CAMDEN COUNCIL PUBLIC EXHIBITION DOCUMENT 2022

INVESTIGATION & DESIGN HARRINGTON PARK MITIGATION WORKS, NARELLAN – NEPEAN STAGE I & STAGE II REPORT: PREFERRED FLOOD MITIGATION OPTIONS AND CONCEPT DESIGN

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PREFERRED FLOOD MITIGATION OPTIONS & CONCEPT DESIGN

Report Number: DC17058

September 2017

A division of the Department of Finance, Services & Innovation

Document Control

Version	Author	Reviewer	Approved for Issue	
			Name	Date
1st Draft for comments	L Collins S Cvetkovic	B McPherson	T Schubach	June 2017
Final Draft	S Cvetkovic	B McPherson	T Schubach	September 2017

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Foreword

NSW government's professional specialist advisor, Public Works Advisory (PWA) was commissioned by Camden Council to undertake the investigation of flooding issues and design of mitigation works in the Narellan Creek catchment in light of various recent developments and the availability of additional datasets.

PWA has extensive experience and knowledge in complex and challenging flooding process evaluation and design of effective flood mitigation works in consideration with social, ecological and economic factors relating to flood risks.

The report was prepared by Leon Collins and Svetlana Cvetkovic.

Executive summary

The Harrington Park Mitigation Works Investigation and Design project is being prepared for Camden Council in order to manage existing, future and residual flood risks in the Study Area.

The primary objective of the New South Wales Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible. The *Floodplain Development Manual: the management of flood liable land* (NSW Government 2005)~~,~~ is provided to assist councils to meet their obligations through the preparation of floodplain risk management plans. The Manual also documents the process for plan preparation, implementation and review.

Camden Council wishes to identify the most beneficial combination of options in the Harrington Park area to meet environmental, social and economic objectives from both a catchment wide and township perspectives.

SMEC (2000), Worley Parson (2014 & 2015) and Public Works (2016) undertook flood modelling of Narellan Creek that helped developed a number of flood mitigation measures for the Harrington Park area. The proposed options are the most beneficial that meets environmental, social and economic objectives from both a catchment wide and township perspectives.

The latest TUFLOW flood model (including a revised hydrologic approach) consistent with the adopted Narellan Creek Flood Study (Worley Parson 2015) has been utilised in the study. The hydraulic model has been updated to reflect changes within the catchment over recent years using best available techniques, survey and hydraulic information to address issues identified in the existing model and accurately predict flood behaviour in the study area.

Council's recommended mitigation options have been further reviewed, together with additional flood mitigation options, and refined in order to maintain the function of the Harrington Park Water Quality and Flood Management System (WQMS). The results of the preliminary hydraulic assessment of short-listed options, identified two options as the preferred solutions, for further investigation, those being:

- Construction of a Levee embankment to 74.5 m AHD for approximately 210 metres between Fairwater Garden residential area and Narellan Creek, known as Fairwater Gardens flood levee. The levee would offer protection to Fairwater Gardens residential area for the 1% AEP design event.
- Widening of the spillway to an off-stream storage lake (Lake 2) east of Narellan Creek to increase its storage capacity. The works would also involve deepening and widening the existing channel downstream of the spillway to the confluence with Narellan Creek and construction of a footbridge. The works would reduce flood levels for all design floods.

In addition, preparation of a vegetation rehabilitation plan for the preferred options has been undertaken, including ongoing management requirements for rehabilitated areas. Proposed rehabilitation works are to include vegetation suitable for the required Manning's level. The full description of this investigation is provided in *Vegetation Management Plan-Narellan Creek proposed spillway channel Harrington Park* (Lesryc Environmental 2017).

The final results of the Investigation & Design Harrington Park Mitigation Works study have identified that two preferred flood mitigation options in the Harrington Park area are not economically viable.

Furthermore, the Investigation & Design Harrington Park Mitigation Works project has detailed the staging Vegetation Management Plan, which provides adequate guidelines for the future implementation of the Vegetation Management Works and budget forecasts. Undertaking Vegetation Management in the Harrington Park area is required both to achieve suitable hydraulic roughness levels and as ongoing vegetation management to maintain the hydraulic roughness levels and flow regime.

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Abbreviations

Abbreviation	Description
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation

1 Introduction

1.1 General

The Harrington Park Mitigation Works Investigation and Design project is being prepared for Camden Council in order to manage existing, future and residual flood risks in the Study Area. The first key stage of the process has been completed with the completion of the Narellan Creek Flood Study (Worley Parsons, 2015) which included a preliminary flood mitigation option study for Harrington Park.

The subject of this study is the detailed investigation and design stage which can lead into the final key stage of the Floodplain Management process for Harrington Park, the implementation of management options.

1.2 Scope of Works

The scope of works is outlined below and is to be undertaken in two stages, namely:

- Stage I – Preferred Mitigation Works;
- Stage IA – Vegetation Management;
- Stage II - Concept Design of 2 selected mitigation options.

Stage I is being undertaken in a phased approach as outlined below:

- Data Collection and Review;
- Hydrology and Hydraulic Modelling of flood mitigation options;
- Engineering Investigation, preliminary Geotechnical Assessment, Environmental Impact Assessment, Economic Analysis and Social Impact Assessment for 2 selected mitigation options.

Stage II is being undertaken as outlined below:

- Concept Design Drawings for 2 selected mitigation options;
- Multiple Benefit Analysis for 2 selected mitigation options;
- Vegetation Management Works

The purpose of this report is to document the information gathered during the Stage I & Stage II in accordance with the study program. This report outlines the methodology, analysis and key outcomes of these stages and is structured to include all the information required for the preferred option to progress further to the Detail Design phase.

2 Study Approach

2.1 Study Location

Harrington Park lies within the Narellan Creek catchment, which is itself a tributary of the Nepean River. Harrington Park is situated in south - western Sydney approximately 65 km from the CBD, and covers an area of approximately 8 km^2. The Narellan Creek local catchment covers an area of approximately 35 km^2, and contains the suburbs of Narellan, Narellan Vale, Smeaton Grange, Harrington Park, Currans Hill, Mount Annan, Elderslie and Kirkham.

The Study Area (see **Figure 2-1**: Study Area) has recently undergone a period of rapid urbanisation, with many areas that were previously farmland being converted to residential areas including Narellan Vale, Smeaton Grange and Elderslie. Portions of the catchment are also located within the South West Growth Centre for NSW and expect to undergo growth in the future.

Flooding along Narellan Creek can be attributed to both local catchment flooding as well as backwater flooding from the Nepean River. The Nepean River Valley has a history of frequent flooding and has a catchment that extends as far as Mittagong in the Southern Highlands. The catchment covers an area of approximately 1,400 km^2 upstream of Narellan Creek.

The majority of developed areas in the Narellan Creek catchment are above the level of flooding from the Nepean River. However, these properties may face a risk of flooding due to local catchment runoff which is the focus of this study.

Figure 2-1: Study Area

2.2 Study Objectives

The proposed flood mitigation works will form an integral part of the flood mitigation measures maintained by Camden Council to achieve the following objectives:

- Reduce 1% AEP flood levels in Harrington Park and Fairwater Gardens;
- Assess and address the flood impacts of the PMF in Harrington Park and Fairwater Gardens;
- Mitigate flood impacts on the properties subject to 1% AEP over-floor inundation in Harrington Park.

2.3 Adopted Approach

The general approach and methodology employed to achieve the study objectives involved:

- Compilation and review of available information, including previously completed flood investigations, streamflow gauge records, rainfall records, topographic mapping of the floodplain and details of bridge crossings and other structures;
- Site inspections and interrogation of aerial photography and other geographical data in order to establish catchment roughness, slope and land-use attributes;
- Vegetation survey and existing vegetation mapping;
- The collection of historical flood information, including records of peak flood levels for historical floods;
- Review and adoption of the existing XP-RAFTS hydrologic model which simulates rainfall-runoff processes across catchment and provides inflows for the hydraulic model;
- Review of the existing TUFLOW hydraulic model which simulates the movement of floodwaters through the Narellan Creek catchment;
- Update of the existing TUFLOW hydraulic model utilising additional datasets, and refinement of particular aspects of the model found to be unsuitably represented;
- Preliminary hydraulic assessment of short listed options to identify two options as the preferred solutions for further investigation;
- Engineering Investigation of the preferred options (construction and operational issues);
- Preliminary Geotechnical Investigation of the preferred options;
- Review of Environmental Factors (REF) for the preferred options;
- Economic Analysis for the preferred options including Flood Damage Assessment, Cost Estimate and Benefit-Cost Analysis for the preferred options;
- Social Impact Assessment for the preferred options;
- Concept Design Drawings for the preferred options;
- Multiple Benefit Analysis of the preferred options;
- Vegetation Management Plan including specifications, staging plan, cost estimate and maintenance for vegetation managements works.

3 Compilation and Review of Available Data

3.1 Previous investigations

A number of previous flood studies have been undertaken for Narellan Creek. Synopses of those investigations considered relevant to this study are provided in the following sections. A number of previous studies have been summarised in the previous flood study (WorleyParsons, 2015) and have not been represented in this study. These studies include:

- Tributary Flood Studies (Lyall & Macoun Consulting Engineers, 1997, 1998 and 1999)
- Harrington Park Hydrologic and Hydraulic Report (SMEC, 2000)
- Report on Drainage Investigation for Somerset Avenue, Narellan (Appleyead Forrest, 2000)
- Tributary Flood Risk Management Study (2001)
- Upper Canal Cross Drainage Analysis Report (SMEC, 2001)
- Smeaton Grange Industrial Estate: Kenny & Narellan Creeks Concept Design & Planting Assessment (Arup, 2004)

3.2 Review of Relevant Studies

Additional studies have been reviewed as part of the flood study update and they are listed below:

- Peer Review of Draft Narellan Creek Flood Study (WMAwater, 2014);
- Peer Review of Draft Narellan Creek Flood Study (Square Link, 2014);
- Peer Review of Draft Narellan Creek Flood Study (Cardno, 2014);
- Harrington Park Lake 3 Physical Model Study (AWACS, 1994)
- Narellan Creek Flood Study (Worley Parsons, 2015)
- Investigation and Design, Harrington Park Mitigation Works (NSW Public Works, 2016)
- Post Flood Event Analysis June 2016 (NSW Public Works Advisory, 2017)
- Narellan Creek Flood Study – Harrington Park Flood Mitigation Options (Worley Parsons 2014)
- Nepean River Flood Study (Worley Parsons 2015)
- Harrington Park – Narellan Creek Water Quality and Flood Management System (WQMS) Operations and Maintenance Manual (SMEC 2005).

Each of these studies is described in more details in Section 3 in the *Update of Narellan Creek Flood Study (*PWA 2017), which updates and supersedes Narellan Creek Flood Study (Worley Parsons 2015).

3.3 Available Data

The data described in the Narellan Creek Flood Study (WorleyParsons, 2015) were also made available to PWA and have not been further described in this report. However, additional data

were provided by Council including:

- Gross pollutant Trap over James Way at Mount Annan survey from 2015 by Apex Surveying;
- Work As Executed (WAE) Boyd Reserve Design Plans from 1998 by Young Consulting Engineers for Land Co. Developers;
- WAE plans of Lake Currans detention basin from 1990 for Department of Housing by Kinhill Engineers;
- Additional topographic data for various residential developments that occurred since 2011 provided in 12d, CAD or pdf format;
- Various drawing of culverts and pipes within the catchment;
- Vegetation survey from February 2016;
- WAE plans as presented in Harrington Park – Narellan Creek WQMS Operations and Maintenance Manual (SMEC 2005);
- Point elevations surveyed by Camden Council in March 2016;
- Narellan Creek / Harrington Park cross-sectional survey completed by Camden Council in 2014;
- Representative channel bed elevations and widths collected by PWA during a site inspection on 30 March 2016;
- Lake 3A spillway physical model report from 1994 by AWACS.

3.4 Existing digital flood models

A summary of the hydrologic and hydraulics models used in relevant flood studies is presented in **Table 3-1**

Table 3-1: Summary of previous flood models

Catchment	Report	Model (Hydrologic / Hydraulic)
Narellan Creek (Flood Study)	Worley Parsons, 2015	XP_RAFTS (no embedded design storm) TUFLOW 1D/2D
Narellan Creek (Flood Study- Harrington Park Mitigation Options)	Worley Parsons, 2014	TUFLOW 'direct rainfall' approach with Embedded Design Storm TUFLOW 1D/2D
Harrington Park (Flood Study)	SMEC, 2000	XP_RAFTS HECRAS 1D
Nepean River (Flood Study)	Worley Parsons, 2015	XP_RAFTS & RORB (upstream catchment) TUFLOW 1D/2D

A review of the Narellan Creek flood model adopted for the *Narellan Creek Flood Study* (Worley Parsons 2015) is presented in Section 4.1 of this report.

3.5 Review of local flood emergency plan

The Camden Flood Emergency Sub Plan (reviewed October 2015) is a sub plan of the Camden Local Emergency Management Plan (EMPLAN). It was prepared in accordance with the *State Emergency Service Act 1989* (NSW) and is authorised by the Local Emergency Management Committee in accordance with the provisions of the *State Emergency and Rescue Management Act 1989* (NSW).

The plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Camden LGA, which lies within the NSW SES Southern Region and is part of the South West Metropolitan Emergency Management Region.

The Sub-Plan outlines responsibilities for emergency response (primary responsibility lying with the NSW SES Camden Local Controller) and strategies for preparedness, response, management, planning, operations and recovery.

The Sub Plan includes mapping of the Camden LGA including the Nepean River and its tributaries. No specific flood intelligence or flood mapping is contained in the plan. The previous version appears to have included mapping of 'sectors' potentially subject to flood risk.

The study area is located within the Harrington Park Sub-Sector as detailed in Map 8 of the Camden Local Flood Plan, August 2010, Sub-Plan of Camden Local Disaster Plan, which is presented in **Figure 3.1** below. This sector is delineated by Northern Road to the west/north west and Camden Valley Way to the south/south east with a number of local roads throughout the sector being subject to local flooding.

The Harrington Park sector consists predominately of new residential developments and the Harrington Park Public School.

Emergency evacuations in this sector will be conducted by the Camden SES Local Controller with assistance from NSW Police Force, NSW Rural Fire Service, NSW Fire Brigades and NSW Ambulance Service.

Evacuation Centres are: Studley Park Golf Course, Lodges Road-Narellan and Full Club Facilities.

Evacuation routes are:

- To Studley Park Golf Course south via Narellan Road, Camden Valley Way, Richardson Road and Lodges Road.
- To Sydney via Camden Valley Way;
- To Sydney via M5 from Narellan Road;
- To Penrith via the Northern Road.

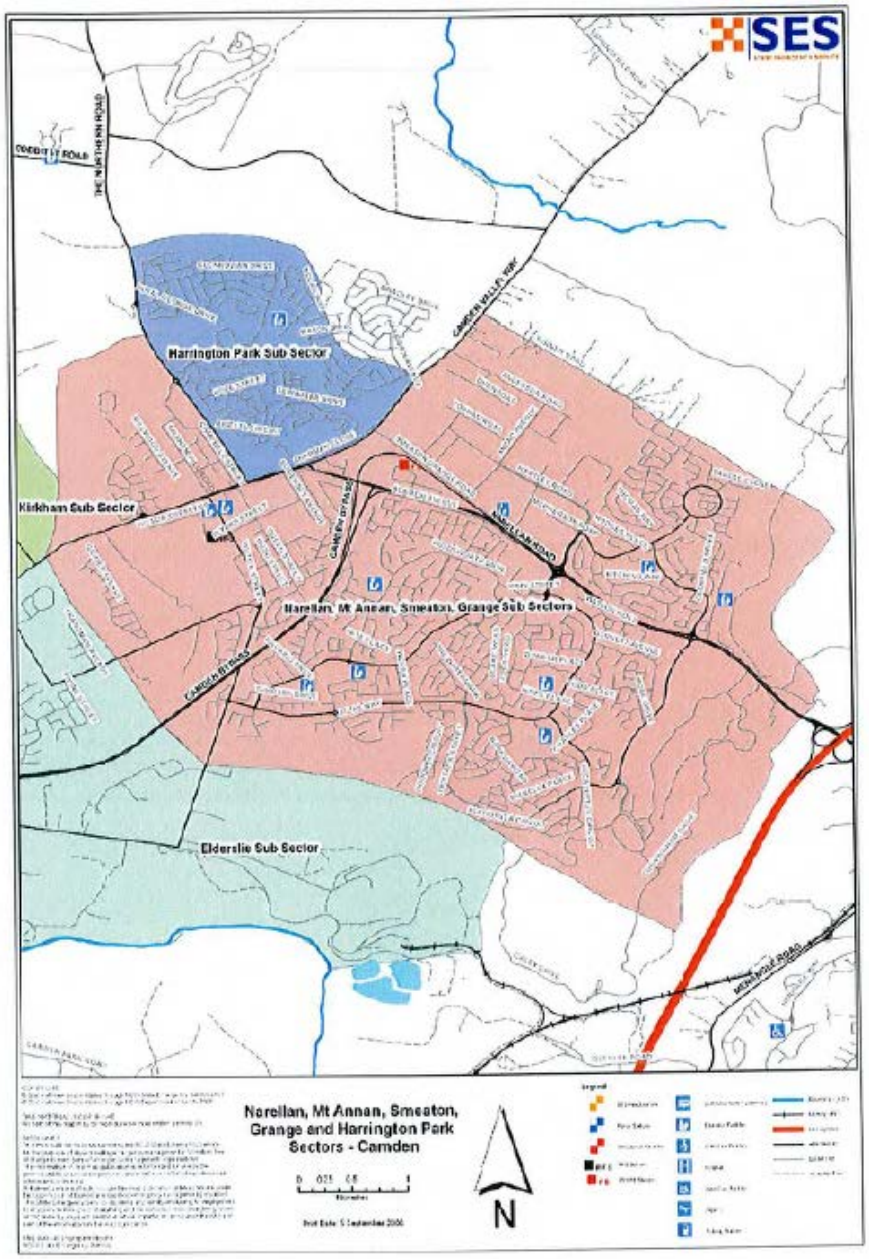


Figure 3.1: Harrington Park Sub Sector Overview Map

3.6 Review of existing planning instruments and policies

For the purpose of the initial options assessment at Harrington Park, existing Council's planning instruments and policies have been reviewed and are detailed below.

3.6.1 Camden Local Environmental Plans (LEPs)

Harrington Park is located within the RE1 Public Recreation zone under the *Camden Local Environmental Plan 2010* (LEP) (see **Figure 3.2**). The objectives of the RE1 zone are:

- To enable land to be used for public open space or recreational purposes.
- To provide a range of recreational settings and activities and compatible land uses.
- To protect and enhance the natural environment for recreational purposes.

Flood mitigation works are permissible with consent under the RE1 land zoning, however the relevant EPI for the works is *State Environmental Planning Policy (Infrastructure) 2007* (ISEPP) which allows the works to proceed without the need to gain development consent (see Section 3.6.2 below).

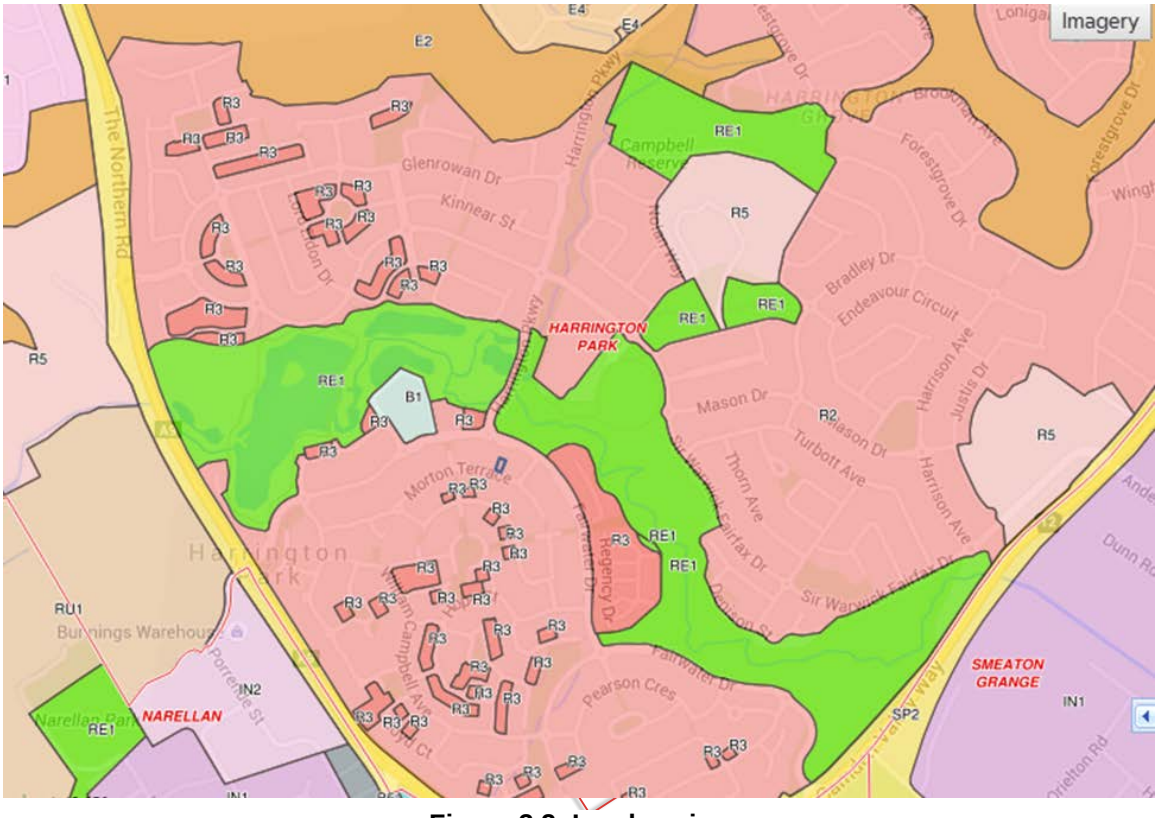


Figure 3.2: Land zoning

3.6.2 State Environmental Planning Policies (SEPPs)

SEPP (Infrastructure) 2007

Flood mitigation work is defined under clause 49 of ISEPP to mean *work designed and constructed for the express purpose of mitigating flood impacts. It involves changing the characteristics of flood behaviour to alter the level, location, volume, speed or timing of flood waters to mitigate flood impacts. Types of works may include excavation, construction or enlargement of any fill, wall or levee that will alter riverine flood behaviour, local overland flooding, or tidal action so as to mitigate flood impacts*.

The vegetation clearing works are considered to meet the definition of flood mitigation works under clause 49 as the aim of the works is to reduce the flooding impacts to the surrounding residential areas.

Clause 50 of ISEPP allows development for the purposes of flood mitigation works to be carried out by or on behalf of a public authority without consent on any land. The proposal would meet the requirements of clause 50 of ISEPP and can therefore proceed without the need to gain

development consent.

State Environmental Planning Policy No 19—Bushland in Urban Areas

The Camden local government area is subject to the provisions of *State Environmental Planning Policy No 19—Bushland in Urban Areas (SEPP 19)*. The general aim of this Policy is to protect and preserve bushland within the urban areas

The specific aims of this policy are:

(a) to protect the remnants of plant communities which were once characteristic of land now within an urban area,

(b) to retain bushland in parcels of a size and configuration which will enable the existing plant and animal communities to survive in the long term,

(c) to protect rare and endangered flora and fauna species,

(d) to protect habitats for native flora and fauna,

(e) to protect wildlife corridors and vegetation links with other nearby bushland,

(f) to protect bushland as a natural stabiliser of the soil surface,

(g) to protect bushland for its scenic values, and to retain the unique visual identity of the landscape,

(h) to protect significant geological features,

(i) to protect existing landforms, such as natural drainage lines, watercourses and foreshores,

(j) to protect archaeological relics,

(k) to protect the recreational potential of bushland,

(l) to protect the educational potential of bushland,

(m) to maintain bushland in locations which are readily accessible to the community, and

(n) to promote the management of bushland in a manner which protects and enhances the quality of the bushland and facilitates public enjoyment of the bushland compatible with its conservation.

Clause 6 (1) requires development consent to disturb bushland zoned or reserved for public open space and clause 6 (4) states that consent cannot be granted unless:

(a) it has made an assessment of the need to protect and preserve the bushland having regard to the aims of this Policy,

(b) it is satisfied that the disturbance of the bushland is essential for a purpose in the public interest and no reasonable alternative is available to the disturbance of that bushland, and

(c) it is satisfied that the amount of bushland proposed to be disturbed is as little as possible and, where bushland is disturbed to allow construction work to be carried out, the bushland will be reinstated upon completion of that work as far as is possible.

Although the Narellan Creek riparian corridor is zoned as RE1 Public Recreation under the

Camden LEP, the ISEPP (see Section above) removes the requirement to gain consent from Council for the works. However the review of environmental factors prepared for the clearing works proposed at Harrington Park would need to consider the requirements under SEPP 19. It is considered that the disturbance of the bushland is essential for a purpose in the public interest and no reasonable alternative is available and is thus consistent with SEPP 19.

Sydney Regional Environmental Plan No 20—Hawkesbury-Nepean River

Narellan Creek falls within the Hawkesbury Nepean River catchment and is subject to the Sydney Regional Environmental Plan No 20—Hawkesbury-Nepean River (SREP 20). The aim of SREP 20 is to protect the environment of the Hawkesbury-Nepean River system by ensuring that the impacts of future land uses are considered in a regional context.

Clause 4 (1) requires that general planning considerations set out in clause 5 of SREP 20, and the specific planning policies and related recommended strategies set out in clause 6 which are applicable to the proposed development, must be taken into consideration by a public authority proposing to carry out development which does not require development consent. These are listed below.

Clause 5 general planning considerations includes:

(a) the aim of this plan, and

(b) the strategies listed in the Action Plan of the Hawkesbury-Nepean Environmental Planning Strategy, and

(c) whether there are any feasible alternatives to the development or other proposal concerned, and

(d) the relationship between the different impacts of the development or other proposal and the environment, and how those impacts will be addressed and monitored.

The specific planning policies and recommended strategies under clause 6 which are considered applicable to the proposed development are listed in **Table 3-2**.

Table 3-2: Relevant SREP 20 Planning Policies

Relevant Issue	Policy
Total catchment management	Total catchment management is to be integrated with environmental planning for the catchment.
Environmentally sensitive areas	The environmental quality of environmentally sensitive areas must be protected and enhanced through careful control of future land use changes and through management and (where necessary) remediation of existing uses.
Water quality	Future development must not prejudice the achievement of the goals of use of the river for primary contact recreation (being recreational activities involving direct water contact, such as swimming) and aquatic ecosystem protection in the river system. If the quality of the receiving waters does not currently allow these uses, the current water quality must be

	maintained, or improved, so as not to jeopardise the achievement of the goals in the future. When water quality goals are set by the Government these are to be the goals to be achieved under this policy.
Water quantity	Aquatic ecosystems must not be adversely affected by development which changes the flow characteristics of surface or groundwater in the catchment.
Cultural heritage	The importance of the river in contributing to the significance of items and places of cultural heritage significance should be recognised, and these items and places should be protected and sensitively managed and, if appropriate, enhanced.
Flora and fauna	Manage flora and fauna communities so that the diversity of species and genetics within the catchment is conserved and enhanced.
Riverine scenic quality	The scenic quality of the riverine corridor must be protected.
Recreation and tourism	The value of the riverine corridor as a significant recreational and tourist asset must be protected.

3.6.3 Other Identified Issues

Heritage Act 1977

A small section of land adjacent to Narellan Creek forms part of a State Heritage listed property – Harrington Park (listing number 01773). The boundary extends to the Narellan Creek line as shown in **Figure 3.3**. The site is also listed under the Camden LEP, National Trust of Australia Register and the Register of National Estate.

Under Section 57(1) of the *Heritage Act* 1977 a person must not carry out any development in relation to the land on which State Heritage Register site is situated or damage, destroy or remove any tree or other vegetation or damage or despoil the land except in pursuance of an approval granted by the Heritage Council. However 57(2) allows for works to a State heritage listed item to proceed with without approval if meet one of the standard exemptions gazetted by the NSW government. It is considered that the clearing works would meet *Standard exemption No. 7: Minor activities with little or no heritage significance*.

In order to assess whether the works will have an adverse effect on heritage significance it is necessary to submit a clear and concise statement of the item's heritage significance and an assessment of whether a proposal impacts on that significance. Therefore a heritage impact assessment would need to accompany the exemption notification to the Heritage Council to undertake clearing on the State heritage listed property.

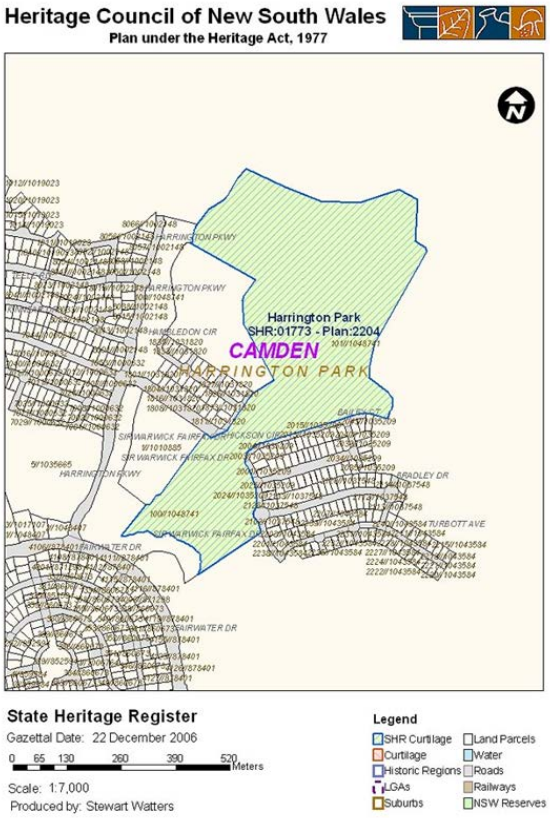


Figure 3.3: State heritage listed area adjacent to Narellan Creek

Threatened Species Conservation Act 1995

The *Threatened Species Conservation Act* 1995 (TSC Act) protects species of threatened flora and fauna, endangered populations and endangered ecological communities and their habitats in NSW.

The majority of riparian vegetation along Narellan Creek has been identified as an endangered ecological community under Schedule 1 of the TSC Act.

Part 1, Section 5A of the *Environmental Planning and Assessment Act* 1979 requires that a determination be made as to whether a proposed action is likely to have a significant effect on species, populations and ecological communities listed on Schedules 1, 1A and 2 of the TSC Act 1995. Where found, the assessment criteria relevant to this Act (seven-part test) will be drawn upon to determine whether there would be a significant effect on these species and hence whether a Species Impact Statement is required.

There is the potential that the required level of clearing to achieve the necessary flood mitigation impact would trigger a significant impact under the EP&A Act thus requiring the preparation of a species impact statement and approval from the Office of Environment and Heritage (OEH).

National Parks and Wildlife Act 1974

The *National Parks and Wildlife Act* 1974 (NPW Act) provides for the statutory protection of Aboriginal cultural heritage places, objects and features. A number of Aboriginal sites have been recorded in the area.

A search of the Aboriginal Heritage Information Management System database revealed that 22 Aboriginal sites have been recorded within 1 km of Narellan Creek at Harrington Park. At least five of these sites were recorded during the EIS for the initial flood works at the Harrington Park site. A due diligence assessment in accordance with the *Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW* (DECCW 2010) would need to be undertaken as part of this REF to clarify the location of the recorded sites and to determine whether any further detailed assessment of Aboriginal heritage would be required.

Bushfire

Harrington Park is mapped as bushfire prone with the creek and riparian vegetation mapped as Vegetation Category 1 (shown in orange on **Figure 3.4**) and the adjacent residential and parkland area mapped as vegetation buffer (shown in red on **Figure 3.4**). Vegetation Category 1 is considered to be the highest risk for bush fire.

There are no implications for the flood mitigation works due to the mapping of the site as bushfire prone.

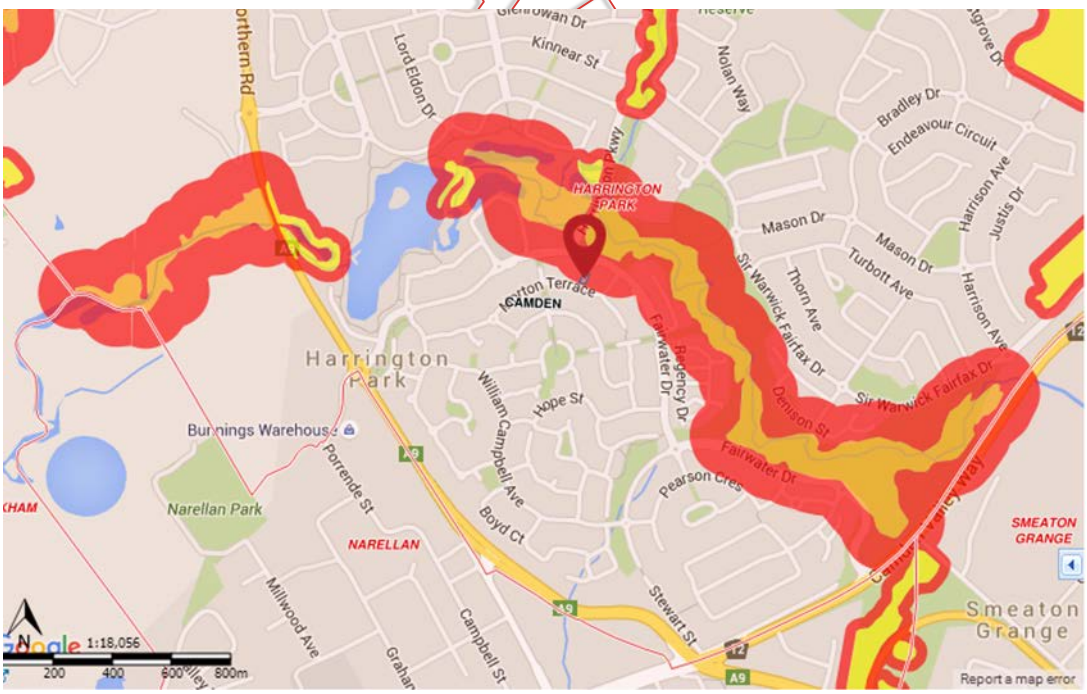


Figure 3.4: Bushfire mapping

3.6.4 Camden Development Control Plan (DCP)

This DCP was made under Section 74C of the Environmental Planning and Assessment Act 1979 and Part 3 of the Environmental Planning and Assessment Regulation 2000. The DCP was adopted by Council on 8 February 2011.

This DCP must be read in conjunction with any environmental planning instrument (EPI) that applies to the land. An environmental planning instrument includes a State Environmental Planning Policy (SEPP), deemed SEPP or a Local Environmental Plan (LEP). In general, Camden LEP 2010 (LEP 2010) will be the only EPI which applies, however a number of SEPPs or deemed SEPPs may still apply to particular sites or developments. The provisions contained in this DCP supplements the provisions of LEP 2010. If there is any inconsistency between this DCP and the LEP, the LEP will prevail.

This DCP applies to all land within the Camden Local Government Area (LGA). In addition to this DCP, Growth Centre precincts gazetted under State Environmental Planning Policy (Sydney Region Growth Centres) 2006 are subject to the Growth Centre specific DCPs which contain additional provisions.

The Study Catchment Area covers ~~of~~ approximately 35 km^2 and contains the suburbs of Narellan, Narellan Vale, Smeaton Grange, Harrington Park, Currans Hill, Mount Annan, Elderslie and Kirkham. Portions of the catchment are also located within the South West Growth Centre for NSW and they are subject to the Growth Centre specific DCP called Turner Road DCP 2014 (see **Figure 3.5**).

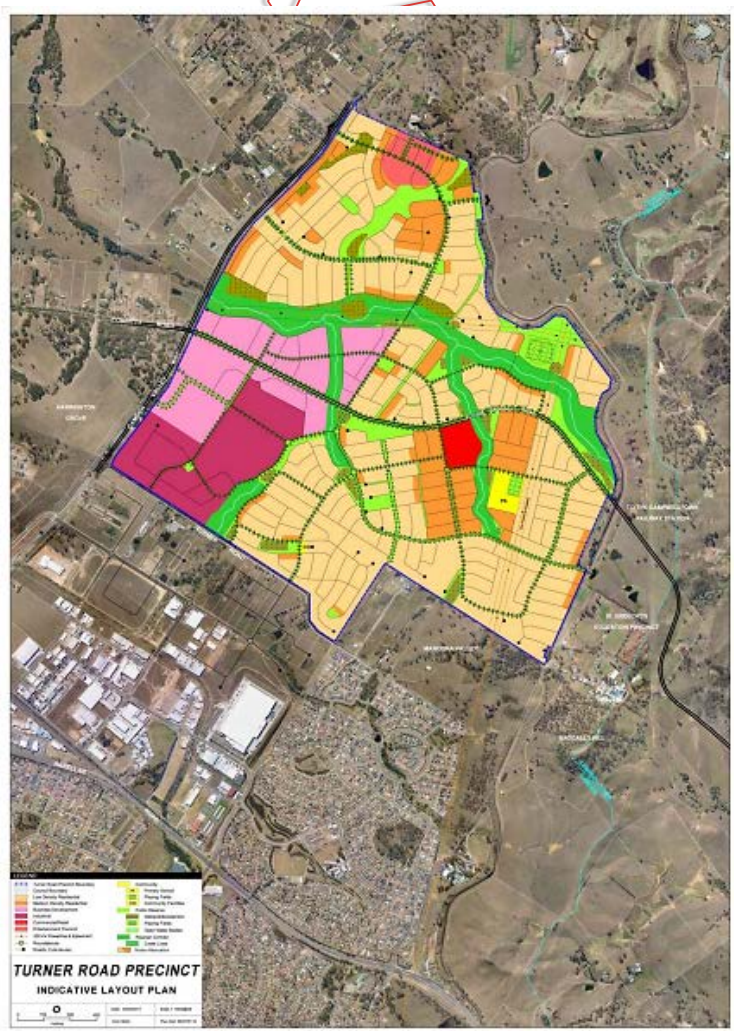


Figure 3.5: Turner Road Precinct Indicative Layout Plan

4 Hydraulic Analysis

4.1 Review and Update of Flood Model

The current flood model for the Narellan Creek catchment utilises an XP-RAFTS hydrologic model to simulate rainfall-runoff processes with resulting flow hydrographs input to a predominantly 2D TUFLOW model for simulation of flood hydraulics. A full description of the existing flood model is provided in the *Narellan Creek Flood Study* (Worley Parsons 2015) with additional interrogation of the model provided in a peer review document prepared by WMA Water.

The Investigation & Design Harrington Park Mitigation Works project scope required the update of the TUFLOW model DEM to include topographic changes associated with various recent developments which were not included in the *Narellan Creek Flood Study* (Worley Parsons 2015). Subsequent to this, the model was to be used to investigate and assess potential flood mitigation options, with particular focus on the Harrington Park area. This process facilitated a detailed interrogation of the existing TUFLOW model representation of the Harrington Park WQMS and upstream areas influencing flows through it.

While the model was found to be generally appropriate for the purposes of a flood study, a number of limitations were identified with the existing TUFLOW hydraulic model for the purposes of the assessment and detailed design of mitigation options. Additional minor issues with the model were identified through a 'Post Flood Event Analysis' for the 5 June 2016 event, a review of a Development Application in Mount Annan, and direction from Council to review particular areas including Lake Yandelora. Various updates were required to ensure that current catchment conditions were accurately represented in the model and thus the impact of mitigation options could be reliably gauged. The combination of these updates resulted in significant changes in design flood levels in some areas, and as such warranted the current *Update of Narellan Creek Flood Study* (PWA 2017).

These updates are discussed in details in Section 4 in the *Update of Narellan Creek Flood Study,* DC17070 (PWA 2017), and they include:

- Model DEM
- Box culverts at The Northern Road
- Lake Y~~e~~andelora
- Hydraulic roughness in riparian areas
- Harrington Park WQMS
- Lake 3A low level outlet structure
- Harrington Parkway Bridge

4.2 Comparison with previous modelling

4.2.1 Harrington Park flood profile

An updated peak 1% AEP flood level profile along Narellan Creek in the Harrington Park area is presented in **Figure 4-1** including comparison with previous results from the existing TUFLOW (Worley Parsons 2015) and MIKE-11 models (SMEC 2000).

Factors contributing to the described reductions in 1% AEP flood levels and extents described below in the Harrington Park area are attributable to the following factors:

- Increased discharge through the Lake 3A low level outlet due to the application of the physical model discharge rating for the structure
- Reduced afflux at the Harrington Parkway bridge associated with improved representation of the bridge using surveyed structural details and validated form loss coefficients
- Increased conveyance through Narellan Creek and other WQMS channels due to modification of bathymetry per WAE plans and site inspection measurements
- Inclusion of low flow pipes in the Harrington Park WQMS
- Changes to hydraulic roughness associated with the riparian vegetation survey, typically resulting in lower roughness in overbank areas.

4.2.2 Harrington Park flood levels and extents

A comparison of 1% AEP flood levels and extents in the Harrington Park area is presented in **Figure 4-2.** Differences are evident throughout the area including the following:

- The flood extent has reduced at Lake 3A, in particular it is notable that the high level weir at Harrington Park Reserve sports field does not overtop
- The flood extent in the area upstream of Harrington Parkway bridge is significantly reduced and Harrington Parkway no longer overtops
- Inundation of Fairwater Gardens is significantly reduced
- Inundation of Fairwater Drive near the southern end of Fairwater Gardens is reduced.

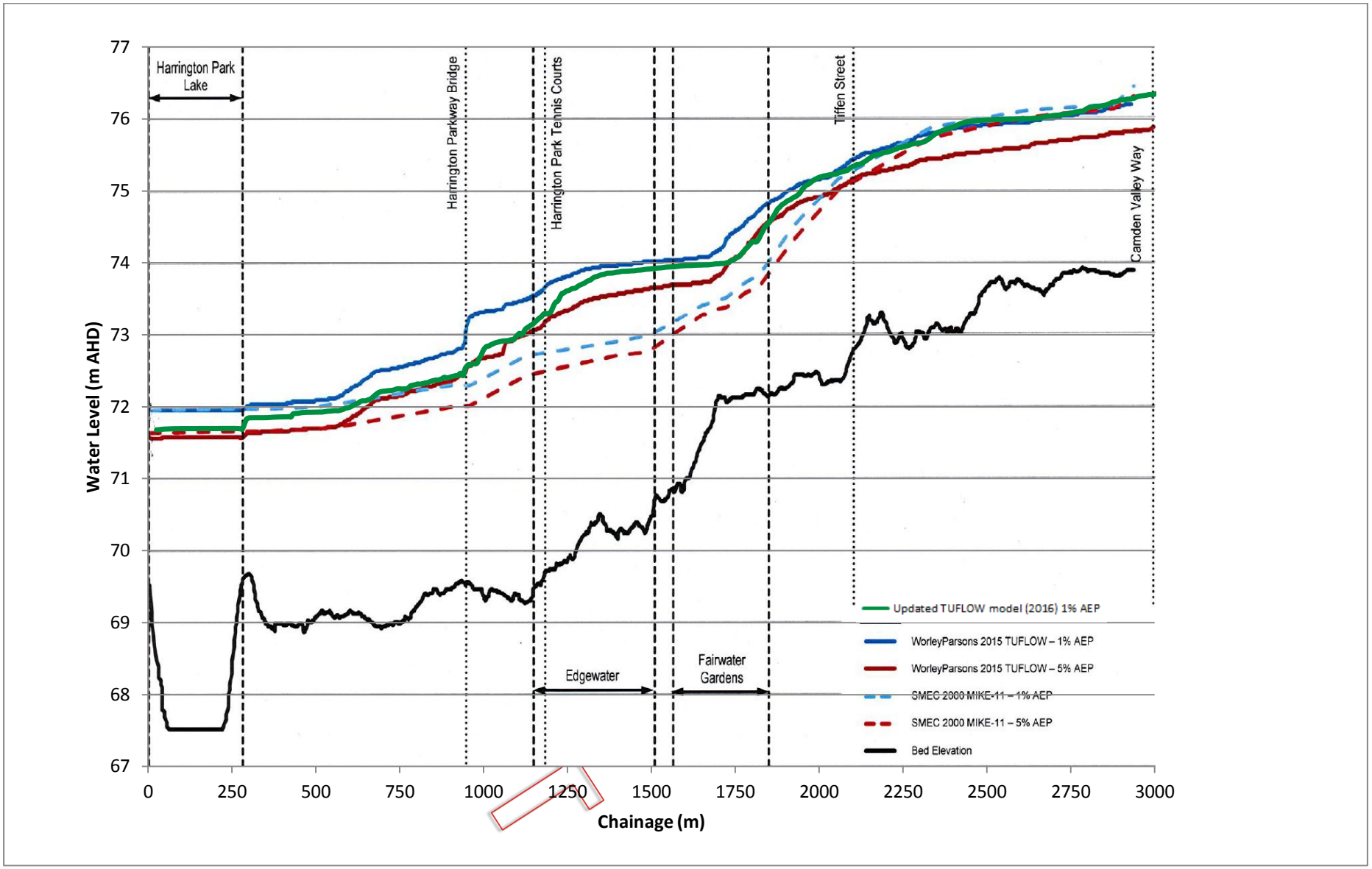


Figure 4-1: Updated 1% AEP flood profile along Narellan Creek alignment, Harrington Park

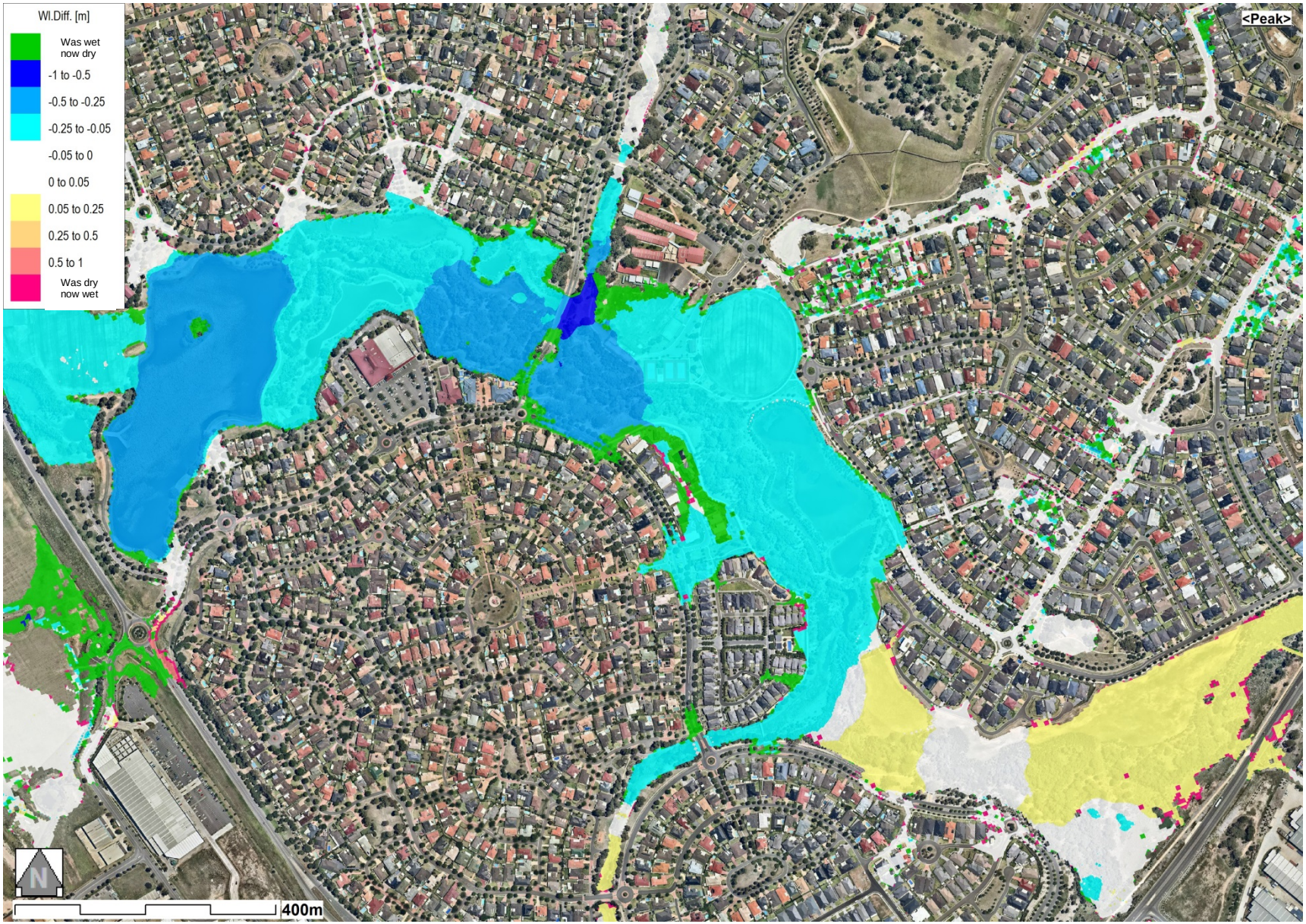


Figure 4-2: Comparison of 1% AEP flood levels for Harrington Park, updated 2016 model minus 2015 model results

4.3 Flood Mitigation Assessment

The primary objective of this study is to investigate, assess and provide detail design for preferred flood mitigation options which reduce 1% AEP flood levels in Harrington Park – particularly in and adjacent to the Fairwater Gardens development – with the aim of protecting dwellings from over-floor inundation. This section of the report focusses on the identification and assessment of flood mitigation measures aimed at alleviating flood impacts within Fairwater Gardens.

Review of updated peak 1% AEP flood levels throughout Fairwater Gardens reveals that no dwellings are likely to be affected by over-floor inundation in this event. Survey or reliably estimated floor levels in the flood affected areas at the southern end of O'meally Place, and the northern ends of Regency Drive and Darling Crescent have been analysed to confirm this, as the degree of over-floor inundation and resulting flood damages will govern the economic viability of mitigation options. Economic analysis of preferred options is presented in Chapter 7.

In order to identify suitable flood mitigation measures, an appreciation of the flood mechanisms at Fairwater Gardens is required. Review of flood model results show that peak 1% AEP flood levels in Fairwater Gardens result from a backwater effect from Narellan Creek, with peak food levels comparable to and in effect controlled by those in Lake 2. As illustrated by the 1% AEP flood profile presented in **Figure 4-1**, there is little flood gradient along much of the Fairwater Gardens / Edgewater development – governed by the detention of flows in Lake 2 and the contraction of Narellan Creek immediately downstream thereof. **Figure 4-1** also illustrates that there is quite a steep flood gradient moving downstream from Lake 2 towards Harrington Parkway bridge, withthe bridge itself producing very little afflux in the 1% AEP event. This indicates that mitigation options that aim to reduce peak flood levels in Lake 2 would have the greatest success in reducing flood levels in Fairwater Gardens, rather than options further downstream.

4.4 Hydraulic Assessment of Mitigation Options

The final list of potential mitigation options was identified as likely to reduce flood levels in Lake 2 and the adjacent Fairwater Gardens, which included total of 8 options and 3 combinations of these options.

Preliminary hydraulic assessment of short-listed options was undertaken including modification of the TUFLOW model and simulation of the 1% AEP design event, and consideration of the likely impact of the option on 1% AEP peak flood levels and the performance of the Harrington Park WQMS based on existing 2 year ARI flood levels. Detailed summary of the assessment of all the short-listed options is presented in **Table 4.1**.

Table 4.1: Summary of hydraulic assessment of options

Option	Description	Impact on 1% AEP peak flood levels		Expected impact on WQMS	Recommendation
		Fairwater Gardens	Other		
Option 1	Vegetation management	Reductions of less than 0.05 m	Reductions of 0.05-0.10 m about 500 m downstream of Camden Valley Way	Nil	Not recommended - has some merit but relatively temporary measure with environmental impacts and likely low BCR
Option 2	Fairwater Gardens levee	Adjacent properties protected	Negligible impact elsewhere	Nil	Consider subject to prevention of pit surcharging and BCR
Option 3	Lake 2 Spillway Widening & Channelization of downstream overbank areas	Reductions of 0.28 m	Levels marginally higher downstream of Lake 2 by up to 0.04 m	Negligible	Consider subject to BCR, environmental and heritage impacts
Option 3B	Additional 0.1 m lowering of Lake 2 spillway	Negligible difference to Option 3	Negligible difference to Option 3	Negligible-Minor	Not recommended - negligible difference to Option 3, potential for increased impact on WQMS
Option 3C	Reduced extent of overbank lowering	Levels ~0.08 m higher than Option 3	Levels 0.05-0.10 m higher than Option 3 between tennis courts and Harrington Parkway bridge	Negligible	Consider - may have advantages in terms of cost (reduced excavation & avoid need for footbridge/culvert) and heritage, however does not take advantage of nearby low areas
Option 4	Diversion of Tributary 1	Negligible benefit	Negligible benefit	Minor	Not recommended
Option 5	Lowering of overbank US of HP bridge	No benefit	Reductions of ~0.05 m between tennis courts and immediate upstream of Harrington Parkway bridge, negligible impact elsewhere	Negligible-Minor	Consider in conjunction with Options 3 subject to BCR
Option 6	Lowering of overbank DS of HP bridge	No benefit	Reductions of ~0.05 m between tennis courts and immediate downstream of Harrington Parkway bridge, negligible impact elsewhere	Negligible-Minor	Consider in conjunction with Option 3 subject to BCR and access issues
Option 7	Lowering of Lake 3D embankment	No benefit	Reductions of ~0.05 m between tennis courts and vicinity of Harrington Plaza, negligible impact elsewhere	Negligible-Minor	Consider in conjunction with Option 3 subject to BCR
Option 8	Lowering of overbank at discharge to Lake 3A	No benefit	Negligible benefit	Nil	Not recommended
Combinations					
Options 3 & 5	Combination	Levels immediately DS of Lake 2 up to 0.04 m lower than Option 3	Negligible difference to Option 3	Negligible-Minor	Not recommended
Options 3 & 6	Combination	Levels immediately DS of Lake 2 ~0.02 m lower than Option 3	Levels ~0.04 m lower than Option 3 in immediate vicinity of Harrington Parkway bridge	Negligible-Minor	Not recommended
Options 3 & 7	Combination	Levels immediately DS of Lake 2 up to 0.04 m lower than Option 3	Levels up to 0.05 m lower than Option 3 between tennis courts and vicinity of Harrington Plaza	Negligible-Minor	Consider subject to BCR, environmental and heritage impacts

The results of the hydraulic assessment identified two options as the preferred solutions, for further investigation, those being:

- Fairwater Gardens flood levee
- Lake 2 spillway widening and channelization of downstream overbank areas.

Fairwater Gardens flood levee (Option 2) would only offer protection to Fairwater Gardens for the 1% AEP design storm event and may have negative impacts on local drainage due to the need for providing non-return flap gates on the existing twin DN1000 stormwater pipes discharging to Narellan Creek. It would however have a lower capital cost and environmental impact.

Lake 2 spillway widening and channelization of downstream overbank areas (Option 3) would offer the advantage of reducing flood levels for all design flood events, but would have a higher capital cost and environmental and heritage impacts.

The feasibility of these options will be assessed in the next chapters of this Report including capital cost estimation, benefit-cost, multiple benefit analysis and preliminary assessment of geotechnical, environmental and heritage impacts.

Peak 1% AEP flood levels for each of the preferred options are presented in **Figure 4-3** and **Figure 4-4**. Changes to existing peak 1% AEP flood levels resulting from each option are presented in **Figure 4-5** and **Figure 4-6.**

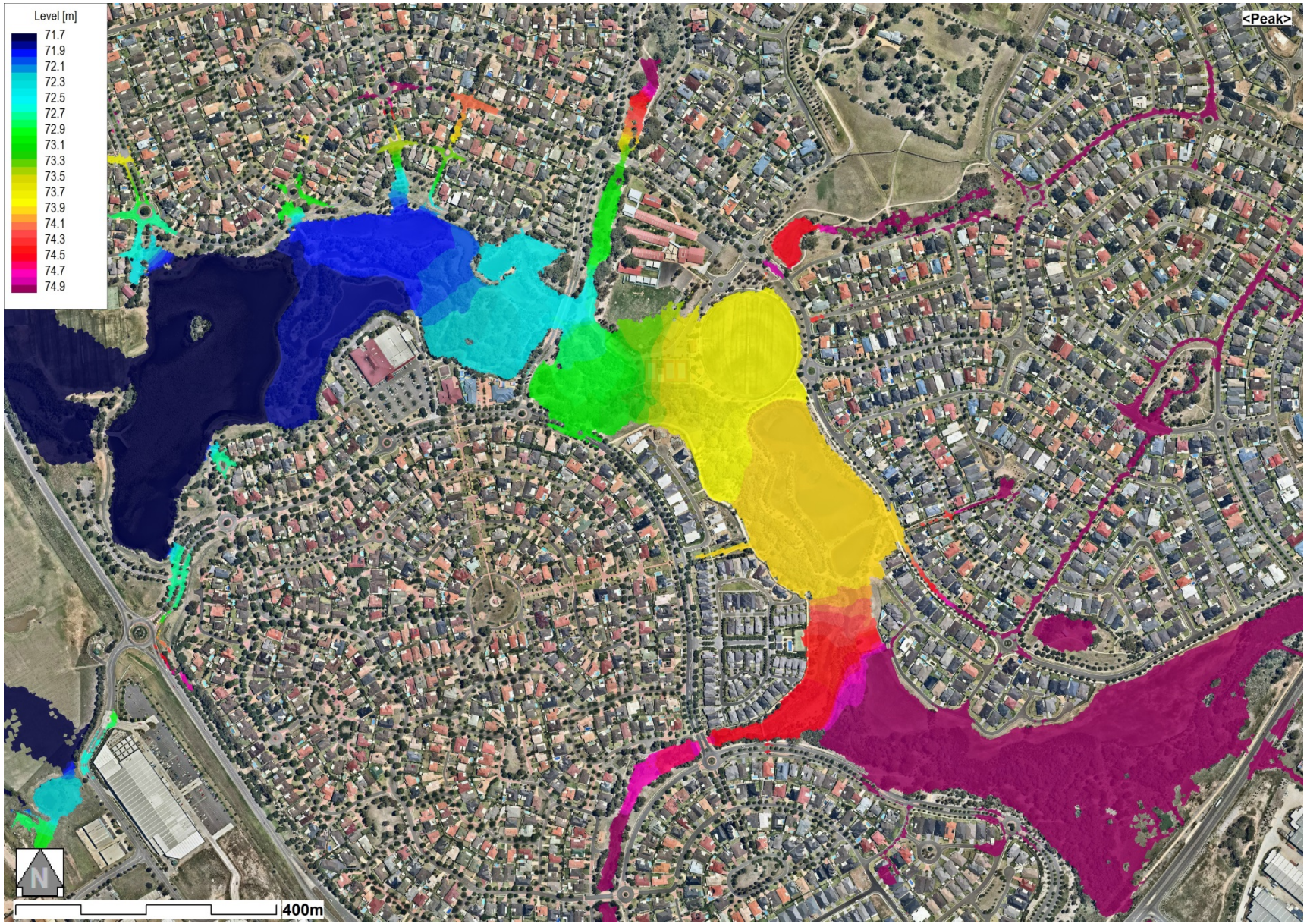


Figure 4-3: Peak 1% AEP flood levels for the Levee Option at Harrington Park

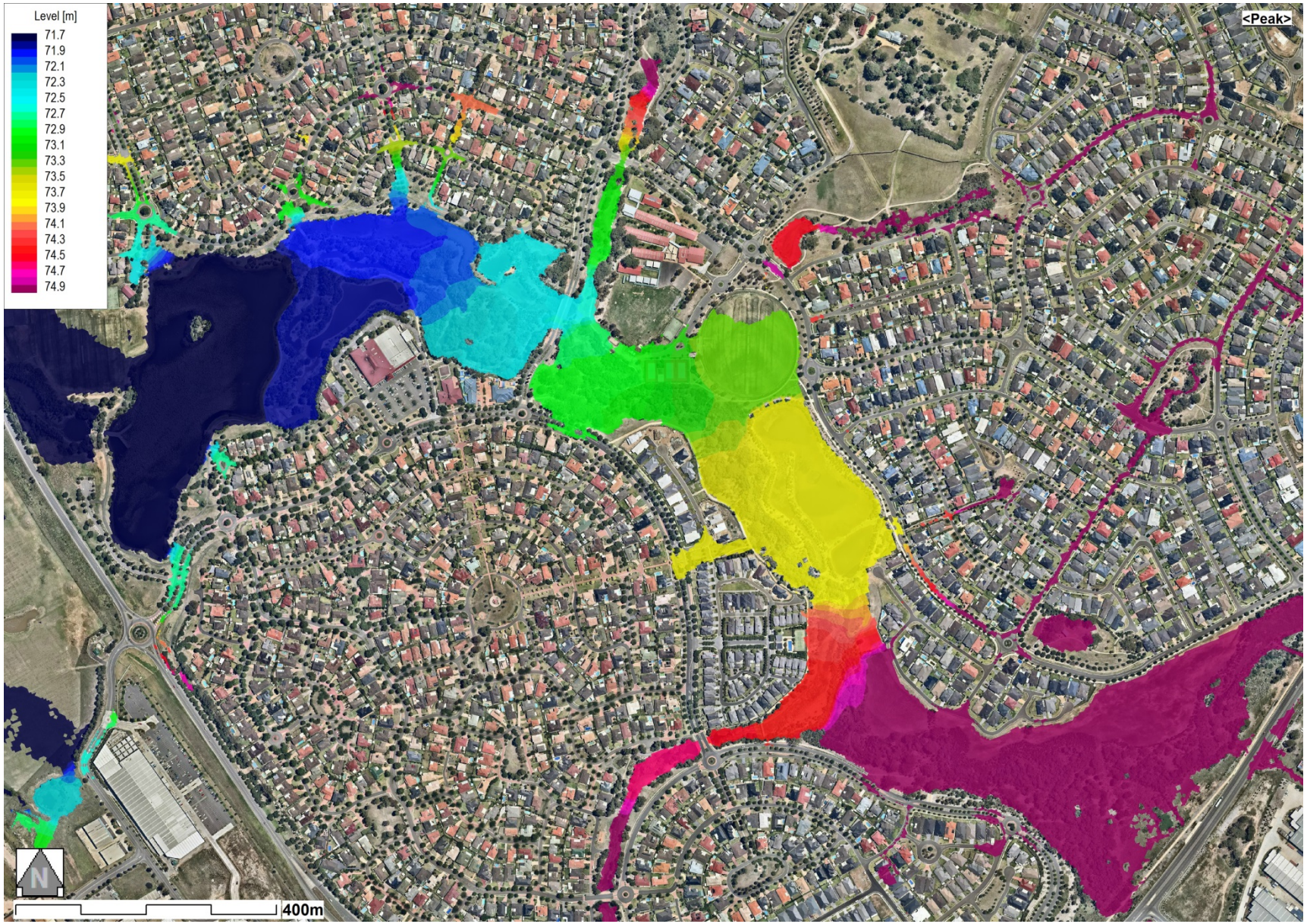


Figure 4-4: Peak 1% AEP flood levels for the Channel Option at Harrington Park

Figure 4-5: Changes in peak 1% AEP flood levels for the Levee Option at Harrington Park

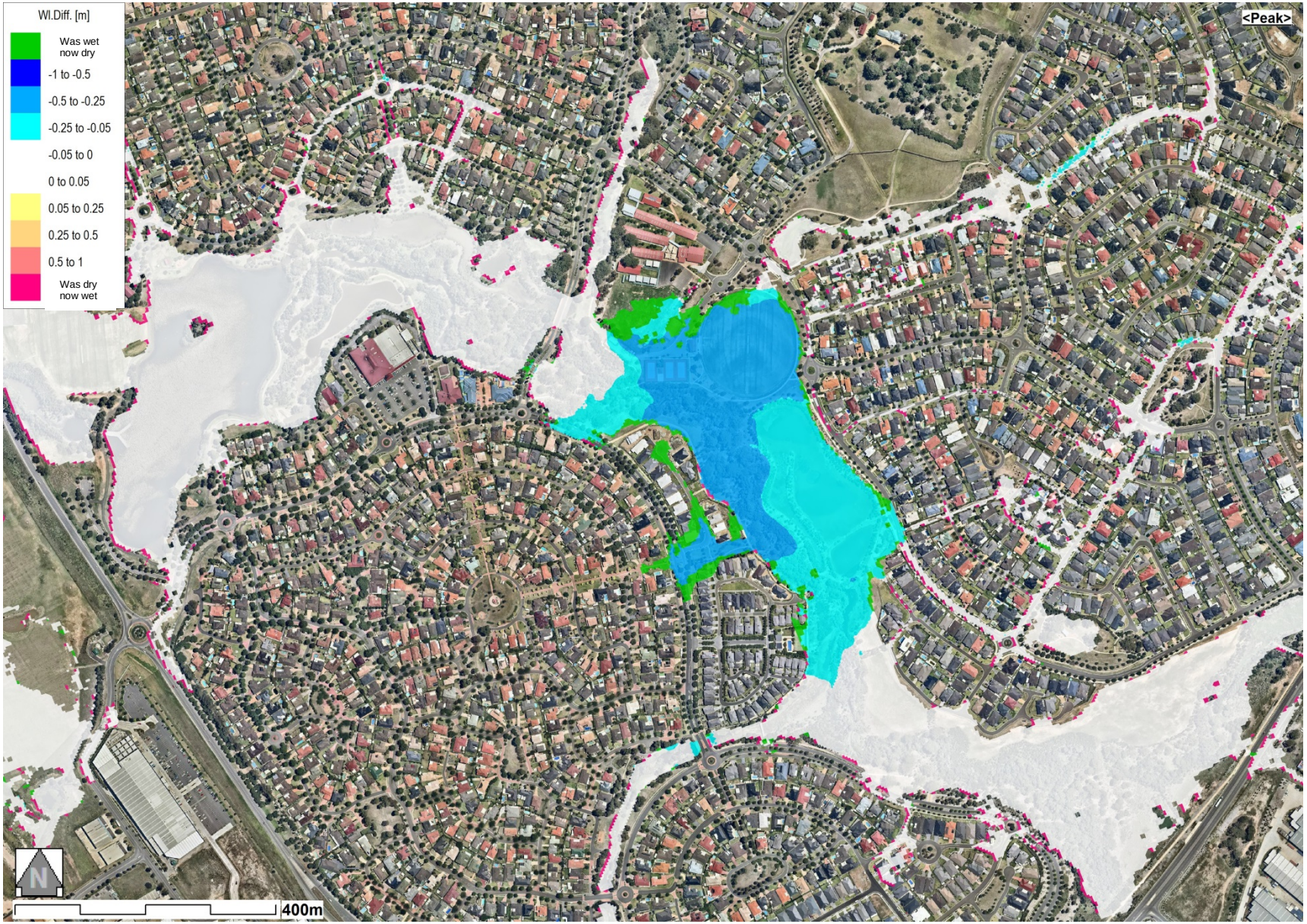


Figure 4-6: Changes in peak 1% AEP flood levels for the Channel Option at Harrington Park

5 Preferred Flood Mitigation Options

5.1 Overview of Options

Two options were recommended as the preferred after the preliminary hydraulic analysis, based on the impacts on 1% AEP peak flood levels in Fairwater Gardens and other areas in Harrington Park, as well as the expected impact on WQMS based on existing 2 year ARI flood levels. These are:

- Fairwater Gardens flood levee (see **Figure 5-1**)
- Lake 2 spillway widening and channelization of downstream overbank areas (see Figure 5-2)

The purpose of these options is to reduce flood levels in Lake 2 and the adjacent Fairwater Gardens.

5.1.1 Fairwater Gardens flood levee

An earth embankment levee has been investigated in the Fairwater Gardens development to protect it from inundation during the 1% AEP flood event. The proposed flood levee is approximately 1m to 1.5m, locally up to 2.4m, in height and in parts comprises a concrete wall where the space between the private properties and top of Narellan Creek's bank is limited. The proposed levee cuts across a broad drainage reserve, which includes the local drainage services consisting of stormwater pits and twin DN1005 pipes draining into the creek. The schematic of the proposed levee extent is shown in **Figure 5-1**.

This option would only offer protection to adjacent properties in Fairwater Gardens for the 1% AEP design event and negligible impact elsewhere. Detail geotechnical investigation should be carried out in detail design stage to assess the foundation conditions along the levee alignment, especially in sections of the levee or the concrete wall spanning the existing stormwater pipes, where foundation improvement may be required. Furthermore, this option requires non-return flap gates on the existing twin DN1000 stromwater pipes draining into Narellan Creek which may have negative impacts on the local drainage due to the closure of flap gates caused by Narellan Creek flood levels. It would however have a lower capital cost and environmental impact.

For the concept layout and typical sections of the proposed levee option refer to Drawings No.C003 and No.C004 in **Appendix A**.1

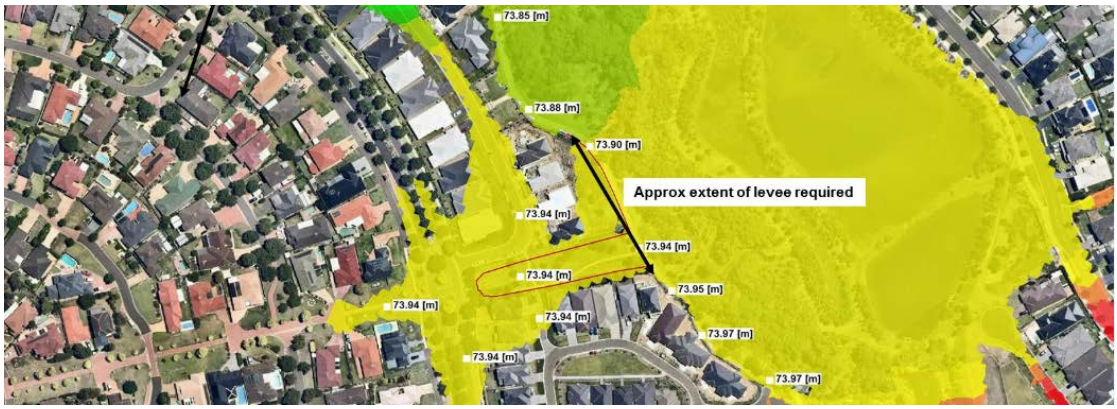


Figure 5-1: Flood Levee Option concept schematic

5.1.2 Lake 2 spillway widening and channelization of downstream overbank areas

This option takes advantage of the steeper flood gradient along Narellan Creek in the vicinity of the tennis courts by increasing discharge from Lake 2 into the area and increasing downstream conveyance. The schematic of the proposed channel is shown in **Figure 5-2**.

For this option the proposed works will include increasing the width of Lake 2 spillway, excavation of 1m to 2.5m deep channel with 10 m base width, for an approximate distance of 300m downstream from the spillway and, provision of a footbridge over the channel in vicinity of the tennis courts.

The current spillway RL is about 72.5 m AHD. Increasing the width of the spillway at this level will provide reductions in Harrington Park flood levels without adversely affecting performance of the WQMS. The proposed channel starts downstream of Lake 2 spillway, past Harrington Park Tennis Courts, until it joins Narellan Creek downstream.

This option would offer the advantage of reducing flood levels for all design flood events, but would have a higher capital cost and environmental and heritage impacts.

For the concept layout and typical sections of the proposed channel option refer to Drawings No.C005 and No.C006 in **Appendix A**.

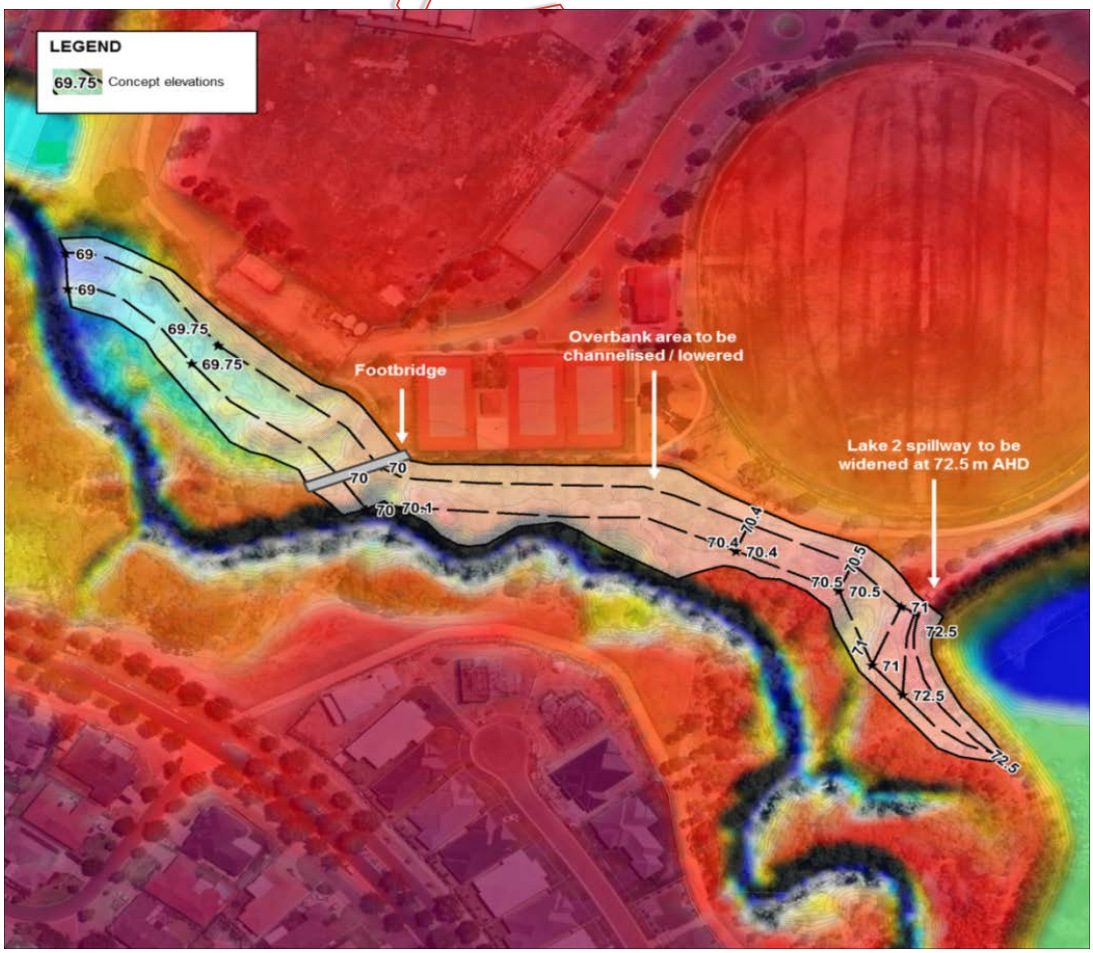


Figure 5-2: Channel Option concept schematic

5.2 Construction

The following provides a summary of the likely construction activities.

`1`

- Establish construction compound and laydown areas.
- Establish access to Fairwater Garden Levee work area and a separate access to the Channel, spillway and bridge work area. Access to the work areas shall occur within existing cleared paths where possible, although some trimming or clearing of vegetation may be required. The works should be undertaken in manner that minimises disturbance.
- Establish erosion and sediment controls, including in stream controls.

Spillway and Channelisation works:

- Vegetation removal to progressively move along the channel below Lake 2.
- All noxious and exotic weeds would be appropriately managed and removed for off-site disposal.
- All debris such as plastic bags, bottles, foam containers and other litter shall be removed
- Rehabilitation of the channel bed and banks using suitably qualified and experienced bush regeneration contractors in accordance with a Vegetation Management Plan.

Fairwater Gardens levee works:

The base of the levee would be constructed from approximately 1,500m3 of imported ENM / VENM or (if suitable) spoil from the channelisation works. The levee would be dressed with topsoil certified as weed free.

Site dis-establishment:

- Removal of all construction equipment;
- General site clean-up.

5.2.1 Construction Equipment

The following construction equipment is likely to be required to undertake the works:

- Bobcat or small excavator for vegetation clearing, works within the channel and construction of spillway;
- Small trucks carrying construction materials,
- Large trucks to transport imported material and excavated material to and from the site;
- -Concrete mixer for footbridge footings;
- -Backhoe/ excavator equipment to construct levee; and
- -Passenger vehicles to transport construction workers.

5.2.2 Construction Issues

Construction Environmental Management Plan

The proposed works would be undertaken in accordance with a Construction Environmental Management Plan (CEMP) prepared by the construction contractor and approved by Camden Council prior to the commencement of works.

The CEMP would incorporate site specific management plans and would reflect all the mitigation measures identified in the Harrington Park Mitigation Works REF, additional mitigation measures identified as a result of the contractors risk assessment and construction methodology and any conditions of the project determination and other licences/approvals.

Construction site layout

The contractor would establish a compound area to accommodate construction facilities for the duration of the construction period. The compound area would accommodate the following facilities:

- Toilets
- Materials storage area
- Site Office
- Fuel storage

Construction timeframe

The construction works are predicted to take up to two months.

Working hours

The *Interim Construction Noise Guidelines* (DECC 2009) outlines recommended standard construction working hours as:

Monday to Friday 7am to 6pm
Saturdays 8am to 1pm
No work on Sundays or public holidays.
The construction would comply with these recommended hours.

5.3 Operational Issues

Maintenance of Lake 2, the spillway and downstream channel and Fairwater Gardens' levee would form part of Camden Council's overall maintenance program within the LGA and in accordance with the Vegetation Management Plan for the Harrington Park Lake System.

Ongoing management procedures would include:

- Annual removal of foreign material such as plastic bags, bottles, foam containers and other litter (does not include leaf litter, branches or logs).
- Weed control undertaken at frequencies specified by the Vegetation Management Plan by an experienced and qualified Bush Regeneration Contractor or Bush Regeneration Staff. Weed control would occur using standard bush regeneration techniques such as hand weeding or use of Glyphosate based herbicides.
- Slashing of indigenous herbland or reedland by qualified Bush Regeneration Contractor or Bush Regeneration Staff. Slashing would be undertaken after the species has flowered and set seed. No herbicide shall be used in association with slashing to allow indigenous species to regenerate from root stock, rhizomes or seed. Slashing would occur using hand operated mechanical equipment. Organic debris material would be removed from site.
- Annual thinning of vegetation to achieve design hydraulic roughness (manning's value) to achieve trees at 3 metre spacing. Thinning of indigenous material would occur using a

chainsaw, bushcutter or similar hand operated equipment. Organic debris material would be removed from site.

5.4 Geotechnical Information

The site was inspected on 22 September, 2016 by a senior engineering geologist from the Geotechnical Section, Public Works Advisory. The desktop study and reporting was carried out by a senior geotechnical engineer. This report presents the data from the inspection and the desktop studies.

5.4.1 Regional Geology and Soil Landscape

Both sites are located within a narrow floodplain terrace of Narellan Creek.

The Wollongong – Port Hacking 1:100,000 Geological Series Sheet 9029-9129 (1st Edition, 1985) indicates that the sites are located within thick deposits of Quaternary sediments comprising quartz and lithic fluvial sand, silt and clay.

The associated Wollongong – Port Hacking Soil Landscape Sheet 9029-9129 indicates that the sites are located within the Theresa Park Fluvial Landscape which comprises floodplain and Quaternary and Tertiary terraces of Nepean River on the Cumberland Plain and its tributaries, including the Narellan Creek. The landscape is characterised by gently undulating slopes, mostly <5%, but range to 10% on high level terraces.

The soils within this landscape comprise Red Earths and Red Podzolic Soils on terraces and minimal Prairie Soils on current floodplains. In the drainage lines Solodic Soils occur. These soils are highly variable and include poorly structured orange to red silty loams, brown loams and sandy loams.

Limitation of this soil group is very high soil erosion hazard for concentrated flows.

5.4.2 Fairwater Gardens Flood Levee

Site Conditions

The concept layout of the proposed levee is shown on Drawing No.C003 (**Appendix A**). The levee bank alignment is approximately 210m in length. It commences at the rear of properties in Darling Crescent (Ch.0m), cuts across a broad drainage reserve between approximate Ch.30m and Ch.60m, and then follows the rear of private properties in O'Meally Place to its termination point at approximate Ch.210m. It is understood that on the western side, the toe of the flood levee bank will typically abut the existing private properties fence lines, apart from a minor section where the alignment encroaches into the broad drainage reserve.

The drainage reserve is typically grassed with occasional mature trees, landscaped areas and traversed by concrete footpaths (see **Plate4, Appendix B**). Between the drainage reserve (Ch.60m) and approximate Ch.210m, the eastern property boundary fence line is a concrete wall which ranges in height from approximately 0.6m at the southern end to 1m at the northern end. There is a break in the wall at approximate Ch.165m where there is an open access way from O'Meally Place to Narellan Creek (see **Plate3, Appendix B**).

A typical view of the alignment at the rear of the properties in O'Meally Place is shown in **Plates 1** and **2, Appendix B**. There is a narrow landscaped garden strip adjoining the concrete wall and a concrete footpath. To the east of the footpath the terrace on top of the creek's bank is typically grassed with stands of trees. The slopes leading to the creek are gentle to moderate (see **Plate5, Appendix B**). In the creek's banks, the exposed sediments are dominantly fine grained silty clays/clayey silts with varying concentrations of fine sand (see **Plates 6** and **7**, **Appendix B**), locally with thin fine gravelly horizons.

The creek's batter and top of the bank at approximate Ch.80m is lined with sandstone rockfill (see **Plate8, Appendix B**). The rock armour is slope protection for the stormwater outlets at this location (see **Plate9**, **Appendix B**).

Summary and Discussions

The walkover inspection revealed the levee bank alignment is located within fluvial sediments associated with Narellan Creek. Exposures in the creek's banks and at the water line indicate that the sediments are dominantly fine grained, clayey silts/silty clays with varying fine sand contents, locally containing some thin, gravelly lenses. Fill, associated with general levelling at the rear of the properties and construction of the footpath, can be expected within the foundation footprint of the embankment. However, given the good condition of the footpath, it is likely that any fill present has been engineered.

The earthen embankment is expected to be typically 1m to 1.5m in height, increasing up to 2.4m at the crossing of drainage reserve and, progressively reducing at the southern and northern ends. The loadings imposed by the levee bank will be in the order of 18kPa to 30kPa, locally increasing to 45kPa. The existing subgrade should be capable of supporting loads of this magnitude without significant settlement.

Between approximate chainages Ch.73m to Ch.102m, and Ch.143m to Ch178m, the flood levee will consist of a concrete retaining wall, due to close proximity of private properties to the Narellan Creek. The approximate heights of the wall are expected to be in the order of 1m to 1.5m.

In general, it is envisaged that foundation preparation will include removal of the landscaped garden bed and concrete footpath adjoining the property fence line; and, removal of any trees and stripping of topsoil in all other areas. The grub holes created by removal of trees would need to be backfilled with engineered fill. Following the stripping, the subgrade would need to be proof-rolled prior to any fill placement.

A geotechnical investigation should be carried in detail design stage. The investigation should assess the foundation conditions and need for any foundation improvement that may be required along the levee alignment, especially in sections of the levee consisting of the concrete retaining wall. Furthermore, the issue of the concrete wall spanning the existing stormwater pipes would need to be addressed. It is envisaged that the wall at this location may need to be supported on deep footings founded below the invert level of the outlet pipes.

Embankment fill would need to be imported from a suitable borrow area. The borrow materials properties would need to be assessed with respect to: material type and plasticity properties; dispersion characteristics and erosion potential; permeability characteristics; and, workability and

compaction properties.

5.4.3 Lake 2 spillway widening and channelisation of downstream overbank areas

Site Conditions

The concept layout of the proposed channel and Lake 2 Spillway widening is shown on Drawing No.C005 (**Appendix A**). The channel is to be located on the northern terrace of Narellan Creek. To the north the site is broadly bounded by Fairfax Reserve and associated tennis courts; and, Harrington Park Primary School grounds. The channel is approximately 300m in length, commencing at the spillway and terminating in Narellan Creek in vicinity of the Harrington Park Way.

The topography along the channel alignment is relatively flat, with surface levels in the order of RL72m to RL73m to an approximate Ch.230m, and then descending at very gentle gradients to Narellan Creek (approximate RL69m). From the terrace, the batter leading to Lake 2 is gentle to moderate and medium timbered (see **Plate11, Appendix B**). Along the Narellan Creek, the creek's banks are gentle to moderately steep (see **Plate14, Appendix B**).

Typically, the alignment is medium to densely timbered (see **Plates 12** and **13**, **Appendix B**) with sparse to thick understorey. The terrace alongside Lake 2 (spillway) is partially cleared but becomes densely timbered on the approaches to Narellan Creek (see **Plate10**, **Appendix B**).

In the creek's banks, the exposed sediments are dominantly fine grained silty clays/clayey silts with varying concentrations of fine sand (see **Plates 14** and **15, Appendix B**); that is, the fluvial sediments are similar to those encountered along flood levee alignment.

One feature of note is a stormwater outlet (see **Plate16, Appendix B**) which is located to the south-west of the tennis courts complex.

Summary and Discussions

The walkover inspection revealed that the proposed channel alignment and widening of the spillway to Lake 2 are located within fluvial sediments associated with Narellan Creek. Exposures in the creek's banks and at the water line indicate that the sediments are dominantly fine grained, clayey silts/silty clays with varying fine sand contents.

The site will require extensive clearing due to medium dense to dense vegetation cover prior to channel excavations and the spillway widening. It is understood that the channel cuttings will be in the order of 1m to 2.5m and are expected to be entirely within fluvial sediments. Excavations in these sediments should be readily achievable using conventional earth moving equipment such as backhoes, excavators and small dozers.

A geotechnical investigation should be carried in detail design stage. The investigation should address the following:

- Material types and physical properties of fluvial sediments within the proposed cutting depths. Especially erosion potential of the sediments exposed in cut batters and the need for any slope protection due to expected flood velocities.

- Slope protection measures for a section of the channel batter where the existing outlet discharges stormwater into the channel.
- Stability of cut batters to confirm that the concept design cut batters of 1(V):3(H) are acceptable.
- Foundation conditions, material properties and suitable footing systems for the proposed timber bridge across the channel.

6 Environmental Information

6.1 Introduction

The Review of Environmental Factors (REF) has been prepared by Public Works Advisory on behalf of Camden Council as the separate report (Report Number DC 16068).

The report presents the investigations undertaken into the environmental impacts of the proposal to implemented flood mitigation works at Harrington Park and for ongoing maintenance of the site.

This REF report provides a true and fair assessment of the proposed activity in relation to its likely effects on the environment. It addresses to the fullest extent possible all matters affecting or likely to affect the environment as a result of the proposed activity and includes Statutory Considerations, Environmental Assessment, Environmental Management, as well as the Heritage Impact Assessment and Flora and Fauna Assessment in the Appendixes of the report.

This chapter presents only a brief summary of the conclusions identified in the REF for Harrington Park Mitigation Works, Report Number DC 16068.

6.2 Conclusion

Based on the REF, the following conclusions are made:

- The activity is not likely to have a significant effect on the environment. Environmental impacts associated with the proposed works are considered to be minor and may include the following:
  - Water quality impacts due to sediment disturbance;
  - Potential for short periods of elevated construction noise emission levels; and
  - Generation of some waste as a result of the works, including green waste (instream vegetation, weeds) and sediment;
- The activity will address the flood impacts of the PMF in Harrington Park and Fairwater Gardens;
- The activity will mitigate flood impacts on the properties subject to 1% AEP over-floor inundation in Harrington Park.
- The activity would have no significant impact upon any threatened species or communities and does not impact on land that is, or is part of, critical habitat.
- The activity is not likely to affect Commonwealth land, be carried out on Commonwealth land or significantly affect any matter of national environmental significance.
- The activity is not likely to affect the heritage significance of Harrington Park Estate.
- The activity would not impact on any Aboriginal heritage items.
- The identified environmental impacts can be adequately managed through the implementation of ‘Best Practice’ environmental management procedures and control measures.

7 Economic Analysis of Preferred Options

7.1 Economic Analysis

This chapter presents an economic analysis of the preferred mitigation options identified in Chapter 3 of this report, those being:

- Fairwater Gardens flood levee (see **Figure 5-1**)
- Lake 2 spillway widening and channelization of downstream overbank areas (see **Figure 5-2**).

An economic appraisal is required for all proposed capital works in NSW, including flood mitigation measures, in order to attract funding from the State Government's Capital Works Program. The NSW Government has published two Treasury Policy Papers to guide this process: *NSW Government Guidelines for Economic Appraisal* (NSW Treasury, 2007a) and a summary in *Economic Appraisal Principles and Procedures Simplified* (NSW Treasury, 2007b).

An economic appraisal is a systematic means of analysing all the costs and benefits of a variety of proposals. In terms of flood mitigation measures, benefits of a proposal are generally quantified as *the avoided costs associated with flood damages*. The avoided costs of flood damage are then compared to the capital (and on-going) costs of a particular proposal in the economic appraisal process.

A flood mitigation proposal may be considered to be potentially worthwhile if the benefit–cost ratio (the present value of benefits divided by the present value of costs) is greater than 1.0. In other words, the present value of benefits (in terms of flood damage avoided) exceeds the present value of (capital and on-going) costs of the project.

However, whilst this direct economic analysis is important, it is not unusual to proceed with urban flood mitigation schemes largely on social grounds, that is, on the basis of the reduction of intangible costs and social and community disruption. In other words, the benefit–cost ratio could be calculated to be less than 1.0.

7.2 Flood Damages Assessment

A flood damage assessment has been undertaken for the Fairwater Gardens area to quantify the impact of flooding in economic terms for existing flood conditions and use this as a means for assessment of the relative merit of potential flood mitigation options through cost-benefit analysis.

The general process for undertaking a flood damages assessment comprises:

- Identifying properties subject to flooding and attaining habitable floor levels
- Defining appropriate stage-damage relationships for various property types
- Determining depth of inundation above floor level for a range of design event magnitudes
- Estimating flood damages for each property and total flood damage for a range of design events
- Calculating Annual Average Damages (AAD), a measure of the cost of flood damage that could be expected each year by the community, on average

- Calculating the present value of flood damages (typically over a 50 year period at a 7% discount rate), which represents the sum of all future flood damages that can be expected over a fixed period (usually 50 years) expressed as a cost in today's value.

7.2.1 Types of Flood Damage

The definitions and methodology used in estimating flood damages are well established. **Figure 7-1** summarises all the types of flood damages examined in this study. The two main categories are tangible and intangible damages. Tangible flood damages are those that can be more readily evaluated in monetary terms. Intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are divided further into direct and indirect damages. Direct flood damages relate to the loss or loss in value of an object or a piece of property caused by direct contact with floodwaters, flood-borne debris or sediment deposited by the flood. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

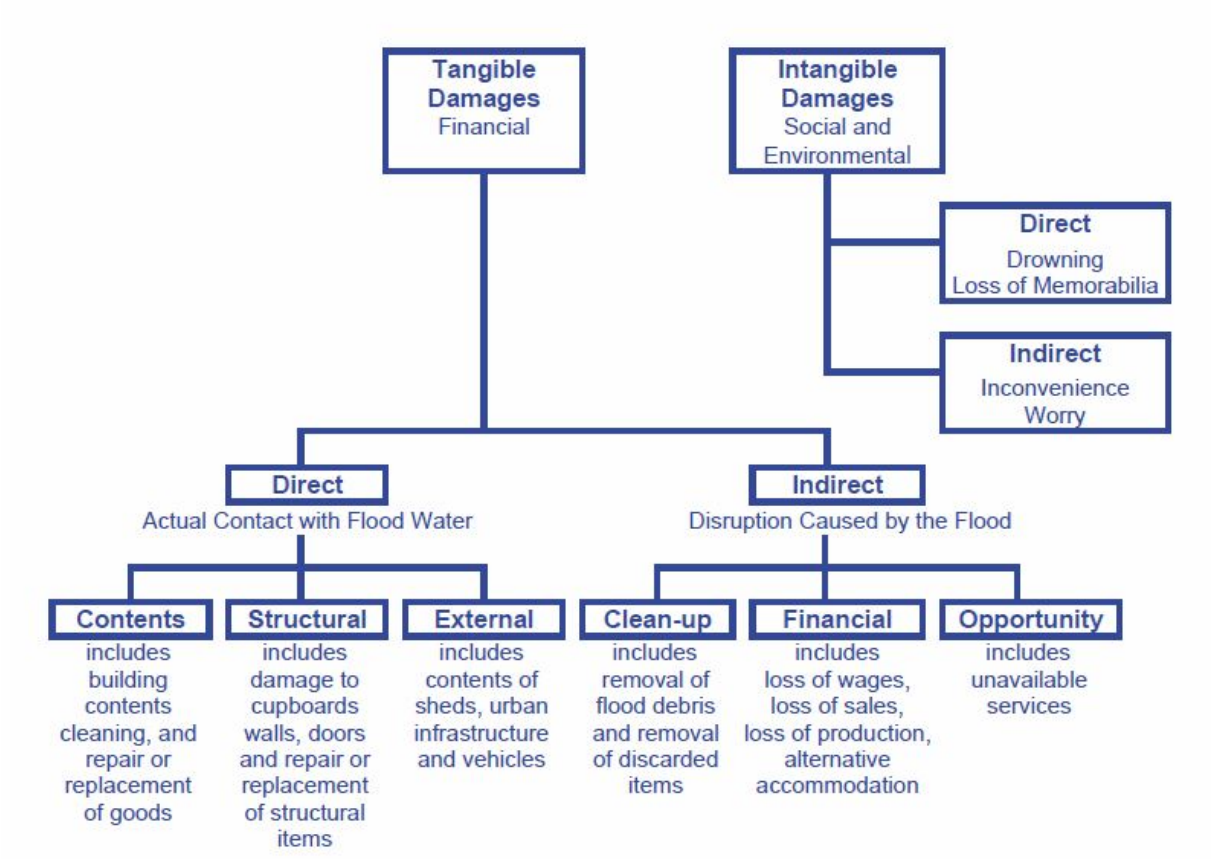


Figure 7-1: Types of flood damage

Source: *Floodplain Development Manual* (NSW Government, 2005)

7.2.2 Basis of Flood Damages Calculations

Flood damages have been estimated by applying one of three stage-damage curves to every property included in the database. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type.

Residential

In October 2007, the then Department of Environment and Climate Change (now OEH) released Guidelines to facilitate a standard methodology for assessing residential flood damages. This involves tailoring stage-damage data for the particular floodplain of interest, and is recommended for use throughout NSW so that the results from one floodplain can be compared with another.

Inputs for this study are listed in **Table 7-1**, together with explanations for each selection. It is noted that the OEH residential stage-damage curves make allowance for both clean-up costs ($4,000 per flooded house) and the cost of time in alternative accommodation. Recent research for Hawkesbury-Nepean flood mitigation assessments suggests that an allowance of 5% is warranted for additional indirect costs for the residential sector, and this allowance has been applied for this study.

Table 7-1: Input variables for residential damages assessment

Input	Value	Explanation
Regional Cost Variation Factor	1.0	Rawlinsons
Post late 2001 adjustments	1.68	Changes in AWE from Nov 2001 to Mar 2016
Post Flood Inflation Factor	1.20	Regional city, medium scale impacts
Typical Duration of Immersion	1 hour	Flash flooding scenario
Building Damage Repair Limitation Factor	0.85	Short duration
Typical House Size	220 m^2	Sample of houses
Contents Damage Repair Limitation Factor	0.75	Short duration
Level of Flood Awareness	Low	Infrequent flood affectation
Effective Warning Time	0 hour	Flash flooding scenario with small catchments
Typical Table/Bench Height	0.90	Standard
External Damage	$6,700	Standard
Clean-up costs	$4,000	Standard
Likely Time in Alternative Accommodation	2 weeks	Typically shallow flooding
Additional Accommodation Costs	$220	Standard

Commercial/Industrial

No standard stage-damage curves have been issued for commercial and industrial damages, and such relationships are often based on investigations by Water Studies (1992) as incorporated into WaterRide.

Only one non-residential property has been included in the flood damage estimations for this study, the Fairfax Reserve Clubhouse. It has been assumed that damages for this property can be appropriately approximated using the stage-damage curve for a 2 storey residential dwelling. While the majority of the ground floor is taken up by amenities, it also contains a canteen with associated stock and appliances.

Other

In previous floodplain risk management studies, it is the best practice that damages to **infrastructure** (roads etc.) be estimated as 15% of total direct residential and commercial/ industrial damages. This allowance has been included as a separate item for this study.

Flooding can have various impacts on people's **health**, both physical and emotional. These include stress-related ailments, influenza, viral infections, heart problems and back problems (from lifting and cleaning). Although it is difficult to quantify the cost of disruption, illness, injury and hospitalisation, in keeping with the best practice, social damages have been estimated (as a separate item) as 25% of 'total damages', which are interpreted as the sum of direct residential damages and direct non-residential damages.

7.3 Property Database

A flood damages database was prepared for the entire Fairwater Gardens subdivision and some adjacent properties. The extent of properties included in the database was determined based on availability of floor level survey, and in consideration of the extent of the 0.2% AEP design flood (as the potential mitigation options have little or no impact on the PMF). The extent of the property database therefore allows for the economic assessment of mitigation options which target flood level reductions in Fairwater Gardens, but resulting flood damages do not represent total damages in the catchment.

The property database was compiled from the following data:

- Fairwater Gardens October 2015 survey by Camden Council
- Narellan Creek Flood Study flood damage database (Worley Parsons 2015)
- Floor level estimation from photography (Fairfax Reserve Clubhouse only).

Properties were characterised into three categories for the application of three different stage-damage curves per OEH's method for assessing residential flood damages:

- Single story high set (applied where floor level > 1.5m higher than ground level, coded '1' in the property database)
- Single storey low set/slab-on-ground (coded '2')
- Two storeys (coded '3').

Flood surfaces for the PMF, 0.2% AEP, 0.5% AEP, 1% AEP, 5% AEP and 20% AEP design events were used to extract flood levels at tag points for each building in the database.

7.4 Summary of Flood Damages

7.4.1 Base Case – Existing Conditions

Calculated flood damages and AAD for the Fairwater Gardens area under existing (base case) conditions are presented in **Table 7-2** and **Table 7-3**. Distinctive features include:

- The total AAD for those properties surveyed is $31,000, which is a measure of the cost of flood damage that could be expected each year, on average, by the community (considering only those properties surveyed – additional damages in surrounding areas would be expected particularly resulting from the PMF event)
- The present value of damages (discounted at 7% over a 50 year period) is $459,000
- The largest contributions to AAD are from the PMF and 1% AEP events
- A significant portion of flood damages for the 5%, 1% and 0.5% AEP events are associated with the Fairfax Reserve Clubhouse and grounds.

Table 7-2: Summary of base case direct flood damage by design event for surveyed properties

Flood Event	Properties Flooded Above Floor	Estimated Direct Damage in Flood Event ($2016)	Event Contribution to Direct AAD($2016)	Direct Average Annual Damage ($2016)	Present Value of Direct Damage ($2016) *
20% AEP	0	$0	$0	$21,300	$315,400
5% AEP	0	$46,000	$3,500		
1% AEP	1	$225,000	$5,400		
0.5% AEP	3	$405,000	$1,600		
0.2% AEP	11	$907,000	$2,000		
PMF	95	$7,939,000	$8,900		

* Based on treasury guidelines of a 7% discount rate and expected life of 50 years

Table 7-3: Components of base case total flood damage for surveyed properties

	Damage Component	Method Assessed	Cost ($2016)	% of Total AAD
A.	Direct Residential Damage	DECC (2007) curves	$21,300	69%
B.	Indirect Residential Damage	5% of A	$1,065	3%
C.	Infrastructure Damage	15% of A	$3,195	10%
D.	Social Damage	25% of A	$5,325	17%
	TOTAL AAD		**$31,000**	100%
	TOTAL PRESENT VALUE		**$459,000**	

7.4.2 Fairwater Gardens levee Option

Calculated flood damages and AAD for the Fairwater Gardens area under the Levee Option conditions are presented in **Table 7-4** and **Table 7-5**. Distinctive features include:

- The total AAD for those properties surveyed was reduced to $24,000
- The present value of damages (discounted at 7% over a 50 year period) was reduced to $355,000, meaning that Option 2 would be estimated to provide benefits of $104,000 in terms of reduction in flood damage over a period of 50 years
- The largest reductions in AAD were achieved for the 1% AEP associated with protection of Fairwater Gardens properties from inundation and associated clean-up costs
- Two properties were protected from above-floor flooding for the 0.5% AEP event.

Table 7-4: Summary of Levee Option direct flood damage by design event for surveyed properties

Flood Event	Properties Flooded Above Floor	Estimated Direct Damage in Flood Event ($2016)	Event Contribution to Direct AAD ($2016)	Direct Average Annual Damage ($2016)	Present Value of Direct Damage ($2016) *
20% AEP	0	$0	$0	$16,400	$243,000
5% AEP	0	$35,000	$2,600		
1% AEP	1	$101,000	$2,700		
0.5% AEP	**1**	$167,000	$700		
0.2% AEP	**11**	$873,000	$1,600		
PMF	95	$7,939,000	$8,900		

* Based on treasury guidelines of a 7% discount rate and expected life of 50 years

Table 7-5: Components of Levee Option total flood damage for surveyed properties

	Damage Component	Method Assessed	Cost ($2016)	% of Total AAD
A.	Direct Residential Damage	DECC (2007) curves	$16,400	69%
B.	Indirect Residential Damage	5% of A	$820	3%
C.	Infrastructure Damage	15% of A	$2,460	10%
D.	Social Damage	25% of A	$4,100	17%
	TOTAL AAD		**$24,000**	100%
	TOTAL PRESENT VALUE		**$355,000**	
	TOTAL BENEFITS (REDUCTION IN PRESENT VALUE OF DAMAGE)		**$104,000**	

7.4.3 Lake 2 spillway widening & channelisation of downstream overbank areas Option

Calculated flood damages and AAD for the Fairwater Gardens area under the Lake 2 spillway widening & cannelisation of downstream overbank areas Option conditions are presented in **Table 7-6** and **Table 7-7**. Distinctive features include:

- The total AAD for those properties surveyed was reduced to $16,000
- The present value of damages (discounted at 7% over a 50 year period) was reduced to $237,000, meaning that Option 3 would be estimated to provide benefits of $222,000 in terms of reduction in flood damage over a period of 50 years
- The largest reductions in AAD were achieved for the 5% AEP and 1% AEP events associated with reductions in flood levels at Fairfax Reserve and Fairwater Gardens, protecting properties from inundation and associated clean-up costs, and protecting one property (Fairfax Reserve Clubhouse) from above-floor flooding
- Significant reductions in damages were also achieved for the 0.2% AEP event including the protection of seven properties from above-floor flooding.

Table 7-6: Summary of Lake 2 spillway widening & channelisation of downstream overbank areas Option direct flood damage by design event for surveyed properties

Flood Event	Properties Flooded Above Floor	Estimated Direct Damage in Flood Event ($2016)	Event Contribution to Direct AAD ($2016)	Direct Average Annual Damage ($2016)	Present Value of Direct Damage ($2016) *
20% AEP	0	$0	$0	$11,000	$163,000
5% AEP	0	$0	$0		
1% AEP	**0**	$69,000	$1,400		
0.5% AEP	**1**	$147,000	$500		
0.2% AEP	**4**	$367,000	$800		
PMF	95	$7,939,000	$8,400		

* Based on treasury guidelines of a 7% discount rate and expected life of 50 years

Table 7-7: Components of Lake 2 spillway widening & channelisation of downstream overbank areas Option total flood damage for surveyed properties

	Damage Component	Method Assessed	Cost ($2016)	% of Total AAD
A.	Direct Residential Damage	DECC (2007) curves	$11,000	69%
B.	Indirect Residential Damage	5% of A	$550	3%
C.	Infrastructure Damage	15% of A	$1,650	10%
D.	Social Damage	25% of A	$2,760	17%
	TOTAL AAD		**$16,000**	100%
	TOTAL PRESENT VALUE		**$237,000**	
	TOTAL BENEFITS (REDUCTION IN PRESENT VALUE OF DAMAGE)		**$222,000**	

7.5 Estimation of Capital Costs

The cost estimates are preliminary "order of cost" and are intended for budgetary purposes. Detailed calculations for both of the flood mitigation management options are outlined in the **Table 7-8** and **Table 7-9**.

Table 7-8: Cost Estimate for Fairwater Gardens Levee Option

Date: November 2016

Item No.	Description	Quantity	Unit	Rate	Amount	Sub-total
1	**SITE ESTABLISHMENT**					
	Site establishment & disestablishment	1	Item	Lump Sum	$ 10,000	$ 10,000
	ENVIRONMENTAL MANAGEMENT					
	Erosion & sedimentation control measures during construction	1	Item	Lump Sum	$ 10,000	
	OH&S procedures	1	Item	Lump Sum	$ 5,000	
	Stormwater diversion and flood protection during construction	1	Item	Lump Sum	$ 5,000	
	Vegetation management / protection of trees	1	Item	Lump Sum	$ 10,000	$ 30,000
	SITE PREPARATION					
	Survey and site pegging out of works	1	Item	Lump Sum	$ 5,000	$ 5,000
2	**ACCESS ROAD WORKS**					
	Temporary Access Road (100mm NGS40)	20	cu.m	$ 140	$ 2,800	
	Compact Roadway Subgrade	200	sq.m	$ 10	$ 2,000	$ 4,800
3	**LEVEE-EARTH WORKS**					
	Clear site vegetation and disposal	2676	sq.m	$ 1	$ 1,338	
	Foundation preparation (150mm stripping)	2676	sq.m	$ 2	$ 5,352	
	Construction of levee clay core inclusive of keyway cut off (assumed homogeneous)	2295	cu.m	$ 30	$ 68,850	
	Placement of Topsoil and revegetate Surface	2304	sq.m	$ 20	$ 46,080	
	Construction of bitumen seal pavement	27.4	cu.m	$ 20	$ 548	
	Concrete Retaining Wall 400 mm thick	57	cu.m	$ 1,500	$ 85,500	$ 207,668
4	**DRAINAGE WORKS**					
	Cap existing Stormwater Pits encroaching the proposed levee	1	Item	Lump Sum	$ 6,000	
	Provide and Install Stormwater Pit (3.1m x 3.1m) and Grate and connect to existing Council Mains	1	Item	Lump Sum	$ 15,309	
	Concrete encasement of the existing sw pipes under the levee	2	No.	$ 1,800	$ 3,600	

	Water jetting for cleaning existing sw pipes/pits	2	No.	$ 2,000	$ 4,000	
	Cast in situ reinforced concrete outlet headwall	2	No.	$ 1,000	$ 2,000	
	New Culvert Floodgates Accessories					
	Supply, delivery and install Gabion wall cages	2	No.	$ 50	$ 100	
	Supply, delivery and placement of Gabion and Rip-Rap rockfill	40	m^3	$ 200	$ 8,000	
	Supply, delivery and install Bidim A34 Geotextile layers	70	m^2	$ 20	$ 1,400	
	New 1000DN Culvert Floodgates (supply, delivery and install top sealing penstock gate valves)	2	No.	$ 12,500	$ 25,000	
	Mobilisation of gates and framework	1	No.	$ 2,000	$ 2,000	$ 67,409
5	**BORROW PITS**					
	Clear borrow pits	1	Item	Lump Sum	$ 2,000	
	Strip topsoil and stockpile	1	Item	Lump Sum	$ 5,000	
	Excavation and stockpile of unsuitable materials	1	Item	Lump Sum	$ 8,000	
	Borrow pit trim, drainage and topsoil spreading	1	Item	Lump Sum	$ 8,000	$ 23,000
	DIRECT COST					**$ 347,877**
	DETAILED DESIGN & CONTINGENCY					
	Project supervision		% of direct cost	10		$ 34,788
	SID		% of direct cost	15		$ 51,182
	Contingency		% of direct cost	45		$ 156,545
	TOTAL ESTIMATED COST					**$ 591,391**

Table 7-9: Cost Estimate for Lake 2 spillway widening and & channelisation of downstream overbank areas Option

Date: November 2016

Item No.	Description	Quantity	Unit	Rate	Amount	Sub-total
1	**SITE ESTABLISHMENT**					
	Site establishment & disestablishment	1	Item	Lump Sum	$ 10,000	$ 10,000
	ENVIRONMENTAL MANAGEMENT					
	Erosion & sedimentation control measures during construction	1	Item	Lump Sum	$ 10,000	
	OH&S procedures	1	Item	Lump Sum	$ 5,000	
	Stormwater diversion and flood protection during construction	1	Item	Lump Sum	$ 5,000	
	Vegetation management / protection of trees	1	Item	Lump Sum	$ 10,000	$ 30,000
	SITE PREPARATION					
	Survey and site pegging out of works	1	Item	Lump Sum	$ 5,000	$ 5,000
2	**ACCESS ROAD WORKS**					
	Temporary Access Road (100mm NGS40)	30	cu.m	$ 140.00	$ 4,200	
	Compact Roadway Subgrade	300	sq.m	$ 10.00	$ 3,000	$ 7,200
3	**SPILLWAY, CHANNEL & OVERBANK WORKS**					
	Clear site vegetation and cart away	8000	sq.m	$ 0.50	$ 4,000	
	Strip and stockpile 150mm topsoil	8000	sq.m	$ 5.25	$ 42,000	
	Channel & overbank excavation to required levels, incl. disposal	9636	cu.m	$ 19.10	$ 184,048	
	Trim excavation to batter	4000	sq.m	$ 2.80	$ 11,200	
	Landscaping - Incl. Spread Topsoil and revegetate Surface	8000	sq.m	$ 20.00	$ 160,000	
	Excavate and re-grade existing rock spillway	250	cu.m	$ 68.00	$ 17,000	$ 418,248
4	**FOOTBRIDGE**					

	Footbridge 25m long x 2.5 m wide	62.5	cu.m	$ 885.00	$ 55,313	
	Approach works, abutments and piling	1	Item	Lump Sum	$ 55,313	$ 110,625
	DIRECT COST					**$ 581,073**
	DETAILED DESIGN & CONTINGENCY					
	Project supervision		% of direct cost	10		$ 58,107.26
	SID		% of direct cost	15		$ 87,161
	Contingency		% of direct cost	45		$ 261,483
	TOTAL ESTIMATED COST					**$ 987,823**

7.6 Benefit-Cost Analysis

A benefit-cost analysis was undertaken to assess the economic viability of implementing the proposed flood management options. The cost of construction works was estimated and compared with the predicted monetary benefit offered by each option in terms of the potential reduction of flood damages.

A summary of the benefit-cost assessment for each of the adopted floodplain management options is presented in **Table 7-10**.

Table 7-10: Benefit-Cost Analysis for the two Options

	Base Case	Fairwater Gardens Levee	Lake 2 spillway widening & channelisation of downstream overbank areas
Direct Residential Damage			
No. buildings flooded over floor in 1% AEP	1	1	0
No. buildings flooded over floor in 0.5% AEP	3	1	1
No. buildings flooded over floor in 0.2% AEP	11	11	4
No. buildings flooded over floor in PMF	95	95	95
Residential AAD	$21,300	$16,400	$11,000
Residential PV (7%, 50y)	$315,400	$243,000	$163,000
Direct Res Benefits (reduced PV of flood damages)	-	$72,400	$152,400
Other			
Indirect residential damage	$1,065	$820	$550
Infrastructure damage	$3,195	$2,460	$1,650
Social damage	$5,325	$4,100	$2,760
Total (including direct residential and non-residential, indirect residential and non-residential, infrastructure and social)			
Total AAD	$31,000	$24,000	$16,000
Total PV (7%, 50y)	$459,000	$355,000	$237,000
Total benefits (reduced PV of flood damages)	-	$104,000	$222,000
Estimated Capital Cost	-	**$591,391**	**$ 987,823**
Benefit-cost ratio	-	**0.18**	**0.23**

8 Social Impact Assessment

8.1 Social Impacts of Flooding

Along with tangible economic impacts, flooding may have significant adverse social impacts including:

- Inconvenience, disruption and isolation
- Physical ill-health such as personal injury, influenza, viral infections, heart problems and back problems (from lifting and cleaning)
- Psychological ill-health such as anxiety arising from stress and trauma.

Although it is difficult to quantify the cost of disruption, illness, injury and hospitalisation, in keeping with advice previously received from OEH, social damages have been estimated in this study (as a separate item) as 25% of 'total damages', which are interpreted as the sum of direct residential damages and direct non-residential damages. However, whilst this direct economic analysis is important, it is not unusual to proceed with urban flood mitigation schemes largely on social grounds, that is, on the basis of the reduction of intangible costs and social and community disruption (i.e. schemes may proceed with a benefit–cost ratio calculated to be less than 1.0). Additionally this figure was based on only the 95 properties for which floor level survey was available.

In the Harrington Park area the potential social impacts of flooding would be quite minor up to and including the 5% AEP flood event, consisting of minor inconvenience and disruption associated with short duration inundation of some recreational areas and roads. The degree of this inconvenience and disruption increases with flood severity, with numerous residential yards becoming inundated in the 1% AEP event; increasing the potential for physical or psychological ill-health and economic losses. Flood events of the 0.5% AEP magnitude and larger result in over-floor flooding of residential dwellings which has potential to cause significant social impacts. The PMF event may result in inundation and over-floor flooding of hundreds of properties in the area and would have a major social impact on the community, although the probability of such an event is very small.

8.2 Social Benefits of Preferred Options

Available information relevant to the assessment of potential intangible social benefits provided by Levee Option and Lake 2 spillway widening and & channelisation of downstream overbank areas Option is presented in **Table 8-1**.

Table 8-1: Social Benefit Analysis of the Preferred Options

	Base Case	Fairwater Gardens Levee	Lake 2 spillway widening & channelisation of downstream overbank areas
No. properties flooded in 5% AEP	2	1	0
No. properties flooded in 1% AEP	14	3	4
No. properties flooded in 0.5% AEP	24	6	8
No. properties flooded in 0.2% AEP	42	41	21
No. buildings flooded over floor in 1% AEP	1	1	0
No. buildings flooded over floor in 0.5% AEP	3	1	1
No. buildings flooded over floor in 0.2% AEP	11	11	4
No. buildings flooded over floor in PMF	>95	>95	>95
Social damage (annual average)	$5,325	$4,100	$2,760
Social benefits (annual average)		$1,225	$2,565

From available information it appears that the potential social benefits of Lake 2 spillway widening & channelisation of downstream overbank areas Option outweigh those of Levee Option, however the social benefits of both options could be characterised as 'low'. This assertion is based on the following:

- Benefits provided by Levee Option are limited to Fairwater Gardens while Lake 2 spillway widening and & channelisation of downstream overbank areas Option provides benefits over a greater area including for example Fairfax Reserve, clubhouse and tennis courts
- Benefits provided by both Options in terms of protection of properties from inundation and over floor flooding are comparable except that Lake 2 spillway widening and & channelisation of downstream overbank areas Option performs significantly better in the 0.2% AEP flood
- While both values are quite low, the estimated monetised value of social benefits provided by Lake 2 spillway widening and & channelisation of downstream overbank areas Option are double those provided by Levee Option
- Levee Option may potentially have minor negative social impacts associated with impacts on local access to Narellan Creek and recreational space.

9 Multiple Benefit Analysis

9.1 Option evaluation

9.1.1 Introduction

Multi Criteria analysis is a tool, which aids in sustainable decision-making. The results indicate how each option weighs up in comparison to one another. Refer to **Table 9-1** and **Table 9-2.**

Table 9-1: Criteria for Assessment of options

ITEM	SCORE				
	1	2	3	4	5
	Negative		Neutral		Positive
Impact on Flood Behaviour (Hydraulic Hazard)	Significant increase in hydraulic hazard	Some increase in hydraulic hazard	Neutral	Some decrease in hydraulic hazard	Significant decrease in hydraulic hazard
Number of Properties Benefited	>2 properties negatively impacted	1-2 negatively impacted	0	1-2	>2
Technical Feasibility	Significant issues (unproven, high risks)	Some issues (complex, some difficulty)	Minor issues	Negligible issues	No issues (proven, well established, no risks)
Economic Merit (benefit/cost ratio)	Very low (0-0.5)	Low (0.5-0.8)	Neutral (0.8-1.2)	High (1.2-2.0)	Very high (>2)
Financial Feasibility (funding, Government assistance & grants)	Very unlikely to receive funding	Unlikely to receive funding	Neutral	Likely to receive funding	Very likely to receive funding
Environmental and Ecological Benefits	Significant dis-benefits	Some dis-benefits	Neutral	Some benefits	Significant benefits
Impact on Risk to Life	Significant increase in risk to life	Some increase in risk to life	Neutral	Some decrease in risk to life	Significant decrease in risk to life
Impacts on SES	Significant dis-benefit to SES	Some dis-benefit to SES	Neutral	Some benefit to SES	Significant benefit to SES
Long-term Performance (design life & climate change)	Very low	Low	Neutral	High	Very high
Legislative & Permissibility Requirements (incl. political & administrative issues)	Significant issues affecting implementation	Some issues affecting implementation	Minor issues affecting implementation	Negligible issues affecting implementation	No issues affecting implementation
Social Impact / Community Acceptance	Majority against, minimal support	Some against	Neutral	Some for	Majority for, few opposed

9.1.2 Results

Table 9-2: Multicriteria Analysis

Option	Assessment Criteria											Rank
	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Economic Merit	Financial Feasibility	Environmental and Ecological Benefits	Impact on Risk to Life	Impacts on SES	Long-term Performance	Legislative & Permissibility Requirements	Social Impact / Community Acceptance	
Lake 2 Spillway and Overbank Works	5	5	3	1	3	2	3	3	3	4	4	1
Fairwater Gardens Flood Levee	4	4	2	1	3	2	3	3	4	2	2	2

9.2 Recommendation

The Multi Criteria Analysis has identified that the preferred option is Lake 2 spillway widening & channelisation of downstream overbank areas Option. If it was agreed that this was the preferred option it could therefore be recommended to be undertaken in the implementation phase and finalise the last step of the Floodplain Risk Management process.

The Multi Criteria analysis has shown the following basis on which the Lake 2 spillway widening & channelisation of downstream overbank areas Option is the recommended concept:

- Both Impact on Flood Behaviour and Number of Properties Benefited criteria, rank the Lake 2 spillway widening and & channelisation of downstream overbank areas Option higher than the Levee Option, which performs significantly better in the 0.2% AEP flood;
- Technical Feasibility criteria, which is the construction feasibility, rank the Lake 2 spillway widening and & channelisation of downstream overbank areas Option higher than the Levee Option;
- Benefit/Cost criteria identify the Lake 2 spillway widening and & channelisation of downstream overbank areas Option as more beneficial than the Levee Option, although more expensive than the Levee Option. However, both options have the same negative score (1) for Economic Merits because of the very low benefit/cost ratio (around 0.2);
- Long-term performance criteria rank the Levee Option higher. Lake 2 spillway widening and & channelisation of downstream overbank areas Option will require ongoing vegetation maintenance program;
- Legislative and Permissibility Requirements criteria rank the Lake 2 spillway widening and & channelisation of downstream overbank areas Option higher than the Levee Option because of the potential administrative issues, e.g. blocking the open access to Narellan Creek for one private property;
- Social Impact criteria identify the Lake 2 spillway widening and Overbank Works Option as the preferred option. Levee Option has the lower score because the proposed levee would potentially disrupt private properties adjacent to the levee in terms of view, access, recreational space etc.

The Investigation & Design Harrington Park Mitigation Works project has identified that both flood mitigation options in the Fairwater Gardens area have a low benefit-cost ratio (around 0.2) and hence these options are economically not viable.

10 Vegetation Management

10.1 Vegetation Management Option

10.1.1 General

As the outcome and the recommendations from the previous flood mitigation option study of the Harrington park area, Vegetation Management Option has been considered as the preferred option that Council wanted to proceed with. Detailed investigations including vegetation mapping, Flora and Fauna survey and preparation of vegetation management plans for implementation, had been undertaken simultaneously with Stage I at the beginning of this project.

10.1.2 Update of Flood Model for Existing Conditions

As a result of the vegetation survey undertaken in February 2016, more detailed information on the nature of riparian vegetation – and therefore appropriate hydraulic roughness values – in the Harrington Park area was made available. In order to ensure that reductions in simulated peak flood levels indicated for subsequent floodplain mitigation option modelling can be relied upon, it was necessary to update existing conditions to reflect this new information.

The delineation of hydraulic roughness zones derived from the vegetation survey and used in the model update of existing conditions is shown in **Figure 10.1**, with corresponding Manning's roughness values contained in **Table 10-1**. Relevant Manning's values used by Worley Parsons are also included for comparison.

In the light of the recent vegetation survey it has been concluded that the extent and level of clearing modelled by Worley Parsons for Vegetation Management Option is not achievable and that Manning's values used for existing condition modelling have been unrealistically high.

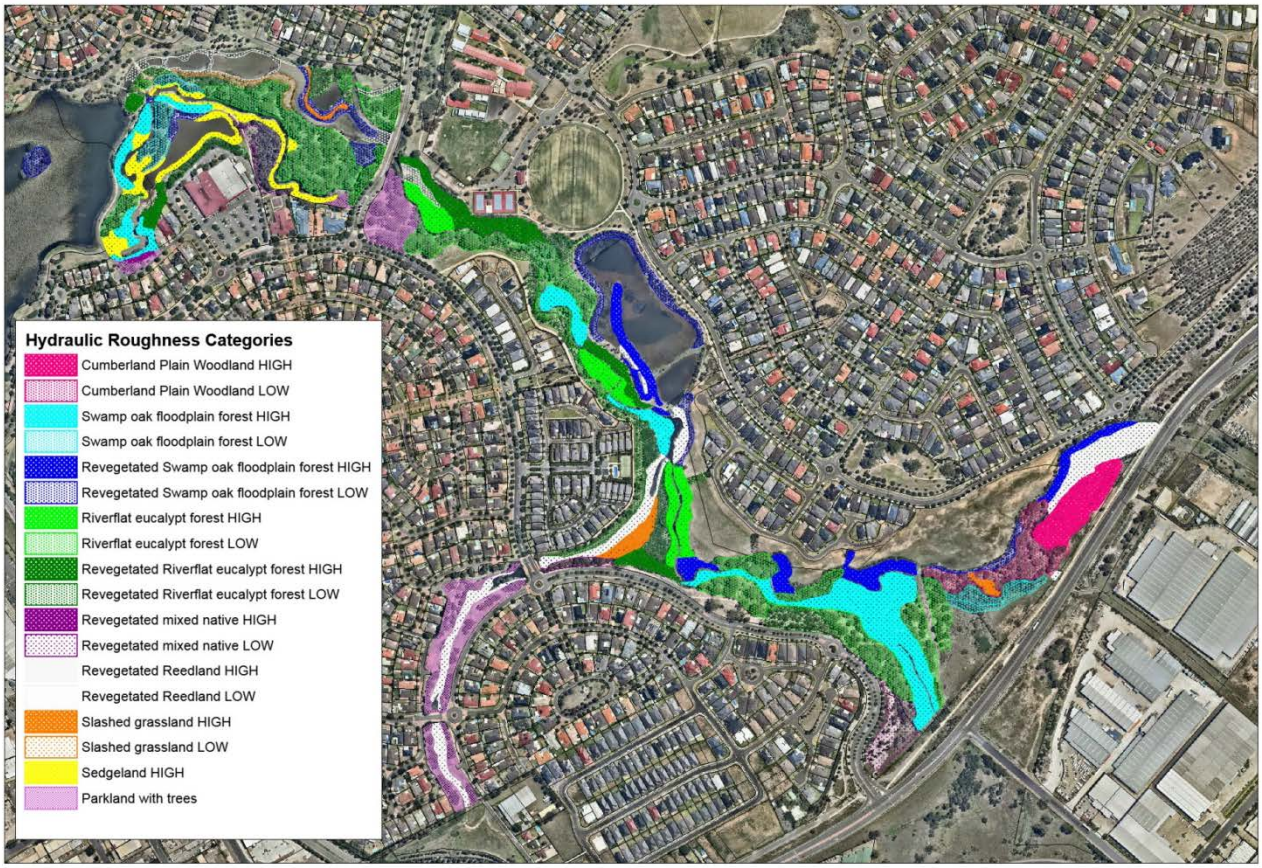


Figure 10.1: Updates to delineation of roughness zones derived from vegetation mapping

Table 10-1: Updated depth varying Manning's 'n' values derived from vegetation mapping

Material	Depth 1 (m)	Manning's 'n' 1	Depth 2 (m)	Manning's 'n' 2	Resulting Manning's values at selected depths		
					Manning's at depth of 1 m	Manning's at depth of 2 m	Manning's at depth of 3 m
Cumberland Plain Woodland HIGH	0.4	0.2	2	0.12	0.17	0.12	0.12
Cumberland Plain Woodland LOW	0.4	0.07	2	0.07	0.07	0.07	0.07
Riverflat eucalypt forest HIGH	0.4	0.2	2	0.12	0.17	0.12	0.12
Riverflat eucalypt forest LOW	0.4	0.1	2	0.07	0.089	0.07	0.07
Revegetated Riverflat eucalypt forest HIGH	0.4	0.2	2	0.12	0.17	0.12	0.12
Revegetated Riverflat eucalypt forest LOW	0.4	0.1	2	0.06	0.085	0.06	0.06
Swamp oak floodplain forest HIGH	0.4	0.2	2	0.12	0.17	0.12	0.12
Swamp oak floodplain forest LOW	0.4	0.1	2	0.09	0.096	0.09	0.09
Revegetated Swamp oak floodplain forest HIGH	0.4	0.2	2	0.12	0.17	0.12	0.12
Revegetated Swamp oak floodplain forest LOW	0.4	0.1	2	0.07	0.089	0.07	0.07
Sedgeland HIGH	0.2	0.1	1	0.06	0.06	0.06	0.06
Sedgeland LOW	0.2	0.06	1	0.06	0.06	0.06	0.06
Revegetated Reedland HIGH	0.4	0.1	2	0.05	0.081	0.05	0.05
Revegetated Reedland LOW	0.4	0.05	2	0.025	0.041	0.025	0.025
Revegetated mixed native HIGH	0.4	0.2	2	0.15	0.181	0.15	0.15
Revegetated mixed native LOW	0.4	0.09	2	0.08	0.086	0.08	0.08
Slashed grassland HIGH	0.1	0.075	0.5	0.05	0.05	0.05	0.05
Slashed grassland LOW	0.05	0.075	0.25	0.03	0.03	0.03	0.03
Parkland with trees	0.05	0.075	0.25	0.04	0.04	0.04	0.04
Comparison with Worley Parsons 2015							
WorleyParsons existing condition all overbank areas	1	0.2	5	0.1	0.2	0.175	0.15
WorleyParsons existing condition waterway/channel	0.5	0.1	2.5	0.075	0.094	0.081	0.075
WorleyParsons Option1 condition all overbank areas	1	0.05	5	0.05	0.05	0.05	0.05
WorleyParsons Option 1 condition waterway/channel	0.1	0.05	0.3	0.035	0.035	0.035	0.035

10.1.3 Hydraulic Assessment of Vegetation Management Mitigation Option

An initial vegetation management option has been developed and modelled based on guidelines from Lesryc Environmental on the conservation value of existing vegetation and recommended degree of clearing, which are detailed in the separate report, *Vegetation Management Plan-Harrington Park Lake System* (Lesryc Environmental 2017).

All the measures of vegetation management, such as weed control and removal, slashing, thinning, etc., detailed in this report, are generally temporary in nature and thus would require on-going maintenance to ensure the associated reductions in flood levels are achieved.

To apply the recommended vegetation management measures in the TUFLOW model the following changes were made to the materials layer:

- All revegetated, sedge land and grassland areas within a 'HIGH' material category were reduced to the corresponding 'LOW' material category (see Table 10-1) to represent weed removal and slashing
- Remnant vegetation areas were reviewed against weed mapping by Lesryc Environmental. Those areas within a 'HIGH material category and with a weed class 3 or 4 (i.e. 'moderate level of weeds' or 'high level of weeds'') were reduced to the corresponding 'LOW' material category to represent weed removal.

The resulting areas where reductions in hydraulic roughness (Manning's 'n') were applied are shown in the **Figure 10-2**.

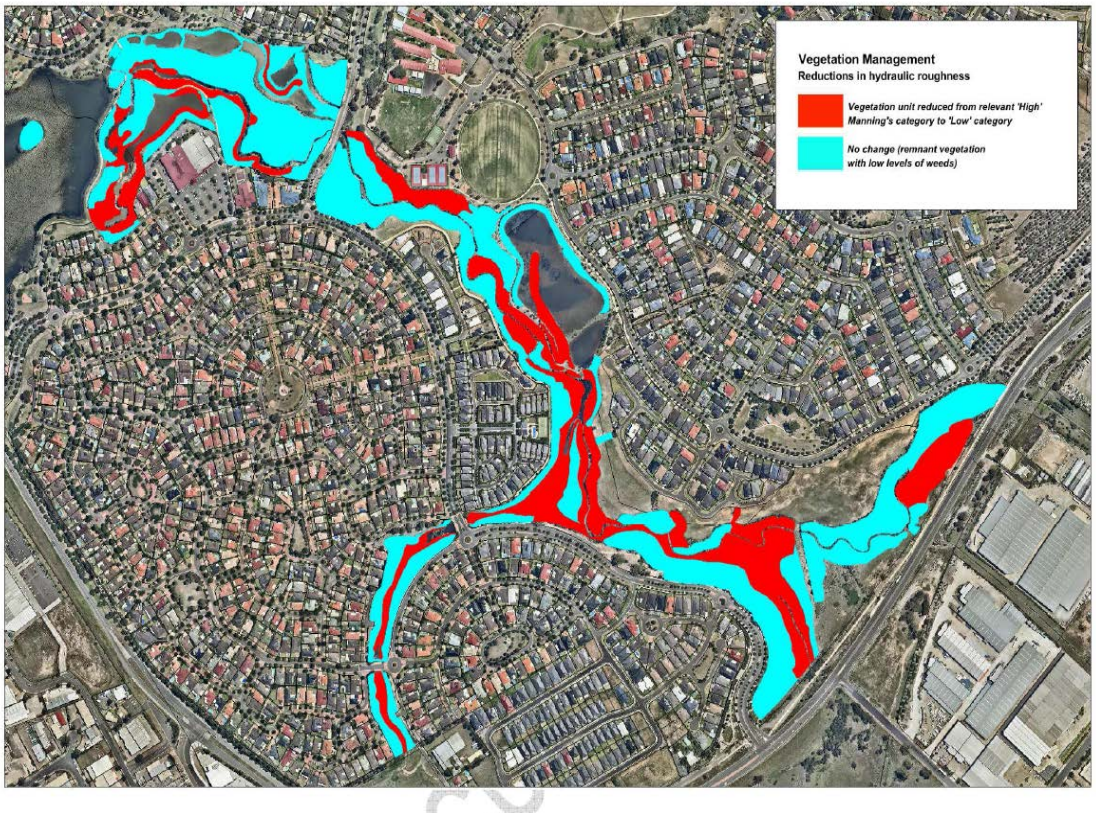


Figure 10-2: Areas with reduction in Manning's 'n' for VM Option at Harrington Park

Reductions in peak 1% AEP flood levels achieved by Vegetation Management Option are presented in the **Figure 10-3**. Changes displayed are relative to the existing condition per Public Works Advisory updated modelling.

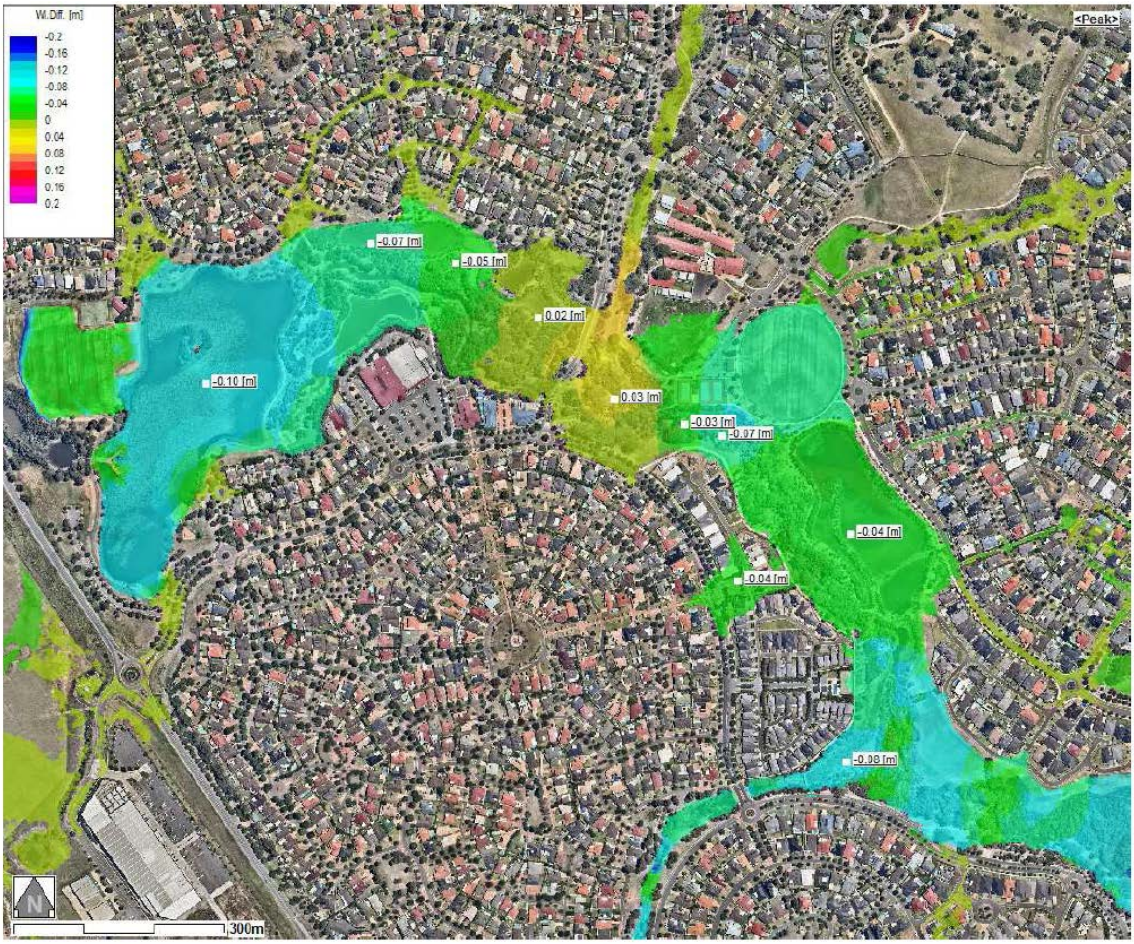


Figure 10-3: Changes in peak 1% AEP flood levels for the VM Option at Harrington Park

It can be seen that reductions in flood levels of up to 0.05 m were achieved in the vicinity of Fairwater Gardens, while reductions in the area 500 m downstream of Camden Valley Way were higher, between 0.05 m and 0.10 m.

The preliminary hydraulic assessment of short-listed flood mitigation options and the negligible impact on 1% AEP peak flood levels of the Vegetation Management Option, resulted in not identifying this option as the preferred one.

10.2 Vegetation Management Works

As part of the overall Vegetation Management Plan and ongoing vegetation maintenance of the Harrington Park area, Council is planning to undertake Vegetation Management Works, which require developing detailed vegetation maintenance and management specifications, schedule of rates, bills of quantities and cost estimates. Furthermore, a staging plan should be developed, including priorities for vegetation treatment works.

Vegetation Management Plan-Harrington Park Lake System (Lesryc Environmental 2017) has been prepared at the request of Public Works Advisory on behalf of Camden Council as the separate report. The report presents the extent and nature of vegetation works required to manage the riparian areas in order to minimise localised flooding.

This report outlines detailed vegetation maintenance and management specifications, frequency of management and maintenance, vegetation management scheduling and priorities and schedule of vegetation management units and areas. The provided information has been used to develop a Vegetation Management Work Programme over two years for the Harrington Park area, which is presented in the Tables below.

Table 10-2 presents Programme for priority management units, where vegetation management is required to reduce hydraulic roughness and **Table 10-3** presents Regular Maintenance Programme for the remaining areas in the Study area. The Tables include cost estimates for the entire Vegetation Management Work Programme over two years. Estimated working hours for each of the proposed vegetation management activities are provided by Lesryc Environmental and hourly rates, based on the average labour rates including plant rates, are provided by Camden Council.

Table 10-2:- VM Work Programme to reduce the hydraulic roughness

WORK PROGRAMME OVER TWO YEARS FOR THE AREA WHERE VM IS REQUIRED TO REDUCE HYDRAULIC ROUGHNESS

Priority Group Stages	Management Unit Areas _Vegetation Unit No.	Vegetation Class	Works / Tasks	Frequency of Management and Maintenance	Management Unit Area (m²)	Quantity (hr.)	Rate	Cost for Scheduled Task	Annual Cost	Subtotal
1	2, 7, 9, 10, 13, 24	herbland	debris / litter removal	annually	7,615	60	$ 50	$ 3,000	$ 3,000	
			weed control	annually	7,615	68	$ 50	$ 3,400	$ 3,400	
			slashing	once in 2 years	7,615	48	$ 50	$ 2,400	$ 1,200	
	45	slashed grassland	debris / litter removal	annually	860	8	$ 50	$ 400	$ 400	
			grass slashing	twice a year	860	4	$ 50	$ 200	$ 400	$ 8,400
2	61	revegetated - river-flat eucalipt forest	debris / litter removal	annually	5,850	80	$ 50	$ 4,000	$ 4,000	
			weed control	8 times in 2 years	5,850	160	$ 50	$ 8,000	$ 32,000	
			thinning of native vegetation	annually	5,850	240	$ 50	$ 12,000	$ 12,000	$ 48,000
3	66, 55	remnant - river-flat eucalipt forest	debris / litter removal	annually	6,270	176	$ 50	$ 8,800	$ 8,800	
			weed control	8 times in 2 years	6,270	352	$ 50	$ 17,600	$ 70,400	
	65, 67, 68, 57, 93, 82	revegetation - river-flat eucalipt forest remnant - swamp oak floodplain forest revegetation - swamp oak floodplain forest	debris / litter removal	annually	12,879	288	$ 50	$ 14,400	$ 14,400	
			weed control	8 times in 2 years	12,879	608	$ 50	$ 30,400	$ 121,600	
			thinning of native vegetation	annually	12,879	576	$ 50	$ 28,800	$ 28,800	
	69, 58, 84	revegetation reedland	debris / litter removal	annually	5,300	352	$ 50	$ 17,600	$ 17,600	
			weed control	annually	5,300	352	$ 50	$ 17,600	$ 17,600	
			slashing	once in 2 years	5,300	352	$ 50	$ 17,600	$ 8,800	$ 288,000
4	52, 50, 77, 76	remnant - swamp oak floodplain forest revegetation - swamp oak floodplain forest	debris / litter removal	annualy	21,016	192	$ 50	$ 9,600	$ 9,600	
			weed control	8 times in 2 years	21,016	736	$ 50	$ 36,800	$ 147,200	
			thinning of native vegetation	annualy	21,016	736	$ 50	$ 36,800	$ 36,800	$ 193,600
5	91	revegetation reedland	debris / litter removal	annually	4465	128	$ 50	$ 6,400	$ 6,400	
			weed control	annually	4465	128	$ 50	$ 6,400	$ 6,400	
			slashing	once in 2 years	4465	128	$ 50	$ 6,400	$ 3,200	$ 16,000
6	73, 74	remnant - cumberland plain woodland	debris / litter removal	annually	8080	128	$ 50	$ 6,400	$ 6,400	
			weed control	8 times in 2 years	8080	128	$ 50	$ 6,400	$ 25,600	$ 32,000
	Total				201,795					
	DIRECT COST									$ 586,000
	PROJECT SUPERVISION & CONTINGENCY									
	Project supervision					% of direct cost	10			$ 58,600
	Contingency					% of direct cost	10			$ 58,600
	TOTAL ESTIMATED COST									$ 703,200

NOTES: The proposed Management Works Activities are quantified by the estimated working hours required for each of the activities, provided by Lesryc Environmental

Hourly rate is the estimation based on the average labour rates including plant rates (utes & trucks), provided by Camden Council

Table 10-3:- VM Regular Maintenance Work Programme

WORK PROGRAMME OVER TWO YEARS FOR THE OTHER VEGETATION MANAGEMENT UNITS IN THE STUDY AREA

AS PART OF THE REGULAR MAINTENANCE PROGRAMME

Management Unit Areas (Vegetation Unit No.)	Vegetation Class	Works / Tasks	Frequency of Management and Maintenance	Management Unit Area (m^2)	Quantity (hours)	Rate	Cost for Scheduled Task	Annual Cost	Subtotal
16, 20, 35, 59, 92	parkland with trees	debris / litter removal	annually	21,820	218	$ 50	$ 10,900	$ 10,900	
		mowing / slashing grass	3 times in 1 years	21,820	109	$ 50	$ 5,450	$ 16,350	
									$ 27,250
	revegetated - mixed native forest	debris / litter removal	annually	132,716	1858	$ 50	$ 92,900	$ 92,900	
		weed control	8 times in 2 years	132,716	4911	$ 50	$ 245,550	$ 982,200	
		thinning of native vegetation	annually	132,716	4911	$ 50	$ 245,550	$ 245,550	
Total				**441,788**					$1,320,650
DIRECT COST									**$1,347,900**
PROJECT SUPERVISION & CONTINGENCY									
Project supervision					% of direct cost	10			**$ 134,790**
Contingency					% of direct cost	10			**$ 134,790**
TOTAL ESTIMATED COST									**$1,617,480**

11 Conclusion

The objective of the study is to undertake an investigation and design of flood mitigation works for Harrington Park within the Narellan catchment and establish models as necessary for accurate flood level prediction. Central to this is the development of appropriate hydrological and hydraulic models.

The study program provides for a staged approach, incorporating:

STAGE I – Preferred Mitigation Works

STAGE IA – Vegetation Management Plan

STAGE II – Concept Design of 2 selected mitigation options

Stage I, IA and II are being undertaken in a phased approach as outlined below:

- Stage I, Part 1 - Data Collection and Review;
- Stage IA, Part 1 – Vegetation Mapping;
- Stage IA, Part 2 – Ecological Assessment and Vegetation Management Plan;
- Stage I, Part 2 – Hydrology Hydraulic Modelling of flood mitigation options;
- Stage I, Part 3 – Cost Benefit Analysis and Feasibility Study for 2 selected mitigation options;
- Stage II – Concept Design and Multiple Benefit Analysis for 2 selected mitigation options;
- Stage II – Vegetation Management Works

This report has been structured to include all the information required for the preferred options to progress further to the Detail Design Stage.

The Investigation & Design Harrington Park Mitigation Works project has identified that flood mitigation options in the Fairwater Gardens area have a low benefit-cost ratio (around 0.2). Hence these options are economically not viable and are unlikely to receive funding from the NSW Government.

During the project, significant update of the Narellan Creek TUFLOW model was undertaken resulting in changes of design flood levels. Rather than proceed with detail design of mitigation options it was concluded that a change of scope be sought to update the Narellan Creek Flood Study (Worley Parsons 2015) to reflect recent developments in the study area and the updated TUFLOW model. The combination of these updates resulted in significant changes in design flood levels in some areas, and as such warranted the current *Update of Narellan Creek Flood Study,* DC17070 (PWA 2017).

The Investigation & Design Harrington Park Mitigation Works project has detailed the staging Vegetation Management Plan, which provides adequate guidelines for the future implementation of the Vegetation Management Works and budget forecasts.

12 References

Austroads, *Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways*, 1994

Crookston, Paxon and Savage, "Hydraulic Performance of Labyrinth Weirs for High Headwater Ratios", 4th IAHR International Symposium on Hydraulic Structures, 9-11 February 2012, Porto, Portugal (http://www.schnabel-eng.com/wp-content/uploads/2013/12/Hydraulic-Performance-of-Labyrinth-Weirs-for-High-Headwater-Ratios.pdf)

Institution of Engineers, *Australian Rainfall and Runoff*, 2006

Institution of Engineers Australia, *Australian Rainfall and Runoff Revision Project 15: "Two Dimensional Modelling in Urban and Rural Flood Plains, Stage 1 and 2 Report",* November 2012

McLuckie, Babister, Smith and Thomson, *Updating National Guidance on Best Practice Flood Risk Management*, 54th Floodplain Management Association Conference, 2014

New South Wales Government, *Floodplain Development Manual: the management of flood liable land, 2005*

SMEC Australia Pty Ltd, *Harrington Park Hydrologic and Hydraulic Report Final*, February 2000

Worley Parsons, *Draft Narellan Creek Flood Study – Harrington Park Flood Mitigation Options Report*, 2014

Worley Parsons, *Narellan Creek Flood Study Report*, 2015

Worley Parsons, *Nepean River Flood Study*", 2015

NSW Public Works Advisory, *Investigation and Design, Harrington Park Mitigation Works, Narellan-Nepean*, DC15227, 2016

NSW Public Works Advisory, *Investigation and Design, Harrington Park Mitigation Works Narellan-Nepean*, DC16089, 2016

NSW Public Works Advisory, *Harrington Park Mitigation Works, Review of Environmental Factors*, DC 16068, December 2016

Lesryc Environmental, *Vegetation Management Plan-Harrington Park Lake System*, April 2017

Lesryc Environmental, *Vegetation Management Plan-Narellan Creek proposed spillway channel Harrington Park*, January 2017

Appendix A Concept Drawings

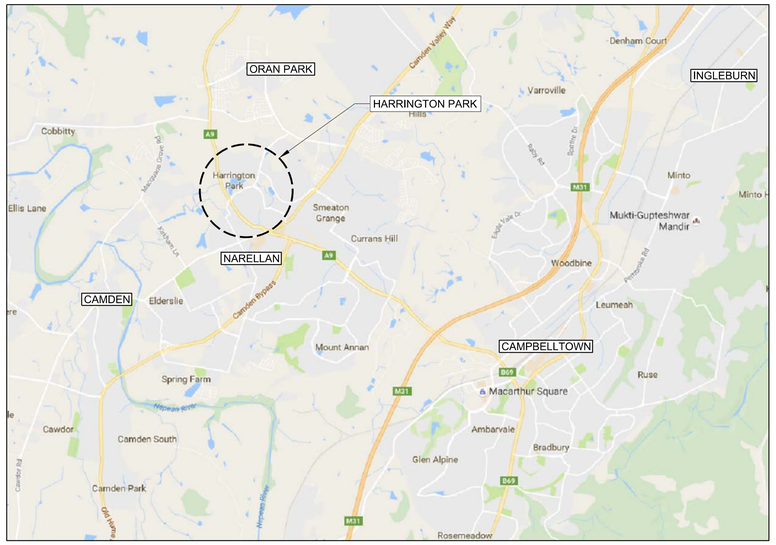
NSW PUBLIC WORKS ADVISORY

HARRINGTON PARK
FLOOD MITIGATION WORKS

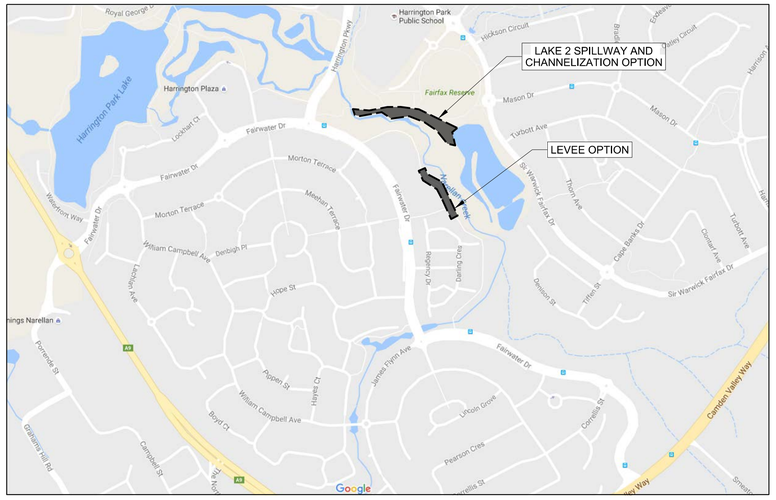
CONCEPT DRAWINGS

DRAWING SCHEDULE

DRAWING TITLE	DRAWING NO.
COVER SHEET, DRAWING SCHEDULE AND LOCALITY PLAN	C001
FLOOD MITIGATION OPTIONS - OVERALL LAYOUT PLAN	C002
LEVEE OPTION - GENERAL ARRANGEMENT PLAN	C003
LEVEE OPTION - LONGITUDINAL SECTION AND DETAILS	C004
LAKE 2 SPILLWAY WIDENING AND CHANNELIZATION OPTION - GENERAL ARRANGEMENT PLAN	C005
LAKE 2 SPILLWAY WIDENING AND CHANNELIZATION OPTION - LONGITUDINAL SECTION AND DETAILS	C006



HARRINGTON PARK LOCATION



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DRAFTED T. PERUSCO
CHECKED S. CVETKOVIC
PRINCIPAL ENGINEER (ACTING) J. GAN

FLOOD MITIGATION OPTIONS CONCEPT DRAWINGS

COVER SHEET, DRAWING SCHEDULE AND LOCALITY PLAN

CONTRACT NO. T.B.C. | A1
SCALE @ A1 N.T.S. | CADD ID. 1609
DRAWING NO. **C001** | REV. 0

CONFIRM SCALE 100mm ON ORIGINAL

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FLOOD MITIGATION OPTIONS - OVERALL LAYOUT PLAN

SCALE 1:1000

1:1000 0 20 40 60 80 100m
20 10

NOTES:

1. CONTOURS GENERATED FROM LiDAR 2.5m GRID DATA.

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FLOOD MITIGATION OPTIONS CONCEPT DRAWINGS

FLOOD MITIGATION OPTIONS OVERALL LAYOUT PLAN

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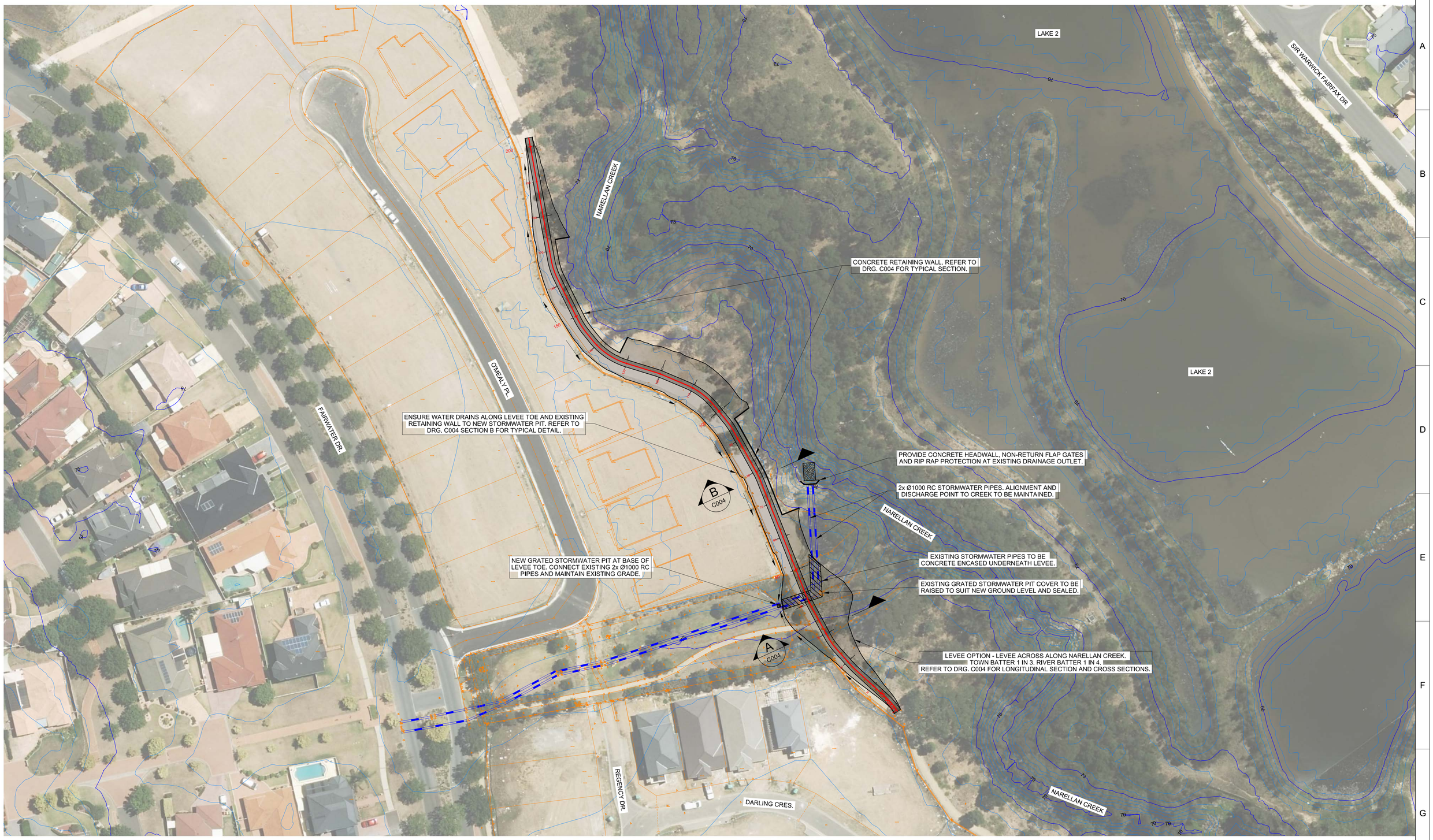

LEVEE OPTION - GENERAL ARRANGEMENT PLAN

SCALE 1:500

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NOTES:

1. CONTOURS GENERATED FROM LiDAR 2.5m GRID DATA.
2. LEVEE ALIGNMENT AND EXTENT OF LEVEE IS SUBJECT TO REFINEMENT DURING DETAILED DESIGN PHASE.

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FLOOD MITIGATION OPTIONS CONCEPT DRAWINGS

LEVEE OPTION
GENERAL ARRANGEMENT PLAN

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REV. 0

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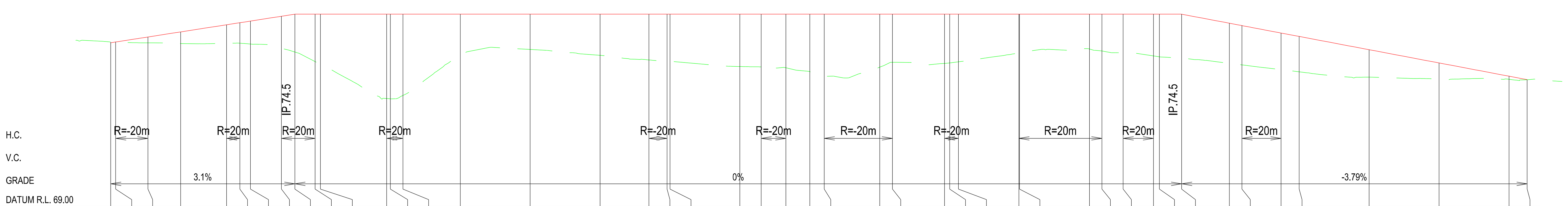
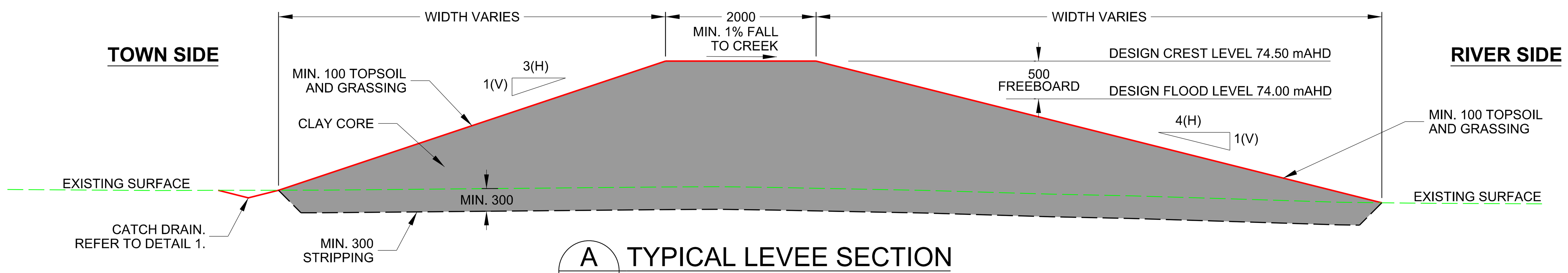


CHAINAGE	DESIGN LEVEL	EXISTING LEVEL
0	73.68	73.7
0.71	73.7	73.7
5.32	73.85	73.68
10	73.99	73.66
16.57	74.2	73.67
18.48	74.26	73.67
20	74.3	73.65
24.43	74.44	73.54
26.34	74.5	73.42
29.23	74.5	73.14
30	74.5	73.06
39.47	74.5	72.09
40	74.5	72.08
41.8	74.5	72.18
50	74.5	73.35
60	74.5	73.49
70	74.5	73.32
77	74.5	73.19
79.57	74.5	73.15
80	74.5	73.15
90	74.5	73
93.05	74.5	72.99
96.58	74.5	72.97
100	74.5	72.86
102.06	74.5	72.72
110	74.5	72.98
111.82	74.5	73.12
119.26	74.5	73.09
120	74.5	73.11
121.26	74.5	73.14
129.9	74.5	73.4
130	74.5	73.4
140	74.5	73.51
141.77	74.5	73.45
144.82	74.5	73.4
149.15	74.5	73.31
150	74.5	73.28
153.18	74.5	73.24
160	74.24	73.1
161.8	74.17	73.05
167.4	73.96	72.92
170	73.86	72.85
180	73.48	72.7
190	73.11	72.65
200	72.73	72.64
202.61		72.63

LEVEE CL - LONGITUDINAL SECTION

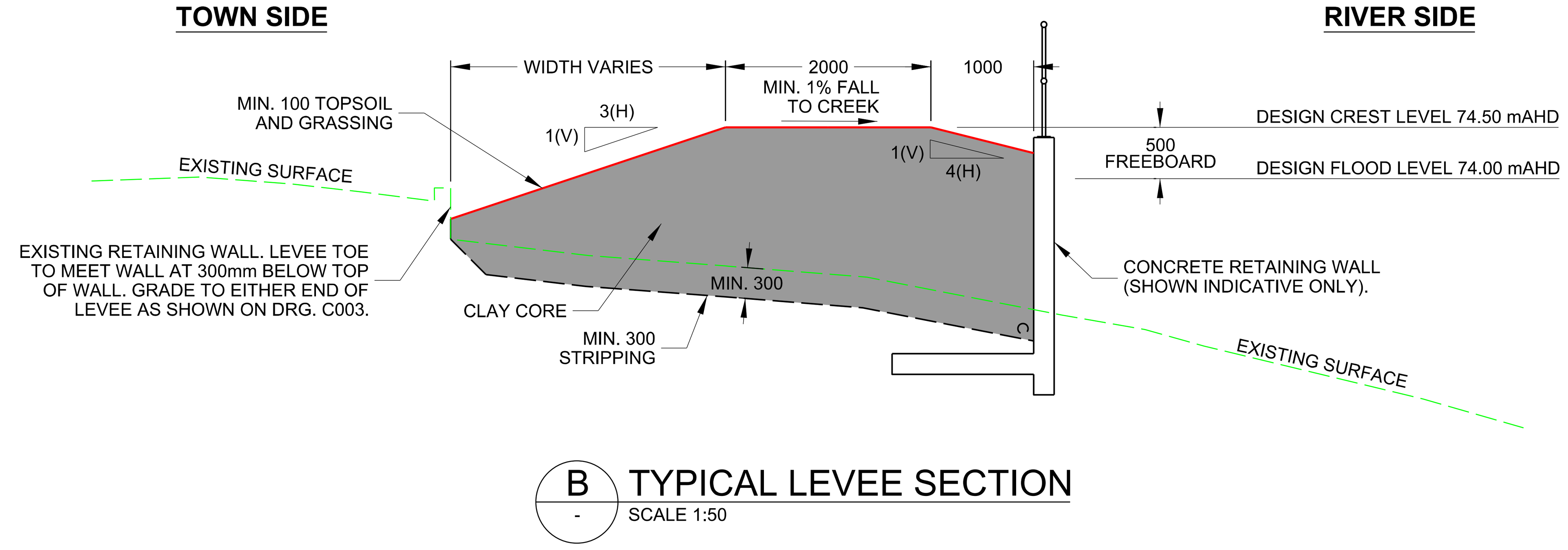
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100

NOTE: VERTICAL EXAGGERATION 5x



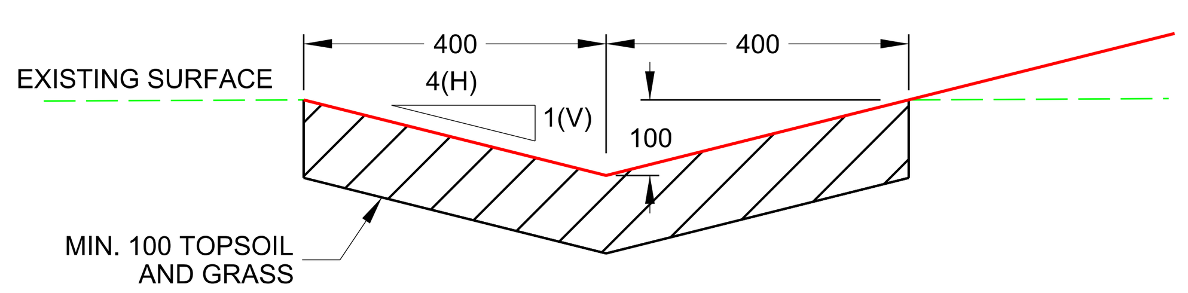
A TYPICAL LEVEE SECTION

SCALE 1:50



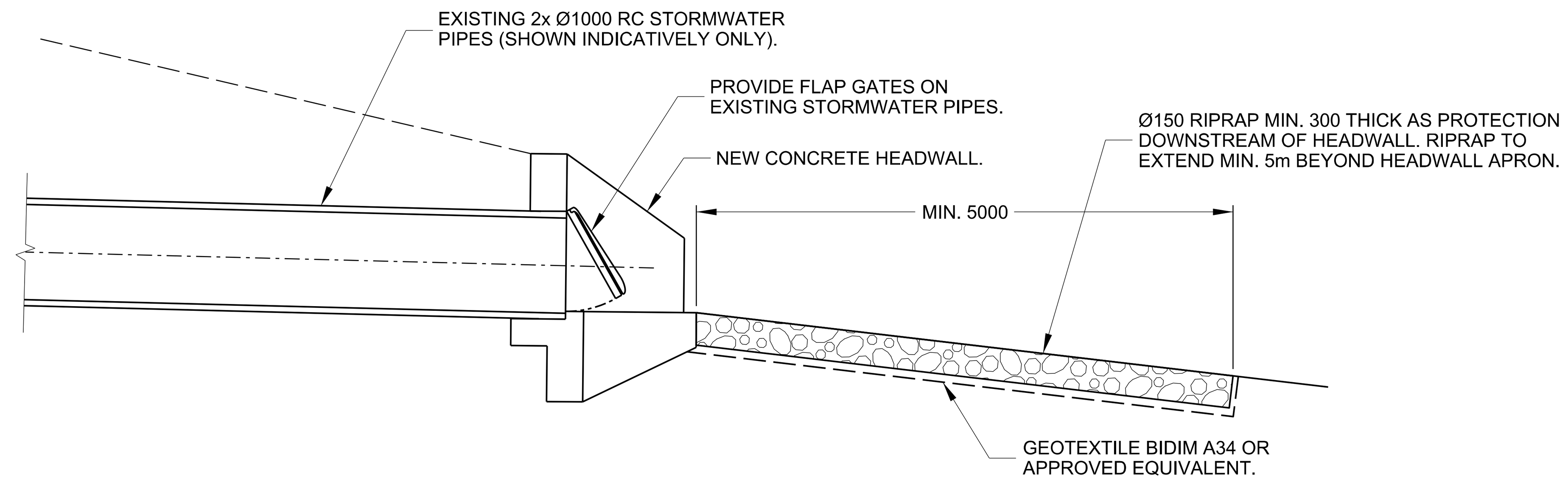
B TYPICAL LEVEE SECTION

SCALE 1:50



1 CATCH DRAIN DETAIL

SCALE 1:10

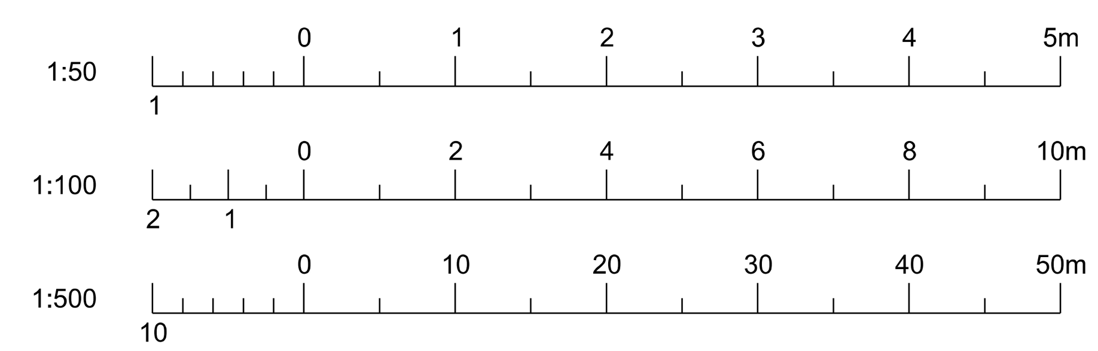


2 OUTLET HEADWALL DETAIL

SCALE 1:50

LEGEND

- EXISTING SURFACE LEVEL
- DESIGN SURFACE LEVEL



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FLOOD MITIGATION OPTIONS
CONCEPT DRAWINGS

LEVEE OPTION
LONGITUDINAL SECTION AND DETAILS

CONTRACT NO. T.B.C.
A1
SCALE @ A1 1:500,1:100,1:50
CADD ID. 1609
DRAWING NO. C004
REV. 0

CONFIRM SCALE ← 100mm ON ORIGINAL →

FILE LOCATION: G:\Watertec\Pcad\1609 - Harrington Park Flood Mitigation Works\2_CONCEPT DESIGN\1609_PHARRINGTON_C004_LEVEE DET.dgn
PLOT BY: Peruscot
PLOT DATE: 16/12/2016
PLOT TIME: 12:19:39 PM

LAKE 2 SPILLWAY WIDENING AND CHANNELIZATION OPTION - GENERAL ARRANGEMENT PLAN

SCALE 1:500

1:500 0 10 20 30 40 50m

NOTES:

1. CONTOURS GENERATED FROM LiDAR 2.5m GRID DATA.
2. CHANNEL ALIGNMENT HAS BEEN LOCATED BASED OF AERIAL PHOTOGRAPHY AND CONTOURS. ALIGNMENT AND EXTENT OF CHANNEL IS SUBJECT TO REFINEMENT DURING DETAILED DESIGN PHASE WHEN FIELD SURVEY DATA IS AVAILABLE.

ISS.	DATE	AMENDMENT / REVISION DETAILS
0	16/12/2016	CONCEPT ISSUE

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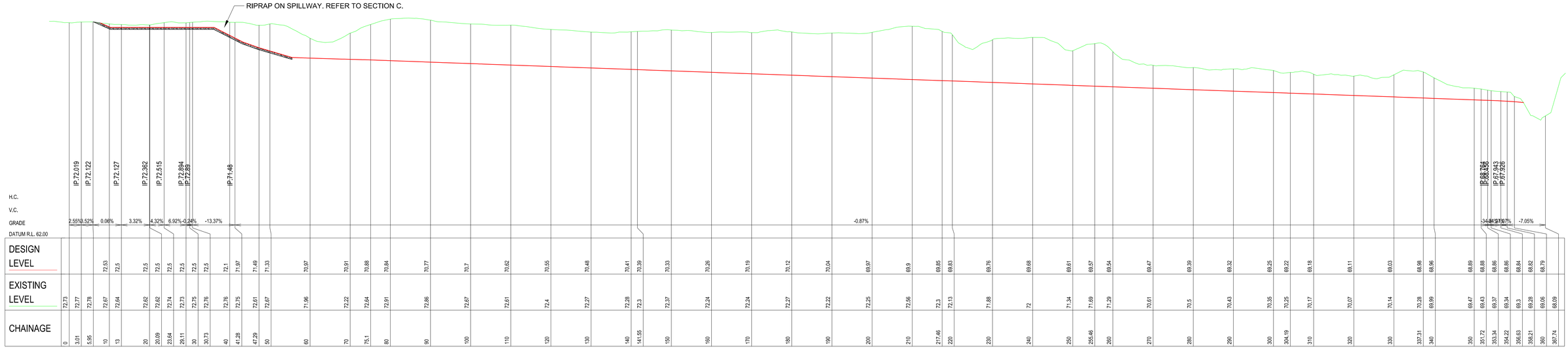
FLOOD MITIGATION OPTIONS CONCEPT DRAWINGS

LAKE 2 SPILLWAY WIDENING AND CHANNELIZATION OPTION GENERAL ARRANGEMENT PLAN

CONTRACT NO. T.B.C. | A1
SCALE @ A1 1:500 | CADD ID. 1609
DRAWING NO. **C005** | REV. 0

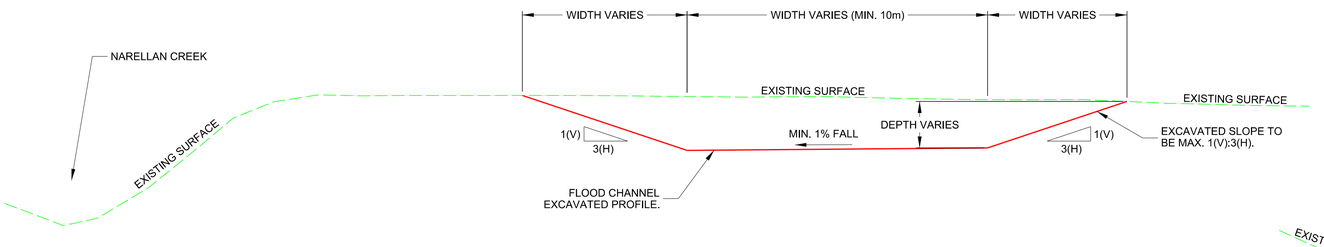
CONFIRM SCALE ◄ 100mm ON ORIGINAL ►



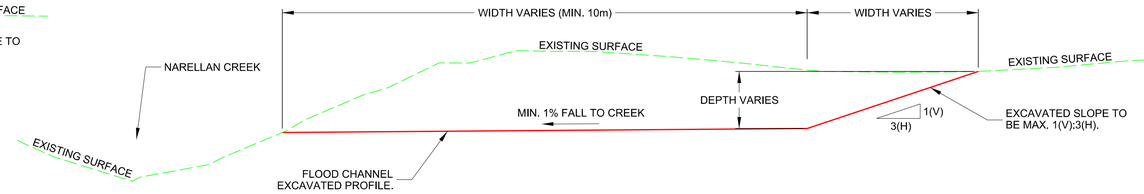
NOTE: VERTICAL EXAGGERATION 5x

CHANNEL SETOUT LINE - LONGITUDINAL SECTION

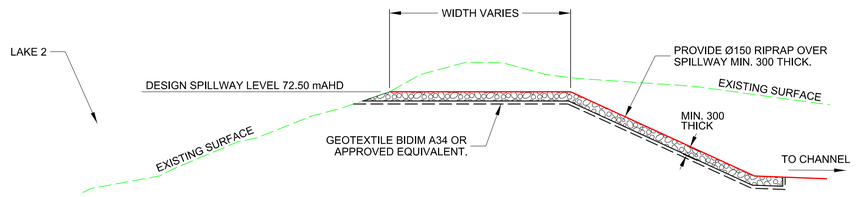
HORIZONTAL SCALE 1:500
VERTICAL SCALE 1:100



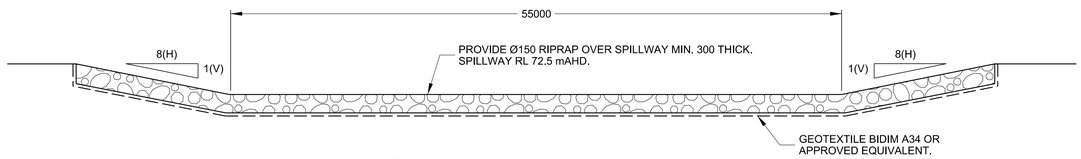
A TYPICAL CHANNEL WIDENING
C005 SCALE 1:100



B TYPICAL CHANNEL WIDENING
C005 SCALE 1:100



C TYPICAL SPILLWAY LONGITUDINAL SECTION
- N.T.S.



D SPILLWAY CROSS SECTION
- N.T.S.

LEGEND

EXISTING SURFACE LEVEL

DESIGN SURFACE LEVEL

1:100 0 2 4 6 8 10m (2 1)

1:500 0 10 20 30 40 50m (10)

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0	16/12/2016	CONCEPT ISSUE

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FLOOD MITIGATION OPTIONS CONCEPT DRAWINGS

LAKE 2 SPILLWAY WIDENING AND CHANNELIZATION OPTION LONGITUDINAL SECTION AND DETAILS

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CADD ID. 1609
DRAWING NO. **C006**
REV. 0

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FILE LOCATION: G:\Watertech\Pcad\1609 - Harrington Park Flood Mitigation Works\2_CONCEPT DESIGN\1609_PHARRINGTON_C006_CHANNEL DET.dgn
PLOT BY: Peruscot
PLOT DATE: 16/12/2016
PLOT TIME: 12:21:24 PM

Appendix B Plates

Plate 1: Levee Option 1 - Typical view of the levee bank alignment following the rear of the properties in O'Meally Place.

Plate 2: Levee Option 1 - Another view of similar site conditions at the rear of the properties.

Plate 3: Levee Option 1 - View of the open access way between O'Meally Place and the Narellan Creek.

Plate 4: Levee Option 1 - View of the eastern end of the drainage reserve between approximate Ch. 30m and Ch.60m on the levee alignment.

Plate 5: Levee Option 1 - View of the moderately steep bank leading to the creek. Top of the bank is in close proximity to the properties.

Plate 6: Levee Option 1 - Close up view of slightly sandy clayey silt/silty clay at the toe of the creek's bank.

Plate 7: Levee Option 1 - Another close up view of fluvial sediment's in the creek's bank.

Plate 8: Levee Option 1 - View of boulder lined upper slope at approximate Ch. 80m on the alignment. The levee at this location will be a concrete wall.

Plate 9: Levee Option 1 - Close up view of stormwater outlets at approximate Ch. 80m.

Plate 10: Channelisation Option 2 - View of the flat terrace adjoining Lake 2, at the proposed Lake 2 spillway site.

Plate 11: Channelisation Option 2 - View of the batter leading to Lake 2 at the spillway site.

Plate 12: Channelisation Option 2 - View of the medium to densely timbered site along the channel alignment.

Plate 13: Channelisation Option 2 - Another view of overgrown channel alignment.

Plate 14: Channelisation Option 2 - View of the moderately steep batter leading to Narellan Creek.

Plate 15: Channelisation Option 2 - Close up view of fine grained fluvial sediments at the toe of the creek's batter.

Plate 16: Channelisation Option 2 - View of the stormwater outlet to the north of the channel, at approximate Ch. 240m on the alignment.

FIGURES

Figure 1: Option 1 – Flood Levee - Locations and Direction of taken Photographs

Figure 2: Option 2 – Channelisation - Locations and Direction of taken Photographs

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