, which is relatively low.

Hydrological calculations conducted in this analysis have adopted absorptive values represented by initial and continuing loss values that are consistent with those used in previous analyses, specifically the New Enfield Marshalling Yards Project (designed by Sinclair Knight Merz). In assessing the existing conditions of the New Enfield Marshalling Yard site (Sinclair Knight 1993), consideration of the capping layer was included in the determination of rainfall losses.

The initial and continuing losses adopted in the RAFTS rainfall runoff modelling are presented in **Table 8**.

- **Table 8: Modelled Loss Coefficients**

Pervious Areas		Impervious Areas	
Initial Loss (mm)	Continuing Loss (mm/hr)	Initial Loss (mm)	Continuing Loss (mm/hr)
13	1.5	1.5	0

It is estimated that under existing conditions, the catchments covering the project area are approximately 85 % pervious, noting the comments above. The proposed development will create large areas of hardstand with very little absorptive capacity. The proposed development will decrease the pervious area of the catchments to approximately 18 %. These estimations exclude consideration of the area to the south of the southern channel, which remains pervious before and after the project implementation.

4.3 Existing and Proposed Conditions

The existing catchment areas A-D were defined in **Section 3.7**, and the peak runoff from each existing catchment was listed in **Table 5**. Likewise, the post-development catchment areas A-D were defined in **Section 3.8**, and the peak runoff from each post-development catchment was listed in **Table 7**. The following section (**Section 4.4**) outlines the approach used to perform the hydrological assessment and the detention requirements for Catchments C and D, reviewing the pre-and post-development flows from those catchments. **Section 4.5** outlines the approach used, the detention requirements and the peak flows for catchments A and B.

4.4 Detention Requirements for Catchments C and D

The proposed development involves creating large areas of impervious “hardstand” surface. An increase in impervious area will result in an increase in rainfall runoff and, if unmitigated, an increase in peak discharges. The additional runoff generated from the site will be controlled and attenuated using detention basins. Peak discharges will not exceed those estimated from the existing site.

To assess the post development discharge from the site and the requirement for detention, the RAFTS rainfall runoff model was augmented to represent the post development condition.

Peak flows from the post development site were assessed for the 2, 10 and 100 year ARI storms. As expected, the peak flow into the main stormwater channel at the southern end of the site increased substantially. This is due to the significantly larger catchment diverted to this point and the impervious nature of the developed catchment. The peak flow into the DELEC drain also increased by a small amount, as – although the catchment area at this point reduced – the impervious fraction of this catchment increased substantially.

4.4.1 Catchment C

The RAFTS modelling results indicate that a 2,000 m^3 detention basin would be adequate to reduce peak flows from Catchment C to pre-development levels. A location for this basin has been identified on the eastern side of the site, just south-east of the proposed warehouse. The detention storage could be provided either above- or below-ground, which could be determined at the detailed design stage. For the purposes of this assessment, the basin was defined as an above-ground basin with a top level of 22 m AHD and a spillway at 21.8 m AHD. A low-level outlet (modelled in this assessment as a 300-mm pipe) would connect to the existing drainage system.

4.4.2 Catchment D

To reduce the peak discharge into the southern stormwater channel, a detention basin is proposed to attenuate peak flows from the site. The basin characteristics were developed and tested in the RAFTS model.

It was determined that a detention basin of approximately 33,000 m^3 is required to attenuate the peak discharge from the site to pre development levels. **Table 9** presents a comparison of the pre development and post development flows for Catchment D, including the post-development flows with and without mitigation (i.e. with and without the detention basin).

- **Table 9: Comparison of Pre- and Post-Development Flows from Catchment D**

Storm event	Pre-development peak flow (m^3/s)	Post-development peak flows without mitigation (m^3/s)*	Post-development peak flows with mitigation (m^3/s)*
2 year ARI	1.30	7.44	1.22
10 year ARI	2.18	11.05	1.62
100 year ARI	3.70	16.09	3.65

*Note that the critical storm duration changes. Refer Appendix A.

Full details of the RAFTS modelling results are presented in **Appendix A**.

In the estimation procedure, characteristics of the required detention basin were developed. Details of the basin parameters are presented in **Table 10**. The final arrangement of the basin is subject to detailed design.

- **Table 10: OSD Basin Characteristics: Catchment D outlet**

Basin	Volume (m^3)	Base of basin		Top of basin	
		RL (m AHD)	Surface Area (m^2)	RL (m AHD)	Surface Area (m^2)
1 (North of catchment 2 culvert)	17,321	14.4	5,210	17.1	6,740
2 (South of catchment 2 culvert)	16,133	13.5	5,770	17.1	7,060
Total	**33,453**				

To control outflows and provide the desired attenuation, as well as incorporate a requirement to treat the first flush, the detention basin will involve a series of stormwater pits and controls. The configuration of the detention and first flush basins is outlined conceptually in the following section.

4.4.3 Detention Basin/First Flush Basin Inlet and Outlet: Catchment D

There are three key requirements relating to stormwater. These are:

- To ensure adequate water quality in the stormwater, it is required that the first flush, assessed as the first 10 mm of any runoff, be captured and treated before discharge to the stormwater system. The water quality analysis completed for the Water Quality Working Paper determined that a water quality basin with a volume of 4,250 m^3 was required to capture the first flush for treatment before discharge to Coxs Creek;
- In order not to increase flow downstream, it is required that stormwater runoff from the developed site be restricted to the pre-development flow. From hydraulic analysis it was determined that a storage volume of 33,450 m^3 is required for peak flow mitigation; and
- The detention basin has to function even when there is a major flood in Coxs Creek.

In order to adequately assess the behaviour of the detention basins, a RAFTS computer model was used to trial different detention basin sizes until the requirement that there be no increase run-off from site was achieved for the critical storm durations and intensities.

The proposed layout of the basins is shown in **Figure 14** and described below.

The stormwater from the ILC site, both pipe flow and overland flow, enters Pit 1 and is directed to the water quality basin. After the first flush volume of 4,250 m^3 is captured, the water flows into a second chamber in Pit 1 where the predevelopment flow is allowed to pass into a low flow pipe connected to Pit 2. Any excess flow is diverted to Detention Basin No.1. This basin is hydraulically connected to Detention Basin No.2, and the two basins will fill together. At an elevation of 16.05 m AHD, water will start to overflow detention Basin No.2, into Pit 2. This flow, combined with the low flow from Pit 1, will flow into a pipe and cross over the culverts that take the Coxs Creek flow to Pit 3. The detention basins are expected to fill to a level of 17.1 m AHD in the 100 year event.

The detention basins will require an embankment around them to a height of approximately 17.5 m AHD, to ensure that the 100 year ARI event in Coxs Creek does not flood the detention basins.

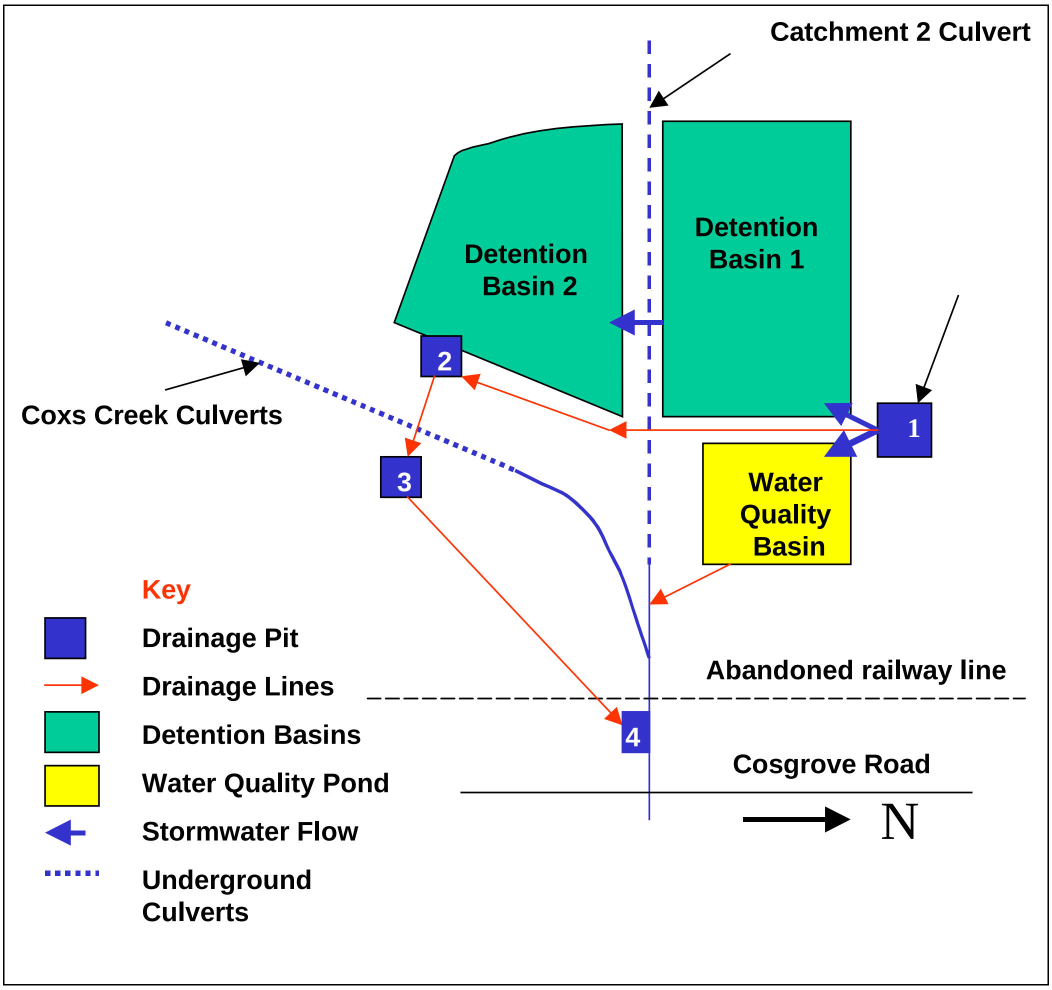
From Pit 3, the pipe flow will be taken to a Pit 4 which is located just downstream of the masonry arches, see **Figure 7**, supporting the abandoned railway line. The reason for discharging to this point and not directly into Coxs Creek near Pit 2, is that the flood level is too high upstream of the

SKM

masonry arches due to the restriction caused by the arches. In order for the basins to operate successfully, it is necessary that the discharge pipe outlet be located where the flood level is approximately 13 m AHD, which therefore requires the pipe to be taken downstream of the masonry arches.

The runoff from events up to and including the 100 year ARI event are contained and managed within the boundaries of the site, whether through a piped system or via an overland flowpath. The depths of overland flows will be limited to 200 mm.

- **Figure 14: Conceptual diagram of the first flush and detention basins**



4.5 Detention Requirements for Catchments A and B

The post-development catchments A and B are planned for light commercial and industrial development. This development will comply with Strathfield Council's requirements for on-site detention (as presented in the Strathfield Council *Stormwater Management Code* 1994), which require that peak flows from the storms between the 2 and 100 year ARI events are mitigated to pre-development levels.

The Code sets out guideline detention requirements for “small” and “large” commercial and industrial developments. These are presented in **Table 11**.

- **Table 11: Strathfield Council OSD requirements for commercial and industrial areas**

Development Type	Permitted discharge from storage per 1000 m^2 of the total development area	
	Storm event (ARI, years)	Permissible site discharge (PSD) max (L/s)
Commercial/Industrial - Small	2	20
	10	25
	100	33
Commercial/Industrial - Large	2	12
	10	16
	100	23

Ref source: Strathfield Council 1994 *Stormwater Management Code*

It can be seen from **Table 11** that the requirements for “large” commercial and industrial developments are more stringent than those for “small” commercial and industrial developments. Strathfield Council indicated that the requirements for “small” developments would usually be applied to areas that are being redeveloped, whereas the requirements for “large” developments would usually be applied to areas that are being developed for the first time. Parts of the light commercial and industrial development area will be deemed to constitute “large” development.

Regardless of the permitted site discharge, there is a requirement that peak flows from storm events up to the 100 year ARI are mitigated to pre-development levels.

Taking into consideration all of the above, the requirements for “large” commercial and industrial developments were applied to Catchments A and B. The methodology and results of the analysis are outlined in the following sections.

4.5.1 Methodology

The first step in determining the detention requirements for Catchments A and B was to model the pre-development scenario in RAFTS. Peak flows were recorded for the 2, 10 and 100 year ARI storm events.

To model the post-development scenario, it was assumed that the areas within the Intermodal Logistics Centre boundary is to be 100% developed. In each catchment, there are some areas within the post-development catchments that are outside the site boundary. These areas were assumed to remain unchanged. Catchment B also includes an area around the central channel outlet that will remain undeveloped. In addition, each of these catchments will include an area of landscaped mound. The landscaped mound areas and areas that will remain unchanged pre- and post-development were modelled in RAFTS to find the peak discharges for the 2, 10 and 100 year ARI storm events. For the areas to be developed, a blanket permissible site discharge (PSD) was applied, in terms of maximum flow per unit area (m^3/s per 1,000 m^2). Peak discharges for each catchment were determined by adding the PSD from developed areas to the peak discharges from landscaped and unchanged areas.

4.5.2 Results

Peak flows from catchments A and B, in the existing and proposed cases, are summarised in Table 12.

Table 12: Pre- and Post-development peak flows from catchments A and B

Storm Event	Catchment A		Catchment B	
	Existing peak flow (m^3/s)	Proposed peak flow (m^3/s)	Existing peak flow (m^3/s)	Proposed peak flow (m^3/s)
2 year ARI	0.26	0.25	1.41	0.28
10 year ARI	0.46	0.36	2.70	0.43
100 year ARI	0.80	0.58	3.55	0.72

There would be a small reduction in the peak flows from catchment A and a significant reduction in the peak flows from catchment B. Therefore flows to the Central drain would be reduced – a positive outcome for a drain which is already under capacity.

Full details of the modelling results for Catchments A and B are presented in Appendix A.

5. Hydraulics

The existing drainage infrastructure was discussed in **Section 3**, and the need to fully analyse the drainage system, particularly issues associated with flooding, was identified by the Director General's requirements.

The existing drainage infrastructure and the proposed modifications have been fully analysed. This section of the working paper describes the methods used to assess drainage and flooding issues and reports on the assessment and impact of the proposed development.

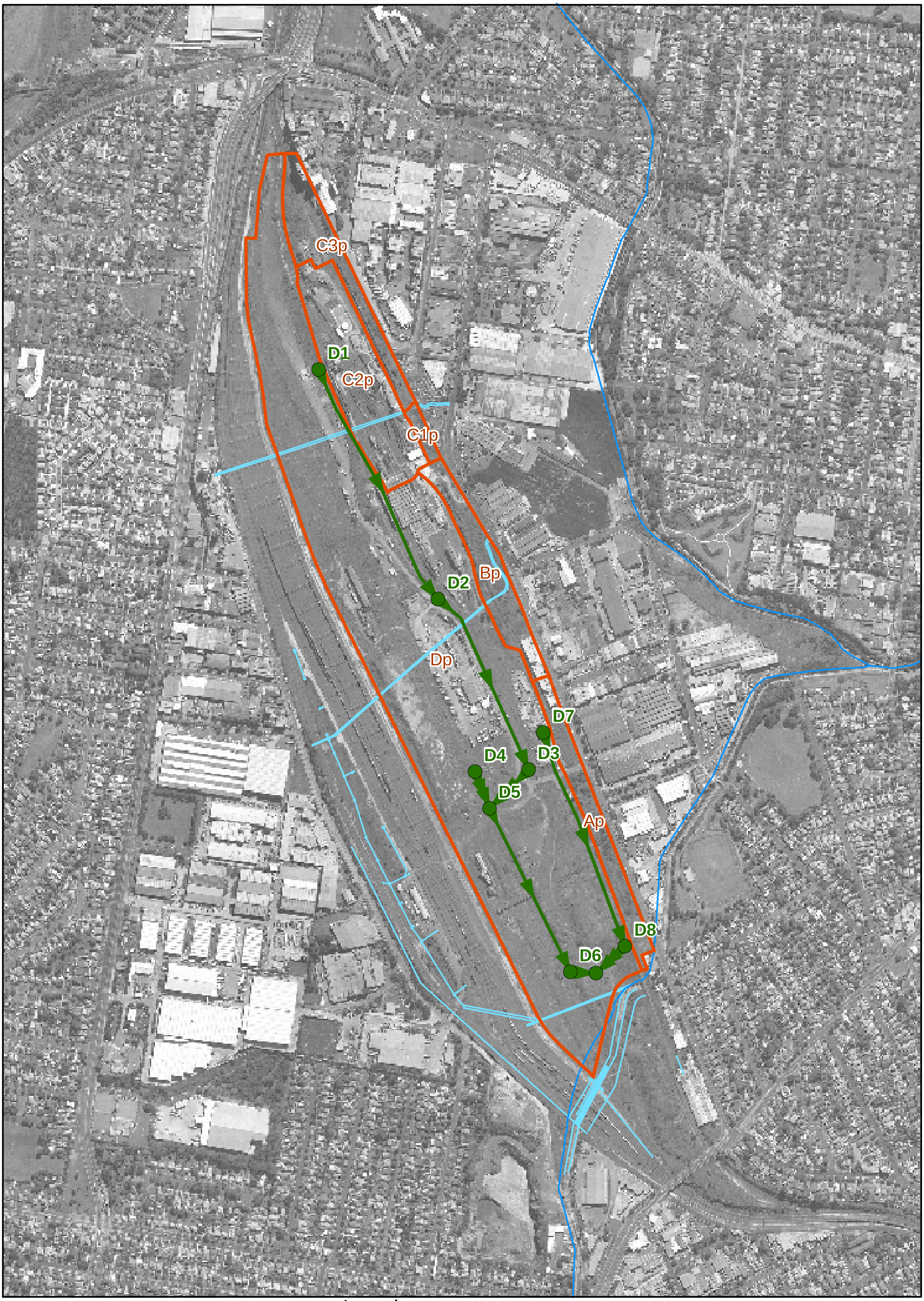
5.1 Internal Site Drainage

As discussed in **Section 3.8**, the proposed development involves regrading the site and redirecting much of the runoff to the Coxs Creek drainage line. In order to achieve this, the internal site drainage will be designed to direct both piped and overland flows towards the southern end of the site.

As part of this study, a preliminary assessment of piped and overland flow rates was undertaken and a concept design of the internal site drainage has been developed. The drainage concept involves:

- Carrying flows up to and including the 10 year ARI peak flows in pipes and/or culverts underground;
- Carrying flows in excess of the 10 year ARI peak flows and up to and including the 100 year ARI peak flows in the system of roads on the site, which will act as overland flowpaths during major storm events; and
- Allowing a maximum depth of overland flow of 0.2 m.

The basic drainage system and overland flowpath layout is shown in **Figure 15**. For the purposes of this assessment, pipes/box culverts were sized and the overland flowpaths were checked at a number of discreet points throughout the site. Results of this assessment are shown in **Table 13** and **Table 14**. Further detailed analysis would be required at the detailed design stage.



Source: Topographic data supplied by SPC, Air photos BY SKM

Projection: MGA 56
Page Size: A4
File Name:EN01709_Wr_005.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 18/4/2005

N

0 100 200
Metres

Legend

- Drainage Nodes
- Drainage Links
- Proposed Subcatchment
- River
- Stormwater infrastructure

Figure 15
Drainage System Layout

SKM

SKM

Table 13: Drainage system concept design

Reach	Pipe flow (10 year ARI flow), m^3/s	Proposed pipe/culvert size	Indicative upstream invert level (m AHD)	Indicative downstream invert level (m AHD)
D1-D2	1.51	600×1200 RCBC	23.02	20.27
D2-D3	4.08	900×1500 RCBC	20.09	18.04
D3-D5	5.05	900×1800 RCBC	17.77	17.27
D4-D5	2.87	600×1800 RCBC	17.59	17.19
D5-D6	7.47	900×2400 RCBC	16.96	15.01
D6-first flush basin	8.25	900×2700 RCBC	14.65	14.40
D7-D8	1.81	600×1200 RCBC	17.38	14.98
D8-first flush basin	3.71	600×2100 RCBC	14.80	14.40

Table 14: Overland flowpath system concept design

Reach	Overland flow (100 year ARI flow – 10 year ARI flow), m^3/s	Indicative overland flowpath cross-section	Maximum depth of flow (m above gutter level))
D1-D2	0.64	10-m wide road, 3% crossfall, min. 0.5 % grade	0.17
D2-D3	1.78	14-m wide road, 1% crossfall, min. 0.5% grade	0.19
D3-D5	2.19	To be designed at the detailed design stage. Flowpath will probably need to extend into landscaped area to achieve depths ≤0.20 m	≤0.20
D4-D5	1.17	Through culverts under access road: e.g. three 300 mm × 900 mm RCBCs	N/A
D5-D6	3.17	Trapezoidal section, 4m wide at base with 2% side slopes. Min. 0.5% grade	0.20
D6-first flush basin	3.60	To be designed at the detailed design stage	≤0.20
D7-D8	0.80	10-m wide road, 3% crossfall, min. 0.5% grade	0.18
D8-first flush basin	1.61	To be designed at the detailed design stage	≤0.20

The drainage system has been designed for all pipes/culverts to be laid at a grade of at least 0.5 %. Box culverts have been selected instead of pipes to minimise their depth and maximise the cover over the drainage system. A check has been performed that all parts of the drainage system would have at least 0.6 m cover. This design should be refined at the detailed design stage to find the most cost-effective solution and ensure that there is adequate separation between the drainage system and existing services.

It has been assumed that all of the roads on site can be designed such that their minimum grade will be 0.5 %. The major roundabout will need to be designed such that overland flows will cross it and continue south, rather than flowing east onto Cosgrove Road. This preliminary investigation has indicated that this should be feasible.

5.2 Minor Culverts

The three minor culverts that traverse both the Enfield Marshalling Yards and the Intermodal Logistics Centre site in the central and northern sections of the site (refer to **Figure 3**), were extensively studied and hydraulically modelled in previous reports (Binnie & Partners 1991 and Sinclair Knight 1993). The results of those studies were drawn upon in this assessment.

5.2.1 Central Culvert

The central culvert traverses both the New Enfield Marshalling Yards and the proposed Intermodal Logistics Centre. Upstream the culvert commences at Wentworth Road as a 1.2 m brick arch and at approximately 10 metres downstream transitions to a 1.5 m brick arch. The catchment upstream is 60 ha. Parts of the existing site also drain to the culvert as discussed in **Section 3**.

The culvert causes a constriction to flow and limits flow to 4.3 m^3/s across the site (Sinclair Knight, 1993). Peak runoff from the catchment upstream is 16, 18 and 23 m^3/s for the 10, 20 and 100 year ARI flood events respectively and consequently frequently exceeds the capacity of the culvert. As a consequence, floodwaters back up at the Wentworth Street entrance to the culvert and are reported to cause flooding. The flooding performs a “natural” detention function, attenuating the flood. This was discussed in **Section 3.6**.

Any amplification to this culvert would increase the flood flow beneath the site and would cause flooding at the downstream (Cosgrove Road) end of the site, unless the downstream infrastructure was suitably amplified to cater for the increased flow. This would as a minimum require amplification of the culverts beneath Cosgrove Road and the properties downstream and possibly the Cooks River drainage channel all the way to the receiving waters of Botany Bay. This is not considered feasible in respect of this development and is a wider drainage problem to be considered in context of the total catchment (the total catchment was shown on the map in **Figure 1**).

The proposed development is actually removing part of the catchment that flows to this drain. While impervious areas will increase in the remaining catchment as a result of the light commercial and industrial development, OSD will attenuate runoff from the commercial and industrial area and the net effect is to lessen the flow into the Central drain. Whilst the reduction in catchment area is not significant in terms of the upstream contributing catchment, and will not necessarily lessen the extent of upstream flooding, it is expected to assist in lessening the duration of flooding experienced upstream.

The channel that conveys water from the brick arch culvert to the Cosgrove Road culvert was analysed. Given the constricting performance of the brick arch, the flow is limited to 4.3 m^3/s, the capacity of the culvert. Overland flows that cannot enter the culvert at the upstream end will not follow the culvert alignment and will not contribute to the flow in the open channel downstream of the culvert.

5.2.2 DELEC Culvert

The culvert adjacent to the existing DELEC Facility (DELEC Culvert) receives flow from both Catchment 3 upstream of the Marshalling Yards as well as contributions from the DELEC facility itself. Currently there are no detention controls on the DELEC site and discharge is relatively uncontrolled.

It is not possible to retard the upstream catchment flows. A detention basin has already been installed at Lee Park and is effective for flows up to the 10 year ARI event.

The development reduces the catchment contribution to the culvert, and detention would be introduced to mitigate impacts of increased imperviousness. The result of these factors is that the peak flows from the catchment will not be increased in events up to and including the 100 year ARI event. It is therefore considered that the net effect of this development is to control flows entering the DELEC culvert and thus cause no significant impacts.

5.2.3 Northern Culvert

This culvert is outside the influence of the project. Whilst it crosses the very northern extremities of the project site, it is not impacted upon by the development. Its connection to the drainage system is downstream of the project site.

There are no reported hydraulic issues associated with this culvert and as such it is proposed that this channel remains in situ and continues to function without modification.

5.3 Major Drainage - Southern Channel (Coxs Creek)

As discussed in **Section 4** of this report, the proposed development encroaches onto the floodway of the Southern Channel. The encroachment is in the form of filling on the northern side of the floodway to provide the working platform area.

To assess the impact of the development on this overland flowpath, a hydrodynamic model was established to test the impact of the development. This section describes the model set up and the results of the analysis.

5.3.1 MIKE11 modelling

A MIKE-11 model of the Southern Channel was set up to represent the hydraulic behaviour of the culverts and overland flowpaths of Coxs Creek and its tributary from Subcatchment 2. MIKE-11 is the industry standard tool for the assessment of hydraulics in open channels. The model commenced upstream of the site in the channel between Juno Parade and the New Enfield Marshalling Yards. The model includes the following elements, which were illustrated in **Figure 10**:

- 3 and 4 cell box culverts underneath the New Enfield Marshalling Yards and SPC sites, draining Subcatchment 1;
- Open trapezoidal channel sections;
- Railway arches;
- Cosgrove Road culverts;
- Twin and single cell box culverts underneath the New Enfield Marshalling Yards and SPC sites, draining Subcatchment 2; and
- Overland flowpaths from both Subcatchments 1 and 2.

The model was established using the topography of the existing site provided by SPC in 2001 and details of the structures as surveyed by Peter Bolan and Associates for the 1993 Sinclair Knight assessment.

Inflow hydrographs for the 10, 20 and 100 year ARI events were extracted from the RAFTS modelling conducted for the 1993 Sinclair Knight report and routed through the model. The peak flows for the various events and times of concentration are presented in **Table 15**. It should be noted that flows from Subcatchments 1 and 2 were routed to determine the critical storm and peak flow at the confluence upstream of the railway arches. Also important to note is that the critical durations were derived from the RAFTS model and only one storm duration was modelled in Mike-11 for each ARI event.

- **Table 15: Peak flows and t_c For Coxs Creek**

Storm Event (ARI, years)	Time of Concentration (mins)	Peak Flow* (m^3/s)
10	60	91
20	120	105
100	60	135

***NB: Peak Flow reported downstream of confluence between subcatchment 1 and 2 flows**

The input hydrographs are presented in **Appendix B**.

Peak flood level results from the model were compared the output from the 1991 Binnie and Partners report at Cosgrove Road, the railway arch culverts and at the western boundary of the site. Throughout the section modelled, significant differences were found between the flood levels reported by Binnie (1991) and those derived from the current modelling. In general, flood levels derived from the Mike-11 model were much higher than those reported by Binnie, with the exception of the area immediately downstream of the railway arches, where flood levels from Mike-11 were lower than Binnie's.

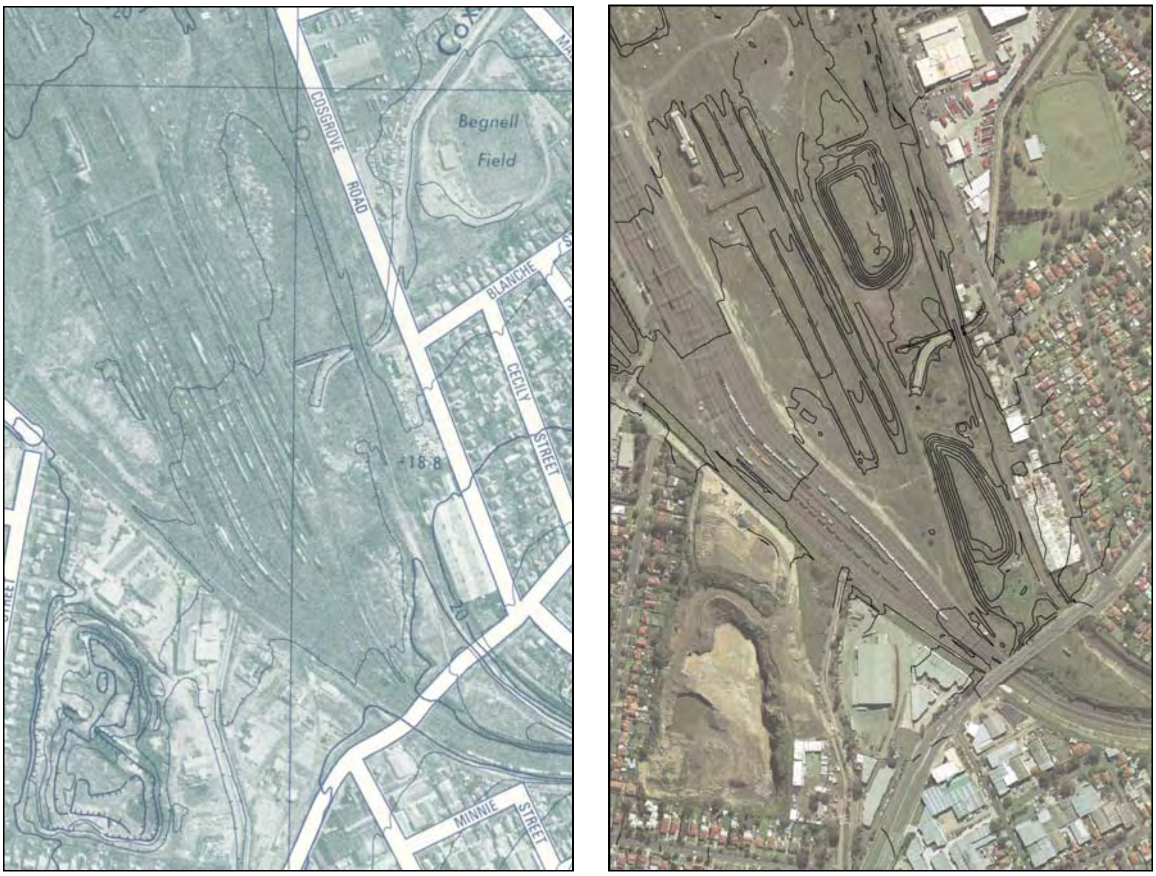
It was found that the key source of the differences was the masonry railway arches. A sensitivity test was performed where these arches were removed from the Mike-11 model; it was found that this reduced the flood profile to levels much more similar to those reported by Binnie (1991). It is possible that the modelling technique used by Binnie in 1991 did not fully represent the contraction and expansion losses caused by the railway arches. Other possible sources of difference between Binnie's 1991 model and the current Mike-11 model are:

- Since 1991, the Coxs Creek floodplain in this area has changed substantially – in 1991 the area within the SPC site was still covered by railway lines rather than the scrub that currently covers the site; and
- The stockpiles that currently protrude into the floodplain had not yet been formed in 1991.

A section of the Regents Park (U0045) 1:10,000 orthophoto map, produced from photography of 1982, is shown in **Figure 16**. This map includes the 2-m contours. Also in **Figure 16** is a section of the recent aerial photography (SKM AusImage™, 2003), including 2-m contours where they are available from the recent survey. The differences in site conditions are apparent on comparing the two images.

SKM

- **Figure 16: Coxs Creek before (left) and after (right) Marshalling Yards redevelopment**



Given the known changes in the floodplain and demonstrated effect of the railway arches, the flood levels from current Mike-11 model were adopted for the purposes of this study.

5.3.2 Existing Flood Behaviour

The existing flood behaviour for the 10, 20 and 100 year ARI events was analysed in the model.

Generally, flows in excess of the Coxs Creek culvert capacity will flow overland directly across the Marshalling Yard railway tracks in an easterly direction. The overland flow eventually rejoins the open channel section of Coxs Creek before flowing under the railway arches and Cosgrove Road.

Flows from the "minor culvert" draining Subcatchment 2, intersect with Coxs Creek just upstream of the railway arches. The overland flowpath for the minor culvert does not follow the route of the culvert. Rather, overland flows travel south until they meet Coxs Creek, where they may either enter the Coxs Creek culverts or join the overland flowpath and continue east with that flow.

The Manning's 'n' dimensionless roughness coefficient in the channel and overland sections were estimated to be:

- 0.012 in box culvert sections;
- 0.015 in concrete channel sections as well as on roads;
- 0.035 in sections of bare soil;
- 0.035-0.045 in grassed areas;
- 0.05 across railway lines;
- 0.06 in areas of scrub (prevalent on the SPC site);

Flood levels were assessed at various points of interest across the floodplain and the results are presented in **Table 16**, **Table 17** and **Table 18**.

- **Table 16: Pre-development Flood Level Results 10 year ARI**

Location	Model Chainage	Flood Level (m AHD)
U/S New Enfield Marshalling Yard @ 3 cell RCBC	Main_Channel 42.0	16.263
Boundary between New Enfield Marshalling Yard and SPC site	Main_Channel 144.65	16.250
Confluence of Coxs Creek and Minor Culvert	Main_Channel 369.60	14.792
U/S of Railway Arches	Main_Channel 390.0	14.784
U/S Cosgrove Road	Cosgrove_Road 0.00	13.067

- **Table 17: Pre-development Flood Level Results 20 year ARI**

Location	Model Chainage	Flood Level (m AHD)
U/S New Enfield Marshalling Yard @ 3 cell RCBC	Main_Channel 42.0	16.486
Boundary between New Enfield Marshalling Yard and SPC site	Main_Channel 144.65	16.476
Confluence of Coxs Creek and Minor Culvert	Main_Channel 369.60	15.221
U/S of Railway Arches	Main_Channel 390.0	15.225
U/S Cosgrove Road	Cosgrove_Road 0.00	13.124

- **Table 18: Pre-development Flood Level Results 100 year ARI**

Location	Model Chainage	Flood Level (m AHD)
U/S New Enfield Marshalling Yard @ 3 cell RCBC	Main_Channel 42.0	16.866
Boundary between New Enfield Marshalling Yard and SPC site	Main_Channel 144.65	16.854
Confluence of Coxs Creek and Minor Culvert	Main_Channel 369.60	16.057
U/S of Railway Arches	Main_Channel 390.0	16.068
U/S Cosgrove Road	Cosgrove_Road 0.00	13.240

The areas inundated by the 10, 20 and 100 year ARI events are presented in **Figure 17**. This map includes AusImage™ aerial photography from 2003 and 0.5-m contours provided by SPC.

Generally, the floodplain is controlled by the structures within it. The railway arches in particular form a major control; the afflux across this structure is around 2-3 m in the modelled events. Other key controls are the earth mounds that protrude into the floodplain, restricting flows.

5.3.3 Sensitivity testing

Some sensitivity testing was performed to check whether the downstream boundary condition would influence flood level results in the model. In the base case, the downstream boundary condition is set 240 m downstream of cross-section Main_Channel_505.00, and has been set to 10.5 m AHD. This level was varied by ±0.5 m and the influence on flood levels checked in the 10, 20 and 100 year ARI events.

It was found that 10, 20 and 100 year ARI flood levels at Main_Channel_505.00 were somewhat dependent on the downstream boundary condition: when the boundary condition was varied by ±0.5 m, the flood level at Main_Channel_505.00 varied from –0.03 to +0.09. Upstream of here (i.e. upstream of Cosgrove Road), flood levels were not affected by the boundary condition.

The Mike-11 model cross-sections are shown on the inundation map in **Figure 17**. Within the limits of mapping, as shown on these figures, flood levels are not sensitive to the boundary conditions in the model.

5.3.4 Proposed modifications to floodplain

The proposed development may potentially modify the overland flowpath of Coxs Creek due to the following works:

- Construction of Detention Basins and Water Quality Basin on the north side of Coxs Creek;
- Filling above flood level for the hardstand areas;
- Extension of sound and visual barriers;
- Potential changes to the area to the south of Coxs Creek; and
- Construction of a new railway line on the western boundary of the site across Coxs Creek.

Consequently the MIKE11 model was modified to reflect the changes to the floodplain envisaged due to the construction of the Intermodal Logistics Centre. This involved:

- Defining the proposed edge of the hardstand/detention basins where they would protrude into the floodplain; and
- Defining the proposed location of the noise mounds and barriers where they would protrude into the floodplain.

It was assumed that the floodplain roughness would remain the same before and after development.

Initial hydraulic model runs showed that the proposed works would have a major impact on flood levels. The two major changes that required mitigation works are discussed below.

a) Construction of railway line

The proposed vertical alignment for the new railway line was that it be flood free in the 100 year event in Coxs Creek and so the railway line was modelled as being raised with culverts carrying the overland flow from Coxs Creek. However even with 55 cells of 3.6 m wide x 2.4 m high, the flood rise upstream was in the order of 60 mm, which is considerable.

In addition, the railway line would need to rise from about 16 m AHD under Punchbowl Road to the required elevation of about 18 m AHD (soffit of culverts at 17.1 m AHD, plus deck of culvert, ballast, sleepers and rails). Even if this rise could be achieved in the available distance, it is likely that in the 100 year flood, the railway line to the south of the Punchbowl Road is likely to be flooded. In summary:

- It would be very expensive to raise the railway line above the 100 year flood level adjacent to Coxs Creek;
- There would be problems of grading the line to achieve the level required;
- There is a likelihood that the line will be flooded to the south off-site, closing the line irrespective of whether the line is above the flood level at Coxs Creek; and
- The upstream flood rise of 64 mm was excessive.

The alternative was to keep the new railway line at the same elevation as the existing ground levels as it passes over Coxs Creek. After reaching the edge of the hardstand, the rails can start to rise to be flood free to the north of the detention basins. This means that the line will be flooded in the 10, 20 and 100 year events, but it is likely that during these events, the line will be closed anyway due to flooding to the south of Punchbowl Road.

It is estimated that water from Coxs Creek will flow over the existing railway lines in any event as large or larger than the 10 year ARI event.

Consequently it is recommended that the railway line remains on-grade across the community & ecological area and starts to rise only after passing the north side of Coxs Creek. This option was included in the final Mike-11 model runs.

b) Location of Detention Basins

Initially it had been proposed to locate the Detention Basins as close as possible to Coxs Creek and this layout was included in the hydraulic model and the impacts of the development investigated. Without mitigation, the development would cause flood level rises both upstream and downstream, including 43mm at the Marshalling Yards and 15mm at Cosgrove Road. This is due to a loss of flood storage on site, particularly on the northern side of Coxs Creek. An estimated 10,000 m^3 of flood storage would be lost as a result of the proposed development.

Several different options were then tested in the model to compensate for the loss of flood storage and minimise the impact on flood levels. Some of the main options tested included:

- Excavating a range of volumes from the western side of the southern mound;
- Excavating material from the other mound that lies within the floodplain;
- Excavating material from the right bank just upstream of the old railway arches;
- Adding some fill to the northern end of the southern mound; and
- Combinations of the above.

Most of the options tested produced mixed results. Some options were effective at minimising upstream impacts, but downstream impacts remained. Others eliminated the downstream impacts, but only at the expense of higher upstream flood levels. Only one option was found that successfully mitigated both upstream and downstream impacts.

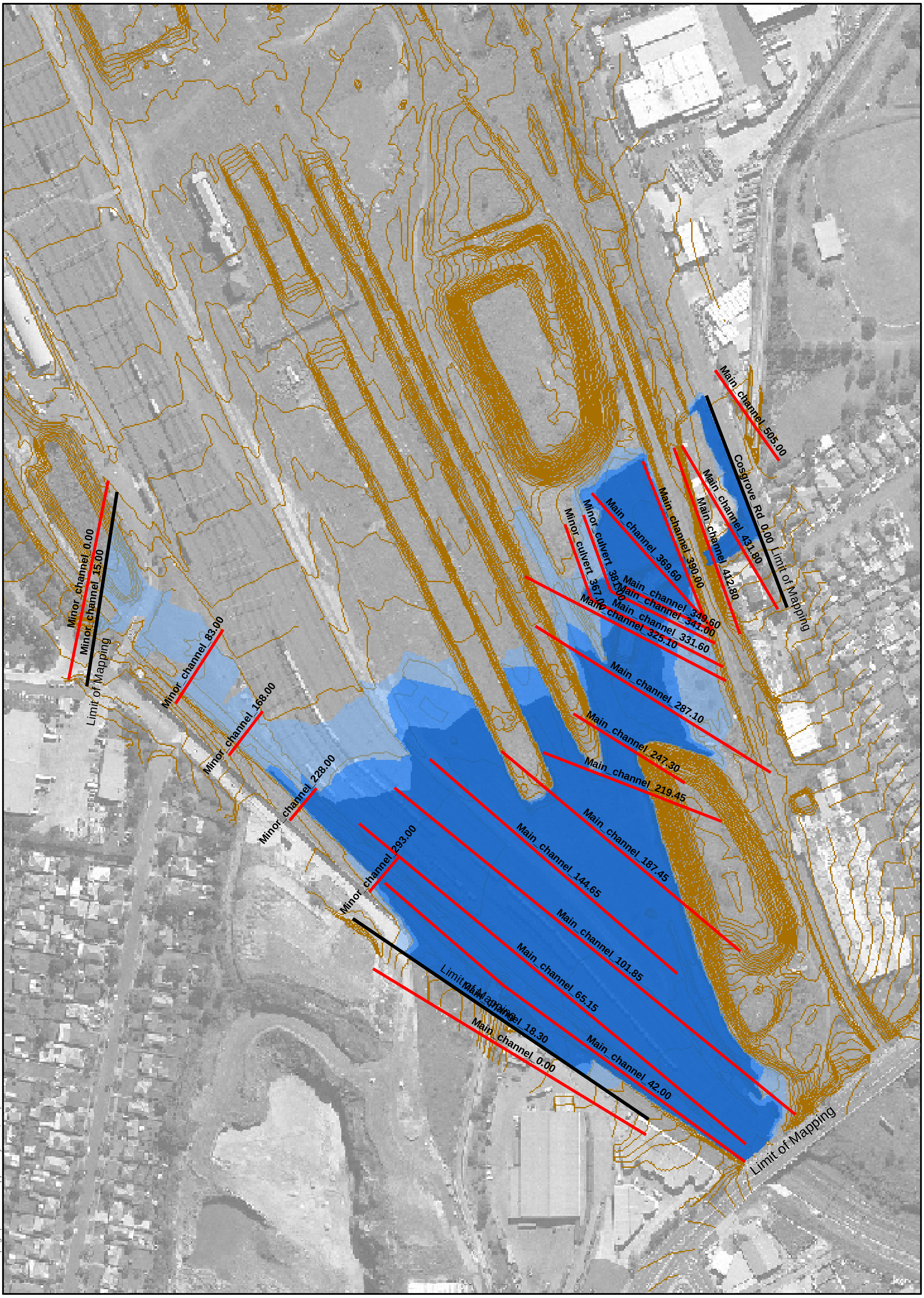
After approximately 10 trial layouts, it was agreed by SPC that it would be necessary to move the Detention basins, at least partially out of the floodway of Coxs Creek. This action, combined with some small amount of land reshaping, has resulted in a negligible impact on flood levels on-site and upstream and downstream.

Proposed floodplain modifications are illustrated in **Figure 18**. The modifications include:

- Addition of the development features (detention basins, noise barriers);
- Levelling of the most westerly mound to 15.0 m AHD;
- Levelling of the adjacent mound to 17.0 m AHD; and
- Addition of 4-m of extra fill to the toe of the southern mound.

It was assumed that the proposed new railway line would be at the same elevation as the existing lines on the New Enfield Marshalling Yards. Therefore no changes to the model were needed to represent this new railway line.

Following modifications outlined above, the floodplain was further assessed. The results of the hydraulic modelling at the key interest points are summarised in **Table 19**, **Table 20** and **Table 21**.



Source: Topographic data supplied by SPC, Air photos BY SKM

A4

File Name:EN01709_Wr_007.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 12 May 2005

Projection: MGA 56

N

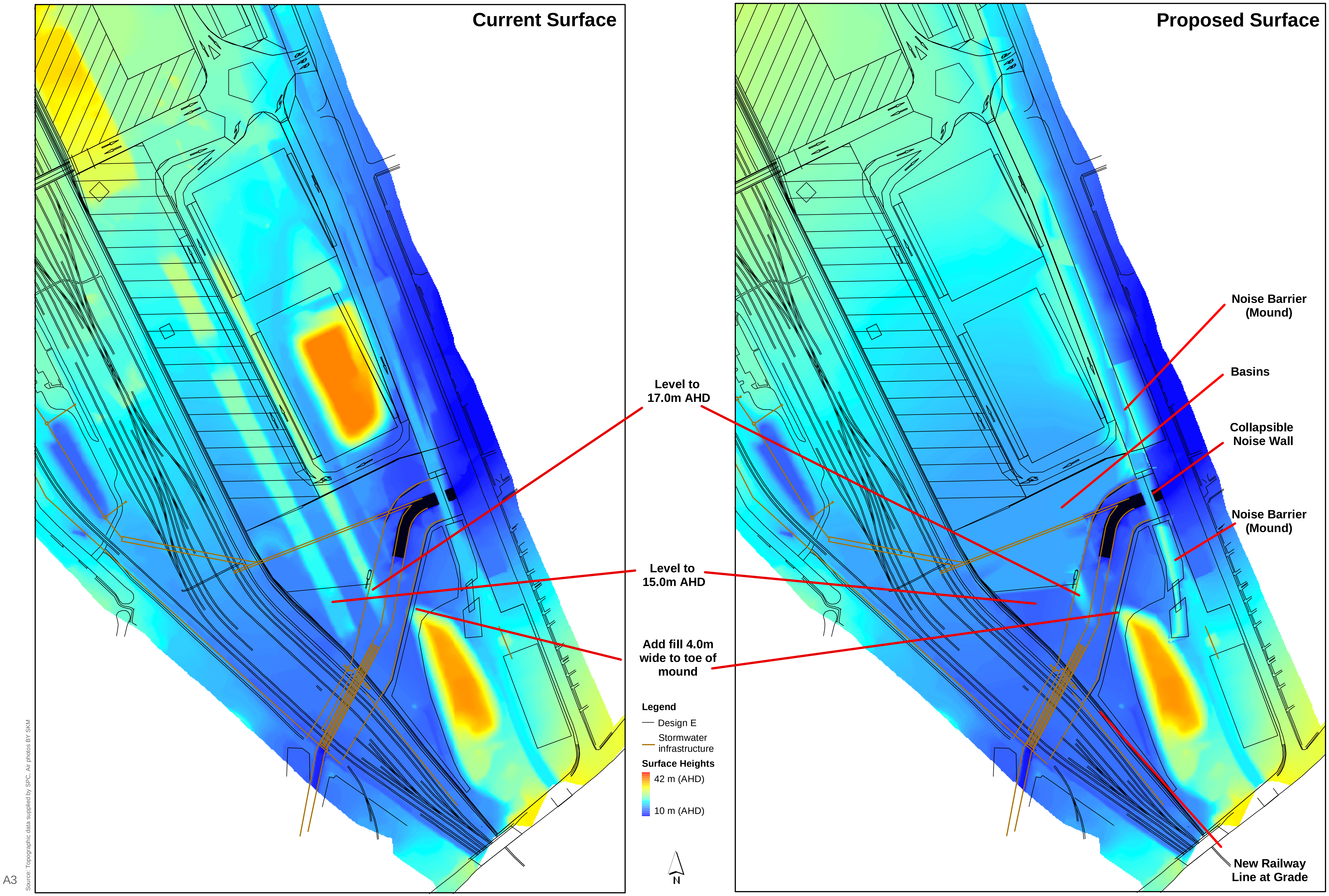
0 30 60
Metres

Legend

- Exisitng 0.5m Contours
- Mike 11 Cross Sections
- Limit of Mapping
- Cross Sections
- Existing 10yr ARI
- Existing 20yr ARI
- Existing 100yr ARI

Figure 17
Existing Inundation Envelope for 10, 20, 100 Year ARI

SKM



File Name:EN01709_Wr_011a.mxd
Location:\\EN01709\Technical\
GIS\Template\
Date: 12 May 2005

Projection: MGA 56

Figure 18
Modified Flood Plain Areas

SKM

SKM

- **Table 19: Post Development Flood Levels for the 10 year ARI Event**

Location	Pre-Development Flood Level (mAHD)	Post-Development Flood Level (mAHD)	Change
U/S New Enfield Marshalling Yard @ 3 cell RCBC	16.263	16.240	-0.023
Boundary between New Enfield Marshalling Yard and SPC site	16.250	16.228	-0.022
Confluence of Coxs Creek and Minor Culvert	14.792	14.643	-0.149
U/S of Railway Arches	14.784	14.612	-0.172
U/S Cosgrove Road	13.067	13.059	-0.008

- **Table 20: Post Development Flood Levels for the 20 year ARI Event**

Location	Pre-Development Flood Level (mAHD)	Post-Development Flood Level (mAHD)	Change
U/S New Enfield Marshalling Yard @ 3 cell RCBC	16.486	16.470	-0.016
Boundary between New Enfield Marshalling Yard and SPC site	16.476	16.460	-0.016
Confluence of Coxs Creek and Minor Culvert	15.221	15.077	-0.144
U/S of Railway Arches	15.225	15.048	-.0177
U/S Cosgrove Road	13.124	13.118	-0.006

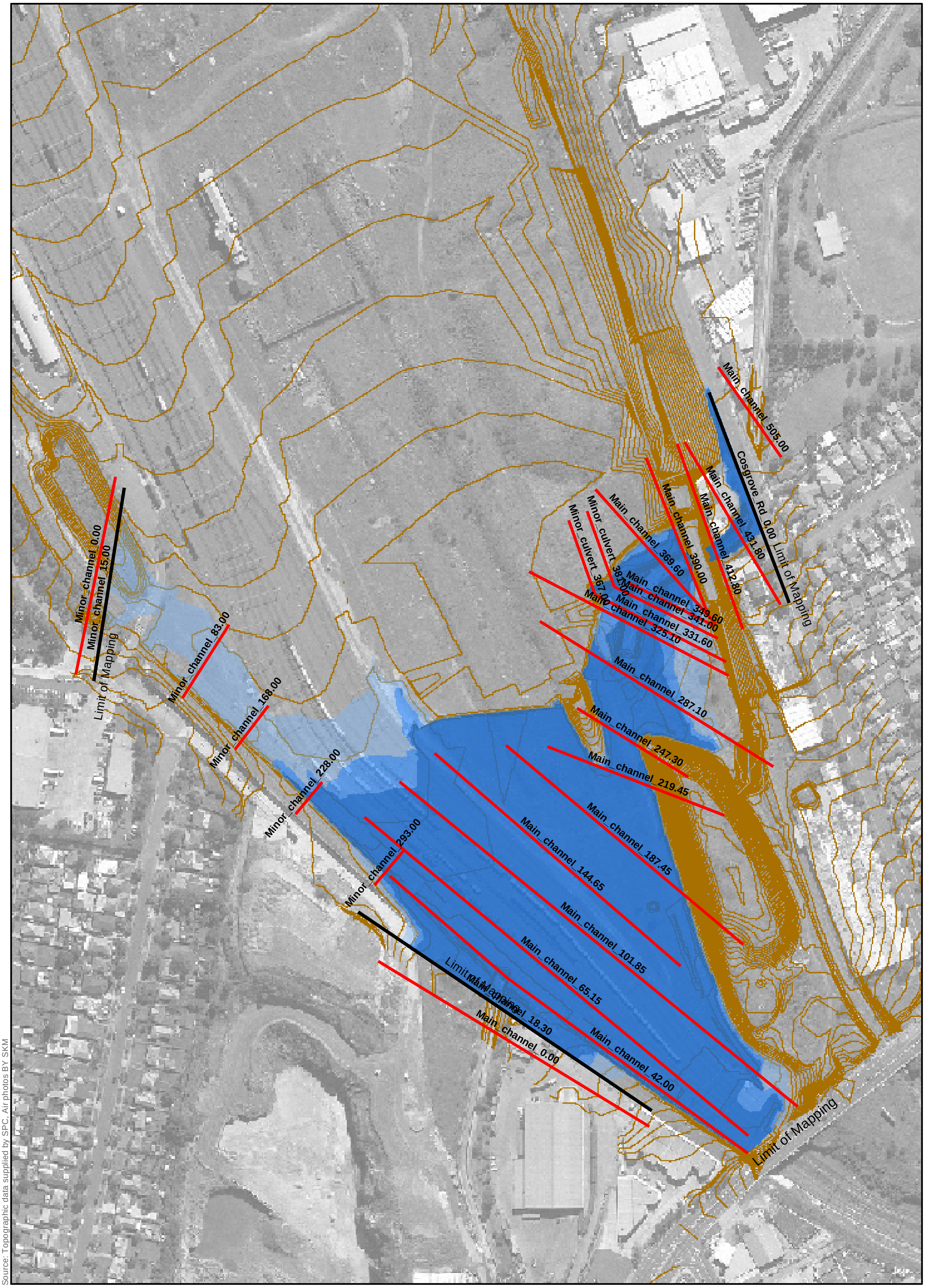
- **Table 21: Post Development Flood Levels for the 100 year ARI event**

Location	Pre-Development Flood Level (mAHD)	Post-Development Flood Level (mAHD)	Change
U/S New Enfield Marshalling Yard @ 3 cell RCBC	16.866	16.859	-0.007
Boundary between New Enfield Marshalling Yard and SPC site	16.854	16.848	-0.006
Confluence of Coxs Creek and Minor Culvert	16.057	15.934	-0.123
U/S of Railway Arches	16.068	15.910	-0.158
U/S Cosgrove Road	13.240	13.242	+0.002

The development would result in improved flood levels both upstream of the site in the Marshalling Yards and downstream where there is existing development on the western side of Cosgrove Road. Improvements are particularly pronounced in the more frequent events. The increase of 2 mm on the upstream side of Cosgrove Road in the 100 year ARI event is negligible.

Full details of all results are given in tables in **Appendix B**.

The areas inundated by the floodway in the post development situation are illustrated in **Figure 19**. This map includes AusImage^{TM} aerial photography from 2003 and 0.5-m contours modified to include the proposed changes as a result of the development.



Source: Topographic data supplied by SPC, Air photos BY SKM

A4

File Name:EN01709_Wr_008.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 12 May 2005

Projection: MGA 56

N

0 30 60
Metres

Legend

Mike 11 Cross Sections
- Limit of Mapping
- Cross Sections

- Proposed 10 yr ARI
- Proposed 20 yr ARI
- Propsed 100yr ARI
- Proposed 0.5m Contours

Figure 19
Proposed Inundation Envelope for 10, 20, 100 Year ARI

SKM

5.3.5 PMP Design Flood assessment

In addition to the above floods, the Probable Maximum Precipitation Design Flood (PMPDF) was assessed. For the purposes of this assessment the PMPDF is assumed to represent the Probable Maximum Flood (PMF).

The procedures outlined in ANCOLD Bulletin 53 were used to assess the Probable Maximum Precipitation (PMP) for the upstream catchment. The PMP design rainfall was routed through the RAFTS model established in the Sinclair Knight 1993 study to develop PMPDF flow hydrographs for catchments upstream of the site.

The hydrological assessment indicated that the critical storm producing the greatest peak discharge in Coxs Creek is the 15-minute event. The peak discharge of the PMPDF event is 857 m^3/s at the railway arch culvert.

The hydrographs for the 15-minute PMF event were then routed through the MIKE-11 model to determine the impact of the development on the performance of the PMF on the floodplain. The following modifications were made to the each of the Mike-11 models (existing and proposed models) before running the PMF event:

- As the PMF would overtop the embankment above the railway arches, a weir was defined over the top of this embankment:
  - In the existing case, this weir was defined to reflect existing ground levels;
  - In the proposed case, this weir was defined to reflect the fact that there will be a noise barrier (in the form of an earth embankment) along the top of the old railway line. It was assumed that this noise barrier would be higher than the PMF flood levels, however would incorporate a section, 52 m long, of collapsible noise wall immediately above the railway arches. This would be the only section where floodwaters could overtop the embankment in the proposed case.
- In the proposed case, the cross-sections were extended across the detention basins and water quality basin, as this part of the site would be flooded in a PMF event.

The results of the existing and proposed case PMF model runs are summarised in **Table 22**.

- **Table 22: Comparison of Flood Levels For PMF Event**

Location	Pre-Development Flood Level (mAHD)	Post-Development Flood Level (mAHD)	Change
U/S New Enfield Marshalling Yard @ 3 cell RCBC	19.351	19.712	+0.361
Boundary between New Enfield Marshalling Yard and SPC site	19.338	19.704	+0.366
Confluence of Coxs Creek and Minor Culvert	18.417	19.666	+1.249
U/S of Railway Arches	18.434	19.651	+1.217
U/S Cosgrove Road	14.373	14.008	-0.365

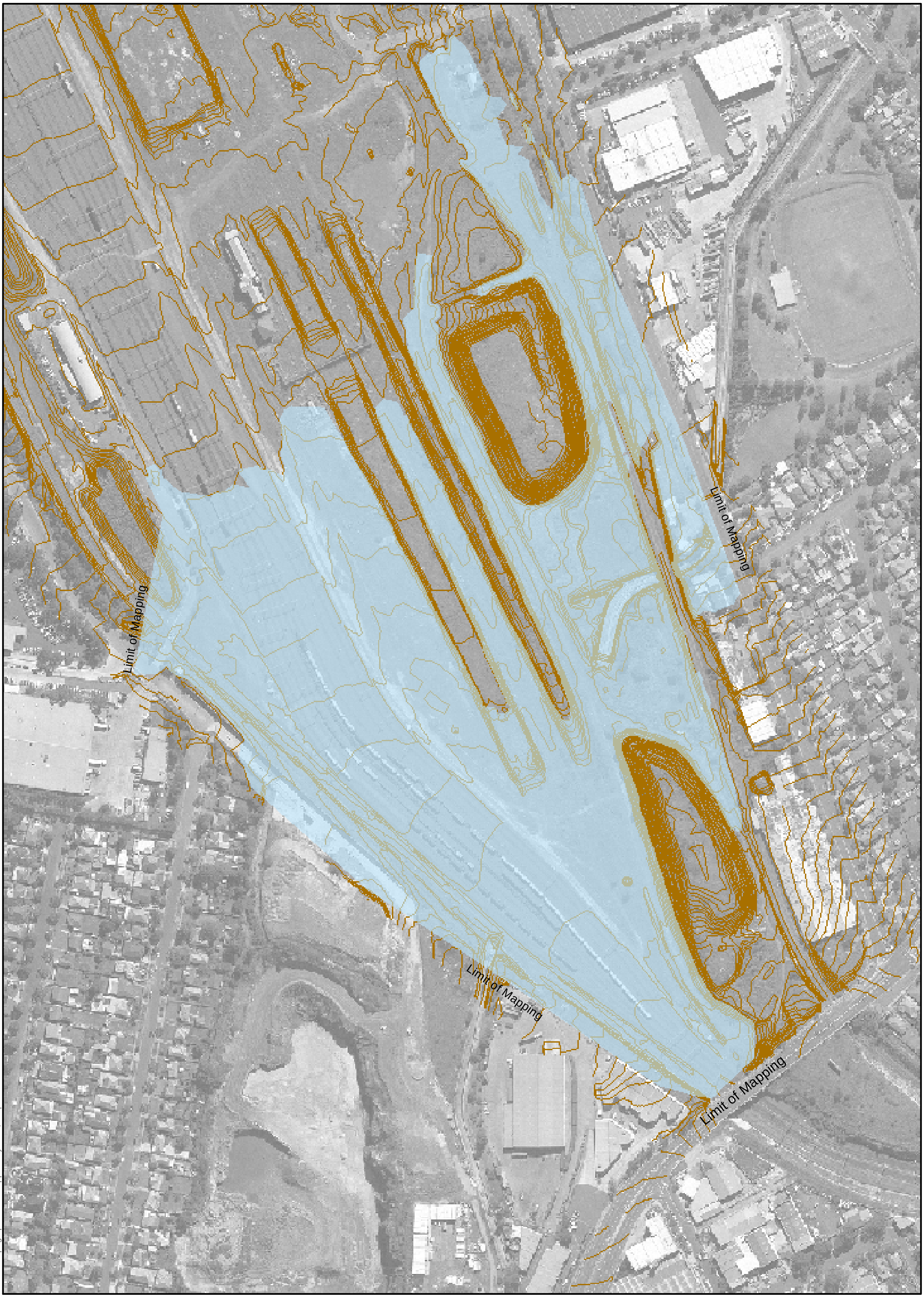
The results above were obtained using a downstream boundary condition of 11.0 m AHD, 240 m downstream of Main_Channel_505.00. The model was also run using boundary conditions of 10.5 and 11.5 m AHD. It was found that flood levels in the PMF are sensitive to the boundary condition at all the cross-sections downstream of the railway arches. The flood level decrease of 0.365 m upstream of Cosgrove Road reported in **Table 22** is based on the premise that the boundary flood level is 11.00 m AHD.

The area inundated by the PMF flood in the pre-development and post development situation is illustrated in **Figure 20** and **Figure 21**.

It is thought that the increases in PMF flood levels as a result of the development are largely brought about by the addition of the earth mound noise barrier above the old railway line. The increase of up to 0.366 m at the Marshalling Yards is considered acceptable, given that the PMF is the largest flood event that can be considered and has a probability of in excess of one in a million years.

5.3.6 Assessment of development on flooding

The results show that with minor modifications to the earthworks associated with the floodplain, the development can be desgned to have negligible impact on Coxs Creek for events up to and including the 100 year ARI event.



Source: Topographic data supplied by SPC, Air photos BY SKM

A4

File Name:EN01709_Wr_010.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 12 May 2005

Projection: MGA 56

N

0 30 60
Metres

Legend

Exisitng 0.5m Contours

Exisitng PMF

Figure 20
Existing Inundation Envelope for the PMF

SKM

A4

Source: Topographic data supplied by SPC, Air photos BY SKM

File Name:EN01709_Wr_009.mxd
Location:\\EN01709\Technical\GIS\Template\
Date: 12 May 2005

Projection: MGA 56

N

0 30 60
Metres

Legend

Proposed PMF

Proposed 0.5m Contours

Figure 21
Proposed Inundation Envelope for PMF

SKM

SKM

5.4 Floodplain Management

The NSW Government issued the Floodplain Management Manual (FMM) in January of 2001. The manual was prepared in accordance with the NSW Government's Flood Prone Land Policy.

The FMM aims to ensure that any development associated with flood prone lands is handled in a sensitive way, having regard for other owners and occupiers of flood prone land, hazard and risk, ecological impacts, social and economic considerations. In general, the FMM aims to ensure that any development in flood prone areas is sensitive to other stakeholders, the greater public and the environment.

The elements of the FMM applicable to this proposed development are:

- An assessment of appropriate development, the "Merit Approach";
- An assessment of the cumulative effect of development in the floodplain;
- Risk and Hazard to users of the development and surrounding residents; and
- The effect of the development on extreme flood events.

5.4.1 Appropriate Floodplain Development

The FMM considers the best way of conditioning a development to make it appropriate for a specific site. Issues such as the impact on operational aspects of the site and the risk posed to the users of the development and surrounding sites is examined.

In the above sections, the proposed development was examined in terms of its physical impact in the floodplain and was found to have little impact on flood levels when compared to the current situation. Little opportunity exists for improvements to the performance of the floodplain and the best result is the maintenance of the status quo.

Whilst the development involves filling in part of the floodplain, few of the operational activities associated with the development take place in flood prone areas. Trains delivering containers to the site will cross over flood prone areas, but during significant flood events, parts of the rail network off-site would be affected by flooding anyway and this is not unique to the development.

The development proposes to rehabilitate the existing Coxs Creek floodplain area and promote an ecologically sustainable environment. This is an improvement to the current ecological value associated with the floodway.

On balance, in terms of the hydrology and hydraulics, the development is considered appropriate for the location as a whole. The environment is a beneficiary from the development, surrounding landowners and occupiers are not adversely affected and users of the development are not unduly put at risk.

5.4.2 Cumulative Development

In a total catchment context, the FMM suggests reviewing the development in terms of the upstream and (where appropriate) downstream catchment. This approach is to examine the risks associated with increased development up or downstream of the site and risk posed to the proposed development from such activity.

In the case of the Enfield Intermodal Logistics Centre proposal, the upstream catchment is already fully urbanised. The urbanisation is “old urban” and offers little in terms of control of its stormwater runoff. Put simply, the floods generated by the upstream catchment in its current state are probably a worst case scenario.

Any future development or redevelopment in the upstream catchment will be subject to stormwater management controls. Similarly, as time passes Councils and Statutory Authorities are likely to address the flood management problems in their areas. As a consequence, the existing peak discharges from the upstream catchment are likely to decrease and the proposed development can only benefit from this.

Alterations to the catchment downstream are likely to have little impact on the development. To impact on the development would require a tailwater level rise of several metres, which would severely inundate downstream residents and is extremely unlikely.

5.4.3 Risk and Hazard

Appendix G of the FMM addresses the hazard associated with a defined floodplain. It requires that as part of a Floodplain Management Plan that the floodway be defined in terms of its hazard and performance. Hazard is defined as either high or low with respect to human life and is based around the hazard posed by the depth or velocity of water, or the combined effect. The hydraulic performance of the floodplain falls into three categories, Floodway, Flood Storage and Flood Fringe. The FMM defines appropriate development for each category by combining the hazard and the performance gives rise to the appropriateness of different types of development in the floodplain.

Section 5.3 deals with the hydraulic performance of Coxs Creek. If the 100 year ARI event is assumed as the design standard (as is common) then depths vary across the floodplain from an average of 1m on the western side of the proposed development floodplain to over 2m on the eastern side. Velocities vary from 0.5m/s to >5m/s.

An assessment of the floodplain, shows that in the present and future condition the floodway and flood prone of Coxs Creek, within the site areas should be considered as a high hazard floodway.

Access and egress from the site is achieved via paths that are unaffected by floodwaters, such as the Cosgrove Road entrance.

5.4.4 Consideration of the PMF

The FMM considers the development in terms of the Probable Maximum Flood, not in the context that this flood should be designed for, rather that the appropriate authorities are aware of the impact the development has on large or extreme floods and the necessary plans and preparations can be made.

Section 5.3 assessed the impact of the PMF (PMPDF) on the proposed development. The assessment shows that the Intermodal Logistics Centre has some impact on the flood behaviour in the PMF.

Furthermore, the site itself would be inundated to a significant extent in a PMF event. Thus, the operators and staff at the site may be at risk from a flood hazard. Evacuation planning should be included in the detailed design stage.

6. Conclusions & Recommendations

6.1 General

This assessment has demonstrated that with appropriate mitigation measures, the development has little or no discernible impact on the environment provided that the proposed mitigation measures are incorporated into the design.

6.2 Internal Drainage

The key feature of the internal drainage system is the rearrangement of the site catchments in order that the drainage from the main Intermodal Logistics Centre hardstand area is conveyed to a single point of control at the southern end of the site. Here, issues associated with both water quality and detention will be addressed with a significant detention and water quality treatment device.

Detention basins with a combined volume of 33,450 m^3 will be required at the southern end of the site, adjacent to Coxs Creek. The sizing of the basin is likely to be optimised at the detailed design stage. In addition, a first flush or water quality basin with a capacity of 4,250 is required also adjacent to Coxs Creek. The proposed location of these basins is shown in **Figure 22**.

Another basin of 2,000 m^3 will be required on the eastern side of the site to provide detention storage for Catchment C.

The commercial areas proposed to be developed adjacent to Cosgrove Road will each cater for their own on-site detention in accordance with Strathfield Council requirements and will be the subject of separate development applications. A preliminary assessment has been made of the detention requirements in these areas.

6.3 Floodplain Management

The NSW Government issued the Floodplain Management Manual (FMM) in January of 2001. The elements of the FMM applicable to this proposed development are summarised below:

- **Appropriate Floodplain Development**

The development proposes to rehabilitate the existing Coxs Creek floodplain area and promote an ecologically sustainable environment. This is an improvement to the current ecological value associated with the floodway.

On balance, in terms of the hydrology and hydraulics, the development is considered appropriate for the location as a whole. The environment is a beneficiary from the development, surrounding landowners and occupiers are not adversely affected and users of the development are not unduly put at risk.

A4

File Name: END1709_Wr_013.mxd
Location: \\END1709\Technical\GIS\Template\
Date: 23 May 2005
Projection: MGA 56

N
0 30 60
Metres

Legend
ILC at Enfield Proposed Design
ILC at Enfield

Figure 23
Proposed Layout of Detention Basins

SKM

- **Cumulative Development**

Any future development or redevelopment in the upstream catchment will be subject to stormwater management controls. Similarly, as time passes Councils and Statutory Authorities are likely to address the flood management problems in their areas. As a consequence, the existing peak discharges from the upstream catchment are likely to decrease and the proposed development can only benefit from this.

Alterations to the catchment downstream are likely to have little impact on the development.

- **Risk and Hazard**

An assessment of the floodplain, shows that in the present and future condition the floodway and flood prone of Coxs Creek, within the site areas should be considered as a high hazard floodway.

Operators and staff at the site may be at risk from a flood hazard. Evacuation planning should be included in the detailed design stage. Access and egress from the site is achieved via paths that are unaffected by floodwaters, such as the Cosgrove Road entrance.

- **Consideration of the PMF**

The assessment shows that the Intermodal Logistics Centre has some minor impact on the flood levels in the PMF. Given the magnitude and probability of the event, the magnitude of the rise is not considered significant.

6.4 Ancillary Infrastructure

Another issue worthy of consideration at the detailed design stage is a structural assessment of the Central and DELEC culverts.

Appendix A RAFTS Modelling

A.1 Existing Case Hydrology Results

Storm event	Duration	Catchment outlet			
		A	B	C	D
2 year ARI	45 min	0.17	1.09	0.67	0.69
	60 min	0.19	1.25	0.86	0.87
	90 min	0.24	**1.41**	1.06	1.00
	2 hour	0.24	1.25	0.94	1.10
	3 hour	0.22	0.81	0.89	1.08
	4.5 hour	0.23	0.79	0.94	1.06
	6 hour	0.25	0.73	1.02	1.20
	9 hour	0.25	0.71	1.03	**1.30**
	12 hour	**0.26**	0.75	**1.07**	1.17
	18 hour	0.20	0.55	0.80	0.94
	Maximum	**0.26**	**1.41**	**1.07**	**1.30**
10 year ARI	45 min	0.34	1.62	1.41	1.40
	60 min	0.38	2.01	1.58	1.72
	90 min	0.45	**2.26**	1.89	1.93
	2 hour	0.45	2.03	1.80	2.09
	3 hour	0.42	1.40	1.68	1.97
	4.5 hour	**0.46**	1.40	**1.90**	1.94
	6 hour	0.42	1.28	1.70	**2.18**
	9 hour	0.40	1.13	1.62	2.10
	12 hour	0.42	1.18	1.73	1.91
	18 hour	0.32	0.86	1.32	1.55
	Maximum	**0.46**	**2.26**	**1.90**	**2.18**
100 year ARI	45 min	0.71	2.46	2.77	2.74
	60 min	0.77	3.09	3.00	3.24
	90 min	0.78	**3.55**	**3.31**	3.56
	2 hour	0.79	3.16	3.23	**3.70**
	3 hour	0.68	2.36	2.72	3.42
	4.5 hour	**0.80**	2.25	3.19	3.39
	6 hour	0.70	1.97	2.81	3.51
	9 hour	0.61	1.71	2.46	3.23
	12 hour	0.65	1.77	2.66	3.03
	18 hour	0.49	1.27	1.98	2.41
	Maximum	**0.80**	**3.55**	**3.31**	**3.70**

A.2 Proposed Case Hydrology Results

Storm event	Duration	Catchment outlet A*	B*	C	D
2 year ARI	45 min			0.37	0.82
	60 min			0.38	0.91
	90 min			0.39	0.98
	2 hour			0.40	1.02
	3 hour			0.38	1.06
	4.5 hour			0.39	1.07
	6 hour			0.44	1.10
	9 hour			0.49	**1.22**
	12 hour			**0.49**	1.15
	18 hour			0.42	1.11
	Maximum	**0.25**	**0.28**	**0.49**	**1.22**
10 year ARI	45 min			0.52	1.15
	60 min			0.56	1.24
	90 min			0.73	1.33
	2 hour			**0.84**	1.38
	3 hour			0.66	1.43
	4.5 hour			0.59	1.45
	6 hour			0.59	1.48
	9 hour			0.53	**1.62**
	12 hour			0.52	1.55
	18 hour			0.49	1.52
	Maximum	**0.36**	**0.43**	**0.84**	**1.62**
100 year ARI	45 min			1.82	1.52
	60 min			1.92	1.77
	90 min			**3.03**	2.21
	2 hour			2.60	2.46
	3 hour			1.93	2.71
	4.5 hour			1.84	2.73
	6 hour			1.57	2.78
	9 hour			1.37	**3.65**
	12 hour			1.41	3.07
	18 hour			0.79	2.72
	Maximum	**0.58**	**0.72**	**3.03**	**3.65**

* Results for catchments A and B in the proposed case were not modelled using RAFTS; the peak flows are based on the permissible site discharge from the proposed commercial and industrial developments

Appendix B Hydraulic Modelling

B.1 Summary of Mike-11 Flood Level Results, 10 and 20 year ARI

Cross-sections		10 year ARI			20 year ARI			Notes
Flowpath	Chainage	Existing	Proposed	Change	Existing	Proposed	Change	
MINOR_CHANNEL	15	16.085	16.085	0	16.798	16.798	0	
MINOR_CHANNEL	83	16.010	15.999	-0.011	16.424	16.415	-0.009	
MINOR_CHANNEL	168	16.038	16.025	-0.013	16.431	16.425	-0.006	
MINOR_CHANNEL	228	16.039	16.025	-0.014	16.442	16.437	-0.005	
MINOR_CHANNEL	293	16.260	16.236	-0.024	16.490	16.469	-0.021	
MAIN_CHANNEL	18.3	16.248	16.225	-0.023	16.476	16.460	-0.016	
MAIN_CHANNEL	42	16.263	16.240	-0.023	16.486	16.470	-0.016	
MAIN_CHANNEL	65.15	16.256	16.234	-0.022	16.480	16.464	-0.016	
MAIN_CHANNEL	101.85	16.252	16.230	-0.022	16.477	16.461	-0.016	
MAIN_CHANNEL	144.65	16.250	16.228	-0.022	16.476	16.460	-0.016	Approx. upstream site boundary
MAIN_CHANNEL	187.45	16.244	16.227	-0.017	16.468	16.459	-0.009	
MAIN_CHANNEL	219.45	16.212	16.221	0.009	16.431	16.452	0.021	
MAIN_CHANNEL	247.3	16.039	16.055	0.016	16.235	16.271	0.036	
MAIN_CHANNEL	287.1	15.593	15.587	-0.006	15.787	15.755	-0.032	
MAIN_CHANNEL	325.1	14.728	14.598	-0.130	15.180	15.038	-0.142	
MAIN_CHANNEL	331.6	14.735	14.608	-0.127	15.182	15.045	-0.137	
MINOR_CULVERT	367	14.773	14.620	-0.153	15.220	15.044	-0.176	
MAIN_CHANNEL	341	14.720	14.592	-0.128	15.166	15.035	-0.131	
MINOR_CULVERT	381	14.783	14.627	-0.156	15.216	15.064	-0.152	
MAIN_CHANNEL	349.6	14.763	14.638	-0.125	15.189	15.066	-0.123	
MAIN_CHANNEL	369.6	14.792	14.643	-0.149	15.221	15.077	-0.144	
MAIN_CHANNEL	390	14.784	14.612	-0.172	15.225	15.048	-0.177	
MAIN_CHANNEL	412.8	12.626	12.627	0.001	12.626	12.626	0	Approx. downstream site boundary
MAIN_CHANNEL	431.8	12.815	12.814	-0.001	12.815	12.815	0	
COSGROVE_RD	0	13.067	13.059	-0.008	13.124	13.118	-0.006	

B.2 Summary of Mike-11 Flood Level Results, 100 year ARI and PMF

Cross-sections		100 year ARI			PMF			Notes
Flowpath	Chainage	Existing	Proposed	Change	Existing	Proposed	Change	
MINOR_CHANNEL	15	17.953	17.953	0	19.440	19.768	0.328	
MINOR_CHANNEL	83	17.127	17.127	0	19.430	19.763	0.333	
MINOR_CHANNEL	168	16.872	16.864	-0.008	19.407	19.755	0.348	
MINOR_CHANNEL	228	16.870	16.862	-0.008	19.399	19.749	0.350	
MINOR_CHANNEL	293	16.865	16.859	-0.006	19.363	19.729	0.366	
MAIN_CHANNEL	18.3	16.855	16.849	-0.006	19.336	19.706	0.370	
MAIN_CHANNEL	42	16.866	16.859	-0.007	19.351	19.712	0.361	
MAIN_CHANNEL	65.15	16.859	16.853	-0.006	19.342	19.704	0.362	
MAIN_CHANNEL	101.85	16.856	16.850	-0.006	19.341	19.704	0.363	
MAIN_CHANNEL	144.65	16.854	16.848	-0.006	19.338	19.704	0.366	Approx. upstream site boundary
MAIN_CHANNEL	187.45	16.841	16.845	0.004	19.283	19.701	0.418	
MAIN_CHANNEL	219.45	16.788	16.834	0.046	19.151	19.686	0.535	
MAIN_CHANNEL	247.3	16.548	16.638	0.090	18.950	19.672	0.722	
MAIN_CHANNEL	287.1	16.184	16.119	-0.065	18.417	19.672	1.255	
MAIN_CHANNEL	325.1	16.042	15.931	-0.111	18.403	19.670	1.267	
MAIN_CHANNEL	331.6	16.019	15.932	-0.087	18.339	19.655	1.316	
MINOR_CULVERT	367	16.151	15.926	-0.225	18.416	19.668	1.252	
MAIN_CHANNEL	341	15.977	15.921	-0.056	18.274	19.641	1.367	
MINOR_CULVERT	381	16.064	15.932	-0.132	18.416	19.667	1.251	
MAIN_CHANNEL	349.6	15.982	15.926	-0.056	18.266	19.638	1.372	
MAIN_CHANNEL	369.6	16.057	15.934	-0.123	18.417	19.666	1.249	
MAIN_CHANNEL	390	16.068	15.91	-0.158	18.434	19.651	1.217	
MAIN_CHANNEL	412.8	12.627	12.626	-0.001	14.336*	13.856*	-0.480*	Approx. downstream site boundary
MAIN_CHANNEL	431.8	12.812	12.814	0.002	14.375*	13.985*	-0.390*	
COSGROVE_RD	0	13.240	13.242	0.002	14.373*	14.008*	-0.365*	

* Flood level results at these cross-sections are subject to boundary condition effects