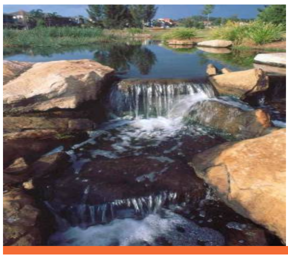
# SYDNEY SCIENCE PARK

## WATER CYCLE & FLOOD MANAGEMENT STRATEGY REPORT




Prepared for:

**APP Corporation on behalf of E J Cooper and Son Pty Ltd**

**December 2013**


Prepared by:

J. WYNDHAM PRINCE

CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

Ref 9765

PO Box 4366
PENRITH WESTFIELD NSW 2750
**P** 02 4720 3300
**F** 02 4721 7638
**W** www.jwprince.com.au
**E jwp@jwprince.com.au**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# Sydney Science Park

# Water Cycle & Flood Management Strategy Report

## - DOCUMENT CONTROL SHEET -

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| A | Draft Issue for Client Review | CR (6/12/2013) | DC (6/12/13) | |
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PO Box 4366, PENRITH WESTFIELD, NSW 2750
580 High Street, PENRITH, NSW 2750
**P** 02 4720 3300
**W** www.jwprince.com.au
**E** jwp@jwprince.com.au

**J. WYNDHAM PRINCE**

**CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS**

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# 1 EXECUTIVE SUMMARY

The Water Cycle and Flood Management Strategy for Sydney Science Park has been prepared to inform the Precinct planning process and support the rezoning of the site. The strategy has been prepared to conform to the statutory requirements and industry best practice for stormwater management in this catchment.

The subject site is located within the Penrith City Council Local Government area and consists of approximately 288 ha of land located at 565- 609 Luddenham Road, Luddenham. The site is bound to the North by major Warragamba Prospect Water Supply Pipelines and Luddenham Road to the East.

The site is bisected by a series of watercourses identified on the 1:25,000 topographic plans. Based on earlier ground truthing at Sydney Science Park undertaken by Worley Parsons (WP, 2011), we understand that the majority of these watercourses generally include a series of existing farm dams which have little ecological value. The site is also bisected by a 330 kV Transgrid Easement with large above ground electrical towers.

The planning for Sydney Science Park includes a new integrated mixed use research and development, employment, education, retail and residential specialised centre. The Master Plan includes:

- Approximately 340,000 $m^2$ of research and development floor space;
- Approximately 100,000 $m^2$ of education floor space;
- Town Centre including a 30,000 $m^2$ mix of retail floor space and residential apartments;
- 3,400 dwellings including student housing;
- A primary school;
- New roads and infrastructure; and
- Sporting fields and parks.

The objective of this investigation is to identify the stormwater and flood management issues to be considered in the future development of Sydney Science Park and to identify flood impacts; an appropriate evacuation strategy; appropriate options and locations for the control of the quantity and quality of stormwater leaving the site. The study has also identified the land areas required to implement the recommended options. An overall Preliminary Cost Estimate is also provided for all major stormwater infrastructure.

The Water Cycle and Flood Management Strategy consists of a treatment train consisting of on lot treatment, street level treatment and subdivision / development treatment measures. The structural elements proposed for the development consist of:

- Proprietary GPT units at each stormwater discharge point;
- Bio-retention raingarden systems;
- Combined detention basin / water quality ponds
- Combined detention basin / wetlands
- Stand alone wetlands (no detention); and
- “On-lot” treatments

The provision of the proposed water quality treatment devices within the development will ensure that the post development stormwater discharges will meet the Office of Environment and Heritage’s and Penrith City Council’s water quality objectives for Sydney Science Park.

As part of the development of the Water Cycle and Flood Management Strategy a two-dimensional flood model was developed. This model was used to test the impacts of the development of the Precinct, on both local and regional (PMF only) flood levels.

The existing and post development case hydrology models incorporate all upstream catchments draining to the site and also including catchments up to approximately 700 m downstream. The hydrologic modelling indicates that inclusion of the proposed detention basins within the Precinct will attenuate peak post development flows to less than existing levels.

The detailed flood assessment completed as part of the strategy has demonstrated that flood levels on the creeks with and without development has shown that urbanisation will result in only a minor increase in flood levels downstream of the site boundary (up to 200mm). This increase in flood levels is associated with the removal of the steep existing dam embankment slope (which has existing supercritical flows). It is noted that the flood levels are returned back to existing where the flowpath crosses the Warragamba Pipelines (approximately 370m downstream) and are located within the downstream riparian corridor and where no development is located. The developed case is therefore considered to be an improvement upon existing conditions.

A number of significant farm dams are located within the Precinct and online to the major water courses. The area of existing flood affectation within the Precinct is therefore greatly exacerbated by these farm dams. All farm dams within the Precinct are to be removed as part of the proposed future development and the water courses re-established and revegetated in accordance with the NSW Office of Water guidelines.

The proposed development at Sydney Science Park aims at embracing the aesthetic nature of watercourses. The Master Plan has therefore proposed to reconstruct / embellish a series of fully vegetated riparian corridors through the site. These corridors will provide the extra advantage of conveying the significant upstream catchment flows and provide the future potential for connectivity. The design of the central watercourse also considers the location of the existing transmission easement and associated towers.

The proposed Water Cycle and Flood Management Strategy for the developed site provides a basis for the detailed design and development of the site to ensure that the environmental, urban amenity, engineering and economic objectives for stormwater management and site discharge are achieved.

The Water Cycle Management Strategy proposed for Sydney Science Park is functional; delivers the required technical performance; lessens environmental impacts and pressure on downstream ecosystems and infrastructure; and provides for a ‘soft’ sustainable solution for stormwater management within the release area

# 2 INTRODUCTION

J Wyndham Prince has been commissioned by APP on behalf of E.J. Cooper and Son Pty Ltd (EJC) to prepare a Water Cycle and Flood Management Strategy Report in support of the proposed development at Sydney Science Park. This report details the procedures used and presents the results of investigations to inform the proposed planning proposal to be submitted to Penrith City Council.

The objective of this investigation is to identify the stormwater and flood management issues to be considered in the future development of Sydney Science Park and to identify flood impacts, an appropriate evacuation strategy, appropriate options and locations for the control of the quantity and quality of stormwater leaving the site. The study has also identified the land areas required to implement the recommended options. An overall Preliminary Cost Estimate is also provided for all major stormwater infrastructure.

The project team met with Penrith City Council on 29th November 2013 where a general overview of the project and the proposed Water Cycle and Flood Management Strategy was presented and was generally well received.

These investigations address engineering considerations, whilst placing a strong focus on conserving and enhancing the bio-diversity and ecological health. Positive water quality benefits in the existing riparian corridors within and adjacent to the Precinct will also provide an integrated natural resource for the incoming residents.

The investigation involved the following specific tasks:

- Provide advice of the required riparian corridor width based on a review of the current Riparian Corridor guidelines developed by the NSW Office of Water.
- Undertake a hydrologic analysis to determine the peak flows for the 50 % AEP and 1 % AEP events, together with the Probable Maximum Flood (PMF) under pre-development conditions.
- Undertake a hydrologic assessment to determine the size and location of detention basins required to restrict peak post development to pre development flows for the 50 % and 1 % AEP events. Determine peak pre and post development 50 %, 1 %, 0.2 % AEP and PMF flows for input to the flood model.
- Develop a 2D flood model using TUFLOW that incorporates all major flows conveyed to and through the site. Determine the existing flood extents for the 50 %, 1 %, 0.2 % year AEP and PMF events. Define the floodway for the 1 % AEP event and identify opportunities for floodplain filling that will not adversely impact on properties outside the site.
- Prepare flood extent, depth and level mapping for the 50 %, 1 %, 0.2 % AEP and PMF events. Prepare flood hazard and hydraulic category mapping for the 1 % AEP and PMF events.
- Assess the impacts of the proposed removal of existing farm dams within the site and the creation of additional land for development along the floodplain.
- Determination of the minimum detention storage requirements to restrict post-development flows to pre-development levels.
- Provide discussion on flood evacuation issues which will need to be considered.
- Undertake a water quality analysis in MUSIC and determine the minimum treatment device areas required to achieve Penrith City Council and the Office of Environment and Heritage (OEH) water quality targets.

- Develop Preliminary Engineering Concept plans (including surface modelling) for use in the developed case flood modelling. Prepare preliminary engineering concept plans for each water quantity device.
- Undertake an assessment to determine the potential impact of Climate Change on the development within TUFLOW.
- Prepare indicative capital cost estimates for the adopted water cycle management controls together with preliminary estimate of costs for the operation and maintenance of these devices.
- Prepare a detailed Water Cycle and Flood Management Strategy Report suitable for submission to Penrith City Council to support the rezoning at Sydney Science Park.

# 3 PREVIOUS REPORTS

## 3.1 Stream Classification and Site Flood Assessment Report (WP, 2011)

In 2011, Worley Parsons prepared a *Stream Classification and Site Flooding Assessment report* for Sydney Science Park which included a detailed ground truthing investigation the watercourses which were previously classified by the NSW Department of Environment, Climate Change and Water (DECCW) and a desktop analysis of the 1 % AEP flood along any watercourses or flowpaths which are proposed to be retained.

The objective of the Worley Parsons Report was to provide information on stream classifications which will form the basis of future negotiations with Council and DECCW (now known as the NSW Office of Water) / Office of the Hawkesbury and the Nepean (OHN) to set an agreed riparian corridor network. The assessment included the following findings and recommendations:

**Central Watercourse Findings**

- The central watercourse has been heavily modified and comprises approximately twelve (12) farm dams in series. These farm dams appear to be man-made with no observed connectively between the dams and have no significant or notable riparian areas aside from a solitary stand of trees in the North.
- The riparian zone is heavily eroded by the traffic of livestock and there is no aquatic or terrestrial fauna
- Recommendation for the Category 2 classification (now known as 2$^{nd}$ order watercourse) of Watercourse 2A to be removed and reclassified as a Category 3 (now known as 1$^{st}$ order watercourse). See Plates 3.1 and 3.2 for the watercourse locations.
- Recommendation for Watercourse 2B and 2C to no longer be riparian corridors. Notwithstanding, a designated flowpath will need to be retained.

**Recommendations**

- *Subject to agreement by the Office of the Hawkesbury and the Nepean (OHN), it is possible that the series of farm dams that constitute Watercourse 2A (including Farm Dam D2) could be removed from the existing classification altogether and therefore, be removed as part of any future development. DECCW has previously indicated that farm dams that do not lie on a watercourse do not require any riparian setback, if they were to be retained at the site.*
- *Strictly speaking, the series of farm dams along Watercourse 2A do lie on the remnants of a former watercourse. However, it is considered that the watercourse has been so heavily modified that it no longer has any environmental or riparian value. The site investigation found that historic land management practices have modified and denaturalised the watercourse that is assumed to have once flowed through the site. In addition to the obvious impacts of removing native riparian vegetation, the farm dams have restricted the natural flows of the river, thereby reducing the ability for fauna to migrate upstream or downstream, increasing the temperature and resulting in increasing de-oxygenation of the water*.
- *The alignment of Watercourse 2A is (or once was) a significant flow-path for stormwater runoff through the site and therefore, sufficient setback needs to be provided anyway so that any future development is not affected by flooding.*
- *In addition, any modification to the storage capacity provided by the existing farm dams (i.e., by way of removal or modification of the dams) will need to consider the potential impacts on flooding and drainage upstream and downstream from the site.*

*In particular, there is potential for removal of any of the farm dams to decrease the detention capacity of the site and thereby, increase flows to downstream areas and exacerbate flooding. Notwithstanding, it would be possible to remove some farm dams if a commensurate volume of detention capacity is provided elsewhere within the site.*

[The issues associated with flooding and the existing farm dams are discussed in Section 11 of this report]

- *It is recommended that Watercourse 1, Watercourse 2B, Watercourse 2C, Watercourse 2D and Watercourse 3 should <u>not</u> be identified or classified as watercourses within the site as part of any future riparian corridor mapping. However, it should be noted that alternative measures may be required to provide for the drainage of stormwater runoff from the site along similarly aligned flowpaths.*
- *A number of Category 3 farm dams and watercourses were identified by the DECCW mapping. The ground truthing exercise found that each of the dams was man-made, was not located on a watercourse and had riparian areas consisting of pasture grass and / or bare soil. The margins of each dam typically were affected by erosion from livestock and the dams had very little ecological value. It is therefore recommended that the existing Category 3 classifications for each farm dam be removed*
- *It is understood that because the farm dams do not lie on any watercourses, no riparian setback would be required around the dams, should they be retained. It is also suggested that the identified farm dams could be removed as part of any future development of the site. According to the existing stream classification mapping, the farm dams identified in the report are to be located on a small Category 3 watercourse. As discussed above, none of these watercourses were actually observed during the site inspection. It is therefore recommended that the existing Category 3 classifications be removed for these watercourses within the site*
- *Reclassification of watercourses would require discussion and approval through DECCW / OHN.*

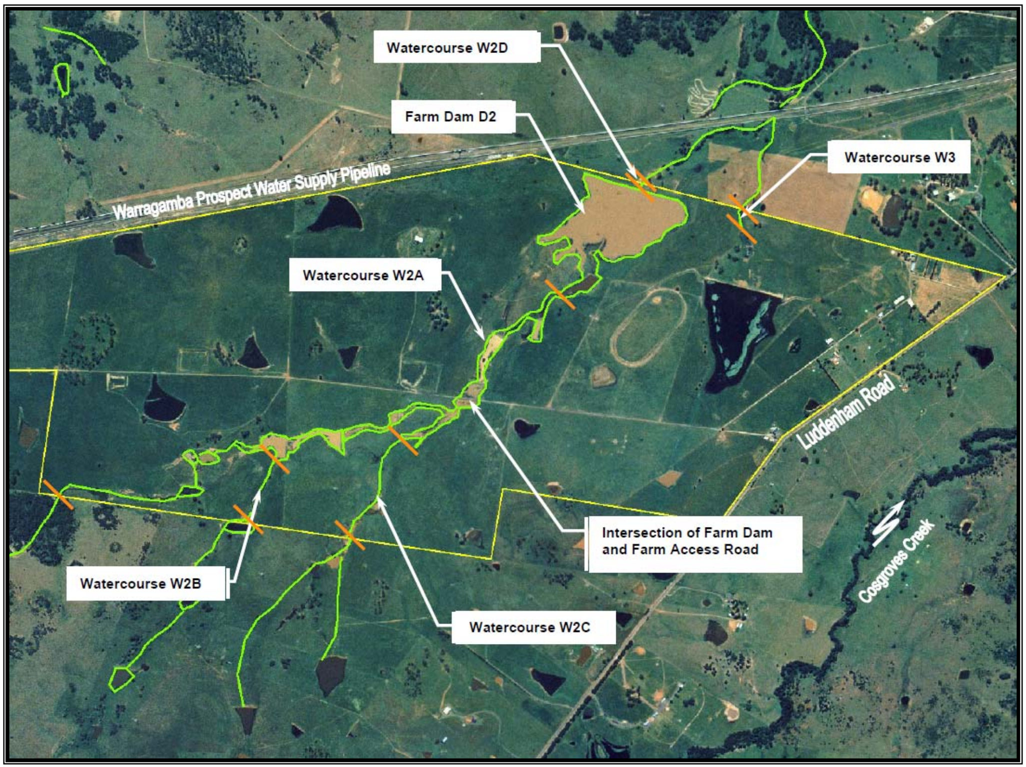



**PLATE 3.1 ‑ CATEGORY 2 WATERCOURSES**
**SOURCE: (WP, 2011)**

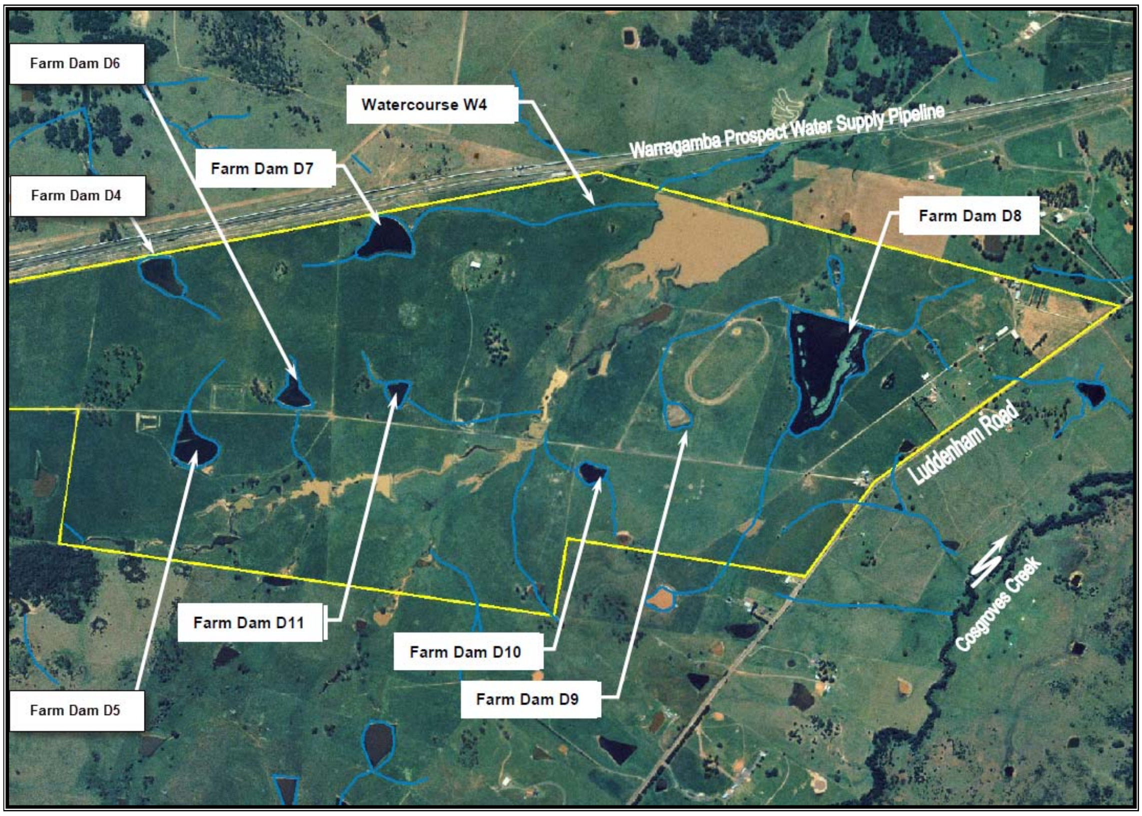



**PLATE 3.2 – CATEGORY 3 WATERCOURSES**
**SOURCE: (WP, 2011)**

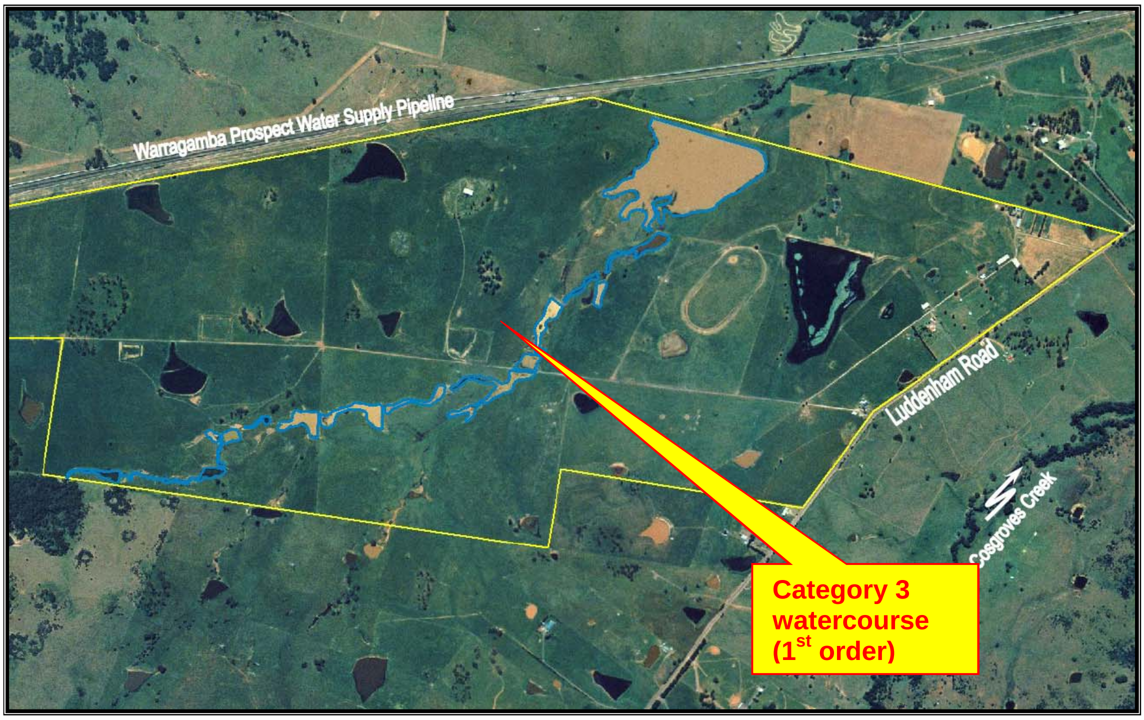



**PLATE 3.3 – RECOMMENDATIONS BY WORLEY PARSONS**

Further discussion on the Riparian Corridors throughout Sydney Science Park in provided in Section 9.

# 4 THE EXISTING ENVIRONMENT

## 4.1 The Site

The subject site is located within the Penrith City Council Local Government area and consists of approximately 288 ha of land located at 565- 609 Luddenham Road, Luddenham. The site is bound to the North by major Warragamba Prospect Water Supply Pipelines and Luddenham Road to the East.

The site is predominantly used for agricultural purposes with an undulating terrain. Refer to Plate 4.1 for the general site layout.

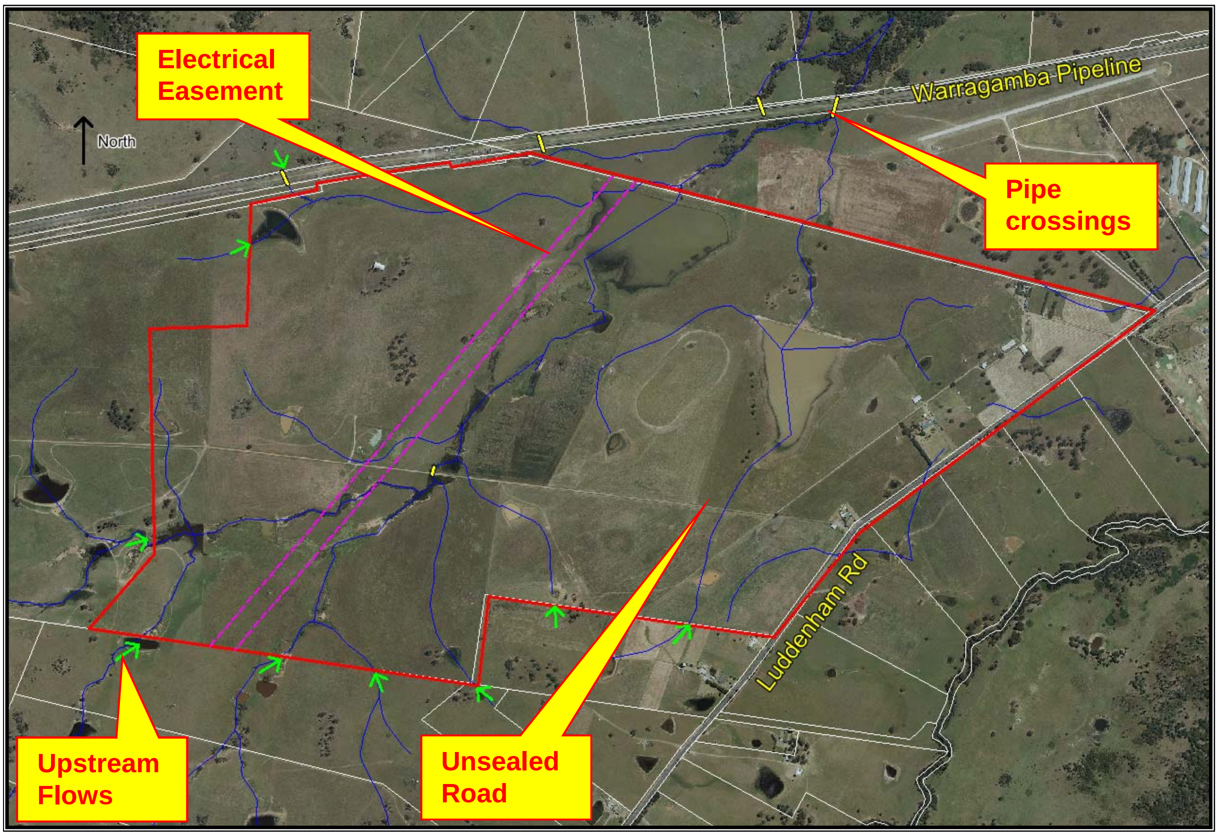



**PLATE 4.1 - EXISTING SITE**

There are a series of significant upstream catchments which are conveyed via watercourses through the subject site (unnamed tributaries) before adjoining South Creek approximately 4 km to the North.

The subject site includes a series of watercourses identified on the 1:25,000 topographic plans. Based on earlier ground truthing at Sydney Science Park undertaken by Worley Parsons (WP, 2011), we understand that the majority of these watercourses generally include a series of existing farm dams which have little ecological value. Refer to Section 9 for further discussion.

The existing site includes an unsealed road which traverses the site from the end of Gates Avenue (accessed from The Northern Road) in the west to Luddenham Road in the east. The site is also bisected by a 330 kV Transgrid Easement with large above ground electrical towers.

PLATE 4.2 – WARRAGAMBA PIPELINE EASEMENT

PLATE 4.3 – PIPE CROSSING AT WARRAGAMBA PIPELINE EASEMENT

PLATE 4.4 – TRANSGRID EASEMENT (330KV)

# 5 THE PROPOSED DEVELOPMENT

This Planning Proposal is submitted to Penrith City Council (Council), on behalf of E.J. Cooper & Son Pty Limited (EJC), in support of an amendment to the Penrith Local Environmental Plan (LEP) 2010. The proposal is to rezone the 288 hectare parcel of land at 565-609 Luddenham Road, Luddenham to accommodate a new integrated mixed use research and development, employment, education, retail and residential specialised centre.

The Planning Proposal is supported by a Master Plan, which represents the overall planning framework and preferred outcome for Sydney Science Park. The Master Plan includes:

- Approximately 340,000 $m^2$ of research and development floor space;
- Approximately 100,000 $m^2$ of education floor space;
- Town Centre including a 30,000 $m^2$ mix of retail floor space and residential apartments;
- 3,400 dwellings including student housing;
- A primary school;
- new roads and infrastructure; and
- sporting fields and parks.

The planning proposal addresses site servicing and environmental conditions. It is also accompanied by an offer to enter into Voluntary Planning Agreements with State Government and Penrith City Council for the delivery of infrastructure and community facilities that are required to meet the future demands of Sydney Science Park. This includes road network improvements, district and local open space and a community facility.

The development also includes provision for the future railway extension and the proposed M9 road network which bisects the site in a North - South direction.

The existing farm dams are planned to be removed as part of the development with riparian corridors re-established where the existing dams are online to water courses.

Stormwater detention basins will be provided throughout the development to mitigate peak flows as a result of urbanisation, while various water quality devices are also proposed throughout the development to minimise the impact on the environment.

The Master Plan for Sydney Science Park is provided in Plate 5.1 below.

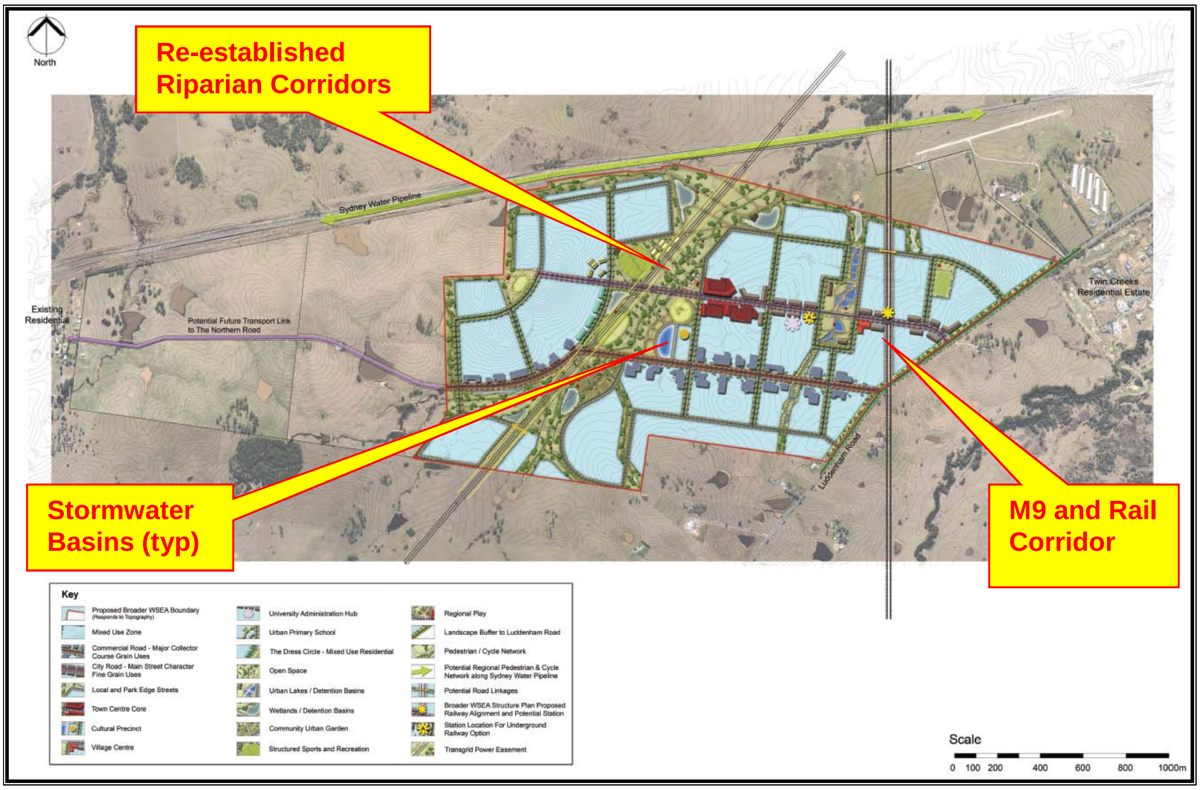



**Plate 4.4 – DRAFT MASTER PLAN FOR SYDNEY SCIENCE PARK**

# 6 DEVELOPMENT GUIDELINES, OPPORTUNITIES AND CONSTRAINTS

The following guidelines were considered in developing the Water Cycle and Flood Management and Flooding Strategy for Sydney Science Park.

## 6.1 Penrith City Council Draft Water Sensitive Urban Design Policy (2013)

In August 2013, Penrith City Council released the "Draft Water Sensitive Urban Design Policy" for public comment (PCC, 2013). Whilst this policy has not yet been finalised, our study has encompassed key criteria of this policy wherever possible.

The target pollutant load reductions defined within the draft policy included:

- 90% reduction in the post development mean annual load of total gross pollutant (greater than 5mm);
- 85% reduction in the post development mean annual load of Total Suspended Solids (TSS);
- 60% reduction in the post development mean annual load of Total Phosphorus (TP); and
- 45% reduction in the post development mean annual load of Total Nitrogen (TN).

The Draft Policy specifies details of the key parameters which shall be used in sizing all Stormwater Treatment Measures in MUSIC. In particular, the criteria includes bio-retention systems, gross pollutant traps, wetlands, swales, rainwater tanks and infiltration systems.

## 6.2 Penrith City Council Development Control Plan (2010)

The Penrith City Council Development Control Plan Part C3 – Water Management) (PCC, 2010) identifies the following objectives for consideration with regard to water management:

- Adopt an integrated approach that takes into account all aspects of the water cycle in determining impacts and enhancing water resources;
- Promote sustainable practices in relation to the use of water resources for human activities;
- Minimise water consumption for human uses by using best practice site planning, design and water efficient appliances;
- Address water resources in terms of the entire water catchment;
- Protect water catchments and environmental systems from development pressures and potential pollution sources;
- Protect and enhance natural watercourses, riparian corridors and wetlands;
- Integrate water management with stormwater, drainage and flood conveyance requirements; and
- Utilise principles of Water Sensitive Urban Design in designing new developments or infill development in existing areas.

The project team met with Penrith City Council in a meeting dated 29th November 2013. A general overview of the project and the proposed Water Cycle and Flood Management Strategy was presented and was generally well received. In particular, these discussions included an overview of proposed water quality, flood and drainage strategy, use of detention basins and wetlands. J. Wyndham Prince explained that the site comprised farm dams, and that there is minimal existing riparian corridor which provide an ecological benefit. J. Wyndham Prince also explained that the proposal was to create a riparian corridor, which is seen as an improvement over existing situation.

### 6.2.1 NSW Office of Environment and Heritage

The NSW Office of Environment and Heritage, formerly the Department of Environment, Climate Change and Water and Environment Protection Authority (EPA), has set guidelines for stormwater quality from urban developments in their Interim Recommended Parameters for Stormwateodelling – North-West and South-West Growth Centres (DECCW). In the absence of specific pollution retention criteria in Council's DCP, this guideline has been adopted for Sydney Science Park.

This document nominates quantitative post construction phase stormwater management objectives for the reduction of various pollutants for a range of new developments. The retention criteria for the Penrith LGA are nominated as follows:

| | |
|---|---|
| Total Phosphorous | 65% retention of average annual load |
| Total Nitrogen | 45% retention of average annual load |
| Suspended Solids | 85% of average annual load for particles 0.5 mm or less |
| Gross Pollutants | 90% retention of material greater than 5mm |

## 6.3 Guidelines for Riparian Corridors on Waterfront land (NOW, 2012)

In 2012 the New South Wales Office of Water released guidelines for riparian corridors on waterfront land. New rules regarding controlled activities within riparian corridors have been established which provide more flexibility in how riparian corridors can be used. These guidelines have been adopted in developing the riparian corridor strategy for the Sydney Science Park Precinct.

As part of the NSW Office of Water guidelines, water courses orders have been classified under the Strahler System using current 1:25,000 topographic maps and are shown in detail on Figure 9.1. The Strahler System classification methodology and corresponding riparian corridor widths are shown on Plates 6.1 and 6.2, respectively. The various water courses within the Precinct include 1st to 4th order water courses.

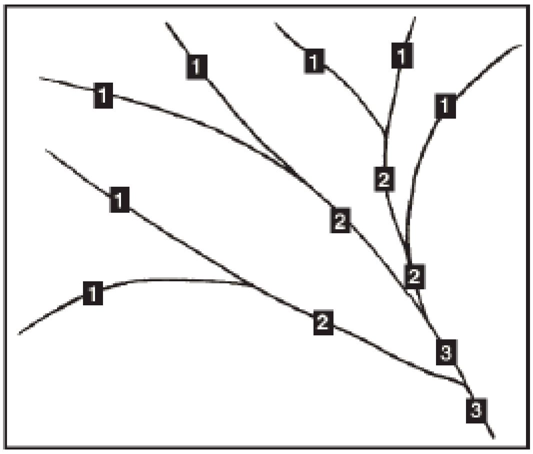



**PLATE 4.5 - THE STRAHLER SYSTEM OF STREAM CLASSIFICATION**

| Watercourse type | VRZ width (each side of watercourse) | Total RC width |
|---|---|---|
| $1^{st}$ order | 10 metres | 20 m + channel width |
| $2^{nd}$ order | 20 metres | 40 m + channel width |
| $3^{rd}$ order | 30 metres | 60 m + channel width |
| $4^{th}$ order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters) | 40 metres | 80 m + channel width |

**Plate 4.6 - RECOMMENDED RIPARIAN CORRIDOR WIDTHS**

The works and activities that are permissible within the riparian corridors for these water courses, as reproduced from the New South Wales Office of Water guidelines, are shown on Plate 6.3.

| Stream order | Vegetated Riparian Zone (VRZ) | RC off-setting for non RC uses | Cycleways and paths | Detention basins | | Stormwater outlet structures and essential services | Stream realignment | Road crossings | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Only within 50% outer VRZ | Online | | | Any | Culvert | Bridge |
| $1^{st}$ | 10m | • | • | • | • | • | • | • | | |
| $2^{nd}$ | 20m | • | • | • | • | • | | • | | |
| $3^{rd}$ | 30m | • | • | • | | • | | | • | • |
| $4^{th}$ + | 40m | • | • | • | | • | | | • | • |

**Plate 4.7 - RIPARIAN CORRIDOR MATRIX**
(Source: NSW Office of Water)

## 6.4 Salinity and Groundwater

Salinity is the accumulation of mineral salts in the soil, groundwater and surface waters. Dry land salinity results when soluble salts are transported to the surface by a rising water table. The groundwater itself can also cause soluble salts to migrate under the ground surface and emerge as saline seepage in low lying areas. Salinity can lead to vegetation loss, weed invasion, soil structure decline and in some cases structural damage to buildings.

If required, a detailed Land Capability and Salinity Assessment can be undertaken in the future to provide guidance and recommendations on salinity and groundwater management for the Sydney Science Park Precinct.

## 6.5 Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design aims to minimise the hydrological impacts of urban development and maximise the multiple use benefits of a stormwater system.

Australian Runoff Quality (ARQ, 2006) identifies the objectives of WSUD to include:

- Reducing potable water demand through water efficient appliances, rainwater and grey water reuse.
- Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse opportunities and/or release to receiving waters.
- Treating urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters.
- Preserving the natural hydrological regime of catchments.
- Australian Runoff Quality also identifies WSUD as the adoption of the following planning and design approaches that integrate the following opportunities into the built form of cities and towns:
- Detention (where appropriate), rather than rapid conveyance of stormwater.
- Capture and use of stormwater as an alternative source of water to conserve potable water.
- Use of vegetation for filtering purposes.
- Protection of water-related environmental, recreational and cultural values.
- Localised water harvesting for various uses.

# 7 WATER CYCLE MANAGEMENT OPTIONS

The Water Cycle and Flood Management Strategy proposed for Sydney Science Park has been prepared with consideration of the statutory requirements and guidelines listed in Section 6 of this report. The strategy focuses on mitigating the impacts of the development on the total water cycle and maximising the environmental, social and economic benefits achievable by utilising responsible and sustainable stormwater management practices.

A range of stormwater management techniques and options considered for the management of nutrients and suspended solids discharging from the site are summarised below.

Each of these management techniques were evaluated and compared with consideration of a range of environmental, social/amenity, economic, maintenance and engineering criteria.

## 7.1 Vegetated Swales and Buffers

Swales are formed, vegetated depressions that are used for the conveyance of stormwater runoff from impervious areas. They provide a number of functions including:

- Removing sediments by filtration through the vegetated surface.
- Reducing runoff volumes (by promoting some infiltration to the sub-soils).
- Delaying runoff peaks by reducing flow velocities.

Swales are typically linear, shallow, wide, vegetation lined channels. They are often used as an alternative to kerb and gutter along roadways but can also be used to convey stormwater flows in recreation areas and car parks.

*Comment: The grade of the land within certain portions of Sydney Science Park is suitable for swales and buffers less than (< 3%), in particular on the fringes of the riparian corridors. However, swales and buffers within urban residential streets are not recommended due to the large number of culvert crossings required for driveways, safety concerns, increased number of GPT's required and significant maintenance requirements. Swales within central road medians, if provided within the development, may be appropriate.*

## 7.2 Sand Filters

Sand filters typically include a bed of filter media through which stormwater is passed to treat it prior to discharging to the downstream stormwater system. The filter media is usually sand, but can also contain sand/gravel and peat/organic mixtures. Sand filters provide a number of functions including:

- Removing fine to coarse sediments and attached pollutants by infiltration through a sand media layer.
- Delaying runoff peaks by providing retention capacity and reducing flow velocities.

Sand filters can be constructed as either small or large scale devices. Small scale units are usually located in below ground concrete pits (at residential/lot level) comprising of a preliminary sediment trap chamber with a secondary filtration chamber. Larger scale units may comprise of a preliminary sedimentation basin with a downstream sand filter basin-type arrangement.

*Comment: Sand filters are generally suited to smaller catchments. They are inefficient when compared to bio-retention systems and require frequent maintenance.*

## 7.3 Permeable Pavement

Permeable pavements, which are an alternative to typical impermeable pavements, allow runoff to percolate through hard surfaces to an underlying granular sub-base reservoir for temporary storage until the water either infiltrates into the ground or discharges to a stormwater outlet. They provide a number of functions including:

- Removing some sediments and attached pollutants by infiltration through an underlying sand/gravel media layer.
- Reducing runoff volumes (by infiltration to the sub-soils).
- Delaying runoff peaks by providing retention/detention storage capacity and reducing flow velocities.
- Commercially available permeable pavements include pervious/open-graded asphalt, no fines concrete, modular concrete blocks and modular flexible block pavements.
- There are two (2) main functional types of permeable pavements:
- Infiltration (or retention) systems – temporarily holding surface water for a sufficient period to allow percolation into the underlying soils.
- Detention systems – temporarily holding surface water for short periods to reduce peak flows and later releasing into the stormwater system.

*Comment: Permeable pavements are generally a more ‘at source’ solution and best suited as an ‘on lot’ approach or for small roadway catchments. Permeable pavers may possibly be considered at the development application stage for on lot treatment or for areas draining small catchment areas with low sediment loads and low vehicle weights. These systems are also prone to clogging and are not suitable in saline soils that may be encountered at Sydney Science Park and are therefore not recommended for the site.*

## 7.4 Infiltration Trenches and Basins

Infiltration trenches temporarily hold stormwater runoff in a sub-surface trench prior to infiltrating into the surrounding soils. Infiltration trenches provide the following main functions:

- Removing sediments and attached pollutants by infiltration through the sub-soils.
- Reducing runoff volumes (by infiltration to the sub-soils).
- Delaying runoff peaks by providing detention storage capacity and reducing flow velocities.

Infiltration trenches typically comprise of a shallow, excavated trench filled with reservoir storage aggregate. The aggregate is typically gravel or cobbles but can also comprise modular plastic cells (similar to a milk crate). Runoff entering the system is stored in the void space of the aggregate material or modular cells prior to percolating into the surrounding soils. Overflow from the trench is usually to downstream drainage system. Infiltration trenches are similar in concept to infiltration basins, however trenches store runoff water below ground in a pit and tank system, whereas basins utilise above ground storage.

*Comment: Infiltration trenches and basins are not appropriate for clay soils or where there is potential for salinity issues. Infiltration trenches and basins are therefore not suitable for Sydney Science Park.*

## 7.5 Constructed Wetlands and Ponds

Constructed wetlands can take the form of either a surface or sub surface system.

- Surface – Conventional wetlands
- Sub Surface – Gravel filled shallow wetland.

Wetlands are shallow water body systems, densely vegetated with emergent aquatic macrophytes. Wetlands are effective in trapping suspended solids, as well as chemical and biological uptake of pollutants. Ponds are similar devices to constructed wetlands, but without the vegetation.

*Comment: Wetlands and ponds are effective in removing sediment and nutrient loads typically generated from urban development however do generally require a higher level of maintenance. The need to manage algal blooms will be paramount to ensure that the system operates as per the design intent. It is likely that a recirculation system will be necessary as part of the detailed design process. Consideration of public safety measures are also required due to permanent deep water areas.*

*Wetlands have an advantage in the urban context as they provide a greater aesthetic appearance along with an environmental habitat for aquatic species. Wetlands provide an important component of Sydney Science Park from both an amenity and Water Cycle Management perspective.*

## 7.6 Bio-retention Raingarden Systems

Bio-retention systems consist of a filtration bed with either gravel or sandy loam media and an extended detention zone typically from 100-300 mm deep designed to detain and treat first flush flows from the upstream catchment. They typically take the form of an irregular bed or a linear swale and are located within the verge area of a road reserve or extend within the bushland corridors or other open space areas. The surface of the bio-retention system can be grassed or mass planted with water tolerant species. Filtration beds of bio-retention systems are typically 0.5 - 0.6 metres deep.

*Comment: Bio-retention systems are an effective and efficient means of treating pollutants from urban development when part of an overall treatment train. Bio-retention systems require a reasonable amount of maintenance during the vegetation establishment phase.*

## 7.7 Cartridge Filtration Systems

Cartridge filtration systems are underground pollution control devices that treat first flush flows. The unit consists of a vault containing a number of cartridges each loaded with media that targets specific pollutants. Each cartridge has a maximum treatable flowrate of approximately 1-1.5 litres per second, and the unit can accommodate up to 24 cartridges providing a maximum treatable flowrate of 24-36 litres per second.

*Comment: Cartridge filtration systems are an efficient means of treating pollutants from urban development as they are typically located underground and therefore do not require additional landtake. As cartridge systems have a low treatable flow rate, additional 'buffer' storage is usually provided to keep the capital costs down. Cartridge filtration systems also need to be supplemented with additional treatment devices to achieve pollutant reduction targets. This requires significant height differences between the inlet to the filtration system and the discharge point from the supplementary system. It also generally results in expensive capital and ongoing maintenance costs.*

## 7.8 Rainwater Tanks

Rainwater tanks are sealed tanks designed to contain rainwater collected from roofs. They provide the following main functions:

- Allow the reuse of collected rainwater as a substitute for mains water supply, for use for toilet flushing, laundry, or garden watering.
- When designed with additional storage capacity above the overflow, provide some on-site detention, thus reducing peak flows and reducing downstream velocities.

The water collected can be reused as a substitute for mains water supply either indoors (toilet flushing) or outdoors (garden watering). Rainwater tanks can be either above ground or underground. Above ground tanks can be placed on stands to prevent the need of installing a pump to distribute the water. Such systems are referred to as gravity systems. Pressure systems require a pump and can be either above or below ground tanks.

Tanks can be constructed of various materials such as ColorbondTM, galvanised iron, polymer or concrete.

*Comment: Rainwater tanks are effective in removing suspended solids and a small amount of nutrient pollutants. They are also effective in reducing overall runoff volumes. The effectiveness of rainwater tanks is also increased when plumbed in for internal use.*

*At Sydney Science Park, Rainwater tanks will be provided as part of the on-lot treatment devices (which is also required for BASIX).*

# 8 PROPOSED WATER CYCLE MANAGEMENT STRATEGY

A critical consideration for the Water Cycle and Flood Management strategy is the long term ecological sustainability of the local watercourses and in particular, the riparian corridors which are being reconstructed. To maintain stormwater quality at the required levels, a 'treatment train' approach is proposed where various types of pollutants are removed and flow volumes and discharge rates are managed by a number of devices acting in series. The stormwater management treatment train will consist of the following elements.

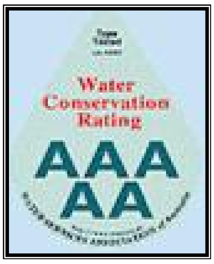
## 8.1 Water Efficiency

### *8.1.1 On Lot Treatment*

Implementation of water efficient fittings and appliances in all dwellings (dual flush toilet, AAA shower heads, water efficient taps and plumbing).

Minimisation of impervious areas through acceptable development controls.

The provision of rainwater tanks on each allotment, along with implementation of the above water efficient devices, will satisfy the requirements of BASIX. The connection of water tank to service internal uses will ensure any requirements are met and additional benefits are realised.




## 8.2 Water Quality Measures

### *8.2.1 Street Level Treatments*

**Inlet Pit Filter Inserts and Gross Pollutant Traps (GPTs)**

GPT devices are typically provided at the outlet to stormwater pipes. These systems operate as a primary treatment to remove litter, vegetative matter, free oils and grease and coarse sediments prior to discharge to downstream (Secondary and Tertiary) treatment devices. They can take the form of trash screens or litter control pits, pit filter inserts and wet sump gross pollutant traps.

In theory, inlet pit filter inserts have several advantages over end of pipe GPT's, such as providing a dry, at source collection of litter, vegetative matter and sediment as well as allowing for staged construction works without having to provide additional / temporary GPT units. They also prevent premature clogging of end pipe GPT's during the construction / building phases. This may be particularly relevant for portions of Sydney Science Park due to the likely staged nature of future development. Pit filter inserts will provide an at source mechanism for treatment of gross pollutants as development proceeds throughout the site.

In practice, feedback from various Councils have found that inlet pit filter inserts result in an unreasonable maintenance burden, particularly through access for cleaning and damage / vandalism. Pit inserts may be appropriate in low density residential areas where on street parking is unlikely or not permitted and where additional primary / secondary treatment measures are provided downstream in case of pit insert failure.

For the purposes of this study, CDS units are adopted at the street level in accordance with Penrith City Council's Draft Policy (PCC, 2013). The form and configuration of GPT's can however be further considered at development application and detailed design stages in conjunction with the streetscape design.

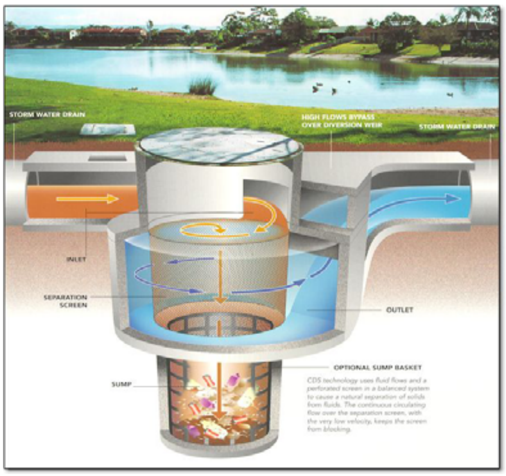



**PLATE 4.8 – VORTEX STYLE GPT**

### Bio-retention Systems and Raingardens

Bio-retention 'raingardens' systems are proposed in isolated locations at Sydney Science Park in order to achieve the nutrient reduction targets outlined in Penrith City Council guidelines (PCC, 2013) and the Office of Environment and Heritage draft guidelines (2006). The bio-retention systems and raingardens will also attenuate first flush flows to reduce the risk of stream erosion within the water courses. The location of the bio-retention systems and raingardens are shown on Figure 10.3. Refer to Section 11.1.1 for further discussion.

**PLATE 4.9 – TYPICAL RAINGARDEN AFTER PLANT ESTABLISHMENT**

### Wetlands / Pond

Wetlands and Ponds are generally proposed within detention basins across Sydney Science Park. These wetlands and ponds will provide multiple benefits including, aesthetics, water quality, potential stormwater harvesting and reuse opportunities and minor volume management.

The strategy for Sydney Science Park does not preclude the use of additional or alternate WSUD elements within the streetscape or landscape. These elements, such as swales or bioretention systems in the medians of dual carriageways, can be considered at the development application and detailed design stages. The use of such elements would require consideration of issues such as practicality in the urban environment, safety, maintenance and performance.

**PLATE 4.10 - TYPICAL WETLAND / POND**

### On-lot Treatment

Since there is a variety of landuses proposed at Sydney Science Park, there is some uncertainty over the potential for rainwater harvesting and reuse upon the proposed lots. Generic treatment nodes have therefore been included within the water quality modelling to represent the required treatment to be delivered “on-lot”. This allows flexibility in the final Water Quality arrangement so that they can be designed as the site development progresses.

The generic treatment nodes represent the contribution of treatment devices which are required “on-lot” such as rainwater tanks, raingardens and proprietary devices. It is assumed that 85 % TSS, 65 % TP and 45 % TN will be removed from all stormwater flows within the lots prior to discharge into the downstream system.

## 8.3 Water Quantity (Flood Control) Measures

### *8.3.1 Subdivision / Development Treatment*

**Detention Basins**

Peak storm flow attenuation up to the 1 % AEP event is addressed through the provision of detention basins which are "offline" to the central watercourse ("online" to some of the more minor tributaries).

Each of the basins are designed to manage both the 50% and 1 % AEP via a slotted weir outlet with excess flows overtopping for those events greater than the 1 % AEP event. Refer to Section 9 for further discussion.

## 8.4 Construction Stage

Erosion and sediment control measures are to be implemented during the construction phase in accordance with the requirements of Penrith City Council and the guidelines set out by Landcom (the “Blue Book” 2004).

As the operation of wetlands and “bio-retention” (raingarden) type water quality treatment systems are sensitive to the impact of sedimentation, construction phase controls should generally be maintained until the majority of site building works (approximately 80%) are complete. Alternatively, a very high level of at source control on individual allotments during the building and site landscaping works, which is regularly inspected by Council officers, would be required.

## 8.5 Interim Treatment Measures

The raingarden media bed should be protected throughout the civil and housing construction phases of the development. The floor of the raingarden should be lined with either a layer of turf or a sacrificial upper media bed layer and planting that would need to be replaced upon 80% completion of housing construction.

Upon 80% completion of housing construction within the catchment, the turf or sacrificial layer can be removed, replaced and the final media planting completed.

## 8.6 Long Term Management

Regular maintenance of the stormwater quality treatment devices is required to control weeds, remove rubbish, and monitor plant establishment and health. Some sediment build-up may occur on the surface of the raingardens and within the swales and may require removal to maintain the high standard of stormwater treatment.

Proper management and maintenance of the water quality control systems will ensure long-term, functional stormwater treatment. It is strongly recommended that a site-specific Operation and Maintenance (O & M) Manual is prepared for the system. The cost of preparing this manual should be a component of the Voluntary Planning Agreement.. The O & M manual will provide information on the Best Management Practices (BMP’s) for the long-term operation of the treatment devices. The manual will provide site-specific management procedures for:

- Maintenance of the GPT structures including rubbish and sediment removal.
- Management of the raingarden including plant monitoring, replanting guidelines, monitoring and replacement of the filtration media and general maintenance (i.e. weed control, sediment removal).

- Management of pond and wetland systems including replanting guidelines. A separate algal control strategy will need to be developed to ensure the long term viability of the wetlands.
- Indicative costing of maintenance over the life of the device.

# 9 RIPARIAN CORRIDORS

In accordance with the NSW Office of Water (NOW) Guidelines, all existing watercourses have been identified under the “Strahler” system (refer to Figure 9.1). Results indicate that 1st to 4th order watercourses bisect the Sydney Science Park site.

As discussed in Section 3, a detailed stream classification and ground truthing study has previously been undertaken by Worley Parsons (WP, 2011). This assessment confirmed that all of the riparian corridors have little ecological significance and subsequently made recommendations for the removal and / or reclassification of all riparian corridors.

Based on this earlier study, we understand that the central watercourse is the only flowpath which was recommended to be reconstructed as a fully vegetated riparian corridor. Importantly however, the proposed development at Sydney Science Park aims at embracing the aesthetic nature of the watercourses. The Master Plan has therefore proposed to reconstruct / embellish a series of fully vegetated riparian corridors through the site (refer to Figure 9.2). These corridors will provide the extra advantage of conveying the significant upstream catchment flows and provide the future potential for connectivity. The design of the central watercourse also considers the location of the existing transmission easement and associated towers. Refer to Figure 9.3 for typical cross section of how the reconstruction may appear.

The watercourses on the site that are proposed to be retained and those earmarked for removal are summarised in Figure 9.2 of this report. As development of the site proceeds to the next phases, liaison with NSW Office of Water will be necessary to secure controlled activity approvals and to ensure that satisfactory riparian outcomes can be established.

# 10 HYDROLOGIC ANALYSIS

The hydrologic analyses for this study were undertaken using the rainfall - runoff flood routing model XP-RAFTS (Runoff and Flow Training Simulation with XP Graphical Interface) (Willing, 1996 & 1994). The hydrologic analysis for the Sydney Science Park Precinct was undertaken to determine the requirement and size of detention basins needed to restrict peak post development to pre development flows. Peak flowrate hydrographs for input to the hydraulic model also form part of this work.

## 10.1 Sub-Catchments (Existing)

Sub-catchment areas contributing to the drainage system were established through site investigations and assessment of a Digital Elevation Model provided by YSCO Geomatics which covered the study area and adjacent areas. Sub-catchment boundaries beyond the extent of the digital elevation model were determined from 2 metre contour data obtained from the Land and Property Management Authority.

CatchmentSIM was used to facilitate the determination of catchment areas under existing conditions. CatchmentSIM automatically delineates sub catchments and calculates their associated spatial and topographic characteristics to assist in the development of a hydrologic model. The catchment extents were reviewed and adjusted manually based on visual inspection and detailed assessment.

Catchment boundaries for the existing areas contributing to the drainage system are shown on Figure 10.1.

The modelling has included catchments to approximately 500 m downstream of the Sydney Science Park study area to ensure that a meaningful analysis of any potential impacts that the development of the Sydney Science Park development may have on downstream areas can be assessed.

Penrith Council (PCC, 2013) do not indicate a specific runoff coefficient for undeveloped site conditions. Therefore, we have taken a conservative position as a result of reviewing of existing aerial imagery and undertaking a detailed site inspection, in adopting a percentage imperviousness of zero for the rural catchments under existing conditions.

Detail flow information for a range of storm events modelled is provided in Appendix A.

## 10.2 Existing Farm Dams

A number of significant farm dams are located within the study area, as indicated on Figure 11.1. It is assumed that the dams would be full to the spillway levels and do not provide significant detention storages.

It should be noted that even with the dams filled to spillway level, significant detention storages are still indicated in the existing condition flood modelling and may skew these results.

## 10.3 Sub-Catchments (Post Development)

The developed case sub-catchment areas contributing to the drainage system were maintained to be the same as the existing case catchment boundaries outside the Precinct. Developed catchment boundaries within the Precinct have had minor adjustments, determined on the best information available with regards to the Master Plan, likely site grading and levels.

Final catchment boundaries and areas contributing to each detention basin and water quality device will be confirmed as part of the Development Approval process. However, preliminary developed case catchment extents are shown on Figure 10.2.

In accordance with Penrith City Council Design Guidelines for Engineering Works (PCC, 2013), an impervious factor of 0.90 was adopted for the proposed employment areas in the developed case. Open space areas as denoted in the Master Plan were also considered in the post development assessment, reducing the imperviousness of these sub-catchments.

Developed condition flow information for the range of storms modelled in provided in Appendix A.

## 10.4 Rainfall Data & XP-Rafts Parameters

### *10.4.1 Intensity-Frequency-Duration (I.F.D.)*

Design rainfall intensity-frequency-duration (I.F.D.) data for the site were obtained using methods set out in Australian Rainfall and Runoff (A.R.R.) (1987). A summary of the rainfall intensities adopted in this study is provided in Table 10.1TABLE 10.1. The critical storm durations were determined using these values for each sub-catchment.

**TABLE 10.1 - LUDDENHAM RAINFALL INTENSITIES**

| Storm Duration (min.) | Luddenham Rainfall Intensities (mm/hr) Recurrence Interval (AEP) | | | |
|---|---|---|---|---|
| | 50% | 1% | 0.2% | PMP |
| 5 | 96 | 219 | 276 | - |
| 10 | 74 | 167 | 211 | - |
| 15 | 62 | 139 | 175 | 840 |
| 20 | 54 | 121 | 152 | - |
| 25 | 48 | 107 | 136 | - |
| 30 | 43 | 98 | 124 | 620 |
| 45 | 34.7 | 78 | 99 | 520 |
| 60 | 29.5 | 66 | 84 | 460 |
| 90 | 23.3 | 52 | 66 | 380 |
| 120 | 19.7 | 43.6 | 55.7 | 320 |
| 150 | - | - | - | 280 |
| 180 | 15.5 | 33.8 | 43.5 | 250 |
| 240 | - | - | - | 220 |
| 270 | 12.2 | 26.2 | 34.0 | - |
| 300 | - | - | - | 190 |
| 360 | 10.3 | 21.8 | 28.5 | 170 |
| 540 | 8.06 | 17.0 | 22.4 | - |
| 720 | 6.47 | 14.3 | 19.0 | - |
| 1080 | 5.20 | 11.0 | 15.1 | - |
| 1440 | 4.28 | 9.52 | 12.91 | - |

### 10.4.2 XP-RAFTS Parameters

The PERN (n) values and losses adopted for the catchments in the XP-RAFTS modelling are listed in Table 10.2.

**TABLE 10.2 – ADOPTED XP-RAFTS PARAMETERS**

| Parameter | Catchment Condition | Adopted Value |
|---|---|---|
| **Pern** | | |
| | Existing Pervious | 0.05 |
| | Urban Pervious | 0.025 |
| | Urban Impervious | 0.015 |
| **Losses** | | |
| Initial Loss | Pervious Catchment | 15.0 |
| Continuing Loss | Pervious Catchment | 2.5 |
| Initial Loss | Impervious Catchment | 1.5 |
| Continuing Loss | Impervious Catchment | 0.0 |

Link lagging between sub-catchments was adopted throughout the hydrological model. The lag times adopted are generally based on a flow velocity of 1 - 2 m/s.

### 10.4.3 Calibration

It is normal practice for flood routing models such as XP-RAFTS to be calibrated with historical rainfall and stream flow data for the catchment being investigated in order to produce the most reliable results. The model parameter values (in particular Bx) are adjusted so that the model adequately reproduces observed hydrographs. As no streamflow records are available for the site, an alternative approach is required.

A Probabilistic Rational Method (PRM) check was undertaken to determine preliminary flow rates for the catchment flows through the site. Results for the PRM calculations with a comparison to XP-RAFTS modelling calculations utilising a Bx factor of 1.0 is shown below on Table 10.3.

**TABLE 10.3 – PRM AND XP-RAFTS 1% AEP DISCHARGES**

| Node | Contributing Catchment Area (ha) | PRM Calculation ($m^3/s$) | XP-RAFTS Modelling Results (Bx=1.0) ($m^3/s$) |
|---|---|---|---|
| 1.05 | 364 | 31.8 | 40.5 |
| 1.06 | 537 | 43.0 | 59.2 |
| 1.07 | 577 | 45.5 | 62.4 |
| 1.08 | 655 | 50.2 | 68.3 |
| 1.09 | 864 | 62.2 | 85.8 |
| 5.04 | 84 | 10.1 | 9.4 |

The preliminary flood assessment which was previously undertaken by Worley Parsons (WP, 2011) estimated the 1 % AEP flows for the main flowpaths using Rational Method Calculations. These estimates were determined at 52.3 $m^3/s$ and 11.6 $m^3/s$ for the central (Node 1.08) and eastern (Node 5.04) watercourse respectively.

By comparison, the results of the XP-RAFTS assessment indicate higher flow rates than those assessed using the PRM calculations for larger catchments, with comparable results for catchments less than 100 ha. Similarly XP-RAFTS results also indicate higher flow rates than those derived under Rational Method calculations but are considered to be within a reasonable order of magnitude (23% and 19%).

However since there are no stream flow records available for the site, we see that the XP-RAFTS assessment provides a more accurate Hydrologic Assessment and subsequently have adopted the default Bx value of 1.0 for modelling.

## 10.5 Proposed Basin Volumes

A summary of the proposed detention basin volumes for the Sydney Science Park Precinct are shown in Table 10.4.

**TABLE 10.4 - SUMMARY OF DETENTION BASIN VOLUMES**

| Basin Name | Storage Volume $m^3$ |
|---|---|
| B1 | 6500 |
| B2 | 5300 |
| B3 | 24000 |
| B4 | 4600 |
| B5 | 17600 |
| B6 | 2500 |
| B7 | 21100 |
| B8 | 500 |
| B9 | 1000 |
| B10 | 1300 |
| B11 | 1200 |
| B12 | 2100 |
| Total Storage | 87700 |

The detention storages that are located online to the water courses will also capture and attenuate flows from catchments upstream of the Sydney Science Park Study Area (Basins B3, B4, B5, B7).

The total development area is 288 hectares. The total volume of storage provided therefore represents approximately 300 $m^3$ / hectare, which is within the range expected for urban development. The location of the detention basins are shown on Figure 10.3.

## 10.6 Discharge Estimates

Discharge estimates were derived for the existing and developed catchments for storms of 50% and 1% AEP as well as the PMP. A range of storm durations from 15 minutes to 24 hours were analysed to determine the critical storm duration for each sub-catchment.

XP-RAFTS modelling was undertaken to determine the estimated peak discharges from the Precinct for the following catchment conditions:

- Undeveloped site under existing rural conditions.
- Site developed with detention systems provided.

The 50 % and 1 % AEP peak flows from the catchment are presented in Table 10.5 and Plate 10.1 below.


**PLATE 10.1 – FLOW COMPARISON POINTS LOCATIONS**

**TABLE 10.5 – SUMMARY OF PEAK FLOWS – 50% AND 1% AEP**
(9765RA4_Ex.xp and 9765RA7_Dev.xp)

| Location | Node | Existing Conditions | | Developed Conditions | | Flow Comparison (Pre/Post) | |
|---|---|---|---|---|---|---|---|
| | | 50% AEP | 1% AEP | 50% AEP | 1% AEP | 50% AEP | 1% AEP |
| Creek near upstream boundary of Site | 1.05 | 15.08 | 40.45 | 14.80 | 39.26 | 98% | 97% |
| Creek at Confluence with Tributary | 1.06 | 22.22 | 59.22 | 20.49 | 53.51 | 92% | 90% |
| Creek at Proposed Road Crossing | 1.07 | 23.51 | 62.38 | 22.01 | 57.71 | 94% | 93% |
| Creek at Downstream Boundary of Site | 1.08 | 25.98 | 68.25 | 25.66 | 67.45 | 99% | 99% |
| Watercourse at Downstream Boundary of Site | 5.04 | 3.43 | 9.37 | 3.42 | 7.21 | 100% | 77% |
| Creek 600m downstream of Site | 1.09 | 32.81 | 85.75 | 31.09 | 80.76 | 95% | 94% |
| Eastern Boundary of Site at Luddenham Road | 10.01 | 0.09 | 0.34 | 0.09 | 0.30 | 98% | 89% |
| Eastern Boundary of Site at Luddenham Road | 10.02 | 0.07 | 0.24 | 0.07 | 0.19 | 96% | 79% |
| Eastern Boundary of Site at Luddenham Road | 10.03 | 0.24 | 0.81 | 0.20 | 0.77 | 84% | 95% |
| Eastern Boundary of Site at Luddenham Road | 10.04 | 0.19 | 0.67 | 0.17 | 0.66 | 86% | 98% |
| Eastern Boundary of Site at Luddenham Road | 10.05 | 0.32 | 1.09 | 0.28 | 1.07 | 87% | 99% |

NOTE: Final Peak Flow values are to be determined upon completion of the detailed designs and preparation of the Development Application for each basin.

Peak flows for all locations within the Study Area are included in Appendix A.

### 10.6.1 Basin Performance

The performance of the basins for the 50% and 1% AEP storm events are detailed in Tables 10.6 and 10.7, respectively.

**TABLE 10.6 - DETENTION BASIN PERFORMANCE - 50% AEP**

| Basin | Peak Inflow $m^3/s$ | Peak Outflow $m^3/s$ | Basin Volume Used $m^3$ | Stage Used RL (m) |
|---|---|---|---|---|
| B1 | 3.23 | 0.77 | 4025 | 56.59 |
| B2 | 3.05 | 0.55 | 3510 | 52.87 |
| B3 | 8.85 | 2.13 | 14090 | 52.13 |
| B4 | 7.19 | 4.63 | 2390 | 49.63 |
| B5 | 7.40 | 0.86 | 12130 | 53.68 |
| B6 | 2.26 | 0.62 | 1600 | 56.22 |
| B7 | 9.87 | 1.91 | 18250 | 53.12 |
| B8 | 0.34 | 0.09 | 235 | 0.71 * |
| B9 | 0.45 | 0.07 | 510 | 0.75 * |
| B10 | 0.88 | 0.20 | 640 | 0.73 * |
| B11 | 0.81 | 0.17 | 610 | 0.75 * |
| B12 | 1.38 | 0.28 | 1065 | 0.75 * |

* Denotes ponding depth within basin - no specific basin design undertaken for device

**TABLE 10.7 - DETENTION BASIN PERFORMANCE - 1% AEP**

| Basin (Node) | Peak Inflow $m^3/s$ | Peak Outflow $m^3/s$ | Basin Volume Used $m^3$ | Stage Used RL (m) |
|---|---|---|---|---|
| B1 | 7.78 | 2.74 | 6460 | 56.89 |
| B2 | 6.48 | 2.05 | 5165 | 52.99 |
| B3 | 19.17 | 6.48 | 23775 | 52.59 |
| B4 | 15.52 | 11.74 | 4550 | 49.86 |
| B5 | 15.76 | 4.34 | 16820 | 53.90 |
| B6 | 4.78 | 3.24 | 2540 | 56.40 |
| B7 | 20.89 | 7.83 | 21310 ** | 53.21 |
| B8 | 0.73 | 0.30 | 490 | 1.18 * |
| B9 | 0.97 | 0.19 | 935 | 1.15 * |
| B10 | 1.89 | 0.77 | 1270 | 1.18 * |
| B11 | 1.73 | 0.66 | 1200 | 1.20 * |
| B12 | 2.95 | 1.07 | 2100 | 1.20 * |

* Denotes ponding depth within basin - no specific basin design undertaken for device
** Basin B7 designed as a 50% AEP basin, with 1% AEP flows diverted to Basin B4

### *10.6.2 Discussion of Modelling Results*

The XP-RAFTS modelling undertaken has determined that the proposed detention storages are adequate to restrict post development peak discharges from the site, to pre-development levels for the 50 % and 1 % AEP storm events. The results of this modelling have been reported in Tables 10.5, 10.6 and 10.7 and demonstrate compliance with Penrith City Council Development Control Plan 2012 (PCC, 2012) stormwater management objectives.

The detention volumes provided reduce peak post development flow rates to pre development flows exiting the site. It is noted that the average storage volume per hectare is approximately 300 $m^3$ / ha (including bypassing catchments), which is considered to be within the appropriate range for urban development.

Opportunities to further optimise the detention basins will be considered at the development application and detailed design stages.

## 10.7 Reduced Basin Strategy

A traditional 'basin strategy' is currently proposed for Sydney Science Park. It is noted however that during preliminary hydrological modelling, J Wyndham Prince identified that detention basin storages may not be required to manage flows from the proposed Sydney Science Park development. This is primarily due to catchment timings, as the un-attenuated peak discharges from the development results in the "releasing" of peak flows from the study area well before the peak flows from the upstream catchment flow through the site.

An assessment upon the 'Reduced Basin Strategy' tested the removal of six (6) detention basins for the Water Cycle Management strategy and concluded that detention facilities for those catchments that discharge directly to the central drainage corridor were not required.

There is an opportunity for a Reduced Basin Strategy to be considered at some time in the future which will include discussions with Penrith City Council. However, for the purposes of this assessment we have adopted a **traditional Water Cycle Management approach**, and have proposed the use of detention basins within the development to manage the change in flood regime.

There are a number of advantages for a Reduced Basin Strategy, these include:

- Reduced development costs which leads to more affordable housing; and,
- Reduction in ongoing maintenance costs for the water management devices in Sydney Science Park.

The Reduced Basin Strategy can be further discussed with Penrith City Council during the Gateway Process.

## 11 FLOOD MODELLING

The 2D flood modelling of the water courses and trunk drainage channels that run through Sydney Science Park was undertaken using TUFLOW (Two-Dimensional Unsteady Flow). TUFLOW is a computational engine that provides two-dimensional (2D) and one-dimensional (1D) solutions of the free-surface flow equations to simulate flood and tidal wave propagation (TUFLOW 2010). TUFLOW is specifically beneficial where the hydrodynamic behaviour in coastal waters, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be difficult to represent using traditional 1D network models.

All flows within the creeks and over the floodplains were modelled as 2D flows. A 2D model provides a better estimation of the effects of momentum transfer between in-bank and overbank flows and the energy losses due to meanders or bends in creeks. MapInfo, a GIS based software tool, was used for interrogating and plotting the results as well as creating the flood extents maps and the flood level difference maps.

Flood modelling for the existing and developed scenarios was undertaken to determine the impact of Sydney Science Park on the flood levels in the creeks.

### 11.1 TUFLOW Model Set-Up and Modelling Assumptions

As with any flood modelling, a number of assumptions are necessary to allow for the modelling process to proceed. The assumptions made within the TUFLOW model for the Sydney Science Park are summarised below and are provided in more detail in Appendix B.

### 11.2 Existing Farm Dams

There are a large number of existing farm dams, associated outlet channels and diversion structures which are located throughout Sydney Science Park. The locations of the farm dams and diversion embankments are shown on Figure 11.1. These farm dams are "online" and vary in surface area, with the largest being approximately 10 hectares and are located upon almost every watercourse across Sydney Science Park. In particular, the central watercourse includes a series of interconnected farm dams which do not include formal outlets or spillways.

Importantly, the farm dams and associated structures significantly affect the existing case flood extent mapping and floodway definition from what would have occurred prior to their construction (i.e due to significant depression storage).

For the purpose of the existing case flood modelling, the water level in the dams have therefore been artificially filled to the spillway height for the storm durations assessed. Provision is also made for those flows from the embankment crest to be conveyed to the downstream channel.

### 11.3 Developed Channels and Riparian Corridors

As discussed in Section 9, there is a significant opportunity for Sydney Science Park to reconstruct / embellish selected watercourses with new Riparian Corridors in order to provide a better environmental outcome.

For the developed case scenario, trunk drainage channels and riparian corridors have been modelled within 12d software which includes the removal of the existing farm dams. Each riparian corridor generally includes a central channel which is sized to convey the 50% AEP event, with the overall corridor to convey the 1 % AEP. The central channel has also taken into consideration the existing electrical easement to ensure that there is no filling in the easement or encroachment on towers. It is noted the modelling of the central watercourse currently includes a straight low flow channel which can be meandered during future detailed design works to better emulate natural creek features. Refer to typical cross section on Figure 9.3.

## 11.4 Dam Break Considerations

The 2010 Dam Safety Committee (DSC) guidelines require that all detention storages, no matter the size of the storage or embankment height, need to be referred to the DSC for a determination on an appropriate Flood Consequence Category for each basin.

This referral would be undertaken in conjunction with a Development Application lodged with Penrith City Council for any basin construction. The PMF analysis of the flood conditions undertaken as part of this study provides the basis of estimating "Population At Risk" (PAR) and could be used as the start point for future assessment of the likely impacts of a dam failure on the Sydney Science Park and the downstream properties / major infrastructure.

In general terms, the location of the proposed detention basins are located "offline" from the main watercourse which would assist in limiting the PAR but would need to be determined as part of a more detailed dam failure assessment.

## 11.5 Hydraulic Structures

The existing watercourses at Sydney Science Park generally drain to the North - East through the Sydney Water Warragamba Pipeline Easement via a series of piped crossings and overland flowpaths. J. Wyndham Prince have confirmed via site inspections the approximate sizes and configuration of the pipe crossings and adopted within the TUFLOW Model. Refer to Plates 4.2 and 4.3. Each pipe crossing within the assessment area has been modelled in TUFLOW as a 1D element.

The proposed Sydney Science Park development will also include a number of bridge and road culvert crossings of water courses. For the purposes of modelling, these crossings have currently been excluded and will need to be appropriately sized during future modelling at development application and detailed design stages to ensure they convey the necessary flows and consider all factors such as losses and blockages. The height restrictions associated with the transmission easement will also drive the final design solution however it is unlikely that this situation will cause any adverse local flood impacts.

## 11.6 Detention Basins

A series of detention basins are proposed as part of the Water Cycle Management Strategy for Sydney Science Park (refer to Figure 10.3 and Section 10 for discussion) with surface modelling included with the TUFLOW model. Basins B4, B5, B7 and W2 are all located "online" to major flowpaths and include an outlet arrangement consistent with the Basin Concept Plans shown in Appendix E.

For the purposes of modelling, those remaining basins which are located "offline", have been excluded from the modelling. The total flow out of the basins have been assigned just downstream of the basin outlets in order to assess the flooding in the main corridors.

## 11.7 Overland Flow Paths

There are a series of significant upstream catchments which are currently conveyed via watercourses through the subject site (unnamed tributaries) before adjoining South Creek approximately 4 km to the North.

A number of the watercourses have been identified to be reconstructed as fully vegetated riparian corridors (refer to Section 9 for discussion). In particular, we understand from previous studies at the site (WP, 2011) that the existing watercourses have "little ecological value" due to the presence of large farm dams. The proposed reconstruction of the watercourses will have an increased hydraulic capacity and will improve flow conveyance through Sydney Science Park.

The reconstructed riparian corridors have therefore been modelled with a profile which will more efficiently convey major flooding through the site (refer to Figure 9.3). This arrangement generally includes a central low flow channel which will convey flows up the 50 % AEP whilst the remainder of the corridor will convey the 1 % AEP (Refer to Figures 11.9 and 11.10).

In addition to the major riparian corridors, there are also a number of trunk drainage corridors which are required to convey upstream overland flows and have been incorporated into the Master Plan. Refer to Figure 10.3 for locations and Figure 9.3 for typical sections..

These Trunk Drainage Corridors will allow overland flow to safely be conveyed through the site to provide sufficient freeboard to the proposed lots, whilst also avoiding the need for excessively large pipes and maintain safe velocity depth products within the road network for larger flows.

The trunk drainage corridors included in Sydney Science Park have also been incorporated in the flood model.

## 11.8 Flood Extent Mapping

Flood extent mapping has been completed for the 50 % AEP and 1 % AEP and PMF events under existing conditions. A series of other maps of specific AEP’s have also been developed for this study as follows:

**Existing Conditions**

- Depth Profile – 50 %, 1 % AEP and PMF
- Hazard Classification (1 % AEP and PMF only)
- Provisional Hydraulic Categorisations (1 % AEP only)

**Post Development Conditions**

- Depth Profile - 50 %, 1 % AEP and PMF
- Hazard Classification - 1 % AEP

The flood depth, extent and hazard mapping is shown in Figures 11.1-11.19.

### *11.8.1 Flood Difference Mapping*

A map has been prepared which indicates the difference in 1 % AEP flood levels arising from the existing case and the proposed development within the study area, which is provided as Figure 11.15.

The figure indicates that development of Sydney Science Park, with the recommended controls, will result in some increases in flood levels within the bounds of the study area which can be accommodated within the riparian corridors and drainage reserves and by the additional filling of the urban areas.

The increase in flood levels external downstream from the site are generally in the order of 200 mm and are associated with the removal of the steep existing dam embankment slope (which had existing supercritical flows). It is noted that the flood levels are returned back to existing where the flowpath crosses the Warragamba Pipelines and are located within the downstream riparian corridor and where no development is located, as shown on Figure 11.15. The developed case is therefore considered to be an improvement upon existing conditions.

As noted in Section 10, the peak post development flows have been over attenuated in the hydrologic model to assist in compensating for the increases in the hydraulic model. The hydraulic modelling can be further refined at the development application and detailed design stages.

### *11.8.2 Hazard Categories*

Hazard can be considered to be a measure of the impact that floodwater may have on both people and/or property. Hazard mapping was undertaken for 1 % AEP and PMF events from the TUFLOW runs completed as part of this study.

Hazard grids are developed directly out of the TUFLOW model and have been used to produce the Hazard plans presented in this report. The floodplain has been divided into three Hazard categories (consistent with the NSW Floodplain Development Manual (FDM, 2005) as follows.

- Low Hazard;
- Transitional Hazard; and
- High Hazard.

Hazards maps are useful to obtain an appreciation of the relative depth and velocity of floodwater within a locality and are a critical element in determining:

- The locations of critical public infrastructure such as hospitals and aged care facilities;
- The areas in the floodplain for which public safety is “at risk”; and
- Assist in the Flood Emergency response and Evacuation Management process.

It should be noted that during the PMF event, significant areas of the floodplain are affected by high hazard flooding and the potential impact on infrastructure within these high hazard areas needs to be considered as part of the future planning of the Precinct.

The existing case flood hazard mapping for the 1 % AEP event is shown on Figure 11.4, with Figure 11.8 indicating the hazard during the PMF event. The developed case scenario flood hazard mapping is shown in Figures 11.11 and 11.15 for the 1 % AEP event and PMF event, respectively.

### *11.8.3 Hydraulic Categorisation*

The methodology for Hydraulic Categorisation which has been adopted for Sydney Science Park is consistent with the technical paper presented at the 52nd Floodplain Management Authority Conference, written by Chris Thomas from Worley Parsons. A copy of the paper is provided in Appendix C.

This methodology has been applied on Sydney Science Park to provide definition of the floodways within the site.

The technical paper (Thomas et al, 2011) uses a combination of two threshold values in the determination of the floodway hydraulic category:

- Initial flood definition, which is based on the examination of Velocity – Depth (V x D) product for the 1 % AEP events and assessing if V x D ≥ 0.5 m/s
- Section Average Velocity for the same event that is ≥ 0.5m/s.

The second stage of the floodway definition process is to look at the width of a corridor that would be required to convey 80 % of the total flow at that location. The process included the use of WaterRIDE and an iterative process to determine the updated flooding definition. Details of the floodway definition across the entire Precinct using the agreed methodology is shown in Figure 11.5.

As discussed in Section 11.2, there are a number of significant farm dams within Sydney Science Park. The farm dam and diversion embankment locations are shown on Figure 11.1. These dams have resulted in much wider flood extents from what would have naturally occurred. Subsequently, flood depth and velocities as well as floodway definition will also be skewed as a result of the farm dams.

Where the floodway definition is not effected by existing farm dams or associated diversion embankments, the floodway extents are generally contained within the proposed riparian corridor / drainage corridor limits. Based on these results, it is expected that the proposed riparian / drainage corridor widths would be adequate to contain the entire floodway prior to construction of the farm dams and diversion embankments.

## 11.9 Climate Change Impacts

An assessment upon Climate Change has been undertaken in TUFLOW by applying a 15 % increase on all hydrograph inflows. The resulting increase in flood levels are indicated in Figure 11.16 and 11.17.

The assessment indicates that generally the increases in the 1 % AEP flood levels as a result of the impact of climate change are less than 0.1 metres, which is within the component of the standard 0.5 m freeboard which relates to climate variability.

## 11.10 Flood Evacuation Strategy

The local PMF event will affect a number of residents adjacent to the riparian corridors and drainage reserves. The local PMF is a short duration event that will occur and recede reasonably quickly (over a number of hours). It is not recommended that affected residents shelter in place, even where second storey house levels are above the PMF, as there is a potential risk of structural damage or failure to dwellings. Affected residents may evacuate locally to community centres, with neighbours or to other higher areas until the flood waters recede. The proposed development layout and general land formation will allow evacuation of affected residents through a continually rising grade to flood free land.

A flood evacuation road will be required for the Southern portion of Sydney Science Park with a continuing rising grade from the lowest point to ensure safe evacuation of these resident is possible during larger events (greater than the 0.2 % AEP event). The evacuation road will be required to be flood free during the 0.2 % AEP event and include two large culvert crossings (refer Figure 10.3).

Flood evacuation for those development areas to the west of the central watercourse can be directed to Gates Road and Northern Road via the new entry road. Similarly those development areas to the east of the central watercourse will be directed to Luddenham Road.

The flood evacuation strategy will ultimately need to be considered and adopted by the State Emergency Services (as applicable) and Penrith City Council.

The flood evacuation strategy will be further developed as part of the staged construction of Sydney Science Park to ensure compliance with the required guidelines and statutory agencies (ie. SES).

## 12 WATER QUALITY ANALYSIS

The stormwater quality analysis for this study was undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). This water quality modelling software was developed by the Cooperative Research Centre (CRC) for Catchment Hydrology, which is based at Monash University and was first released in July 2002. Version 5.1 Build 16 was released in 2012 and this was adopted for this study.

The model provides a number of features relevant for the development:

- It is able to model the potential nutrient reduction benefits of gross pollutant traps, constructed wetlands, grass swales, bio-retention systems, sedimentation basins, infiltration systems, ponds and it incorporates mechanisms to model stormwater re-use as a treatment technique;
- It provides mechanisms to evaluate the attainment of water quality objectives;
- In August 2013, Penrith City Council released the “Draft Water Sensitive Urban Design Policy” for public comment (PCC, 2013). The target pollutant load reductions defined within the draft policy included:
- 90% reduction in the post development mean annual load of total gross pollutant (greater than 5mm)
- 85% reduction in the post development mean annual load of Total Suspended Solids (TSS)
- 60% reduction in the post development mean annual load of Total Phosphorus (TP)
- 45% reduction in the post development mean annual load of Total Nitrogen (TN)

MUSIC modelling was undertaken to demonstrate that the water cycle management system proposed for Sydney Science Park will result in reductions in overall post-development pollutant loads and that concentrations being discharged from the study area to comply with these designated target objectives.

The Office of Environment and Heritage have established default parameters for use in MUSIC models to represent the generation of various pollutants by different land uses. The MUSIC model also demonstrates compliance with the recommended post development annual load reductions (DECCW, 2006).

### 12.1 Catchments

A MUSIC model was established for the proposed stormwater management system at Sydney Science Park. The study area was split into twelve (12) sub-catchments ranging in size from 9 Ha to 48 Ha. The sub-catchments which are directed to each of the proposed water quality element are shown on Figure 12.1. A typical layout of a sub-catchment is shown on Plate 12.1 with the general arrangements of the MUSIC model included in Appendix D.

The proposed development at Sydney Science Park includes an integrated mix of employment, educational, retail and residential land uses. The development footprint has been split into “Roads”, “Parks” and “Commercial” areas based on the current Master Plan as appropriate to represent each post development sub-catchment within Sydney Science Park.

Park areas were measured digitally with the remaining development areas then assumed at 20 % Roads and 80 % Commercial. All Commercial areas have adopted a fraction impervious of 100 %, Roads at 90 % and Parks at 0 %. Refer to summary tables in Appendix D.

Since Sydney Science Park predominately includes "Commercial" development areas, there is some uncertainty over the potential for rainwater harvesting and reuse within proposed lots. Generic treatment nodes have therefore been included within the model to represent the water quality measures which will be required to be delivered "on-lot". This allows flexibility in the final Water Quality arrangement so that they can be designed as the site develops progressively.

These generic treatment nodes have been assigned pollutant removals for 85 % Total Suspended Solids (TSS), 65 % Total Phosphorus and 45 % Total Nitrogen (TN) and represent the contribution of treatment devices which are required "on-lot" such as rainwater tanks, raingardens and proprietary devices. The high flow bypass is set at the 400 % AEP (3 month ARI) flow.

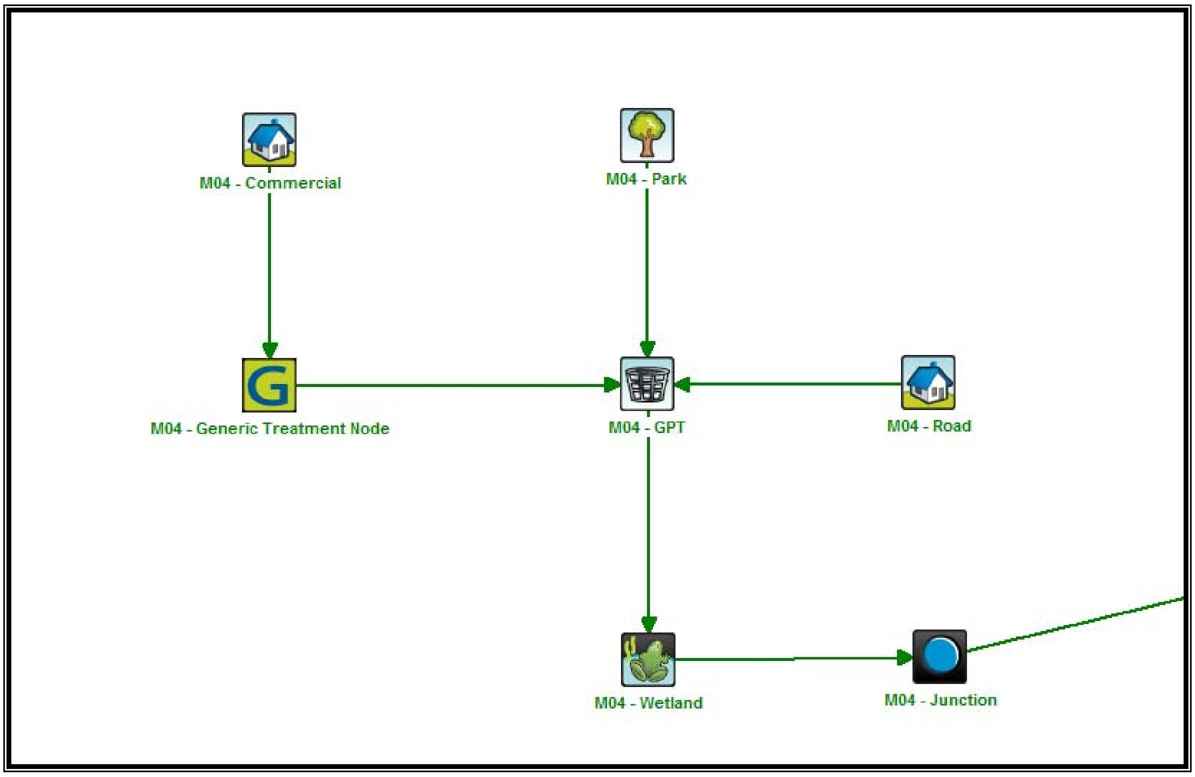



**PLATE 12.11 - TYPICAL SUB-CATCHMENT MUSIC LAYOUT**
(9765MU4.SQZ)

The overall proposed strategy includes a series of proposed Water Quality treatment measures which have been designed to achieve Penrith City Council's pollutant removal targets. These devices include ponds, wetlands, gross pollutant traps and bio-retention raingardens.

These regional devices will receive flows from each sub-catchment and provide treatment prior to discharge to the nearby creek systems. Each device is discussed in Sections 12.1.1 to 12.1.4.

### *12.1.1 Bio-Retention Systems and Raingardens*

Bio-retention / filtration systems are proposed on two (2) sub-catchments within Sydney Science Park. The preliminary development layout facilitates the provision of co-located raingardens within the detention basins fronting Luddenham Rd to the East (Devices B8 - 12) as well as independent devices in open spaces (Device R1).

The media beds of the bio-retention systems are typically 500 - 600mm deep with an average particle size of 0.5 mm, a minimum hydraulic conductivity of 100 mm/hr and minimum depth of storage above the media of 300 mm. Flows in excess of the 400 % AEP (3 month ARI) storm event will bypass the raingardens.

It is assumed that trash and gross sediments will be effectively removed prior to entering the raingardens by the proposed GPT units. In order to reduce the ongoing maintenance requirements for the raingardens. Refer to Section 12.1.4 for discussion.

Treatment within bio-retention raingardens is attained by detaining flows to promote sedimentation, direct filtration of particulate matter and nutrient stripping by bio-films which establish on the surface of the media bed and within the gravel layer. The organic sandy loam bed and plant system minimises evaporation losses and the raingarden will be constructed with an impermeable barrier to prevent seepage losses and to avoid groundwater salinity impacts.

The location of the proposed bio-retention and raingarden systems are shown on Figure 12.1. The general features and configuration of the bio-retention raingarden systems for Sydney Science Park, as modelled in MUSIC, are detailed in Table 12.1.

**TABLE 12.1 - BIO-RETENTION SYSTEMS**
**GENERAL FEATURES AND CONFIGURATIONS**

| Device Number | Total Receiving Catchment (Ha) | Bio-retention filter area ($m^2$) |
|---|---|---|
| R1 | 9.49 | 450 |
| B8-B12 | 16.26 | 800 |

The filter area of the bio-retention / raingardens for the selected catchments is approximately 0.5 % of the catchment that drains to them.

Details of the expected removal performance together with the general modelling parameters and rainfall data used in the MUSIC modelling are provided in Appendix D.

### 12.1.2 Ponds

Two (2) ponds are proposed at Sydney Science Park within the eastern portion of the site. These ponds will provide an aesthetic feature for the development while also providing a water quality / quantity benefit. Stormwater flows up to at least the 400 % AEP (3 month ARI) will be treated to a high level by both (a) gross pollutant traps; and (b) on-lot water quality treatment devices, prior to entering the ponds.

The two (2) ponds will have approximate areas of 2.45 Ha and 2.4 Ha with an extended detention depth of 300 mm and a hydraulic retention time of 72 hours. The ponds provide a combined quality / detention function and include detention over the extended detention zone along with freeboard to adjacent development. The ponds may incorporate wetland planting at appropriate locations, however has been conservatively omitted for modelling purposes.

The location of the proposed ponds are shown on Figure 12.1 and in Table 12.2. The general features and configuration of the proposed pond servicing Sydney Science Park, as modelled in MUSIC, are provided in Appendix D.

**TABLE 12.2 - WATER QUALITY PONDS**

| Device Number | Adopted Pond Area ($m^2$) |
|---|---|
| B5 | 24000 |
| B7 | 24500 |

### 12.1.3 Wetlands

As discussed in Section 7.5, wetlands are effective in removing sediment and nutrient loads which are typically generated from urban developments.

Eight (8) wetlands are proposed across Sydney Science Park, both in standalone water quality control lakes and within combined quality / detention basins. The proposed wetlands will provide an effective means of improving water quality whilst also providing aesthetic features for the future residents and users of Sydney Science Park.

The depth of permanent water within the wetlands have been conservatively adopted at 1 m depth with 100 – 300 mm extended detention depth over the static water level and a 72 hour hydraulic retention time. The majority of the proposed wetlands will be adopted within detention basins with detention volume being provided over the extended detention zone.

The wetlands will require gross pollutant traps to be positioned over all piped outlets prior to discharge to the wetland. Detailed design will also need to consider scour protection and flow velocity dissipation for all stormwater runoff entering the wetlands.

The location of the proposed wetlands are shown on Figure 12.1 and in Table 12.3. The general features and configuration of the proposed wetlands servicing Sydney Science Park, as modelled in MUSIC, are provided in Appendix D.

**TABLE 12.3 - WETLANDS**

| Device Number | Wetland Type | Extended Detention Depth (mm) | Adopted Wetland Area ($m^2$) |
|---|---|---|---|
| B1 | Detention / Wetland | 300 | 5100 |
| B2 | Detention / Wetland | 100 | 12400 |
| B3 | Detention / Wetland | 300 | 17100 |
| B4 | Detention / Wetland | 300 | 8200 |
| B6 | Detention / Wetland | 300 | 4040 |
| W1 | Wetland | 300 | 8000 |
| W2 | Wetland | 300 | 2000 |
| W3 | Wetland | 300 | 5500 |

### 12.1.4 Gross Pollutant Traps

As discussed in Section 8.2.1, GPT devices operate as a primary treatment to remove litter, vegetative matter, free oils, grease and coarse sediments prior to discharge to downstream treatment devices.

The proposed strategy for Sydney Science Park includes GPTs being located at all pipe discharges to detention basins, wetlands and raingardens. The high flow bypass has been set to the 3 month ARI flowrate for the sub-catchment (based on the rational method) and has been adopted as a proprietary CDS Unit (TSS removal 70 % of inflow concentrations greater than 75 mg/L and TP removal for inflow concentrations greater than 0.5 mg/L). Multiple GPTs have been considered at certain basin locations in order to suit the Master Plan layout. Refer to Figure 12.1 for indicative locations and Appendix D for further discussion and summary tables.

Alternative GPT units can form part of the detailed design process however the pollutant removal criteria used in the modelling would need to be satisfied or additional modelling of the alternate GPT arrangements would be necessary.

## 12.2 Pollutant Load Estimates

Total annual pollutant load estimates were derived from the results of a MUSIC model based on a stochastic assessment of the developed site incorporating the proposed water quality treatment system. The overall estimated annual pollutant loads and reductions for TSS, TP, TN and Gross Pollutants for Sydney Science Park is presented in Table 12.5.

**TABLE 12.5 - SUMMARY OF OVERALL ESTIMATED MEAN ANNUAL POLLUTANT LOADS AND REDUCTIONS**

| | Mean Annual Loads (kg/yr) | | | |
|---|---|---|---|---|
| | **GP** | **TSS** | **TP** | **TN** |
| Total Development Source Loads (ML/yr) | 42200 | 329000 | 541 | 3410 |
| **Target Removal (%)** | **90%** | **85%** | **60%** | **45%** |
| Minimum Reduction Required | 37980 | 279650 | 324.6 | 1534.5 |
| Total Residual Load | 284 | 42500 | 168 | 1650 |
| Total Reduction Achieved (kg/yr) | 41916 | 286500 | 373 | 1760 |
| **Total Reduction Achieved (%)** | **99.3%** | **87.1%** | **68.9%** | **51.6%** |

The pollutant removals were also assessed on individual sub-catchment level in order to determine sizes of treatment devices (i.e wetlands, ponds, raingardens, etc) and to ensure localised compliance with the Water Quality targets.

## 12.3 Discussion of Modelling Results

The performance of the proposed water quality management strategy for Sydney Science Park, as determined through a stochastic MUSIC assessment, is summarised in Table 12.5. The results demonstrate that the proposed strategy achieves the reduction targets specified by the Penrith City Council.

# 13 DETAILED CONCEPT DESIGNS

Detailed concept designs were prepared for each of the proposed combined detention / water quality basins. The detailed concept designs for the combined detention / water quality basins are included in Appendix E.

## 13.1 Preliminary Construction Cost Estimates

Estimates of quantities and preliminary cost estimates were also prepared for the basins and drainage reserves. This information will assist Penrith City Council in the preparation of the Voluntary Planning Agreement for the development.

A summary of the costs associated with the construction of the detention basins, raingardens and the drainage reserves are presented in Table 13.1. All assumptions adopted in the preparation of this estimate are included in Appendix E.

**TABLE 13.1 – SUMMARY OF DET. BASINS, RAINGARDEN & DRAINAGE RESERVE CHANNEL CONST. COSTS**

J. WYNDHAM PRINCE CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

# PRELIMINARY COST ESTIMATE

## PROJECT: Sydney Science Park

### CLIENT: APP C/- EJ Cooper and Sons Pty Ltd

**BASIN, PONDS / WETLANDS, GPTs, RAINGARDEN AND CHANNELS COST SUMMARY**

| NO. | ITEM | | AMOUNT Exc GST$ |
|---|---|---|---|
| 1 | BASIN B1 | | $1,210,950.00 |
| 2 | BASIN B2 | | $1,526,050.00 |
| 3 | BASIN B3 | | $2,728,950.00 |
| 4 | BASIN B4 | | $1,439,800.00 |
| 5 | BASIN B5 | | $2,970,450.00 |
| 6 | BASIN B6 | | $686,550.00 |
| 7 | BASIN B7 | | $4,789,750.00 |
| | | COMBINED BASINS / WETLANDS SUB-TOTAL | $15,352,500.00 |
| 8 | WETLAND W1 | | $1,109,750.00 |
| 9 | WETLAND W2 | | $394,450.00 |
| 10 | WETLAND W3 | | $664,700.00 |
| | | WETLAND SUB-TOTAL | $2,168,900.00 |
| 11 | RAINGARDEN 1 | | $312,800.00 |
| 12 | BASIN's B8-B12 | | $1,534,100.00 |
| | | RAINGARDEN SUB-TOTAL | $1,846,900.00 |
| 13 | TRUNK DRAINAGE CORRIDOR 1 | | $526,700.00 |
| 14 | TRUNK DRAINAGE CORRIDOR 2 | | $312,800.00 |
| 15 | TRUNK DRAINAGE CORRIDOR 3 | | $664,700.00 |
| | | CHANNELS SUBTOTAL | $1,504,200.00 |
| 16 | OPERATIONS AND MAINTENANCE MANUAL | | $ 7,500.00 |
| | | TOTAL COST ESTIMATE | $20,880,000.00 |

## 14 SUMMARY & CONCLUSION

The Water Cycle and Flood Management Strategy for Sydney Science has been prepared to inform the proposed planning and support the rezoning submission to Penrith City Council. The strategy has been prepared to conform with the statutory requirements and industry best practice for stormwater management in this catchment.

The Water Cycle and Flood Management Strategy consists of a treatment train consisting of on lot treatment, street level treatment and subdivision / development treatment measures. The structural elements proposed for the development consist of:

- Proprietary GPT units at each stormwater discharge point;
- Bio-retention raingarden systems;
- Combined detention basin / water quality ponds
- Combined detention basin / wetlands
- Stand alone wetlands (no detention); and
- "On-lot" treatment to achieve 85 % TSS, 65 % TP and 45 % TN removal from all stormwater flows prior to discharge into the downstream system. This includes a contribution of treatment devices such as rainwater tanks, raingardens and proprietary devices.

The provision of the proposed water quality treatment devices within the development will ensure that the post development stormwater discharges will meet the Office of Environment and Heritage's and Penrith City Council's water quality objectives for Sydney Science Park.

Existing and post development case hydrology models have been prepared for Sydney Science Park, which incorporate all upstream catchments draining to the site and also including catchments up to approximately 700 m downstream. The hydrologic modelling indicates that inclusion of the proposed detention basins within the Precinct will attenuate peak post development flows to less than existing levels.

The detailed flood assessment completed for the strategy has demonstrated that flood levels on the creeks with and without development has shown that urbanisation will result in only a minor increase in flood levels downstream of the boundary (up to 200mm). This increase in flood levels is associated with the removal of the steep existing dam embankment slope (which has existing supercritical flows). It is noted that the flood levels are returned back to existing where the flowpath crosses the Warragamba Pipelines and are located within the downstream riparian corridor and where no development is located. The developed case is therefore considered to be an improvement upon existing conditions.

The proposed Water Cycle and Flood Management Strategy for the developed site provides a basis for the detailed design and development of the site to ensure that the environmental, urban amenity, engineering and economic objectives for stormwater management and site discharge are achieved.

The Water Cycle Management Strategy proposed for Sydney Science Park is functional; delivers the required technical performance; lessens environmental degradation and pressure on downstream ecosystems and infrastructure; and provides for a 'soft' sustainable solution for stormwater management within the release area.

# 15 REFERENCES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# 16 GLOSSARY OF TERMS

**12D Model** is a powerful terrain modelling, surveying and civil engineering software package used to develop the underlying surface for the 2D modelling.

**Airborne Laser Survey (ALS)** is a technique for obtaining a definition of the surface elevation (ground, buildings, power lines, trees, etc.) by pulsing a laser beam at the ground from an airborne vehicle (generally a plane) and measuring the time taken for the laser beam to return to a scanning device fixed to the plane. The time taken is a measure of the distance which, when ground truthed, is generally accurate to + 150mm.

**Annual Exceedance Probability (AEP)** means the probability that a given rainfall total over a given duration will be exceeded in any one year.

**Average Recurrence Interval (ARI)** means the average statistical interval (in years) between occurrences of floods, storms and flows of a particular magnitude. This has recently been replaced by the AEP (see above).

**Australian Rainfall and Runoff (AR&R)** refers to the current edition of Australian Rainfall and Runoff published by the Institution of Engineers, Australia.

**CatchmentSIM** is a 3D-GIS application specifically tailored to hydrology based applications. CatchmentSIM is used to delineate a catchment, break it up into sub catchments, determine their areas and spatial topographic attributes and analyse each sub catchment's hydrologic characteristics to provide insight into the rainfall response of various catchments and the resultant assignment of hydrologic modelling parameters.

**Council** refers to Penrith City Council

**DECCW** refers to the NSW Department of Environment, Climate Change and Water

**Digital Terrain Model (DTM)** is a spatially referenced three-dimensional (3D) representation of the ground surface represented as discrete point elevations where each cell in the grid represents an elevation above an established datum.

**Floodplain Development Manual (FDM)** and Guidelines (April 2005), the FDM is a document issued by DECCW that provides a strategic approach to floodplain management. The guidelines have been issued by the NSW DoP to clarify issues regarding the setting of FPL's.

**Hydrograph** is a graph that shows how the stormwater discharge changes with time at any particular location.

**Hydrology** The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

**J. Wyndham Prince Pty Ltd (JWP)** Consultant Civil Infrastructure Engineers and Project Managers undertaking these investigations

**MUSIC** is a modelling package designed to help urban stormwater professionals visualise possible strategies to tackle urban stormwater hydrology and pollution impacts. MUSIC stands for Model for Urban Stormwater Improvement Conceptualisation and has been developed by Cooperative Research Centre (CRC),

**OHN** refers to the Office of the Hawkesbury and the Nepean

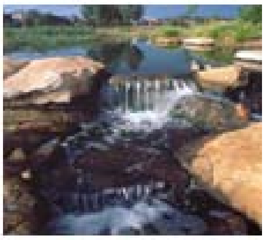
**Peak Discharge** is the maximum stormwater runoff that occurs during a flood event

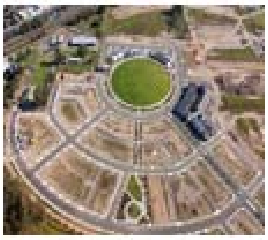
**Probable Maximum Flood (PMF)** is the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends." largest flood that could be

**Triangular Irregular Network (TIN)** is a technique used in the created DTM by developing a mass of interconnected triangles. For each triangle, the ground level is defined at each of the three vertices, thereby defining a plane surface over the area of the triangle

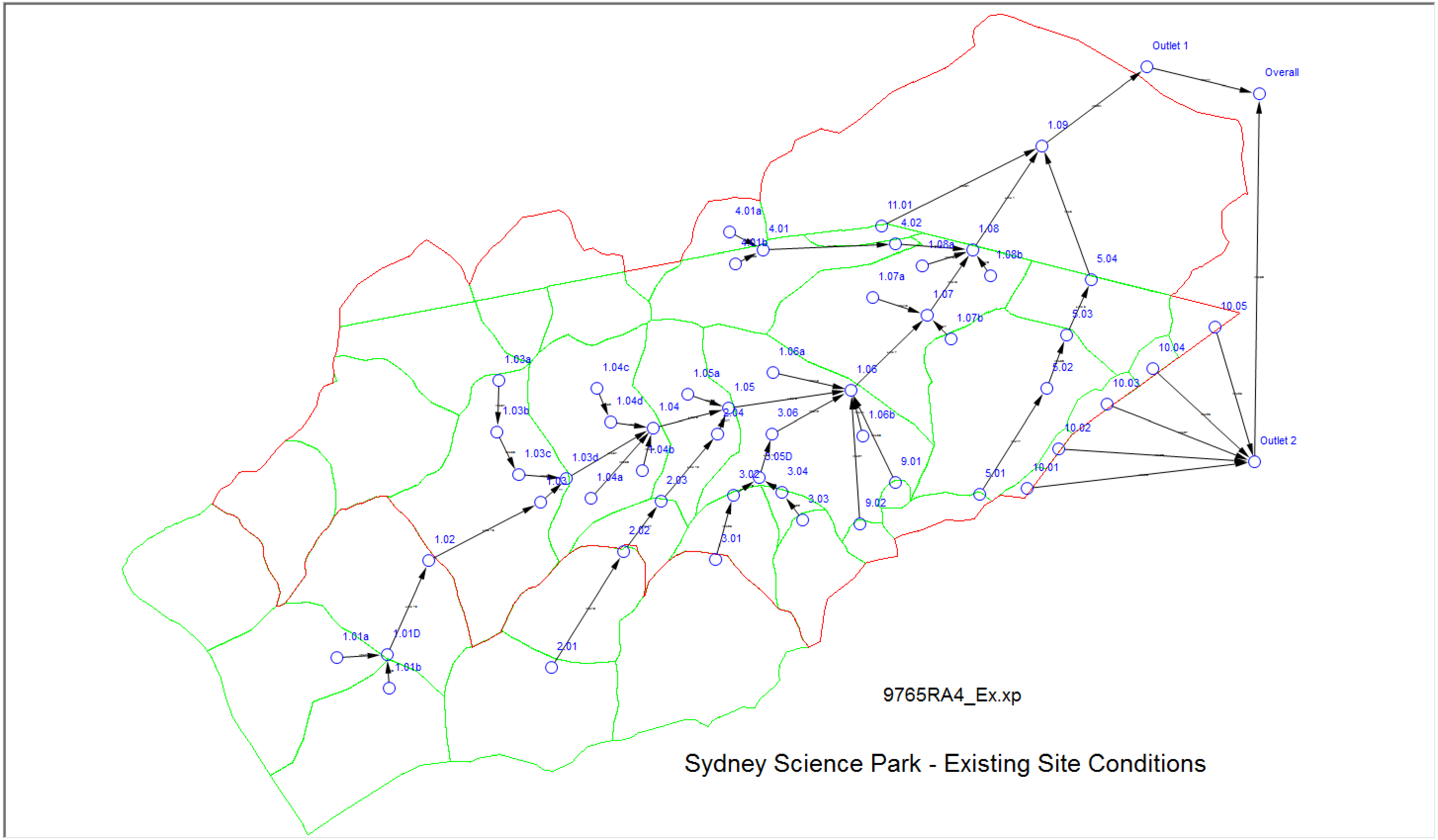
**TUFLOW** is a computer program that provides two-dimensional (2D) and one-dimensional (1D) solutions of the free surface flow equations to simulate flood and tidal wave propagation. It is specifically beneficial where the hydrodynamic behaviour, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be awkward to represent using traditional 1D network models.

**XP-RAFTS** runoff routing model that uses the Laurenson non-linear runoff routing procedure to develop a sub catchment stormwater runoff hydrograph from either an actual event (recorded rainfall time series) or a design storm utilising Intensity-Frequency-Duration data together with dimensionless storm temporal patterns as well as standard AR&R 1987 data.



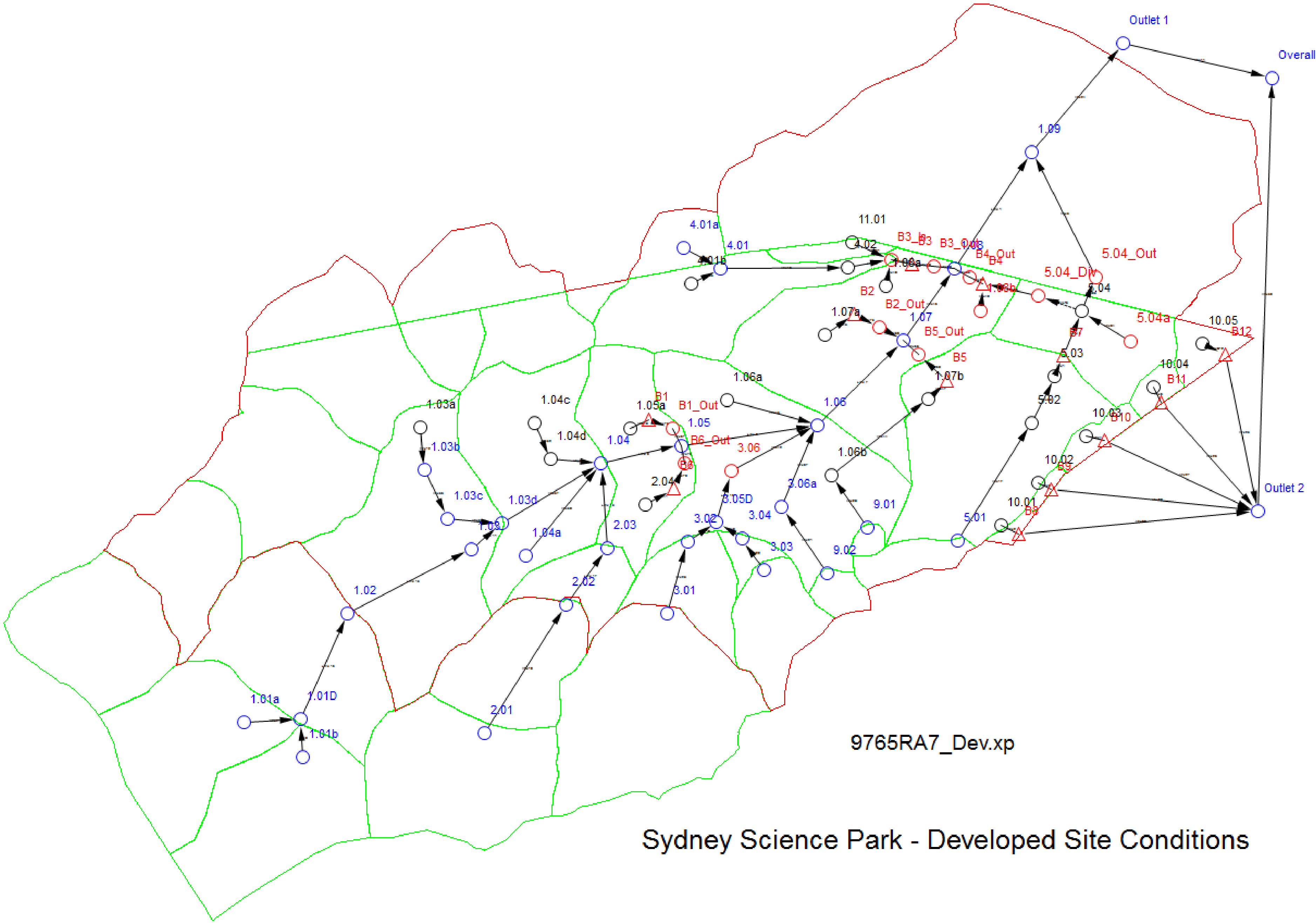


# APPENDIX A – HYDROLOGIC MODELLING INFORMATION




Sydney Science Park - Existing Site Conditions

| XP-RAFTS MODEL - EXISTING CONDITIONS | | | | | |
|---|---|---|---|---|---|
| Node | Total Area | Pervious Area | Impervious Area | Percentage of Impervious | Slope |
| | (ha) | (ha) | (ha) | (%) | (%) |
| 1.01a | 40.5 | 2.9 | 0 | 0 | 3.2 |
| 1.01b | 43.4 | 4.4 | 0 | 0 | 3.2 |
| 1.02 | 40.4 | 8.0 | 0 | 0 | 3.1 |
| 1.03 | 44.8 | 1.9 | 0 | 0 | 2.2 |
| 1.03a | 1.7 | 0.6 | 0 | 0 | 5.0 |
| 1.03b | 6.8 | 2.7 | 0 | 0 | 4.1 |
| 1.03c | 1.9 | 17.3 | 0 | 0 | 4.3 |
| 1.03d | 11.4 | 3.4 | 0 | 0 | 0.5 |
| 1.04 | 6.7 | 6.8 | 0 | 0 | 0.5 |
| 1.04a | 8.0 | 6.1 | 0 | 0 | 5.5 |
| 1.04b | 2.5 | 9.2 | 0 | 0 | 1.0 |
| 1.04c | 19.1 | 0.3 | 0 | 0 | 3.2 |
| 1.04d | 16.8 | 16.5 | 0 | 0 | 2.9 |
| 1.05 | 4.4 | 1.7 | 0 | 0 | 0.5 |
| 1.05a | 19.8 | 1.7 | 0 | 0 | 2.9 |
| 1.06 | 10.1 | 44.8 | 0 | 0 | 0.5 |
| 1.06a | 17.8 | 2.1 | 0 | 0 | 3.6 |
| 1.06b | 28.5 | 1.9 | 0 | 0 | 2.1 |
| 1.07 | 11.6 | 2.0 | 0 | 0 | 0.5 |
| 1.07a | 11.4 | 2.1 | 0 | 0 | 4.1 |
| 1.07b | 17.2 | 5.9 | 0 | 0 | 2.0 |
| 1.08 | 8.3 | 40.5 | 0 | 0 | 0.5 |
| 1.08a | 7.2 | 0.2 | 0 | 0 | 3.1 |
| 1.08b | 18.2 | 0.1 | 0 | 0 | 2.1 |
| 1.09 | 125.8 | 2.1 | 0 | 0 | 2.5 |
| 2.01 | 46.0 | 2.5 | 0 | 0 | 3.2 |
| 2.02 | 29.7 | 8.4 | 0 | 0 | 4.2 |
| 2.03 | 13.0 | 8.3 | 0 | 0 | 3.0 |
| 2.04 | 7.0 | 8.7 | 0 | 0 | 1.0 |
| 3.01 | 61.8 | 4.8 | 0 | 0 | 2.8 |
| 3.02 | 16.7 | 11.4 | 0 | 0 | 2.4 |
| 3.03 | 17.9 | 7.8 | 0 | 0 | 3.8 |
| 3.04 | 3.6 | 8.3 | 0 | 0 | 2.3 |
| 3.06 | 17.2 | 2.7 | 0 | 0 | 2.4 |
| 4.01 | 3.4 | 0.9 | 0 | 0 | 1.2 |
| 4.01a | 6.1 | 2.2 | 0 | 0 | 4.4 |
| 4.01b | 16.0 | 5.8 | 0 | 0 | 2.6 |
| 4.02 | 16.6 | 43.4 | 0 | 0 | 2.3 |
| 5.01 | 8.7 | 2.3 | 0 | 0 | 2.9 |
| 5.02 | 27.4 | 0.4 | 0 | 0 | 1.6 |
| 5.03 | 21.5 | 40.4 | 0 | 0 | 1.9 |
| 5.04 | 25.9 | 7.5 | 0 | 0 | 2.0 |
| 9.01 | 2.0 | 1.3 | 0 | 0 | 4.6 |
| 9.02 | 4.3 | 1.9 | 0 | 0 | 3.5 |
| 10.01 | 1.4 | 125.8 | 0 | 0 | 3.5 |
| 10.02 | 1.3 | 46.0 | 0 | 0 | 2.0 |
| 10.03 | 4.4 | 29.7 | 0 | 0 | 3.2 |
| 10.04 | 3.4 | 13.1 | 0 | 0 | 3.2 |
| 10.05 | 5.8 | 1.0 | 0 | 0 | 3.6 |
| 11.01 | 1.0 | 61.8 | 0 | 0 | 1.4 |




Sydney Science Park - Developed Site Conditions

| XP-RAFTS MODEL - DEVELOPED CONDITIONS | | | | | |
|---|---|---|---|---|---|
| Node | Total Area | Pervious Area | Impervious Area | Percentage of Impervious | Slope |
| | (ha) | (ha) | (ha) | (%) | (%) |
| 1.01a | 40.5 | 40.5 | 0.0 | 0 | 3.2 |
| 1.01b | 43.4 | 43.4 | 0.0 | 0 | 3.2 |
| 1.02 | 40.4 | 40.4 | 0.0 | 0 | 3.1 |
| 1.03 | 44.8 | 44.8 | 0.0 | 0 | 2.2 |
| 1.03a | 1.7 | 1.7 | 0.0 | 0 | 5 |
| 1.03b | 6.8 | 6.8 | 0.0 | 0 | 4.1 |
| 1.03c | 1.9 | 1.9 | 0.0 | 0 | 4.3 |
| 1.03d | 11.4 | 11.4 | 0.0 | 0 | 0.5 |
| 1.04 | 8.3 | 8.3 | 0.0 | 0 | 0.5 |
| 1.04a | 8.0 | 8.0 | 0.0 | 0 | 5.5 |
| 1.04c | 19.1 | 2.9 | 16.2 | 85 | 3.2 |
| 1.04d | 16.8 | 2.5 | 14.3 | 85 | 2.9 |
| 1.05a | 19.8 | 7.5 | 12.3 | 62 | 2.9 |
| 1.05 | 4.4 | 4.4 | 0.0 | 0 | 0.5 |
| 1.06 | 8.3 | 8.3 | 0.0 | 0 | 0.5 |
| 1.06a | 9.2 | 0.9 | 8.3 | 90 | 3.6 |
| 1.06b | 13.5 | 2.3 | 11.2 | 83 | 2.1 |
| 1.07 | 8.4 | 8.4 | 0.0 | 0 | 0.5 |
| 1.07a | 12.9 | 1.3 | 11.6 | 90 | 4.1 |
| 1.07b | 19.2 | 1.9 | 17.2 | 90 | 2 |
| 1.08 | 7.8 | 7.8 | 0.0 | 0 | 0.5 |
| 1.08a | 16.5 | 4.8 | 11.8 | 71 | 3.1 |
| 1.08b | 21.2 | 2.1 | 19.1 | 90 | 2.1 |
| 1.09 | 125.8 | 125.8 | 0.0 | 0 | 2.5 |
| 2.01 | 46.0 | 46.0 | 0.0 | 0 | 3.2 |
| 2.02 | 29.7 | 29.7 | 0.0 | 0 | 4.2 |
| 2.03 | 13.1 | 13.1 | 0.0 | 0 | 3 |
| 2.04 | 9.6 | 1.0 | 8.6 | 90 | 1 |
| 3.01 | 61.8 | 61.8 | 0.0 | 0 | 2.8 |
| 3.02 | 16.5 | 16.5 | 0.0 | 0 | 2.4 |
| 3.03 | 17.3 | 17.3 | 0.0 | 0 | 3.8 |
| 3.04 | 2.2 | 2.2 | 0.0 | 0 | 2.3 |
| 3.06 | 5.8 | 5.8 | 0.0 | 0 | 2.4 |
| 3.06a | 20.7 | 2.7 | 18.0 | 87 | 2.4 |
| 4.01 | 3.4 | 3.4 | 0.0 | 0 | 1.2 |
| 4.01a | 6.1 | 6.1 | 0.0 | 0 | 4.4 |
| 4.01b | 16.0 | 9.2 | 6.9 | 43 | 2.6 |
| 4.02 | 16.6 | 1.7 | 14.9 | 90 | 2.3 |
| 5.01 | 8.7 | 8.7 | 0.0 | 0 | 2.9 |
| 5.02 | 27.4 | 2.7 | 24.7 | 90 | 1.6 |
| 5.03 | 20.6 | 2.1 | 18.5 | 90 | 1.9 |
| 5.04 | 12.6 | 1.9 | 10.7 | 85 | 1.5 |
| 5.04a | 14.3 | 2.1 | 12.1 | 85 | 2 |
| 9.01 | 2.0 | 2.0 | 0.0 | 0 | 4.6 |
| 9.02 | 5.9 | 5.9 | 0.0 | 0 | 3.5 |
| 10.01 | 1.4 | 0.1 | 1.3 | 90 | 3.5 |
| 10.02 | 1.9 | 0.2 | 1.7 | 90 | 2 |
| 10.03 | 3.7 | 0.4 | 3.4 | 90 | 3.2 |
| 10.04 | 3.4 | 0.3 | 3.1 | 90 | 3.2 |
| 10.05 | 5.8 | 0.6 | 5.3 | 90 | 3.6 |
| 11.01 | 4.0 | 0.4 | 3.6 | 90 | 1.4 |

| Existing Condition Discharges - 50% AEP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Node | Storm Duration | | | | | | | | | | |
| | 15 min | 25 min | 60 min | 90 min | 120 min | 180 min | 360 min | 540 min | 720 min | 1080 min | 1440 min |
| 1.01a | 0.00 | 0.17 | 0.77 | 1.03 | 1.18 | 1.25 | 1.46 | 1.83 | 1.69 | 1.17 | 1.34 |
| 1.01b | 0.00 | 0.18 | 0.80 | 1.09 | 1.23 | 1.33 | 1.55 | 1.96 | 1.80 | 1.24 | 1.42 |
| 1.01D | 0.01 | 0.35 | 1.57 | 2.12 | 2.42 | 2.59 | 3.01 | 3.79 | 3.50 | 2.41 | 2.76 |
| 1.02 | 0.01 | 0.51 | 2.32 | 3.12 | 3.56 | 3.82 | 4.44 | 5.53 | 5.09 | 3.55 | 4.08 |
| 1.03 | 0.02 | 0.65 | 2.96 | 4.02 | 4.63 | 5.02 | 5.80 | 7.22 | 6.55 | 4.58 | 5.44 |
| 1.03a | 0.00 | 0.02 | 0.09 | 0.09 | 0.10 | 0.09 | 0.11 | 0.11 | 0.11 | 0.07 | 0.07 |
| 1.03b | 0.00 | 0.07 | 0.32 | 0.36 | 0.40 | 0.37 | 0.43 | 0.46 | 0.48 | 0.34 | 0.33 |
| 1.03c | 0.00 | 0.10 | 0.40 | 0.44 | 0.49 | 0.46 | 0.53 | 0.56 | 0.60 | 0.42 | 0.40 |
| 1.03d | 0.02 | 0.76 | 3.27 | 4.39 | 5.05 | 5.47 | 6.32 | 7.91 | 7.16 | 5.02 | 6.03 |
| 1.04 | 0.03 | 1.03 | 4.20 | 5.51 | 6.33 | 6.86 | 7.99 | 9.87 | 8.85 | 6.25 | 7.67 |
| 1.04a | 0.00 | 0.07 | 0.31 | 0.36 | 0.39 | 0.37 | 0.42 | 0.44 | 0.47 | 0.33 | 0.31 |
| 1.04b | 0.00 | 0.01 | 0.04 | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.11 | 0.07 | 0.08 |
| 1.04c | 0.00 | 0.10 | 0.45 | 0.59 | 0.67 | 0.67 | 0.80 | 0.93 | 0.90 | 0.65 | 0.67 |
| 1.04d | 0.00 | 0.18 | 0.82 | 1.10 | 1.25 | 1.24 | 1.50 | 1.74 | 1.68 | 1.21 | 1.27 |
| 1.05 | 0.04 | 1.56 | 6.55 | 8.59 | 9.73 | 10.48 | 12.16 | 15.08 | 13.34 | 9.48 | 11.51 |
| 1.05a | 0.00 | 0.10 | 0.43 | 0.57 | 0.66 | 0.66 | 0.79 | 0.94 | 0.90 | 0.64 | 0.69 |
| 1.06 | 0.06 | 2.27 | 9.48 | 12.51 | 14.33 | 15.39 | 17.80 | 22.22 | 19.67 | 13.88 | 17.02 |
| 1.06a | 0.00 | 0.11 | 0.46 | 0.59 | 0.66 | 0.66 | 0.80 | 0.88 | 0.88 | 0.63 | 0.65 |
| 1.06b | 0.00 | 0.10 | 0.44 | 0.63 | 0.74 | 0.82 | 0.92 | 1.19 | 1.07 | 0.72 | 0.89 |
| 1.07 | 0.05 | 2.40 | 9.99 | 13.18 | 15.13 | 16.27 | 18.82 | 23.51 | 20.65 | 14.65 | 18.14 |
| 1.07a | 0.00 | 0.08 | 0.34 | 0.43 | 0.48 | 0.46 | 0.56 | 0.58 | 0.61 | 0.44 | 0.43 |
| 1.07b | 0.00 | 0.06 | 0.29 | 0.42 | 0.49 | 0.52 | 0.60 | 0.76 | 0.70 | 0.48 | 0.56 |
| 1.08 | 0.05 | 2.69 | 11.02 | 14.50 | 16.67 | 18.00 | 20.85 | 25.98 | 22.53 | 16.15 | 20.31 |
| 1.08a | 0.00 | 0.04 | 0.21 | 0.25 | 0.28 | 0.28 | 0.34 | 0.36 | 0.37 | 0.27 | 0.27 |
| 1.08b | 0.00 | 0.06 | 0.31 | 0.45 | 0.53 | 0.55 | 0.64 | 0.81 | 0.74 | 0.52 | 0.60 |
| 1.09 | 0.05 | 3.24 | 13.51 | 17.99 | 20.96 | 23.01 | 26.60 | 32.81 | 28.00 | 20.29 | 26.41 |
| 2.01 | 0.00 | 0.18 | 0.83 | 1.14 | 1.29 | 1.40 | 1.63 | 2.05 | 1.90 | 1.29 | 1.50 |
| 2.02 | 0.01 | 0.34 | 1.56 | 2.02 | 2.29 | 2.35 | 2.84 | 3.45 | 3.24 | 2.27 | 2.54 |
| 2.03 | 0.01 | 0.41 | 1.86 | 2.41 | 2.72 | 2.78 | 3.38 | 4.06 | 3.80 | 2.68 | 2.99 |
| 2.04 | 0.01 | 0.43 | 1.96 | 2.56 | 2.88 | 2.96 | 3.59 | 4.33 | 4.03 | 2.84 | 3.20 |
| 3.01 | 0.01 | 0.20 | 0.92 | 1.32 | 1.55 | 1.74 | 1.97 | 2.52 | 2.26 | 1.49 | 1.91 |
| 3.02 | 0.01 | 0.27 | 1.24 | 1.74 | 2.00 | 2.22 | 2.56 | 3.25 | 2.95 | 1.99 | 2.46 |
| 3.03 | 0.00 | 0.11 | 0.49 | 0.60 | 0.67 | 0.67 | 0.82 | 0.89 | 0.89 | 0.65 | 0.65 |
| 3.04 | 0.00 | 0.13 | 0.60 | 0.73 | 0.81 | 0.81 | 0.99 | 1.07 | 1.08 | 0.78 | 0.79 |
| 3.05D | 0.01 | 0.40 | 1.82 | 2.41 | 2.76 | 2.87 | 3.42 | 4.29 | 3.99 | 2.74 | 3.24 |
| 3.06 | 0.01 | 0.47 | 2.15 | 2.86 | 3.28 | 3.38 | 4.06 | 5.04 | 4.68 | 3.24 | 3.81 |
| 4.01 | 0.00 | 0.13 | 0.62 | 0.78 | 0.89 | 0.88 | 1.07 | 1.22 | 1.21 | 0.87 | 0.91 |
| 4.01a | 0.00 | 0.05 | 0.23 | 0.26 | 0.29 | 0.26 | 0.31 | 0.32 | 0.34 | 0.25 | 0.23 |
| 4.01b | 0.00 | 0.07 | 0.34 | 0.46 | 0.53 | 0.52 | 0.64 | 0.76 | 0.72 | 0.52 | 0.56 |
| 4.02 | 0.01 | 0.20 | 0.92 | 1.22 | 1.39 | 1.39 | 1.69 | 1.96 | 1.88 | 1.35 | 1.46 |
| 5.01 | 0.00 | 0.05 | 0.23 | 0.29 | 0.33 | 0.32 | 0.40 | 0.43 | 0.43 | 0.31 | 0.32 |
| 5.02 | 0.00 | 0.12 | 0.58 | 0.81 | 0.91 | 0.99 | 1.13 | 1.48 | 1.34 | 0.91 | 1.11 |
| 5.03 | 0.01 | 0.18 | 0.91 | 1.30 | 1.47 | 1.59 | 1.83 | 2.37 | 2.12 | 1.46 | 1.79 |
| 5.04 | 0.01 | 0.27 | 1.30 | 1.87 | 2.13 | 2.32 | 2.67 | 3.43 | 3.05 | 2.10 | 2.60 |
| 9.01 | 0.00 | 0.03 | 0.10 | 0.11 | 0.11 | 0.10 | 0.12 | 0.12 | 0.13 | 0.09 | 0.08 |
| 9.02 | 0.00 | 0.03 | 0.16 | 0.18 | 0.20 | 0.19 | 0.22 | 0.23 | 0.24 | 0.17 | 0.17 |
| 10.01 | 0.00 | 0.02 | 0.06 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.09 | 0.06 | 0.06 |
| 10.02 | 0.00 | 0.01 | 0.04 | 0.05 | 0.05 | 0.05 | 0.06 | 0.07 | 0.07 | 0.05 | 0.05 |
| 10.03 | 0.00 | 0.03 | 0.15 | 0.17 | 0.19 | 0.18 | 0.22 | 0.23 | 0.24 | 0.17 | 0.17 |
| 10.04 | 0.00 | 0.03 | 0.13 | 0.14 | 0.16 | 0.15 | 0.17 | 0.18 | 0.19 | 0.14 | 0.13 |
| 10.05 | 0.00 | 0.04 | 0.20 | 0.23 | 0.25 | 0.24 | 0.29 | 0.31 | 0.32 | 0.23 | 0.22 |
| 11.01 | 0.00 | 0.01 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 |
| Outlet 1 | 0.01 | 3.24 | 13.51 | 17.99 | 20.96 | 23.01 | 26.60 | 32.81 | 28.00 | 20.29 | 26.41 |
| Outlet 2 | 0.00 | 0.13 | 0.58 | 0.66 | 0.73 | 0.69 | 0.82 | 0.86 | 0.90 | 0.65 | 0.63 |
| Overall | 0.05 | 3.31 | 13.64 | 18.15 | 21.16 | 23.31 | 26.92 | 33.15 | 28.20 | 20.50 | 26.83 |

| Existing Condition Discharges - 1% AEP | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Node** | **Storm Duration** | | | | | | | | | |
| | **15 min** | **25 min** | **60 min** | **90 min** | **120 min** | **180 min** | **360 min** | **720 min** | **1080 min** | **1440 min** |
| 1.01a | 1.38 | 2.44 | 4.60 | 4.94 | 5.17 | 4.70 | 4.80 | 4.38 | 3.41 | 3.48 |
| 1.01b | 1.45 | 2.57 | 4.87 | 5.22 | 5.44 | 5.00 | 5.12 | 4.68 | 3.63 | 3.72 |
| 1.01D | 2.83 | 5.01 | 9.48 | 10.16 | 10.61 | 9.71 | 9.91 | 9.07 | 7.04 | 7.20 |
| 1.02 | 4.18 | 7.38 | 13.88 | 14.85 | 15.57 | 14.30 | 14.64 | 13.11 | 10.25 | 10.60 |
| 1.03 | 5.32 | 9.43 | 17.67 | 19.28 | 20.37 | 18.79 | 19.27 | 16.94 | 13.36 | 14.15 |
| 1.03a | 0.21 | 0.33 | 0.42 | 0.43 | 0.48 | 0.35 | 0.28 | 0.24 | 0.17 | 0.16 |
| 1.03b | 0.70 | 1.17 | 1.67 | 1.66 | 1.77 | 1.36 | 1.28 | 1.13 | 0.82 | 0.79 |
| 1.03c | 0.90 | 1.49 | 2.06 | 2.05 | 2.21 | 1.69 | 1.57 | 1.39 | 1.00 | 0.97 |
| 1.03d | 6.11 | 10.44 | 18.98 | 20.87 | 22.11 | 20.54 | 21.15 | 18.53 | 14.67 | 15.73 |
| 1.04 | 8.06 | 13.33 | 22.95 | 25.38 | 26.90 | 25.33 | 26.32 | 22.76 | 18.18 | 19.81 |
| 1.04a | 0.67 | 1.16 | 1.61 | 1.61 | 1.71 | 1.30 | 1.22 | 1.08 | 0.77 | 0.75 |
| 1.04b | 0.09 | 0.16 | 0.29 | 0.31 | 0.32 | 0.29 | 0.30 | 0.27 | 0.21 | 0.22 |
| 1.04c | 0.80 | 1.48 | 2.59 | 2.65 | 2.77 | 2.43 | 2.42 | 2.25 | 1.74 | 1.72 |
| 1.04d | 1.50 | 2.74 | 4.84 | 4.95 | 5.17 | 4.56 | 4.54 | 4.22 | 3.25 | 3.23 |
| 1.05 | 12.41 | 20.57 | 35.86 | 38.53 | 40.45 | 37.77 | 39.77 | 34.83 | 27.80 | 29.75 |
| 1.05a | 0.77 | 1.41 | 2.55 | 2.64 | 2.76 | 2.46 | 2.45 | 2.28 | 1.77 | 1.77 |
| 1.06 | 17.72 | 29.47 | 52.19 | 56.38 | 59.22 | 55.04 | 58.38 | 51.00 | 41.06 | 44.13 |
| 1.06a | 0.83 | 1.53 | 2.59 | 2.59 | 2.70 | 2.32 | 2.33 | 2.16 | 1.65 | 1.63 |
| 1.06b | 0.78 | 1.44 | 2.84 | 3.06 | 3.23 | 3.03 | 3.21 | 2.89 | 2.29 | 2.38 |
| 1.07 | 16.67 | 30.71 | 54.43 | 59.27 | 62.38 | 58.23 | 61.58 | 53.73 | 43.38 | 47.05 |
| 1.07a | 0.69 | 1.23 | 1.92 | 1.91 | 1.96 | 1.56 | 1.60 | 1.45 | 1.09 | 1.06 |
| 1.07b | 0.56 | 0.97 | 1.90 | 2.06 | 2.13 | 1.96 | 2.03 | 1.86 | 1.44 | 1.48 |
| 1.08 | 18.03 | 33.18 | 58.57 | 64.68 | 68.25 | 64.28 | 67.54 | 58.57 | 47.57 | 52.55 |
| 1.08a | 0.40 | 0.74 | 1.17 | 1.17 | 1.19 | 0.97 | 1.00 | 0.91 | 0.68 | 0.66 |
| 1.08b | 0.60 | 1.07 | 2.04 | 2.18 | 2.26 | 2.09 | 2.14 | 1.99 | 1.53 | 1.57 |
| 1.09 | 17.50 | 39.85 | 70.69 | 80.40 | 85.75 | 81.86 | 84.81 | 71.69 | 59.42 | 68.04 |
| 2.01 | 1.51 | 2.67 | 5.09 | 5.45 | 5.68 | 5.24 | 5.39 | 4.95 | 3.82 | 3.93 |
| 2.02 | 2.87 | 5.05 | 8.91 | 9.31 | 9.69 | 8.82 | 8.97 | 8.19 | 6.36 | 6.53 |
| 2.03 | 3.48 | 6.11 | 10.55 | 10.97 | 11.42 | 10.34 | 10.54 | 9.53 | 7.48 | 7.65 |
| 2.04 | 3.66 | 6.42 | 11.20 | 11.68 | 12.17 | 11.06 | 11.30 | 10.19 | 7.99 | 8.22 |
| 3.01 | 1.67 | 2.93 | 5.94 | 6.46 | 6.85 | 6.46 | 6.88 | 6.19 | 4.87 | 5.10 |
| 3.02 | 2.29 | 4.03 | 7.74 | 8.38 | 8.74 | 8.24 | 8.71 | 7.92 | 6.23 | 6.53 |
| 3.03 | 0.89 | 1.58 | 2.65 | 2.65 | 2.75 | 2.34 | 2.37 | 2.19 | 1.67 | 1.64 |
| 3.04 | 1.09 | 1.95 | 3.22 | 3.19 | 3.30 | 2.81 | 2.85 | 2.61 | 1.99 | 1.96 |
| 3.05D | 3.38 | 5.96 | 10.64 | 11.18 | 11.70 | 10.73 | 11.27 | 10.43 | 8.14 | 8.45 |
| 3.06 | 4.01 | 7.08 | 12.67 | 13.26 | 13.85 | 12.70 | 13.25 | 12.15 | 9.52 | 9.91 |
| 4.01 | 1.24 | 2.17 | 3.51 | 3.47 | 3.58 | 3.17 | 3.20 | 3.03 | 2.30 | 2.29 |
| 4.01a | 0.48 | 0.83 | 1.18 | 1.18 | 1.24 | 0.95 | 0.91 | 0.81 | 0.58 | 0.57 |
| 4.01b | 0.64 | 1.13 | 2.07 | 2.13 | 2.23 | 2.01 | 1.98 | 1.85 | 1.42 | 1.43 |
| 4.02 | 1.85 | 3.23 | 5.49 | 5.56 | 5.75 | 5.10 | 5.20 | 4.69 | 3.63 | 3.69 |
| 5.01 | 0.45 | 0.79 | 1.33 | 1.32 | 1.36 | 1.14 | 1.16 | 1.07 | 0.81 | 0.80 |
| 5.02 | 1.10 | 1.95 | 3.64 | 3.81 | 3.98 | 3.69 | 3.93 | 3.61 | 2.87 | 2.99 |
| 5.03 | 1.72 | 3.05 | 5.83 | 6.17 | 6.43 | 6.01 | 6.34 | 5.78 | 4.56 | 4.78 |
| 5.04 | 2.44 | 4.36 | 8.39 | 8.94 | 9.37 | 8.76 | 9.19 | 8.28 | 6.58 | 6.92 |
| 9.01 | 0.23 | 0.37 | 0.48 | 0.48 | 0.53 | 0.40 | 0.32 | 0.28 | 0.20 | 0.19 |
| 9.02 | 0.30 | 0.58 | 0.81 | 0.81 | 0.85 | 0.66 | 0.65 | 0.58 | 0.42 | 0.40 |
| 10.01 | 0.15 | 0.24 | 0.32 | 0.31 | 0.34 | 0.26 | 0.22 | 0.20 | 0.14 | 0.13 |
| 10.02 | 0.10 | 0.17 | 0.23 | 0.23 | 0.24 | 0.19 | 0.19 | 0.17 | 0.12 | 0.12 |
| 10.03 | 0.29 | 0.55 | 0.79 | 0.79 | 0.81 | 0.64 | 0.64 | 0.57 | 0.42 | 0.41 |
| 10.04 | 0.25 | 0.45 | 0.64 | 0.64 | 0.67 | 0.51 | 0.51 | 0.45 | 0.33 | 0.32 |
| 10.05 | 0.38 | 0.71 | 1.05 | 1.05 | 1.09 | 0.85 | 0.85 | 0.76 | 0.56 | 0.54 |
| 11.01 | 0.05 | 0.11 | 0.17 | 0.17 | 0.17 | 0.14 | 0.14 | 0.13 | 0.10 | 0.09 |
| Outlet 1 | 17.50 | 39.85 | 70.69 | 80.40 | 85.75 | 81.86 | 84.81 | 71.69 | 59.42 | 68.04 |
| Outlet 2 | 1.16 | 2.12 | 3.01 | 3.00 | 3.14 | 2.43 | 2.41 | 2.15 | 1.57 | 1.52 |
| Overall | 17.84 | 40.00 | 70.96 | 80.95 | 86.55 | 82.88 | 85.74 | 72.14 | 59.99 | 69.09 |

| Existing Condition Discharges - PMP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Node | Storm Duration | | | | | | | | | | |
| | 15 min | 30 min | 45 min | 60 min | 90 min | 120 min | 150 min | 180 min | 240 min | 300 min | 360 min |
| 1.01a | 34.51 | 57.67 | 74.23 | 82.94 | 91.49 | 90.77 | 84.64 | 80.67 | 73.89 | 67.27 | 61.92 |
| 1.01b | 36.59 | 60.75 | 78.26 | 87.64 | 97.10 | 96.73 | 90.18 | 86.02 | 78.86 | 71.83 | 66.05 |
| 1.01D | 71.10 | 118.42 | 152.49 | 170.57 | 188.59 | 187.52 | 174.82 | 166.70 | 152.75 | 139.09 | 127.96 |
| 1.02 | 103.12 | 169.98 | 216.78 | 245.90 | 268.87 | 266.68 | 256.06 | 243.63 | 221.75 | 204.84 | 188.42 |
| 1.03 | 128.91 | 210.83 | 269.33 | 307.95 | 335.62 | 339.92 | 326.19 | 311.88 | 292.69 | 270.38 | 251.43 |
| 1.03a | 4.76 | 6.25 | 6.48 | 6.26 | 5.66 | 5.22 | 4.83 | 4.54 | 4.06 | 3.63 | 3.24 |
| 1.03b | 16.37 | 23.50 | 26.39 | 27.07 | 25.40 | 23.80 | 21.71 | 20.28 | 18.30 | 16.87 | 15.42 |
| 1.03c | 20.11 | 28.61 | 32.38 | 33.13 | 31.11 | 28.97 | 26.44 | 24.72 | 22.37 | 20.62 | 18.88 |
| 1.03d | 135.87 | 221.95 | 285.36 | 328.01 | 359.80 | 367.80 | 353.62 | 341.80 | 323.54 | 299.74 | 279.62 |
| 1.04a | 15.89 | 22.72 | 25.84 | 26.04 | 24.27 | 22.44 | 20.47 | 19.24 | 17.66 | 16.16 | 14.71 |
| 1.04b | 2.38 | 3.80 | 4.90 | 5.45 | 5.92 | 5.75 | 5.38 | 5.12 | 4.64 | 4.23 | 3.89 |
| 1.04c | 21.16 | 33.39 | 41.77 | 46.02 | 47.98 | 45.80 | 42.98 | 40.53 | 36.34 | 33.30 | 30.90 |
| 1.04d | 39.31 | 62.08 | 77.74 | 86.10 | 89.86 | 85.87 | 80.41 | 75.95 | 68.19 | 62.51 | 57.97 |
| 1.04 | 151.76 | 243.07 | 315.02 | 362.90 | 404.60 | 419.96 | 410.59 | 405.11 | 388.48 | 368.29 | 343.75 |
| 1.05a | 20.43 | 32.27 | 41.05 | 45.34 | 48.28 | 46.45 | 43.60 | 41.23 | 37.17 | 33.96 | 31.42 |
| 1.05 | 215.32 | 337.63 | 430.45 | 493.21 | 568.52 | 603.56 | 602.67 | 593.12 | 574.15 | 541.65 | 503.24 |
| 1.06a | 21.71 | 34.03 | 41.68 | 45.86 | 46.35 | 44.01 | 41.06 | 38.56 | 34.49 | 31.77 | 29.58 |
| 1.06b | 20.86 | 34.89 | 45.73 | 52.08 | 58.18 | 59.93 | 56.86 | 53.95 | 50.05 | 45.96 | 42.10 |
| 1.06 | 317.32 | 502.85 | 629.71 | 717.12 | 814.03 | 870.07 | 868.40 | 853.28 | 815.71 | 776.02 | 730.08 |
| 1.07a | 17.26 | 26.05 | 30.81 | 32.86 | 31.58 | 29.93 | 27.56 | 25.61 | 23.27 | 21.67 | 20.06 |
| 1.07b | 14.04 | 23.73 | 30.53 | 34.20 | 38.24 | 38.21 | 35.63 | 33.96 | 31.20 | 28.44 | 26.15 |
| 1.07 | 327.55 | 517.13 | 648.83 | 739.62 | 843.26 | 903.09 | 902.63 | 889.54 | 852.18 | 812.58 | 765.82 |
| 1.08b | 15.15 | 25.28 | 32.60 | 36.54 | 40.79 | 40.55 | 37.83 | 36.10 | 33.06 | 30.11 | 27.70 |
| 1.08a | 10.37 | 15.91 | 19.14 | 20.53 | 19.82 | 18.78 | 17.30 | 16.05 | 14.52 | 13.50 | 12.53 |
| 1.08 | 342.58 | 536.32 | 672.73 | 768.56 | 886.14 | 951.47 | 953.83 | 947.05 | 914.75 | 872.22 | 829.80 |
| 1.09 | 352.62 | 598.32 | 750.18 | 859.50 | 1004.99 | 1085.41 | 1101.61 | 1104.21 | 1088.11 | 1059.31 | 1018.42 |
| 2.01 | 38.33 | 63.26 | 81.72 | 91.66 | 101.85 | 101.76 | 95.01 | 90.58 | 83.23 | 75.80 | 69.69 |
| 2.02 | 68.81 | 109.75 | 136.63 | 153.66 | 164.29 | 166.28 | 157.24 | 148.57 | 136.01 | 124.87 | 115.47 |
| 2.03 | 81.11 | 127.67 | 160.24 | 178.04 | 190.57 | 192.48 | 181.90 | 172.72 | 158.68 | 146.17 | 135.42 |
| 2.04 | 85.43 | 134.85 | 169.72 | 188.58 | 202.48 | 204.47 | 193.57 | 184.57 | 170.12 | 157.00 | 145.59 |
| 3.03 | 22.47 | 35.24 | 42.85 | 46.99 | 47.06 | 44.62 | 41.54 | 38.93 | 34.87 | 32.17 | 29.97 |
| 3.04 | 27.24 | 42.39 | 51.69 | 56.32 | 56.16 | 53.67 | 49.79 | 46.59 | 41.92 | 38.74 | 36.05 |
| 3.01 | 42.70 | 72.22 | 94.62 | 108.96 | 122.14 | 127.05 | 121.42 | 115.23 | 107.28 | 98.89 | 90.36 |
| 3.02 | 57.47 | 93.91 | 121.83 | 138.13 | 155.44 | 158.96 | 152.43 | 146.60 | 135.56 | 124.77 | 114.71 |
| 3.05D | 83.44 | 132.31 | 165.65 | 188.04 | 205.07 | 207.66 | 199.22 | 189.77 | 174.26 | 160.51 | 147.75 |
| 3.06 | 98.07 | 155.54 | 194.59 | 219.89 | 237.62 | 241.42 | 231.51 | 221.62 | 203.57 | 188.03 | 173.46 |
| 4.01a | 11.35 | 16.44 | 19.09 | 19.44 | 18.13 | 16.82 | 15.30 | 14.33 | 13.16 | 12.10 | 11.05 |
| 4.01b | 16.15 | 25.98 | 32.85 | 36.40 | 39.14 | 37.56 | 35.18 | 33.30 | 30.04 | 27.50 | 25.45 |
| 4.01 | 30.35 | 46.57 | 56.20 | 62.63 | 64.31 | 61.45 | 57.27 | 53.70 | 48.18 | 44.54 | 41.55 |
| 4.02 | 44.46 | 69.77 | 85.87 | 95.07 | 97.48 | 96.00 | 90.93 | 85.49 | 78.41 | 72.36 | 67.03 |
| 5.01 | 11.36 | 17.75 | 21.50 | 23.44 | 23.20 | 22.02 | 20.43 | 19.03 | 17.13 | 15.85 | 14.75 |
| 5.02 | 27.90 | 46.17 | 59.44 | 67.45 | 73.31 | 75.28 | 72.14 | 68.46 | 63.09 | 58.06 | 53.40 |
| 5.03 | 43.11 | 71.99 | 92.82 | 105.39 | 115.25 | 118.08 | 113.60 | 108.55 | 100.09 | 92.64 | 85.16 |
| 5.04 | 60.53 | 100.44 | 130.11 | 147.98 | 163.69 | 167.10 | 161.78 | 156.23 | 144.08 | 133.50 | 123.04 |
| 9.01 | 5.16 | 6.97 | 7.43 | 7.23 | 6.59 | 6.05 | 5.59 | 5.28 | 4.76 | 4.28 | 3.83 |
| 9.02 | 7.74 | 11.35 | 13.26 | 13.65 | 12.79 | 11.93 | 10.85 | 10.14 | 9.30 | 8.60 | 7.88 |
| 10.05 | 9.84 | 14.52 | 17.17 | 17.90 | 16.85 | 15.82 | 14.41 | 13.42 | 12.28 | 11.38 | 10.45 |
| 10.04 | 6.07 | 8.99 | 10.44 | 10.73 | 10.04 | 9.37 | 8.52 | 7.98 | 7.32 | 6.75 | 6.18 |
| 10.03 | 7.36 | 10.96 | 12.92 | 13.43 | 12.65 | 11.85 | 10.80 | 10.07 | 9.21 | 8.55 | 7.86 |
| 10.02 | 2.32 | 3.31 | 3.84 | 3.96 | 3.72 | 3.48 | 3.17 | 2.97 | 2.71 | 2.52 | 2.30 |
| 10.01 | 3.38 | 4.65 | 5.05 | 4.93 | 4.53 | 4.13 | 3.79 | 3.58 | 3.26 | 2.95 | 2.66 |
| 11.01 | 1.51 | 2.35 | 2.76 | 2.92 | 2.80 | 2.65 | 2.43 | 2.26 | 2.07 | 1.93 | 1.77 |
| Outlet 1 | 352.62 | 598.32 | 750.18 | 859.50 | 1004.99 | 1085.41 | 1101.61 | 1104.21 | 1088.11 | 1059.31 | 1018.42 |
| Outlet 2 | 28.82 | 42.05 | 49.22 | 50.85 | 47.73 | 44.60 | 40.57 | 37.90 | 34.77 | 32.13 | 29.44 |
| Overall | 353.21 | 598.81 | 750.90 | 860.55 | 1007.19 | 1089.31 | 1106.41 | 1109.71 | 1095.91 | 1067.91 | 1027.92 |

| Developed Condition Discharges - 50% AEP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Node | Storm Duration | | | | | | | | | | |
| | 15 min | 25 min | 60 min | 90 min | 120 min | 180 min | 360 min | 540 min | 720 min | 1080 min | 1440 min |
| 1.01a | 0.00 | 0.17 | 0.77 | 1.03 | 1.18 | 1.25 | 1.46 | 1.83 | 1.69 | 1.17 | 1.34 |
| 1.01b | 0.00 | 0.18 | 0.80 | 1.09 | 1.23 | 1.33 | 1.55 | 1.96 | 1.80 | 1.24 | 1.42 |
| 1.01D | 0.01 | 0.35 | 1.57 | 2.12 | 2.42 | 2.59 | 3.01 | 3.79 | 3.50 | 2.41 | 2.76 |
| 1.02 | 0.01 | 0.51 | 2.32 | 3.12 | 3.56 | 3.82 | 4.44 | 5.53 | 5.09 | 3.55 | 4.08 |
| 1.03 | 0.02 | 0.65 | 2.96 | 4.02 | 4.63 | 5.02 | 5.80 | 7.22 | 6.55 | 4.58 | 5.44 |
| 1.03a | 0.00 | 0.02 | 0.09 | 0.09 | 0.10 | 0.09 | 0.11 | 0.11 | 0.11 | 0.07 | 0.07 |
| 1.03b | 0.00 | 0.07 | 0.32 | 0.36 | 0.40 | 0.37 | 0.43 | 0.46 | 0.48 | 0.34 | 0.33 |
| 1.03c | 0.00 | 0.10 | 0.40 | 0.44 | 0.49 | 0.46 | 0.53 | 0.56 | 0.60 | 0.42 | 0.40 |
| 1.03d | 0.02 | 0.76 | 3.27 | 4.39 | 5.05 | 5.47 | 6.32 | 7.91 | 7.16 | 5.02 | 6.03 |
| 1.04 | 7.94 | 8.00 | 7.10 | 7.71 | 8.83 | 9.54 | 10.84 | 13.45 | 11.51 | 8.31 | 10.49 |
| 1.04a | 0.00 | 0.07 | 0.31 | 0.36 | 0.39 | 0.37 | 0.42 | 0.44 | 0.47 | 0.33 | 0.31 |
| 1.04c | 4.26 | 4.28 | 3.81 | 4.09 | 3.97 | 2.15 | 1.53 | 1.37 | 1.38 | 0.92 | 0.87 |
| 1.04d | 7.94 | 7.99 | 7.09 | 7.63 | 7.34 | 4.02 | 2.87 | 2.57 | 2.59 | 1.73 | 1.64 |
| 1.05 | 8.39 | 8.62 | 7.86 | 8.66 | 9.78 | 10.58 | 11.94 | 14.80 | 12.75 | 9.14 | 11.56 |
| 1.05a | 3.23 | 3.23 | 2.89 | 3.15 | 2.98 | 1.72 | 1.41 | 1.34 | 1.37 | 0.92 | 0.87 |
| 1.06 | 8.40 | 8.86 | 9.90 | 11.66 | 13.26 | 14.46 | 16.27 | 20.49 | 17.83 | 12.64 | 16.07 |
| 1.06a | 2.17 | 2.19 | 1.95 | 2.09 | 2.02 | 1.09 | 0.75 | 0.67 | 0.67 | 0.45 | 0.42 |
| 1.06b | 2.92 | 2.93 | 2.60 | 2.80 | 2.67 | 1.47 | 1.12 | 1.07 | 1.08 | 0.73 | 0.69 |
| 1.07 | 8.68 | 9.29 | 10.67 | 12.32 | 14.30 | 15.60 | 17.49 | 22.01 | 19.12 | 13.61 | 17.45 |
| 1.07a | 3.04 | 3.05 | 2.72 | 2.94 | 2.82 | 1.52 | 1.05 | 0.93 | 0.93 | 0.62 | 0.59 |
| 1.07b | 7.33 | 7.40 | 6.52 | 7.01 | 6.69 | 3.68 | 2.64 | 2.43 | 2.46 | 1.66 | 1.58 |
| 1.08 | 9.32 | 10.27 | 13.32 | 15.72 | 16.81 | 18.27 | 20.47 | 25.66 | 21.93 | 15.84 | 20.91 |
| 1.08a | 3.10 | 3.10 | 2.77 | 3.01 | 2.86 | 1.63 | 1.25 | 1.15 | 1.16 | 0.78 | 0.74 |
| 1.08b | 4.94 | 4.98 | 4.41 | 4.73 | 4.53 | 2.46 | 1.70 | 1.52 | 1.53 | 1.03 | 0.97 |
| 1.09 | 9.77 | 11.26 | 15.92 | 18.85 | 20.51 | 22.31 | 25.11 | 31.09 | 26.24 | 19.42 | 25.94 |
| 2.01 | 0.00 | 0.18 | 0.83 | 1.14 | 1.29 | 1.40 | 1.63 | 2.05 | 1.90 | 1.29 | 1.50 |
| 2.02 | 0.01 | 0.34 | 1.56 | 2.02 | 2.29 | 2.35 | 2.84 | 3.45 | 3.24 | 2.27 | 2.54 |
| 2.03 | 0.01 | 0.41 | 1.86 | 2.41 | 2.72 | 2.78 | 3.38 | 4.06 | 3.81 | 2.68 | 2.99 |
| 2.04 | 2.24 | 2.26 | 2.00 | 2.14 | 2.05 | 1.11 | 0.75 | 0.68 | 0.69 | 0.46 | 0.44 |
| 3.01 | 0.01 | 0.20 | 0.92 | 1.32 | 1.55 | 1.74 | 1.97 | 2.52 | 2.26 | 1.49 | 1.91 |
| 3.02 | 0.01 | 0.27 | 1.24 | 1.73 | 2.00 | 2.21 | 2.55 | 3.25 | 2.95 | 1.98 | 2.46 |
| 3.03 | 0.00 | 0.11 | 0.47 | 0.59 | 0.65 | 0.65 | 0.79 | 0.86 | 0.86 | 0.63 | 0.63 |
| 3.04 | 0.00 | 0.13 | 0.54 | 0.66 | 0.73 | 0.74 | 0.90 | 0.97 | 0.98 | 0.71 | 0.71 |
| 3.05D | 0.01 | 0.39 | 1.76 | 2.34 | 2.68 | 2.81 | 3.32 | 4.18 | 3.89 | 2.66 | 3.16 |
| 3.06 | 0.01 | 0.44 | 1.93 | 2.52 | 2.88 | 2.96 | 3.55 | 4.44 | 4.16 | 2.86 | 3.36 |
| 3.06a | 4.68 | 4.72 | 4.17 | 4.46 | 4.31 | 2.33 | 1.73 | 1.69 | 1.75 | 1.21 | 1.16 |
| 4.01 | 1.81 | 1.80 | 1.65 | 1.95 | 1.68 | 1.21 | 1.29 | 1.46 | 1.55 | 1.07 | 1.03 |
| 4.01a | 0.00 | 0.05 | 0.23 | 0.26 | 0.29 | 0.26 | 0.31 | 0.32 | 0.34 | 0.25 | 0.23 |
| 4.01b | 1.81 | 1.80 | 1.62 | 1.84 | 1.67 | 1.04 | 1.00 | 1.02 | 1.06 | 0.72 | 0.68 |
| 4.02 | 3.89 | 4.86 | 4.61 | 4.36 | 4.42 | 2.81 | 2.32 | 2.47 | 2.63 | 1.84 | 1.78 |
| 5.01 | 0.00 | 0.05 | 0.23 | 0.29 | 0.33 | 0.32 | 0.40 | 0.43 | 0.43 | 0.31 | 0.32 |
| 5.02 | 6.38 | 6.43 | 5.70 | 6.12 | 5.88 | 3.19 | 2.33 | 2.26 | 2.36 | 1.62 | 1.57 |
| 5.03 | 9.51 | 9.87 | 8.27 | 8.61 | 8.94 | 5.54 | 3.92 | 3.70 | 3.81 | 2.60 | 2.50 |
| 5.04 | 5.92 | 6.04 | 5.49 | 6.03 | 5.64 | 3.48 | 2.99 | 3.20 | 3.38 | 2.43 | 2.61 |
| 5.04a | 3.15 | 3.17 | 2.81 | 3.02 | 2.90 | 1.59 | 1.13 | 1.02 | 1.03 | 0.69 | 0.65 |
| 5.04_Div | 2.56 | 2.62 | 2.34 | 2.61 | 2.42 | 1.34 | 1.10 | 1.20 | 1.29 | 0.82 | 0.91 |
| 5.04_Out | 3.36 | 3.42 | 3.14 | 3.41 | 3.22 | 2.14 | 1.90 | 2.00 | 2.09 | 1.62 | 1.71 |
| 9.01 | 0.00 | 0.03 | 0.10 | 0.11 | 0.11 | 0.10 | 0.12 | 0.12 | 0.13 | 0.09 | 0.08 |
| 9.02 | 0.00 | 0.04 | 0.20 | 0.23 | 0.25 | 0.24 | 0.30 | 0.31 | 0.32 | 0.23 | 0.23 |
| 10.01 | 0.34 | 0.34 | 0.31 | 0.33 | 0.32 | 0.17 | 0.12 | 0.10 | 0.10 | 0.07 | 0.07 |
| 10.02 | 0.45 | 0.45 | 0.40 | 0.43 | 0.41 | 0.23 | 0.16 | 0.14 | 0.14 | 0.09 | 0.09 |
| 10.03 | 0.88 | 0.88 | 0.79 | 0.85 | 0.82 | 0.45 | 0.30 | 0.27 | 0.27 | 0.18 | 0.17 |
| 10.04 | 0.80 | 0.81 | 0.72 | 0.78 | 0.74 | 0.41 | 0.28 | 0.25 | 0.25 | 0.17 | 0.16 |
| 10.05 | 1.38 | 1.38 | 1.23 | 1.33 | 1.28 | 0.70 | 0.48 | 0.42 | 0.42 | 0.28 | 0.27 |
| 11.01 | 0.95 | 0.95 | 0.85 | 0.91 | 0.88 | 0.47 | 0.32 | 0.29 | 0.29 | 0.20 | 0.18 |
| B1 | 3.23 | 3.23 | 2.89 | 3.15 | 2.98 | 1.72 | 1.41 | 1.34 | 1.37 | 0.92 | 0.87 |
| B1_Out | 0.22 | 0.31 | 0.51 | 0.57 | 0.62 | 0.61 | 0.68 | 0.77 | 0.70 | 0.53 | 0.61 |
| B2 | 3.04 | 3.05 | 2.72 | 2.94 | 2.82 | 1.52 | 1.05 | 0.93 | 0.93 | 0.62 | 0.59 |
| B2_Out | 0.14 | 0.20 | 0.32 | 0.35 | 0.37 | 0.37 | 0.41 | 0.55 | 0.46 | 0.34 | 0.39 |
| B3 | 7.88 | 8.85 | 8.14 | 8.24 | 8.04 | 4.90 | 3.89 | 3.91 | 4.08 | 2.81 | 2.70 |
| B3_In | 7.88 | 8.85 | 8.14 | 8.24 | 8.04 | 4.90 | 3.89 | 3.91 | 4.08 | 2.81 | 2.70 |
| B3_Out | 0.46 | 0.67 | 1.22 | 1.42 | 1.54 | 1.63 | 1.77 | 2.13 | 1.83 | 1.47 | 1.79 |
| B4 | 7.03 | 7.21 | 6.16 | 6.68 | 6.26 | 3.75 | 2.76 | 2.70 | 2.80 | 1.83 | 1.87 |
| B4_Out | 3.68 | 4.58 | 4.38 | 4.66 | 4.58 | 3.37 | 2.57 | 2.55 | 2.67 | 1.77 | 1.83 |
| B5 | 7.33 | 7.40 | 6.52 | 7.01 | 6.69 | 3.68 | 2.64 | 2.43 | 2.46 | 1.66 | 1.58 |
| B5_Out | 0.16 | 0.23 | 0.42 | 0.51 | 0.57 | 0.63 | 0.69 | 0.86 | 0.81 | 0.74 | 0.80 |
| B6 | 2.24 | 2.26 | 2.00 | 2.14 | 2.05 | 1.11 | 0.75 | 0.68 | 0.69 | 0.46 | 0.44 |
| B6_Out | 0.26 | 0.35 | 0.54 | 0.54 | 0.62 | 0.51 | 0.50 | 0.51 | 0.56 | 0.36 | 0.37 |
| B7 | 9.51 | 9.87 | 8.27 | 8.61 | 8.94 | 5.54 | 3.92 | 3.70 | 3.81 | 2.60 | 2.50 |
| B8 | 0.34 | 0.34 | 0.31 | 0.33 | 0.32 | 0.17 | 0.12 | 0.10 | 0.10 | 0.07 | 0.07 |
| B9 | 0.45 | 0.45 | 0.40 | 0.43 | 0.41 | 0.23 | 0.16 | 0.14 | 0.14 | 0.09 | 0.09 |
| B10 | 0.88 | 0.88 | 0.79 | 0.85 | 0.82 | 0.45 | 0.30 | 0.27 | 0.27 | 0.18 | 0.17 |
| B11 | 0.80 | 0.81 | 0.72 | 0.78 | 0.74 | 0.41 | 0.28 | 0.25 | 0.25 | 0.17 | 0.16 |
| B12 | 1.38 | 1.38 | 1.23 | 1.33 | 1.28 | 0.70 | 0.48 | 0.42 | 0.42 | 0.28 | 0.27 |
| Outlet 1 | 9.77 | 11.26 | 15.92 | 18.85 | 20.51 | 22.31 | 25.11 | 32.81 | 26.24 | 19.42 | 25.94 |
| Outlet 2 | 0.45 | 0.57 | 0.74 | 0.75 | 0.77 | 0.72 | 0.75 | 0.86 | 0.74 | 0.58 | 0.60 |
| Overall | 9.99 | 11.57 | 16.47 | 19.58 | 20.94 | 22.79 | 25.60 | 31.62 | 26.65 | 19.81 | 26.47 |

| Developed Condition Discharges - 1% AEP | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Node | Storm Duration | | | | | | | | | |
| | 15 min | 25 min | 60 min | 90 min | 120 min | 180 min | 360 min | 720 min | 1080 min | 1440 min |
| 1.01a | 1.38 | 2.44 | 4.60 | 4.94 | 5.17 | 4.70 | 4.80 | 4.38 | 3.41 | 3.48 |
| 1.01b | 1.45 | 2.57 | 4.87 | 5.22 | 5.44 | 5.00 | 5.12 | 4.68 | 3.63 | 3.72 |
| 1.01D | 2.83 | 5.01 | 9.48 | 10.16 | 10.61 | 9.71 | 9.91 | 9.07 | 7.04 | 7.20 |
| 1.02 | 4.18 | 7.38 | 13.88 | 14.85 | 15.57 | 14.30 | 14.64 | 13.11 | 10.25 | 10.60 |
| 1.03 | 5.32 | 9.43 | 17.67 | 19.28 | 20.37 | 18.79 | 19.27 | 16.94 | 13.36 | 14.15 |
| 1.03a | 0.21 | 0.33 | 0.42 | 0.43 | 0.48 | 0.35 | 0.28 | 0.24 | 0.17 | 0.16 |
| 1.03b | 0.70 | 1.17 | 1.67 | 1.66 | 1.77 | 1.36 | 1.28 | 1.13 | 0.82 | 0.79 |
| 1.03c | 0.90 | 1.49 | 2.06 | 2.05 | 2.21 | 1.69 | 1.57 | 1.39 | 1.00 | 0.97 |
| 1.03d | 6.11 | 10.44 | 18.98 | 20.87 | 22.11 | 20.54 | 21.15 | 18.53 | 14.67 | 15.73 |
| 1.04 | 17.21 | 17.55 | 30.18 | 34.11 | 36.24 | 33.77 | 35.72 | 30.27 | 24.76 | 26.77 |
| 1.04a | 0.67 | 1.16 | 1.61 | 1.61 | 1.71 | 1.30 | 1.22 | 1.08 | 0.77 | 0.75 |
| 1.04c | 9.06 | 8.95 | 8.44 | 9.08 | 8.59 | 4.95 | 3.23 | 2.84 | 1.96 | 1.90 |
| 1.04d | 16.92 | 16.68 | 15.65 | 16.86 | 15.88 | 9.29 | 6.07 | 5.34 | 3.69 | 3.58 |
| 1.05 | 19.85 | 20.68 | 32.50 | 36.66 | 39.26 | 36.48 | 39.00 | 33.81 | 27.43 | 29.39 |
| 1.05a | 7.05 | 7.25 | 7.01 | 7.78 | 7.04 | 4.68 | 3.29 | 2.89 | 2.00 | 1.94 |
| 1.06 | 22.84 | 26.01 | 43.86 | 49.35 | 53.51 | 50.42 | 53.49 | 46.99 | 37.85 | 41.27 |
| 1.06a | 4.66 | 4.59 | 4.27 | 4.54 | 4.36 | 2.42 | 1.56 | 1.38 | 0.95 | 0.92 |
| 1.06b | 6.25 | 6.15 | 5.76 | 6.31 | 5.92 | 3.64 | 2.57 | 2.27 | 1.58 | 1.53 |
| 1.07 | 23.97 | 27.78 | 46.19 | 53.12 | 57.09 | 54.79 | 57.71 | 50.65 | 40.94 | 45.55 |
| 1.07a | 6.48 | 6.39 | 5.96 | 6.36 | 6.00 | 3.38 | 2.18 | 1.92 | 1.33 | 1.29 |
| 1.07b | 15.76 | 15.39 | 14.30 | 15.37 | 14.53 | 8.49 | 5.80 | 5.11 | 3.56 | 3.45 |
| 1.08 | 26.64 | 32.07 | 51.33 | 62.00 | 66.04 | 64.71 | 67.45 | 58.24 | 47.53 | 55.20 |
| 1.08a | 6.71 | 6.81 | 6.51 | 7.14 | 6.54 | 4.14 | 2.77 | 2.44 | 1.68 | 1.63 |
| 1.08b | 10.61 | 10.30 | 9.57 | 10.23 | 9.81 | 5.48 | 3.58 | 3.15 | 2.18 | 2.12 |
| 1.09 | 30.32 | 37.93 | 61.44 | 73.56 | 79.58 | 78.16 | 80.76 | 70.58 | 57.52 | 67.88 |
| 2.01 | 1.51 | 2.67 | 5.09 | 5.45 | 5.68 | 5.24 | 5.39 | 4.95 | 3.82 | 3.93 |
| 2.02 | 2.87 | 5.05 | 8.91 | 9.31 | 9.69 | 8.82 | 8.97 | 8.19 | 6.36 | 6.53 |
| 2.03 | 3.48 | 6.12 | 10.56 | 10.97 | 11.43 | 10.35 | 10.54 | 9.54 | 7.48 | 7.65 |
| 2.04 | 4.78 | 4.62 | 4.32 | 4.59 | 4.36 | 2.45 | 1.62 | 1.43 | 0.99 | 0.96 |
| 3.01 | 1.67 | 2.93 | 5.94 | 6.46 | 6.85 | 6.46 | 6.88 | 6.19 | 4.87 | 5.10 |
| 3.02 | 2.28 | 4.03 | 7.72 | 8.35 | 8.72 | 8.22 | 8.68 | 7.90 | 6.22 | 6.52 |
| 3.03 | 0.86 | 1.55 | 2.59 | 2.57 | 2.67 | 2.26 | 2.30 | 2.12 | 1.61 | 1.58 |
| 3.04 | 1.01 | 1.81 | 2.95 | 2.92 | 3.02 | 2.55 | 2.60 | 2.39 | 1.81 | 1.78 |
| 3.05D | 3.29 | 5.82 | 10.39 | 10.92 | 11.42 | 10.46 | 11.01 | 10.20 | 7.96 | 8.26 |
| 3.06 | 3.71 | 6.44 | 11.04 | 11.53 | 12.05 | 11.08 | 11.61 | 10.80 | 8.39 | 8.74 |
| 3.06a | 10.03 | 9.74 | 9.09 | 9.78 | 9.34 | 5.49 | 4.20 | 3.76 | 2.69 | 2.61 |
| 4.01 | 4.39 | 5.02 | 5.28 | 6.27 | 5.70 | 4.48 | 3.87 | 3.48 | 2.47 | 2.41 |
| 4.01a | 0.48 | 0.83 | 1.18 | 1.18 | 1.24 | 0.95 | 0.91 | 0.81 | 0.58 | 0.57 |
| 4.01b | 4.12 | 4.44 | 4.45 | 5.14 | 4.50 | 3.39 | 2.60 | 2.29 | 1.60 | 1.55 |
| 4.02 | 8.42 | 10.25 | 10.05 | 10.10 | 9.69 | 7.26 | 6.32 | 5.73 | 4.16 | 4.05 |
| 5.01 | 0.45 | 0.79 | 1.33 | 1.32 | 1.36 | 1.14 | 1.16 | 1.07 | 0.81 | 0.80 |
| 5.02 | 13.61 | 13.21 | 12.36 | 13.28 | 12.61 | 7.51 | 5.63 | 5.08 | 3.62 | 3.52 |
| 5.03 | 20.89 | 20.60 | 18.41 | 19.15 | 19.57 | 12.44 | 8.97 | 8.07 | 5.72 | 5.57 |
| 5.04 | 12.78 | 12.81 | 12.42 | 13.62 | 12.64 | 9.15 | 9.33 | 10.39 | 7.62 | 7.85 |
| 5.04a | 6.77 | 6.61 | 6.20 | 6.66 | 6.31 | 3.65 | 2.41 | 2.12 | 1.47 | 1.42 |
| 5.04_Div | 5.99 | 6.01 | 5.81 | 6.41 | 5.92 | 4.18 | 4.26 | 4.80 | 3.41 | 3.53 |
| 5.04_Out | 6.79 | 6.81 | 6.61 | 7.21 | 6.72 | 4.98 | 5.06 | 5.60 | 4.21 | 4.33 |
| 9.01 | 0.23 | 0.37 | 0.48 | 0.48 | 0.53 | 0.40 | 0.32 | 0.28 | 0.20 | 0.19 |
| 9.02 | 0.37 | 0.71 | 1.06 | 1.05 | 1.09 | 0.85 | 0.86 | 0.77 | 0.57 | 0.55 |
| 10.01 | 0.73 | 0.72 | 0.69 | 0.73 | 0.72 | 0.37 | 0.24 | 0.21 | 0.15 | 0.14 |
| 10.02 | 0.96 | 0.95 | 0.89 | 0.94 | 0.90 | 0.50 | 0.32 | 0.28 | 0.20 | 0.19 |
| 10.03 | 1.89 | 1.89 | 1.76 | 1.89 | 1.79 | 0.98 | 0.63 | 0.56 | 0.38 | 0.37 |
| 10.04 | 1.72 | 1.73 | 1.61 | 1.73 | 1.64 | 0.89 | 0.58 | 0.51 | 0.35 | 0.34 |
| 10.05 | 2.95 | 2.93 | 2.75 | 2.91 | 2.82 | 1.53 | 0.99 | 0.87 | 0.60 | 0.58 |
| 11.01 | 2.00 | 1.96 | 1.84 | 1.97 | 1.88 | 1.05 | 0.68 | 0.60 | 0.41 | 0.40 |
| B1 | 7.05 | 7.25 | 7.01 | 7.78 | 7.04 | 4.68 | 3.29 | 2.89 | 2.00 | 1.94 |
| B1_Out | 0.78 | 1.44 | 2.74 | 2.70 | 2.73 | 2.41 | 2.46 | 2.60 | 1.82 | 1.88 |
| B2 | 6.48 | 6.39 | 5.96 | 6.36 | 6.00 | 3.38 | 2.18 | 1.92 | 1.33 | 1.29 |
| B2_Out | 0.66 | 1.28 | 1.90 | 1.87 | 2.05 | 1.56 | 1.71 | 1.75 | 1.26 | 1.26 |
| B3 | 17.11 | 19.00 | 18.15 | 19.17 | 17.90 | 12.45 | 9.77 | 8.77 | 6.25 | 6.08 |
| B3_In | 17.11 | 19.00 | 18.15 | 19.17 | 17.90 | 12.45 | 9.77 | 8.77 | 6.25 | 6.08 |
| B3_Out | 1.76 | 2.65 | 5.68 | 6.12 | 6.41 | 6.01 | 6.48 | 6.45 | 4.66 | 5.26 |
| B4 | 15.80 | 15.54 | 14.16 | 15.32 | 14.30 | 9.11 | 7.37 | 7.86 | 5.55 | 5.62 |
| B4_Out | 10.52 | 11.75 | 11.23 | 11.76 | 11.54 | 8.44 | 6.91 | 7.58 | 5.39 | 5.55 |
| B5 | 15.76 | 15.39 | 14.30 | 15.37 | 14.53 | 8.49 | 5.80 | 5.11 | 3.56 | 3.45 |
| B5_Out | 0.60 | 0.89 | 3.00 | 3.29 | 3.53 | 3.34 | 3.67 | 4.34 | 3.09 | 3.30 |
| B6 | 4.78 | 4.62 | 4.32 | 4.59 | 4.36 | 2.45 | 1.62 | 1.43 | 0.99 | 0.96 |
| B6_Out | 1.82 | 2.50 | 2.84 | 3.24 | 3.02 | 2.20 | 1.60 | 1.41 | 0.99 | 0.96 |
| B7 | 20.89 | 20.60 | 18.41 | 19.15 | 19.57 | 12.44 | 8.97 | 8.07 | 5.72 | 5.57 |
| B8 | 0.73 | 0.72 | 0.69 | 0.73 | 0.72 | 0.37 | 0.24 | 0.21 | 0.15 | 0.14 |
| B9 | 0.96 | 0.95 | 0.89 | 0.94 | 0.90 | 0.50 | 0.32 | 0.28 | 0.20 | 0.19 |
| B10 | 1.89 | 1.89 | 1.76 | 1.89 | 1.79 | 0.98 | 0.63 | 0.56 | 0.38 | 0.37 |
| B11 | 1.72 | 1.73 | 1.61 | 1.73 | 1.64 | 0.89 | 0.58 | 0.51 | 0.35 | 0.34 |
| B12 | 2.95 | 2.93 | 2.75 | 2.91 | 2.82 | 1.53 | 0.99 | 0.87 | 0.60 | 0.58 |
| Outlet 1 | 30.32 | 37.93 | 61.44 | 73.56 | 79.58 | 78.16 | 80.76 | 70.58 | 57.52 | 67.88 |
| Outlet 2 | 1.59 | 2.09 | 2.69 | 2.80 | 2.93 | 2.25 | 2.11 | 2.06 | 1.48 | 1.52 |
| Overall | 30.88 | 38.60 | 62.45 | 74.37 | 80.59 | 79.43 | 81.82 | 71.56 | 58.40 | 69.05 |

| Developed Condition Discharges - PMP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Node | Storm Duration | | | | | | | | | | |
| | 15 min | 30 min | 45 min | 60 min | 90 min | 120 min | 150 min | 180 min | 240 min | 300 min | 360 min |
| 1.01a | 34.51 | 57.67 | 74.23 | 82.94 | 91.49 | 90.77 | 84.64 | 80.67 | 73.89 | 67.27 | 61.92 |
| 1.01b | 36.59 | 60.75 | 78.26 | 87.64 | 97.10 | 96.73 | 90.18 | 86.02 | 78.86 | 71.83 | 66.05 |
| 1.01D | 71.10 | 118.42 | 152.49 | 170.57 | 188.59 | 187.52 | 174.82 | 166.70 | 152.75 | 139.09 | 127.96 |
| 1.02 | 103.12 | 169.98 | 216.78 | 245.90 | 268.87 | 266.68 | 256.06 | 243.63 | 221.75 | 204.84 | 188.42 |
| 1.03a | 4.76 | 6.25 | 6.48 | 6.26 | 5.66 | 5.22 | 4.83 | 4.54 | 4.06 | 3.63 | 3.24 |
| 1.03b | 16.37 | 23.50 | 26.39 | 27.07 | 25.40 | 23.80 | 21.71 | 20.28 | 18.30 | 16.87 | 15.42 |
| 1.03c | 20.11 | 28.61 | 32.38 | 33.13 | 31.11 | 28.97 | 26.44 | 24.72 | 22.37 | 20.62 | 18.88 |
| 1.03d | 135.87 | 221.95 | 285.36 | 328.01 | 359.80 | 367.80 | 353.62 | 341.80 | 323.54 | 299.74 | 279.62 |
| 1.03 | 128.91 | 210.83 | 269.33 | 307.95 | 335.62 | 339.92 | 326.19 | 311.88 | 292.69 | 270.38 | 251.43 |
| 1.04a | 15.89 | 22.72 | 25.84 | 26.04 | 24.27 | 22.44 | 20.47 | 19.24 | 17.66 | 16.16 | 14.71 |
| 1.04c | 130.46 | 121.77 | 113.67 | 100.09 | 81.44 | 70.12 | 61.09 | 54.88 | 46.83 | 40.95 | 36.24 |
| 1.04d | 234.41 | 201.80 | 194.00 | 181.89 | 148.84 | 129.47 | 113.03 | 102.98 | 87.97 | 76.99 | 68.18 |
| 1.04 | 243.70 | 314.94 | 405.06 | 465.14 | 527.36 | 558.64 | 551.71 | 541.00 | 526.74 | 497.24 | 460.67 |
| 1.05a | 105.92 | 101.28 | 97.14 | 86.99 | 72.11 | 65.94 | 59.03 | 54.57 | 47.66 | 42.12 | 37.44 |
| 1.05 | 288.46 | 320.07 | 411.63 | 474.84 | 543.48 | 581.42 | 576.41 | 565.48 | 554.38 | 532.42 | 495.64 |
| 1.06a | 65.32 | 61.12 | 57.37 | 50.54 | 41.20 | 35.43 | 30.79 | 27.65 | 23.43 | 20.40 | 17.99 |
| 1.06b | 90.41 | 83.59 | 78.49 | 70.02 | 58.47 | 50.68 | 44.68 | 40.90 | 35.97 | 32.19 | 28.94 |
| 1.06 | 362.34 | 414.19 | 500.24 | 588.13 | 701.31 | 748.12 | 765.33 | 762.61 | 744.69 | 705.94 | 677.97 |
| 1.07a | 91.26 | 85.29 | 79.86 | 70.12 | 57.22 | 49.49 | 43.05 | 38.50 | 32.42 | 28.31 | 25.05 |
| 1.07b | 176.20 | 159.59 | 156.18 | 150.01 | 136.43 | 118.21 | 104.81 | 95.08 | 82.03 | 72.71 | 64.93 |
| 1.07 | 374.50 | 432.55 | 508.87 | 597.52 | 722.06 | 778.39 | 799.06 | 797.90 | 780.28 | 746.48 | 716.86 |
| 1.08a | 98.98 | 93.83 | 89.02 | 78.86 | 64.69 | 57.20 | 50.97 | 46.63 | 40.27 | 35.35 | 31.31 |
| 1.08b | 151.14 | 137.05 | 126.59 | 111.45 | 90.41 | 77.50 | 67.12 | 60.73 | 51.78 | 45.35 | 40.15 |
| 1.08 | 397.25 | 464.04 | 553.16 | 618.75 | 756.43 | 837.80 | 858.33 | 870.74 | 852.05 | 831.18 | 811.71 |
| 1.09 | 439.93 | 554.58 | 662.67 | 742.95 | 858.34 | 923.03 | 956.85 | 979.47 | 1003.31 | 997.86 | 969.55 |
| 2.01 | 38.33 | 63.26 | 81.72 | 91.66 | 101.85 | 101.76 | 95.01 | 90.58 | 83.23 | 75.80 | 69.69 |
| 2.02 | 68.81 | 109.75 | 136.63 | 153.66 | 164.29 | 166.28 | 157.24 | 148.57 | 136.01 | 124.87 | 115.47 |
| 2.03 | 81.16 | 127.76 | 160.33 | 178.14 | 190.66 | 192.59 | 182.00 | 172.82 | 158.77 | 146.26 | 135.50 |
| 2.04 | 68.09 | 60.45 | 55.85 | 49.18 | 40.11 | 34.89 | 30.45 | 27.39 | 23.40 | 20.52 | 18.19 |
| 3.01 | 42.70 | 72.22 | 94.62 | 108.96 | 122.14 | 127.05 | 121.42 | 115.23 | 107.28 | 98.89 | 90.36 |
| 3.02 | 57.34 | 93.67 | 121.54 | 137.81 | 155.07 | 158.62 | 152.07 | 146.24 | 135.24 | 124.46 | 114.42 |
| 3.03 | 22.00 | 34.29 | 41.68 | 45.71 | 45.62 | 43.33 | 40.30 | 37.65 | 33.75 | 31.17 | 29.04 |
| 3.04 | 25.23 | 38.73 | 47.27 | 51.50 | 51.18 | 48.94 | 45.38 | 42.33 | 38.11 | 35.26 | 32.81 |
| 3.05D | 81.42 | 128.83 | 161.12 | 182.99 | 200.18 | 202.70 | 194.40 | 185.46 | 170.34 | 156.91 | 144.41 |
| 3.06a | 142.14 | 130.09 | 121.86 | 109.11 | 91.34 | 80.36 | 71.05 | 64.94 | 57.42 | 52.05 | 47.29 |
| 3.06 | 86.02 | 134.63 | 168.47 | 191.64 | 208.75 | 212.30 | 203.82 | 195.10 | 179.20 | 165.31 | 152.49 |
| 4.01a | 11.35 | 16.44 | 19.09 | 19.44 | 18.13 | 16.82 | 15.30 | 14.33 | 13.16 | 12.10 | 11.05 |
| 4.01b | 64.81 | 64.51 | 64.16 | 58.94 | 52.11 | 49.08 | 44.61 | 42.15 | 37.60 | 33.71 | 30.13 |
| 4.01 | 74.14 | 76.44 | 78.23 | 79.21 | 74.52 | 70.10 | 64.41 | 61.97 | 56.42 | 51.34 | 46.43 |
| 4.02 | 118.17 | 115.24 | 116.28 | 104.48 | 109.75 | 102.65 | 98.64 | 95.37 | 84.73 | 76.06 | 70.95 |
| 5.01 | 11.36 | 17.75 | 21.50 | 23.44 | 23.20 | 22.02 | 20.43 | 19.03 | 17.13 | 15.85 | 14.75 |
| 5.02 | 194.17 | 173.70 | 160.84 | 144.12 | 121.95 | 108.86 | 96.03 | 89.43 | 78.96 | 71.04 | 64.31 |
| 5.03 | 217.00 | 218.00 | 230.29 | 216.67 | 186.67 | 180.06 | 160.52 | 144.87 | 125.30 | 112.25 | 101.20 |
| 5.04_Div | 65.08 | 84.85 | 98.32 | 104.07 | 108.10 | 103.57 | 97.16 | 90.41 | 80.43 | 75.32 | 69.95 |
| 5.04_Out | 65.88 | 85.65 | 99.12 | 104.87 | 108.90 | 104.37 | 97.96 | 91.21 | 81.23 | 76.12 | 70.75 |
| 5.04a | 97.44 | 89.49 | 83.19 | 73.24 | 59.80 | 51.61 | 44.78 | 40.66 | 34.88 | 30.56 | 27.07 |
| 5.04 | 130.97 | 170.50 | 197.44 | 208.93 | 217.00 | 207.93 | 195.13 | 181.64 | 161.66 | 151.45 | 140.69 |
| 9.01 | 5.16 | 6.97 | 7.43 | 7.23 | 6.59 | 6.05 | 5.59 | 5.28 | 4.76 | 4.28 | 3.83 |
| 9.02 | 9.80 | 14.52 | 17.22 | 18.03 | 17.02 | 16.00 | 14.60 | 13.59 | 12.41 | 11.52 | 10.58 |
| 10.01 | 10.63 | 9.34 | 8.98 | 7.84 | 6.43 | 5.54 | 4.81 | 4.31 | 3.64 | 3.18 | 2.82 |
| 10.02 | 13.46 | 12.66 | 11.90 | 10.49 | 8.57 | 7.39 | 6.45 | 5.78 | 4.85 | 4.21 | 3.71 |
| 10.03 | 26.56 | 24.68 | 23.40 | 20.49 | 16.76 | 14.43 | 12.55 | 11.26 | 9.56 | 8.34 | 7.37 |
| 10.04 | 24.33 | 22.51 | 21.34 | 18.67 | 15.27 | 13.15 | 11.45 | 10.29 | 8.73 | 7.60 | 6.73 |
| 10.05 | 41.21 | 38.77 | 36.51 | 31.98 | 26.17 | 22.60 | 19.67 | 17.63 | 14.89 | 12.96 | 11.45 |
| 11.01 | 28.71 | 26.42 | 24.59 | 21.65 | 17.59 | 15.11 | 13.11 | 11.74 | 9.93 | 8.63 | 7.63 |
| B1 | 105.92 | 101.28 | 97.14 | 86.99 | 72.11 | 65.94 | 59.03 | 54.57 | 47.66 | 42.12 | 37.44 |
| B1_Out | 72.13 | 80.20 | 78.68 | 76.86 | 68.91 | 63.19 | 57.11 | 53.09 | 46.80 | 41.74 | 37.29 |
| B2 | 91.26 | 85.29 | 79.86 | 70.12 | 57.22 | 49.49 | 43.05 | 38.50 | 32.42 | 28.31 | 25.05 |
| B2_Out | 39.93 | 48.70 | 49.45 | 47.62 | 43.74 | 40.91 | 37.18 | 34.51 | 30.44 | 27.08 | 24.17 |
| B3 | 243.21 | 229.50 | 222.61 | 198.43 | 175.93 | 163.63 | 146.49 | 137.08 | 130.88 | 119.81 | 109.89 |
| B3_In | 243.21 | 229.50 | 222.61 | 198.43 | 175.93 | 163.63 | 146.49 | 137.08 | 130.88 | 119.81 | 109.89 |
| B3_Out | 88.08 | 136.30 | 153.16 | 156.95 | 153.94 | 148.86 | 140.53 | 132.58 | 121.85 | 113.81 | 105.46 |
| B4 | 182.57 | 166.37 | 158.12 | 162.78 | 156.96 | 155.69 | 142.17 | 133.93 | 122.90 | 116.71 | 107.86 |
| B4_Out | 150.41 | 148.48 | 152.83 | 158.06 | 153.71 | 149.72 | 140.03 | 132.03 | 120.78 | 114.32 | 106.23 |
| B5 | 176.20 | 159.59 | 156.18 | 150.01 | 136.43 | 118.21 | 104.81 | 95.08 | 82.03 | 72.71 | 64.93 |
| B5_Out | 66.22 | 93.62 | 105.61 | 106.73 | 101.04 | 94.80 | 87.63 | 82.55 | 74.74 | 68.12 | 61.96 |
| B6 | 68.09 | 60.45 | 55.85 | 49.18 | 40.11 | 34.89 | 30.45 | 27.39 | 23.40 | 20.52 | 18.19 |
| B6_Out | 48.21 | 47.44 | 44.06 | 42.36 | 36.94 | 33.43 | 29.57 | 27.07 | 23.26 | 20.46 | 18.16 |
| B7 | 217.00 | 218.00 | 230.29 | 216.67 | 186.67 | 180.06 | 160.52 | 144.87 | 125.30 | 112.25 | 101.20 |
| B8 | 10.63 | 9.34 | 8.98 | 7.84 | 6.43 | 5.54 | 4.81 | 4.31 | 3.64 | 3.18 | 2.82 |
| B9 | 13.46 | 12.66 | 11.90 | 10.49 | 8.57 | 7.39 | 6.45 | 5.78 | 4.85 | 4.21 | 3.71 |
| B10 | 26.56 | 24.68 | 23.40 | 20.49 | 16.76 | 14.43 | 12.55 | 11.26 | 9.56 | 8.34 | 7.37 |
| B11 | 24.33 | 22.51 | 21.34 | 18.67 | 15.27 | 13.15 | 11.45 | 10.29 | 8.73 | 7.60 | 6.73 |
| B12 | 41.21 | 38.77 | 36.51 | 31.98 | 26.17 | 22.60 | 19.67 | 17.63 | 14.89 | 12.96 | 11.45 |
| Outlet 1 | 439.93 | 554.58 | 662.67 | 742.95 | 858.34 | 923.03 | 956.85 | 979.47 | 1003.31 | 997.86 | 969.55 |
| Outlet 2 | 87.53 | 87.54 | 82.50 | 76.21 | 65.46 | 59.01 | 51.89 | 46.99 | 39.96 | 34.93 | 30.92 |
| Overall | 440.70 | 556.89 | 667.10 | 747.00 | 864.38 | 933.14 | 960.94 | 984.50 | 1011.81 | 1005.61 | 976.49 |



# APPENDIX B – TUFLOW MODELLING ASSUMPTIONS

**Digital Terrain Model (DTM)**

The terrain for the Sydney Science Park TUFLOW model consists of the survey data provided by YSCO Geomatics and supplementary data from the Land and Property Management Authority. Modifications to the terrain were incorporated to reflect the proposed development in the developed conditions, such as site regrading, filling of the dams and creation of trunk drainage channels.

A grid size of 4 m was adopted in the TUFLOW model. This grid size was found to be a reasonable balance between computing time and flooding definition.

**Conveyance Of Flows From Upstream Catchments**

Flows from a number of upstream catchments adjacent to the study area need to be managed through the site. Where the upstream catchment is generally greater than 15 hectares, it is proposed to provide a drainage channel from the boundary to collect and convey the flows through the site. Where the upstream catchment area is less than 15 hectares, it is proposed to capture and pipe the flows until the total catchment area exceeds approximately 15 hectares, at which point an open drainage channel will be provided to convey the flows.

**Catchment Roughness**

One of the advantages of using TUFLOW for the hydraulic assessment is that different landuse can be assigned different roughness factors. For Sydney Science Park the following roughness assumptions are summarised in the below table.

**TABLE B.1 – TUFLOW MATERIAL ROUGHNESS**

| Material ID | Mannings 'n' | Description |
|---|---|---|
| 1 | 0.035 | Floodplain high grass / rural (default) |
| 2 | 0.015 | Roads |
| 3 | 0.05 | Light vegetation |
| 4 | 0.08 | Medium Vegetation |
| 5 | 0.1 | Dense Vegetation |
| 6 | 0.02 | Farm dams with vegetation |
| 7 | 3 | Building and houses |
| 8 | 0.03 | Open space |
| 9 | 0.015 | Concrete surfaces |
| 10 | 0.1 | Commercial / Residential areas |
| 11 | 0.04 | Farm lots with houses |
| 12 | 0.07 | Drainage channel |
| 13 | 0.045 | Rail Corridor |

.

For the purpose of the current assessment, given it is to inform a rezoning proposal and the final development layout is likely to change, the Manning's values within the commercial / residential areas have not been broken down into roads, buildings, etc. Instead, a flat Manning's value of 0.1 has been conservatively adopted in the developed case assessment. This will only impact results during the PMF assessment.

It was assumed that the riparian corridors within Sydney Science Park in the developed case will be revegetated. A Manning's value of 0.1 has therefore been applied.

### Boundary Conditions

The boundary conditions adopted in the TUFLOW model are as follows:

- UPSTREAM – Flow hydrographs were applied as inputs at the upstream boundary of Sydney Science Park
- LOCAL INFLOWS – Local inflow hydrographs were included in the model (as SA layers) at locations representing various sub catchments within Sydney Science Park..
- DOWNSTREAM – Sydney Science Park is not affected by the regional flood events below the 1 % AEP event. Therefore normal depth of flow was adopted as the downstream boundary condition.

# APPENDIX C – TECHNICAL PAPER BY CHRIS THOMAS FROM WORLEY PARSONS

# REFINMENT OF PROCEDURES FOR DETERMINING FLOODWAY EXTENT

**C R Thomas**[1], R Golaszewski[2]

[1] Manager, Environment & Water Resources, WorleyParsons
[2] Water Resources Engineer, WorleyParsons

**Abstract:** Floodways are defined as those areas where a significant discharge of water occurs during floods. However, there are no specific procedures for identifying floodways or for defining their extent. The methodology for defining floodway extent is left to practitioners and flood risk management committees to determine. As a result, the outcomes are often subjective and can lead to conjecture due to the legal implications of land being classified as a floodway.

Over the last decade, there has been considerable advancement in the tools used to simulate flooding. Accessibility to improved and more detailed topographic data has also occurred, as has the capacity to more rigorously interrogate flood characteristics derived from computer modelling using this data. In particular, the increasing use of this data in 2D hydrodynamic models has allowed more meaningful representation of flood flow across floodplains.

A range of data-sets such as depth, velocity, velocity-depth product, distribution of flow and unit stream power, can now be readily exported from flood models. This data can be combined with reliable topographic data to facilitate the hydraulic categorization of floodplains, including the identification of floodways. At the same time, the modelling tools can be more easily adapted to test the impact of floodplain encroachment and confirm initial estimates of floodway corridors.

This paper expands upon the issues discussed in a paper presented by the same authors for the 50th FMA Conference. It outlines a more rigorous methodology that has been developed for application to all river and floodplain systems. It also documents examples of major and minor river systems where this methodology has been applied and considers the impact that increased rainfall intensity due to climate change could have on floodway extent.

**Keywords:** hydraulic categorization, floodway, flood storage, afflux, geomorphology

## 1. INTRODUCTION

Floodways are those areas of a floodplain where a significant discharge of water occurs during floods [2]. They are often aligned with naturally defined channels and are areas that if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood level. By definition floodways are areas of high flow conveyance and can often be identified by areas of high flow velocity.

The blocking of floodways typically results in significant impacts on flood characteristics such as increases in predicted peak flood level and changes in flow velocities. Therefore, it is important to define floodways in floodplain risk management so that areas where development is undesirable can be identified.

Although no formal criteria are currently available, some “rules of thumb” have been presented as procedures for the delineation of floodway areas. For example, quantitative approaches were outlined in the 1986 version of the Floodplain Development Manual. These quantitative approaches suggested that the floodway zone can be defined by:

- determining the extent of encroachment that will cause a maximum change in water surface elevation of no more than 100 mm;
- determining areas where the velocity / depth product is greater than 1; and/or
- by the extent of the 20 year recurrence flood.

These approaches are all relevant but potentially ignore the significance of discharge and the impact of hydraulic controls and geomorphic features on floodwater movement.

In 2004 Howells et al [4] established that no “one size fits all” approach could be applied to define floodways for all types of floodplains. In 2007, Rigby [5] also raised this issue, highlighting that there is no known and universally agreed modelling procedure for the determination of the floodway and flood fringe boundaries.

Rigby rightly emphasised that there is a clear need to establish a procedure for delineation of floodways. This procedure does not necessarily need to be a strict mathematically derived outcome or a direct output from a flood model, but it does need to be more rigorous in order to avoid different interpretations between practitioners and different outcomes for similar types of floodplains.

In 2010, the authors of this paper (Thomas et al [9]) determined that although a one size fits all approach is not apparent, a more rigorous approach can be employed to define floodway corridors. The aim of this paper is to present the results of work that has been carried out since 2010 where efforts have been made to develop a more uniform approach to floodway delineation.

## 2. DETERMINATION OF FLOODWAY CORRIDORS – WORKING TOWARDS A UNIVERSAL APPROACH

### 2.1 Background

Although there remains no definitive flood modelling procedure that can be applied to automate the process of generating floodway extents, access to improved data-sets and better analytical tools provides the opportunity for a more uniform and rigorous methodology for floodway delineation.

Thomas et al [9] noted that this methodology should typically involve an iterative assessment that considers:

- section averaged velocity in the planning level flood at both the peak and on the rising limb of the hydrograph;
- maximum velocity-depth product for the planning level flood;
- topographic and geomorphic features along the floodplain;
- hydraulic controls such as structures that cause backwater effects; and,
- the results of hydraulic analysis and / or flood modelling that incorporates simulation of a blockage scenario or encroachment testing.

Thomas et al [9] acknowledged that this iterative process required further investigation to better define the steps. It was also recognised that application of such an iterative process would remain the domain of experienced practitioners with the skills to holistically evaluate the physical features of the floodplain and all available hydraulic / flood modelling outputs [9].

Since publication of the 2010 paper further investigations have been undertaken to determine floodway corridors throughout New South Wales. These investigations have been undertaken for a variety of river and creek systems including the larger coastal rivers and stream and channels in inland NSW. The contrasting characteristics of these streams and their floodplains led to the application of a modified methodology for floodway delineation which considered the variation in floodplain type.

The modified approach led to the refinement of the iterative process outlined in 2010 by Thomas et al [9]. The refinement involved the inclusion of an additional step that places greater emphasis on conveyance; more specifically consideration of the extent of floodplain that conveys 80% of the peak flow during the planning level flood.

## 2.2 A Practical Application of the Iterative Procedure

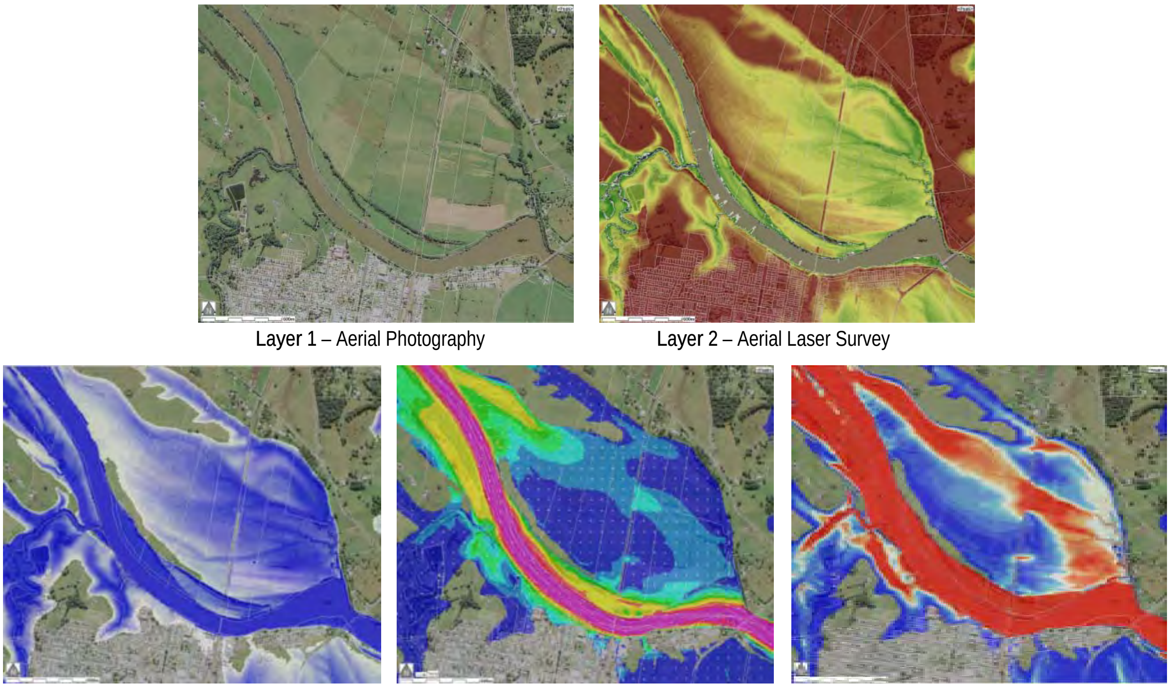
The practicality of applying the iterative procedure outlined by Thomas et al [9] was tested as part of investigations undertaken for the lower Hastings River. Specifically, the investigations sought to apply the iterative procedure to determine the alignment of floodway corridors along the lower Hastings and Maria River system.

The Hastings River is located along the Mid North Coast of NSW approximately 300 kilometres north of Sydney. The river drains a catchment of 3,700 $km^2$ and discharges to the Pacific Ocean at Port Macquarie. Flooding along lower Hastings River is influenced by a number of natural and man-made features such as the North Coast Railway, the Pacific Highway and numerous geological formations. The Maria River is the major tidal tributary joining the Hastings River approximately 10 kilometres upstream from the ocean entrance. Flooding of the Maria River is largely influenced by flood levels within the Hastings River and occurs due to the "backing-up" of floodwaters from the Hastings River confluence.

Although much of the floodplain is undeveloped, there is significant pressure for future development to occur within and adjacent to flood prone land. As a consequence, the reliable determination of floodway corridors is of importance to the community and to land use planning.

Application of the iterative procedure suggested by Thomas et al [?] requires specialist input from practitioners in order to interpret the available flood data (*i.e., flood modelling results*), floodplain geomorphology and hydraulic controls throughout the study area. The ability for practitioners to interpret this data is heavily reliant on the tools available to present and analyse them. In this case, the waterRIDE™ tool developed by WorleyParsons was employed.

A waterRIDE™ presentation package was developed for the lower Hastings River which combined all relevant inputs such as aerial photography, LiDAR, cadastral layers and modelling results for the planning level flood; i.e., the design 100 year ARI flood. The results for the 100 year ARI flood were presented as depth mapping, velocity mapping and mapping of the velocity-depth product. Each of these parameters were assigned as different 'layers', allowing efficient transition between the range of inputs. An example of each of these 'layers' for a sample location along the Hastings River is shown in **Figure 1**.



Layer 1 – Aerial Photography    Layer 2 – Aerial Laser Survey

Layer 3 – Depth Mapping    Layer 4 – Velocity Mapping    Layer 5 – Velocity-Depth Mapping

Figure 1 Example of waterRIDE Layers used as part of the Iterative Procedure

An initial estimate of the floodway corridor was plotted onto a hard copy plan of the study area based on an interpretation of each of the waterRIDE™ layers (*refer* **Figure 1**). Through completion of this process it became increasingly apparent that the velocity-depth mapping provided a reasonable initial estimate of the floodway corridor. At locations where a satisfactory level of confidence was not present, the remaining layers were interrogated in order to gain a better understanding. This typically involved answering the following questions:

- Is the velocity-depth product dominated by floodwater depths or velocities?
- Are there any structural features that would impact local floodwaters?
- Are all topographic features, such as crests and gullies, reliably represented in the flood modelling?

Although the layers shown in **Figure 1** were generally sufficient to determine an initial estimate of the floodway corridor, there were a number of locations where floodwater depth and velocity were relatively uniform over considerable expanses of floodplain; i.e., where there was little to no variation in parameters such as velocity or velocity-depth product. This resulted in uncertainty over the boundary between floodway and flood storage.

Although modelling of blockage scenarios or encroachment testing could be undertaken to determine the floodway corridor at these locations, the process of modelling is time consuming and costly. Accordingly, the potential to consider an additional flood or floodplain parameter was investigated.

### 2.3 Extension of the Iterative Procedure

Based on the definition of floodways as those areas where a significant volume of water flows during floods [1] it was considered that an additional parameter that could be considered is the distribution of floodwaters in terms of the volume of water conveyed. That is, the floodway corridor at any one cross-section across the floodplain should have the capacity to convey a '*significant*' percentage of the total flood discharge and volume.

While the velocity-depth product provides a measure of the unit flow per metre width, this only allows a discrete representation of flow at any one point. Although this provides a useful indicator on a local scale, it does not consider the total distribution of flow.

Therefore, mapping of the velocity-depth product in conjunction with the ability to extract the distribution of flow at any cross-section throughout the floodplain was considered to provide a more reliable understanding of both the localised concentrations of flow and the floodplain wide distribution of flow. Access to and an understanding of both allows practitioners to determine local flowpaths or '*localised floodways*' and also to determine the '*total*' floodway corridor (*which may be a combination of 'localised floodways'*).

In order to determine the percentage of flow that could be considered representative of the floodway corridor, the flow distribution was first determined for a section of the floodplain where the floodway corridor had been defined with confidence. Utilising the flow extraction tool available in waterRIDE™, peak flows were extracted along a number of cross-sections taken along the alignment of the "initial estimate" of the floodway corridor.

This process established that the corridor required to convey approximately 80% of the peak 100 year ARI flow correlated well with most of the other parameters that are relied upon to estimate floodway extent (refer Thomas et al [9]). Repetition of this process throughout other sections of the Hastings River returned a similar percentage.

Accordingly, it was concluded that for the lower Hastings River, the floodway corridor corresponded to that section of the floodplain that is required to convey approximately 80% of the total flow during the planning level flood.

With this in mind, those locations of the floodplain where uncertainty existed were re-visited and re-assessed based on a detailed investigation of the flow distribution. This involved extraction of the peak flows at a number of cross-sections across the floodplain, focusing particularly on determining the variation in peak flows across:

- Locations of distinct changes in velocity-depth product i.e., *to determine flows across areas of high and low velocity-depth product*; and
- Locations immediately upstream and downstream of hydraulic controls such as levees and bridges.

**Figure 2** shows an example of the flow mapping that was prepared for a sample location along the Hastings River. For the sample case shown, the distribution of flow was used to determine whether further investigation of the initial floodway estimate was required or whether blockage testing should be undertaken. Generally, no further investigations were considered necessary where the initial floodway estimate coincided with areas characterised by higher values of velocity-depth product and where the corridor was found to convey close to 80% of the total flow.

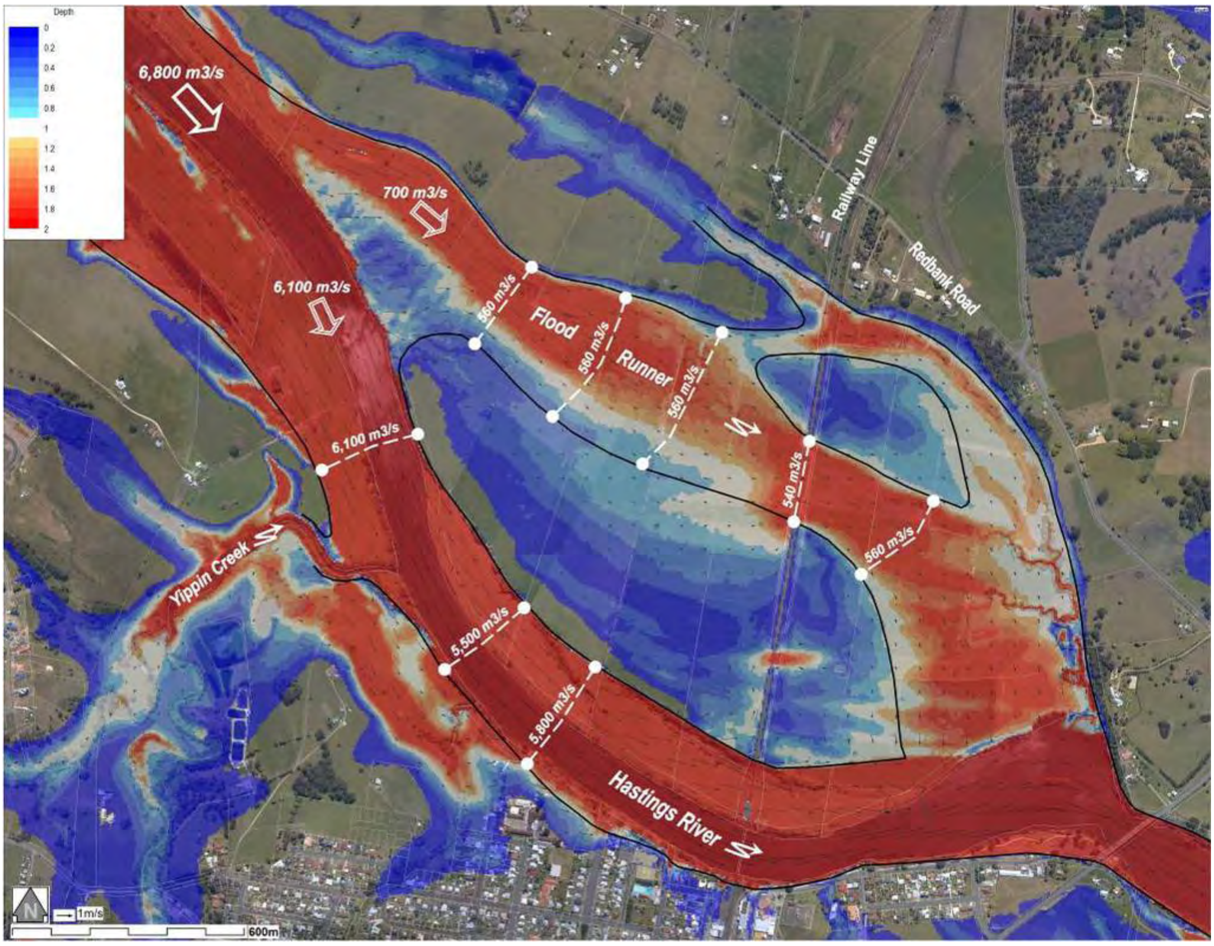



Figure 2 Example of Flow Distribution Mapping along the Hastings River

'*Blockage*' testing was undertaken throughout the study area for locations where further confidence was required due to either uncertainty inherent in the determination of the initial estimate of the floodway corridor or to gain further confidence at locations of existing development or at locations of potential future development.

Adjustments to the initial floodway estimate were then made in accordance with the flood level increases predicted from the '*blockage*' testing. Flood level increases of approximately 100 mm were considered to confirm the initial floodway corridor.

### 2.4 Conclusion

Application of the iterative procedure suggested in 2010 by Thomas et al [9] to determine floodway corridors along the Hastings and Maria Rivers was found to result in the determination of a reliable floodway corridor for much of the study area. This conclusion was made through rigorous testing of the floodway corridor which involved simulations to test numerous partial blockage scenarios. The flood level increases determined as a result of each blockage scenario were generally less than the upper bound value of 100 mm and thereby supported the proposed floodway alignment and the procedure adopted to determine it.

It is also important to note that identification of the extent of the floodplain required to convey 80% of the total flow served to refine the floodway extent and improve the confidence in the results of the analysis. It also allowed for a more reliable determination of floodway extent where floodwater depths and velocities are relatively uniform over considerable expanses of floodplain.

Analysis of the flow distribution and determination of the floodplain extent required to convey 80% of the total flow is considered to be a reliable procedure for assisting practitioners in determining floodway extents in complex areas of the floodplain. Furthermore, this criterion was found to be practical for ‘testing’ purposes where previously determined floodway corridors could be checked in terms of their potential flow conveyance.

## 3. APPLICATION OF THE 80% FLOW CRITERIA – SUCCESSFUL TEST CASES

In order to test the 80% flow “parameter” and determine whether it is a reliable criterion for floodway definition, the extended iterative approach described above was applied to a small creek system and to a low gradient inland river system. Each of these cases is discussed in the following sections.

### 3.1 Small Coastal Creek System

As a means of further testing the extended iterative approach described above, it was applied to a test section of Browns Creek at South Nowra. Two methodologies were adopted for this investigation, each considering a different set of parameters to characterise the floodway extent.

The two methodologies are:

- Method 1 - Determination of a preliminary floodway corridor based on analysis of velocities and velocity-depth product as key parameters.
- Method 2 - Determination of a preliminary floodway corridor based on mapping of the 80% flow corridor.

#### Method 1 – Preliminary Floodway Corridor Based on Velocities and Velocity-Depth Product

waterRIDE$^{TM}$ was used to present the variation in 100 year ARI velocity and velocity-depth product along the length of the test reach of Browns Creek. This mapping was based on the results of flood modelling undertaken for the ‘*Nowra and Browns Creek Flood Study*’ [11].

This mapping was used to generate an initial estimate of floodway corridor. The initial floodway corridor was characterised by the following parameters:

- Velocity-Depth product ≥ 0.5 $m^2/s$ (*refer* **Figure 3**); <u>and</u>,
- Section averaged velocity ≥ 0.5 m/s (*refer* **Figure 4**).

A third layer was prepared showing each of the above parameters for the range of values considered representative of the floodway corridor (*refer* **Figure 5**). Based on this mapping, an initial estimate of the floodway corridor was plotted as shown in **Figure 5**.

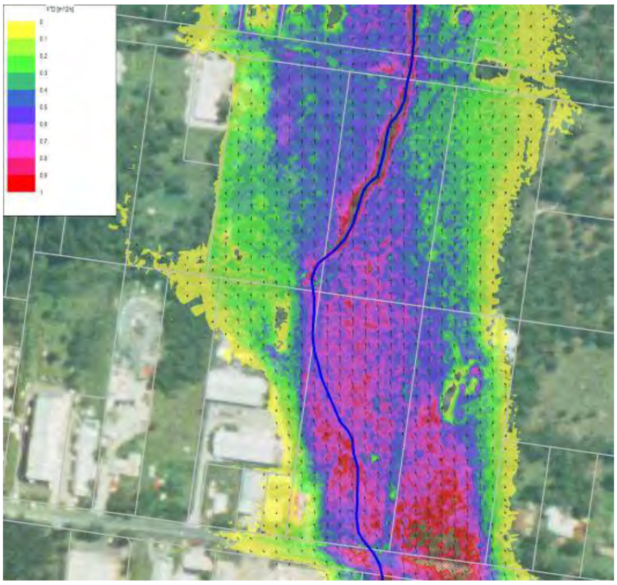


Figure 3 Variation in Velocity-Depth Product

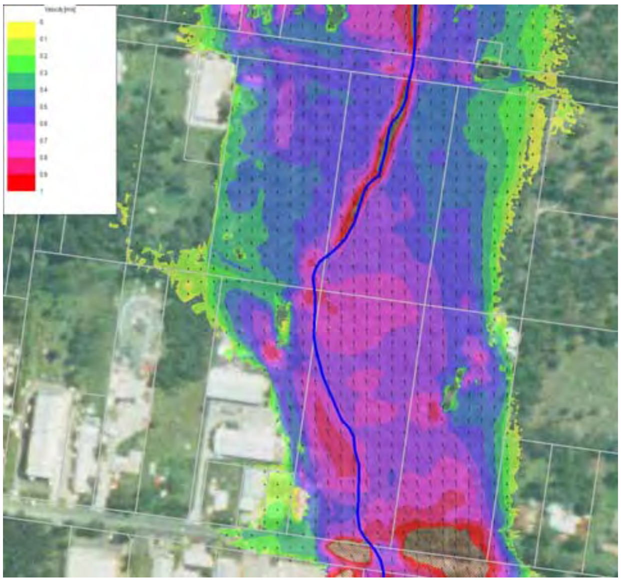


Figure 4 Variation in Velocity

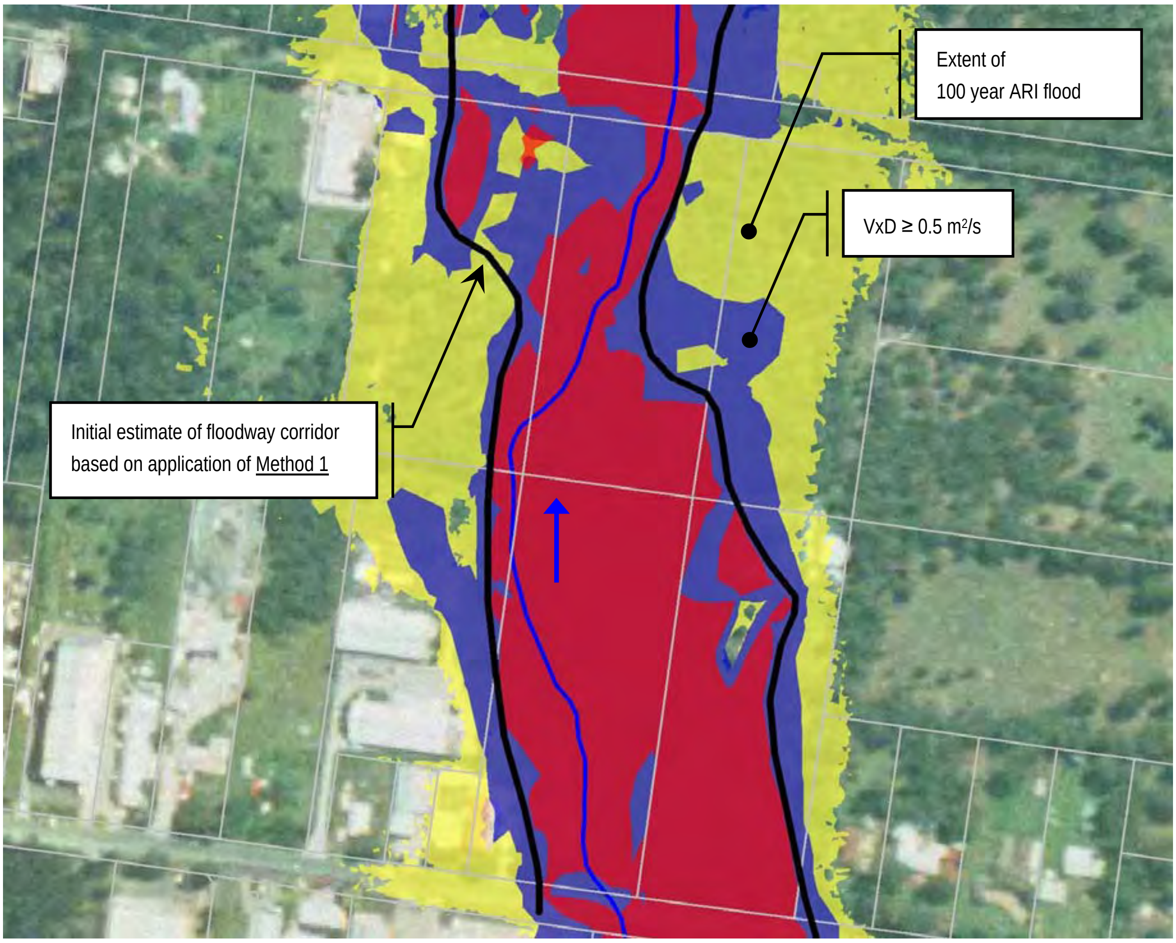



Figure 5 Initial estimate of floodway corridor based on the floodplain extent characterised by Velocities ≥ 0.5 m/s and VxD ≥ 0.5 m²/s

### Method 2 – Preliminary Floodway Corridor Based on Mapping of the 80% Flow Corridor

The flow extraction tool available in waterRIDE™ was used to extract flows from the 100 year ARI flood modelling results at each of a series of cross-sections positioned along the test reach of Browns Creek. As well as extracting the total flow along each cross-section, flows were also extracted along discrete sections of each cross-section. This allowed the distribution of floodwaters along each cross-section to be determined and in turn the determination of the floodplain extent predicted to convey 80% of the total flow.

The alignments of the cross-sections selected along the test reach of Browns Creek are shown in **Figure 6**. The initial estimate of the floodway corridor based on application of Method 2 is also shown in **Figure 6**. The floodway corridor determined through application of Method 1 is superimposed for comparative purposes.

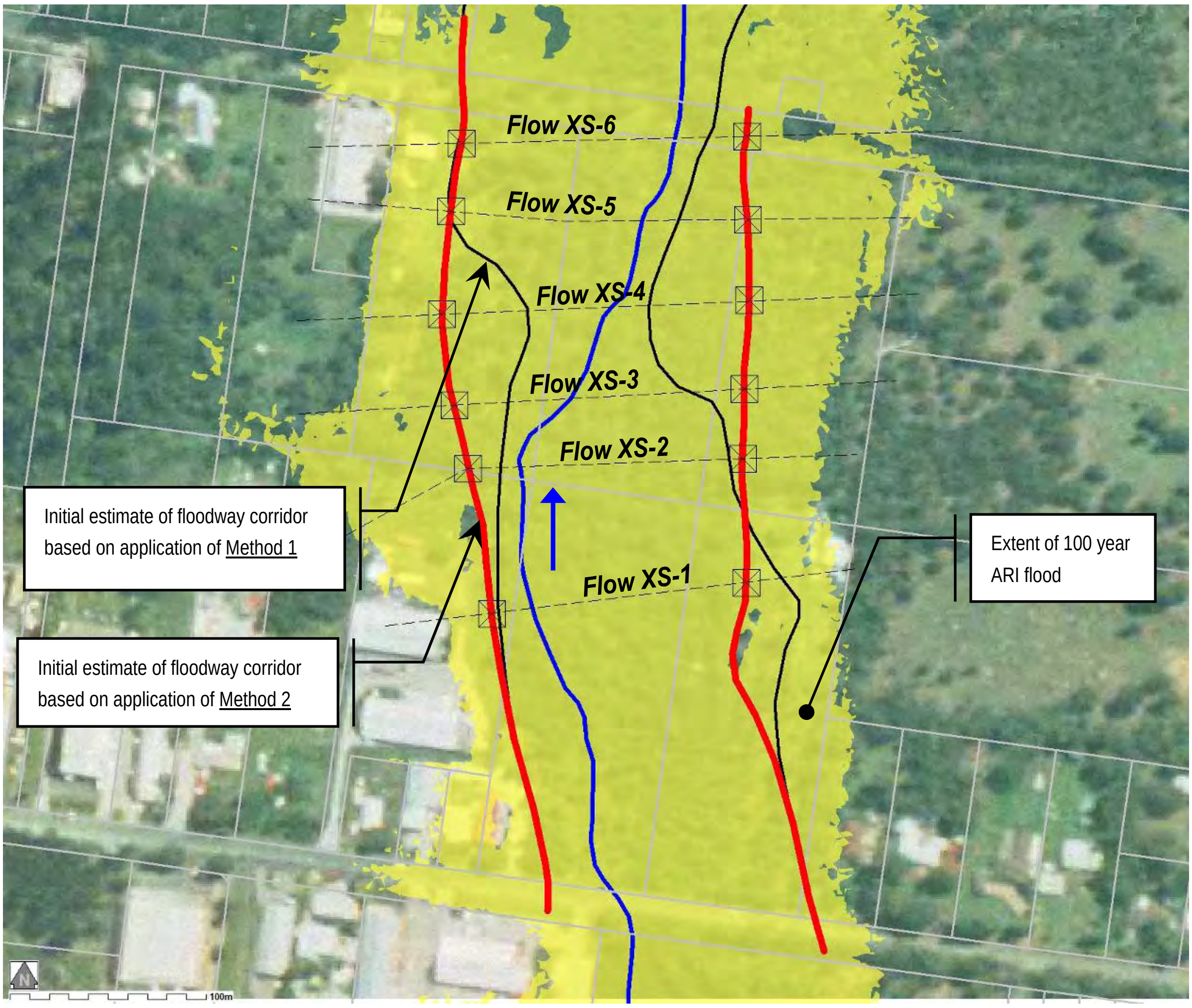



Figure 6 Initial Estimate of Floodway Corridor based application of Method 2

As shown in **Figure 6**, there is a substantial difference between the extents of floodway corridors towards the centre of the test reach. The wider floodway corridor predicted through application of Method 2 implies that consideration of velocities and velocity-depth alone does not provide a reliable indication of the flow conveyed or does not ensure a consistent percentage of the floodwaters are conveyed within the floodway corridor. This disparity would normally be detected during encroachment or blockage testing, which as discussed previously, can be time consuming and costly.

Therefore, the application of the 80% of flow criterion can result in a less costly delineation of the floodway.

### Encroachment Testing of Method 1 and Method 2 Floodway Corridors

Encroachment testing was undertaken for both of the floodway corridors determined through application of Method 1 and Method 2. The encroachment testing was undertaken by raising the terrain elevations along areas outside of the extent of the floodway corridor to a height above the peak 100 year ARI flood level. Therefore, under the encroachment scenarios no flow would travel through areas of the floodplain outside of the floodway corridors.

The predicted flood level increases for each of these encroachment scenarios are shown in **Figure 7** and **Figure 8**, for Method 1 and Method 2, respectively.

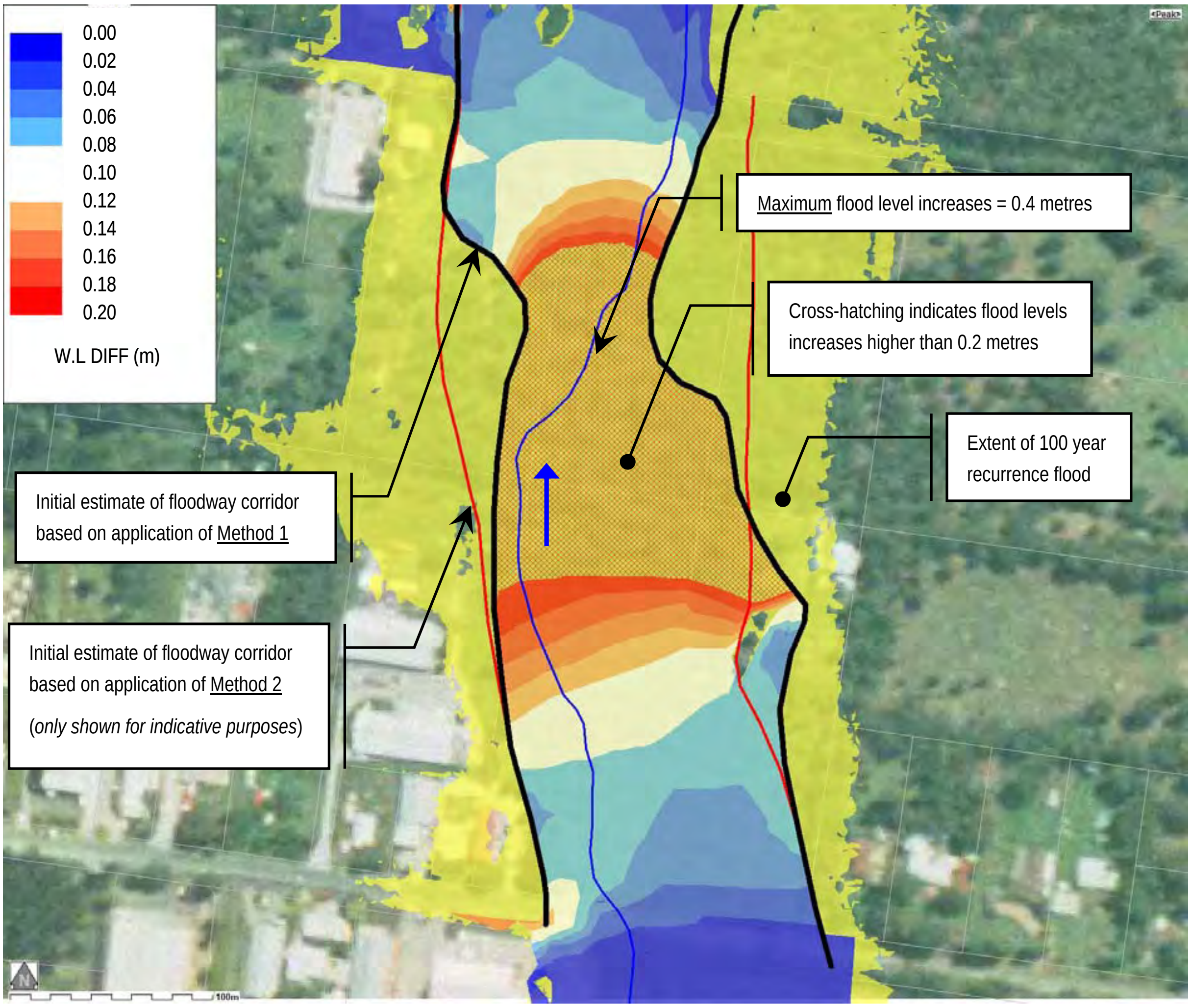



Figure 7 Results of Encroachment Testing undertaken for Floodway Corridor determined through application of Method 1

As shown in **Figure 7**, flood level increases associated with encroachment testing of the floodway corridor derived from Method 1 are generally greater than 0.20 metres. A maximum flood level increase of 0.40 metres occurs at the narrowest section of the floodway corridor at a location where '*necking*' of the floodplain causes floodwaters to 'back-up'. This highlights the importance of flow conveyance; i.e., that the corridor at this narrowest location was not sized to convey sufficient flow to prevent unacceptable upstream impacts (*greater than 100 mm*).

The flood level increases shown in **Figure 8** for the floodway corridor determined through application of Method 2 (*the 80% flow criterion*), are generally around 0.10 metres with the exception of some localised increases of up to 0.13 metres. These flood level increases are considered to be in line with the rule of thumb upper bound increase of 0.10 metres.

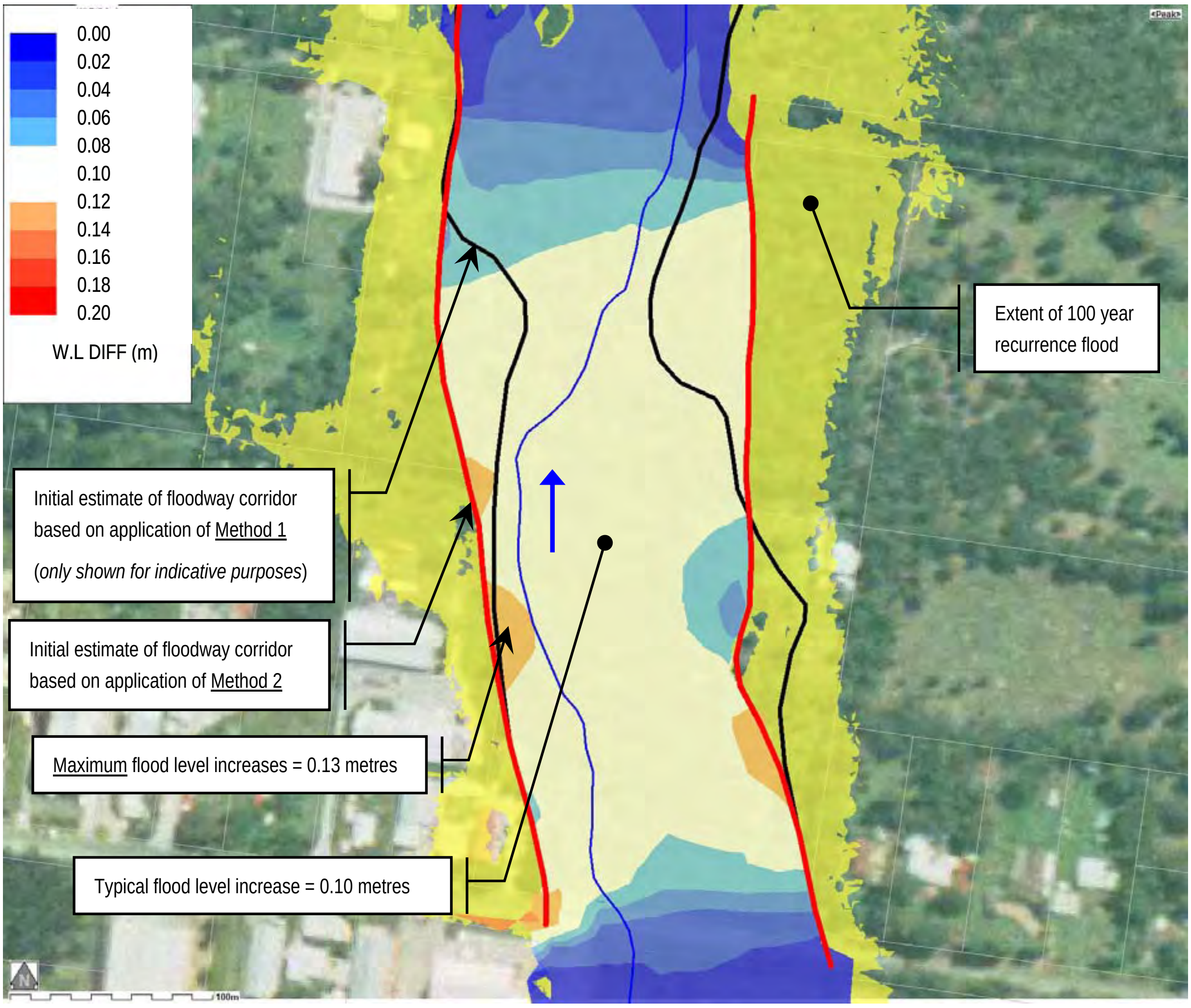



Figure 8 Results of Encroachment Testing undertaken for Floodway Corridor determined through application of Method 2

Comparison of the modelling results shown in **Figures 7** and **8** suggests that application of the 80% flow criteria will result in a more reliable representation of the floodway corridor than reliance on flow velocity or velocity-depth product. Notwithstanding, it is noted that both methodologies did provide similar floodway alignments along parts of the test reach.

## 3.1 Low Gradient Inland River Floodplain System

Floodway investigations undertaken along the Hastings River and for the test reach of Browns Creek found that consideration of the distribution of floodwaters, and more specifically the extent of floodplain predicted to convey 80% of the total flow, was a useful criterion that could be used to aid practitioners in their delineation of floodway extent.

This suggests that the 80% flow criterion should be applied as an additional step in the iterative procedure outlined in 2010 by Thomas et al [9]. This could result in less dependence on the velocity-depth product and could reduce the dependence on '*blockage*' and encroachment testing to resolve problem locations.

A revised version of the iterative procedure, taking into consideration the 80% flow criteria, was applied to a section of floodplain at Griffith in south-western NSW. The procedure was predominantly applied to the floodplain along Main Drain 'J', a man made earth-lined channel that was originally built to drain the agricultural areas east of Griffith.

Because of the complex nature of flooding within the Main Drain 'J' system, all of the following characteristics were considered as part of the process of developing an initial estimate of the floodway corridor:

- Location of flood storages that are readily identifiable from aerial photography.
- Location and potential impact of hydraulic controls and geomorphic features that could influence flood characteristics.
- Secondary drainage channels, which drain to Main Drain 'J'.
- Variation in peak flow velocity.
- Distribution of flow across the floodplain ~ 80% flow criteria.
- The impact of flood events rarer than the 100 year recurrence flood event.
- Testing of the floodway corridor using selective encroachment / blockage investigations.

Because of the very flat floodplain and gentle longitudinal slope along Main Drain 'J', flooding during the 100 year ARI flood is characterised by relatively low flow velocities and shallow depths of flooding. For example, in-channel velocities do not typically exceed 0.8 m/s, and overbank flows rarely travel at velocities greater than 0.2 m/s.

In addition, due to the flat terrain no obvious flood storages were able to be identified from aerial photography. Also, the limited variation in flow velocity across overbank areas did not provide a significant measure for floodway definition.

Due to these constraints, the initial assessment of floodway corridors was undertaken based on a combination of the distribution of flows and the <u>variations</u> in velocity-depth product. Two figures showing the variation in velocity-depth product along a test section of Main Drain 'J' are shown in **Figures 9** and **10**.

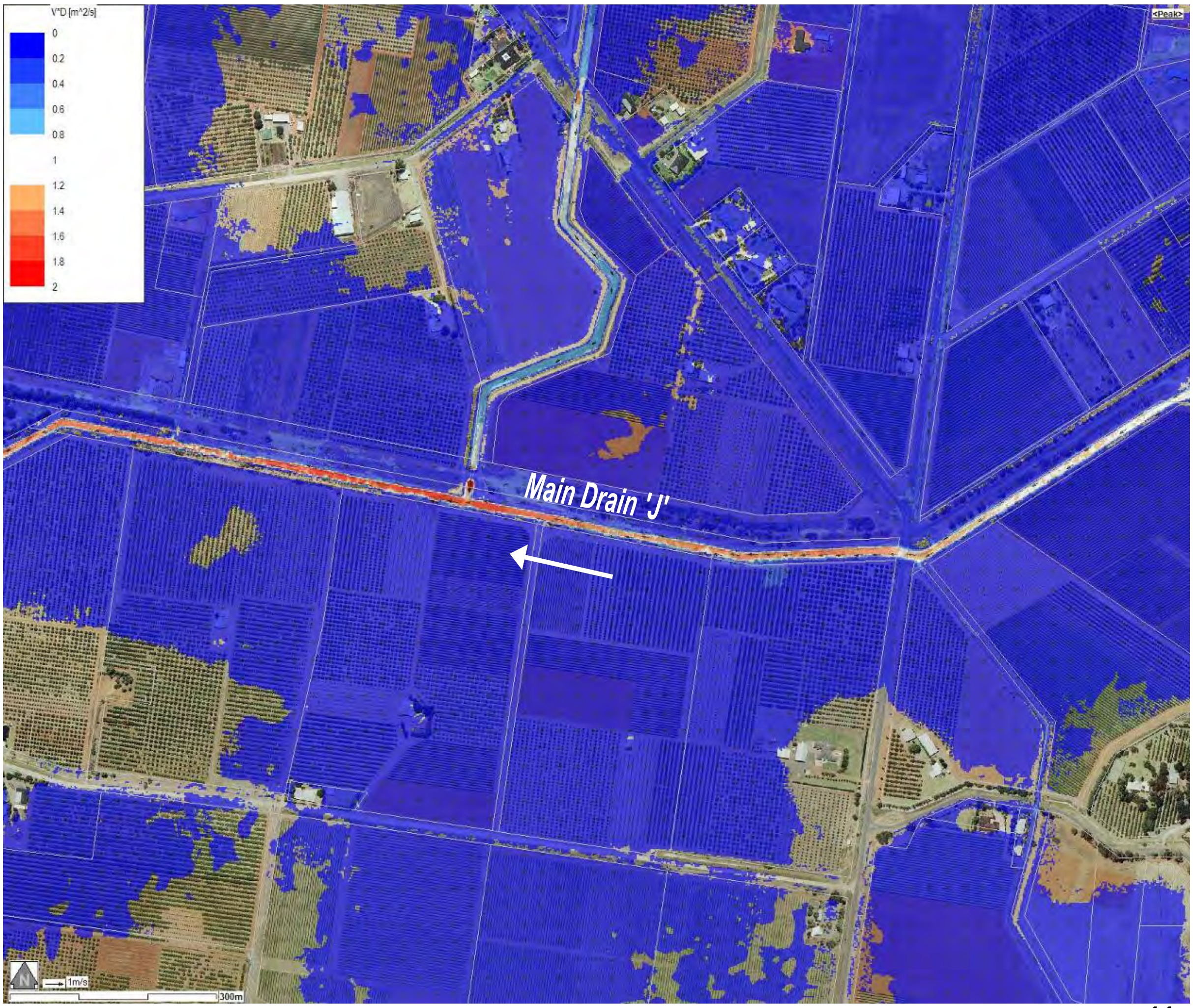



Figure 9 Velocity-Depth Mapping across the Main Drain 'J' floodplain – Range relative to in-channel values

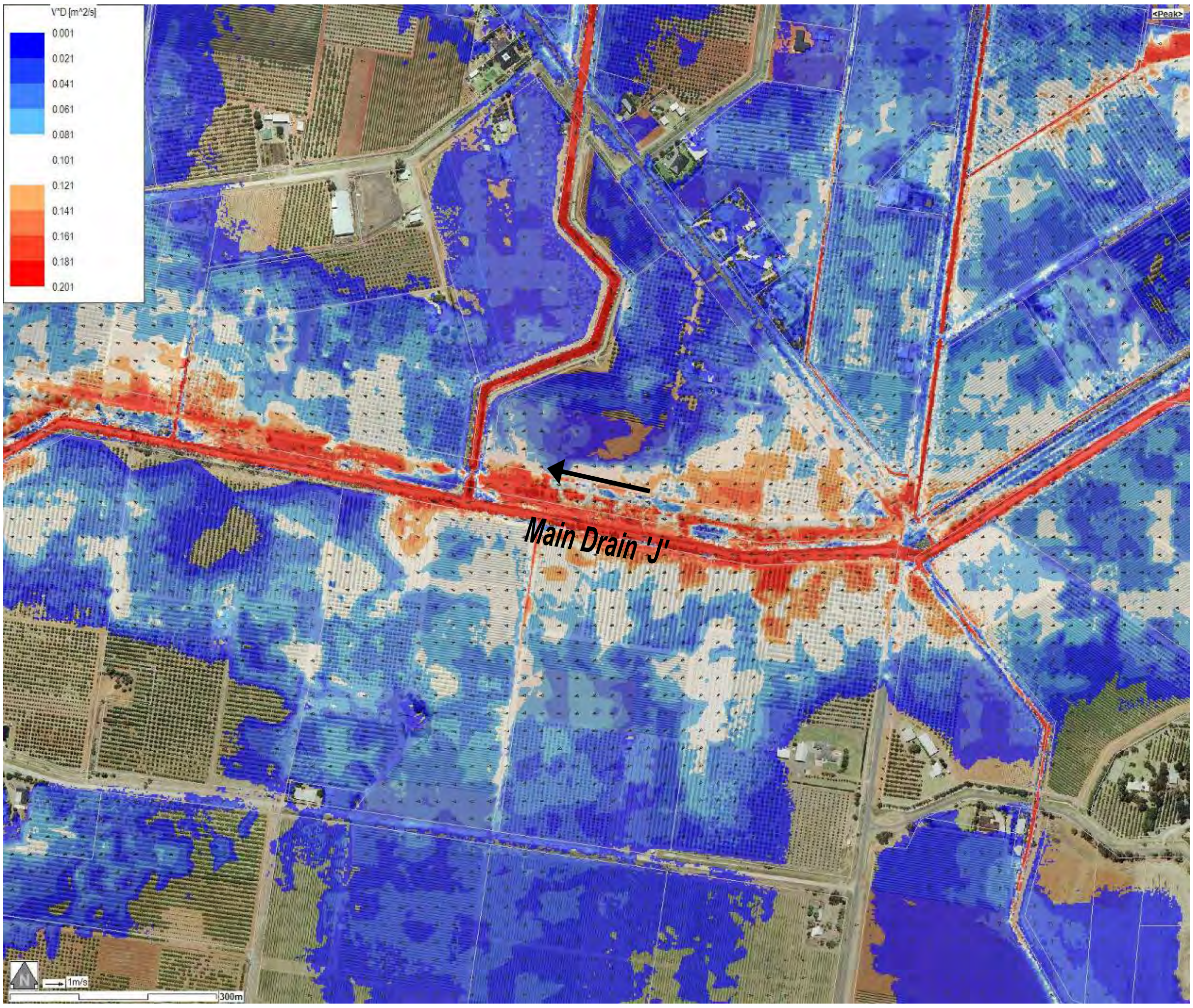



Figure 10 Velocity-Depth Mapping across the Main Drain 'J' floodplain – Range relative to values of velocity-depth across floodplain areas

**Figure 9** shows the variation in the velocity-depth product across the floodplain based on selection of a scale relative to the values representative in the main channel (*where the VxD product is as high as 2.2 $m^2/s$*). The lack of colour variation along floodplain areas highlights the very low range of velocity-depth values in overbank areas. As shown by the scale at the top-left hand corner of **Figure 9**, the dark blue shading represents velocity-depth values of no greater than 0.2 $m^2/s$.

**Figure 10** shows the variation in the velocity-depth product across the floodplain based on selection of a scale relative to the values representative along overbank areas of the floodplain (*where the VxD product does not typically exceed 0.3 $m^2/s$*). The scale adopted for the mapping shown in **Figure 10** was selected for the purposes of mapping out the initial estimate of the floodway corridor.

Assessment of the flow distribution within the Main Drain 'J' network revealed that only a small proportion of flow is conveyed in-channel during the peak of the 100 year ARI flood event. In addition, as a consequence of the flat topography, flow is in most areas, evenly distributed across the floodplain. As a result, it is difficult to determine those sections of the floodplain that are conveying concentrated flows.

Notwithstanding, the Flow Extraction tool available in WaterRIDE™ was used once again to determine the flow distribution across flooded areas.

The following findings were made during this process:

- The 80% flow criterion is suitable for determining a provisional floodway extent for areas of the floodplain where flow distribution was not overly uniform and distributed. i.e., *where differences between velocities and velocity-depth product were less discernible*.
- Comparison of the 80% flow extent indicated a correlation with a velocity-depth product of approximately 0.1 $m^2/s$ or higher.
- Assessment of floodplain topography (*LiDar*) and locations of hydraulic controls was important along locations of the floodplain where flow distribution was less discernible.

The alignment of flow cross-sections that were adopted along a test section of Main Drain 'J' are shown in **Figure 11**. The initial estimate of the floodway corridor is also shown.

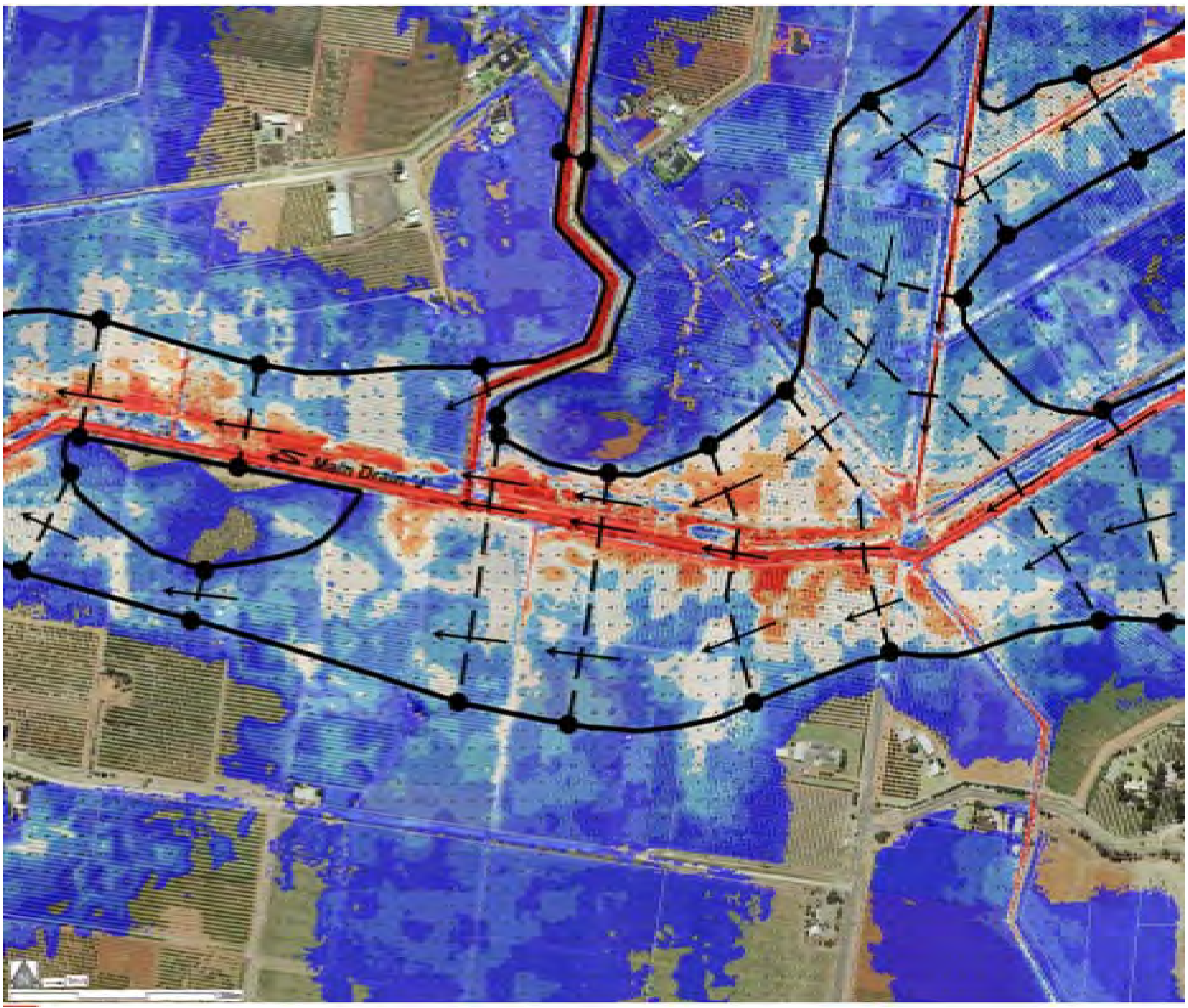


Figure 11 Preliminary floodway corridor and flow cross-sections along a sample extent of the Main Drain 'J' floodplain

## 4. CONCLUSIONS

### 4.1 Discussion

Thomas et al in 2010 [9] proposed an iterative approach to floodway delineation that considered a range of floodplain criteria and floodwater characteristics. The approach recognised the difficulties inherent in floodway delineation due to the variability in floodplain type. For example, the floodplains of coastal NSW river systems are typically hydraulically steep in which areas of high velocity or high velocity-depth product may be indicative of floodway extent. In contrast, inland streams are characterised by extremely flat floodplains and low gradient channels. Velocity-depth product in these systems may also be indicative of floodway extent, but will invariably be much lower than for coastal NSW systems.

This issue can be overcome by validating initial estimates of floodway extent by modelling encroachment scenarios to test the impact of floodway blockage. The principle here is to partially block the floodway corridor and establish whether the associated blockage causes an unacceptable increase in upstream flood levels. The rule of thumb has been to assume that the maximum acceptable encroachment and therefore floodway extent, should be such that upstream flood level increases in the 100 year ARI event are no greater than 100 mm.

This is relatively straightforward in streams where the floodwaters exhibit relatively one-dimensional characteristics, but is more problematic for major river systems or flat floodplains where off-channel storages exist. The floodplains of the larger coastal rivers typically have well defined estuarine backwater areas which serve as significant flood storages. Similar could be said of many of the rivers of western NSW, which are often characterised by effluents that connect the main channel to enormous off-channel storages.

Hence, it is difficult to apply the encroachment approach referred to above in these much larger systems. In such systems, modellers are also presented with the dilemma of determining how to simulate blockage without effectively removing the flood storage and skewing the impact. These issues mean that encroachment scenarios modelling can be expensive and time consuming.

Similarly, the application of a velocity-depth product approach has limitations in the larger floodplains where the velocity-depth product is dominated by depth. A rudimentary application of the velocity-depth approach where large storage areas exist could lead to these areas being identified as floodways when in fact they are not. This of course can be overcome by considering flow velocity in tandem with velocity-depth product, but this serves to introduce another parameter in the process which can complicate such an assessment.

The outcomes of recent investigations (*as documented in this paper*) indicate that the iterative process previously proposed should be refined to include a step that involves the identification of the proportion of the floodplain that carries approximately 80% of the 100 year ARI flow. In some situations the identification of this “extent” and its combination with other floodplain characteristics and flood data will negate the need for encroachment scenario testing.

### 3.2 Preferred Approach

The analysis discussed in the preceding sections highlights the difficulties associated with selecting an appropriate methodology for determining floodway extent. It also highlights the importance of different floodplain types. The examples presented involve reaches of river and creek systems that range between large coastal systems (*see Section 3.1*) to relatively one-dimensional systems (*see Section 3.2*). An example was also presented for a man-made agricultural channel located at south-west NSW (*see Section 3.3*).

While the assessment of floodways remains the domain of experienced practitioners with the skills to holistically evaluate the physical features of the floodplain and all available hydraulic / flood modelling outputs, there appears to be a more rigorous methodology that can be employed to ensure reliable outcomes for floodway delineation. This methodology involves an iterative approach that considers:

- section averaged velocity in the planning level flood at both the peak and on the rising limb of the hydrograph
- <u>the variation in velocity-depth product</u> for the planning level flood
- topographic and geomorphic features along the floodplain
- hydraulic controls such as structures that cause backwater effects
- <u>flow conveyance</u> and the distribution of flow – specifically the extent of floodplain required to carry approximately 80% of the total flow
- the results of hydraulic analysis and / or flood modelling that incorporates encroachment or blockage scenarios similar to that outlined above for Method 2.








# APPENDIX D – MUSIC MODELLING PARAMETERS

## MAJOR POND SYSTEM

**TABLE D.1 – MAJOR POND SYSTEM – GENERAL FEATURES & CONFIGURATION**

| Storage Properties | Pond B5 | Pond B7 |
|---|---|---|
| Surface Area ($m^2$) | 24000 | 24500 |
| Extended Detention Depth (m) | 0.3 | 0.3 |
| Permanent Pool Volume ($m^3$) | 24000 | 24500 |
| Seepage loss (mm/hr) | 0 | 0 |
| **Outlet Properties** | | |
| Equivaluent Pipe diameter (mm) | 147 | 149 |
| Overflow Weir Width (m) | 2 | 50 |
| Notional detention time (hr) | 72.5 | 72.1 |

The expected sediment and nutrient removal performance of the pond system was determined using the default equations and parameters provided in the MUSIC model. The water quality reduction mechanisms in MUSIC are based on an exponential decay equation referred to as the k – C* curve

The viability of the pond and the longevity of its pollutant removal efficiency is dependent on the capacity of the pre-treatment GPTs to intercept and remove light litter, detritus and coarse sediment.

A summary of the estimated performance of the pond system is detailed in Section 12 of this report, and the configuration is indicated on the attached Preliminary Engineering Concept drawing for the pond. (Refer to Appendix E).

Once the catchment upstream of the pond is stabilised, maintenance would generally involve plant replacement, weed control, repair of localised erosion and minor structural damage and the removal of localised sediment build-up. This would be undertaken on a quarterly basis on average with vegetation replacement budgeted for on a decadal cycle.

**Rainfall Data**

The MUSIC model is able to utilise rainfall data based on 6 minute, hourly, 6 hourly and daily time steps. A 6 minute time step was used in the analysis which was chosen in accordance with the recommendations for selecting a time step within the MUSIC User's Manual.

Rainfall records for the area were obtained from the Bureau of Meteorology. The nearest rainfall station to the site with a reasonable period of 6 minute rainfall data for a suitably representative period of rainfall for the site was Richmond:

| Station No | Location | Years of Record | Type of Data |
|---|---|---|---|
| 67033 | Richmond | 1980 - 1990 | 6 minute |

The mean annual rainfall in the data set used in the modelling is 831mm, while the mean annual rainfall for Richmond is 802mm. The rainfall and potential evapo-transpiration data for the period analysed is shown on the graph which is provided in Plate D.1.

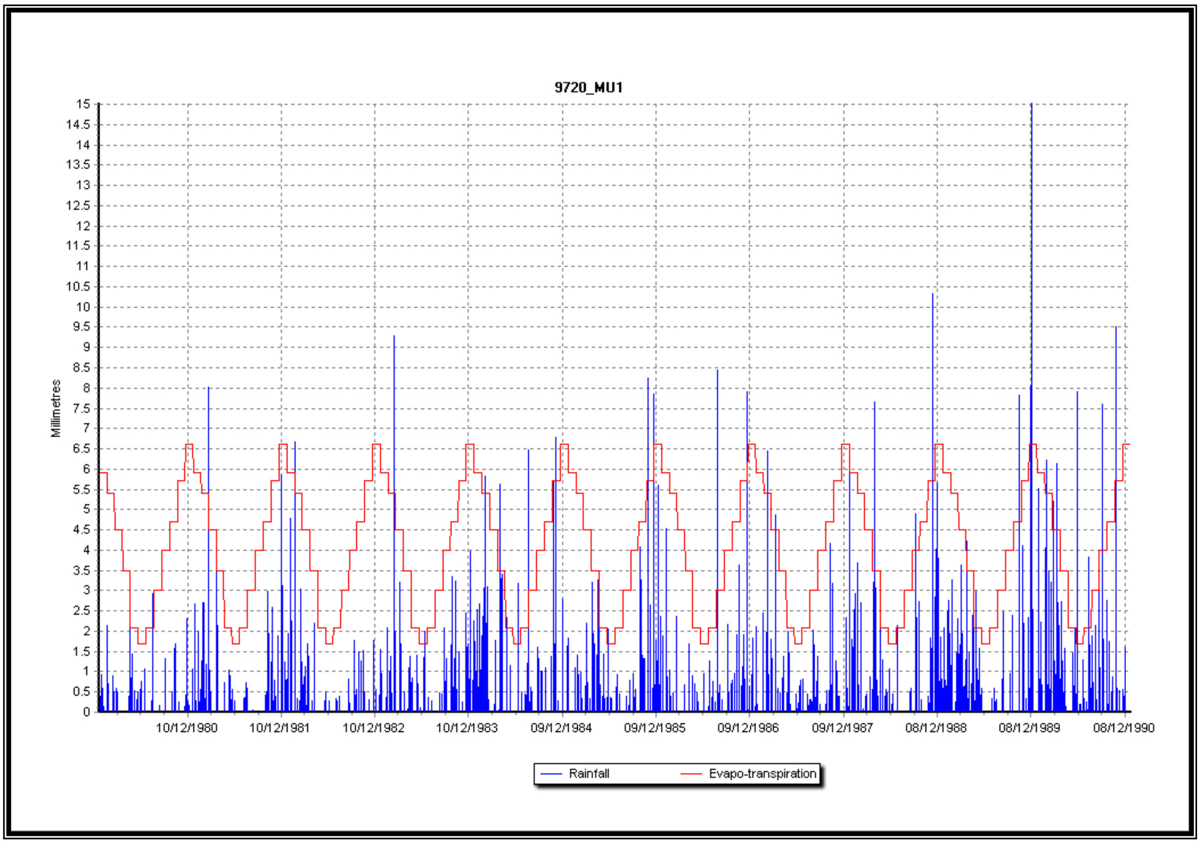



**PLATE D.1 – RAINFALL & EVAPO-TRANSPIRATION DATA ADOPTED FOR LUDDENHAM**

A summary of the rainfall data set (Richmond 1980 – 1990) used in the MUSIC model for Sydney Science Park and comparable rainfall data sets provided by the Bureau of Meteorology rainfall station gauge at nearby Badgery's Creek is shown below in Table D.3.

**TABLE D.3 - SUMMARY OF RAINFALL DATA FOR THE SITE**

| Property | MUSIC Model Data Set - Richmond (1980 - 1990) | Bureau of Meteorology Data (Badgery's Creek) |
|---|---|---|
| Mean Yearly Rainfall (mm) | 831 | 790.1 |
| Decile 1 Rainfall (mm) | 474 | 427.2 |
| Decile 5 Rainfall (mm) | 843 | 770.7 |
| Decile 9 Rainfall (mm) | 1086 | 1142.6 |
| Mean No. Rain Days | 126 | 80.5 |
| Mean No. Rain Days > 1 mm | 76 | 65.2 |
| Mean No. Rain Days > 10 mm | 25 | 22.3 |
| Mean No. Rain Days > 25 mm | 9 | 8.4 |

## Soil / Groundwater Parameters and Pollutant Loading Rates

In the absence of site specific data, the soil / groundwater parameters and pollutant loading rates adopted for the natural and urban catchments of Sydney Science Park, were based on the recommended parameters provided by the Department of Environment and Climate Change for areas within Western Sydney and the Cooperative Research Centre for Catchment Hydrology The adopted parameters are presented in Tables D.4 and D.5.

**TABLE D.4 - ADOPTED SOIL / GROUNDWATER PARAMETERS**

| Property | Units | Urban |
|---|---|---|
| **Impervious Area Parameters** | | |
| Rainfall Threshold (Roof 0.5, Road 1) | mm/day | 1.4 |
| **Pervious Area Parameters** | | |
| Soil storage capacity | mm | 170 |
| Initial storage | % of capacity | 30 |
| Field capacity | mm | 70 |
| Infiltration capacity coefficient - a | | 210 |
| Infiltration capacity coefficient - b | | 4.7 |
| **Groundwater Properties** | | |
| Initial Depth | mm | 10 |
| Daily Recharge rate | % | 50 |
| Daily Baseflow Rate | % | 5 |
| Daily deep seepage rate | % | 0 |

**TABLE D.5 - ADOPTED EVENT MEAN CONCENTRATIONS (Source: CRCCH)**

| | Roofs | | Roads | | Remaining Urban | |
|---|---|---|---|---|---|---|
| Pollutant | Base Flow (mg/L) | Storm Flow (mg/L) | Base Flow (mg/L) | Storm Flow (mg/L) | Base Flow (mg/L) | Storm Flow (mg/L) |
| TSS | - | 20.0 | - | 269 | 15.8 | 141 |
| TP | - | 0.129 | - | 0.501 | 0.141 | 0.251 |
| TN | - | 2.00 | - | 2.19 | 1.29 | 2.00 |

### Treatment Device Performance

Each element of the series of treatment practice (commonly referred to as a treatment train), as represented in the MUSIC model for Sydney Science Park, is described below.

### Litter and Sediment Control Structures

Drainage systems collecting runoff from local roads and hardstand areas, throughout Sydney Science Park, have been modelled with Gross Pollutant Traps (GPTs) to remove litter and coarse sediment prior to discharge into the downstream drainage systems, bio-retention raingardens and riparian corridors. GPTs are available as inlet pit filter inserts, purpose built cast in situ systems or precast proprietary traps using either dry or wet sump storage chambers.

The criterion, used to assess the performance of the GPTs in the MUSIC model, was based on the credit given a proprietary CDS Unit (TSS removal 70 % of inflow concentrations greater than 75 mg/L and TP removal for inflow concentrations greater than 0.5 mg/L). No credit was given to the GPTs capacity to remove oils, other nutrients or metals. However, if required it is possible to incorporate oil skimming or oil absorbent materials within a wet sump GPT for the purpose of removing non-emulsified, free floating oils.

Multiple GPTs have been considered at certain basin locations in order to suit the masterplan layout. It is expected that the site drainage strategy would require approximately twenty four (24) major GPTs (at least one per bio-retention, wetland or pond and at road connections into trunk drainage systems).

Wherever possible, dewatering systems should be provided to facilitate de-watering of the wet sumps. These dewatering lines must be discharged to the raingardens or some other appropriate filtration system to allow nutrients and fine particulates to be stripped out of the supernatant water. The approximate locations of the proposed GPT units are indicated on Figure 12.1.

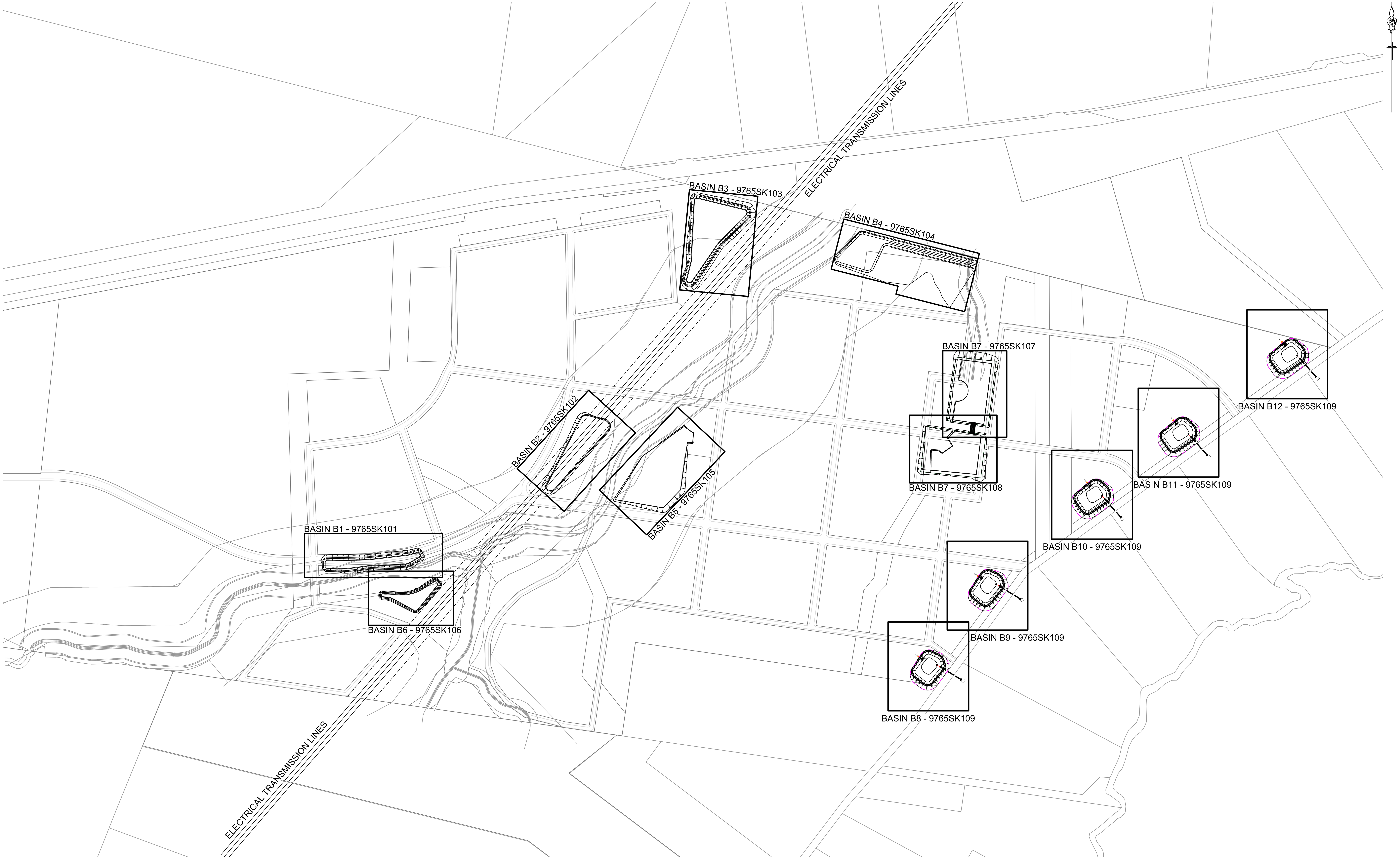







# APPENDIX E – PRELIMINARY ENGINEERING CONCEPTS AND ESTIMATE OF QUANTITIES

APPENDIX E




1:5000 (AT A1)

100 50 0 50 100 150 200 250 300 350 400 450 500

METRES

CLIENT:

APP

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BASIN SETOUT PLAN

PLAN No: 9765/SK100 A

FILE No: 9765SK100

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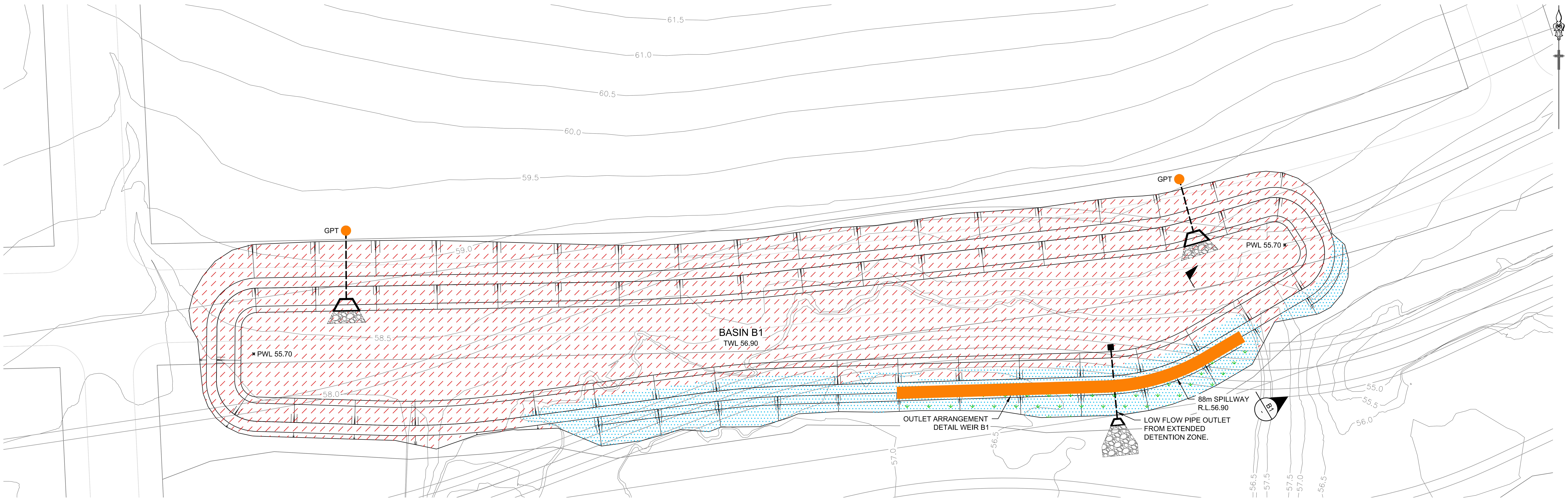
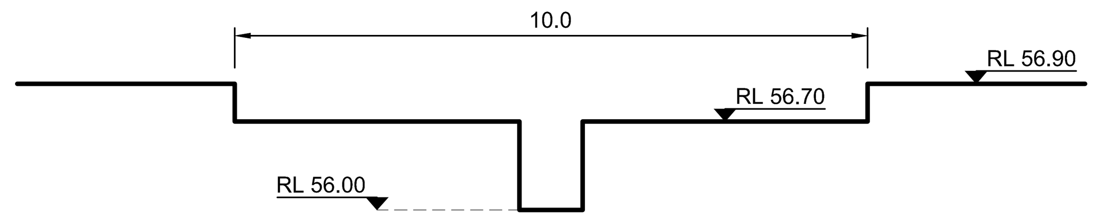



WEIR B1 DETAIL
NTS

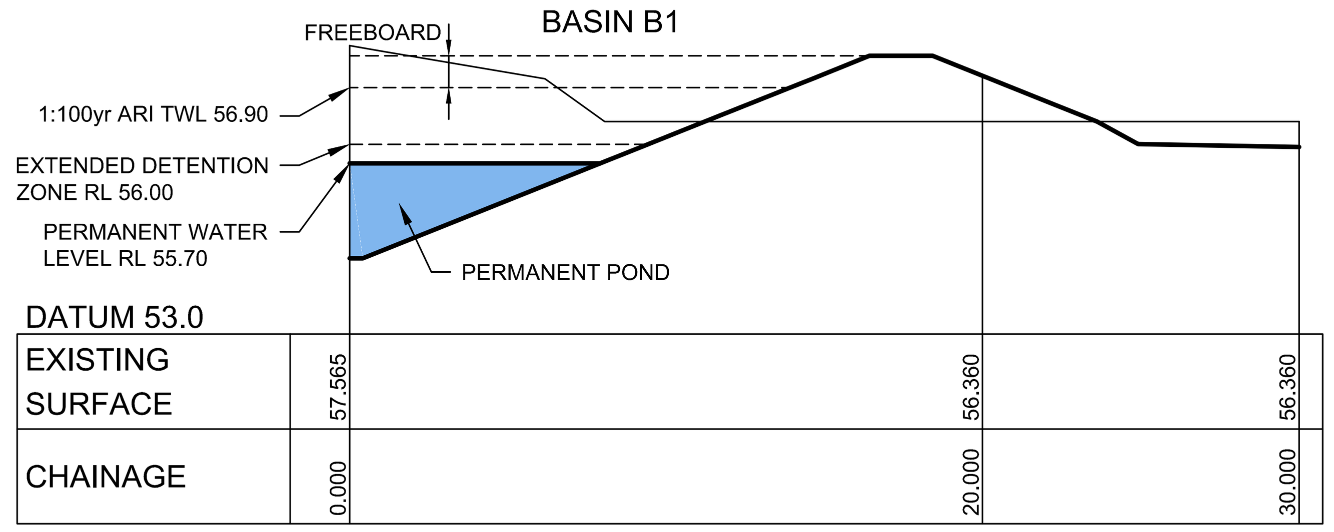
## LEGEND

- EXTENT OF CUT
- EXTENT OF FILL
- OSD BASIN WEIR/SPILLWAY
- REINFORCED TURF
- ROCK SCOUR PROTECTION
- STORMWATER DRAINAGE LINE
- GPT — GPT AND OUTLET
- —SS—SS— SUBSOIL DRAINAGE LINE
- LEVEL SPREADER
- FLOW SPREADER
- -28.00- DESIGN CONTOURS
- 28.00 EXISTING CONTOURS
- RETAINING WALL

## BASIN SUMMARY TABLE

| BASIN NAME | B1 |
|---|---|
| OSD STORAGE VOLUME ($m^3$) | 6500 |
| WETLAND AREA ($m^2$) | 5100 |
| CUT ($m^3$) | -16120 |
| FILL ($m^3$) | 1100 |
| POND VOLUME ESTIMATE ($m^3$) | -5200 |
| BALANCE ($m^3$) | -20220 |
| DISTURBED AREA ($m^2$) | 13300 |

NOTES:
- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
- NO ALLOWANCES HAVE BEEN MADE FOR TOPSOIL STRIPPING OR REPLACEMENT.
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.




LONGITUDINAL SECTION B1
HORIZONTAL SCALE 1:200
VERTICAL SCALE 1:100

1:100 (AT A1) 2 1 0 1 2 3 4 5 6 7 8 9 10 METRES
1:200 (AT A1) 4 2 0 4 8 12 16 20 METRES
1:500 (AT A1) 10 0 10 20 30 40 50 METRES

| | | | | | | |
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PLAN No: 9765/SK101 A
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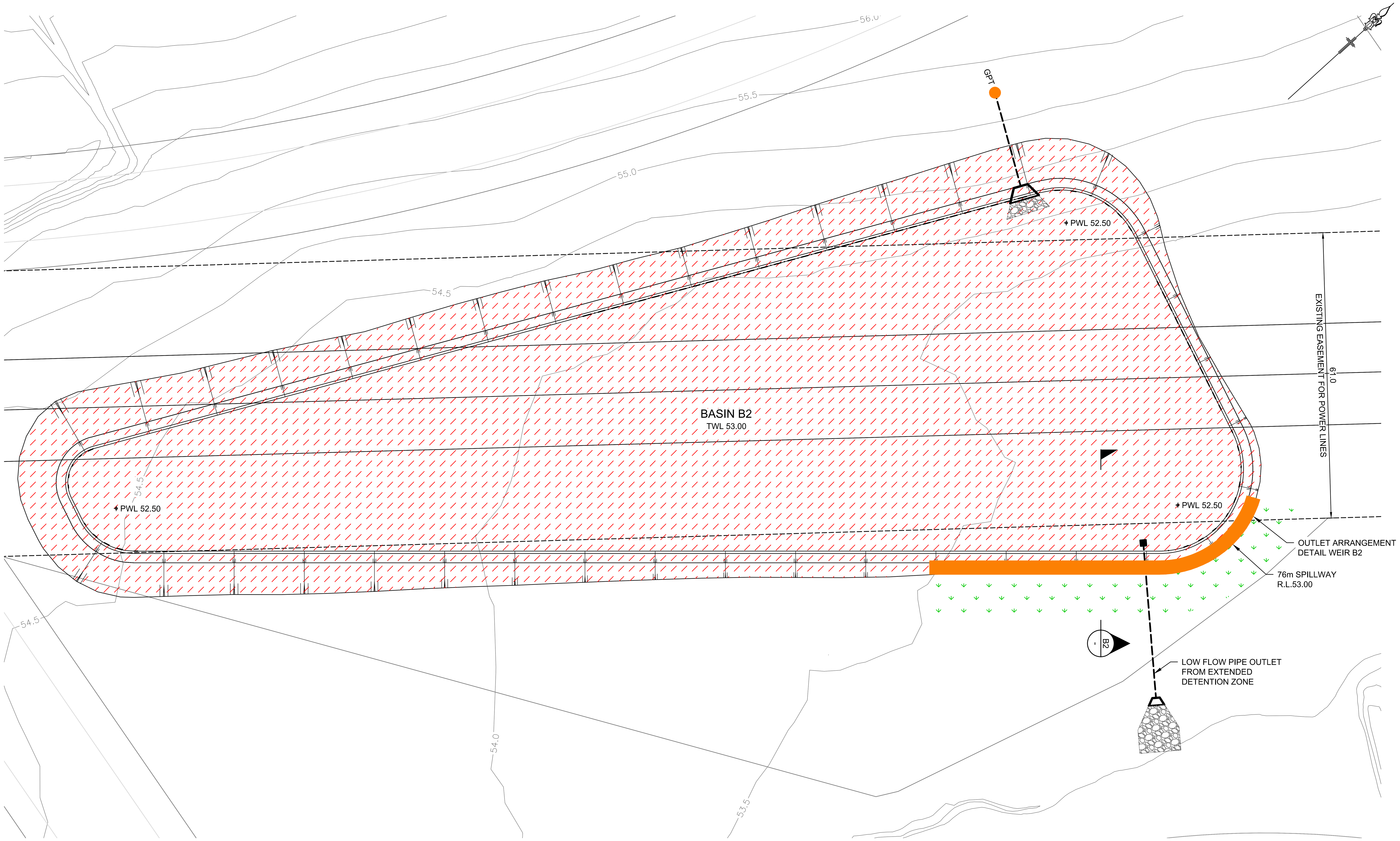
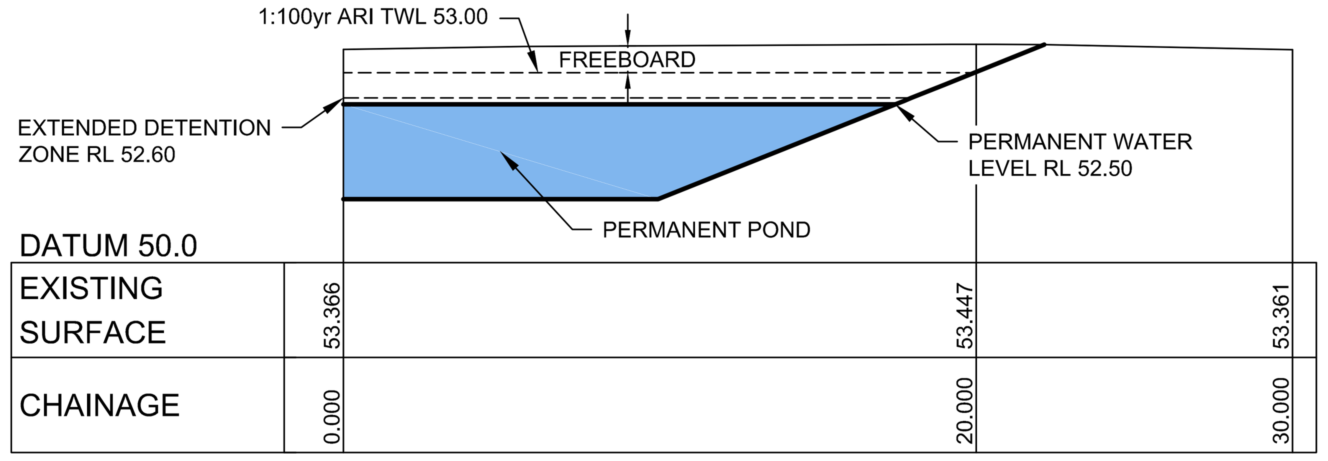



## LEGEND

- EXTENT OF CUT
- EXTENT OF FILL
- OSD BASIN WEIR/SPILLWAY
- REINFORCED TURF
- ROCK SCOUR PROTECTION
- STORMWATER DRAINAGE LINE
- GPT — GPT AND OUTLET
- SS — SUBSOIL DRAINAGE LINE
- LEVEL SPREADER
- FLOW SPREADER
- 28.00 — DESIGN CONTOURS
- 28.00 — EXISTING CONTOURS
- RETAINING WALL

## BASIN SUMMARY TABLE

| BASIN NAME | B2 |
|---|---|
| OSD STORAGE VOLUME (m³) | 5300 |
| WETLAND AREA (m²) | 12400 |
| CUT (m³) | -19800 |
| FILL (m³) | 0 |
| POND VOLUME ESTIMATE (m³) | -16275 |
| BALANCE (m³) | -36075 |
| DISTURBED AREA (m²) | 17150 |




LONGITUDINAL SECTION B2

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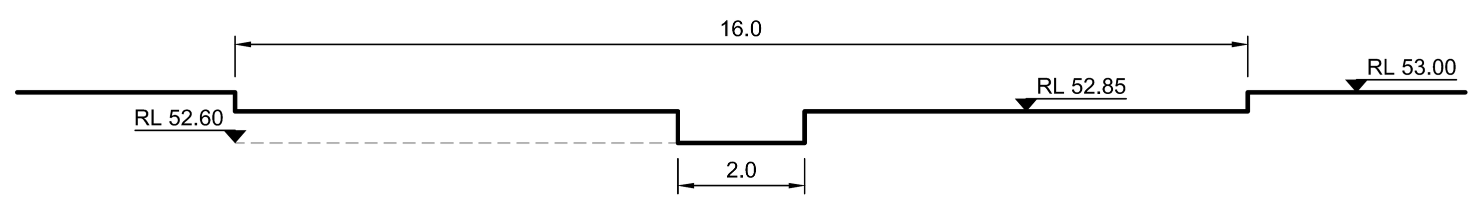
VERTICAL SCALE 1:100




WEIR B2 DETAIL

NTS

NOTES:

- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
- NO ALLOWANCES HAVE BEEN MADE FOR TOPSOIL STRIPPING OR REPLACEMENT.
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.

H 1:200 (AT A1) 4 2 0 4 8 12 16 20 METRES

V 1:100 (AT A1) 2 1 0 1 2 3 4 5 6 7 8 9 10 METRES

1:500 (AT A1) 10 0 10 20 30 40 50 METRES

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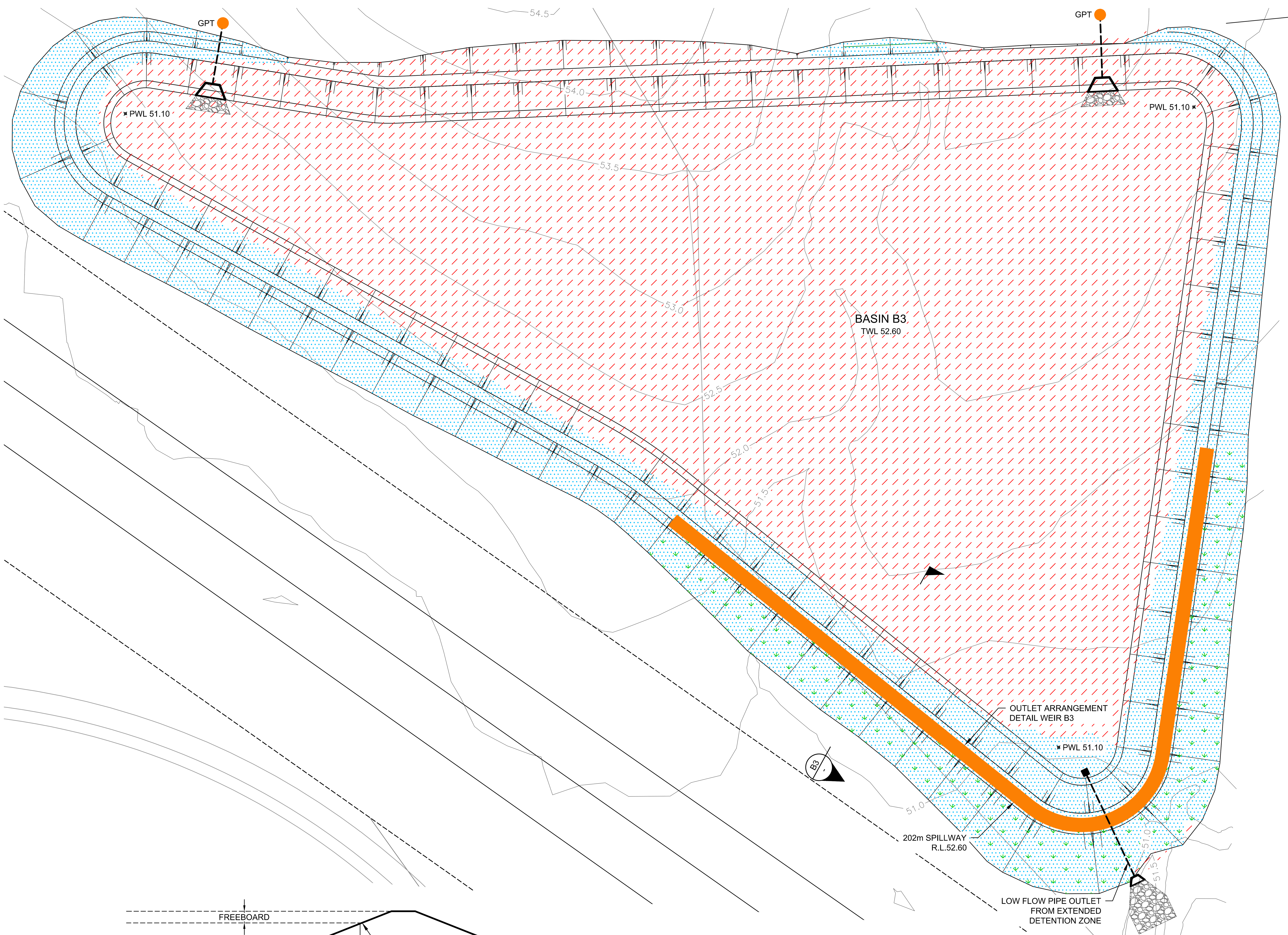
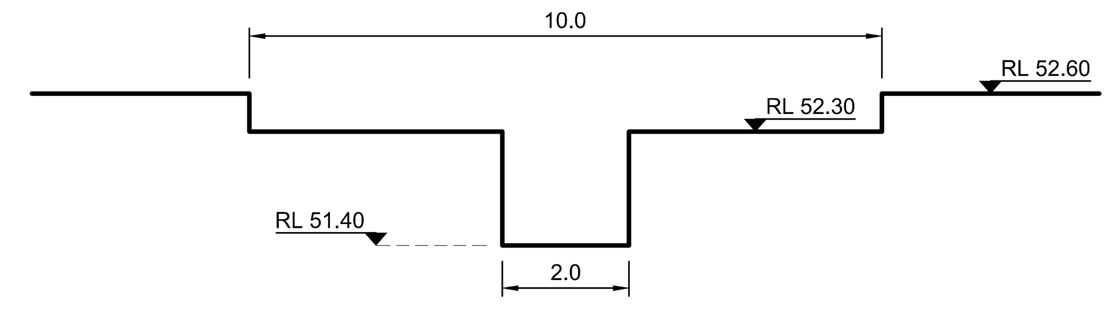



## LEGEND

- EXTENT OF CUT
- EXTENT OF FILL
- OSD BASIN WEIR/SPILLWAY
- REINFORCED TURF
- ROCK SCOUR PROTECTION
- STORMWATER DRAINAGE LINE
- GPT AND OUTLET
- SUBSOIL DRAINAGE LINE
- LEVEL SPREADER
- FLOW SPREADER
- 28.00 DESIGN CONTOURS
- 28.00 EXISTING CONTOURS
- RETAINING WALL

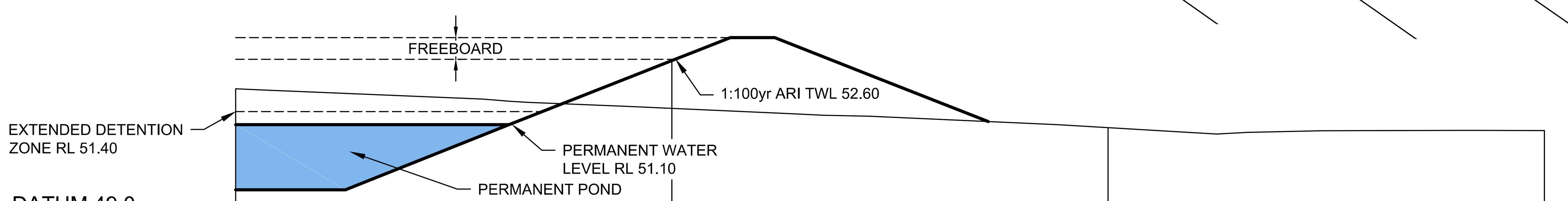



WEIR B3 DETAIL
NTS

| BASIN SUMMARY TABLE | |
|---|---|
| BASIN NAME | B3 |
| OSD STORAGE VOLUME ($m^3$) | 24000 |
| WETLAND AREA ($m^2$) | 17100 |
| CUT ($m^3$) | -26900 |
| FILL ($m^3$) | 7190 |
| POND VOLUME ESTIMATE ($m^3$) | -22860 |
| BALANCE ($m^3$) | -42570 |
| DISTURBED AREA ($m^2$) | 30000 |

NOTES:

- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
- NO ALLOWANCES HAVE BEEN MADE FOR TOPSOIL STRIPPING OR REPLACEMENT.
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.




DATUM 49.0

| | | | | |
|---|---|---|---|---|
| EXISTING SURFACE | 51.923 | 51.473 | 51.030 | 50.964 |
| CHAINAGE | 0.000 | 20.000 | 40.000 | 60.000 |

LONGITUDINAL SECTION B3
HORIZONTAL SCALE 1:200
VERTICAL SCALE 1:100

H 1:200 (AT A1) 4 2 0 4 8 12 16 20 METRES

V 1:100 (AT A1) 2 1 0 1 2 3 4 5 6 7 8 9 10 METRES

1:500 (AT A1) 10 0 10 20 30 40 50 METRES

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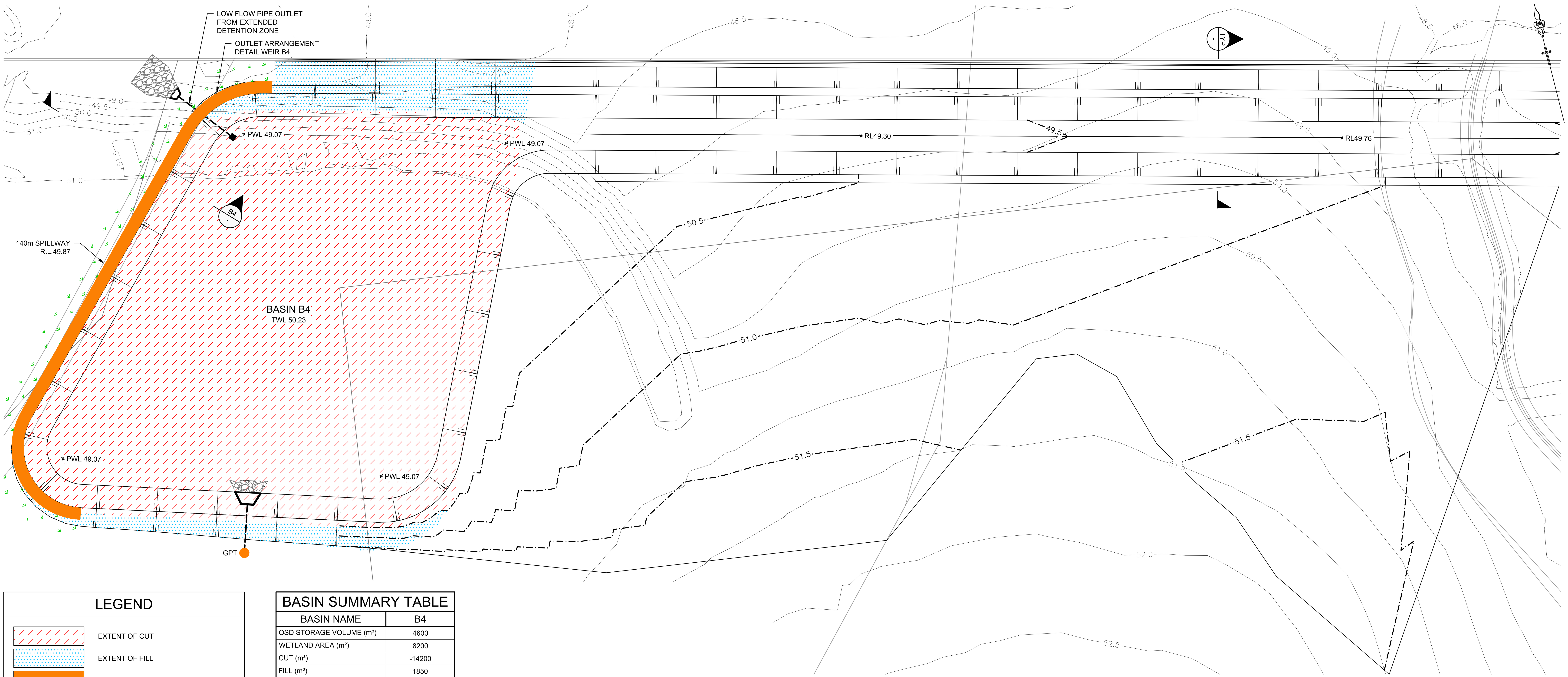


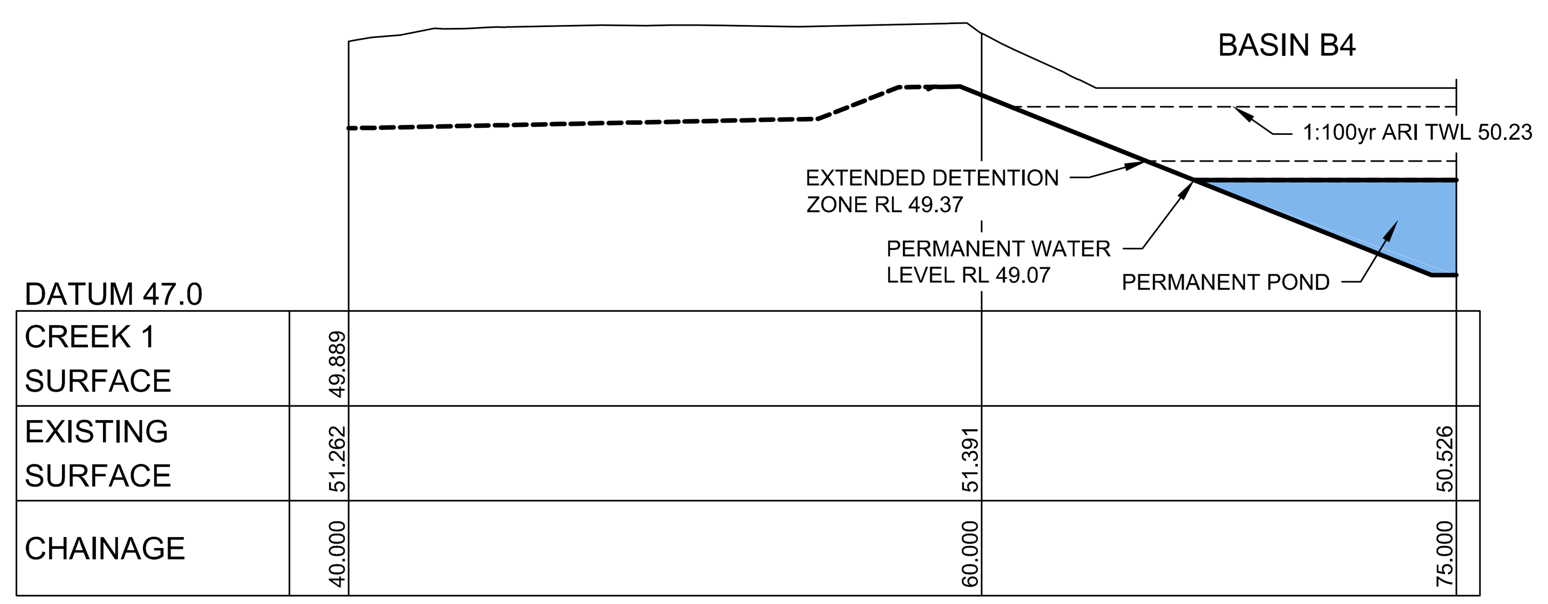

## LEGEND

| | |
|---|---|
| | EXTENT OF CUT |
| | EXTENT OF FILL |
| | OSD BASIN WEIR/SPILLWAY |
| | REINFORCED TURF |
| | ROCK SCOUR PROTECTION |
| | STORMWATER DRAINAGE LINE |
| GPT | GPT AND OUTLET |
| SS | SUBSOIL DRAINAGE LINE |
| | LEVEL SPREADER |
| | FLOW SPREADER |
| 28.00 | DESIGN CONTOURS |
| 28.00 | EXISTING CONTOURS |
| | RETAINING WALL |

## BASIN SUMMARY TABLE

| BASIN NAME | B4 |
|---|---|
| OSD STORAGE VOLUME ($m^3$) | 4600 |
| WETLAND AREA ($m^2$) | 8200 |
| CUT ($m^3$) | -14200 |
| FILL ($m^3$) | 1850 |
| POND VOLUME ESTIMATE ($m^3$) | -10700 |
| BALANCE ($m^3$) | -23050 |
| DISTURBED AREA ($m^2$) | 12700 |

NOTES:
- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
- NO ALLOWANCES HAVE BEEN MADE FOR TOPSOIL STRIPPING OR REPLACEMENT.
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.




LONGITUDINAL SECTION B4
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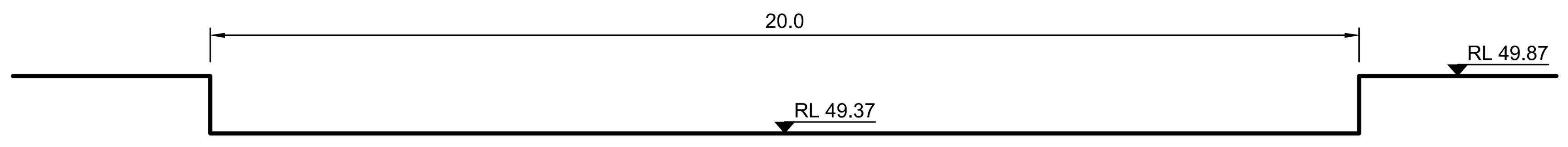
VERTICAL SCALE 1:100




WEIR B4 DETAIL
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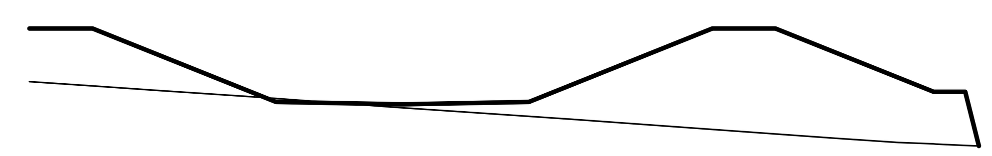

TYPICAL CROSS SECTION
HORIZONTAL SCALE 1:200
VERTICAL SCALE 1:100

H 1:200 (AT A1) — METRES
V 1:100 (AT A1) — METRES
1:500 (AT A1) — METRES

| | | | | | | |
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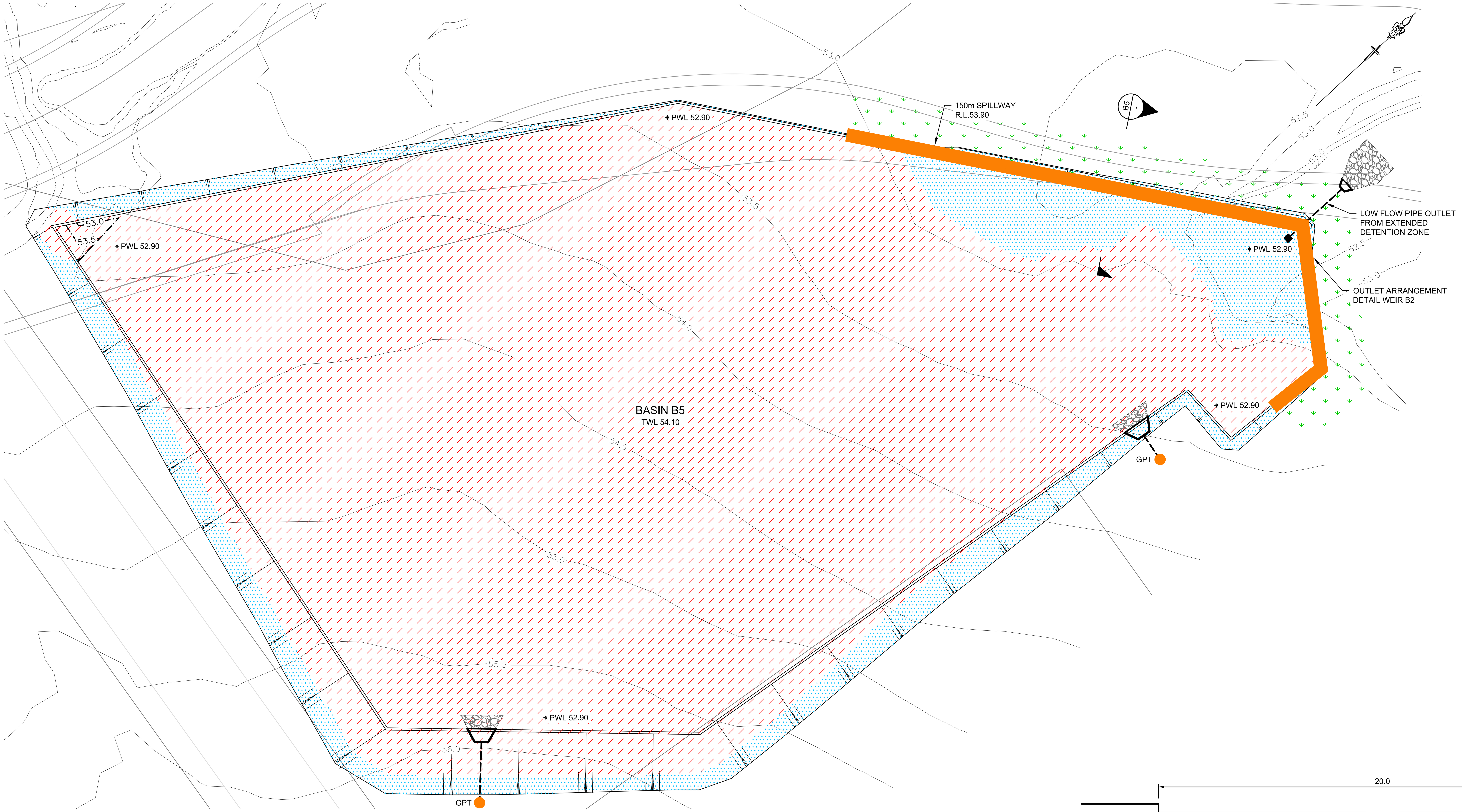
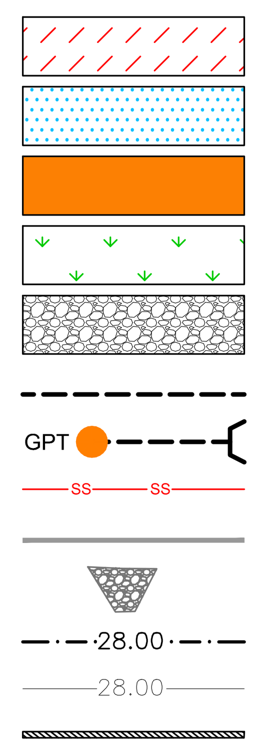
SYDNEY SCIENCE PARK
STORMWATER MANAGEMENT STRATEGY
BASIN No. B4

PLAN No: 9765/SK104 A
FILE No: 9765SK104
SHEET SIZE: A1 ORIGINAL

Plotted: 13 December , 2013 1:48:15 PM File Name: J:\9765D\SK\9765SK104.dwg




## LEGEND

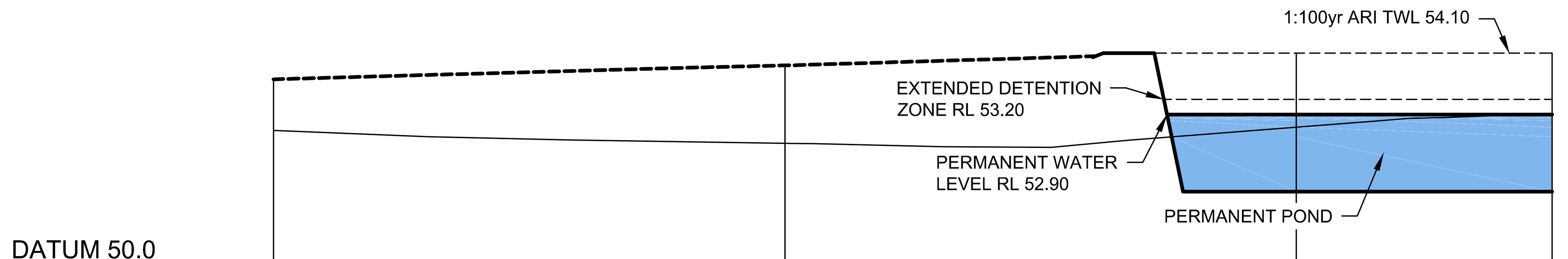


| |
|---|
| EXTENT OF CUT |
| EXTENT OF FILL |
| OSD BASIN WEIR/SPILLWAY |
| REINFORCED TURF |
| ROCK SCOUR PROTECTION |
| STORMWATER DRAINAGE LINE |
| GPT AND OUTLET |
| SUBSOIL DRAINAGE LINE |
| LEVEL SPREADER |
| FLOW SPREADER |
| DESIGN CONTOURS |
| EXISTING CONTOURS |
| RETAINING WALL |

## BASIN SUMMARY TABLE

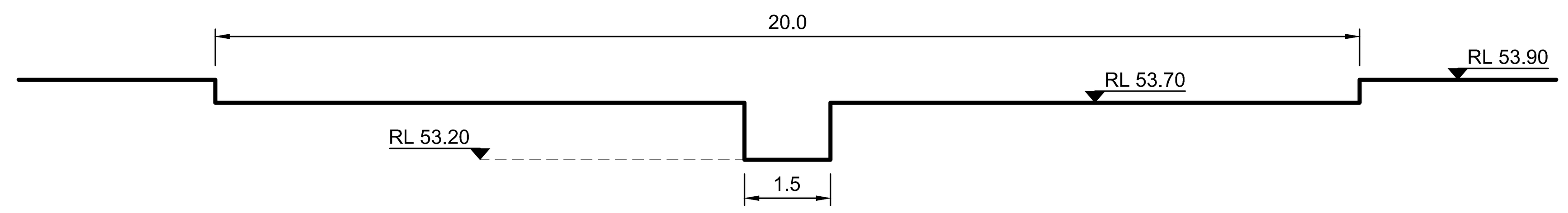
| BASIN NAME | B5 |
|---|---|
| OSD STORAGE VOLUME ($m^3$) | 17600 |
| WETLAND AREA ($m^2$) | 24000 |
| CUT ($m^3$) | -32450 |
| FILL ($m^3$) | 2100 |
| POND VOLUME ESTIMATE ($m^3$) | -38115 |
| BALANCE ($m^3$) | -68465 |
| DISTURBED AREA ($m^2$) | 29900 |

NOTES:
- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
- NO ALLOWANCES HAVE BEEN MADE FOR TOPSOIL STRIPPING OR REPLACEMENT.
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.




| DATUM 50.0 | | | | |
|---|---|---|---|---|
| CREEK 1 SURFACE | 53.590 | 53.860 | | |
| EXISTING SURFACE | 52.594 | 52.342 | 52.655 | 52.927 |
| CHAINAGE | 60.000 | 80.000 | 100.000 | 110.000 |

LONGITUDINAL SECTION B5
HORIZONTAL SCALE 1:200
VERTICAL SCALE 1:100




WEIR B5 DETAIL
NTS

H 1:200 (AT A1) METRES
V 1:100 (AT A1) METRES
1:500 (AT A1) METRES

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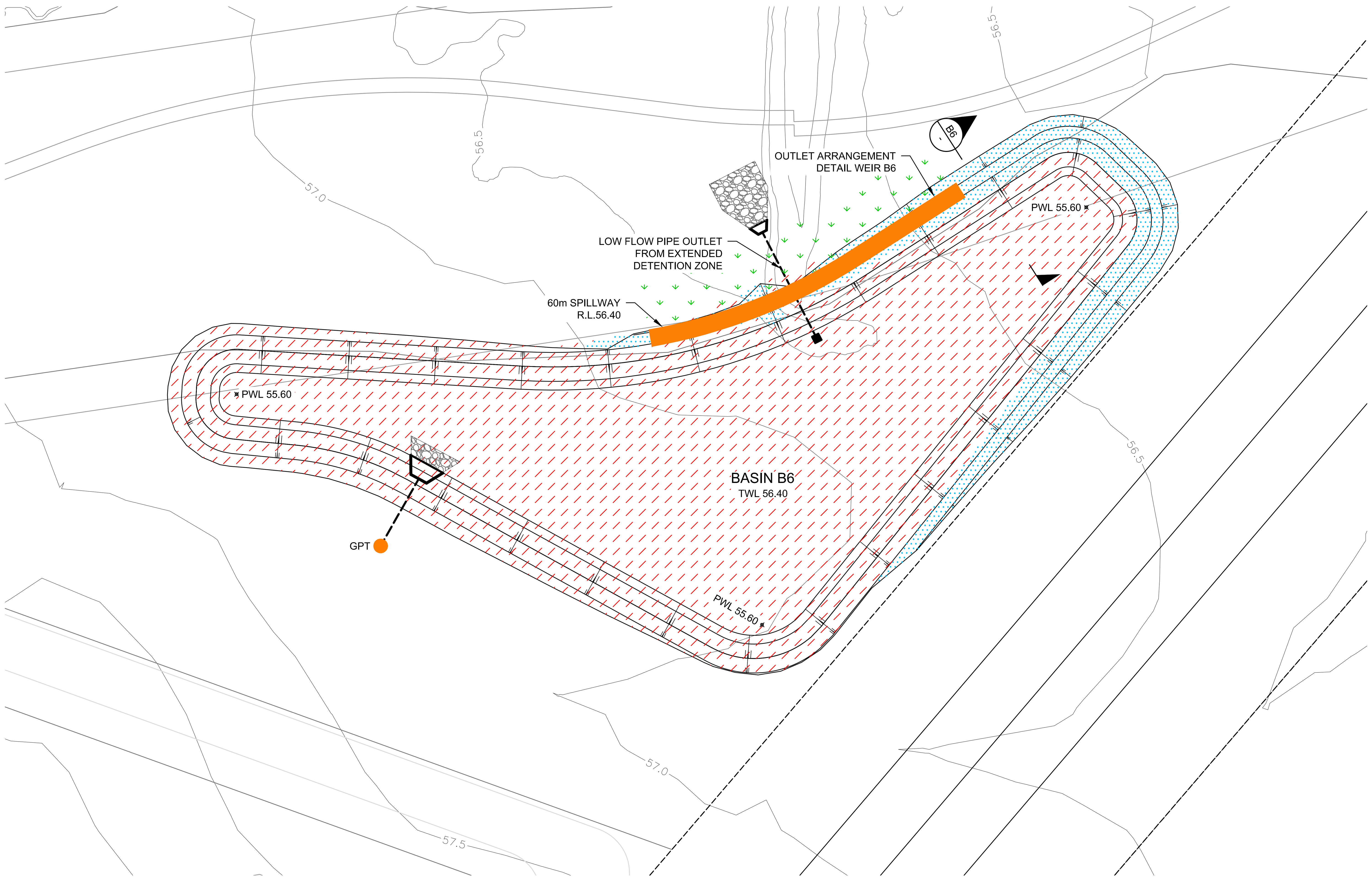
SYDNEY SCIENCE PARK
STORMWATER MANAGEMENT STRATEGY
BASIN No. B5

PLAN No: 9765/SK105 A
FILE No: 9765SK105
SHEET SIZE: A1 ORIGINAL

Plotted: 13 December , 2013 1:50:13 PM File Name: J:\9765D\SK\9765SK105.dwg




## LEGEND

- EXTENT OF CUT
- EXTENT OF FILL
- OSD BASIN WEIR/SPILLWAY
- REINFORCED TURF
- ROCK SCOUR PROTECTION
- STORMWATER DRAINAGE LINE
- GPT — GPT AND OUTLET
- SS — SUBSOIL DRAINAGE LINE
- LEVEL SPREADER
- FLOW SPREADER
- 28.00 — DESIGN CONTOURS
- 28.00 — EXISTING CONTOURS
- RETAINING WALL

## BASIN SUMMARY TABLE

| BASIN NAME | B6 |
|---|---|
| OSD STORAGE VOLUME ($m^3$) | 2600 |
| WETLAND AREA ($m^2$) | 4040 |
| CUT ($m^3$) | -7300 |
| FILL ($m^3$) | 240 |
| POND VOLUME ESTIMATE ($m^3$) | -4300 |
| BALANCE ($m^3$) | -11360 |
| DISTURBED AREA ($m^2$) | 7600 |

NOTES:

- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
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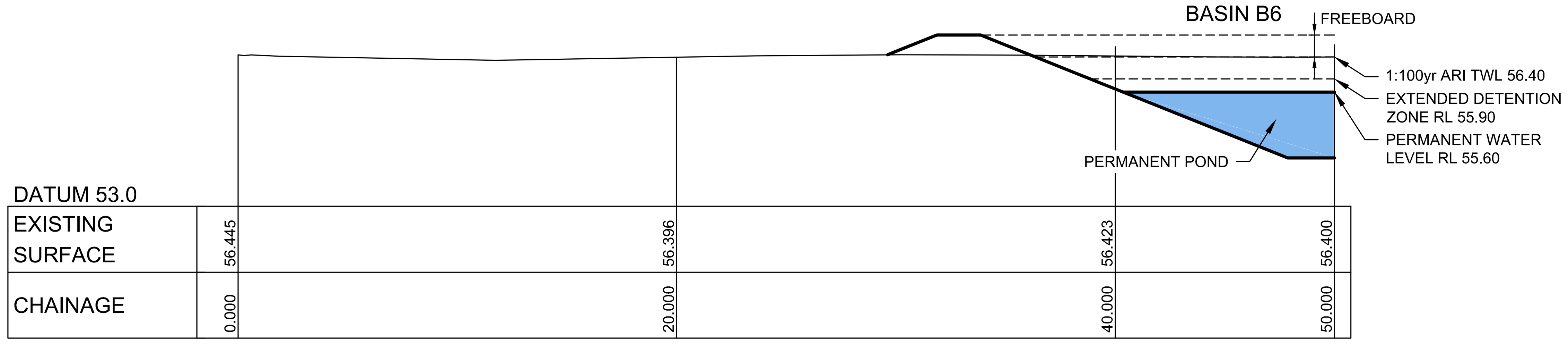
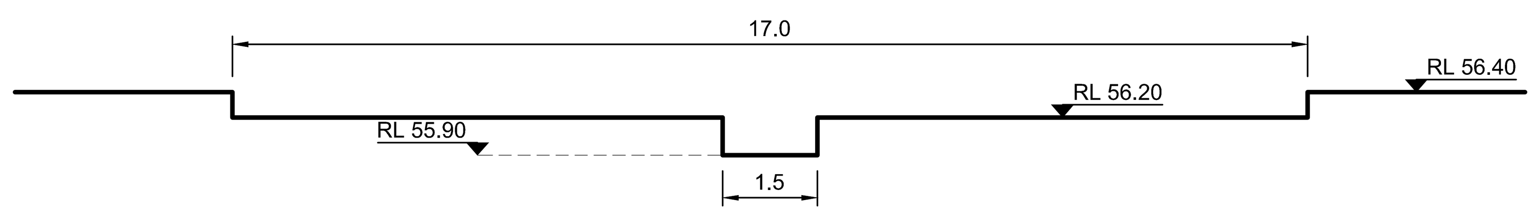
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.




LONGITUDINAL SECTION B6

HORIZONTAL SCALE 1:200
VERTICAL SCALE 1:100




WEIR B6 DETAIL

NTS

1:200 (AT A1) 4 2 0 4 8 12 16 20 METRES

1:500 (AT A1) 10 0 10 20 30 40 50 METRES

| | | | | | | |
|---|---|---|---|---|---|---|
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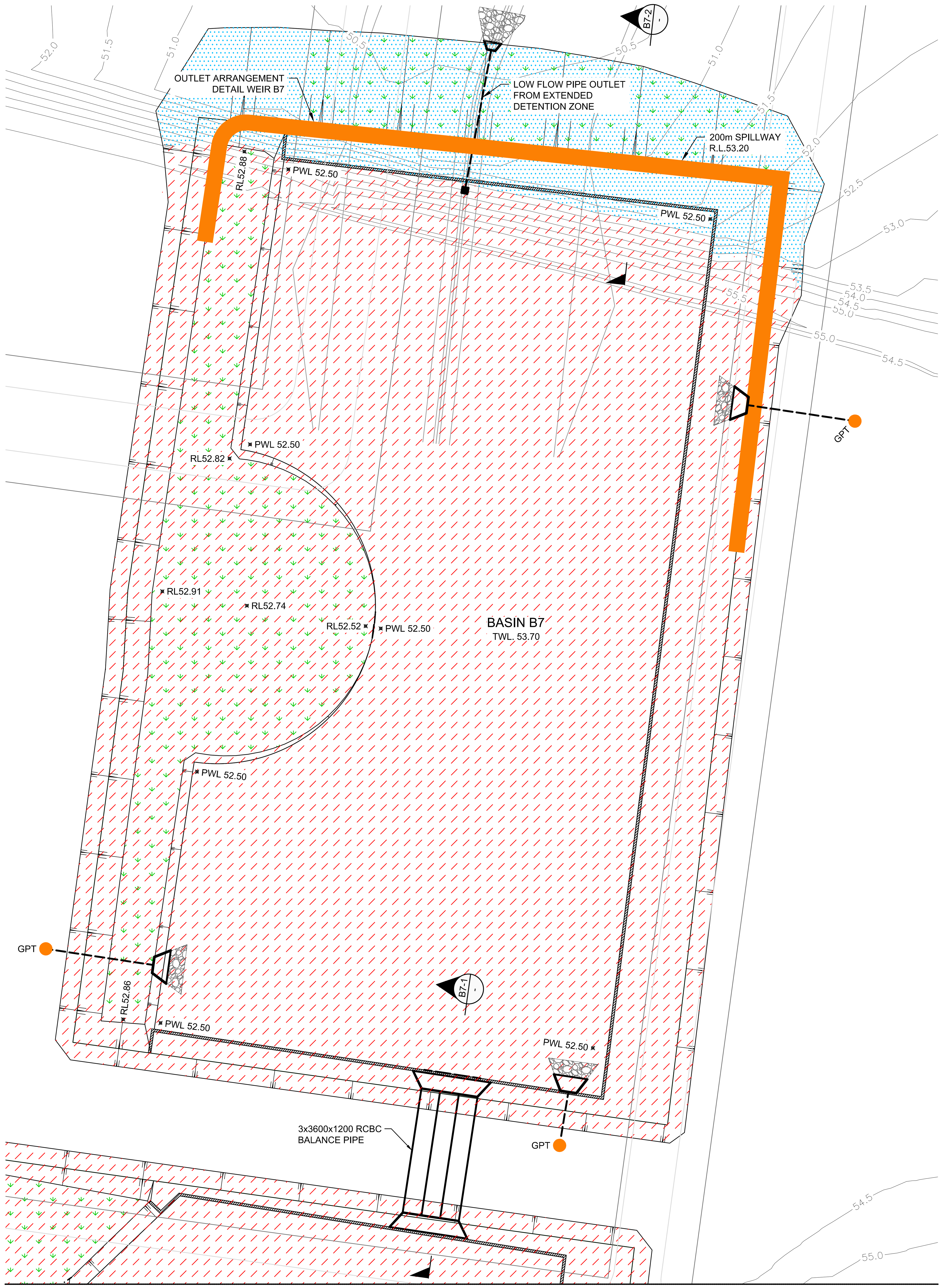
SYDNEY SCIENCE PARK
STORMWATER MANAGEMENT STRATEGY
BASIN No. B6

PLAN No: 9765/SK106 A

FILE No: 9765SK106

SHEET SIZE: A1 ORIGINAL

Plotted: 13 December , 2013 1:51:14 PM File Name: J:\9765D\SK\9765SK106.dwg




REFER TO DRAWING 9765SK108 FOR CONTINUATION

H 1:200 (AT A1) METRES

V 1:100 (AT A1) METRES

1:500 (AT A1) METRES

## LEGEND

| | |
|---|---|
| | EXTENT OF CUT |
| | EXTENT OF FILL |
| | OSD BASIN WEIR/SPILLWAY |
| | REINFORCED TURF |
| | ROCK SCOUR PROTECTION |
| | STORMWATER DRAINAGE LINE |
| GPT | GPT AND OUTLET |
| SS | SUBSOIL DRAINAGE LINE |
| | LEVEL SPREADER |
| | FLOW SPREADER |
| 28.00 | DESIGN CONTOURS |
| 28.00 | EXISTING CONTOURS |
| | RETAINING WALL |

## BASIN SUMMARY TABLE

| BASIN NAME | B7 |
|---|---|
| OSD STORAGE VOLUME ($m^3$) | 21100 |
| WETLAND AREA ($m^2$) | 24000 |
| CUT ($m^3$) | -63925 |
| FILL ($m^3$) | 4740 |
| POND VOLUME ESTIMATE ($m^3$) | -36810 |
| BALANCE ($m^3$) | -95995 |
| DISTURBED AREA ($m^2$) | 49500 |

NOTES:

- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
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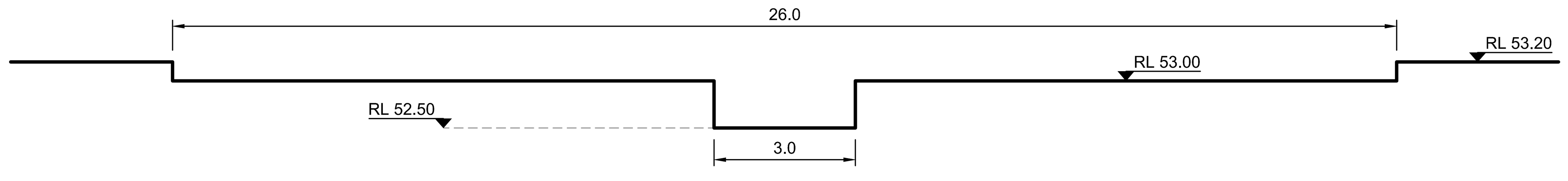
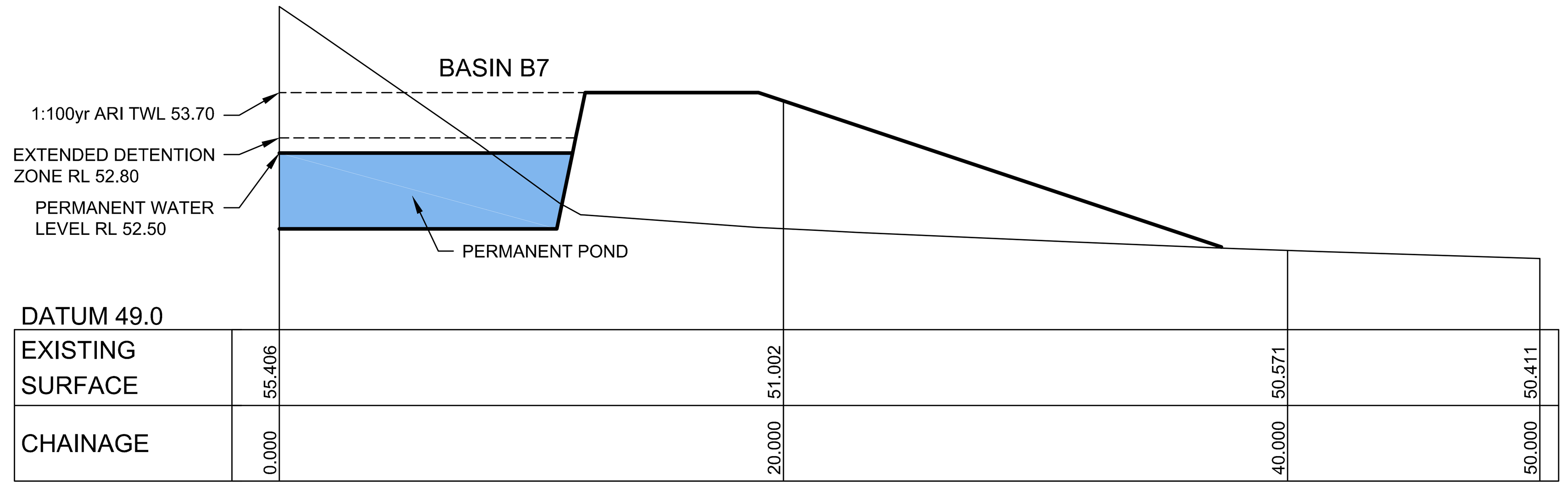
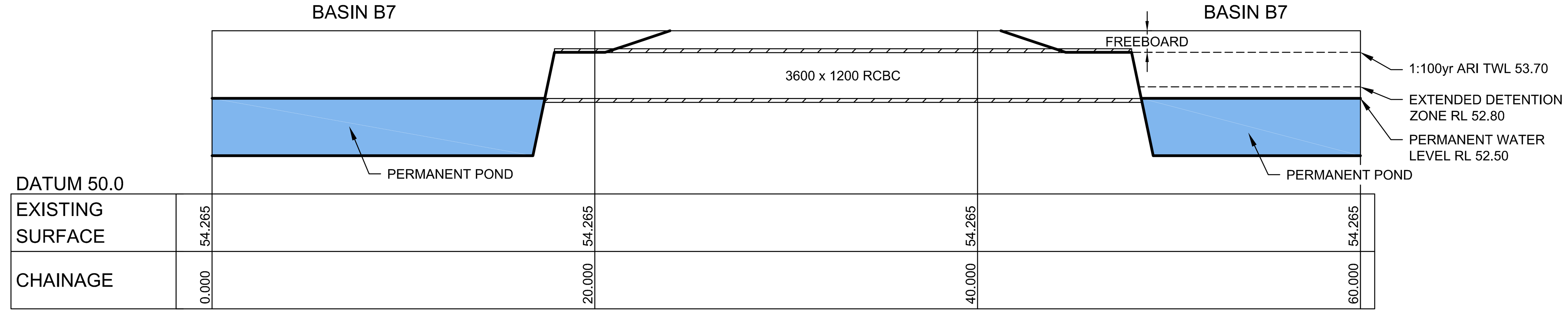
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.




WEIR B7 DETAIL
NTS




LONGITUDINAL SECTION B7-2
HORIZONTAL SCALE 1:200
VERTICAL SCALE 1:100




LONGITUDINAL SECTION B7-1
HORIZONTAL SCALE 1:200
VERTICAL SCALE 1:100

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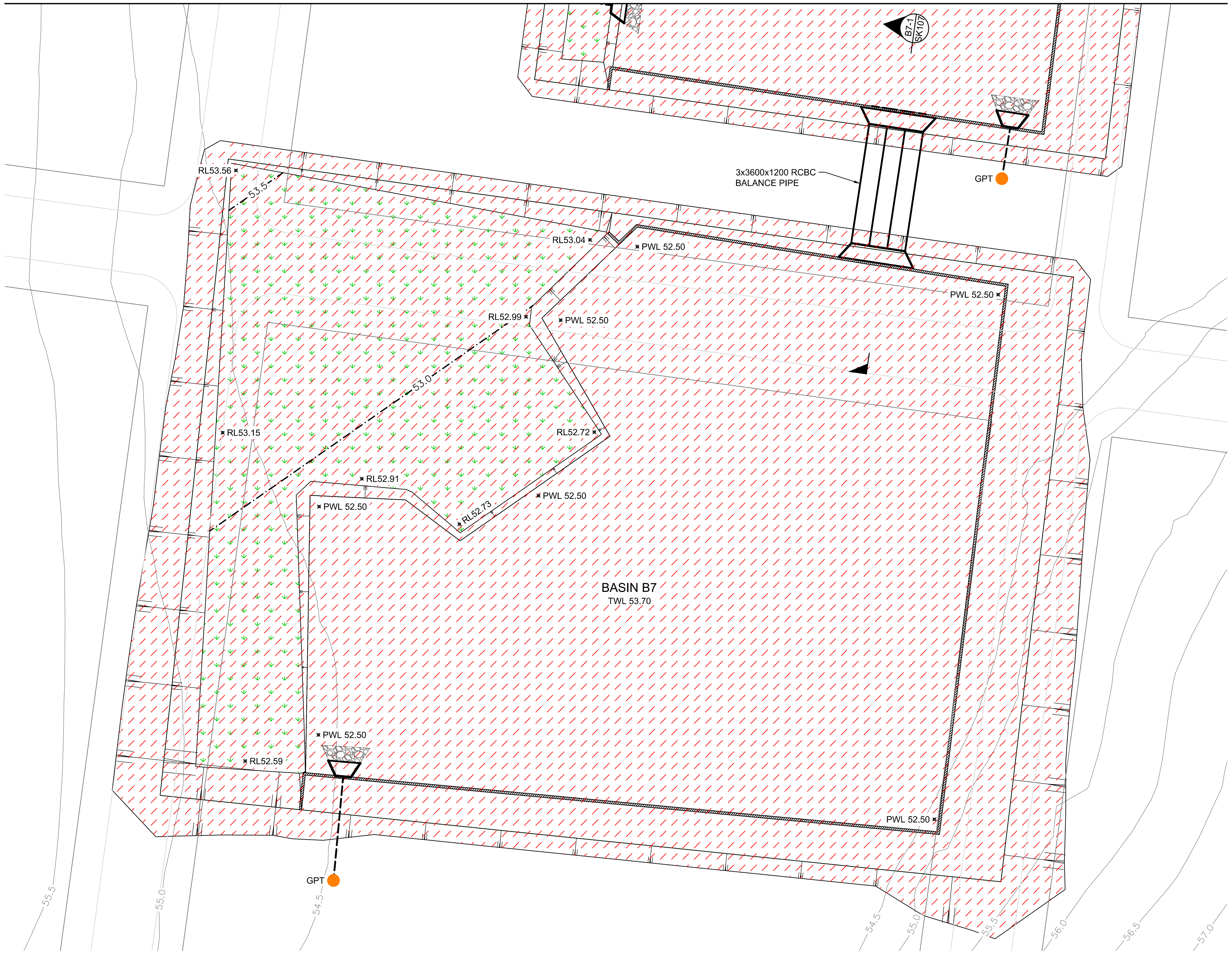
# SYDNEY SCIENCE PARK
## STORMWATER MANAGEMENT STRATEGY
BASIN No. B7
SHEET 1

PLAN No: 9765/SK107 A
FILE No: 9765SK107
SHEET SIZE: A1 ORIGINAL

Plotted: 13 December , 2013 1:52:35 PM File Name: J:\9765D\SK\9765SK107.dwg

REFER TO DRAWING 9765SK107 FOR CONTINUATION




## LEGEND

- EXTENT OF CUT
- EXTENT OF FILL
- OSD BASIN WEIR/SPILLWAY
- REINFORCED TURF
- ROCK SCOUR PROTECTION
- STORMWATER DRAINAGE LINE
- GPT AND OUTLET
- SUBSOIL DRAINAGE LINE
- LEVEL SPREADER
- FLOW SPREADER
- 28.00 DESIGN CONTOURS
- 28.00 EXISTING CONTOURS
- RETAINING WALL

## BASIN SUMMARY TABLE

| BASIN NAME | B7 |
|---|---|
| OSD STORAGE VOLUME ($m^3$) | 21100 |
| WETLAND AREA ($m^2$) | 24000 |
| CUT ($m^3$) | -63925 |
| FILL ($m^3$) | 4740 |
| POND VOLUME ESTIMATE ($m^3$) | -36810 |
| BALANCE ($m^3$) | -95995 |
| DISTURBED AREA ($m^2$) | 49500 |

NOTES:
- ALL VOLUME MEASUREMENTS ARE TAKEN BETWEEN THE EXISTING SURFACE AND DESIGN SURFACE AND DO NOT INCLUDE CHANNEL WORKS.
- POND VOLUMES ARE BASED ON AN ASSUMED 1.5M DEPTH OF PERMANENT WATER WITH 1V:4H BATTERS (BASINS B5 AND B7 ASSUME VERTICAL WALLS).
- NO ALLOWANCES HAVE BEEN MADE FOR TOPSOIL STRIPPING OR REPLACEMENT.
- SEPARATE CORRIDOR REGRADING/RECONSTRUCTION WILL BE NECESSARY TO FACILITATE THE BASIN CONSTRUCTION.
- ALL BATTERS ARE 1v:5h UNLESS NOTED OTHERWISE.

H 1:200 (AT A1) 4 2 0 4 8 12 16 20 METRES
V 1:100 (AT A1) 2 1 0 1 2 3 4 5 6 7 8 9 10 METRES
1:500 (AT A1) 10 0 10 20 30 40 50 METRES

| | AMENDMENT | DES | DRN | CKD | APR | DATE |
|---|---|---|---|---|---|---|
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SYDNEY SCIENCE PARK
STORMWATER MANAGEMENT STRATEGY
BASIN No. B7
SHEET 2

PLAN No: 9765/SK108 A
FILE No: 9765SK108
SHEET SIZE: A1 ORIGINAL

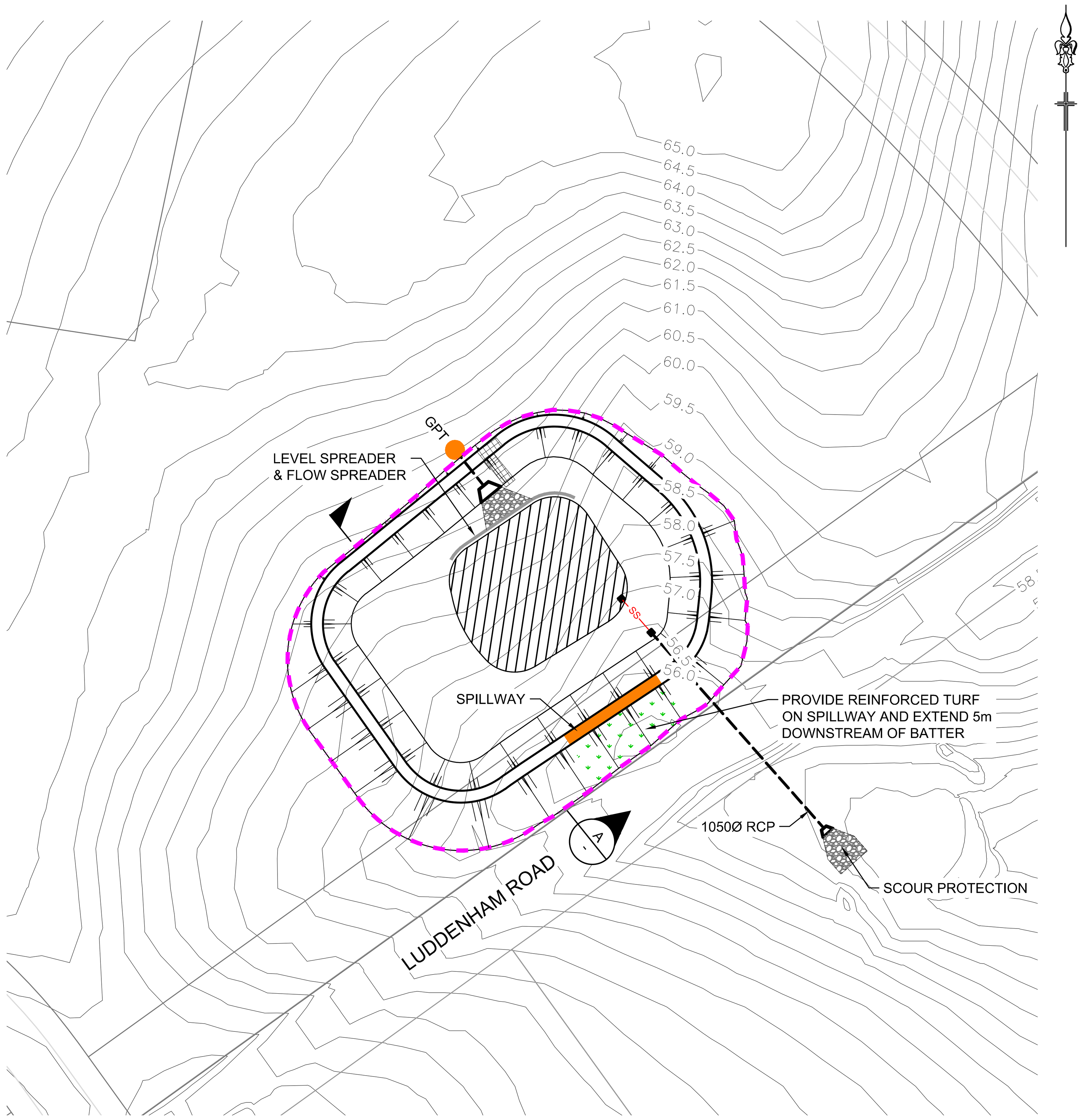
Plotted: 13 December , 2013 1:53:23 PM File Name: J:\9765D\SK\9765SK108.dwg

| BASIN | NODE | CATCHMENT AREA (ha) | 50% AEP FLOW TARGET (m³/s) | 1% AEP FLOW TARGET (m³/s) | STORAGE VOLUME (m³) | RAINGARDEN BED AREA (m²) |
|---|---|---|---|---|---|---|
| B8 | 10.01 | 1.42 | 0.09 | 0.34 | 500 | 70 |
| B9 | 10.02 | 1.91 | 0.07 | 0.24 | 1000 | 95 |
| B10 | 10.03 | 3.73 | 0.24 | 0.81 | 1300 | 185 |
| B11 | 10.04 | 3.40 | 0.19 | 0.67 | 1200 | 170 |
| B12 | 10.05 | 5.84 | 0.32 | 1.09 | 2100 | 290 |

## LEGEND

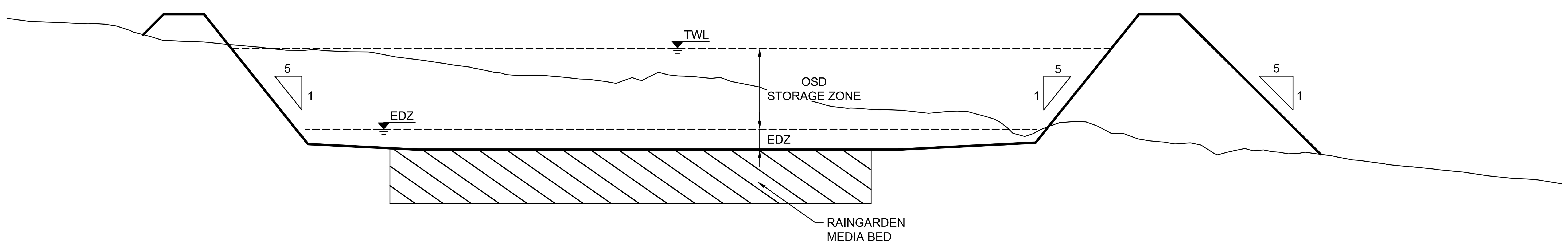
- RAINGARDEN MEDIA BED
- OSD BASIN SPILLWAY
- REINFORCED TURF
- ROCK SCOUR PROTECTION
- STORMWATER DRAINAGE LINE
- GPT AND OUTLET
- SUBSOIL DRAINAGE LINE
- EXTENT OF BLACKTOWN CITY COUNCIL SECTION 94 CONTRIBUTIONS
- LEVEL SPREADER
- FLOW SPREADER
- DESIGN CONTOURS
- EXISTING CONTOURS

NOTES:
ALL BATTERS ARE 1v:5h
UNLESS NOTED OTHERWISE




TYPICAL BASIN / RAINGARDEN PLAN
SCALE 1:1000

TYPICAL BASIN / RAINGARDEN SECTIONS




SECTION A
SCALE H N.T.S.
V N.T.S.

1:1000 (AT A1)
20 10 0 10 20 30 40 50 60 70 80 90 100
METRES

| | | | | | | |
|---|---|---|---|---|---|---|
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SYDNEY SCIENCE PARK
STORMWATER MANAGEMENT STRATEGY
TYPICAL BASIN & SECTION

PLAN No: 9765/SK109 A
FILE No: 9765SK109
SHEET SIZE: A1 ORIGINAL

# PRELIMINARY COST ESTIMATE

## PROJECT: Sydney Science Park

**CLIENT: APP C/- EJ Cooper and Sons Pty Ltd**

**BASIN, PONDS / WETLANDS, GPTs, RAINGARDEN AND CHANNELS COST SUMMARY**

| NO. | ITEM | AMOUNT Exc GST$ |
|---|---|---|
| 1 | BASIN B1 | $1,210,950.00 |
| 2 | BASIN B2 | $1,526,050.00 |
| 3 | BASIN B3 | $2,728,950.00 |
| 4 | BASIN B4 | $1,439,800.00 |
| 5 | BASIN B5 | $2,970,450.00 |
| 6 | BASIN B6 | $686,550.00 |
| 7 | BASIN B7 | $4,789,750.00 |
| | COMBINED BASINS / WETLANDS SUB-TOTAL | $15,352,500.00 |
| 8 | WETLAND W1 | $1,109,750.00 |
| 9 | WETLAND W2 | $394,450.00 |
| 10 | WETLAND W3 | $664,700.00 |
| | WETLAND SUB-TOTAL | $2,168,900.00 |
| 11 | RAINGARDEN 1 | $312,800.00 |
| 12 | BASIN's B8-B12 | $1,534,100.00 |
| | RAINGARDEN SUB-TOTAL | $1,846,900.00 |
| 13 | TRUNK DRAINAGE CORRIDOR 1 | $526,700.00 |
| 14 | TRUNK DRAINAGE CORRIDOR 2 | $312,800.00 |
| 15 | TRUNK DRAINAGE CORRIDOR 3 | $664,700.00 |
| | CHANNELS SUBTOTAL | $1,504,200.00 |
| 16 | OPERATIONS AND MAINTENANCE MANUAL | $ 7,500.00 |
| | TOTAL COST ESTIMATE | $20,880,000.00 |

**CLARIFICATIONS**

The following clarifications and assumptions have been adopted:

**1** Water Cycle Management Devices include bio-retention raingardens, combined wetland / detention basins, wetlands, combined pond / detention basins, gross pollutant traps and Trunk Drainage Corridors.

**2** Costs associated with Riparian Corridors enhancement / upgrade are <u>not included</u> below and instead are covered separately in the Infrastructure Costing Breakdown.

**3** This Cost Estimate is based on J. Wyndham Prince's experience and judgment as a firm of practicing professional civil engineers familiar with the construction industry and that the cost estimate can not be guaranteed as we have no control over Contractor's prices, market forces, material supply costs, competitive bids from tenderers and specific site conditions that may be encountered but not yet investigated.

**4** This Cost Estimate is based on the information supplied by the client prior to the date of preparation and is subject to traffic investigation and modelling, geotechnical investigation and design and detail civil design works.

**5** The Cost Estimate is based on present day costs (2013).

**6** The Cost Estimate has been prepared for the purposes of identifying indicative Voluntary Planning Agreement costs for elements within the proposed Precinct.

**7** Establishment Costs have been assumed to be approximately 5% of the Construction Works of the elements (including additional contingencies).

**8** Rainwater Tanks are not included;

**9** Clearing Costs are indicative only and are based on assumptions after assessing recent aerial photography of the area

**10** Trunk drainage corridors will be required in isolated locations to convey overland flows. Refer to Figure 9.3 for typical details. A block work retaining wall will be required along the Northern site boundary to enable construction of the Trunk Drainage Corridors TDC 1 and TDC2.

**11** Excavation in rock has not been considered. Geotechnical Investigations to confirm site conditions in future detailed design stage.

**12** Basin outlets generally include a slotted weir rock spillway. The spillway includes stacked rock walls and are assumed at 10m wide which provide the opening for a staged basin discharge. Walling and base (floor) armoured protection is provided.

**13** The PMF spillway includes Reinforced Turfing and is assumed to utilise 18mm 3D synthetic matting, which will be placed on the weir and the downstream side of Spillways from the weir to the finished ground level, for the full width of the spillway and weir.

**14** Soil & Water Management costs have been assumed to be based on a general allowance involving generic erosion protection measures.

**15** Raingarden costs include the excavation, placement of subsoil drainage system, placement of drainage media and 500mm deep treatment filter media layer. Planting has been excluded from the general cost, but has been itemised in the following line item.

**16** GPT devices cost are assumed to includes supply and placement of device and also includes the provision for a diversion splitter pit and related pipework.

**17** The costs associated with the Gross Pollutant Traps have assumed GPT over the outlets to each detention basin, wetland or raingarden location. These are costed based on a CDS Unit and assumed at the rates shown below. Multiple GPTs have been considered at certain basin to suit the masterplan layout.
- 10Ha at $50,000 unit Cost
- 10Ha to 20Ha at $100,000 unit Cost
- 21Ha to 50Ha at $200,000 unit Cost

**18** Main Inlet costs include the supply and placement of an assumed 750mm dia outlet pipe with headwall and wingwalls.

**19** Low-flow piped outlet is the piped connection between the extended detention zone (EDZ) and the nearby creek profile.

**20** Rock Erosion Protection costs include placement of rock armouring downstream of the basin outlet into the channel. Includes rock ramps and energy dissipaters.

**21** An allowance of an additional 15% has been assumed for Plant & other Contingencies.

**22** Clay basin liner refers to import clean engineering fill suitable to create an impervious layer and stabilisation for the wetland / pond base. Costs include provision for certificates, handling, cartage, place, spread, form and compact

**23** Consultancy and Project Management Fees are not included below and instead are covered separately in the Infrastructure Costing Breakdown.

**24** Government Agency approvals (DSC, RMS, NOW, etc) are not included below and instead are covered separately in the Infrastructure Costing Breakdown. No research has been undertaken to assess whether certain Government Authorities have approval rights over any or all of the various drainage devices to be provided.

**25** Council DA Fees and planFIRST Levy costs are not included below and instead are covered separately in the Infrastructure Costing Breakdown.

**26** Costs associated with Principal Certifiier Approvals, whether they be undertaken by Council or any other approved Certifier are not included below and instead are covered separately in the Infrastructure Costing Breakdown.

**27** All costs are inclusive of GST

**28** Whist the land areas required for Water Management is an integral component of a Voluntary Planning Agreement, the value of the land is variable and will be dependent on 1) the time the contribution plan being finalised and 2) the market value of the land. Therefore, we have excluded the cost of landtake for the above calculation at this stage.

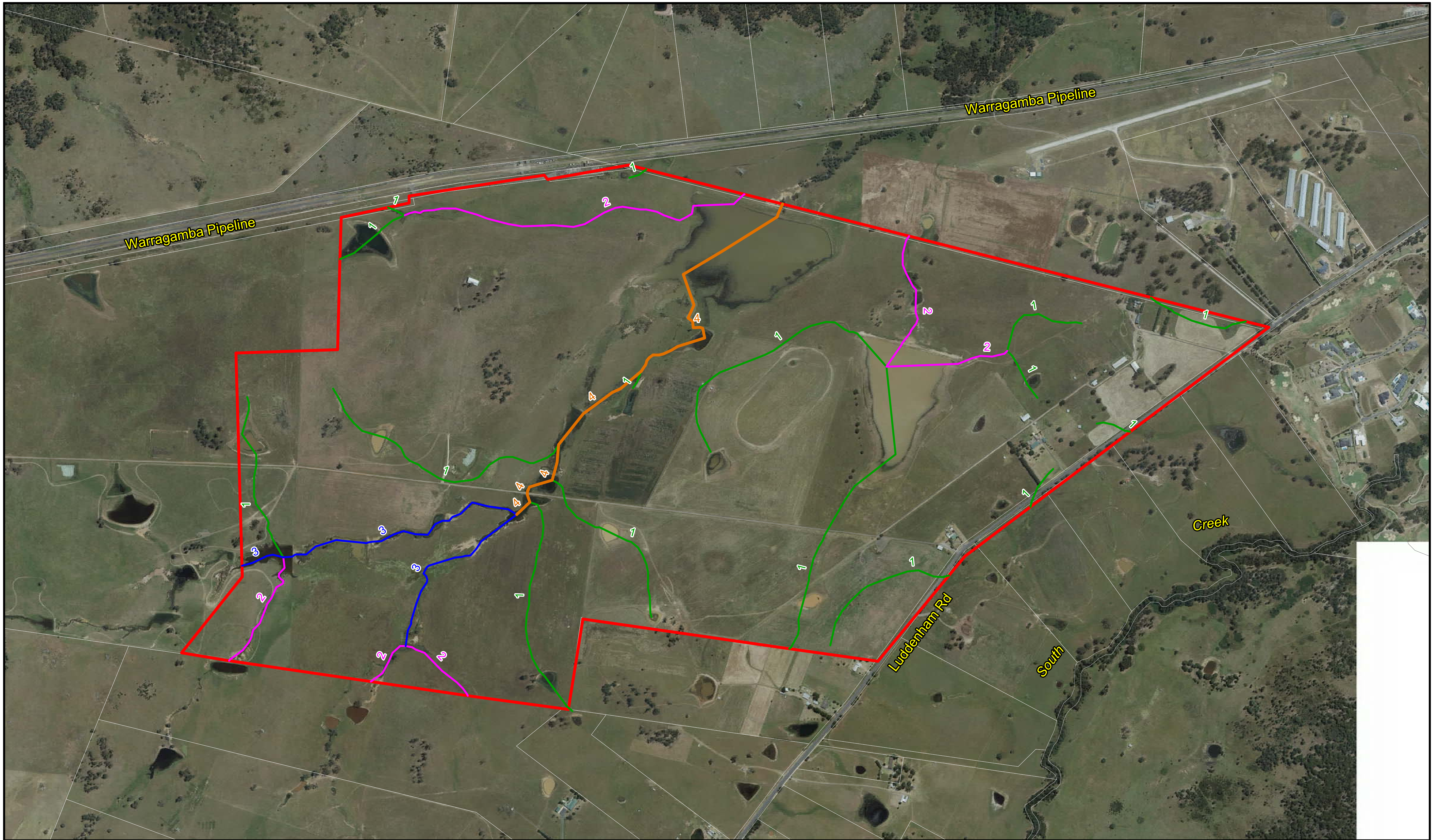







# APPENDIX F – FIGURES

APPENDIX F





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CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 9.1 (Strahler Exi) 11/12/2013
Issue: B

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

SYDNEY SCIENCE PARK STUDY AREA

1ST ORDER WATER COURSE

2ND ORDER WATER COURSE

3RD ORDER WATER COURSE

4TH ORDER WATER COURSE

# FIGURE 9.1

## SYDNEY SCIENCE PARK

EXISTING STRAHLER SYSTEM
STREAM CLASSIFICATION PLAN


J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS


PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 9.2 (Strahler Prop) 16/12/2013
Issue: C

N W E S

Scale 1: 10,000 @ A3

200 0 200 m

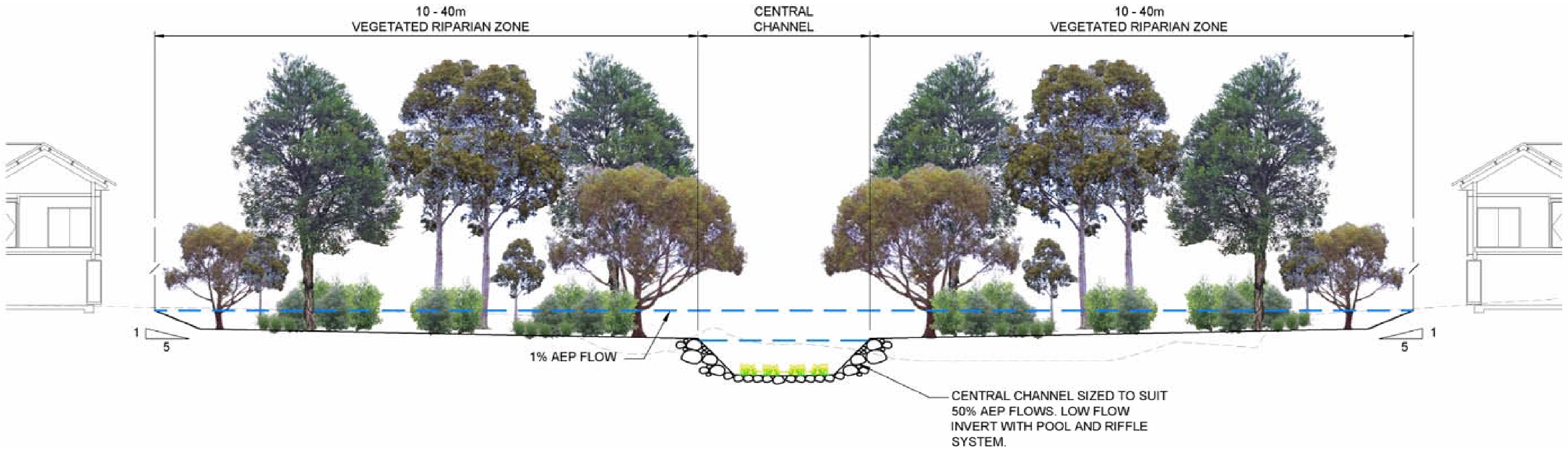
**LEGEND**

- SYDNEY SCIENCE PARK STUDY AREA
- 1ST ORDER WATER COURSE
- 2ND ORDER WATER COURSE
- 3RD ORDER WATER COURSE
- 4TH ORDER WATER COURSE
- VARIOUS WATERCOURSES TO BE REMOVED
- VARIOUS WATERCOURSES TO BE REALIGNED

# FIGURE 9.2

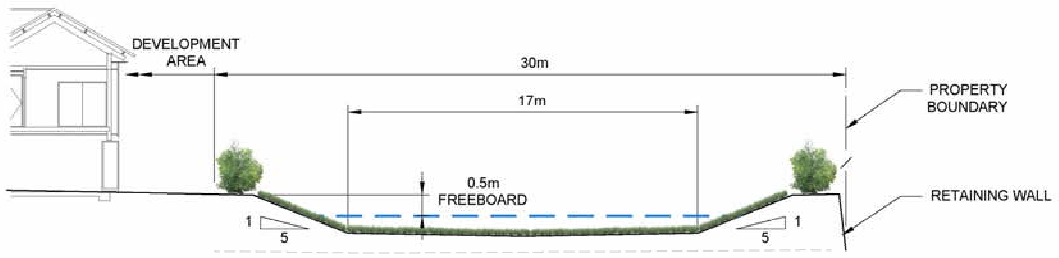
## SYDNEY SCIENCE PARK

PROPOSED STRAHLER SYSTEM
STREAM CLASSIFICATION PLAN



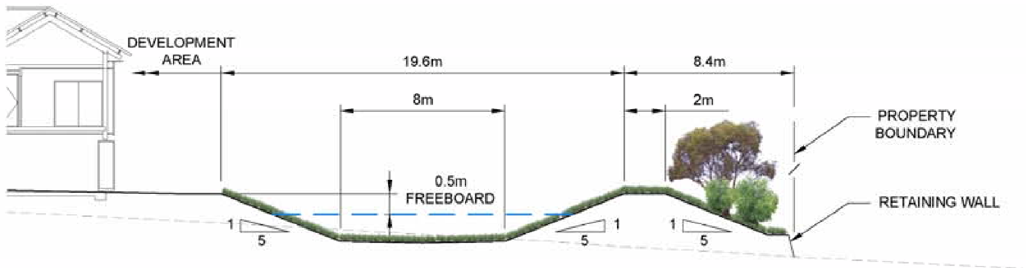

RIPARIAN CORRIDOR
TYPICAL CROSS SECTION

NOT TO SCALE
VERTICAL EXAGGERATION 1(H):2(V)



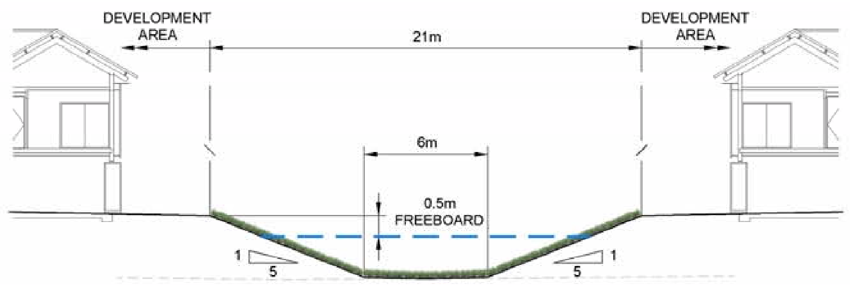

TRUNK DRAINAGE CORRIDOR SECTION (TDC2)

NOT TO SCALE
VERTICAL EXAGGERATION 1(H):2(V)




TRUNK DRAINAGE CORRIDOR SECTION (TDC1)

NOT TO SCALE
VERTICAL EXAGGERATION 1(H):2(V)




TRUNK DRAINAGE CORRIDOR SECTION (TDC3)

NOT TO SCALE
VERTICAL EXAGGERATION 1(H):2(V)

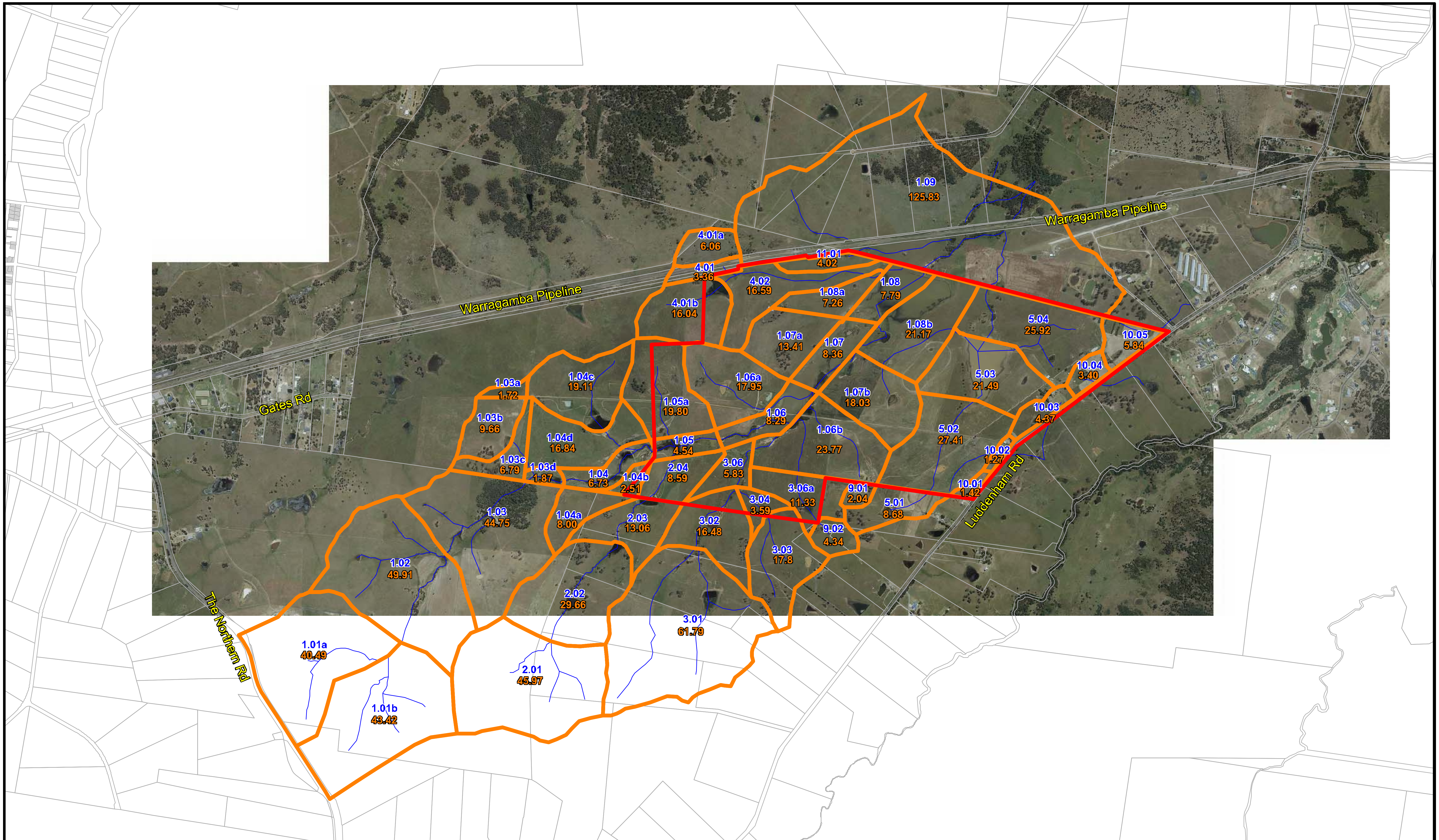
J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 9.3 TDC Sections 12/12/2013
Issue: A

# FIGURE 9.3

## SYDNEY SCIENCE PARK

PROPOSED TRUNK DRAINAGE CORRIDOR
SECTIONAL PROPERTIES

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CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638

W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 10.1 (Existing Catchment Plan) 11/12/2013
Issue: B

N
W E
S

Scale 1: 20,000@ A3

500 0 500 m

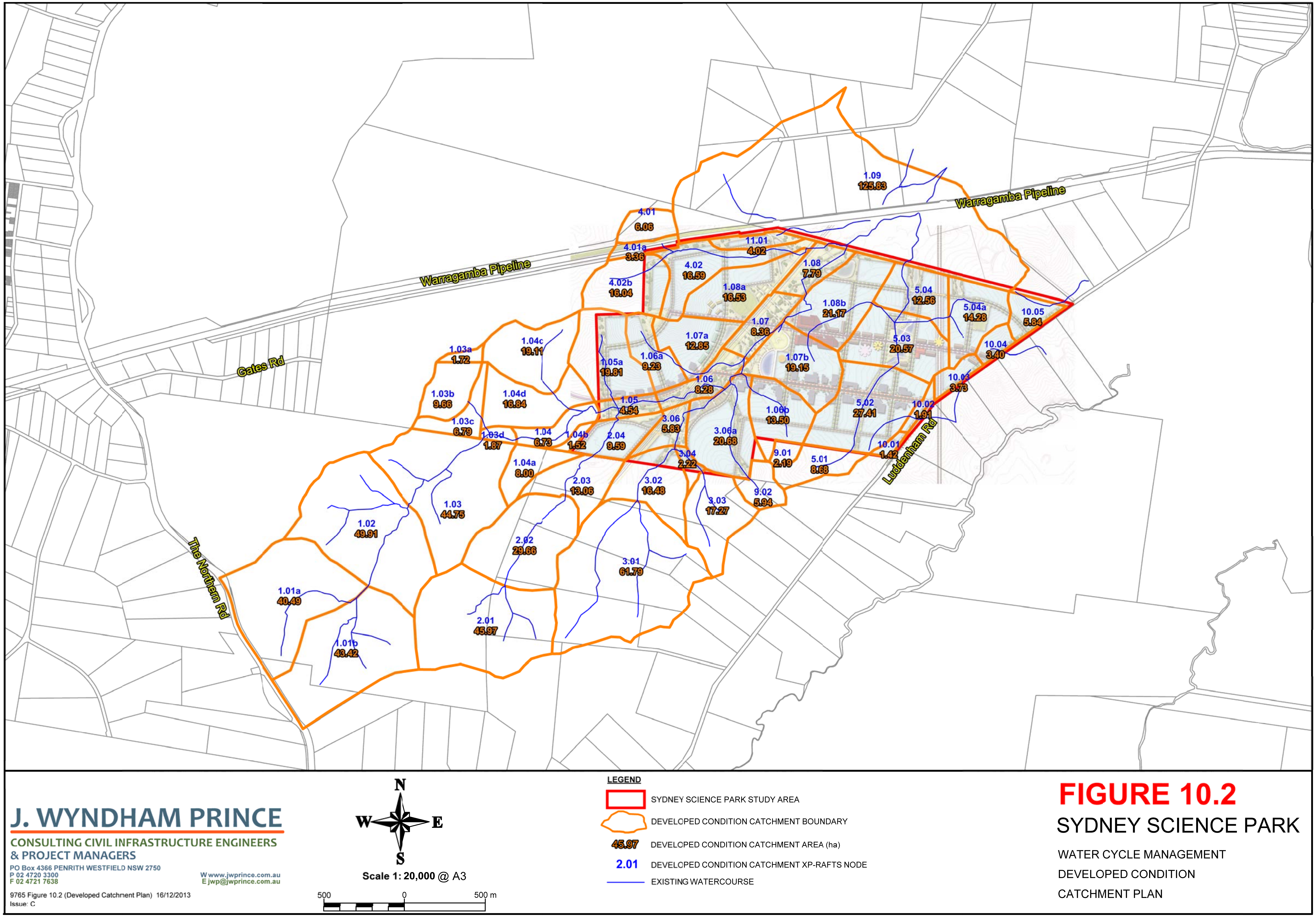
**LEGEND**

- SYDNEY SCIENCE PARK STUDY AREA
- EXISTING CONDITION CATCHMENT BOUNDARY
- 45.97 EXISTING CONDITION CATCHMENT AREA (ha)
- 2.01 EXISTING CONDITION CATCHMENT XP-RAFTS NODE
- EXISTING WATERCOURSE

# FIGURE 10.1

## SYDNEY SCIENCE PARK

WATER CYCLE MANAGEMENT
EXISTING CONDITION
CATCHMENT PLAN




LEGEND

SYDNEY SCIENCE PARK STUDY AREA

DEVELOPED CONDITION CATCHMENT BOUNDARY

45.97 DEVELOPED CONDITION CATCHMENT AREA (ha)

2.01 DEVELOPED CONDITION CATCHMENT XP-RAFTS NODE

EXISTING WATERCOURSE


J. WYNDHAM PRINCE

CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

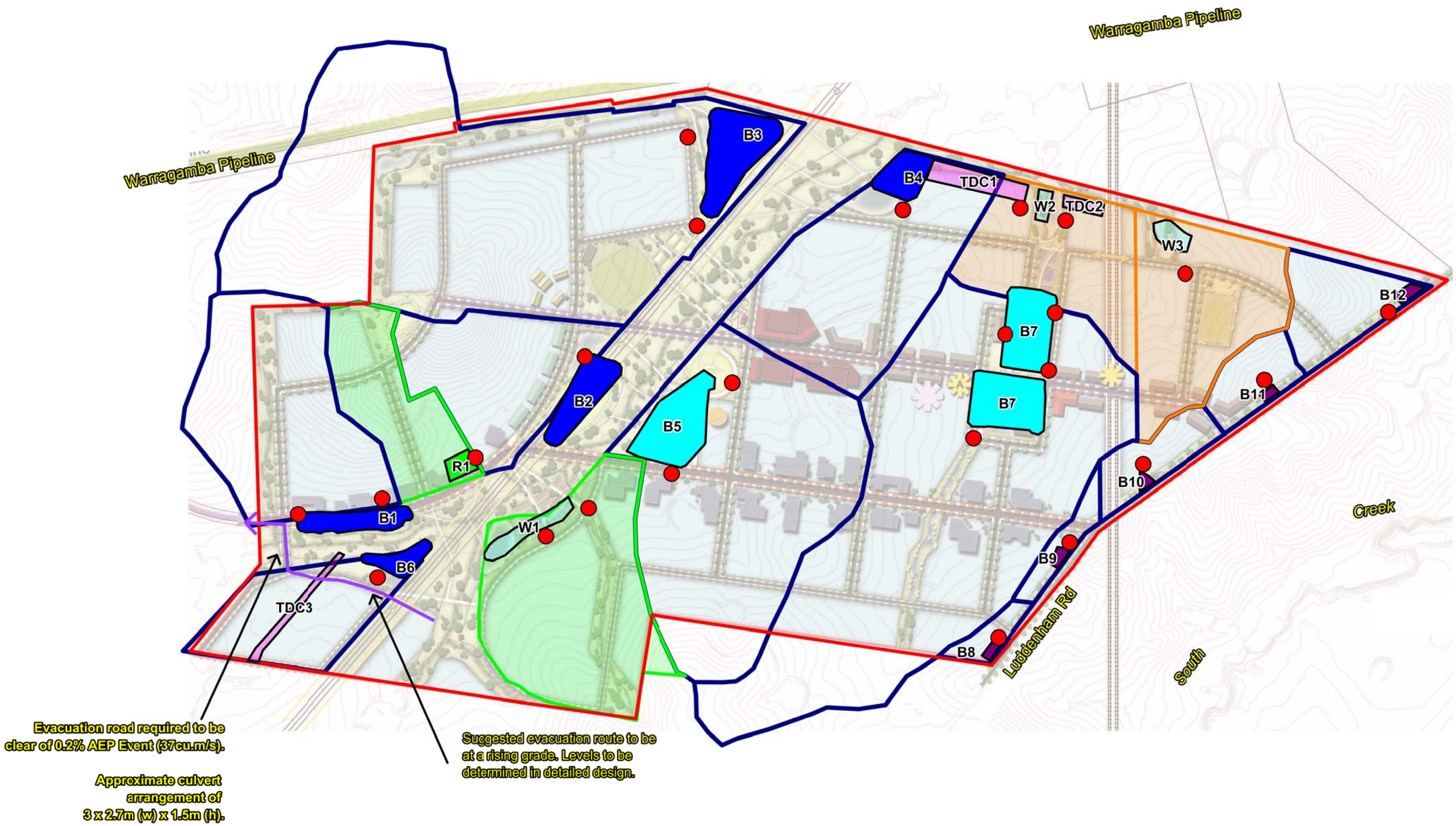
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 10.2 (Developed Catchment Plan) 16/12/2013
Issue: C

# FIGURE 10.2

## SYDNEY SCIENCE PARK

WATER CYCLE MANAGEMENT
DEVELOPED CONDITION
CATCHMENT PLAN




J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS
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P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 10.3 (WCMP) 16/12/2013
Issue: C

N W E S

Scale 1: 10,000 @ A3

200 0 200 m

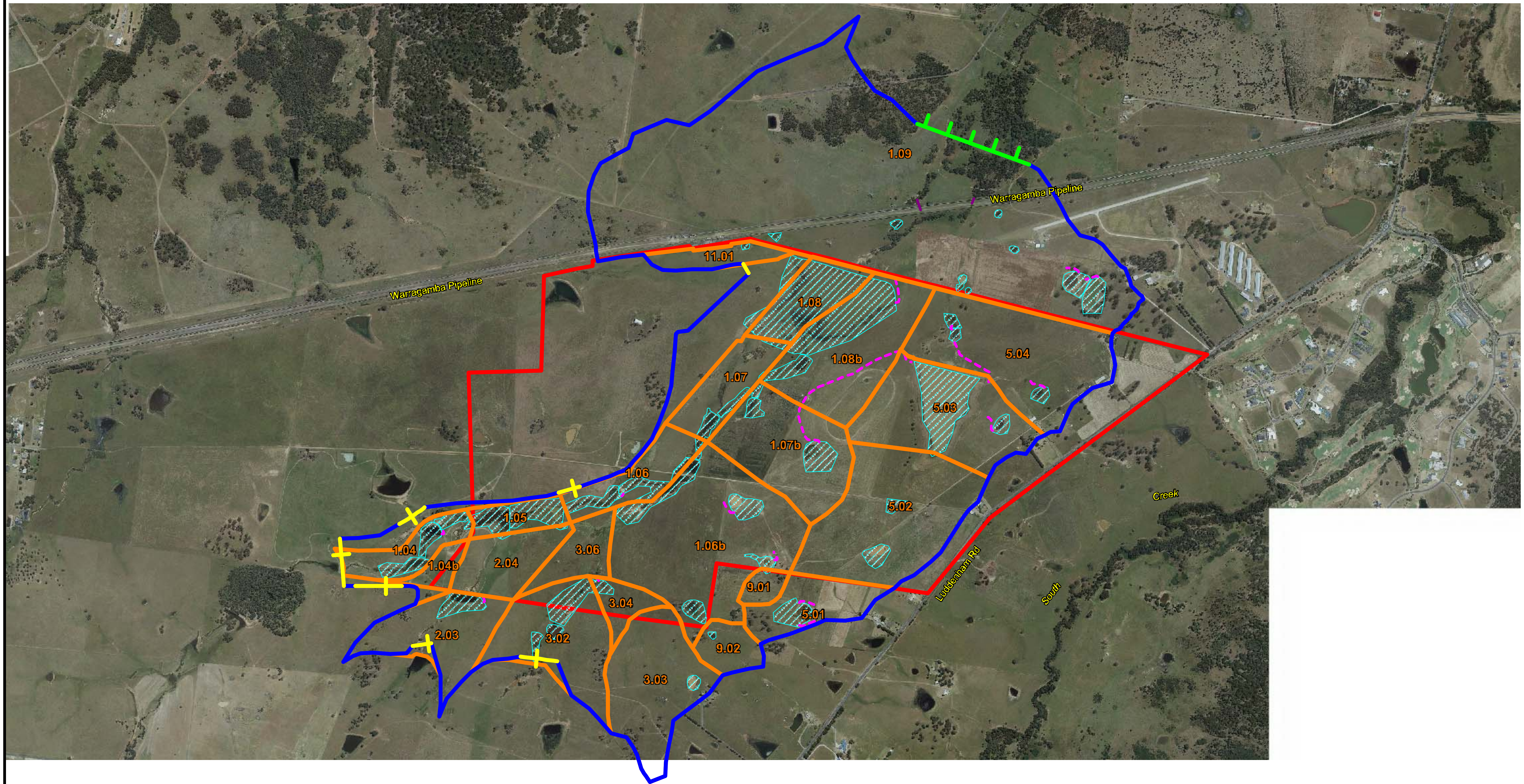
**LEGEND**

| | |
|---|---|
| | SYDNEY SCIENCE PARK SITE BOUNDARY |
| B10 | PROPOSED DETENTION BASIN WITH RAINGARDEN |
| B1 | PROPOSED DETENTION BASIN COMBINED WITH WETLAND |
| B5 | PROPOSED DETENTION BASIN COMBINED WITH POND |
| | PROPOSED EVACUATION ROUTE |
| R1 | PROPOSED RAINGARDEN DEVICE |
| W1 | PROPOSED WETLAND |
| | PROPOSED TRUNK DRAINAGE CHANNEL (REFER FIGURE 9.3 FOR DETAILS) |
| | APPROXIMATE LOCATION OF PROPOSED GPT |
| | DETENTION BASIN CATCHMENT EXTENTS |
| | WATER QUALITY CATCHMENT EXTENTS BYPASSING DETENTION |
| | WATER QUALITY CATCHMENT EXTENTS PARTLY DETAINED VIA DIVERSIONS |

# FIGURE 10.3

## SYDNEY SCIENCE PARK

WATER CYCLE MANAGEMENT PLAN




J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.1 (TUFLOW Inputs) 11/12/2013
Issue: B

N
W E
S

Scale 1: 15,000 @ A3
500 0 m

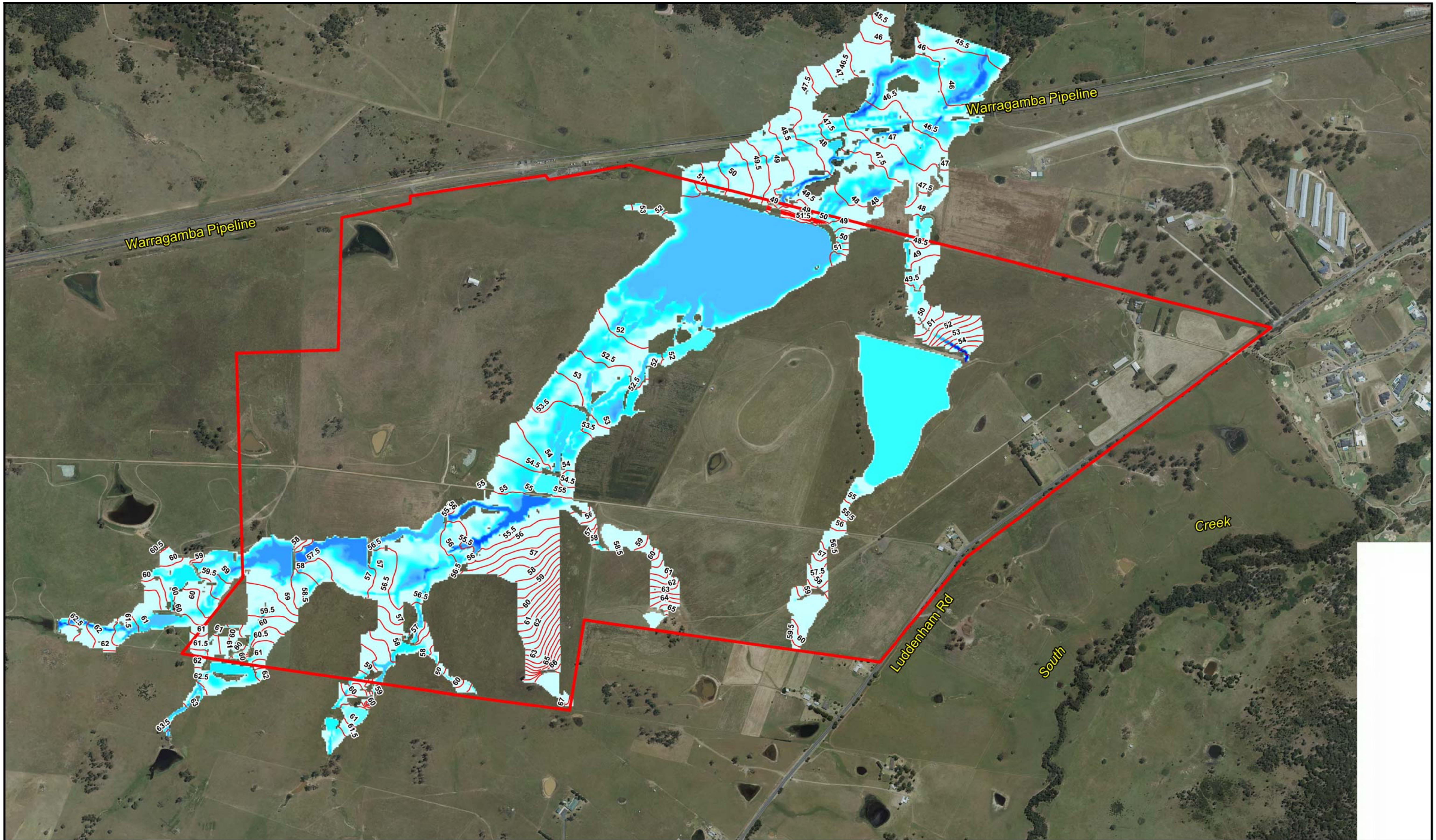
**LEGEND**

- SYDNEY SCIENCE PARK STUDY AREA
- TUFLOW BOUNDARY
- 3.03 SOURCE AREA (SA) CATCHMENT BOUNDARY WITH NAME
- EXISTING FARM DAMS
- EXTERNAL CATCHMENT FLOW INPUTS
- 1D ELEMENT
- HQ MODEL OUTLET
- DIVERSION EMBANKMENTS

# Figure 11.1

## SYDNEY SCIENCE PARK

TUFLOW INPUTS





J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.2 (Peak 50% AEP Existing Conditions) 11/12/2013
Issue: B

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

DEPTH (m)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

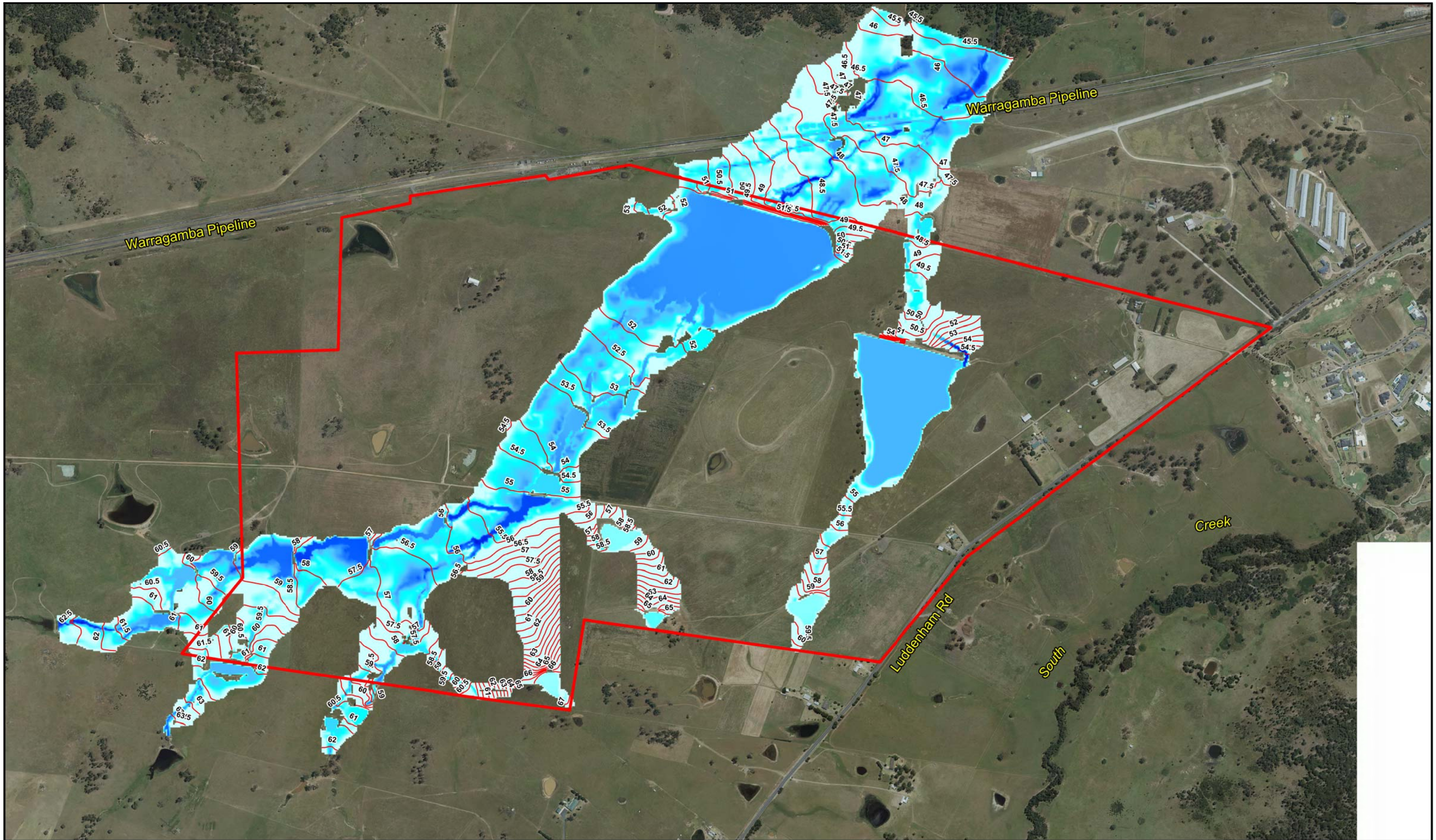
30.5 FLOOD CONTOUR & LEVEL

SYDNEY SCIENCE PARK STUDY AREA

# Figure 11.2

## SYDNEY SCIENCE PARK

PEAK 50% AEP EXISTING CONDITIONS
FLOOD DEPTH & LEVEL PLAN




J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.3 (Peak 1% AEP Exsting Conditions) 11/12/2013
Issue: B

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

DEPTH (m)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

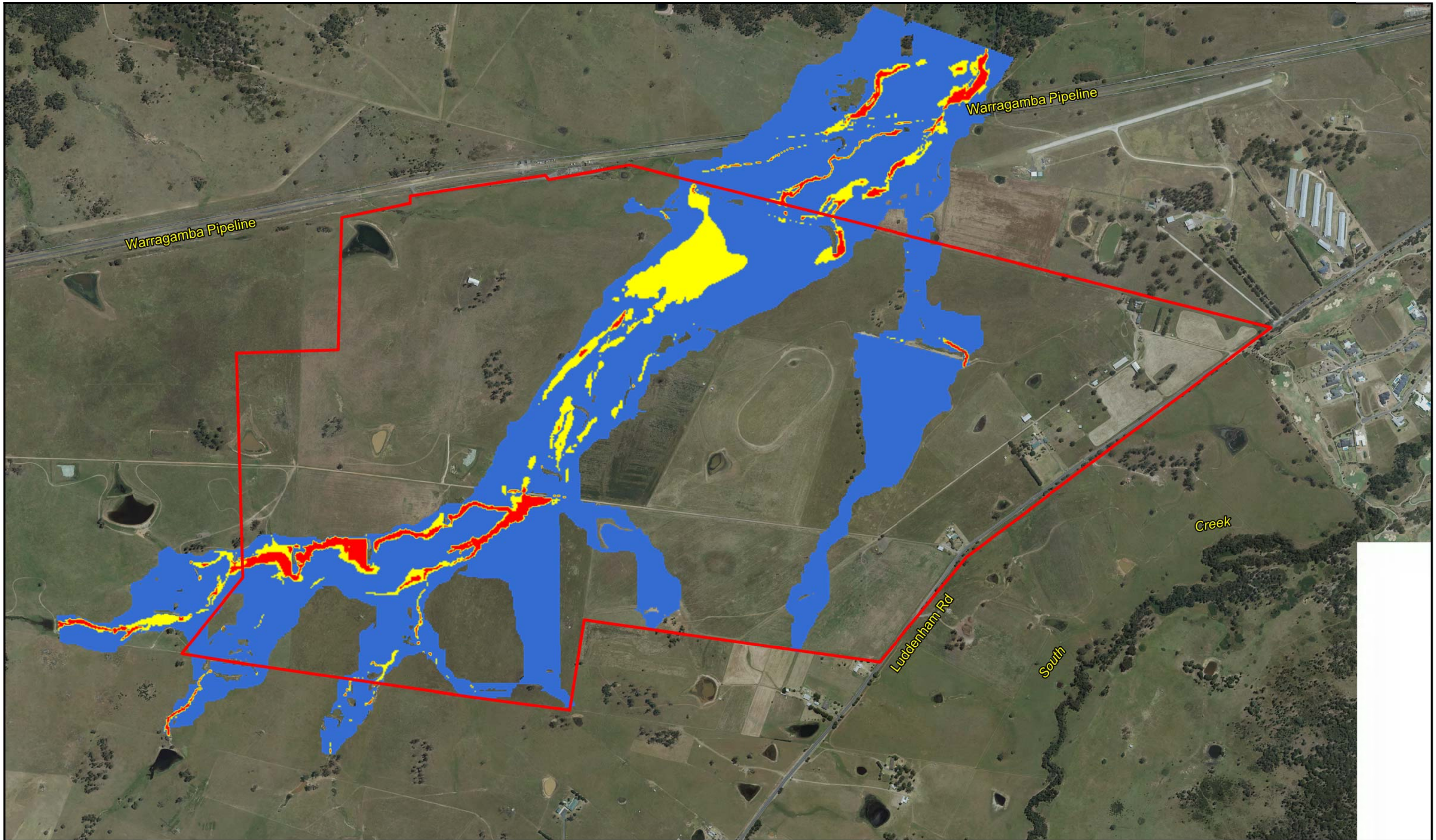
30.5 FLOOD CONTOUR & LEVEL

SYDNEY SCIENCE PARK STUDY AREA

# Figure 11.3

## SYDNEY SCIENCE PARK

PEAK 1% AEP EXISTING CONDITIONS
FLOOD DEPTH & LEVEL PLAN




J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.4 (Peak 1% AEP Existing Flood Hazards)11/12/2013
Issue: B

N W E S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

SYDNEY SCIENCE PARK STUDY AREA

HAZARD CATEGORISATION

LOW HAZARD

TRANSITION HAZARD

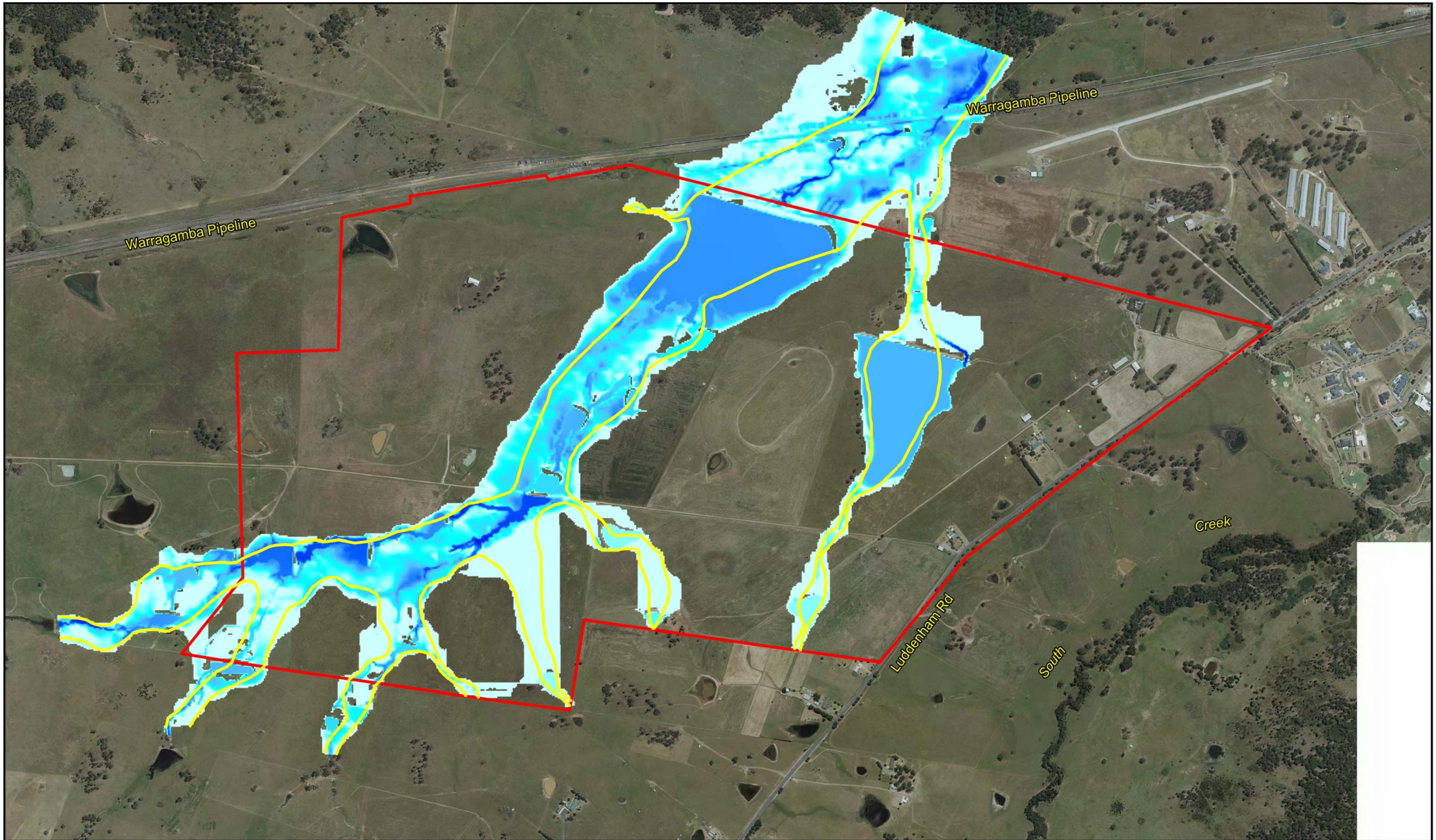
HIGH HAZARD

# Figure 11.4

## SYDNEY SCIENCE PARK

PEAK 1% AEP EXISTING CONDITIONS

FLOOD HAZARD




**LEGEND**

**DEPTH (m)**

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

- ESTIMATED FLOODWAY EXTENT
- SYDNEY SCIENCE PARK STUDY AREA

N W E S

Scale 1: 10,000 @ A3

200 0 200 m

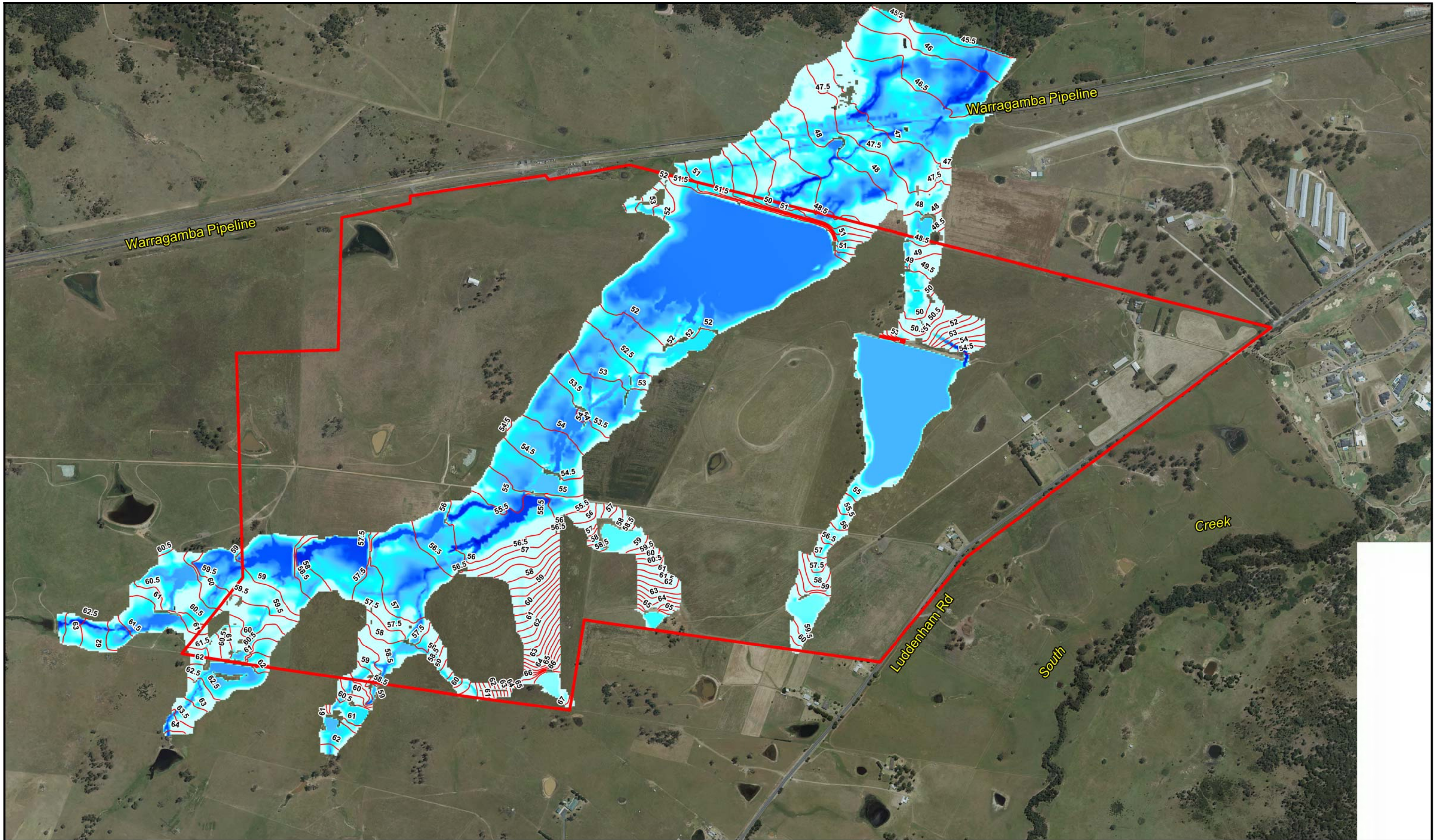
J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.5 (Peak 1% AEP Existing Conditions Hyra. Cat.) 11/12/2013
Issue: B

# Figure 11.5

## SYDNEY SCIENCE PARK

PEAK 1% AEP EXISTING CONDITIONS
HYDRAULIC CATEGORISATION




J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.6 (Peak 500 Existing Conditions) 11/12/2013
Issue: B

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

**DEPTH (m)**

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

30.5 FLOOD CONTOUR & LEVEL

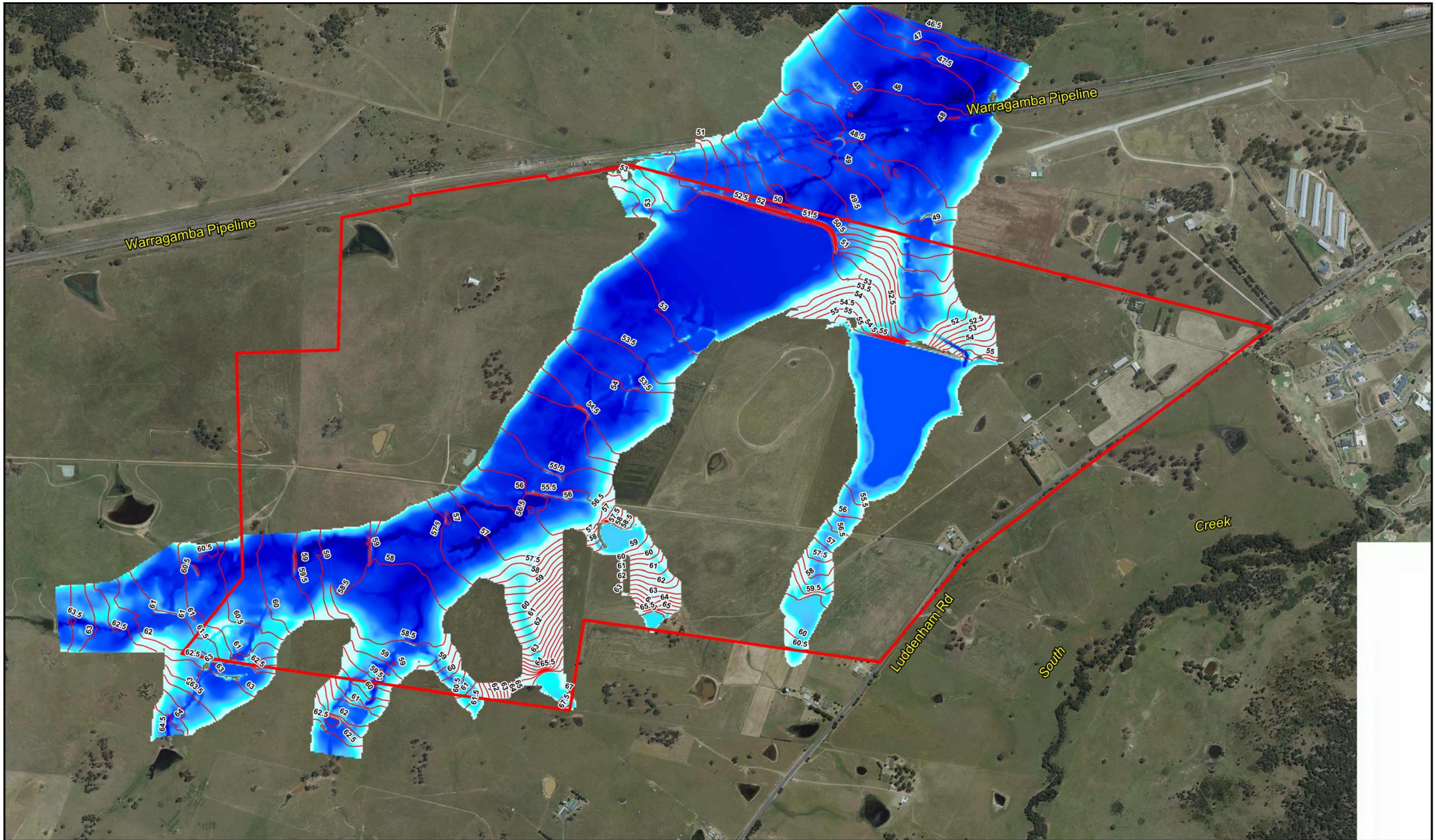
SYDNEY SCIENCE PARK STUDY AREA

# Figure 11.6

## SYDNEY SCIENCE PARK

PEAK 0.2% AEP EXISTING CONDITIONS

FLOOD DEPTH & LEVEL PLAN




**J. WYNDHAM PRINCE**

CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS


PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.7 (Peak PMF Existing Conditions) 11/12/2013
Issue: B

N W E S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

**DEPTH (m)**

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

30.5 FLOOD CONTOUR & LEVEL

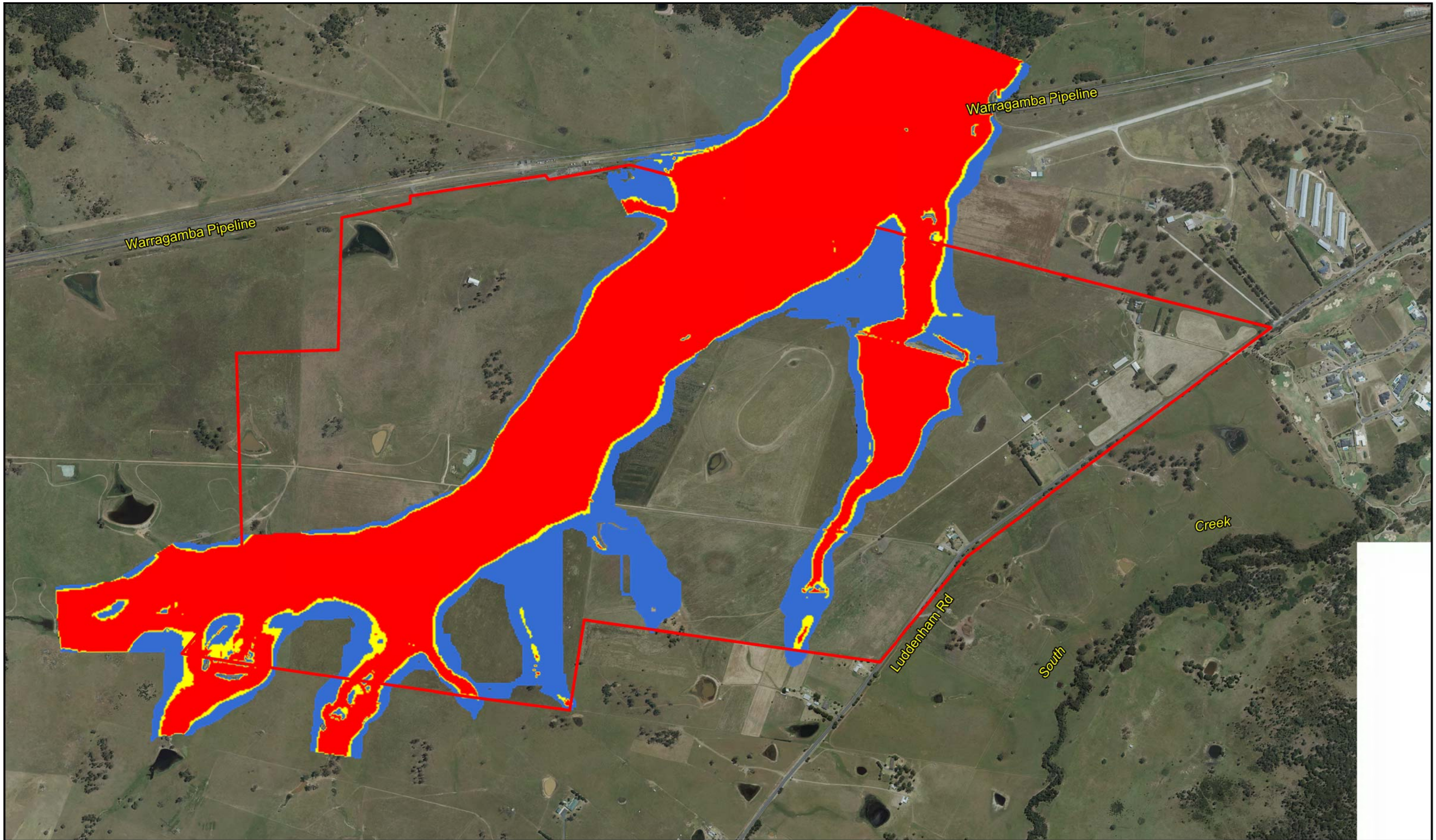
SYDNEY SCIENCE PARK STUDY AREA

NOTE: FLOODING WITHIN THE UPPER REACHES IS RESTRICTED BY THE TUFLOW BOUNDARY

# Figure 11.7

## SYDNEY SCIENCE PARK

PEAK PMF EXISTING CONDITIONS
FLOOD DEPTH & LEVEL PLAN




J. WYNDHAM PRINCE

CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS


PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.8 (Peak PMF Existing Flood Hazards) 11/12/2013
Issue: B

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

SYDNEY SCIENCE PARK STUDY AREA

HAZARD CATEGORISATION

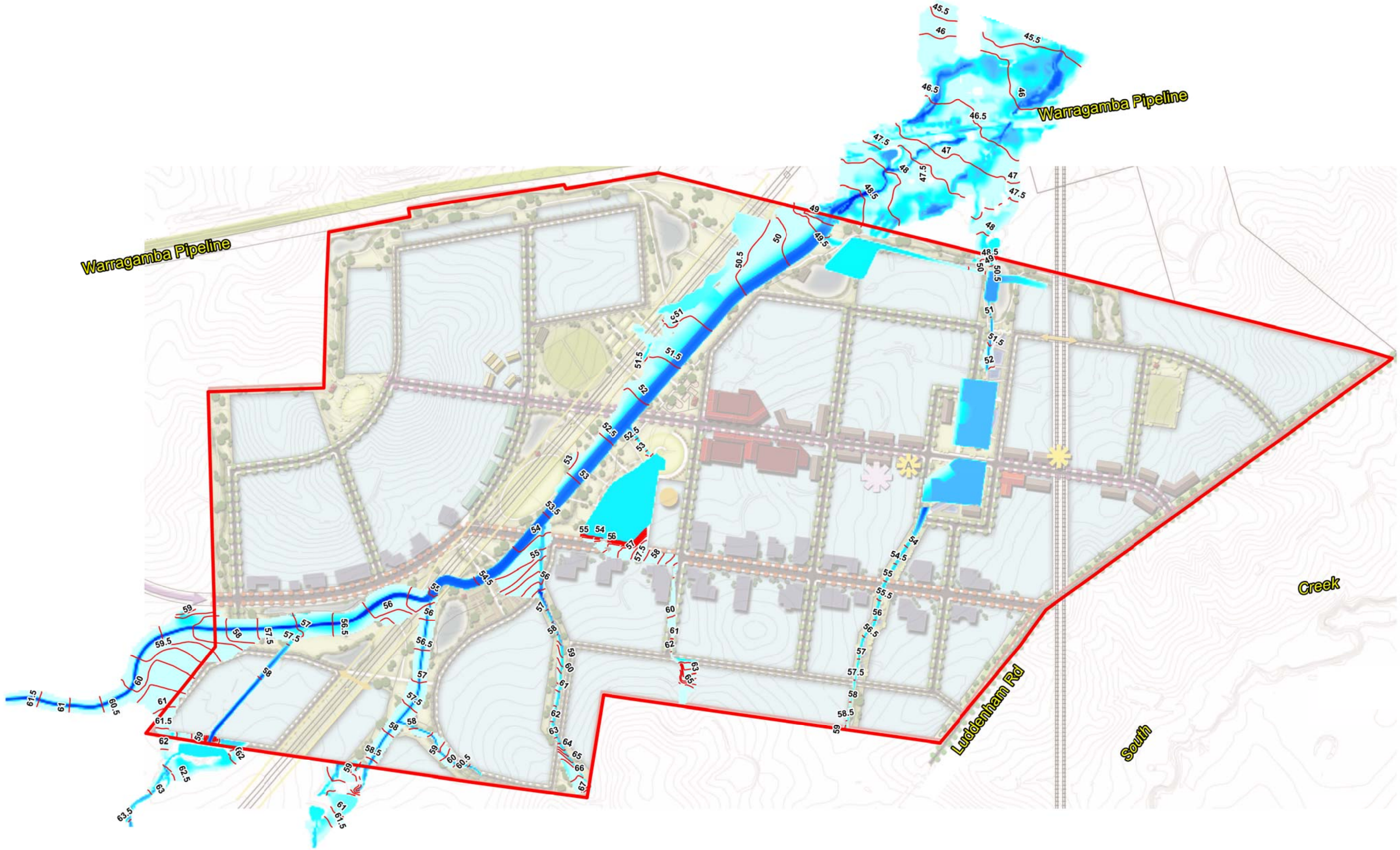
LOW HAZARD
TRANSITION HAZARD
HIGH HAZARD

NOTE: FLOODING WITHIN THE UPPER REACHES IS RESTRICTED BY THE TUFLOW BOUNDARY

# Figure 11.8

SYDNEY SCIENCE PARK

PEAK PMF EXISTING CONDITIONS FLOOD HAZARD







J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
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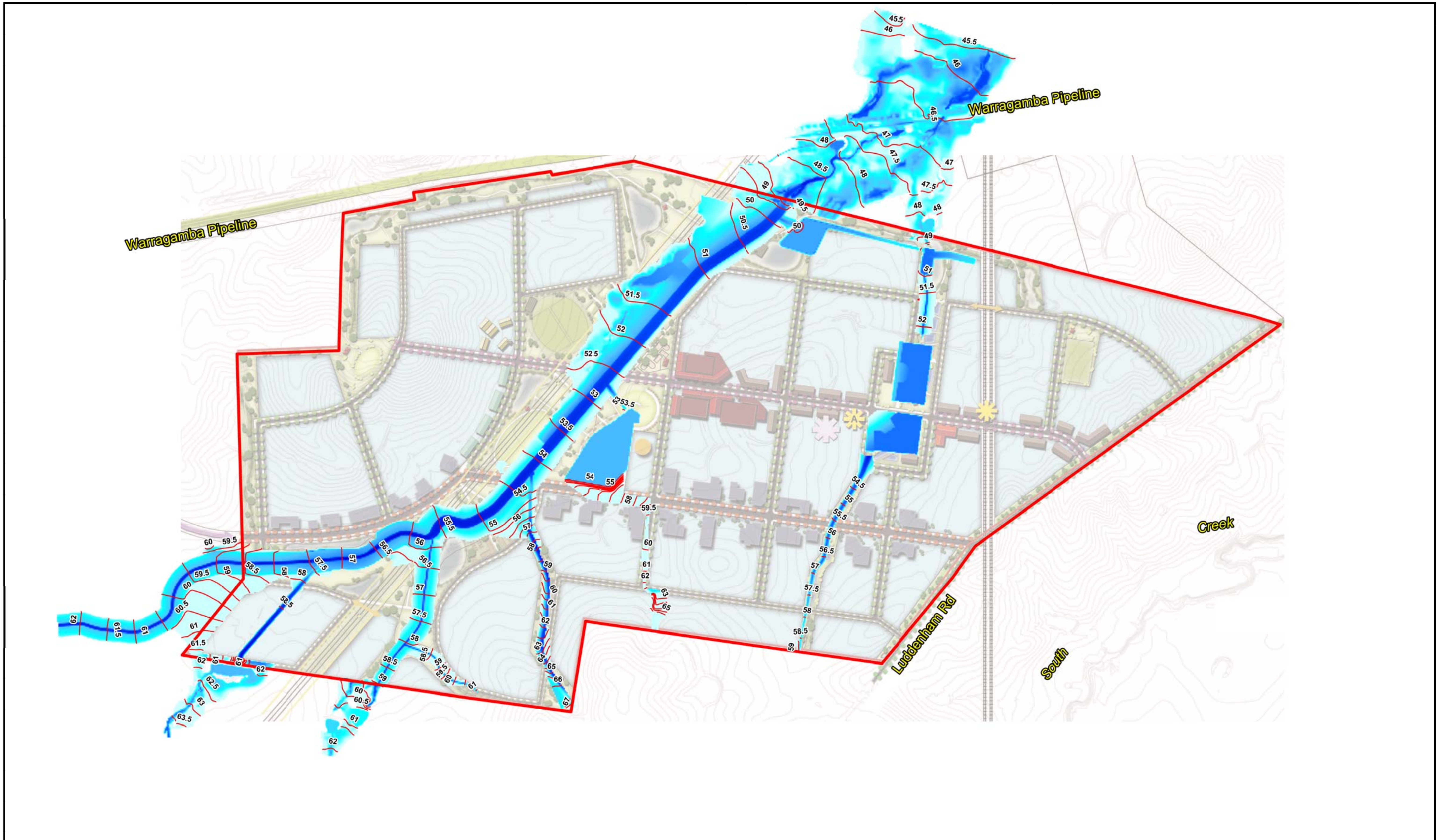
9765 Figure 11.9 (Peak 50% AEP Developed Flood Depth) 16/12/2013
Issue: C

# Figure 11.9

## SYDNEY SCIENCE PARK

PEAK 50% AEP DEVELOPED CONDITIONS
FLOOD DEPTH & LEVEL PLAN




J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.10 (Peak 1% AEP Developed Flood Depth) 16/12/2013
Issue: C

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

**DEPTH (m)**

| | |
|---|---|
| | 0.0 to 0.1 |
| | 0.1 to 0.2 |
| | 0.2 to 0.3 |
| | 0.3 to 0.5 |
| | 0.5 to 1.0 |
| | 1.0 to 2.0 |
| | 2.0 + |

30.5 FLOOD CONTOUR & LEVEL

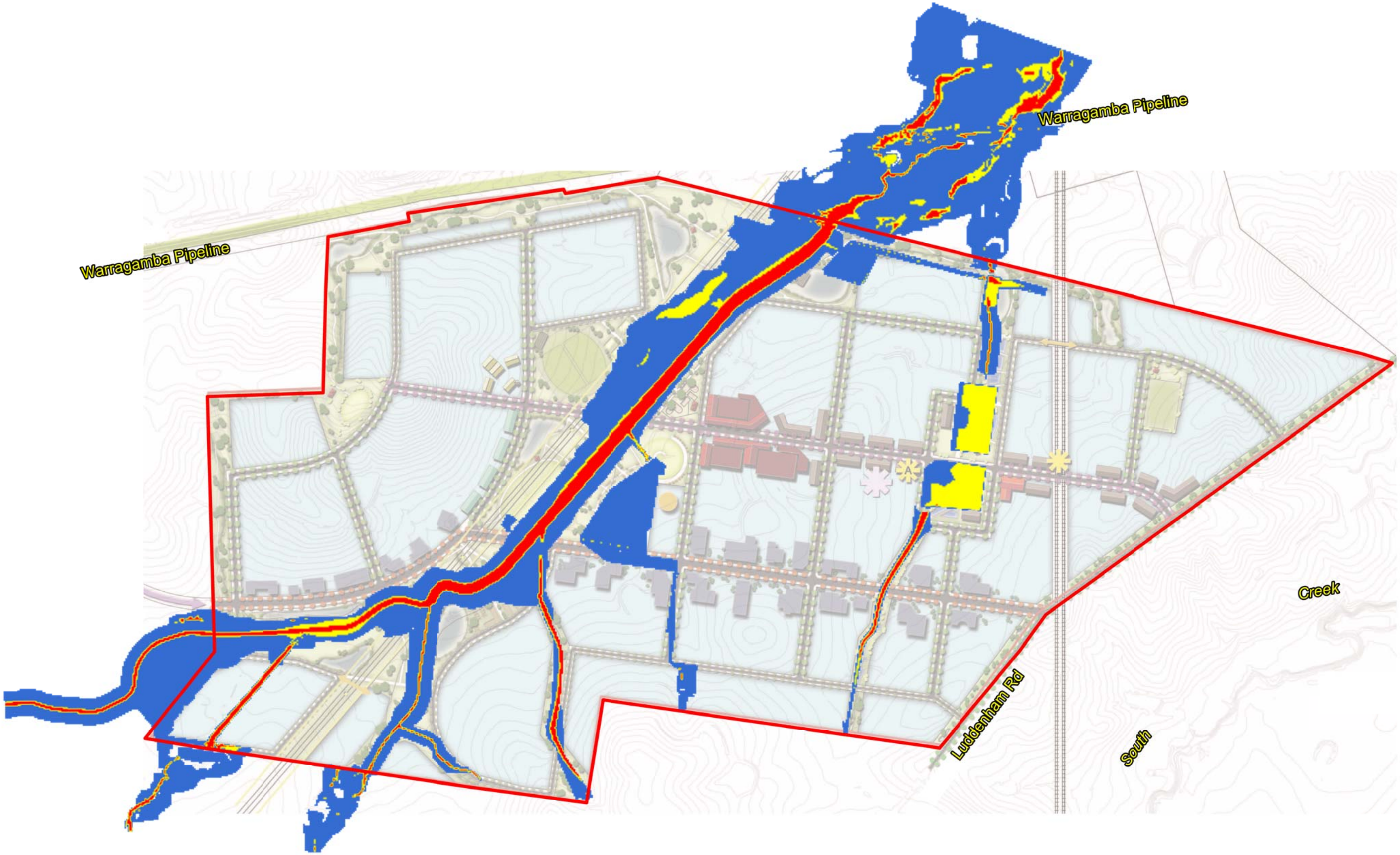
SYDNEY SCIENCE PARK STUDY AREA

# Figure 11.10

## SYDNEY SCIENCE PARK

PEAK 1% AEP DEVELOPED CONDITIONS

FLOOD DEPTH & LEVEL PLAN




J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.11 (Peak 1% AEP Developed Flood Hazards) 16/12/2013
Issue: C

N W E S

Scale 1: 10,000 @ A3

200 0 200 m

LEGEND

SYDNEY SCIENCE PARK STUDY AREA

HAZARD CATEGORISATION

LOW HAZARD

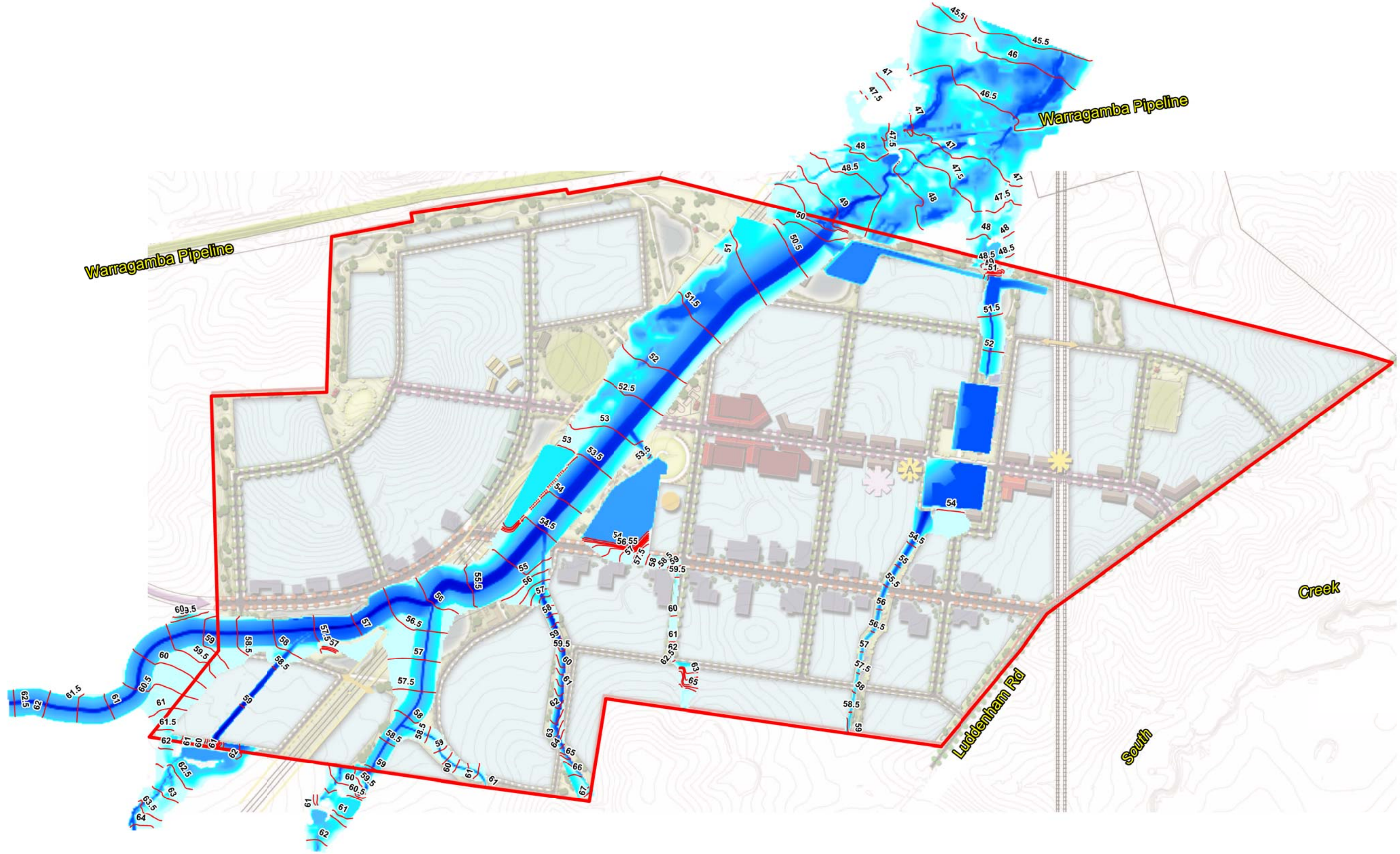
TRANSITION HAZARD

HIGH HAZARD

# Figure 11.11

SYDNEY SCIENCE PARK

PEAK 1% AEP DEVELOPED CONDITIONS FLOOD HAZARD




J. WYNDHAM PRINCE

CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS


PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.12 (Peak 0.2% AEP Developed Flood Depth) 16/12/2013
Issue: B

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W E
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Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

**DEPTH (m)**

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

30.5 FLOOD CONTOUR & LEVEL

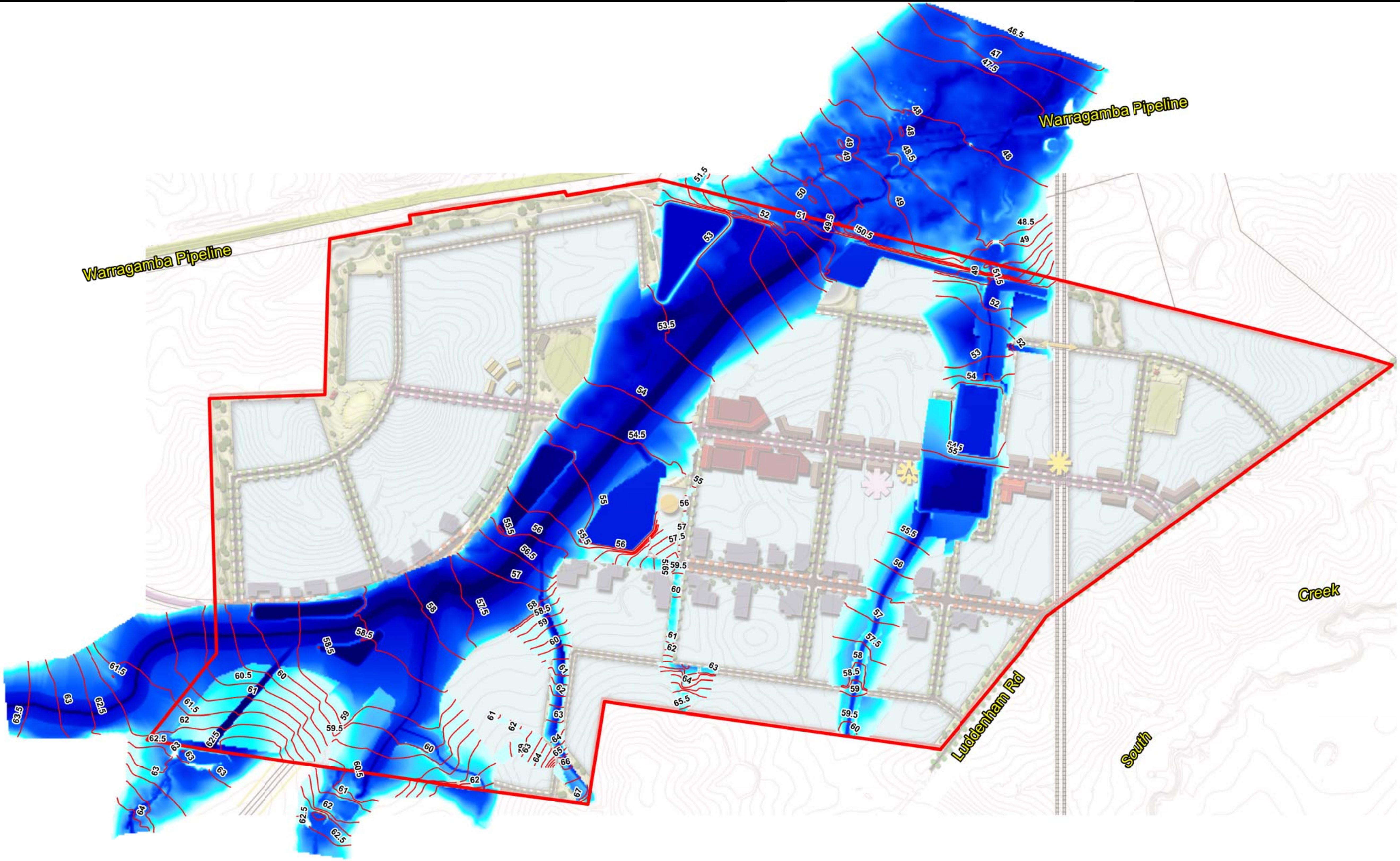
SYDNEY SCIENCE PARK STUDY AREA

# Figure 11.12

## SYDNEY SCIENCE PARK

PEAK 0.2% AEP DEVELOPED CONDITIONS

FLOOD DEPTH & LEVEL PLAN




LEGEND

DEPTH (m)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

30.5 FLOOD CONTOUR & LEVEL

SYDNEY SCIENCE PARK STUDY AREA

NOTE: FLOODING WITHIN THE UPPER REACHES IS RESTRICTED BY THE TUFLOW BOUNDARY

Scale 1: 10,000 @ A3

200 0 200 m


J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.13 (Peak PMF Developed Flood Depth) 16/12/2013
Issue: B

# Figure 11.13

## SYDNEY SCIENCE PARK

PEAK PMF DEVELOPED CONDITIONS
FLOOD DEPTH & LEVEL PLAN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& PROJECT MANAGERS


PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.14 (Peak PMF Developed Flood Hazards) 16/12/2013
Issue: B

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

SYDNEY SCIENCE PARK STUDY AREA

HAZARD CATEGORISATION

LOW HAZARD

TRANSITION HAZARD

HIGH HAZARD

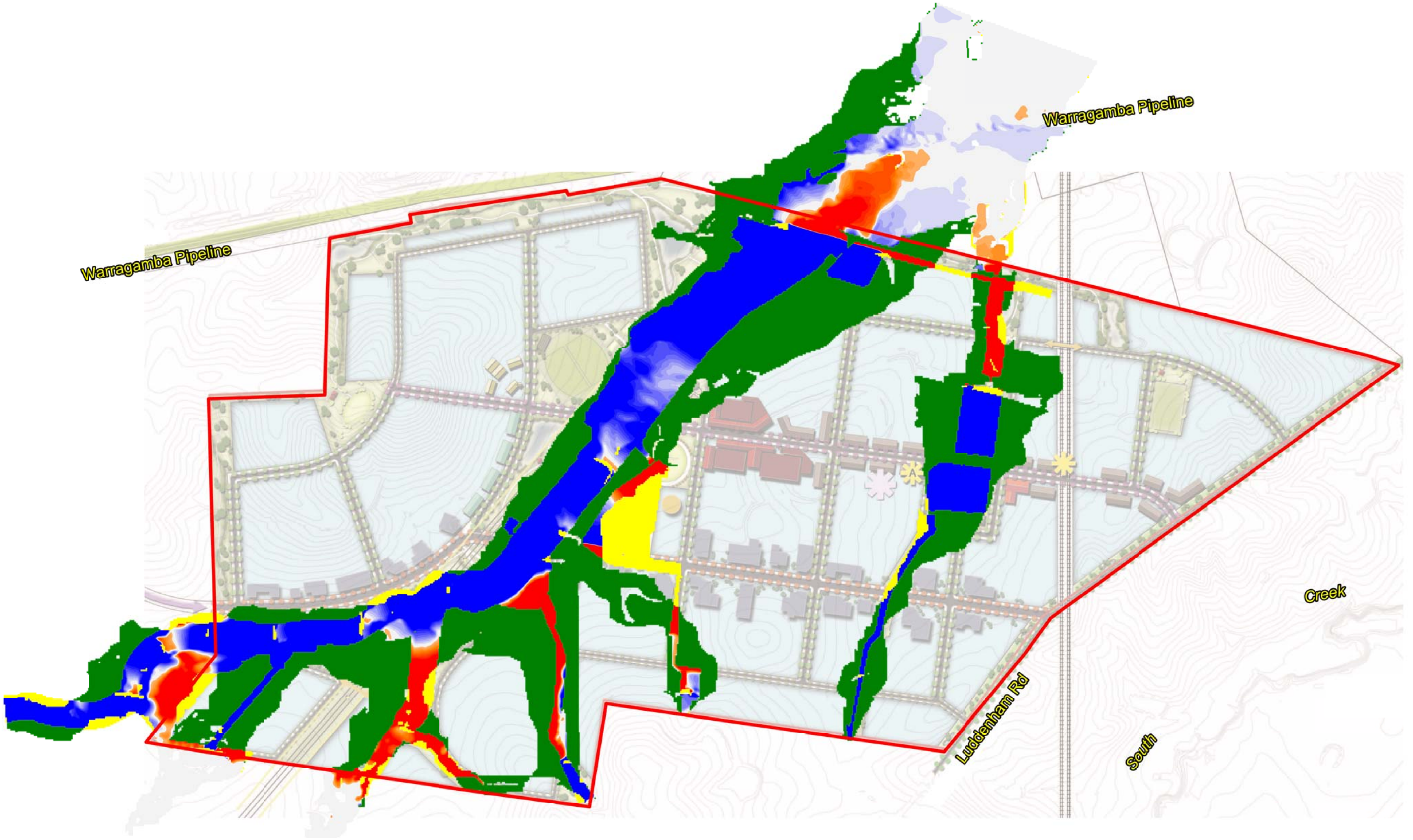
NOTE: FLOODING WITHIN THE UPPER REACHES
IS RESTRICTED BY THE TUFLOW BOUNDARY

# Figure 11.14

SYDNEY SCIENCE PARK

PEAK PMF DEVELOPED CONDITIONS

FLOOD HAZARD




**LEGEND**

INCREASE IN FLOOD LEVELS (m)

| | |
|---|---|
| -0.2+ | 0.02 |
| -0.18 | 0.04 |
| -0.16 | 0.06 |
| -0.14 | 0.08 |
| -0.12 | 0.10 |
| -0.10 | 0.12 |
| -0.08 | 0.14 |
| -0.06 | 0.16 |
| -0.04 | 0.18 |
| -0.02 | 0.2+ |
| 0 | |

SYDNEY SCIENCE PARK STUDY AREA

AREAS NOW FLOOD FREE

AREAS NOW FLOOD AFFECTED

N W E S

Scale 1: 10,000 @ A3

200 0 200 m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CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.15 (Peak 1% AEP Flood Difference) 16/12/2013
Issue: C

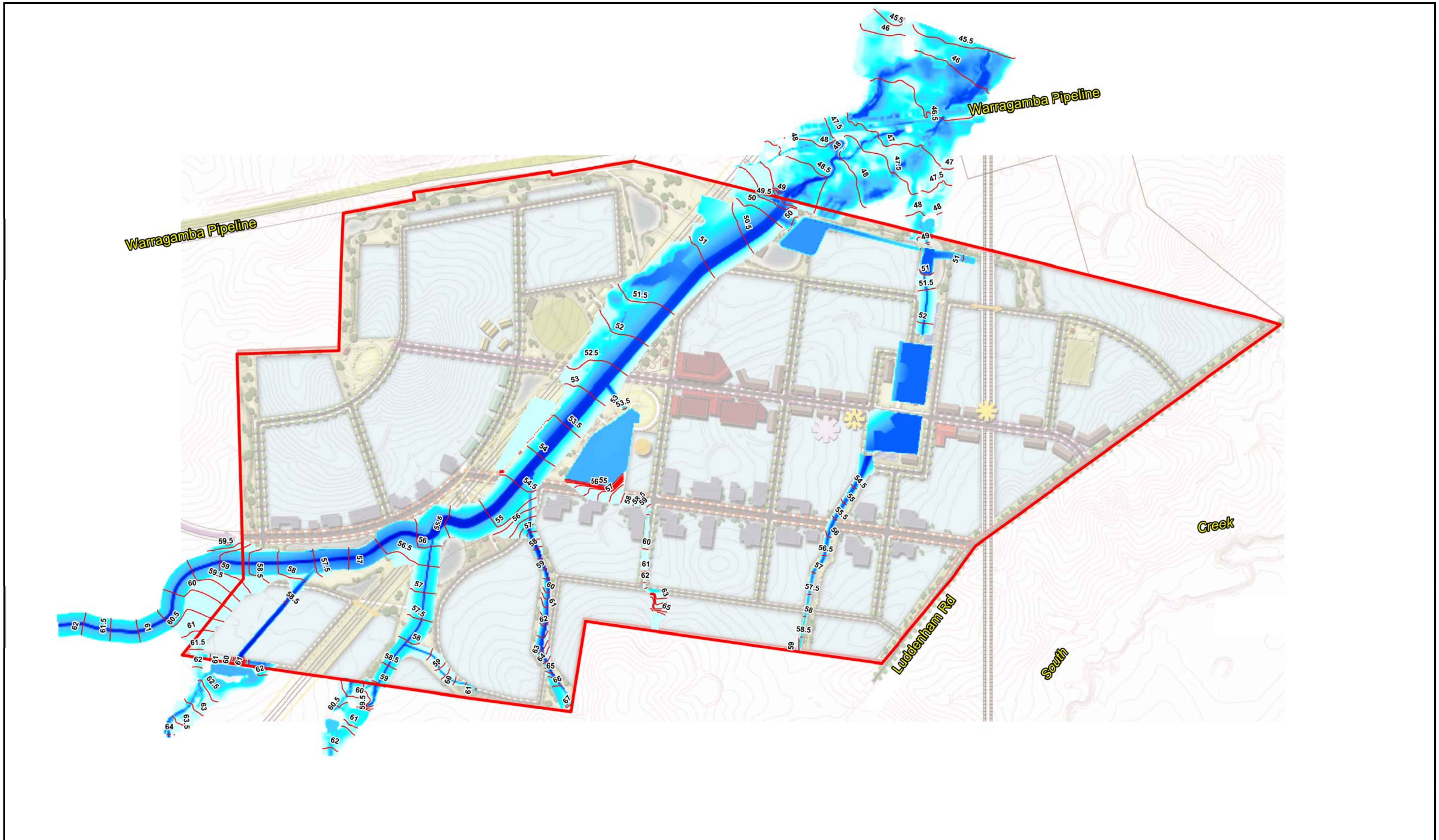
# Figure 11.15

## SYDNEY SCIENCE PARK

PEAK 1% AEP

FLOOD DIFFERENCE MAP

DEVELOPED - EXISTING





J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au


9765 Figure 11.16 (Peak 1% AEP CC Developed Flood Depth) 16/12/2013
Issue: B

N S W E

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

DEPTH (m)

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 +

30.5 FLOOD CONTOUR & LEVEL

SYDNEY SCIENCE PARK STUDY AREA

# Figure 11.16

## SYDNEY SCIENCE PARK

PEAK 1% AEP
FLOOD DEPTH & LEVEL PLAN
CLIMATE CHANGE CONDITIONS


J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 11.17 (Peak 1% AEP CC Flood Difference) 16/12/2013
Issue: B

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

INCREASE IN FLOOD LEVELS (m)

| | |
|---|---|
| -0.2+ | 0.02 |
| -0.18 | 0.04 |
| -0.16 | 0.06 |
| -0.14 | 0.08 |
| -0.12 | 0.10 |
| -0.10 | 0.12 |
| -0.08 | 0.14 |
| -0.06 | 0.16 |
| -0.04 | 0.18 |
| -0.02 | 0.2+ |
| 0 | |

SYDNEY SCIENCE PARK STUDY AREA
AREAS NOW FLOOD FREE
AREAS NOW FLOOD AFFECTED

# Figure 11.17
## SYDNEY SCIENCE PARK

PEAK 1% AEP
FLOOD DIFFERENCE MAP
CLIMATE CHANGE CONDITIONS


J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS
& PROJECT MANAGERS
PO Box 4366 PENRITH WESTFIELD NSW 2750
P 02 4720 3300
F 02 4721 7638
W www.jwprince.com.au
E jwp@jwprince.com.au

9765 Figure 12.1 (MUSIC Layout) 16/12/2013
Issue: C

N
W E
S

Scale 1: 10,000 @ A3

200 0 200 m

**LEGEND**

| | |
|---|---|
| | SYDNEY SCIENCE PARK SITE BOUNDARY |
| B9 | PROPOSED DETENTION BASIN WITH RAINGARDEN |
| B1 | PROPOSED DETENTION BASIN COMBINED WITH WETLAND |
| B5 | PROPOSED DETENTION BASIN COMBINED WITH POND |
| R1 | PROPOSED RAINGARDEN DEVICE |
| | PROPOSED WETLAND |
| | PROPOSED TRUNK DRAINAGE CHANNEL |
| | MUSIC CATCHMENT EXTENTS |
| | APPROXIMATE LOCATION OF PROPOSED GPT |
| | COMMERCIAL/MIXED USE |
| | PARK |
| | LAKE |
| | MAJOR ROAD/RAIL |

# FIGURE 12.1

## SYDNEY SCIENCE PARK

MUSIC CATCHMENT LAYOUT