2. Available Data

2.1 List of Reference Data

The following data was used in the hydrologic and hydraulic model development:

- Powells Creek ILSAX hydrologic model from the *Powells Creek and Saleyards Creek Flood Study* (Webb McKeown & Associates, 1998), prepared for Strathfield Municipal Council.
- DRAINS hydrologic model for local catchments on the eastern side of Powells Creek, developed for the North Strathfield Rail Underpass (NSRU) flood impact assessment and drainage design (SKM/Jacobs, 2012).
- TUFLOW flood hydraulic model of Powells Creek and Saleyards Creek downstream of Parramatta Road, developed for the NSRU flood impact assessment and drainage design (developed by SKM/Jacobs and WMAwater, 2012).
- Spatial data (stormwater assets, overland flow paths, Council comments on drainage, cadastre).
- Various plans, studies, drainage and flooding reports and complaints and other documentation from the study area collected by Council.
- Various site photos from site inspection and previous studies.
- AUSIMAGE aerial imagery dated 2014.
- Supplementary LiDAR data collected for Sydney Olympic Park Authority (SOPA) and provided by Council.
- Survey of stormwater pits and pipes and selected open channels and hydraulic structures commissioned for this study.
- Concept design drawings and 3D CAD files for the Powells Creek channel naturalisation project, provided by Sydney Water.

Specific findings and issues relating to the above data are discussed in the sections below.

2.2 LiDAR Data

The existing TUFLOW model for the NSRU project was developed using LiDAR data captured by AAM Hatch in 2008 for the NSRU project. Comparison of the LiDAR ground spot levels to the aerial imagery around Homebush Bay indicated that the data was captured at or near high tide, with some features being covered by bay water levels and not accurately represented in the LiDAR data.

The SOPA LiDAR data set, obtained and provided by Council, was captured on 31 March 2012 approximately 2 hours after a neap low tide and therefore included survey of some intertidal features. This data was used to supplement the NSRU LiDAR data in the lower areas of Powells Creek and around Homebush Bay.

2.3 Drainage Network Details from Council Asset Database

Stormwater asset data (including pipe and pit network layouts) for City of Canada Bay Council area within and outside the study area were provided by Council. Review of this data indicated that the pit and pipe invert levels, where available, were unsuitable for use in the modelling, necessitating the collection of topographic survey for the stormwater system.

2.4 Ground Survey and Hydraulic Structures Survey

Survey was collected from August to October 2014 of all stormwater pits and pipes, culverts, bridges and selected topographic features in the study area. Surface and invert levels, dimensions of conduits and pit inlets and degrees of blockage were among the details collected in the survey.

The ground survey was also used to validate the accuracy of the LiDAR data used in the hydraulic modelling, refer to **Section 2.9**.

2.5 Council Reports and other Documentation

A number of reports were provided by Council, including:

- Canada Bay Primary School Flood Study Report (NSW Dept. of Education and Communities, 2012) and Flood Study Addendum (NSW Dept. of Education and Communities, 2013). Addresses a flood study undertaken for a proposed school (currently being constructed) located at 66 Victoria Avenue, Concord West. Includes proposed drainage upgrades in the road adjacent to the school.
- Various Council engineering and planning reports and other documents from residents relating to flooding, drainage and development in King Street, Concord West. The documentation confirms that a number of properties on King Street are at particular risk to flooding and drainage issues.
- Information from the Bureau of Meteorology for the 2 January 1996 historic storm event confirming the AEP of this storm event of between approximately 5% AEP (for 2 hour storm duration) and 1% AEP (for 30 minutes storm duration).
- Drainage plans for various developments and road drainage upgrades in the study area.
- Site contamination reports and statements for several properties on George Street, Concord Avenue and Rothwell Avenue, Concord West.

2.6 Historic Data for Model Calibration

A review of potentially suitable historic storm and flood events for model calibration was undertaken during the Powells Creek and Saleyards Creek Flood Study (Webb McKeown & Associates, 1998). The data reviewed included rainfall and stream gauging data and community questionnaire responses, which concluded that the period in February 1990 contained four separate flood peaks which could be used for hydrologic and hydraulic model calibration in that study. Other flood events occurring in the 1980's and 1990's were discounted for model calibration due to malfunction of rainfall or streamflow gauges, or absence of reported flood marks.

The data on the February 1990 flood events are summarised in **Table 2-1**. The rainfall and stream flow/stage data are both from the UNSW Elva Street, Strathfield gauging site, located on Powells Creek upstream of Parramatta Road. The site is the nearest-located pluviograph to the study area (approximately 1.8km). The pluviographs for each storm are shown in **Appendix A**.

Table 2-1 Details on February 1990 flood events

Storm Event	Daily Rainfall (mm)[1]	Max 2 Hour Rainfall Intensity (mm/hr)	Peak Flow (m^3/s)[2]	Peak Stage (m RL)[2]
3 Feb 1990	120	7	15.5	1.46
7 Feb 1990	103	22	15.6	1.47
10 Feb 1990	63	28	20.9	1.79
17 Feb 1990	31	11	11.8	1.20

1 Pluviograph total rainfall depth at UNSW Elva Street, Strathfield gauge, as reported in Webb McKeown & Associates, 1998.

2 Peak flow at UNSW Elva Street, Strathfield gauge, as reported in Webb McKeown & Associates, 1998.

Although the 10 February 1990 storm did not result in the greatest daily rainfall depth, the large majority of rain fell within a 2 hour interval from 2:30pm, resulting in the highest rainfall intensity over a 2 hour duration for each of the storm events. In contrast, most of the rain for the 3 February and 7 February storms fell over a 12 hour and 6 hour interval, respectively, resulting in lower 2 hour duration rainfall intensities than the 10 February storm. Hence, the higher rainfall intensity combined with the catchment pre-wetting from the 3 February and 7 February storms resulted in the higher peak flows and flood levels during the 10 February 1990 event.

The 10 February 1990 flood peak was used to calibrate the HEC-RAS hydraulic model in the 1998 flood study given that it produced a higher flood peak than the other events. The report states that it was assumed that the flood marks reported as being from "February 1990" were due to this event, instead of the other February 1990 events. The 10 February 1990 event was approximately a 20% AEP event (Webb McKeown & Associates, 1998).

2.7 Community Consultation

Questionnaires were distributed to property owners within the study area, with 15 responses received from 77 questionnaires mailed out. Seven responses included observations of flood behaviour and flood depths which were considered to be potentially useful in model validation.

2.8 Site Inspection

A site inspection was carried out on 1 August 2014 by Jacobs and Council staff. Locations inspected included areas within Sydney Olympic Park at the outlet of Powells Creek, Victoria Avenue, Concord Avenue, Station Avenue, King Street and Liberty Grove. Features which were inspected included hydraulic structures, proposed development sites, stormwater drainage network configurations in key locations and potential hydraulic controls.

2.9 Validation of LiDAR Data

Ground levels were sampled at thirteen locations in and around the study area for the LiDAR data validation, with the results displayed in **Figure 2-1**. Sample locations were selected where clear LiDAR readings were expected, such as open areas free of vegetation and roads.

The LiDAR data was generally within +/- 0.15m of the surveyed levels, which is the typical accuracy of LiDAR datasets. Three samples had level variances of +0.16m or -0.16m, which is close to the specified bounds of accuracy of the LiDAR data.

There is a tendency for the LiDAR levels to be higher than the surveyed levels, with eight samples recording a positive difference in level, compared to five with a negative difference in level. There is a relatively high frequency of samples in the 0.10 – 0.15m level difference bracket (five samples).

There appears to be a tendency for the positive differences in levels to occur in the southern half of the sample area (see **Figure 2-2**).

In summary, as the LiDAR data is typically within (or close to) the acceptable bounds of accuracy of +/- 0.15m and there appear to be no gross errors or variances from the surveyed ground levels (e.g. LiDAR datasets in other localities have been observed by Jacobs to have variances of +/- 0.5m from survey), then there is no significant justification for modification of the LiDAR dataset. It is expected that estimated flood levels from the hydraulic modelling will be slightly higher than the flood levels from the equivalent storm event in the field. However, the relative depths of flooding are expected to be consistent between the model and the field.

Figure 2-1 LiDAR data validation

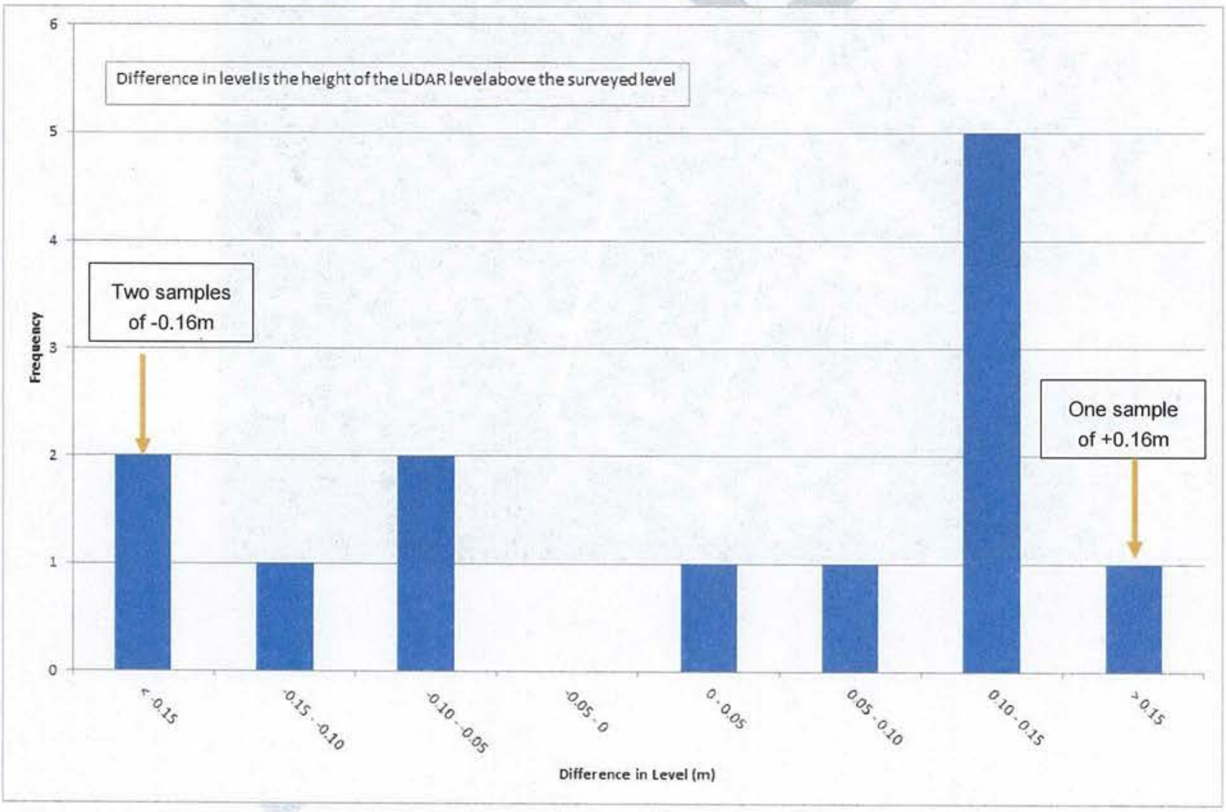


Figure 2-2 Spatial distribution of LiDAR data validation samples

3. Hydrologic Model Development

3.1 Overview

Hydrologic analysis undertaken for this study includes:

- DRAINS hydrologic modelling for local sub-catchments draining the area to the east of Powells Creek. This modelling was developed for the NSRU project previously involving Jacobs, and was updated to suit the objectives of this current flood study. The flows from the DRAINS model were used to estimate overland flooding conditions in and around the study area.
- ILSAX hydrologic modelling for the *Powells Creek and Saleyards Creek Flood Study* (Webb, McKeown and Associates, 1998, now WMAwater). The WMAwater hydrologic model was calibrated against five observed storm events which occurred on 3, 7, 10 and 17 February 1990 and 18 March 1990 and the model was used to simulate rainfall runoff within the catchment for a range of storm events up to and including the Probable Maximum Flood (PMF). The largest calibration storm event was similar to a 20% Annual Exceedance Probability (AEP) event. The flows from the ILSAX model were used to determine tailwater conditions in Powells Creek.

Details on the DRAINS model development are discussed in this section. Information on the ILSAX model setup is not discussed in the WMA (1998) flood study report, and is therefore not detailed in this current report. The ILSAX catchments are shown in **Figure 3-1**. The model sub-catchments are a sub-set of each catchment.

3.2 DRAINS Local Sub-Catchment Model

3.2.1 Sub-Catchment Data

The local sub-catchments in and around the study area were delineated based on the LiDAR ground levels and to fit the stormwater drainage network and patterns. The DRAINS sub-catchments are shown in **Figure 3-2**.

Sub-catchment imperviousness was estimated based on the assumed land use impervious fractions presented in **Table 3.1**.

Table 3-1 Adopted Impervious Fractions for Different Land Use

Land Use	Impervious Fraction
Road	0.7
Low-Medium Density Residential	0.5
High Density residential, Commercial, Industrial	0.9
Open Space	0.1
Vegetated	0
Mangroves and Dense Vegetation	0
Rail Corridor	0.7

Sub-catchment flow travel times were estimated based on runoff flow velocities during a storm event of 0.5m/s for grassed areas and 1m/s for paved areas.

The DRAINS model was developed for the purpose of deriving local catchment runoff hydrographs for input into the flood hydraulic model. Pits and pipes were therefore not represented in the DRAINS model.

Legend

ILSAX Catchments

Study Area

JACOBS

A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

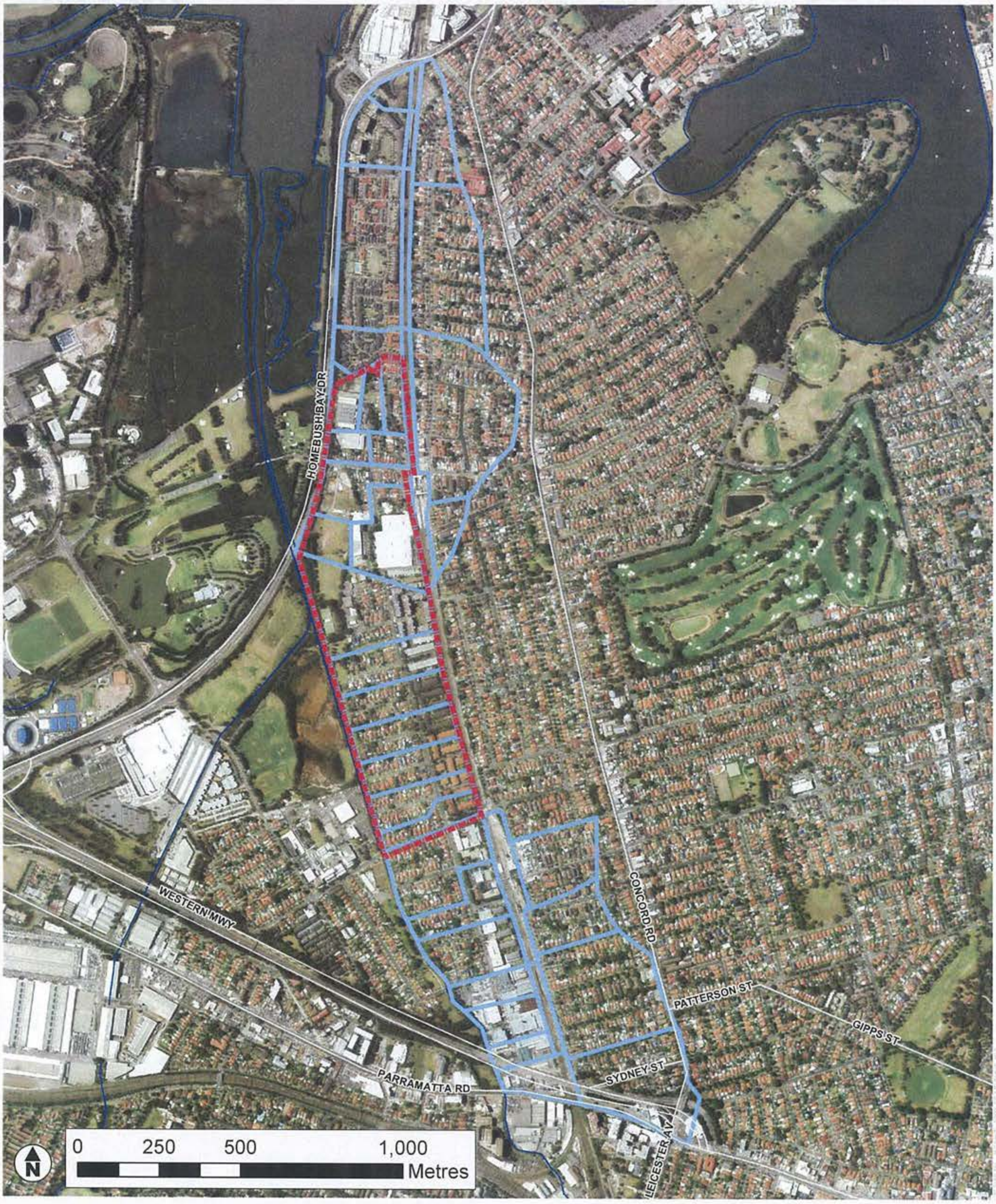
TITLE ILSAX Catchments

PROJECT Concord West Precinct Masterplan Flood Study

CLIENT City of Canda Bay

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA046900	FIGURE 3-1	1	1

CHECK	DATE
LC	16/12/2014



Legend

DRAINS Sub-Catchment

Study Area

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SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE DRAINS Sub-Catchments

PROJECT Concord West Precinct Masterplan Flood Study

CLIENT City of Canda Bay

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA046600	FIGURE 3-2	1	1

CHECK	DATE
LC	9/12/2014

3.2.2 Hydrologic Parameters

The following parameter values were adopted in the DRAINS modelling for the calibration and design storms:

- Depression storage: Paved areas – 1mm; Grassed areas – 5mm.
- Soil type: Type 3, which represents a not-particularly well drained soil landscape.
- Antecedent Moisture Condition: This represents the degree of soil wetness at the onset of a storm, which affects its infiltration capacity. A value of 4 was adopted for storms from the 50% AEP event up to the PMP event. A value of 4 represents "completely saturated" soil conditions due to total rainfall exceeding 25mm in the preceding 5 days prior to the modelled storm event (DRAINS User Manual, Watercom, 2012). This is consistent with the antecedent conditions adopted in the ILSAX model.

4. Hydraulic Modelling

4.1 Background

A TUFLOW flood hydrodynamic model was developed for the NSRU project at concept and detailed design stage to assist with drainage design and flood impact and mitigation assessments, covering the mainstream and overland floodplain downstream of Parramatta Road, including the current Concord West study area. The TUFLOW modelling package is a DOS-based program with a GIS based interface and is ideal for simulating depth-averaged 2D (Dimensional) and 1D free surface flows. TUFLOW has capability of dynamically linking 1D networks with 2D model domains and has the ability to model 1D culvert and bridge structures as well as stormwater pit and pipe networks within the 1D and 2D domains.

The model was set up as a 1D stream network nested in a 2D domain to accurately represent the in-channel hydraulics and two-dimensional flow patterns on the floodplain and in the local overland flow catchments, such as flows around structures and obstructions. The model was set up and run using TUFLOW version 2013-12-AA-w64.

A number of updates to the Powells Creek TUFLOW model have been made to suit the current study objectives. The general model setup in addition to the updates is discussed in this section. The model configuration is shown in **Figure 4-1**.

4.2 1D Domain Setup

The stream reaches were digitised based on the Digital Elevation Model (DEM) using the LiDAR and aerial photography. The stream reaches include open channel (natural profiles and concrete-lined), hydraulic structures (culverts, bridges etc), associated overflows when the structures are overtopped (modelled as weirs), Council and railway stormwater networks and other conveyance structures in the floodplain such as pedestrian underpasses.

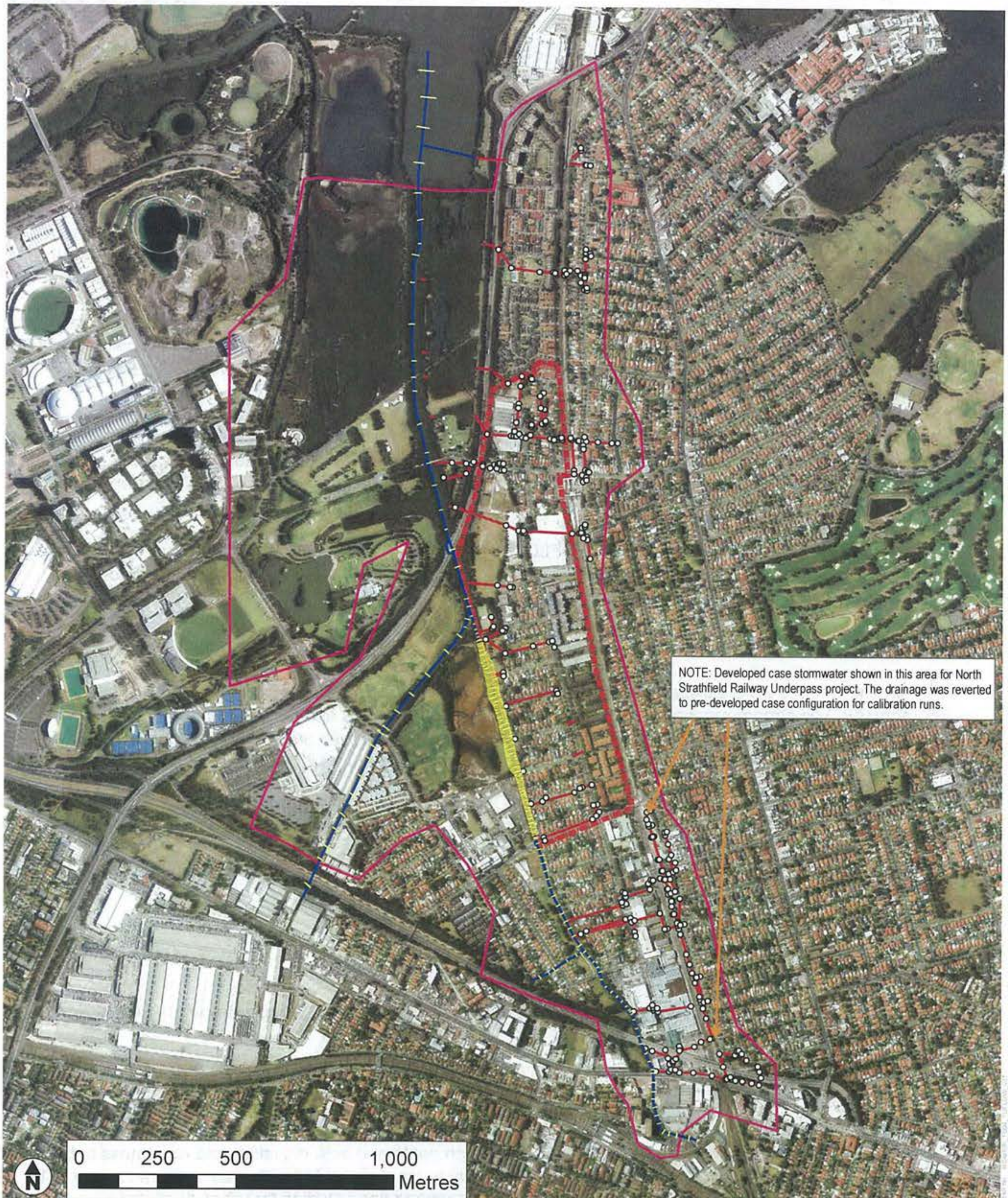
Channels represented in the model include:

- Powells Creek upstream of Parramatta Road to Homebush Bay;
- The portion of Homebush Bay itself within the model;
- Saleyards Creek from M4 Motorway to Powells Creek; and
- Strathfield Creek from 100m upstream of Ismay Avenue to Powells Creek.

The in-channel geometry was defined using cross sections presented in the Sydney Water (1997) Powells Creek capacity report.

4.3 2D Domain Setup

The 2D domain was set up to represent flow patterns and flood storage in the floodplain. The 2D domain consisted of a grid of cells with two (2) metre spacing, which contained both elevation and roughness data. The grid size was selected to allow the features of the floodplain to be represented with reasonable accuracy. The grid size is consistent with the size commonly adopted in overland flood studies for urban floodplains.



Legend

	1D Channel		Model Domain
	1D Cross Section		Study Area
o	1D Stormwater Pit		
	1D Stormwater Pipe		

A3

SHEET 1 of 1

GDA 1994 MGA Zone 56

TITLE TUFLOW Model Configuration

PROJECT Concord West Precinct Masterplan Flood Study

CLIENT City of Canda Bay

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA048600	FIGURE 4-1	1	1

CHECK	DATE
LC	16/12/2014

Ground surface elevations in the 2D domain were defined based on the following data sets:

- LiDAR data for the broader floodplain;
- Ground survey of the Rail Corridor, selected roads and areas which in the close proximity of the Rail Corridor collected for the NSRU project;
- Ground survey of selected topographic features collected for this current flood study; and
- Design surface levels for disturbed areas for the proposed case runs, including railway formations, access roads, catch drains, raised berms/ barriers and general earthworks. 3D breaklines were used to accurately define the elevations of catch drains and barriers in the 2D domain.

4.4 Hydraulic Roughness

The roughness of the 1D model reaches was estimated based on knowledge of the channel type and observations of in-channel condition. Typical values used are summarised in **Table 4-1**.

Table 4-1 Roughness for 1D Model Reaches

Channel	Manning's n	Description	Channel
Concrete-line open channel, concrete culverts	0.017	Concrete channels, pipes and culverts	Concrete-line open channel, concrete culverts
Natural open channel – sand or mud bed	0.025	Typically clear, straight reaches in lower reaches of Powells Creek	Natural open channel – sand or mud bed
Mangroves	0.1	Vegetated mangrove sections in lower reaches of Powells Creek	Mangroves

The 2D model cells were assigned roughness values, based on land use in the study area. A catchment materials plan was derived based on cadastral and LEP data in GIS, and aerial photography. The cell roughness was assigned in accordance with the land use/catchment materials defined in **Table 4-2** below.

Table 4-2 Catchment Materials and Roughness Values, 2D Domain

Channel	Manning's n
Road	0.02
Low-Medium Density Residential	0.15
High Density residential, Commercial, Industrial	0.03
Open Space	0.035
Vegetated	0.05
Swamp and Marshes	0.035
Open Water	0.03
Mangroves and Dense Vegetation	0.10
Rail Corridor	0.04

The Manning's n values were assigned at a block-scale, and were typically representative of the average roughness across each street block and accounted for on-lot obstructions to flow, such as fences and miscellaneous structures, which were not represented explicitly.

4.5 Bridges and Culverts

Data on the invert and obvert levels, pier widths, footpath levels and railing heights were input for the upstream and downstream ends of each structure.

Bridges and culverts were typically modelled as a 1D reach object with a parallel 1D weir object representing the overflow path over the bridge deck during high flows. The weir geometry was defined as a simple weir (weir level and length only).

Hand railings on the road and foot bridges were assumed to be fully blocked if the spacing between bars was less than 150mm. Other hand railings with greater than 150mm bar spacing were assumed unblocked.

4.6 Drainage Network

4.6.1 General

Stormwater asset data provided by Council was used to represent the existing stormwater drainage systems (pits and pipes) in the TUFLOW model. Survey, including surface and invert levels and dimensions of pit inlets was collected for the stormwater network in and around the study area.

For the model calibration runs, the pre-NSRU modelled stormwater network was represented in the vicinity of the NSRU project site. Significant drainage modifications have been carried out for the NSRU project, which have an impact on Powells Creek flood levels of 0.1 – 0.2m without mitigation measures in place, and hence would affect the quality of the model calibration.

Design details of the developed NSRU drainage system were input into the model for the design event runs. The existing drainage network was modified to reflect the proposed drainage arrangements, including new pipes, abandoning selected existing pipes crossing the rail corridor (to accommodate the rail underpass dives and tunnel) and connections between existing pipes and new pipes.

4.6.2 Stormwater Pits

The stormwater pits provide a dynamic linkage between the underground drainage network and the 2D TUFLOW model domain, representing the floodplain. Water is able to flow between the drainage network and floodplain, depending on the hydraulic conditions.

The location of the stormwater pits and associated attributes were exported directly from the DRAINS model to GIS format. Pit inflow relationships were defined in terms of flow depths versus pit inflow. The pit types and inflow relationships adopted in the DRAINS model were also used in the TUFLOW model.

TUFLOW automatically calculates hydraulic energy losses in the pits based on the alignment of pipes connected to each pit and the flows in each pipe. The calculations are based on the Engelhund manhole loss approach (*TUFLOW User Manual*, BMT WBM, 2010).

4.7 Modelling of Flow Obstructions in the Floodplain

4.7.1 Fences

Fence lines have typically not been explicitly represented in the model and floodwaters are allowed to flow across them freely. Although fences may obstruct overland flood flows in some parts of the catchment, experience indicates that representing fences in the hydraulic model requires making unvalidated assumptions about depths at which fences overflow or fail.

Hence, the potential obstruction to flow caused by fences was represented in the model by increasing the cell roughness (Manning's n values) for certain land uses, as described in **Section 4.4.** This approach is consistent with the current practice for 2D flood modelling.

4.7.2 Buildings

Buildings were explicitly represented in the model as solid obstructions. This means that buildings form impermeable boundaries within the model, and while water can flow around buildings, it cannot flow across their footprint.

The building footprints in the TUFLOW model were digitised based on 2014 aerial imagery. The building polygons were superimposed on the model grid to make model computational cells under the footprints inactive.

The exception to the typical approach for representing buildings was the existing building at 7 Concord Avenue (Site 1 on the Master Plan). Advice from Council was that this building would experience internal flooding during a flood event as flood waters fill the low-lying site. This location in the study area is a significant flood storage area and the existing building does not pose a major flow obstruction. The building footprint was therefore omitted from the TUFLOW model.

4.7.3 Railway Formation

Although the railway ballast formations are porous, their capacity to transmit flood flows through the formation is considered low and hence may be considered obstructions to overland floodwaters flowing from east of the rail corridor to the west, towards Powells Creek. The ballast formations were therefore represented as solid features in the terrain.

4.8 Boundary Conditions

4.8.1 Tailwater Conditions

The downstream boundary of the model was defined approximately 1500m downstream of Homebush Bay Drive to Homebush Bay where a fixed tailwater level at 1m AHD was defined in the model, which approximately translates to a neap high tide in Homebush Bay.

4.8.2 Model Inflows

Inflow locations into the model were determined based on the sub-catchment delineation used in the ILSAX and DRAINS models. The ILSAX model inflows were input as mainstream flows in Powells Creek and Saleyards Creek.

The DRAINS model inflows were input as inflow hydrographs at the surface of stormwater pit inlets located within each sub-catchment. The hydrograph is distributed equally among the pits within each sub-catchment. Sealed pits are not assigned a flow. The amount of surface flow entering the pit is dictated by the pit inflow relationship. Flows in excess of the pit inlet capacity remain in the 2D model domain as point inflows, subsequently forming overland flow.

Pit surcharge flows are caused when flows in the drainage network exceed network capacity and spill out of the pits and into the 2D domain. Pit surcharges would similarly form overland flow in the model. Depending on the hydraulic conditions in the pipe system, overland flows can re-enter the pipe system via the stormwater pits.

5. Model Calibration and Verification

5.1 Hydrologic Modelling

The ILSAX hydrologic model of Powells Creek was previously calibrated against the automatic stream height gauge in Powells Creek at Elva Street, Strathfield (approximately 1.6km upstream of the current study area) to the 10 February 1990 flood event. The Antecedent Moisture Condition (AMC) in the ILSAX model was set at a value of 4, corresponding to saturated catchment conditions with high runoff potential, for the model calibration.

The study indicates that there was a good match between recorded and modelled peak flows, although the model produced a slight overestimate of total flood volume. No modifications to the ILSAX model and its hydrograph outputs were made as a part of this study.

As there are no flow gauges which measure overland flows in the study area (nor typically in other overland flow areas) it is not possible to calibrate the DRAINS model to a measured flow rate. The DRAINS model results were therefore validated against independent runoff calculations based on the rational method (reference: Volume 1 Book 8, *Australian Rainfall and Runoff*, Institute of Engineers Australia, 2001). Comparison of peak modelled sub-catchment flows in the 1% AEP 25 minute storm event (the critical duration for the majority of the sub-catchments) to the flows calculated by the rational method indicated that the DRAINS model estimated peak flows to be typically 20 - 25% higher than the rational method estimate, which is considered to be a satisfactory result. Refer to **Appendix B**.

The AMC in the DRAINS model for the model calibration was also set to a value of 4, consistent with the adopted value in the ILSAX model for the February1990 event.

5.2 Hydraulic Modelling

5.2.1 Mainstream Flooding Calibration

Calibration of the TUFLOW hydraulic model involved adjustment of model parameters such as friction losses and energy losses at hydraulic structures until a reasonable match was achieved between modelled and observed flood behaviour. The mainstream flooding aspect of the model was calibrated to the 10 February 1990 event.

Only one of the recorded flood levels from the February 1990 flood (at the rear of 34 Ismay Avenue, Homebush) lies within the modelled reach of Powells Creek. The flood mark is plotted on the flood profile for the calibration event in **Figure 5-1**, which indicates a difference between the recorded and modelled flood levels of 0.08m. This is within the normally accepted bounds of +/- 0.1m adopted for hydraulic model calibration, and is therefore considered a satisfactory calibration.

5.2.2 Overland Flooding Verification

Rigorous model calibration of overland flood models cannot generally be carried out because direct measurements of overland flows and accurate measurements of flood levels are usually not available. Hence, overland flood models are often verified using observations of flood depths and flood behaviour as a way of "sanity-checking" the modelling and confirming its reliability.

This study has relied mainly on observed depths of flooding during past flood events given by local residents. This anecdotal information is considered indicative as only the general location of the observation is usually given, with the observer unlikely to have measured actual depths and may have estimated the depth of flow in the watercourse from a distance, and the depths are often rounded up to the nearest 0.1m. However, the reported flood depths are still useful information for validating the general behaviour of flooding predicted by the flood models.

The 10 February 1990 flood event was assessed in the TUFLOW model for the calibration and verification stage, while residents reported in the questionnaire responses flooding depths from a range of storm events including 1985, 1986, 1988, 1990, 2011, 2012 and 2013 events. These were all relatively significant storm events with daily rainfall depths of greater than approximately 70mm recorded at the nearby Bureau of Meteorology station at Concord Golf Club (Station 66013). The reported depths were compared to the modelled flood depths as a broad check of the degree of flooding likely to be experienced at each location, and were generally found to be similar in depth (Refer to **Table 5-1**). Locations of the questionnaire responses and flood observations are shown on **Figure 5-2**.

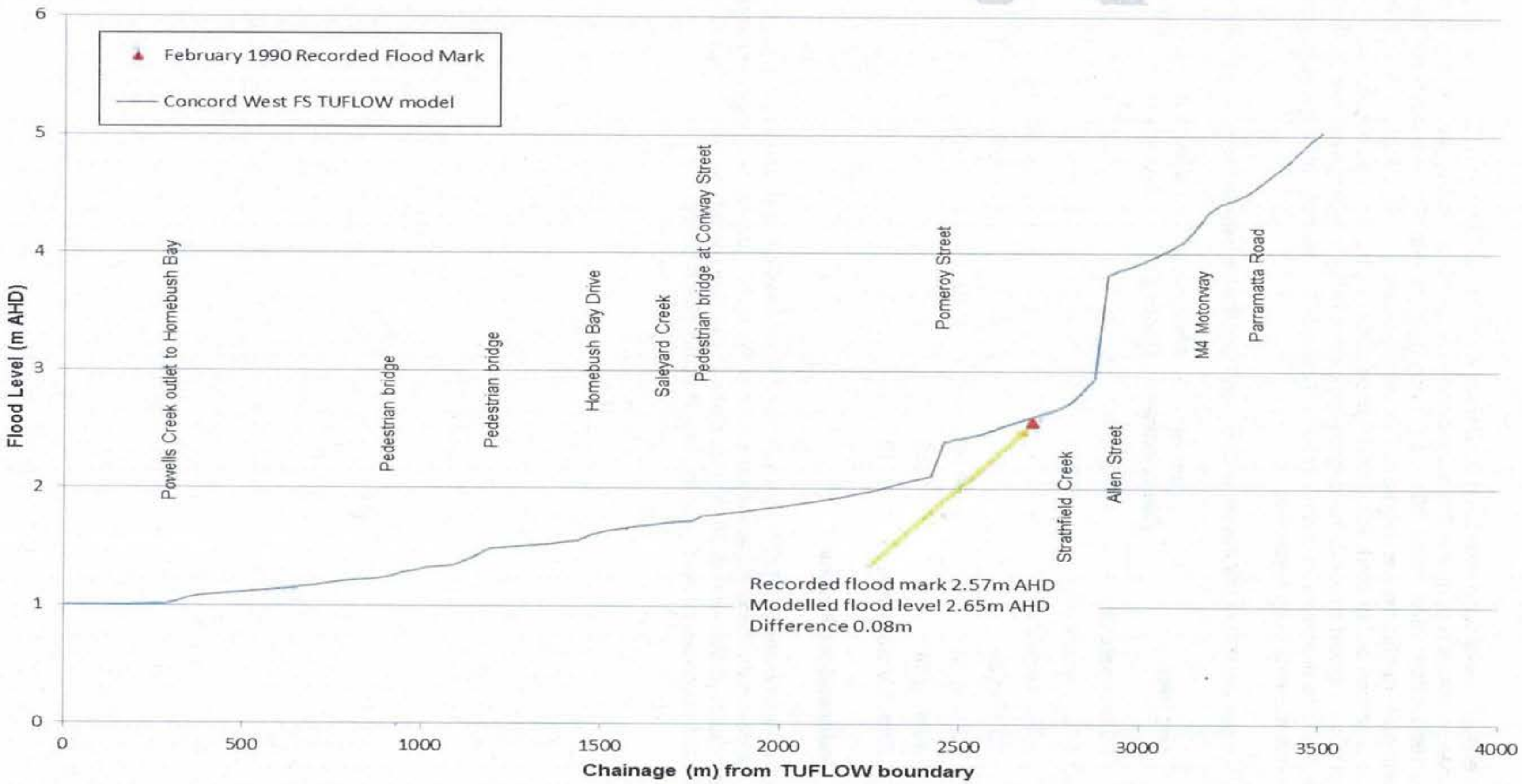
Table 5-1 Comparison of TUFLOW Results to Observed Flood Depths (refer to Figure 5-2 for locations)

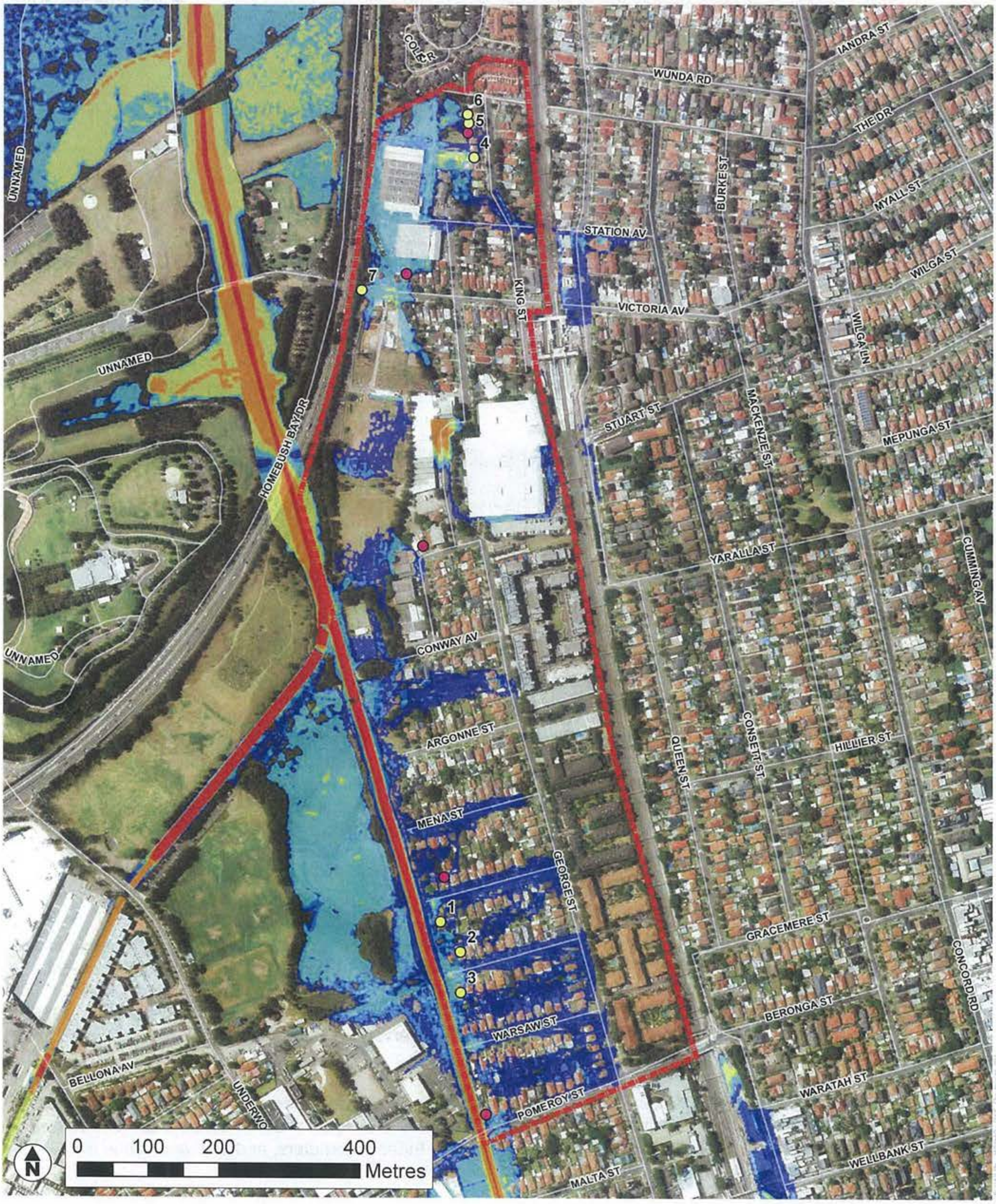
ID	Location	Year of Observation	Observed Depth (m)	Modelled Depth (m)	Difference (m)
1	20 Brussels St	1990	0.5	0.6	0.1
2	17 Lorraine Ave	2012	0.3	0.18	-0.12
3	20 Lorraine Ave	2011	0.3	0.34	0.04
4	30 King St	1985	0.75	0.84	0.09
5	38 King St	1986?	0.75	0.66	-0.09
6	40 King St	1988	0.75	0.49	-0.26
7	End of Victoria Ave	2013	0.3	0.31	0.01

5.2.3 Independent Review

An earlier version of the TUFLOW hydraulic model of Powells Creek and surrounds, which was developed and used by Jacobs in the flood impact assessment of the NSRU project, was independently reviewed and verified for robustness by WMAwater in 2013. This earlier TUFLOW model has been adopted as a base model and refined for the purposes of the Concord West Precinct Flood Study.

Figure 5-1 Powells Creek mainstream flood profile, 10 February 1990 calibration event





Legend

- Response with observed depth
- Other mapped response
- Study Area

10 February 1990 Flood Depth (m)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

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SHEET 1 of 1 GDA 1994 MGA Zone 56

TITLE Questionnaire Response Flood Marks

PROJECT Concord West Precinct Masterplan Flood Study

CLIENT City of Canda Bay

DRAWN	PROJECT #	MAP #	REV	VER
LC	IA046600	FIGURE 5-2	1	1

CHECK LC DATE 17/12/2014

5.3 Sensitivity Analysis

Sensitivity of the model to variation in model parameter values was assessed for the 10 February 1990 calibration event. The parameters adjusted were:

- Hydraulic roughness: Increase and decrease in Manning's n values of 20% for channels and floodplain.
- Rainfall losses: Increase and decrease in rainfall losses as summarised in **Table 5-2**. Note that an AMC of 4 represents a saturated catchment condition with minimised rainfall losses. Lower values of AMC represent drier catchment conditions with higher infiltration rates and continuing rainfall losses.

Table 5-2 Adopted rainfall losses for sensitivity analysis

Parameter	Calibration	Sensitivity – Increased Rainfall Loss	Sensitivity – Decreased Rainfall Loss
Paved Depression Storage (mm)	1	2	0
Grassed Depression Storage (mm)	5	10	0
Antecedent Moisture Condition	4	3	4*

* Max AMC value is 4, corresponding to saturated catchment conditions. The value cannot be raised to further decrease the rainfall losses.

The sensitivity analysis outcomes in the vicinity of the study area are summarised in **Table 5-3**. The modelling indicates that peak flood levels are not overly sensitive to the varied rainfall loss and hydraulic roughness scenarios tested, with changes in Powells Creek 1% AEP flood levels of less than 0.10m in the study area. Areas affected by overland flooding are less sensitive, particularly to the adopted changes in rainfall losses, of -70mm to +30mm in areas where overland flows pond. The sensitivity tests indicate that variance in these parameters is not likely to markedly affect the model calibration.

5.4 Conclusions

Hydrologic and hydraulic models have been developed to represent Powells Creek and overland flooding in and around the Concord West precinct. The models were calibrated to the 10 February 1990 historic flood event, which is approximately a 20% AEP event. Modelled overland flood depths for the calibration event were compared to those reported by local residents for a range of significant storm events including the 1985, 1986, 1988, 1990, 2011, 2012 and 2013 events. The historic flood observations were consistent with the overland flow patterns indicated by the hydraulic model.

Sensitivity analyses were undertaken to determine the variance in peak flood levels due to changes in rainfall losses and hydraulic roughness of the channels and floodplain. The sensitivity tests indicate that the modelled flood levels are not overly sensitive to the adopted variance in these parameters, and that variation in the parameters is not likely to markedly affect the model calibration.

Table 5-3 Summary of sensitivity analysis outcomes

<table>
<tr><th>Scenario</th><th>Flood Level Changes</th></tr>
<tr><td>Hydraulic roughness - increase</td><td>In Powells Creek:
Typically 0.02m – 0.04m increase in flood levels.
Up to 0.09m increase in the section of creek downstream of Pomeroy Street.
The mainstream flood level increases affect the area up to 40m from the creek bank (including private properties) for the reach between Pomeroy Street and Conway Avenue. Increases are contained within the creek downstream of Conway Avenue.
Overland flooding:
No impact to flood levels.</td></tr>
<tr><td>Hydraulic roughness - decrease</td><td>In Powells Creek:
Reduction in flood levels of 0.03m – 0.10m.
The mainstream flood level decreases affect the area up to 30m from the creek bank (including private properties) for the reach between Pomeroy Street and Brussels Street.
Overland flooding:
No impact to flood levels.</td></tr>
<tr><td>Rainfall losses – increase</td><td>In Powells Creek:
Reduction in flood levels of 0.04m – 0.07m.
The mainstream flood level decreases affect the area up to 30m from the creek bank (including private properties) for the reach between Pomeroy Street and Argonne Street.
Overland flooding:
Reduction in flood levels of 0.06m – 0.07m in areas of overland flow ponding, including George Street road sag, and immediately east of Homebush Bay Drive between Victoria Avenue and Concord Avenue.
Generally no change to overland flood levels elsewhere.</td></tr>
<tr><td>Rainfall losses - decrease</td><td>In Powells Creek:
Increase in flood levels of 0.01m – 0.02m.
Typically less than 0.01m increase on properties adjacent to the creek.
Overland flooding:
Increase in flood levels of 0.01m – 0.03m in areas of overland flow ponding, including George Street road sag, and immediately east of Homebush Bay Drive between Victoria Avenue and Concord Avenue.
Generally no change to overland flood levels elsewhere.</td></tr>
</table>

6. Flood Assessment for Baseline Condition

6.1 Background

The calibrated TUFLOW model was run to establish baseline conditions, which included current catchment development conditions in addition to a number of developments which are currently being constructed or are approved for construction, including:

- The NSRU project;
- The new Canada Bay Primary School, including adjacent Victoria Avenue road and drainage upgrades; and
- The upgraded playing fields to the south of the new school.

The baseline conditions were agreed with Council during the course of the study.

6.2 Estimation of Design Inflows

The ILSAX and DRAINS models were run for a range of storm events to derive the sub-catchment inflow hydrographs for input into the TUFLOW model. An antecedent moisture condition of 4 (completely saturated) was adopted for all design storms, which is consistent with the antecedent conditions adopted in the ILSAX model of Powells Creek.

6.2.1 Design Event Rainfall Parameters

ARR 1987 design rainfalls were adopted for the storm events up to the 1% AEP both in the ILSAX model and the DRAINS model. Details on the design rainfall adopted in the ILSAX model are provided in Webb McKeown & Associates (1998) and the IFD parameters used in the DRAINS model are summarised in **Table 6-1**.

Table 6-1 Design IFD rainfall parameters (ARR 1987) used in the DRAINS model

Parameter	2 year ARI	50 year ARI
1 hr Event Intensity (mm/h)	35.61	68.8
12 hr Event Intensity (mm/h)	7.41	15.62
72 hr Event Intensity (mm/h)	2.42	5.01
Frequency Factor	4.29	15.84
Skewness	0	

* IFD parameters obtained from BOM for 33.850°S 151.075°E.

6.2.2 Probable Maximum Precipitation

Design rainfall time series were derived for the Probable Maximum Precipitation (PMP) events, based on the Generalised Short Duration Method (GSDM) in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (BOM, 2003). The PMP depths were estimated with a moisture adjustment factor of 0.71, an elevation adjustment factor of 1 and 100% of the catchment defined as "rough".

The 2 hour duration PMP event was found to be critical for Powells Creek in Webb McKeown & Associates (1998). This event was also run for the local overland flow catchments in the DRAINS model. A PMP depth of 620mm was applied using the GSDM temporal pattern.

6.3 Flood Events Assessed

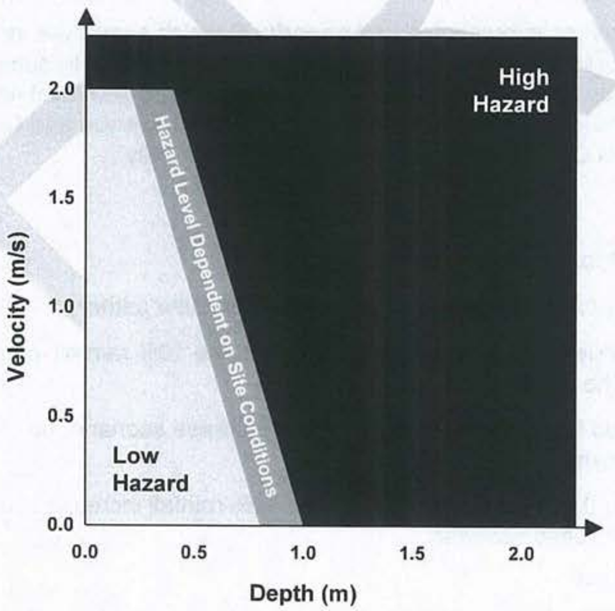
A range of flood events were assessed for baseline conditions, including the 50%, 20% 10%, 5%, 2% and 1% AEP and Probable Maximum Flood (PMF) events. The 25 minute and 2 hour duration storm events were assessed, covering the critical event durations for the overland flow and mainstream flood areas of the study area.

6.4 Flood Mapping

A series of flood maps are presented in **Appendix C** for baseline conditions, including

- Flood level (**Map C-1 to Map C-8**)
- A provisional flood planning area map for the study area was prepared which involved filtering of areas subject to shallow overland flooding up to a depth of 0.15m and adoption of different freeboards to the 1% AEP flood levels due to overland flooding and flooding from Powells Creek. A 0.5m freeboard was adopted for areas which are impacted by flooding in Powells Creek and a 0.3m freeboard was adopted for areas which are impacted by overland flooding. The flood planning area map with the adopted freeboards are shown in **Map C-9**.
- Peak flood depth (**Map C-10 to Map C-17**)
- Peak flow velocity (**Map C-18 to Map C-25**)
- Flood hazard (refer to **Map C-26 to Map C-28**), depicting low and high hazard areas as shown in **Figure 6-1** for 5% AEP, 1% AEP and PMF events. High flood hazard is defined as being areas where floodwaters present a danger to personal safety, could cause structural damage to buildings and where the resultant social disruption and financial losses could be high (*Floodplain Development Manual*, NSW Government, 2005). Hazard categories delineated in this study are based on depths and velocities of floodwaters and do not consider evacuation, isolation, flood damages and social impacts of flooding, hence, these categories are considered provisional.

Figure 6-1 : Hydraulic Hazard Category Diagram (reproduced from Figure L2 in *NSW Floodplain Development Manual, 2005*)



The flood mapping confirms the following about flood behaviour in the study area:

- Mainstream flooding from Powells Creek affects those properties immediately adjacent to the creek corridor, given the relatively steep hillside on the eastern side of the creek.
- Parts of the study area at elevations higher than 2 – 3m AHD are affected by overland flows of typically shallow depths.
- The low-lying area to the north of, and including, the new Canada Bay Public School is situated in a trapped depression, caused mainly by the Homebush Bay Drive embankment and by slightly higher ground levels on Sydney Olympic Park land, between Victoria Avenue and Powells Creek. This depression fills with floodwater in events as frequent as the 50% AEP event to depths of up to 0.5m (typically 0.2m), and is drained over time by the existing, low capacity stormwater network. The area is generally low flood hazard up to the 1% AEP event, although there is a localised area of high hazard at the rear of several properties on King Street due to a localised low-point in the terrain.
- There is a trapped sag point on George Street to the north of the Rothwell Avenue junction, where an existing industrial building at 176 – 184 George Street (Site 5 in the Master Plan) prevents floodwaters from flowing overland towards Powells Creek. Flood depths are up to 1.5m deep in the 1% AEP event.

6.5 Impacts of Climate Change

6.5.1 Scenarios Considered

The impact of climate change on flooding behaviour in the study area was assessed for baseline conditions. The scenarios considered included:

- Sea level rise: Projected sea levels at the year 2050 (0.4m increase) and 2100 horizons (0.9m increase). The sea level increases were added on to the adopted tailwater level in Homebush Bay of 1m AHD. The 5% and 1% AEP and PMF events were assessed with no change in design rainfall intensity.
- Increased rainfall intensity: Three scenarios of a 10%, 20% and 30% increases in the 1% AEP storm rainfall intensity were assessed with no change in sea level.

6.5.2 Flood Impacts

Flood impact mapping for the climate change scenarios is presented in **Appendix C** which shows the increase in peak flood levels during the climate change scenario from baseline/existing climate conditions. In summary, a number of areas experience flood level increases due to both increased rainfall intensity and sea level rise, most notably low-lying and poorly drained areas including the area to the north of Victoria Avenue and George Street sag in addition to the area within the Powells Creek mainstream floodplain. Specifically:

- Increased rainfall intensity (refer to **Map C-29** to **Map C-34**)
  - Overland flow areas: typically less than 0.02m change, up to 0.05m in active flow paths.
  - Flood storage area north of Victoria Avenue: from 0.05m flood level rise in the 10% rainfall increase scenario, up to 0.18m flood level rise in the 30% increase scenario.
  - George Street sag point: from 0.16m flood level rise in the 10% rainfall increase scenario, up to 0.36m flood level rise in the 30% increase scenario.
  - Eastern overbank of Powells Creek: from 0.09m flood level rise in the 10% rainfall increase scenario, up to 0.27m flood level rise in the 30% increase scenario.
- Sea Level Rise (refer to **Map C-35** to **Map C-46**)
  - The impacts of sea level rise propagate some distance along Powells Creek upstream of the study area (the location where the impact is nil is outside the mapped area). Increases in flood levels are

greater and propagate further up the creek in the year 2100 scenario compared to the year 2050 scenario, as expected.

- Within the study area developed areas which are affected by sea level rise scenarios include the low-lying area to the north of Victoria Avenue, Canada Bay Public School, sag point on George Street and adjoining properties and the residential properties adjacent to Powells Creek, between Conway Avenue and Pomeroy Street. In the 5% and 1% AEP floods, areas located above approximately 3m AHD do not experience increased flood levels due to sea level rise. In the PMF, areas above approximately 4.5m AHD do not experience increased flood levels due to sea level rise.
- Flood levels within the study area for the modelled flood events are not impacted with the year 2050 scenario and the maximum increase in flood level within the study area is 0.2m event with the year 2100 scenario. However, the low lying areas within the precinct would be subject to tidal flooding with potential sea level rise. The 1% tide levels are estimated at 1.9 mAHD and 2.4mAHD with the year 2050 and 2100 sea level rise scenarios respectively.

6.6 Conclusions

The flooding assessment for baseline conditions confirms that some parts of the study area are significantly affected by flooding even during frequent storm events, most notably the trapped low-lying area located to the north of Victoria Avenue.

There is also a trapped sag point on George Street which becomes flooded to excessive depths. George Street is the only vehicular access route to properties to the north of Rothwell Avenue and inundation of this sag point means that vehicular access to these properties would be cut off during significant storm events.

A number of areas in the study area are sensitive to flood level increases resulting from sea level rise and increased rainfall intensity, most notably low-lying and poorly drained areas including the area to the north of Victoria Avenue and George Street sag in addition to the area within the Powells Creek mainstream floodplain.

7. Flood Assessment for Proposed Conditions

7.1 Background

A number of developments are proposed in the study area which are not included in the baseline conditions. These include:

- "Developed Condition": The Powells Creek Bank Renewal Project is being undertaken by Sydney Water, who is the asset owners of the Powells Creek trunk drainage line. Design Drawings for Sydney Water's Tender No. 0510023642 shows that the project involves renewal of banks for the section of Powells Creek between Pomeroy Street to downstream of the Saleyards Creek junction. The project includes relining of the existing concrete banks with sandstone block work and re-profiling and re-vegetation of the overbank corridor. The Bank Renewal Project would provide a net-increase in the waterway area in this section of Powells Creek.
- "Master Plan conditions": The Concord West Precinct Master Plan of 27 May 2014, developed by JBA & GTA Consultants in consultation with Council, involves rezoning of industrial sites identified in **Figure 7-1**. **Figure 7-1** shows the current zoning for the study area. Most of the sites are developed, but some are vacant or under utilised. Council is considering to rezone the sites from General Industrial (IN1) to Medium Density Residential (R3) with the exception of Site 4 (Westpac) to be rezoned to Business Park (B7) and Site 3 (5 King Street) to be rezoned from Low Density Residential (R2) to Medium Density Residential (R3). The proposed building footprints on each site were identified from the Master Plan and replaced the existing building footprints in the TUFLOW model as solid obstructions to flow. Given the absence of further design information it was assumed that the finished ground levels on the redeveloped sites would be the same as in the baseline case. The Master Plan conditions were imposed in addition to the developed condition.

7.2 Developed Condition

7.2.1 Flood Events Assessed

Flooding was assessed for the 5%, 1% AEP and PMF events for the developed conditions.

7.2.2 Flood Mapping

Flood mapping of the flood impacts and flood hazard in the developed case are presented in **Appendix D** (refer to **Map D-1** to **Map D-6**).

7.2.3 Flood Impacts

The developed condition flooding has been compared to the baseline case flooding. As expected, there are flood level reductions in the 5%, 1% AEP and PMF events in the vicinity of the Bank Renewal Project, with the largest reductions immediately downstream of Pomeroy Street (up to 0.07m in the 1% AEP). There is a small area denoted as newly flooded at the western end of Conway Street, which is associated with the removal of an earth mound for the bank renewal works. Note that this mound removal increases the flow capacity of the floodplain in particular during the PMF, which results in localised flood level increases of up to 0.1m downstream of the mound location.

There are minor increases in the high flood hazard area in the 5% and 1% AEP events within Powells Creek due to the enlarged channel width and slight increases in velocity. There are no marked changes in the flood hazard areas in other areas for 5%, 1% AEP and PMF events.

- **Figure 7-1** Subject Sites and Canada Bay LEP 2013 Zoning Map *(source: JBA & GTA 2014)*

7.2.4 Conclusions

There are some improvements in flood levels as a result of the Powells Creek naturalisation particularly on properties adjacent to the creek and immediately downstream of Pomeroy Street. There are some localised increases in flood levels in the PMF, but these are considered minor impacts in the context of the PMF.

7.3 Master Plan

7.3.1 Flood Events Assessed

Flooding was assessed for the 5%, 1% AEP and PMF events for the Master Plan conditions.

7.3.2 Flood Mapping

Flood mapping of the flood impacts and flood hazard in the developed case are presented in **Appendix E** (refer to **Map E-1** to **Map E-6**).

7.3.3 Flood Impacts

The Master Plan case flooding is compared to the developed case flooding to determine the incremental change in flood levels. There are increases in flood levels and changes in flooding extent resulting from implementation of the Master Plan in the 1% and 5% AEP flood events.

An increase of 0.05m (refer to **Map E-2**) in the 1% AEP flood level is experienced at the Victoria Avenue frontage of the Canada Bay Public School and the low-lying area to the north of Victoria Avenue as a result of the loss of floodplain storage from the increased total area of building footprints. At the rear (western and southern side) of the School and on the playing fields, flood levels in the 1% AEP event are increased by up to 0.07m as a result of the Site 5 redevelopment. The proposed Master Plan buildings at this location (Site 5) provide a gap between the buildings to allow conveyance of overland flows, thus releasing floodwaters from the sag point. A portion of these increased flows are conveyed to the low point at Victoria Avenue, however, they do not significantly contribute to the increased flood levels in this area.

The area of flood increases exceeding 0.06m and up to 0.09m in the 1% and 5% AEP events (area shaded red on **Map E-1** and **Map E-2**) at the rear of the residential properties on King Street adjoining Site 1 is due to the partial obstruction of an overland flow path by proposed buildings.

Reductions in the 1% AEP flood level of up to 0.5m are experienced at the George Street sag point as a result of the redevelopment of Site 5. Further reductions in flooding are prevented by existing ground levels to the west of the sag point being higher than the sag point surface levels. However, the George sag point is subject to high flood hazards in the 5% AEP event.

Flood levels at Canada Bay Public School and the low-lying area to the north of Victoria Avenue are reduced by 0.02 – 0.03m in the PMF event. This is attributed to the flows originating from the George Street sag point being allowed to flow through Site 5 and then southwards at the playing fields, rather than being directed northwards from the sag by the existing building 176 – 184 George Street. Inflows into the low-lying point north of Victoria Avenue are therefore reduced in the PMF as a result of the Master Plan. There are localised increases in the PMF levels on properties in Conway Street of up to 0.02m.

There are no changes in the extent of the high flood hazard area outside the building footprints as a result of the Master Plan.

7.3.4 Conclusions

The Master Plan results in the following flood impacts:

- increased flood levels up to 0.09m in the 5% and 1% AEP events on a number of existing residential properties on King Street which are already sensitive to existing flooding conditions;
- An increase in flood levels up to 0.05m in the 1% AEP flood level at the Victoria Avenue frontage of the Canada Bay Public School and the low-lying area to the north of Victoria Avenue; and
- Increased flood levels up to 0.07m in the 1% AEP flood levels at the rear (western and southern side) of the Canada Bay Public School and on the playing fields, flood levels in the 1% AEP event are increased by up to 0.07m as a result of the Site 5 redevelopment.

While there are significant reductions in flood depths in the George Street sag point as a result of the Master Plan, the George Street sag point is still subject to high flood hazard in the 5% AEP event. Hence further mitigation works are required to ensure the following:

- Flood free access to properties north of the George Street sag point, at least, in up to the 1% AEP event; and
- Flooding conditions on the existing properties are not exacerbated by the Master Plan, and should be improved where possible.

8. Concept Design of Flood Mitigation Options

8.1 Background

A flood mitigation strategy has been developed to mitigate the potential flood impacts of the Master Plan redevelopment in addition to existing flood problem areas where practical. A number of mitigation options have been considered in consultation with Council and tested in the TUFLOW model, including stormwater network upgrades, construction of floodways and land regrading. Analysis of the various options indicated that surface treatments (i.e. regrading and floodways for drainage) are more efficient options than pit and pipe upgrades given the site constraints of low site elevations, minimal grades and depths of cover. The selected mitigation options for further investigation are described in **Section 8.2**. Alternative options which were considered but not selected are described in **Section 8.4**.

8.2 Flood Mitigation Options Considered

Options for mitigating flood impacts in two key areas of the study area were focussed on namely Site 1 and Site 2 at the northern portion of the study area, and the trapped sag point in George Street to the north of Rothwell Avenue. These locations have been selected since:

- Their proposed development has the potential to result in impacts to flooding conditions on adjacent properties (Site 1/Site 2 and Site 5); or
- An existing flood problem exists at the location and could be improved as a part of the site is developed (Site 5).

Details on the selected mitigation options and limitations of the options and recommended further investigations are outlined in the following sections.

8.2.1 Site 1 and Site 2

Site 1 and Site 2 of the Master Plan are located on existing industrial properties with access from the western end of Station Avenue. The sites are located in a low-lying area which experiences ponding of floodwaters during storm events. Overland flows approach the sites from the east, with flows from the Station Avenue railway underpass discharging onto Station Street which then flows westward along the street and through residential properties on King Street and then onto the sites. In particular, there is an overland flow path located on 28A and 30 King Street which concentrates overland flows before discharging onto Site 1. Ponded water in this area drains out via an existing open drain to the west of the site along the Homebush Bay Drive embankment to a 2.1m x 0.9m box culvert under the embankment, which discharges into the mangroves to the west of Homebush Bay Drive.

Re-development of the sites would most likely entail filling of the sites to provide a flood-free pad for proposed buildings and internal roads. Filling has the potential to reduce flood storage in the area and result in peak flood level increases on neighbouring residential properties, which are already sensitive to baseline flood conditions. A regrading and filling strategy has therefore been developed to minimise flooding impacts, based on the following features:

- A 10m wide floodway channel from east to west through Site 1, conveying flows from the existing overland flow path on 28A and 30 King Street to the existing open drain. Culverts were not considered practical due to the flat grades and minimal available cover;
- The footprints of two buildings in the Master Plan need to be separated by several metres to accommodate the floodway;
- Regrade areas to lower finished levels on Sites 1 and 2, typically at the rear of the proposed buildings, to counter any loss in flood storage. Levels range from 1.5 – 1.7m AHD, a lowering in ground levels of

typically 0.3 – 0.5m. It is to be noted that an RL of 1.5 m AHD corresponds to 1% AEP high tide level at Ford Denison tide gauge (SKM 2005);

- Open channel catch drains along the eastern side of Site 1 to intercept dispersed overland flows off the King Street residential properties, discharging them into the proposed floodway;
- Internal roads and parking areas would be on fill with a finished surface level of minimum 2.1m AHD;
- A vehicular bridge over the floodway would be required;
- A cut-off drain may be required at the site entrance off Station Avenue to intercept any sheet overland flow in Station Street before it enters the site. It would discharge into the adjacent open channel catch drain. An easement is to be created along the cut-off drain to satisfy Council requirements for stormwater management (refer to Council's Specification for the Management of Stormwater Policy of 2009).

Refer to **Figure 8-1** for illustration of the flood mitigation strategy (further details are provided in **Map F-1** in **Appendix F**).

Construction of the Site 1 and Site 2 mitigation strategy may encounter acid sulphate soils, however, it is likely that other excavation works for building foundations and underground services etc. would also encounter acid sulphate soils on the site, and appropriate management plans will need to be considered.

8.2.2 George Street Sag Point

The existing building at 176 – 184 George Street, on the western side of the sag point, would be demolished as a part of the Master Plan. Two proposed buildings on the site (Site 5) would provide a corridor to allow for flows to exit the currently trapped sag point. However, existing ground levels to the west of the sag point, on Site 5 and the adjacent playing fields, are up to 2m higher than the sag level and hence regrading of the site combined with raising of the road at the sag is required to ensure that vehicular access on George Street is not cut off at the sag point. The following features of the mitigation strategy are proposed:

- Raising of the road sag point by 1m to a finished sag level of 3.4m AHD. This amount of filling is required to provide sufficient grade to drain surface flows in the sag point and provide cover for proposed culverts under the road (refer to description below);
- Regrading Site 5 to form a floodway to drain surface water from the sag point, and to remove any low points relative to the raised sag point;
- Construction of a floodway through the playing fields to drain flows to Powells Creek which involves relocating the existing amenities block and an irrigation tank;
- To limit ponding depths in George Street the road crown should be low profile with a 0.10m rise above the carriageway outer level. It is preferable not to construct the road at this tight curve in super-elevation as it would trap ponded water on the higher side of the road;
- A low profile kerb (approximately 0.05m high) is required on the lower side of the road sag to limit the depth of ponding in the road, and allow excess flows to be intercepted by the floodway.
- High capacity stormwater pit inlets, or alternatively 3x 4.2m lintel grated kerb inlet pit (GKIP) are proposed on each side of the road at the sag.

Refer to **Figure 8-2** for illustration of the flood mitigation strategy (further details are provided in **Map F-2** in **Appendix F**). It is to be noted that in order to comply with the requirements of Council's stormwater management policy, adequate easements are to be provided. Consultation with stakeholders (e.g. OEH, Sydney Water) may be required to obtain approval to construct and discharge the proposed floodway into Powells Creek.

Further, that approval will be required from the City of Canada Bay for the proposed floodway on public land to the west of site 5, and that consultation would also likely be required with the Department of Education and Communities in terms of the option for culverts under the school oval.

Figure 8-1 Site 1 and Site 2 Flood Mitigation Option

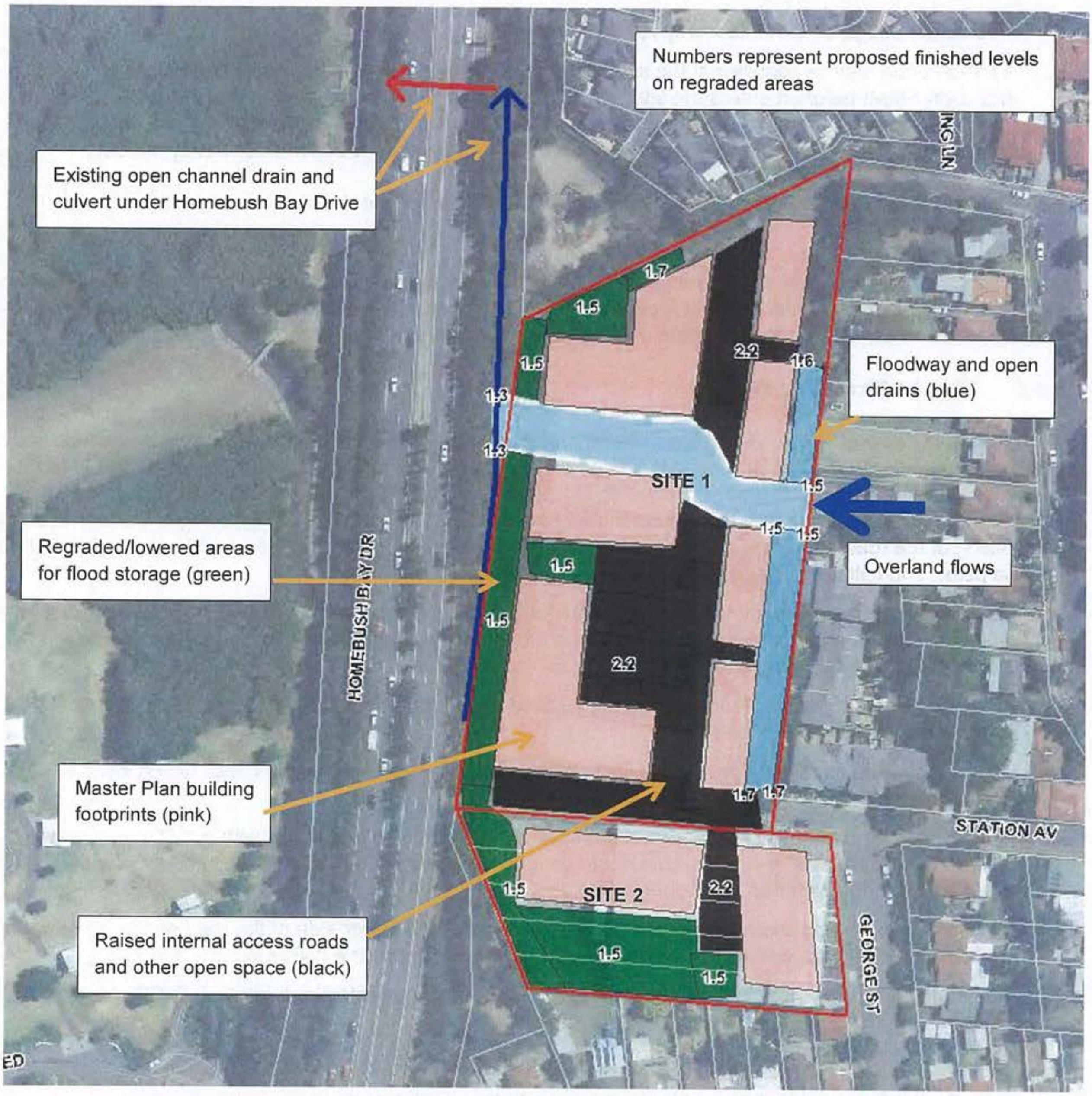
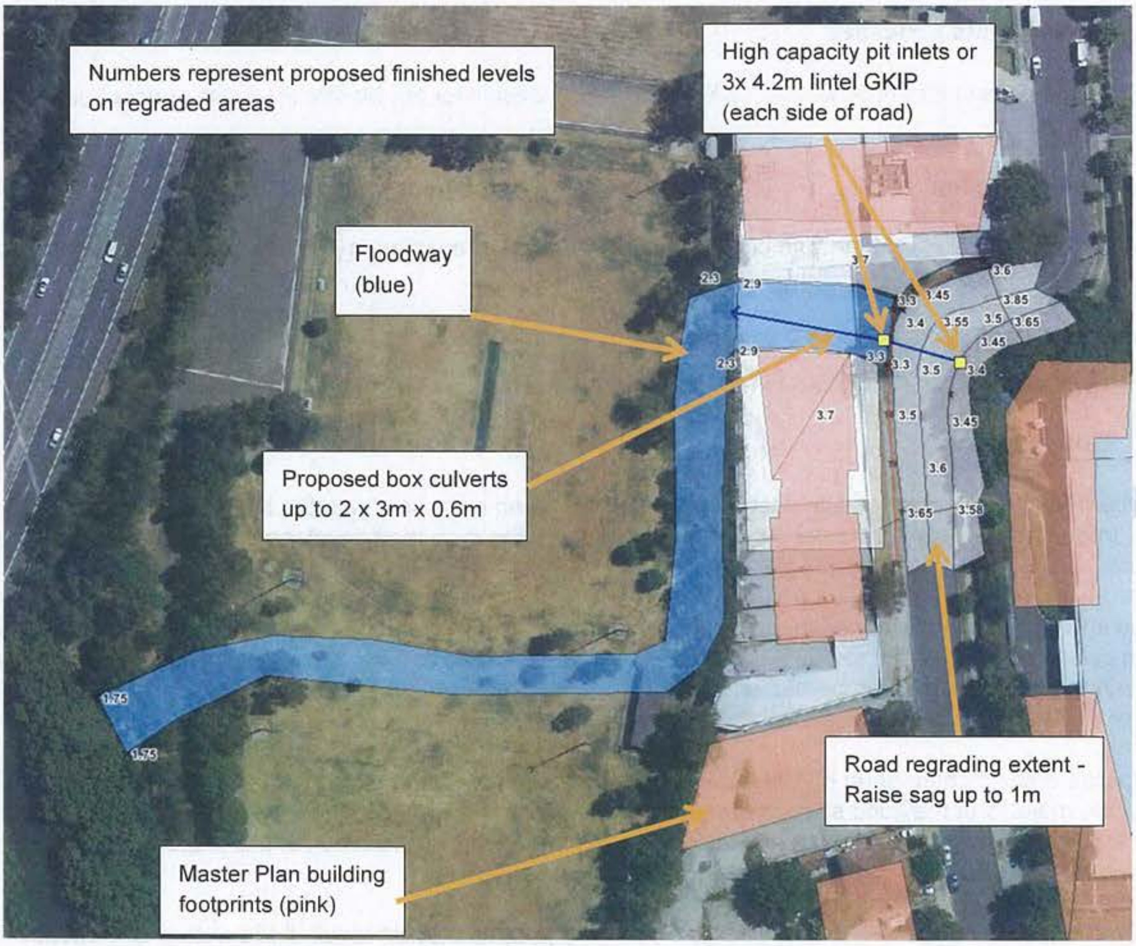


Figure 8-2 George Street Sag Point Flood Mitigation Option



8.3 Flood Assessment

8.3.1 Flood Events Assessed

Flooding was assessed for the 50%, 20%, 5% and 1% AEP events for the Master Plan with concept design scenario.

8.3.2 Flood Mapping

Flood mapping for the Master Plan with concept design case are presented in **Appendix F** as detailed below:

- Flood depth – **Map F-3** to **Map F-6**
- Changes in flood depth – **Map F-7** to **Map F-10**
- Flood hazard – **Map F-11** to **Map F-14**.

8.3.3 Flood Impacts

The Master Plan with concept design scenario flooding has been compared with the baseline conditions flooding, to determine the incremental change in flooding with the proposed development and mitigation measures.

The flood impact mapping indicates that with the proposed mitigation measures there are no increases in flood levels on existing properties for the 50%, 20%, 5% and 1% AEP flood events. Some reductions in flood levels are experienced at the rear of properties on King Street and Victoria Avenue in the 50% and 20% AEP floods as a result of the Site1 and Site 2 mitigation strategy.

Flood storage areas located north of Site 1 are subject to up to 0.5m depth of inundation in the 50% AEP. Although the majority of the flood storage areas along the western and the northern boundaries of Site 1 and Site 2 are subject to Low Hazard up to and including the 1% AEP event, a section of the proposed floodway at the western end is subject to High Hazard in the 1% AEP event.

There are changes in flood levels in the George Street sag point as a direct result of the raising of the road levels, however, the flood depths and flood hazard are reduced. Flood depths are approximately 0.15m in the 1% AEP flood which would permit vehicular access through the sag point.

8.3.4 Flows in Proposed Site 5 and George Street Sag Floodway

The proposed floodway draining the George Street sag point and located in the playing fields conveys the peak flows as summarised in **Table 8-1** in the design floods assessed. It is to be noted that a culvert solution, instead of a floodway, has not been considered as the concentrated flows and high discharge velocities are likely to increase risk of scour in Powells Creek, which is likely to be a concern for stakeholders. Additionally, culverts on very flat grades are likely to lead to silting and maintenance problems.

Table 8-1 George Street sag floodway peak flows

Flood Event AEP	Peak Flow (m^3/s)
50%	1.53
20%	2.25
5%	3.19
1%	3.94

8.4 Alternative Mitigation Options Considered

A number of alternative options were investigated to mitigate the impacts of the Master Plan and improve existing flooding conditions, but were not selected for detailed investigation due to the reasons outlined below:

- Upgrade or amplification of the existing pipe network upstream of Homebush Bay Drive was found to be ineffective at improving flooding conditions, with nil- or minor improvements (< 0.01m) to Master Plan case flood levels.
- Providing an overland flow path from Victoria Avenue sag point through Sydney Olympic Park land to Powells Creek provided small improvements (0.20m) in 1% AEP flood levels at Canada Bay Public School and in the low-lying area to the north of Victoria Avenue. This option could be utilised to provide further mitigation of existing and Master Plan scenario flooding. The option has not been selected as a preferred option at this stage as it requires approval from Sydney Olympic Park Authority.
- Amplification of the drainage culverts under Homebush Bay Drive were not considered in detail due to the presence of existing underground services and potential opposition from stakeholders (i.e. Roads and Maritime Services).

8.5 Contamination Issues

8.5.1 Background

The following reports on contamination were available to this study:

- Phase 1 & 2 Contamination Assessment, 7 Concord Avenue & 202-210 George Street Concord West, November 2007, prepared by Douglas Partners for Fred Hosking Pty Ltd; and
- Site Audit Statement No. FM39R for 176/184 George Street and 6 Rothwell Avenue, Concord West prepared by Environment Resource Management Australia Pty Ltd on 24 September 2002.

An overview on the contamination issues for the sites is provided in the following sections on the basis of the information presented in the above reports.

8.5.2 Site 1 (7 Concord Avenue) and Site 2 (202-210 George Street)

The following information is summarised from Douglas Partners (2007) report:

- Site History – Sites were undeveloped up until 1950 and construction activities commenced in Site 2 around 1951. Significant filling was undertaken to level the site prior to construction of each of the factory buildings. Site 2 was probably used for manufacturing and distribution of pool products from 1963 to 1987. From 1987 onwards, Site 2 was used as a printing facility. Site 1 was developed possibly after 1964 and the site has been used as a printing facility since 1964. Council records make reference to the storage of petrol in Site 1 in 1965. According to Council records, in 1986, the western boundary of the site was buried in "hundreds of tonnes of earths" from road works associated with Homebush Bay Drive. The site was possibly used as a "builder's yard" since 1966 and was filled without consent from Council.
- Potential Sources of Contamination – the use of fill to form/level the site; leaks from underground storage tanks and bowsers; spills from aboveground storage tanks; spills of chemicals; general littering and dumping; previous site uses (including chemical storage); and previous neighbouring land uses (including chemical storage).
- Filling – Filling was observed to be to depths of up to 2.6m below ground level.
- Groundwater – Free groundwater was observed during augering at numerous test bores and groundwater levels measured in the five piezometers were noted to be at depths ranging from approximately 0.75m to

2.5m below ground. The measured groundwater depths indicate that the direction of groundwater flow is potentially influenced by an old creek channel. Hardness results indicate that the majority of groundwater at the site is saline.

- Acid Sulphate Soils – Test results suggest that acid sulphate soils are prevalent across the site. Any excavation works at the site will need to consider the impacts on the disturbance of acid sulphate soils and an Acid Sulfate Soil Management Plan is required for site development.

8.5.3 Site 5 (176/184 George Street) and Site 6 (6 Rothwell Avenue)

The summary site audit report certifies that the sites are suitable for commercial/industrial use. It is anticipated that remediation works are to be undertaken for residential development within Site 5 & 6.

8.5.4 Implications for Flood Mitigation Options

The existing site contamination issues and presence of potential acid sulphate soils (PASS) have cost and construction implications for the proposed, and alternative, flood mitigation options. Broadly, excavation works to form floodways or trenches for the placement of culverts are likely to encounter either contaminated soils or PASS. The exact extent and magnitude of the contamination and PASS issues relating to the construction of the mitigation options cannot be quantified based on the available data, and further site-specific investigations are recommended as a part of the design development of the mitigation options.

8.6 Preliminary Cost Estimates

An options costing assessment was performed to determine the costs associated with the flood mitigation options.

8.6.1 Methodology

Two areas (Sites 1 & 2 and George Street sag point) are proposed for development and flood mitigation works. The works were disaggregated into individual elements so that costs for each element could be derived. To determine the costs of each element, the unit costs out of the Australia Construction Handbook (Rawlinsons, 2015) have been used. Each element location was noted with the costs associated with the works occurring on private and public land separated. All the excavated material produced on site was assumed to be contaminated due to prior land uses and/or acid sulfate soils. A low level of contamination has been assumed and potential EPA levees have not been included in the costing. Due to the high variability in the cost of fencing, costs of fencing drainage infrastructure for safety purposes were not estimated.

8.6.1.1 Sites 1 & 2

The works assumed for costing at Sites 1 & 2 include:

- The excavation of various channels and compensatory storage (volume ~ 1630m^3). The volume included an extra 0.5m of cut that would be backfilled. The cost includes the disposal of all the excavated material in a contaminated waste landfill site within 50km of the site. The price does not include the cost of dealing with any additional contamination issues on site or ongoing management.

- Fill required to raise buildings and proposed roads (volume ~ 1460m^3). The fill is assumed to be an imported sand fill which would be deposited, spread, levelled and compacted to 90%. This has been assumed to be carted from a distance not exceeding 10km.

- Road works to pave new roads on site (area ~ 4070m^2). This item includes a 200mm thick crushed blue metal basecourse with a two coat bitumen seal. The cost does not include any pedestrian paths or kerbing required.

- Bridge construction (span area ~ $300m^2$). This includes a two lane 11m wide reinforced concrete single span bridge over the proposed floodway including safety rails, balustrades but excluding approach works, abutments and piling.
- Landscaping (area ~ $1360m^2$). This includes the provision of top soil, loam and seeding in channel areas. In the other areas, top soil and shrub plantings (1 per square metre) were included in the costing.
- Removal of approximately 40 trees.

All works were assumed to occur on private land.

8.6.1.2 Re-grading of George Street

The works assumed for costing at George Street include the following:

- The excavation of various channels and compensatory storage (volume ~ $4160m^3$). The volume included an extra 0.5m of cut that would be backfilled. The cost includes the disposal of all the excavated material in a contaminated waste landfill site within 50km of the site. The price does not include the cost of dealing with any additional contamination issues on site or ongoing management.
- Fill required to raise buildings (volume ~ $900m^3$). The fill is assumed to be an imported sand fill which would be deposited, spread, levelled and compacted to 90%. This has been assumed to be carted from a distance not exceeding 10km.
- Road works to pave new roads on site (area ~ $1253m^2$). This item includes a 200mm thick crushed blue metal basecourse with a two coat bitumen seal for a length of 77m along George St. The cost also includes the kerbing and pedestrian paths on the side of George St.
- Culverts and pits to convey flow across buildings to proposed channel. The culverts proposed are 3 x 0.6m diameter pipes across George St before 6 x 0.6m diameter pipes to convey flow across the buildings. The total length of pipe estimated was 88m. The cost for 200m of trenching and nine pits was also included.
- Landscaping (area ~ $2324m^2$). This includes the provision of top soil, loam and seeding in channel areas.
- Fill required to re-grade road (volume ~ $1090m^3$). The fill is assumed to be an imported sand fill which would be deposited, spread, levelled and compacted to 90%. This has been assumed to be carted from a distance not exceeding 10km.
- Demolition and construction of the existing amenities block and irrigation tank.
- Construction of a new bridge across the floodway to provide access between the two fields.
- Removal of approximately 40 trees.

Filling of these sites were assumed to occur on private land. All other works were assumed to occur in the road corridor or on public land.

8.6.2 Costing

The unit costs out of Rawlinsons (2015) were multiplied to the volumes and areas calculated in GIS to determine the direct costs associated with the elements. Indirect costs were also included the final cost calculation to account of contractor design costs, contractor indirect costs, contractor margins and contractor risk contingency. Estimated direct costs, indirect costs, and total costs for each element are provided in **Appendix G** and a summary of the costs is provided in **Table 8-2**.

Table 8-2 Summary of Costs (in thousands)

Item	Location of Works	Direct Costs	Indirect Costs	Total Costs
Site 1	Private land	$749	$515	$1,264
Site 2	Private land	$55	$38	$93
George Street	Private land	$39	$26	$65
	Public land	$1,186	$815	$2,001

8.7 Conclusions and Recommendations

8.7.1 Site 1 and Site 2

The Site 1 and Site 2 mitigation strategy maintains existing flooding conditions by balancing cut (lands located below 1% AEP flood event) and fill volumes due to the proposed buildings, in line with flood impact mitigation being the main focus of this study, but does not provide improvements to existing flooding issues. The flooding assessment with the selected mitigation options for Site 1 & 2 was undertaken for the existing climate and it was assumed that all proposed flood storage areas and the floodway were empty prior to start of a storm event. The effectiveness of the mitigation options would be diminished if the proposed flood storage areas and the floodway were full with water prior to start of a storm event due to poor drainage and sea level rise.

The low-lying nature of the site, flat grades and shallow water table depth of 0.75m may result in extended duration of ponding within the proposed flood storage areas and the floodway. The potential rise in groundwater table due to extended duration of pondage could result in a permanently wet floodway bed if management measures are not included to improve sub-soil drainage. Sea level rise may also impact on the site in terms of direct seawater inundation and interaction with flooding. Further investigations and design development are recommended to ensure the long-term viability of the flood mitigation strategy.

Areas proposed for flood storages and the floodway are affected by acid sulphate soils and other industrial contamination and would be subject to greater than 0.5m depth of flooding during frequent storm events. Hence, these areas are not considered safe for children and need to be fenced off with porous fencing. Ponding in these areas may also pose other amenity, health and safety issues.

Site 1 and Site 2 are located north of the George Street sag point. Access to Site 1 and Site 2 is cut off when the George Street sag point is subject to flooding. The mitigation measure for George Street sag point is critical for flood risk management for Site 1 and Site 2 and the adjoining areas if alternative flood emergency access from Homebush Bay Drive to the area north of the sag point is not feasible.

The focus of this study has been on flood impact mitigation and hence issues relating to groundwater and drainage have not been considered in detail. Further investigations are required to determine if the high groundwater and poor drainage can be managed or if the proposed mitigation strategy design can be refined to minimise their impacts. Additionally, if sub-soil drainage is installed, an assessment needs to be undertaken on whether it increases the risk of site contamination leaching into the site runoff.

Alternative options for managing flood impacts and flood risk due to development of Site 1 and 2 include the following:

- The mitigation option involving an overland flow path from Victoria Avenue sag point through Sydney Olympic Park land to Powells Creek should be investigated further, initially by discussion with Sydney Olympic Park Authority;
- The proposed development (buildings) could be consolidated further to minimise flood impacts without requiring excavation of low laying lands; and
- Alternative vehicular access to Site 1 and Site 2 from Homebush Bay Drive for flood emergency access, in lieu or substituting for of the improvement of flood access in George Street.

These alternative options have not been assessed in this study as they require ongoing stakeholder consultation (SOPA and RMS) and design inputs (Site 1 and 2 layout and traffic management for potential Homebush Bay Drive access), which is outside the scope of this study. However, it is recommended that Council considers these alternative options in the overall suite of measures available for Site 1 and 2. Considering the broad range of issues identified, a holistic and integrated design and environmental assessment study is required for Site 1 and 2 to address these issues and provide a sustainable design.

8.7.2 George Street

The mitigation option to service the George Street sag point improves the existing flood immunity at the sag point. Depths of flooding in the gutter are reduced from over 0.5m in the baseline case to 0.15m in the concept design case, for the 1% AEP event. Analysis of the flow conditions in relation to the Australian Rainfall and Runoff interim guidelines defining safe/hazardous flow conditions for vehicles indicates that the sag point is trafficable in up to the 1% AEP flood. The sag point is subject to up to 0.7m flood depth in the PMF event with the mitigation strategy.

Access to the proposed buildings on Site 1 and Site 2 in addition to the existing adjacent properties would be required to facilitate emergency (e.g. fire, medical needs) evacuation needs during flood events larger than the 1% AEP event. If flood emergency access to Site 1 and Site 2 from Homebush Bay Drive is found to be unfeasible, further design work is required to develop the modified road design, confirm the flood hazard to vehicles and assess whether larger drainage infrastructure (pits and culverts) than that proposed can be implemented to further improve the flood accessibility of the modified George Street sag for the PMF event.

The new bypass floodway would discharge into Powells Creek, parts of which are owned by Sydney Water. Hence Sydney Water should be consulted as a stakeholder, and approval may be required prior to construction of the proposed bypass floodway. Other stakeholders relevant to discharging into Powells Creek may include OEH.

A culvert solution, instead of a floodway, has not been considered as the concentrated flows and high discharge velocities are likely to increase risk of scour in Powells Creek and which is likely to be a concern for stakeholders. Additionally, culverts on very flat grades are likely to lead to silting and maintenance problems.

The bypass floodway involves excavation of existing soil, may also encounter contaminated soils and involve demolition of the existing amenities block and an irrigation tank.

The following recommendations are made for the mitigation option for the George Street sag point:

- Further design development of George Street sag modifications for road design and traffic aspects to ensure trafficability in the PMF event.
- The option is to be refined further to avoid demolition of the existing amenities block and the irrigation tank by installing culverts under the corner of the oval to short-cut the floodway corner near the amenities block. This would avoid the floodway encroaching on the amenities block and the light or transmitter pole adjacent, and would negate the need for a footbridge.
- Stakeholders (Sydney Water, OEH) are to be consulted about the option and discharge into Powells Creek.

It should be noted that approval will be required from the City of Canada Bay for the proposed floodway on public land to the west of site 5, and that consultation would also likely be required with the Department of Education and Communities in terms of the option for culverts under the school oval.

9. Flood Policies and Planning Controls

9.1 Background

This section provides an overview on the NSW flood risk management framework and existing policies and planning controls applicable to the study area and recommends additional controls to be considered for the Concord West Precinct.

9.2 NSW Flood Risk Management Framework

9.2.1 Objectives and Approach

The primary objective of NSW Flood Risk Management (FRM), as expressed within the NSW Flood Prone Lands Policy (Floodplain Development Manual 2005, page 1) is as follows:

"*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.*"

Within the scope of this report, the relevance of the above objective is primarily to ensure that the Master Plan for Concord West Precinct does not lead to increased flood risk to property and persons and that the planning controls proposed to achieve this outcome form part of a consistent and coordinated strategy to reduce flood risks.

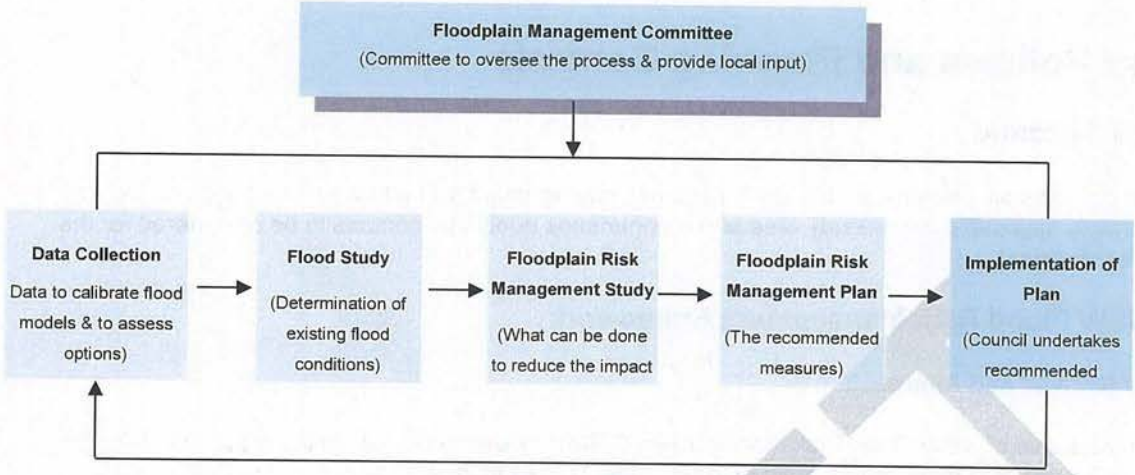
9.2.2 NSW FRM Policy and Guidelines

The NSW Flood Prone Land Policy as produced within Section 1.1 of the Floodplain Development Manual (FDM 2005) is consistent with that first introduced in 1984, which places the primary responsibility for implementation on local councils. This provides the opportunity for FRM to be integrated within council's normal planning processes.

The NSW Flood Policy and the FDM provide a platform for the management of floodplains in a manner that follows a risk management approach. The FDM is a manual which provides guidance with regard to how to implement the NSW Flood Prone Land Policy. The FDM requires the level of flood risk acceptable to the community is to be determined through a process overseen by a committee comprised of local elected representatives, community members and state and local Government officials (including the SES). This process is shown in **Figure 9-1**.

The ultimate outcome is the preparation of a Floodplain Risk Management Plan (FRMP), which is a plan formally adopted by a local council in accordance with the NSW Flood Prone Land Policy. FRMPs should have an integrated mix of management measures that address existing, future and continuing risk.

City of Canada Bay is yet to form a Floodplain Management Committee (FMC) which is a key requirement for preparation of Floodplain Risk Management Plan for the study area. Council could consider forming a FMC to comply with the requirements of the FDM 2005.



- **Figure 9-1 NSW FRM Process (Adapted from FDM 2005)**

9.2.3 2007 Flood Planning Guideline

On January 31, 2007 the NSW Planning Minister announced a new guideline for development control on floodplains (the "Flood Planning Guideline"). An overview of the new Guideline and associated changes to the Environmental Planning and Assessment Act, 1979 (EPA Act) and Environmental Planning and Assessment Regulation 2000 (Regulation) was issued by the Department of Planning in a Circular dated January 31, 2007 (Reference PS 07-003). The Flood Planning Guideline issued by the Minister in effect relates to a package of directions and changes to the EPA Act, Regulation and FDM.

This Flood Planning Guideline provides an amendment to the Manual. The Guideline confirms that unless there are "exceptional circumstances", Councils are to adopt the 100 year flood as the flood planning level (FPL) for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. The Guideline does provide that controls on residential development above the 100 year flood may be imposed subject to an "exceptional circumstance" justification being agreed to by the Department of Natural Resources (now the Office of Environment and Heritage -OEH) and the Department of Planning (now the Department of Planning and Infrastructure - DPI) prior to the exhibition of a Draft LEP or Draft DCP.

The "Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual" defines Standards for Flood Controls for Residential Development. Whilst the flood used to define the residential FPL is a decision of Council, FDM highlights that FPLs for typical residential development would generally be based around the 100 year flood (i.e. 1% AEP) plus an appropriate freeboard (typically 0.5m).

A flood planning area (FPA) map has been prepared for the study area in accordance with this guideline. A review of the FPA for the study area indicates that more than two-thirds of the study area is located at or below the FPL. The review also indicates that excluding Site 3, the remaining sites are located within the FPA.

9.2.4 Flood Risk Management Measures

The FDM provides that the measures incorporated into a FRMP for managing flood risk to life and property can be grouped into three categories:

- **property modification measures** - these comprise controls on future development of property and community infrastructure. Planning and development controls can generally be implemented for minimal cost and would ensure that the potential for flood damage does not increase in the future;

- **response modification measures** - these modify people's response to flooding and usually include measures that provide additional warning of flooding, improved public awareness of the flood risk and improvements to emergency management during floods; and
- **flood modification measures** - being structural measures such as the construction of levees and detention basins, channel widening/deepening, etc.

This section is primarily concerned with property modification measures and secondly with response modification measures. Planning's role relates primarily to the implementation of property modification measures, and to a lesser extent response modification measures, particularly in regard to the manner in which it informs the community through planning policies in regard to flood risk. Accordingly, the role of planning can be summarised as follows:

- **Strategic Planning**: Directing strategic planning as to the location of new areas or the redevelopment of areas in a manner which does not expose people and property to unacceptable flood risk.
- **Development and Building Controls**: Where development is permitted in locations where flood risk remains, to ensure that planning and building controls are applied in a manner which minimises risk to acceptable levels.
- **Communication of Flood Risk**: Ensuring that the planning policies and controls and associated documentation communicates flood risk in a responsible manner to allow the community to make informed decisions where discretion exists and to complement emergency management education and preparedness programs.

The George Street sag point is subject to high flood hazard under the existing conditions. Properties north of the sag point are only accessible by George Street. Access to properties located north of the sag point is problematic during significant storm events. The Master Plan with the concept design includes works to improve flood access at the George Street sag point up to and including the 1% AEP event.

Considering the fact that the majority of the sites are located within the FPA, the following issues need to be considered for the Precinct:

- "Safety of people and damages to vehicles in basement car parks (if possible and provided)";
- Access and egress to properties during flood events rarer than the 1% AEP event;
- Safety of people on excavated flood storage areas and floodways; and
- Flood education and preparedness.

9.2.5 Relationship with EPA Legislation

The plan-making processes under the EPA Act, such as for a Local Environmental Plan (**LEP**) and a Development Control Plan (**DCP**), operate independently of the preparation of FRMPs under the FDM. While these two processes could be overlapped, it has been the usual practice to undertake the processes separately. Ultimately the planning recommendations of the FRMP will need to be reflected in planning instruments and policies brought into force in accordance with the EPA Act.

9.3 Existing Policies & Planning Controls

The imposition of planning controls can be an effective means of managing flood risks associated with future development (including redevelopment). Such controls might vary from prohibiting certain land uses to specifying development controls such as minimum floor levels and building materials.

In principle, the degree of restriction that is imposed on development due to flooding relates to the level of risk that the community is prepared to accept after balancing economic, environmental and social considerations. In practice, the planning controls that may ultimately be imposed are influenced by a complex array of considerations including state imposed planning policy and directions, existing local planning strategies and policies and ultimately the acceptability of conditions that could be imposed through the development application process.

The following provides an outline of policy that is potentially relevant because it either directs the FRM planning controls that could be adopted or affects the way flood risk is identified in the planning controls.

9.3.1 State Environmental Planning Policies

A State Environmental Planning Policy (SEPP) is a planning document prepared in accordance with the EPA Act by the NSW Department of Planning and Environment and eventually approved by the Minister, which deals with matters of significance for environmental planning for the State. Clause 1.19 of the Codes SEPP has been amended so that land identified as 'flood control lot' is no longer excluded from the application of the General Housing Code. Instead, specified development and development standards have been added to the General Housing Code for development on low hazard flood control lots. The development standards have been designed to ensure that complying development is not allowed on high hazard or high risk flood control lots including floodways, flood storage areas, a flowpath or areas identified in local flood plans as high hazard or high risk.

In the 1% AEP event, some lots within the precinct are subject to low flood hazards and all high hazard areas are located on public lands.

9.3.2 Regional Planning Strategies

The study area is located within the Central subregion of the Draft Sydney Metropolitan Strategy to 2031 which is relatively general but identifies the following policies relating to natural hazard including flooding:

- *Natural hazards will be considered and planned for at an early stage*
- *Development, particularly infrastructure, will be avoided in locations at risk from natural hazards unless the risks are demonstrated to be manageable*

9.3.3 Climate Change Policies

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have a significant influence on flood behaviour at specific locations. Rainfall intensities will have a wide influence on flooding while the sea level rise will have a diminished effect as the distance from the tidal influences of coastal waters increases. The study area is located within the catchment area of Powells Creek, which is, to some extent, hydraulically influenced by ocean tides.

Scientific data regarding the effect of climate change on rainfall intensities is not sufficiently advanced to provide specific guidance for the assessment of flood risk. No relevant planning benchmarks have been adopted by Government related to rainfall intensity changes. However, NSW Government guidelines recommend the undertaking of a sensitivity analysis, which assumes nominal increases in rainfall intensities.

In 2009, the NSW Government adopted sea level rise planning benchmarks (measured as an increase above 1990 mean sea levels) of 0.40m by 2050 and 0.90m by 2100. The NSW Government disbanded these benchmarks as Government policy in September 2012 and requires Council to consider local conditions when determining future hazards.

Implications of climate change within the study area have been assessed for the baseline case only. The assessment shows that parts of study area experience flood level increases due to both increased rainfall intensity and sea level rise, most notably low-lying and poorly drained areas including the area to the north of

Victoria Avenue and George Street sag in addition to the area within the Powells Creek mainstream floodplain. The 1% AEP high tide level in Homebush Bay is approximately 1.5 mAHD. The proposed floodway and flood storage areas for Site 1 & 2 to mitigate flood impacts due to the Master Plan would be flooded due to the 1% AEP high tide with a small increase in sea level rise.

In recognition of the potential impacts of sea level rise, it is considered prudent to consider additional freeboard to set the access level to basement car park and the habitable floor level at or above RL 3 m AHD. It is to be noted that the flood level for the PMF event is 1.6m higher than the 1% AEP event on the low lying areas of the precinct.

9.3.4 Section 117 Directions

Ministerial directions pursuant to Section 117(2) of the EPA Act specify matters which local councils must take into consideration in the preparation of LEPs. Direction 4.3, as currently applies, deals specifically with flood [liable] prone land and has the following two objectives:

"(a)To ensure that the development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual, 2005.

(b) To ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land".

The Direction applies to all councils that contain flood prone land when an LEP proposes to "*create, remove or alter a zone or provision that affects flood prone land.*" In such cases, the Direction requires draft LEPs to ensure the following:

(4) A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).

(5) A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

(6) A planning proposal must not contain provisions that apply to the flood planning areas which:

- *a. permit development in floodway areas,*
- *b. permit development that will result in significant flood impacts to other properties,*
- *c. permit a significant increase in the development of that land,*
- *d. are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*
- *e. permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.*

(7) A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(8) For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the

Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

The Master Plan includes significant increase in development on lands located within the FPA and the Master Plan would result in substantial increase in resident population within the study area. Whilst the Master Plan with concept design improves flood access to properties located north of the George Street sag point up to and including the 1% AEP event, access to all proposed buildings are required to facilitate emergency (eg. fire and medical needs) evacuation needs during floods rarer than the 1% AEP event to be consistent with this Direction. Further investigation is required to improve trafficability of George Street sag point for the PMF event. Alternatively, new access routes to the area north of the George Street sag e.g. off Homebush Bay Drive would be required to ensure consistency with the S117 Direction.

9.3.5 Local Environmental Plan (LEP)

Canada Bay Local Environmental Plan 2013 applies to the study area. The study area contains land within a number of standard urban zones such as IN1 General Industrial, R2 Low Density Residential, R3 Medium Density Residential, RE1 Public Recreation and SP2 School. These zones and the sites proposed for rezoning are shown in **Figure 7-1**.

Clause 6.2 of the LEP deals with earthworks to ensure that earthworks for which development consent is required will not have a detrimental impact on environmental functions and processes, neighbouring uses, cultural or heritage items or features of the surrounding land.

The flood assessment confirms that the Master Plan with the concept design will have negligible flood impacts on existing properties on the assumption that the compensatory flood storage included in the concept design for Site 1 and Site 2 would be empty prior to the commencement of a storm event. The scope of the flood assessment did not include an impact assessment on the environmental function and processes due to excavation of low lying areas within Site 1 and Site 2 and the long-term implications on land drainage.

Council intends to amend its LEP to apply the model local provisions clause 7.3 (flood planning) based on the flood planning area map. Part of this model local provision requires the identification of a freeboard area for the definition of "flood planning level". Council should amend its LEP to apply the model local provisions clause 7.3 (flood planning) to all lands located within the flood planning area defined in this study. Council should adopt the flood planning levels defined in this study based on the following freeboards above the 1% AEP flood levels:

- 0.5m for areas impacted by flooding in Powells Creek; and
- 0.3m for areas impacted by overland flooding.

9.3.6 Development Control Plan (DCP)

City of Canada Bay Development Control Plan 2013 (DCP 2013) applies to the study area. Council's guidelines on stormwater controls are provided in the City of Canada Bay "Specification for the Management of Stormwater" (SMS) document revised in February 2009.

The objectives of Council's Stormwater Policy as detailed in SMS (2009) are:

- *To provide uniform guidelines and application of systems to achieve consistency in the assessment and conditioning of development applications in relation to stormwater runoff from all developments*
- *To minimise any adverse impact on properties caused by stormwater runoff from developments*
- *To ensure that the water qualities of receiving waterways are not adversely affected by pollutants such as nutrients, pathogens, and situation, resulting from development sites.*
- *To ensure that uniform stormwater controls are applied throughout the whole of the City of Canada Bay Council Local Government Area.*

The following controls are recommended in SMS (2009) to achieve the above objectives:

- *The provision of safe overland flowpaths within developments and on public land*
- *The definition of floodways for major storms within developments and on public land*
- *The provision of controls such as on-site stormwater detention, community basins and the like and on-site retention systems to reduce and control stormwater runoff*
- *The application of alternative methods of merit based stormwater control and conveyance devices*
- *The removal of flood effected development from known floodways and the prohibition of future developments in such floodways*
- *The provision of minimum free-boards for assigning floor levels to reduce the risk of flood damage to property*
- *The installation of pipe/channel systems to minimise hazard to pedestrian and vehicular traffic caused by uncontrolled surface stormwater runoff*
- *The installation of water quality control devices such as trash screens, gross pollutant traps, water quality ponds and the like to protect the quality of receiving waters.*

In addition to the above controls, SMS (2009) makes the following specific stormwater controls will be applicable to the study area:

- Overland flow routes are to be provided in the following locations:
  - Within the road carriageway excluding footpaths and the footway reserve. Flows across footpaths will only be permitted where this will not cause flooding to property or create danger to pedestrians and is subject to Council approval.
  - Within drainage easements. Where it is not practical to provide an overland flow route along an easement, the piped drainage system shall be sized to accept the runoff for the major storm event i.e. the 100-year ARI.
  - Within the flood storage areas and the floodway included in the mitigation strategy for Site 1 & 2.
- The minimum freeboard according to SMS (2009) shall be as follows:
  - *150mm for roadways - between the 100-year ARI overland flow route and warehouse, factory, and garage floor levels and entrances to underground carparks.*
  - *300mm for roadways - between the 100-year ARI overland flow route and office, living rooms, retail space, storeroom, and show room floor levels.*
  - *300mm for surcharge paths e.g. easements - between the 100-year ARI overland flow route and all internal building floor levels, garages and basement carparks.*
  - *500mm for channels, creeks and rivers - between the 100-year flood water level and all internal building floor levels, garages, and basement carparks.*
- *Design velocities and depths of surface flows shall be in accordance with Figures G1 and G2 of the* ***New South Wales Government Floodplain Management Manual: The management of flood liable land****, with hazard category classed as "low hazard".* It is to be noted that SMS (2009) needs to be updated to refer to Figures L1 and L2 of the FDM 2005.
- Easements for stormwater drainage are to be provided within private properties to comply with Council's Policy on Drainage Easements – this means proposed flood storage areas and the floodway included in the mitigation strategy for Site 1 and 2 should be classified as drainage easements.

Freeboards specified in the SMS (2009) are inconsistent with the FPL adopted in this study. The SMS (2009) does not include any controls based on emergency flood evacuation needs (e.g. fire, medical needs) during extreme events or identify flood compatible materials for building components to be used for new development or redevelopment. In addition, the SMS does not consider potential impacts of climate change and specify types of fencing to be used to mitigate flood impacts to neighbouring properties.

Considering the gaps in the current DCP, it is recommended that Council considers to develop a new DCP specifically for the Concord West Precinct to address requirements of Section 117 Directions specifically for the Master Plan and overall for the study area. The new DCP should identify controls for defining habitable floor levels and access to basement car parks for the low lying areas within the precinct. It is recommended that as a minimum, habitable floor levels and access to basement car park be set at RL 3 m AHD for the precinct.

9.3.7 Section 149 Certificates

Council under the provisions of Section 149 of the Environmental Planning and Assessment Act 1979 issues Certificates which are also known as zoning certificates. The certificate provides information on planning controls and any development restrictions which may apply to a particular parcel of land within the Council area. They are usually required upon the sale or purchase of a property.

There are two types of certificates:

- 149 (2) Certificate - Provides information about the zoning of the property, the relevant state, regional and local planning controls, other planning affectations such as heritage, land contamination and road widening and whether or not complying development can be carried out on the land.
- 149 (2) & (5) Certificate - Provides additional advice regarding demolition, foreshore building lines, other heritage considerations and general advice.

It is not known whether Council provides any information flooding in Section 149 Certificates. Given that information on flooding for the study area is available to Council from this study, Council should include information on flooding in Section 149 Certificates. In particular, information on flood levels, flood hazards and FPL for the baseline case is to be included in Section 149 Certificates.

9.4 Conclusions

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. Under the Policy, the management of flood prone land within the study area remains the responsibility of City of Canada Bay Council. Whilst the 2013 LEP and 2013 DCP addresses Council's responsibility for the management of flood prone land policy to some extent, additional controls are required for the Concord West Precinct to comply with the requirements of Government's Flood Prone Land Policy.

A flood planning area (FPA) map has been prepared for the study area according to the 2007 Flood Planning Guideline. A review of the FPA map for the study area indicates that approximately 25% of the study area is located at or below the Flood Planning Level (FPL). The review also indicates that excluding Site 3 and Site 7, the remaining five sites (i.e. Site 1, Site 2, Site 4, Site 5 and Site 6) are located within the FPA where several new high rise buildings are proposed. This means that the Master Plan would result in substantial increase in resident population within the flood planning area.

The Master Plan with concept design improves flood access to properties located north of the George Street sag point up to and including the 1% AEP event. George Street sag point is subject to 0.7m depth of flooding in the PMF event with the mitigation strategy which is considered untrafficable. However, access to all proposed buildings will be required to facilitate emergency (eg. fire and medical needs) evacuation needs during floods rarer than the 1% AEP event to be consistent with Section 117 Directions. If flood emergency access to Site 1 and 2 from Homebush Bay Drive is found to be unfeasible, further design work will be required to ensure flood accessibility of the modified George Street sag for the PMF event to ensure consistency with the S117 Direction.

Additional issues to be considered for the precinct include the following:

- Flood compatible materials for building components to be used for new development/redevelopment;
- Safety of people and damages to vehicles in the basement car park (if possible and provided);
- Safety of people living near constructed flood storage areas and floodways;
- Requirements for porous fencing on flood liable land;
- Improved flood education and preparedness;
- The consequent cumulative impact on flood behaviour due to filling and/or new buildings; and
- Impacts of climate change and sea level rise.

The Master Plan with concept design for Site 1 and Site 2 involves excavation of flood storage areas and a floodway to balance the fill due to the proposed buildings. Areas proposed for excavation include acid sulphate soils that are contaminants from previous land use. The flood assessment was undertaken for the existing climate and it was assumed that the proposed flood storage areas and the floodway would be empty prior to occurrence of a storm event. It is very likely that in combination with the existing poor land drainage in the area, potential sea level rise and the interaction with groundwater (saline), the proposed flood storages and the floodway may be filled up with water if a sustainable measure for sub-surface drainage is not incorporated in the concept design for Site 1 and 2.

The Master Plan for Site 1 and Site 2 includes proposed flood storages and a floodway which are located close to the building foot prints. Both the flood storage areas and the floodway are considered hazardous to children on the basis of depth of the flood behaviour. Considering safety to people, both the flood storage areas and floodway would require flood compatible fencing.