Leichhardt Floodplain Risk Management Study and Plan

APPENDIX C

ONSITE DETENTION ASSESSMENT - DRAFT

1 Introduction

On-site detention (OSD) is the temporary storage of site stormwater so as to restrict the discharge leaving the site to a predetermined rate. The purpose of OSD is to either ensure no worsening of downstream flooding issues as a result of a development or it can also be used to decrease flooding downstream.

Leichhardt Council has Requirements for OSD within the former Leichhardt Local Government Area (study area) are set out in the Leichhardt Development Control Plan DCP 2013. These requirements currently aim to reduce flooding within the study area by applying OSD to significant proposed developments.

A review has been undertaken as part of the Leichhardt Floodplain Risk Management Study to incorporate the findings of Leichhardt LGA Flood Study into Council's OSD Policy and to review Council's Policy against current best practice. Catchment based analysis has been undertaken to determine the effectiveness of the current OSD policies as a flood mitigation / management tool. The purpose of the assessment is to identify:

- Site storage requirements (SSR);
- Permissible site discharge (PSD);
- Appropriate on-site detention offsets using on-site retention (rainwater tanks);
- Appropriate requirements for properties drainage against grade to the street above; and
- An OSD calculation sheet (provided to Council separately).

2 Desktop Review of Current OSD Policies

2.1 Leichhardt Council OSD Policy

2.1.1 Current Guidelines

Leichhardt DCP 2013 requires that residential and non-residential developments incorporate OSD in accordance with Council's Stormwater Management Policy (outlined in the Draft Drainage Code, 1995).

On-site detention is required for the following development types:

- Single residential (except for cases where increased roof and paved areas is less than 40m2).
- Dual occupancy.
- Villa, flats, town houses etc.
- Commercial, industrial and institutional.
- Tennis courts,
- Some paving (depending on the details of the development).

Design Values and Calculation Methods

Hydraulic calculations are required to demonstrate the 100 Year Average Recurrence Interval (ARI) post development site run-off does not exceed the 5 year ARI pre-development site runoff.

Calculation methods considered acceptable for this demonstration are:

- Triangular Hydrographs.
- Swinburne.
- Time Area models such as Ilsax.
- Other methods may be accepted at the discretion of Council's Engineer.

Times of concentration are to be calculated using the kinematic wave equation from p300 of Australian Rainfall and Runoff (1987).

Other Design Requirements

Council's Draft Drainage Code (1995) outlines the following design requirements:

- The outflow control structure is to be designed to control variable outflow rate in accordance with the storage discharge relationship (calculated as above).
- All roof and paved areas are to drain through the storage.
- Storages are to be located separate from any external surface flow paths.
- Finished ground levels are to be constructed so that impervious area runoff, in excess of the pipe system capacity, drains to the storages.
- The maximum storage level is to be such that habitable floor levels are at least 0.3m above the maximum water level, and garages 0.15m above.
- An emergency overflow with flowpath is to be provided, and is to be free of obstructions such as fences.
- Maximum ponding depths for above ground storages are to be 0.15m in parking areas, 0.3m in landscaping and 1m in a fenced off area.
- Storage volumes in landscaping areas are to be doubled to allow for vegetation growth.
- Surface storage areas in strata or community title development are not be in privately controlled areas such as courtyards.
- Hydraulic control devices are to be constructed to be non-removable.
- Existing stormwater storages can be incorporated into the new design.

2.1.2 On-Site Retention

DCP 2013 allows for the volume of OSD to be reduced where on-site retention (OSR) facilities for rainwater reuse and/or stormwater reuse are proposed to service all toilets, laundries and outdoor usage. Where OSR is proposed in lieu of OSD, Council requires the offset to be calculated at a rate of 1m^3 from the OSD storage volume, for every 2.5m^3 of OSR storage provided (up to a maximum OSD offset of 10m^3).

2.1.3 Areas not Draining to OSD

Whilst Council's Policy requires "all roof and paved areas are to drain through the storage", it is acknowledged that this is not always possible. Council does not have a formal policy regarding properties which cannot completely or at all discharge to OSD (e.g. properties which discharge against the grade to the street and have no free discharge from the OSD orifice). However, it is understood that Council assesses application relating to properties of this type on a merits based approach. Council accepts that in many cases, new developments on the low side of the road will not be able to obtain easements, and consequently will need to drain against the grade to the street above. Council currently looks at the context of the nature and scale of the proposed development and its position within the catchment to determine an appropriate approach to OSD. Typically, an existing building that is to the replaced or renovated already has a portion of the front roof area that drains out to the street. In these cases, Council generally applies OSD on the principal of limiting the site discharge rate to at least the existing rate. Where no existing surfaces currently drain to the street, the criteria are often based on a typical area.

2.2 OSD Guidelines in Similar Governance Areas

The following OSD guidelines have been summarised for comparison and use in this review:

- Upper Parramatta River Catchment Trust;
- Auburn City Council (former); and
- Kogarah Council.

The relevant components of these guidelines have been summarised in the table below.

	Upper Parramatta River Trust	Auburn City Council (former)	Kogarah Council (former)
Source Document	On-site Stormwater Detention Handbook – Fourth Edition (Upper Parramatta River Catchment Trust, 2005)	Auburn Development Control Plan 2010 (Auburn City Council, 2012)	Water Management Policy: Site Drainage and Flood Management – Practice Note #1 (Kogarah Council, 2006)
Purpose of the Guidelines	To ensure that new developments and redevelopments do not increase peak stormwater flows in any downstream area during major storms up to and including 100 year ARI events. The secondary aims of the policy are to reduce post development peaks throughout the catchment in the 1.5 year ARI event to be as close to natural levels as practical and to encourage the integration of OSD with other water quality measures.	To ensure that through the OSD of stormwater, discharge is controlled thereby ensuring the development does not increase the risk of downstream flooding of roads and properties, or erosion of unstable waterways. Sufficient storage is provided to ensure peak flow rates at any point within the downstream drainage system do not increase as a result of the development during all storm events up to the 100 year ARI.	To ensure that a development does not increase the risk of flooding on downstream properties.
Development to which OSD Applies	OSD requirements generally apply to all types of development and redevelopment on both flood liable and flood-free sites. These include the following: • subdivisions (including residential) approved after 1991; • single dwellings on lots created by a subdivision approved after 1991, unless a communal OSD system was constructed as part of the subdivision; • all commercial, industrial and special-use developments and buildings; • town houses, villas, home units, duplexes and dual occupancies; • semi-detached residential/commercial and residential/industrial properties; • buildings, car parks and other sealed areas of public sport and recreational facilities; • single dwellings, extensions and additions (In the Parramatta City Council area only where the proposed development involves an increase in impervious area greater than 150 m2 and the land is within a designated catchment area which drains to a location of a known drainage problem area); • sites that include WSUD and water re-use. • tennis courts; • roads, car parks, paths and other sealed areas; and • public buildings.	All development except those noted below.	All development except those noted below.
Development to which OSD does not apply	OSD policy does not apply to: • most development types on subdivisions and lots created prior to 1991. Exceptions apply; • dual occupancy residences on a lot with an existing residence involving less than 150 m2 of development area; • sub-divisions of existing dual occupancies where no changes to the buildings or site are proposed; • boundary adjustments and consolidations of allotments where no a additional lots are created; • one-off minor developments, minor additions and repairs where the proposed development area is less than 150 m2 (subsequent minor developments or additions shall require OSD). This exclusion is aimed principally at small areas within large commercial or industrial sites. It does not apply to any developments	OSD is not required where: • The proposal is a one-off extension up to: o 50m2 of impervious area for a single dwelling or an outbuilding; or o 150 m2 impervious area for industrial development. Note: Subsequent extensions require OSD facility. • The proposal is a single dwelling where the site coverage exceeds Section 2.2 Development Control D1 in the Dwellings and Dual Occupancies DCP; • The applicant can demonstrate to Council's satisfaction, the development is subject to mainstream flooding or is subjected to major overland flow. A flood report	OSD will not be required when: • The Water Management Policy only applies to the proposed development instead of the whole site. • The discharge from the property does not pass through any drainage structure before reaching the receiving bays. These drainage structures include any pipe, culvert, lined channel or other restrictive structure. • When the property is wholly within a flood-affected area. For properties which are partly flood affected by the 100 year design flood, the area of the floodway and the area of the site discharging to the floodway would be exempted from the provision of OSD. • The total coverage by impervious area is less than 50% of the site area. The impervious area for the site should include roofs, paving and driveways.

	Upper Parramatta River Trust	Auburn City Council (former)	Kogarah Council (former)
	where the development area includes more than 150 m2 of impervious surfaces nor to dual occupancies; • change of use where no physical changes to the outside of the property are proposed; • areas within large properties (usually commercial or industrial but may be residential) not covered by the development application or construction certificate; • new developments in subdivisions where OSD has already been provided for the entire subdivision; • buildings in Rural/Non-urban areas (Baulkham Hills Shire Council does require OSD for buildings in Rural/Non-urban areas. Contact Council's Subdivision Section to obtain the OSD requirements); • the grassed playing field and vegetated area of public sports and recreational facilities that are not part of a development.	prepared by a suitably qualified engineer is required in this case; or • The property falls within zones 6, 7 and 8.	• Single dwelling sites discharging to an absorption system, which is sized to cater to the 100 year ARI design storm.
Control Standards	• SRD_L = 40 L/s/ha • SRD_U = 150 L/s/ha • SSR = 455 m^3/ha (partitioned into extended detention (lower) and flood detention (upper) storages. Maximum SSR for the extended detention is 300 m^3/ha. • Minimum outlet size = 25mm • Maximum ponding depths above ground = 600 mm (allowable depth of ponding will be varied depending on the nature of the development and the location of the storage).	The SSR and PSD values vary across the catchments within the LGA as follows: PSD = • Zone 1: 80 L/s/ha • Zone 2: 100 L/s/ha • Zone 3: 130 L/s/ha • Zone 4: 150 L/s/ha • Zone 5: 130 L/s/ha SSR = • Zone 1: 530 m3/ha • Zone 2: 455 m3/ha • Zone 3: 370 m3/ha • Zone 4: 325 m3/ha • Zone 5: 370 m3/ha Minimum outlet size: Pipes or orifices with a diameter less than 150mm shall not be acceptable except where protected against blockages using a removable, rustproof screen or wire cage installed around the outlet.	The OSD system shall be designed in accordance with the storage discharge relationships presented in Figure 2.1 below that shows the Site Storage Requirements (SSR) and the Permissible Site Discharge (PSD) relevant to the site's impervious area. The relationships in Figure 2.1 were derived based on catchment investigation undertaken by Kogarah Council.
Rainwater Tank Offsets for OSD	Dedicated Airspace The following reductions in the SSR values may be allowed subject to Council approval: • 50% of the dedicated airspace can be credited against the SSRL; • 100% of the dedicated airspace can be credited against the SSRT; Subject to: • a maximum dedicated airspace credit no greater than the ratio of the area of roof discharging to the rainwater tank to the lot area times the overall site storage volume that is required;	No guidelines provided.	When a rainwater tank is used on the property and is connected to supply toilet flushing and laundry demands, 1/3 of the provided storage volume can be used to offset the required volume for OSD (i.e. SSR).

	Upper Parramatta River Trust	**Auburn City Council (former)**	**Kogarah Council (former)**
	• the rainwater tank has a dedicated outlet to ensure that the dedicated airspace is recovered after a storm event and the maintenance schedule specifically requires checking and cleaning of the outlet; • the PSD for the dedicated rainwater tank outlet is no greater than 40 L/s/ha; • all outflows from the rainwater tank (outflows from the dedicated outlet and overflows from the rainwater tank) are discharged to the OSD storage. Dynamic Airspace The reduced SSR values due to dynamic rainwater tank airspace is calculated using: • SSR_L = 300 - (1,950 x Dynamic Airspace (kL) 2.1 x Roof Area (m2) -1.5) • SSR_T = 455 - (1,650 x Dynamic Airspace (kL) 2.3 x Roof Area (m2) -1.5) Subject to: • the development being residential, or its water usage can be considered to approximate that of a residence; • the design is in accordance with Sydney water requirements (visit the Sydney Water website for the current requirements); and • all overflows from the rainwater tanks are directed to the OSD storage.		
Site Area not Draining to OSD	When it is not feasible to direct runoff from the entire site to the OSD system (pending Council's approval) up to 30% of the residual site area may be permitted to bypass the OSD systems. The storage volume is still calculated on the entire site area while the SRD is adjusted downwards.	A portion of the new impervious areas (excluding roof area) shall discharge directly to Council's system if it cannot be drained to the storage facility, provided that the PSD is reduced to compensate for the smaller catchment. No more than 15% of the total site area shall be permitted to bypass the basin. The modified PSD shall be selected from the figure in the OSD calculation sheet. The calculation of storage requirement shall be based on the area which bypasses the basin.	Where possible, the drainage system shall be designed to direct runoff from all the impervious area of the site to the OSD system. If this is not feasible, then up to 20% of the impervious area of the site can bypass the OSD system provided that all the roof runoff is directed to the OSD and the PSD is modified according to the procedure below. The modified SSR (m3/ha) is calculated as = SSR for the whole site / ((1 – X/ total site area) where X is the area of the site bypassing the detention facility. The new PSD is then calculated from Figure 2.1 against the modified SSR. The total provided OSD volume should not be less than that originally calculated for the whole site.
Calculation Methods	An On-Site Detention Calculation spreadsheet has been prepared to ensure that calculations are undertaken in a manner consistent with the procedures described in the guidelines by all OSD designers.	Alternative values for the required storage volume shall be permitted if the applicant can demonstrate to Council's satisfaction, using appropriate computer modelling, that the relevant PSD shall be satisfied. Computation methods based on the approximate triangular method or the rational method shall not be acceptable.	For more complex situations, more detailed modelling can be undertaken using models such as DRAINS to demonstrate meeting the required PSD for the site.

SRD_L – Site Reference Discharge for primary (lower) orifice outlet.

SRD_U – Site Reference Discharge for secondary (upper) orifice outlet.

SSR – Site Storage Requirements

SSR_L – Extended Detention Volume

SSR_T – Overall Detention Volume

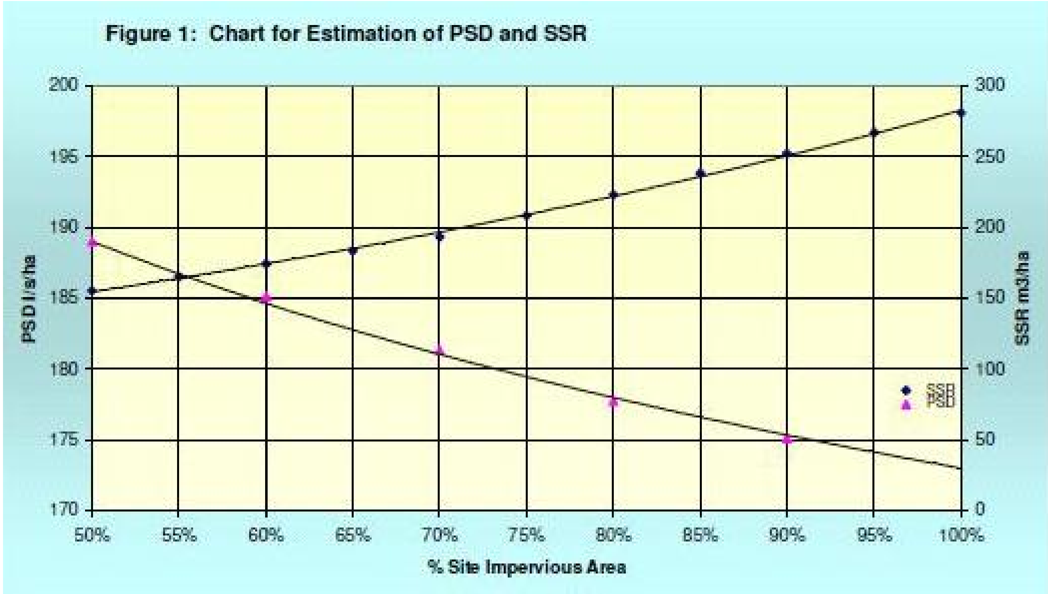


Figure 2-1 Kogarah Council SSR and PSD relationships depending on-site's impervious area

3 Onsite Retention Offsets – Existing Industry Research

Studies have been done within the stormwater industry assessing the appropriateness of incorporating rainwater tanks and OSD. Several key studies and their findings have been discussed briefly below.

Impact of Rainwater Tank and On-site Detention Options on Stormwater Management in the Upper Parramatta River Catchment (Coombes, P., Frost, A. and Kuczera, G., 2001)

In 2000 the Upper Parramatta River Catchment Trust (UPRCT) engaged Associate Professor George Kuczera, Peter Coombes and Dr Geoff O'Loughlin to determine how much of the volume of a rainwater tank, whose water is used for non-potable purposes, can be included in the site's OSD storage, without compromising the OSD system's flood mitigation performance.

The investigation involved generating a 1000-year rainfall record at six-minute intervals for the upper Parramatta River catchment. The record has been applied to a computer model of water usage on individual properties to simulate the performance over 1000 years of different combinations of OSD-only, rainwater tank only and combined systems.

The principal objective of this study is to determine by how much do rainwater tanks reduce the amount of OSD storage required to satisfy UPRCT's policy.

The study identified an average percentage of rainwater tank volume that could be counted as storage for OSD for various allotment scenarios as shown in Table 3.1.

Table 3.1 Average percentage of rainwater tank volume that can be counted as OSD site storage Volume of rainwater tank counting as OSD storage (%)

Scenario	No airspace in tank	50% airspace in tank
Allotment	42	65
Duplex	50	72
Townhouses	40	53
Walk up apartments	32	51

The study also found that on the lot scale the OSD systems reduced the peak discharge as required, but the on-site retention only reduced the volume of discharge, the peak flows remained the same. It was argued that peak discharges at the lot scale had little or no bearing on the floods at a catchment scale, as flooding is a volume driven process. However, a management measure that may reduce peak discharges at the lot scale but also reduces flood volumes can make an important contribution to reduce flooding.

Study on the Combined Effects of OSD and Rainwater Tanks on the Upper Parramatta River Catchment at Varying Sub-Catchment Scales (Cardno Willing, 2002, Additional Assessments: 2004, Supplementary Assessments: 2005)

The results provided by Coombes et al (2001) were considered to provide only an interim answer because the study only looked at individual sites and did not investigate the cumulative impact on peak discharges from groups of dwellings with rainwater tanks. As part of further detailed analysis of the cumulative impacts on peak discharges was undertaken by Cardno Willing in 2003 and 2004, the interaction of rainwater tanks and OSD tanks was investigated. Analyses were undertaken of both rainwater tanks with dedicated airspace and dynamic airspace.

Based on the analysis of the results reported in Cardno Willing, 2004 the SSR values in the UPRCT OSD Handbook – Fourth Edition (2005), were reduced based on the dedicated airspace of rainwater tanks.

Based on the analyses of the results of various rainwater tank simulations undertaken in 2004 and reported by Cardno Willing, 2005, the procedures outlined in Table 2.1 and used in the UPRCT OSD Handbook (2005) were allowed to calculate reductions in the SSR values as a result of likely dynamic airspace.

Rainwater Tanks for On-site Detention in Urban Developments in Western Sydney: An Overview (van der Sterren, M., Rahman, A., Barker, G., Ryan, G. and Shrestha, S., 2007)

This paper presents a brief overview of the on-site detention and retention practices adopted in greater Western Sydney. It has been found that policies differ significantly for different councils.

Since 1991, the UPRCT has conducted stormwater modelling works using XP-RAFTS model for 100 year average recurrence interval (ARI) flow which resulted in a permissible site discharge (PSD) and site storage requirement (SSR) (UPRCT, 2005). These requirements are used to design the OSD system, which generally results in very large detention tanks.

Some Councils have followed the lead by UPRCT and conducted modelling to determine PSD. Penrith City Council, for example, has conducted a simulation, which resulted in different PSDs for different areas of the Council. On the other hand, Councils such as the Blue Mountains City Council and Hawkesbury City Council have not conducted such modelling, and use the pre-development run-off as the constraint to design the OSD system (Hawkesbury City Council, 2000; Blue Mountain City Council, 2005). Furthermore, Hawkesbury City Council and Blue Mountain City Council do not have a significant local catchment flooding problem and have therefore not implemented the UPRCT requirements.

Mains Water Savings and Stormwater Management Benefits from Large Architecturally-Designed

Under-Floor Rainwater Storages **(Lucas, L. and Coombes, P., 2009)**

This paper provides monitoring of water use between January 2008 and December 2008 at a residential home in Hornsby Heights (NSW) that employs large architecturally-designed under-floor rainwater storages (4 x 16 kL cells). Water demand was continuously monitored using smart water meters to reveal intra-daily water use patterns. Based on this data, the PURRS model was used to continuously simulate the performance of the rainwater harvesting system using long-term climate records (at 6-minute timesteps) at the Hornsby House. The attributes of the rainwater harvesting strategy at this house was then applied to Adelaide, Brisbane, Canberra, Darwin, Hobart, Melbourne, Sydney and Perth; and simulated using PURRS with appropriate water demands (3-person household) and long-term rainfall records. Results indicate significant mains water savings and stormwater management benefits, such as reduced requirements for OSD, can be obtained using large architecturally-designed under-floor rainwater storages in all Australian capital cities.

The long-term rainfall record for Sydney (BOM data, Observatory Hill) and attributes of the Hornsby house, such as water demand, diurnal water use pattern and lot, roof and impervious areas, were used in the PURRS to determine reductions in runoff volumes and peak discharge.

Five different scenarios were investigated:

- BAU: “business-as-usual” (no demand management or rainwater storage);
- DM Only: demand management only (water saving appliances such as dual-flush toilets, and rated shower heads, dishwasher and washing machine);
- DM+5kL: Demand Management and 5kL rainwater storage;

- DM+16kL: Demand Management and 16kL rainwater storage; and
- DM+64kL: Demand Management and 64kL rainwater storage.

Table 3.2 shows the % reduction in runoff volumes compared to BAU. Note that "DM only" does not reduce stormwater runoff volumes. The use of larger rainwater storages only slightly reduced stormwater runoff volumes when compared to the DM+5kL scenario.

Table 3.2: Reduction in Runoff Volumes from the Allotment (Lucas et al, 2009)

	DM Only	DM + 5kL	DM + 16kL	DM + 64 kL
% reduction compared to BAU	0	18	24	26

The results showed that when allotment-scale rainwater storages are present there is a considerable reduction in peak discharge over a range of ARI values. However, the significance of these reductions depends on the criteria used to design stormwater treatment structures (i.e. sediment control, street drainage or flood management). It was found that only the 64kL rainwater storage provided significant benefits with regards flood management and reduce the requirement for OSD.

The Use of Rainwater Tanks as a Supplement or Replacement for On-site Stormwater Detention (OSD) in the Knox area of Victoria **(Coombes, 2009)**

This study investigated the use of rainwater tanks to supplement or replace on-site detention for stormwater management in the Knox City Council area in Victoria. The performance of a range of infill development scenarios is compared to the objectives outlined in Knox City Council's stormwater drainage guidelines that require on-site detention to limit peak stormwater discharges from 5 year ARI storm events as indicated by a weighted runoff coefficient of 0.4. The use of discrete rational method assessments reliant on weighted runoff coefficients is compared to the results of continuous simulation using local rainfall. This study has assumed that an effective impervious area of 0% coincides with a weighted runoff coefficient of 0.4.

Many local government authorities (including Knox City Council) currently recommend the use of discrete triangular hydrograph methods for evaluation of on-site detention systems. However, methods that employ design storms based on annual series evaluation of peak discharges cannot replicate the actual performance of volume sensitive systems. Actual rainfall events contain greater range of rainfall volumes than design storms; include many peaks in each storm event and a number of significant peak discharges in any year.

The PURRS model utilises real continuous rainfall records (6 minute time steps) and partial series analysis of peak discharges (a process which includes a maximum peak discharge from each storm event rather than a single maximum peak discharge for each year in the analysis) to understand the impact of on-site detention and rainwater tanks.

Analysis of duplex, triplex, townhouse, unit and warehouse developments reveals that rainwater tanks can provide a similar service to on-site detention systems whilst also providing significant water conservation. The on-site detention service provided by rainwater tanks is primarily dependent on rainwater use from the tank and roof areas connected to the tanks. Tank size was found to be a secondary variable.

An additional important aspect of designing rainwater harvesting systems for the management of peak stormwater discharges highlighted by this study is that there are optimum combinations of rainwater demands and connected roof areas. Reducing the area of roof connected to each rainwater tank for a given rainwater demand can improve the performance of the system. Up to a threshold, reductions in connected roof areas can allow water levels in rainwater tanks to be drawn down more frequently allowing greater reductions in peak discharges. Connection of large roof areas to rainwater tanks can produce a situation

where runoff into tanks from roof catchments overwhelms water demands from the tanks resulting in limited reductions in peak stormwater discharges.

The retention number proposed in this study in combination with the proportion of the development that is roof area connected to rainwater tanks was shown to be an indicator of the performance of rainwater tanks for stormwater detention. This study has also utilised the concept of "effective impervious area" to bridge the technical void between continuous simulation and discrete Rational Method assessments. It is noted that this study is limited to several development scenarios at a single rainfall location. This analysis has also focused on a single demographic profile and a sole objective of reducing 5 year ARI peak stormwater discharges to a given rate as defined by a weighted runoff coefficient.

A summary of the study results in shown in **Table 3.3.**

Table 3.3: Roof Area and Rainwater Tank Size for Compliance with Knox City Council's OSD Policy (Coombes, 2009)

	% of Site Area = Roof Area	Tank Size to Achieve Compliance with Council's OSD Policy
Duplex	11 %	No Compliance
	21 %	> 3 kL
	42 %	10 kL
Triplex	8.8 %	No Compliance
	17.5 %	> 2 kL
	35 %	> 4 kL
Townhouse	8.5 %	No Compliance
	16.9 %	> 3 kL
	33.9 %	10 kL
Units	10 %	No Compliance
	20 %	> 30 kL
	40 %	> 30 kL
Warehouse	13 %	No Compliance
	26 %	> 50 kL
	51 %	No Compliance

Rainwater Tank Options for Stormwater Management in the Upper Parramatta River Catchment (Coombes, P., Frost, A., Kuczera, G., O'Loughlin, G. and Lees, S., 2004)

This study investigated the extent to which rainwater tanks reduce the amount of on-site stormwater detention (OSD) storage required to satisfy the Upper Parramatta River Catchment Trust's (UPRCT's) OSD policy. In view of the limitations of the design storm approach, a continuous simulation approach was adopted. The DRIP stochastic rainfall model was linked with an allotment water balance model to evaluate different allotment scenarios using a 1000-year synthetic pluviograph record. The DRIP model was calibrated to a 53-year pluviograph located at Ryde. Comparison with statistics not used in calibration showed that DRIP performed satisfactorily. In particular, good agreement with observed intensity-frequency duration (IFD) curves was obtained, whereas AR&R IFD curves consistently underestimated the observed IFDs. Scenarios involving combinations of OSD, using 10kL rainwater tanks with 0 and 5 kL of detention storage were examined. For allotments with single dwellings between 50 to 70% of the tank volume can be counted towards the allotment's OSD volume. For a townhouse development, this percentage varied between 36% and 53%. Rainwater tanks used in the single dwelling and townhouse scenarios are expected to reduce mains water consumption by 39% - 30% and 32% - 27% respectively. The variation depends on the number of occupants and the amount of tank airspace reserved for detention storage and the fraction of allotment drained by the rainwater tank(s).

UPRCT On-site Detention Handbook (Fourth Addition)

In addition to the assessments outlined above which were undertaken on behalf of the UPRCT, The Handbook (Fourth Edition) also outlined the results of various rainwater tank simulations to identify the airspace at the start of a storm within a rainwater tank.

The following procedure was identified to calculate the rainwater tank dynamic airspace at the start of a storm:

$$\text{Dynamic airspace (kL)} = 8.7 \times \text{Nett Tank Volume (kL)}^{1.05} \times \text{Roof Area (m}^{2})^{-0.5} \times \text{Demand (kL/d)}^{0.35}$$

Where the Nett Tank Volume = Total Tank Volume – Dedicated Airspace – Top Up Volume.

4 Catchment Analysis

4.1 RAFTS Development

An XP-RAFTS hydrological model was established for the Whites Creek Catchment. The Whites Creek catchment is approximately 187 ha. The catchment rises to the south of Parramatta Road (external to the study area) to an elevation of approximately 46m AHD and includes portions of Leichhardt and Annandale. The southern portion of the Creek is a box culvert and Whites Creek Lane follows the majority of the length of this culvert. The culvert discharges into an open channel between Booth Street and Piper Street, and eventually discharges into Rozelle Bay to the east of The Crescent at an elevation of approximately 0m AHD. The land use within the catchment is highly urbanised and is predominantly residential.

Whites Creek Catchment has been selected as a representative catchment for the entire study area of the Leichhardt Flood Risk Management Study. Catchment analysis of various on-site detention (OSD) scenarios within this catchment will be used to inform the recommendations regarding OSD policy in the study area.

4.1.1 Model Set Up

Sub-Catchment Delineation

The catchment was divided into 160 sub-catchments based on the topographic and structural features. Contour data (0.5m contours), pipe network data and the cadastre was utilized to perform the subcatchment delineation. The average area of each sub-catchment is 1.2 hectares. The sub-catchment layout of the Whites creek catchment is presented in **Figure 4-1** and the RAFTS nodes are shown in **Figure 4-2**.

Land Use

Each sub-catchment was categorised according to the land uses contained within and appropriate impervious percentages were applied to each land use category. **Table 4-1** shows the impervious/pervious percentages used for each category.

Table 4-1: Impervious/Pervious Percentages

Land Use Category	Impervious (%)	Pervious (%)
Residential	60	40
Commercial	80	20
Open Space	5	95

Residential land use roughly occupied 137 hectares which represents 73% of the Whites Creek Catchment.

Figure 4-1 - Whites Creek Sub-Catchments

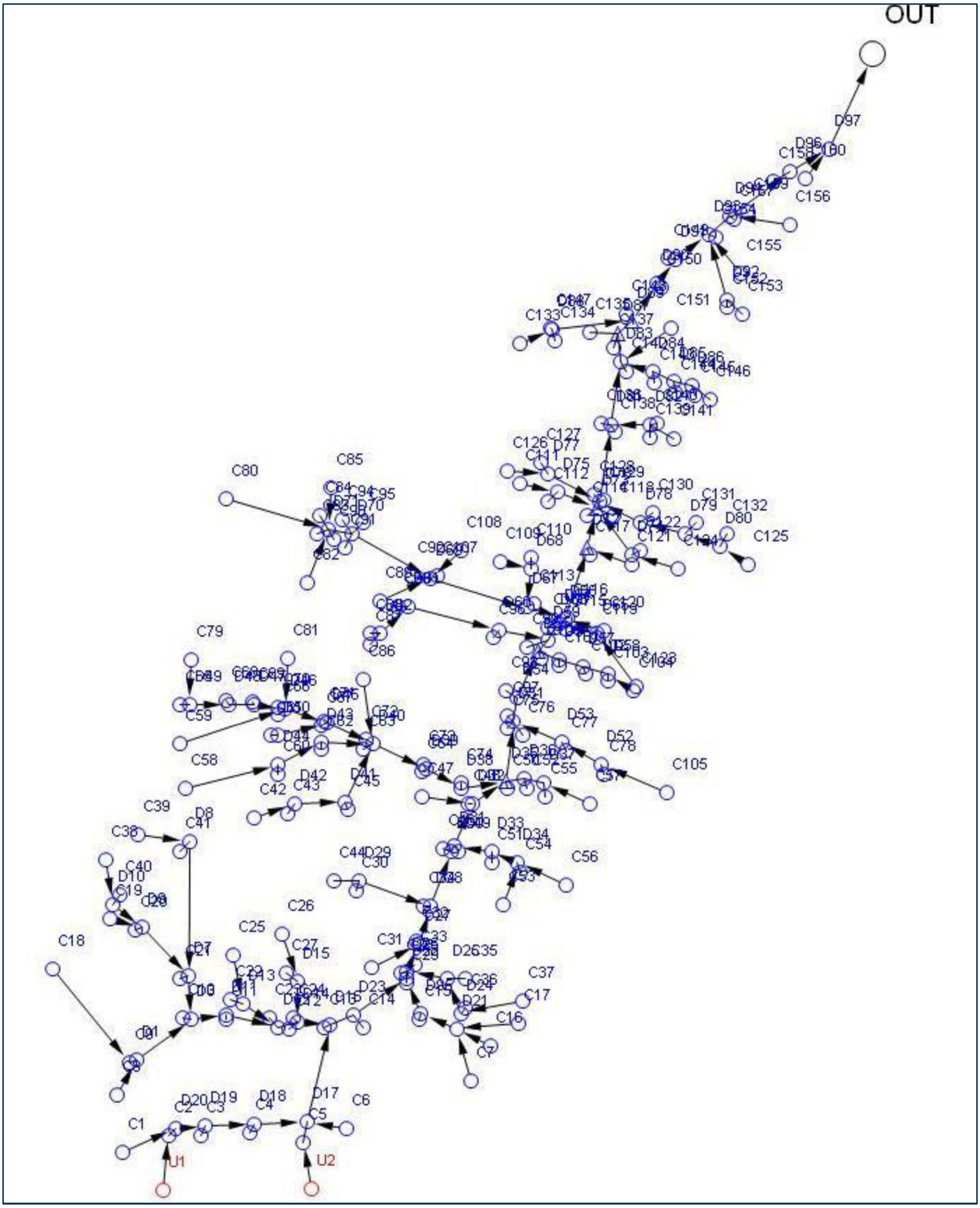


Figure 4-2 - RAFTS Model (160 node catchment model)

Rainfall Losses

The initial and continuing rainfall loss rates for impervious/pervious areas are presented in **Table 4-2**, which are based on Leichhardt LGA Flood Study (Cardno, 2014).

Table 4-2: Rainfall Loss Rate

Rainfall Loss Rate	Impervious Area	Pervious Area
Initial loss (mm)	1.5	10
Continuing loss (mm/hr)	0	2.5

Catchment Roughness

The values of catchment roughness were also based on Leichhardt LGA Flood Study (Cardno, 2014). The adopted values were 0.015 for impervious area, and 0.10 for pervious area.

Design Rainfall

The design rainfall was based on Leichhardt LGA Flood Study (Cardno, 2014). The rainfall intensities for the 5 year, 20 year and 100 year ARI events are provided in **Table 4-3**. The 1-2 hour duration event was critical for the majority of the Whites Creek Catchment.

Table 4-3: Key Rainfall Intensities

Rainfall Event	Intensity (mm/hr)		
	5yr ARI	20yr ARI	100yr ARI
45 minute	62	83	110
1 hour	53	71	95
90 minute	41	55	73
2 hour	34	45	60

4.1.2 Model Verification

The verification of the RAFTS model was undertaken by comparing the results of the 100 year ARI event extracted from the hydraulic model (SOBEK) with that of the hydrological model (XP- RAFTS). The SOBEK model was run using “rainfall on the grid” to simulate flows. It is not always expected that the results of the hydraulic and hydrologic models will exactly match (in fact, even two separate traditional hydrological models with similar parameters can produce significantly different results). However, where there are differences some interpretation of the results can be made, and the models can be checked as to why this is the case.

The comparison was undertaken along the major flow paths. It must be noted that the significant hydraulic controls, such as culverts and localised depression storages, would not be accounted in the hydrological model. The primary aim of this comparison was to ensure that the timing and peak flows from the direct rainfall hydraulic model (SOBEK) were reasonable, with a focus on the runoff areas rather than the mainstream flooding areas.

The locations where the models are compared are shown in **Figure 4-3**. Peak flow and volume estimated by the XP-RAFTS and SOBEK models at the comparison points for the 100 year ARI 60 minute event from the two sub-catchments are listed in **Table 4-5**.

Table 4-5: Sub-catchment Results for SOBEK and XP-RAFTS Models

Category	Catchment Area (ha)	Peak Flow (m^3/s)			Volume (m^3)		
		XP-RAFTS	SOBEK	% Change	XP-RAFTS	SOBEK	% Change
Node D14	24.17	10.15	8.15	19.85%	21771	19585	10.00%
Node D26	51.29	27.05	25.45	5.80%	64021	58743	8.25%
Node D40	22.32	8.60	8.65	-0.90%	19658	16225	17.45%
Node D54	104.42	42.50	40.80	3.98%	112046	98998	11.65%
Node D69	19.94	7.80	6.95	11.1%	17383	13175	24.20%

These results indicate a very reasonable agreement between the Direct Rainfall (SOBEK) and the XPRAFTS models. The overall volume of runoff is higher in the XP-RAFTS model than in the SOBEK model due to storage effects. The SOBEK model has an elevation grid that details localised depression storages, such as at roads, properties, and buildings, that are not represented in the XP-RAFTS model.

Peak flows are also reduced in the SOBEK model compared to the XP-RAFTS model due to the storage effects and due to the elevation and roughness grids in SOBEK that result in more detailed assessment of the conveyance and concentration of flows. Time-series hydrographs extracted at these locations are shown in **Chart 1** to **Chart 5** which show a similar rise and fall timing between the two models. The RAFTS hydrographs generally show an earlier start to flow than the SOBEK model due the lack of detailed storage and conveyance calculations.

Figure 4-3 - Comparison Nodes

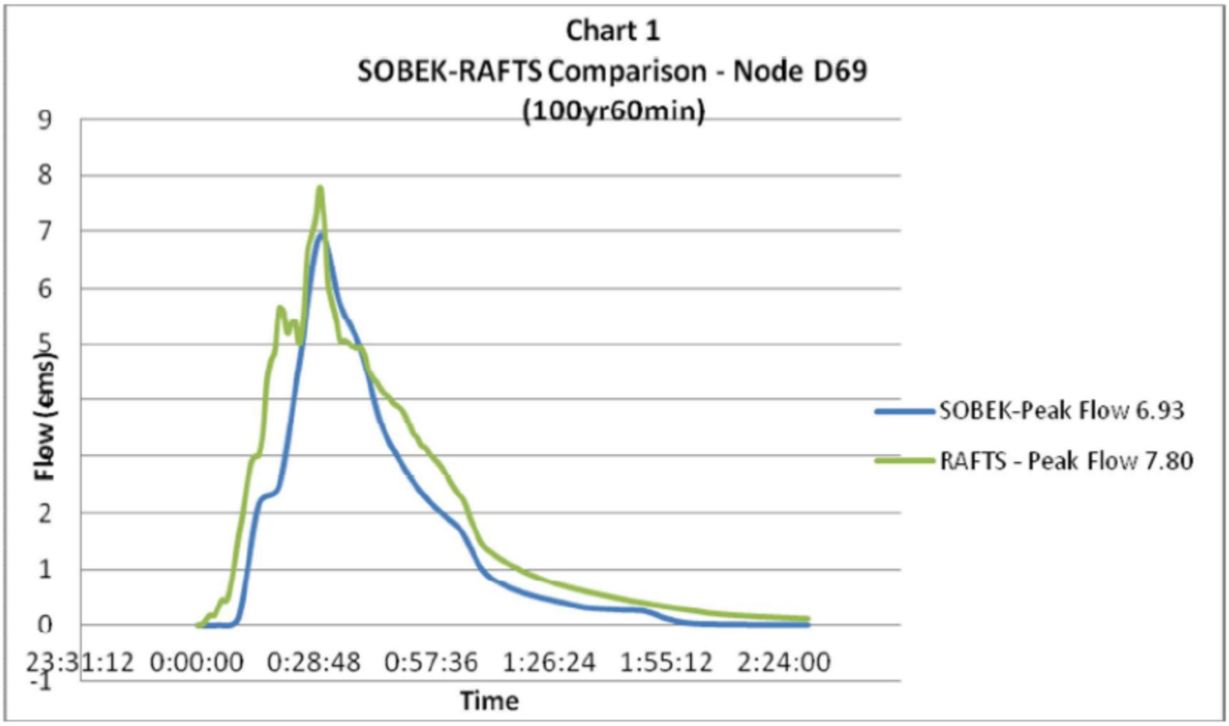


Chart 1
SOBEK-RAFTS Comparison - Node D69
(100yr60min)
Flow (cms)
Time
23:31:12
0:00:00
0:28:48
0:57:36
1:26:24
1:55:12
2:24:00
SOBEK-Peak Flow 6.93
RAFTS - Peak Flow 7.80

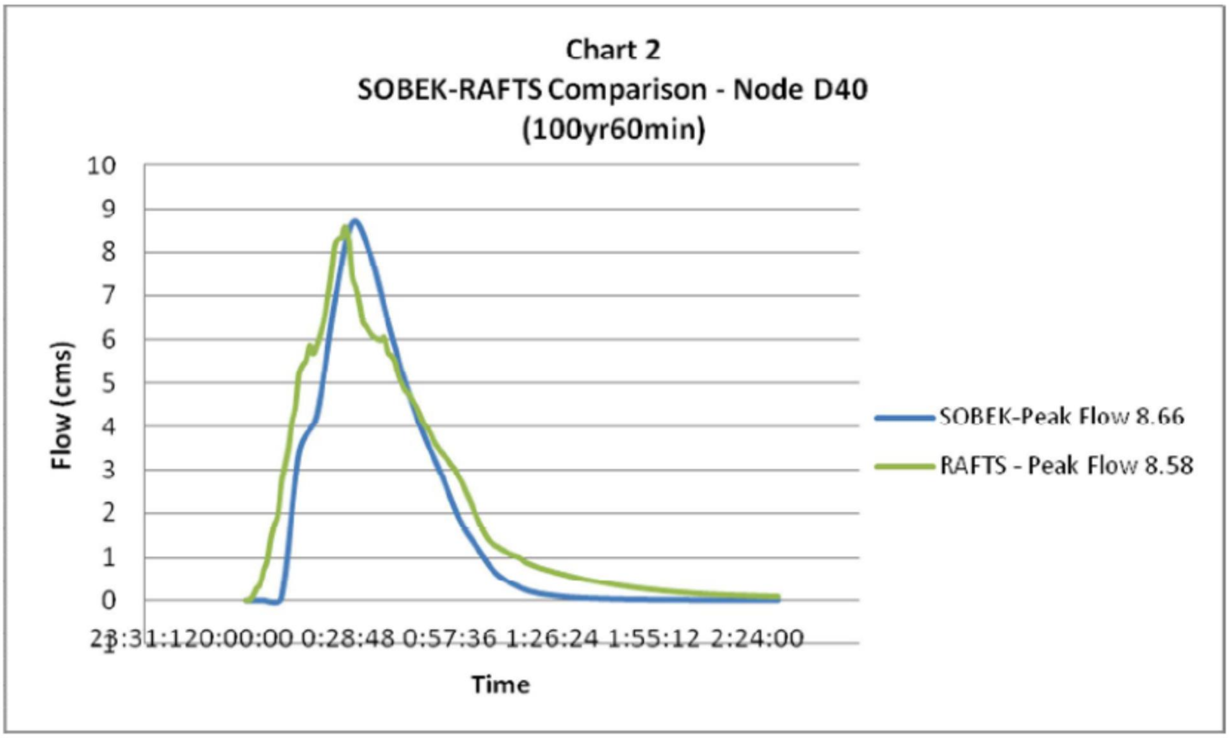


Chart 2
SOBEK-RAFTS Comparison - Node D40
(100yr60min)
Flow (cms)
Time
23:31:12
0:00:00
0:28:48
0:57:36
1:26:24
1:55:12
2:24:00
SOBEK-Peak Flow 8.66
RAFTS - Peak Flow 8.58

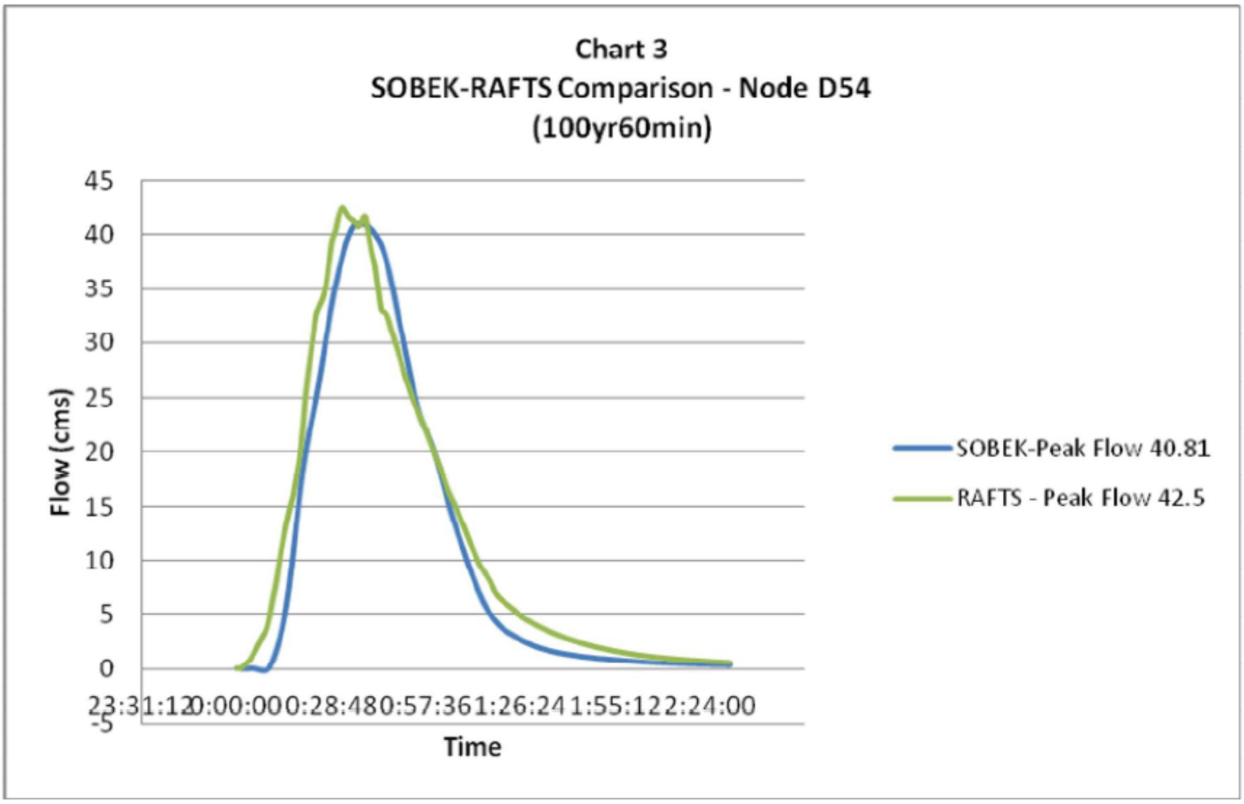


Chart 3
SOBEK-RAFTS Comparison - Node D54
(100yr60min)
Flow (cms)
45
40
35
30
25
20
15
10
5
0
-5
23:31:12
0:00:00
0:28:48
0:57:36
1:26:24
1:55:12
2:24:00
Time
SOBEK-Peak Flow 40.81
RAFTS - Peak Flow 42.5

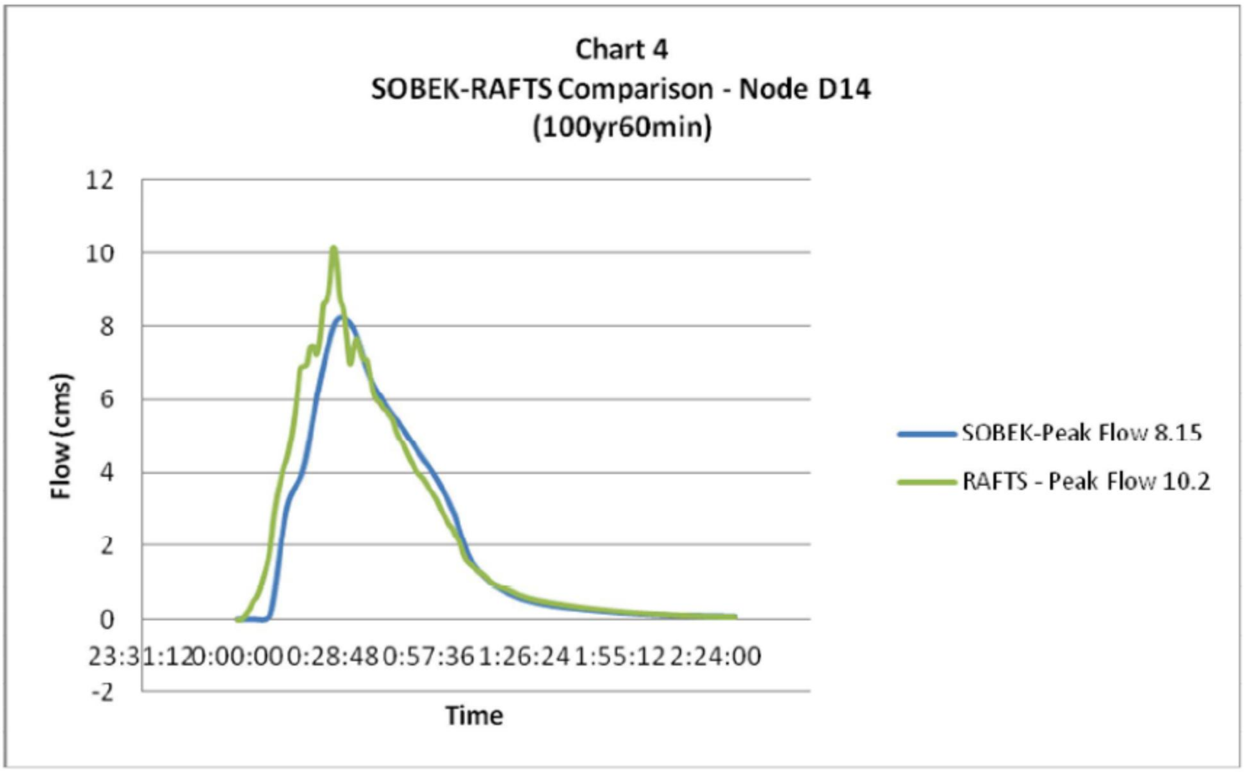
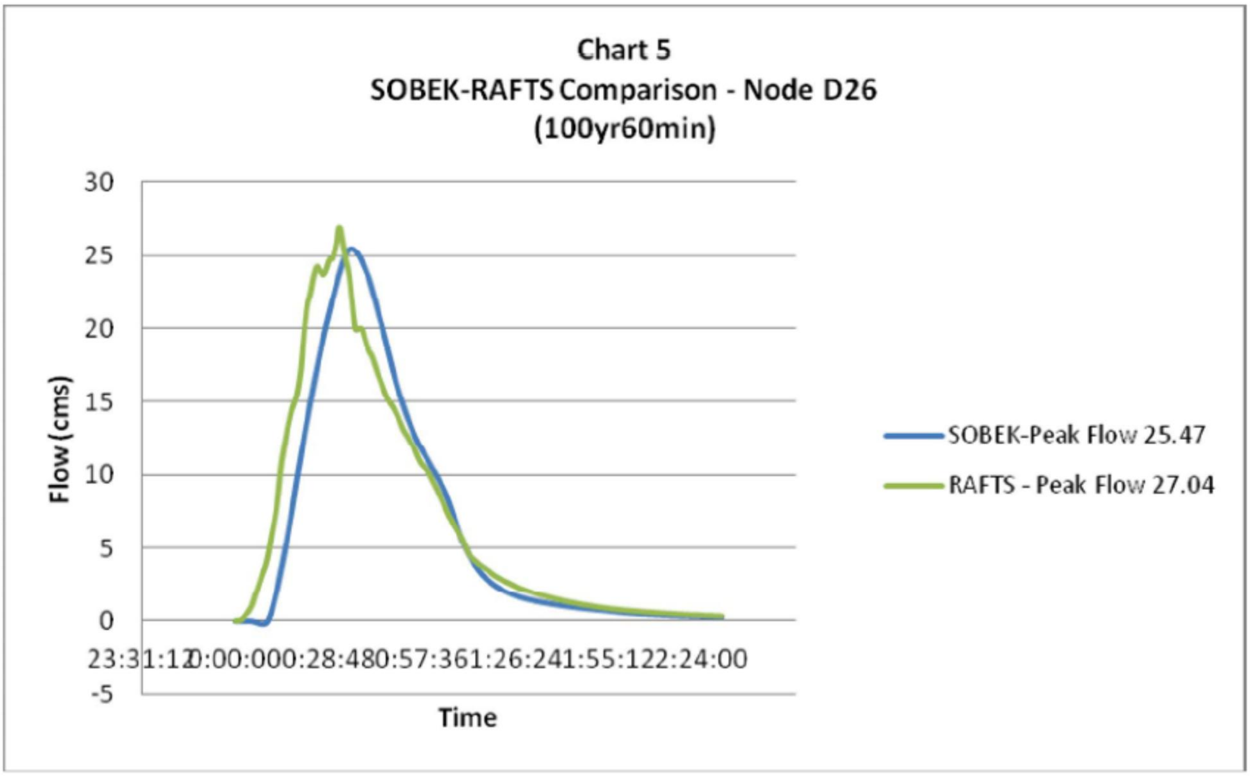


Chart 4
SOBEK-RAFTS Comparison - Node D14
(100yr60min)
Flow (cms)
12
10
8
6
4
2
0
-2
23:31:12
0:00:00
0:28:48
0:57:36
1:26:24
1:55:12
2:24:00
Time
SOBEK-Peak Flow 8.15
RAFTS - Peak Flow 10.2



4.1.3 Incorporating OSD into the Model

On-site detention was initially incorporated into the model for a test sub-catchment only. This allowed the model results to be verified on a small scale to ensure the OSD module was performing appropriately and also allowed a comparison of local effects of OSD compared to regional impacts.

The test sub-catchment is shown in **Figure 4-4**. The test sub-catchment was selected to ensure an appropriate combination of commercial / industrial, residential and road areas. The test sub-catchment has a total area of 13.6 ha which consists of 48% combined commercial and industrial, 35% residential, and 17% road.

As discussed in **Section 2.1.3**, a portion of properties may not feasibly be able to drain to OSD either partially or completely due to site topography. It was determined that those properties with greater than 1.5m fall from the street level would face difficulties draining to OSD. The test catchment was identified to contain approximately 5 percent of the property area within these “downhill” properties. For the purposes of the hydrological assessment, it was assumed that these properties would not contain OSD.

4.1.3.1 High Early Discharge

High early discharge (HED) systems work by routing stormwater runoff into a smaller secondary pit, located inside the OSD system at the location of the control outlet, allowing overflow to spill stormwater runoff to the main OSD storage. The stormwater runoff reaches its peak discharge rate faster as the water in the secondary pit fills up quicker due to the smaller area of the secondary pit. By allowing a greater rate of runoff at the commencement of the storm event the OSD volume to be provided to restrict post development flows back to pre-development levels may be reduced.

All hydrologic modelling was undertaken for scenarios with High Early Discharge (HED) turned on and off. The use of OSD without HED reduces the peak local drainage discharges when compared to OSD with HED.

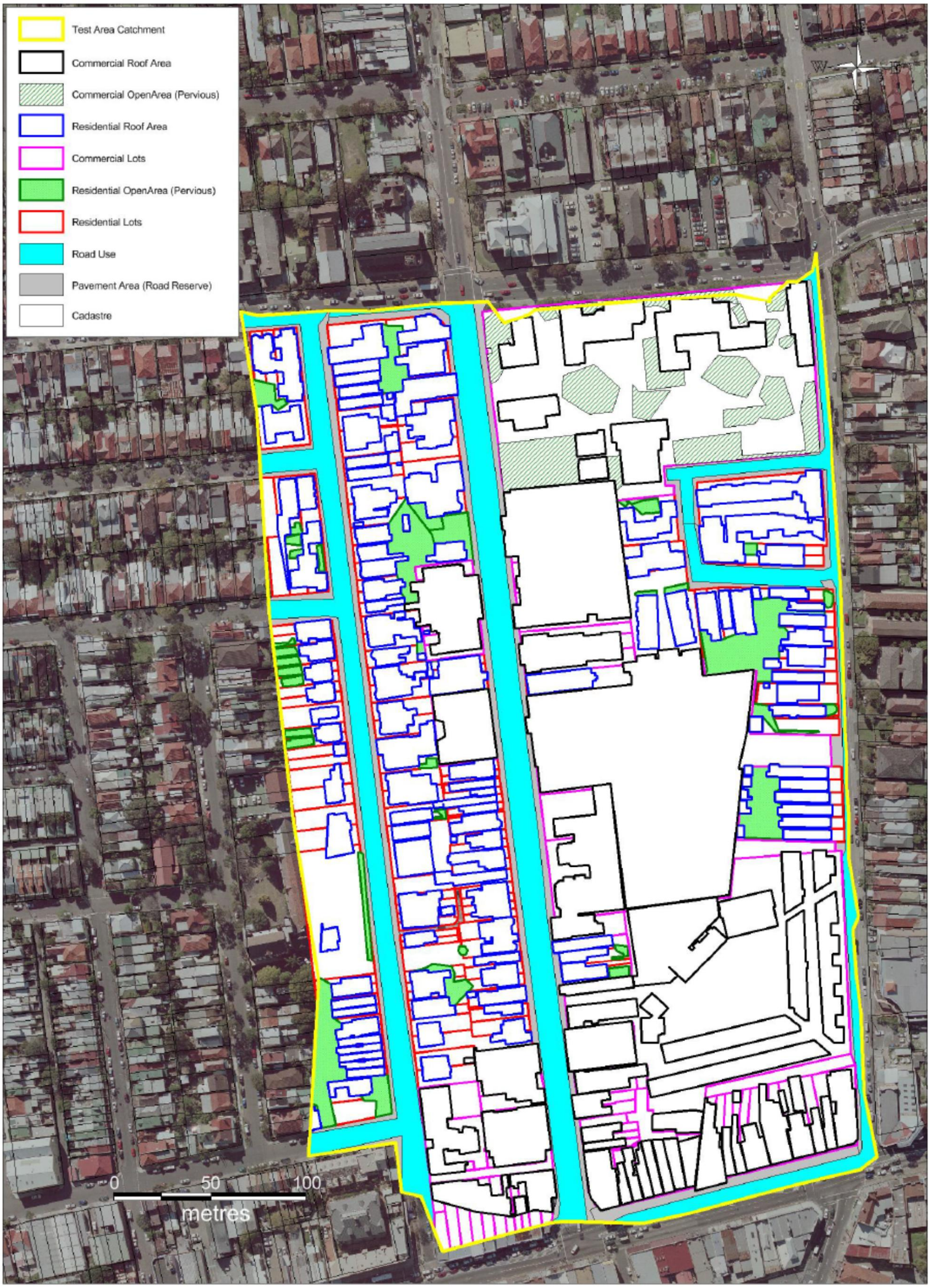


Figure 4-4 Land Use for Test Sub-Catchment

4.2 On-site Detention Scenario Analysis

The hydrological model was utilised to review Council's existing approach to OSD and to assess serval alternative approaches.

The modelling of Council's existing OSD approach involved:

- **Review of Council's current policy with regards to catchment wide flood impacts:** Council's current policy requires the discharge from the site in a 100 Year ARI event (post development) to be equal to the 5 Year ARI pre-development flows from the site. The RAFTS model was utilised to assess the SSR required to achieve this objective for the catchment as a whole.
- **Review of the existing calculation methods in Council's policy:** Council's existing OSD Policy is fairly flexible with regards to the calculation methods employed. This generally results in calculations only accounting for the immediate catchment and therefore assessing a critical duration of likely less than 30 minutes. On average, the existing calculation methods result in an SSR of approximately 2,000 L per lot. The benefits of this storage volume were assessed for the catchment as a whole.

Additional scenarios were then modelled as follows:

- **No OSD in Downstream Portion of Catchment:** Hydrological modelling was undertaken to assess the impacts of not applying OSD to the downstream portions of the Whites Creek Catchment.
- **No OSD on Low Density Residential Development:** While OSD can often more readily be included in commercial, industrial and high density developments, low density (i.e. single lot) residential development can be restricted by lot size and other site constraints such as the ability to excavate for OSD. As such, the impacts of not applying OSD to low density residential development was assessed.
- **Rainwater Tank Offsets for Low Density Residential Development:** The use of rainwater tanks instead of OSD was modelled for all low density residential development across the catchment.

4.3 Results

4.3.1 Review Council's Existing OSD Policy

Council's existing OSD Policy requires post development 100 Year ARI flows to be reduced to 5 Year ARI flows using OSD. The SSR and PSD values required to meet this objective were calculated using the test sub-catchment. The results were then extrapolated across the Whites Creek Catchment to see if the local catchment calculations resulted in the same reductions in flows across the wider catchment.

The test sub-catchment was modelled in RAFTS with no OSD for the 5 year, 20 year, 50 year and 100 year ARI events and each for the 45 minute, 1 hour, 90 minute and 2 hour duration storms. The resulting hydrographs were used to calculate the volume difference between the 100 year and 5 year ARI for the four durations. The results are shown in **Table 4-6**.

Table 4-6 – SSR required for 100 year ARI flows to be reduced to 5 year ARI flows

	45 min	1 hour	90 min	2 hour
SSR (m^3/ha)	256.1	300.4	248.0	229.4

The PSD was calculated using the 5 year ARI peak flow for the four durations since the objective of the OSD was to achieve a 5 year ARI flow from a 100 year ARI flow. The peak flows were then divided by the area of the representative sub-catchment. The results are presented in **Table 4-7**.

Table 4-7 – PSD required for 100 year ARI to fall to a 5 year ARI

	45 min	1 hour	90 min	2 hour
5yr Peak Flow (m^3/s)	3.7	4.1	4.3	4.0
PSD (L/s/ha)	353.4	384.2	409.1	374.0

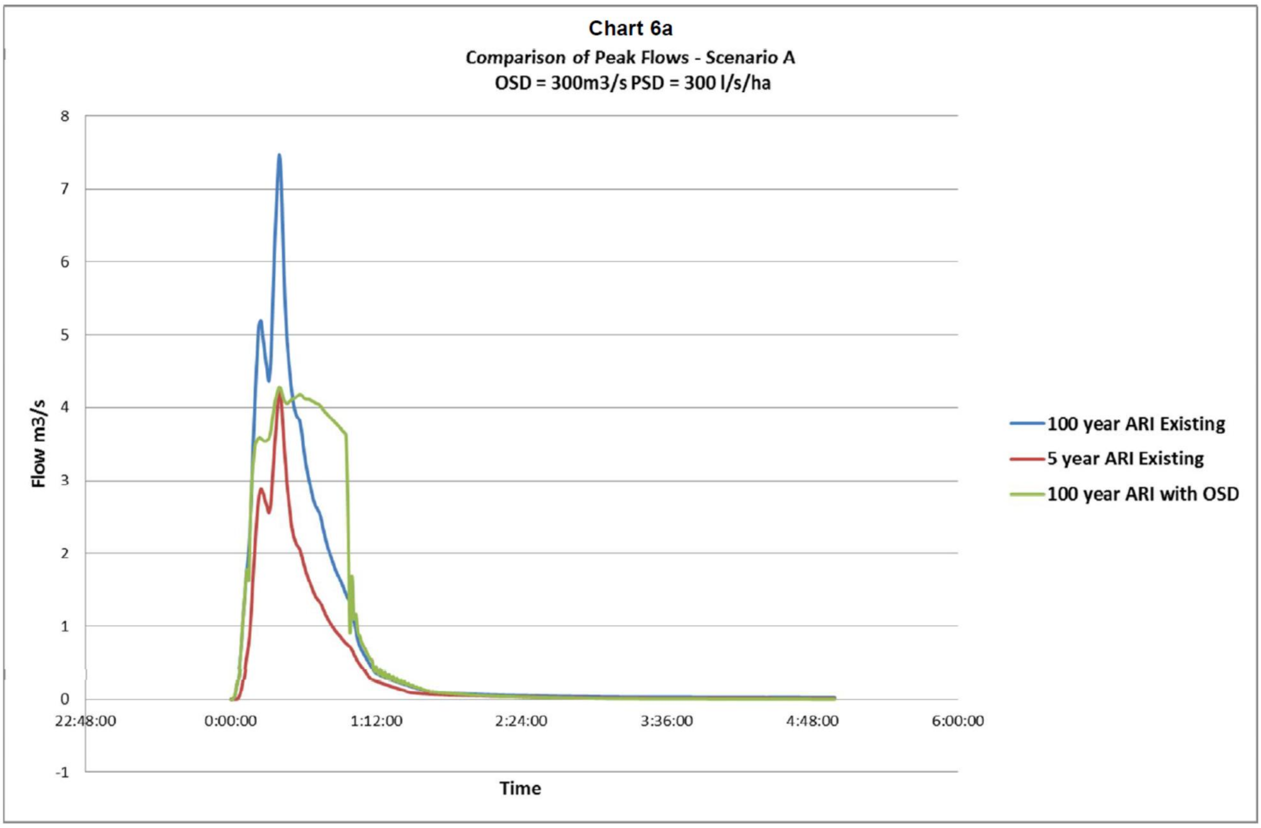
The critical duration for the test sub-catchment is 1 hour. Therefore, the following 1 hour SSR and PSD values were used as initial estimates for the OSD modelling in RAFTS:

- SSR = 300 m3/ha
- PSD = 384 l/s/ha

The above values were then refined and verified for the local test sub-catchment using RAFTS. The updated SSR and PSD requirements are:

- SSR = 300 m3/ha
- PSD = 300 l/s/ha

The updated estimates reduced the 100 year ARI flow for the 1 hour duration to the 5 year ARI flow in the representative catchment modelled in RAFTS. The hydrograph for Scenario A is depicted in **Chart 6a**.



The OSD parameters were then applied to the Whites creek catchment. Charts 6b to 10 depict the comparison of the flows with and without OSD for the nodes in **Table 4-5**.

It was found that while the OSD parameters calculated for the test sub-catchment were effective for the local catchment, the larger the contributing catchment became, the less effective the same OSD parameters were. At the catchment outlet (i.e. the most downstream point), there is almost no resulting difference in the peak flows as a result of OSD.

Some testing was also undertaken for large SSR requirements. However, very little difference in the results was observed.

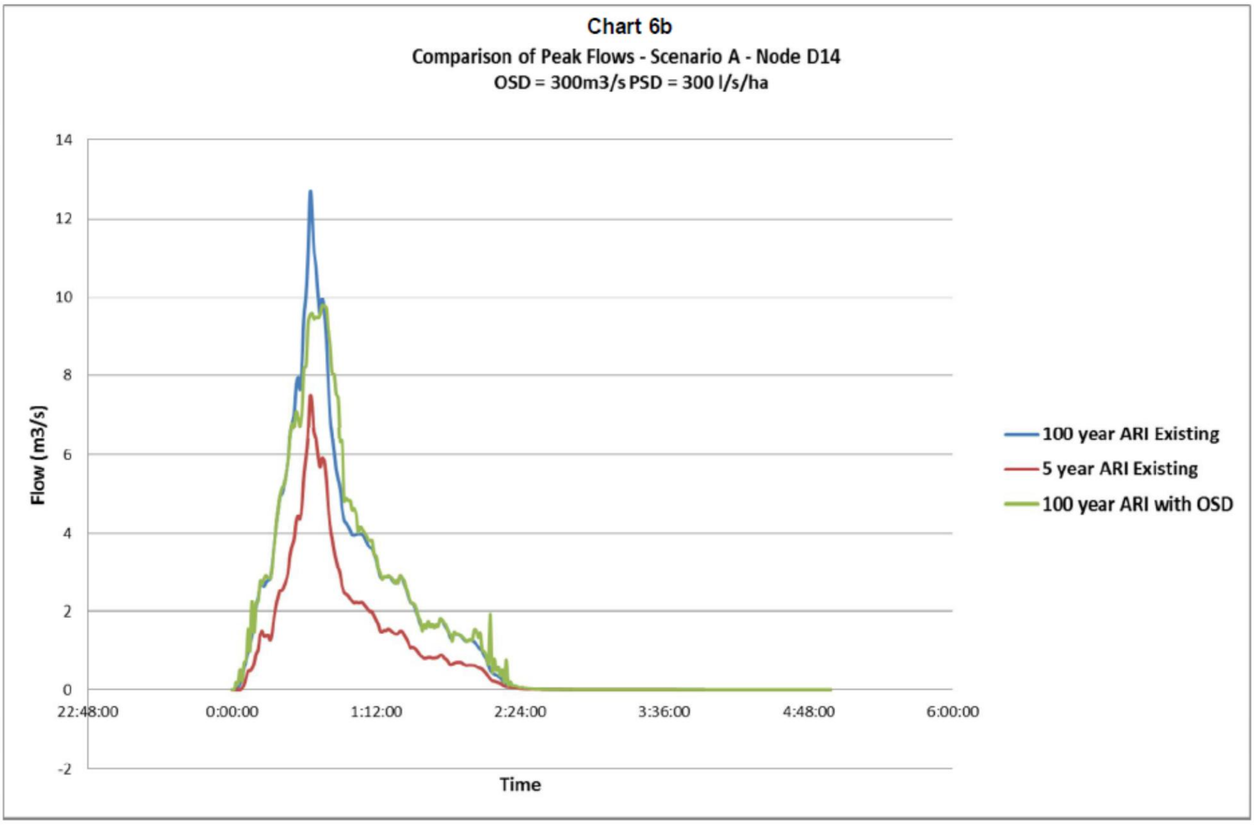


Chart 6b
Comparison of Peak Flows - Scenario A - Node D14
OSD = 300m3/s PSD = 300 l/s/ha
Flow (m3/s)
14
12
10
8
6
4
2
0
-2
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD

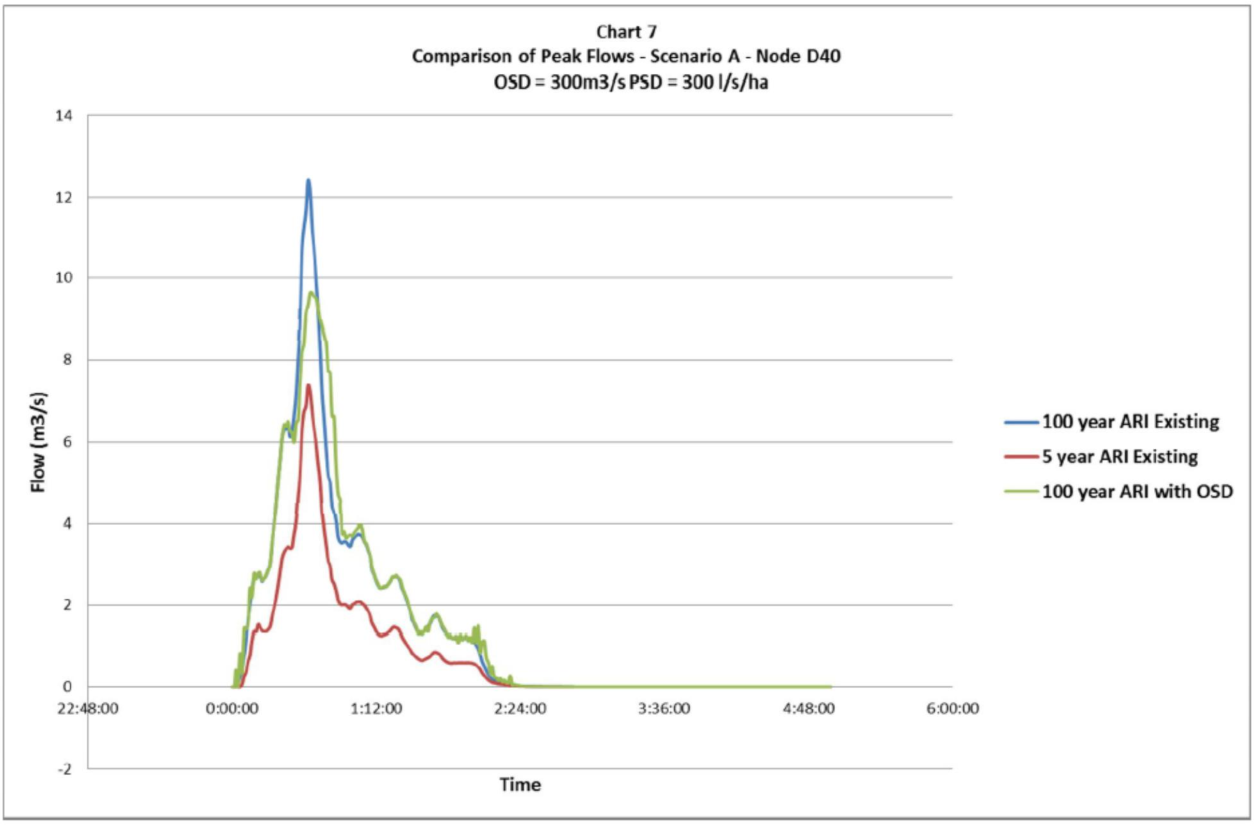


Chart 7
Comparison of Peak Flows - Scenario A - Node D40
OSD = 300m3/s PSD = 300 l/s/ha
Flow (m3/s)
14
12
10
8
6
4
2
0
-2
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD

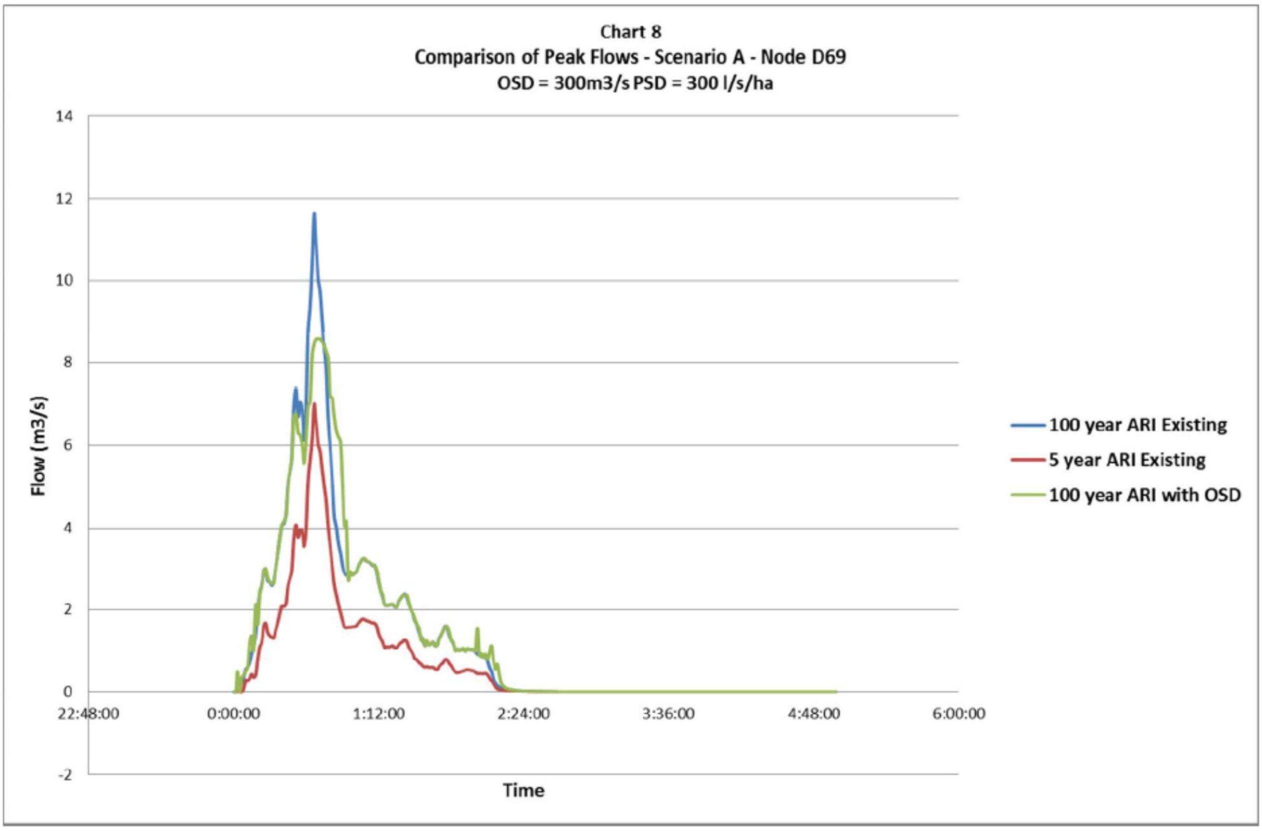


Chart 8
Comparison of Peak Flows - Scenario A - Node D69
OSD = 300m3/s PSD = 300 l/s/ha
Flow (m3/s)
14
12
10
8
6
4
2
0
-2
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD

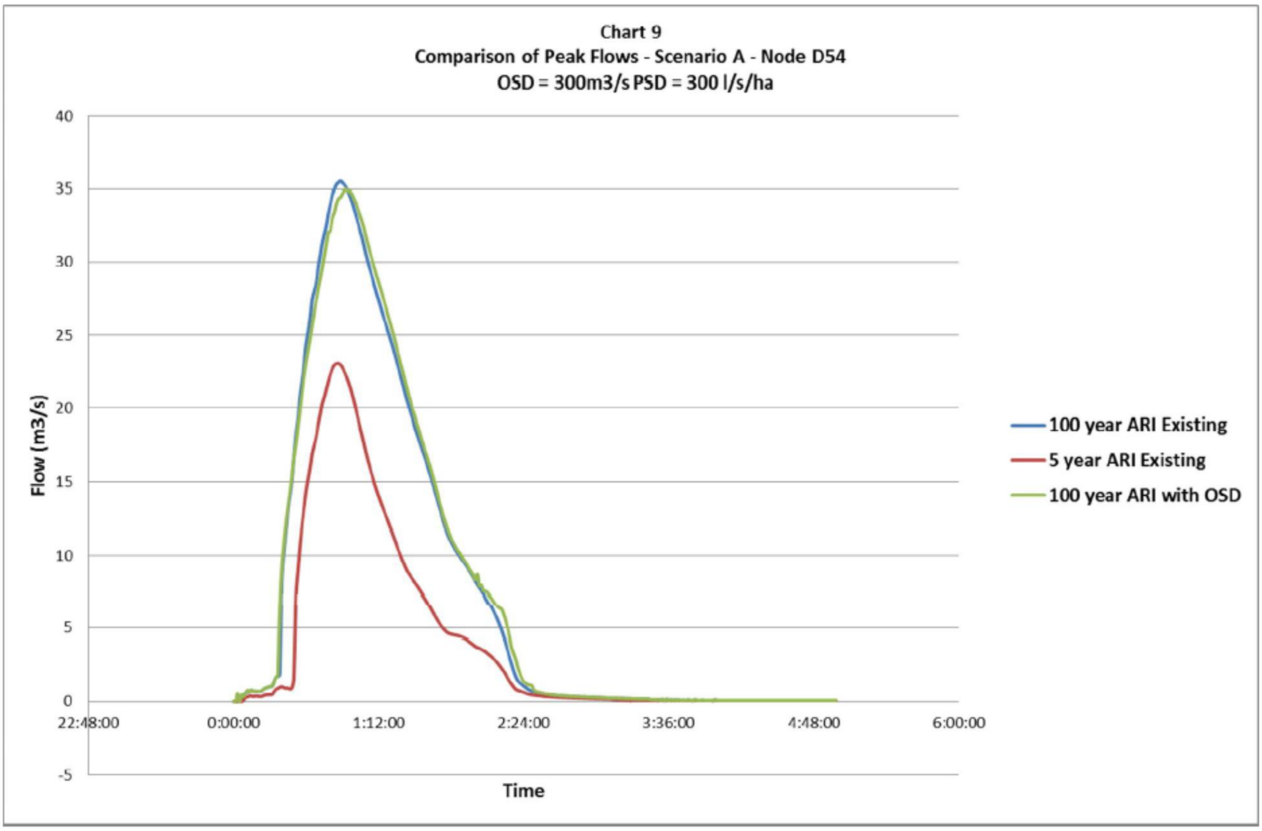
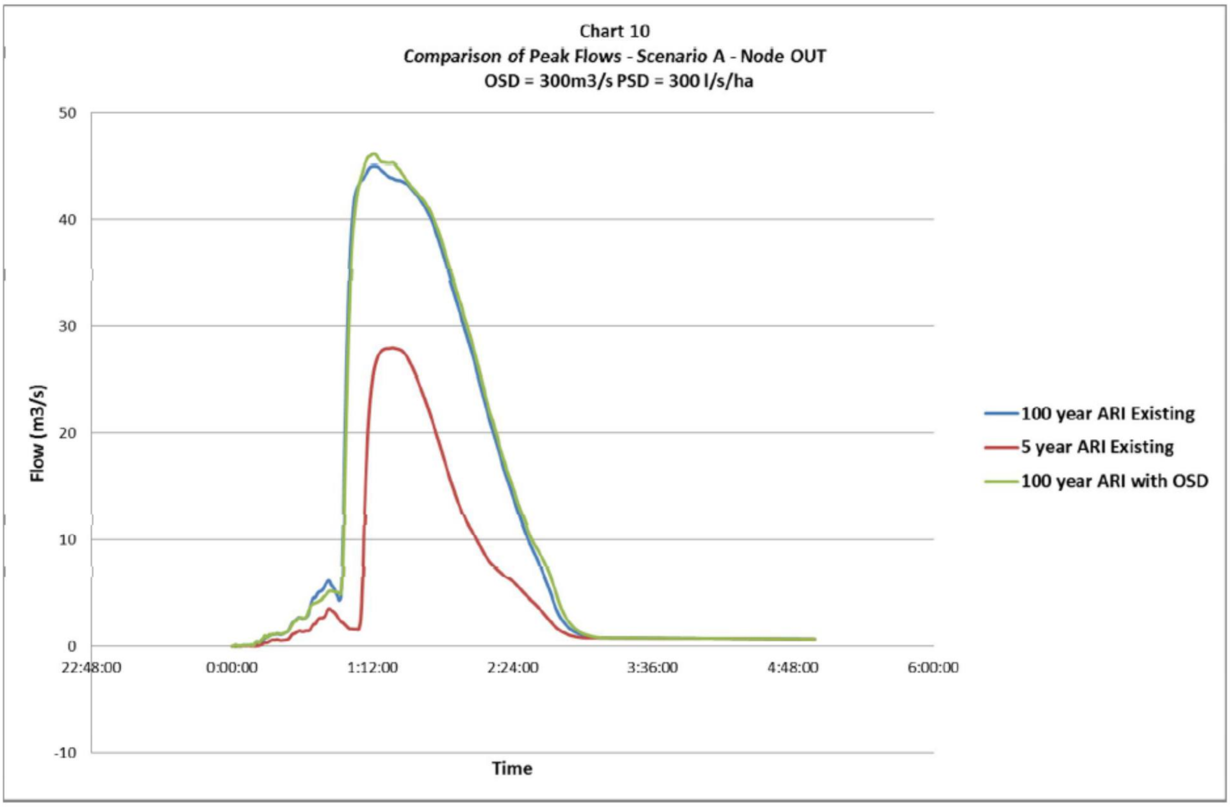


Chart 9
Comparison of Peak Flows - Scenario A - Node D54
OSD = 300m3/s PSD = 300 l/s/ha
Flow (m3/s)
40
35
30
25
20
15
10
5
0
-5
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD



4.3.2 Review of the existing calculation methods in Council's policy

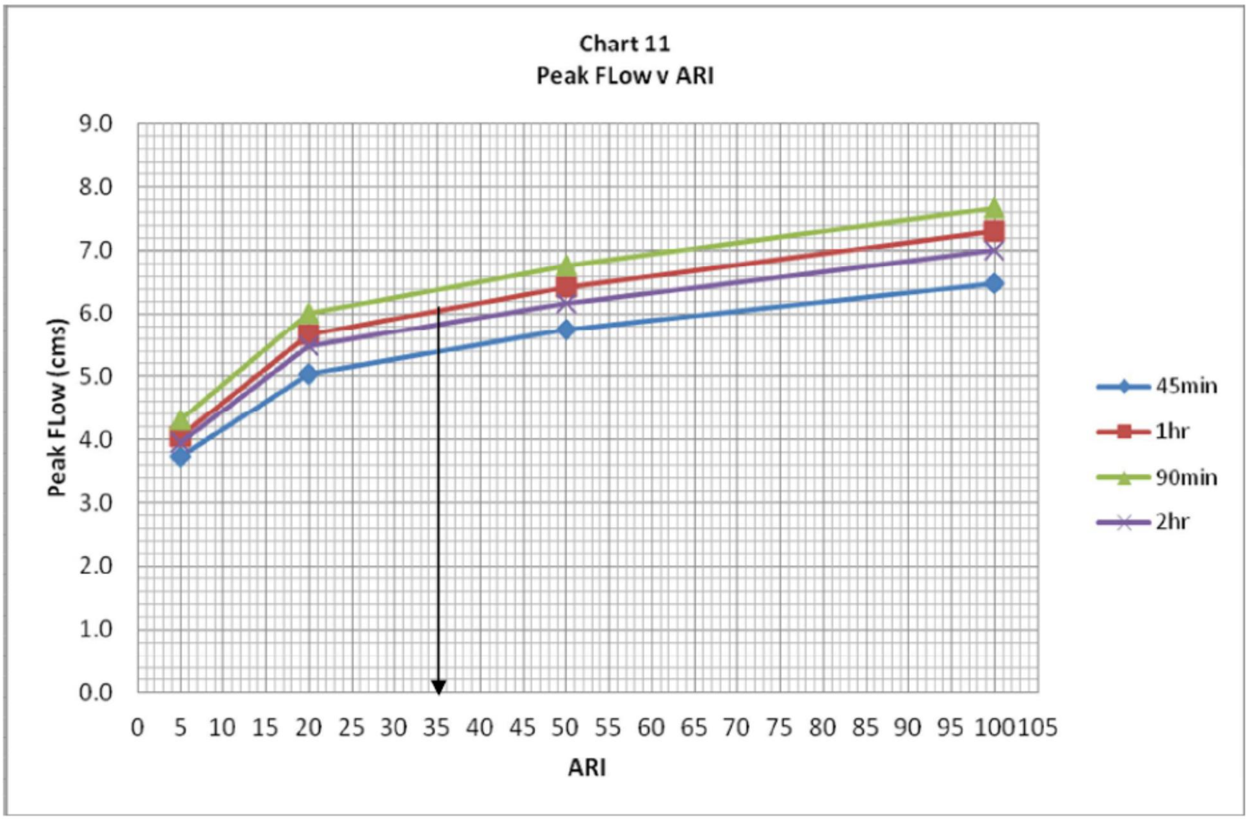
Council has advised that the existing calculation methods generally result in an approximately SSR of 2,000 L/lot. This equates to approximately 68 m^3/ha. This is significantly less than the SSR calculated above. This is likely to be due to the fact that in the absence of any specifications, calculations have generally been done for the immediate catchment only resulting in the application of a short critical duration (likely to be less than 30 minutes). The critical duration for the catchment is generally greater than 1 hour. This would result in a significantly smaller volume of rainfall being assessed for OSD application.

The existing policy was tested for the test sub-catchment within a spreadsheet and RAFTS. The policy was then also applied across the Whites Creek Catchment.

The test sub-catchment has a peak flow of 7.5 m^3/s for the 100 year ARI, 1 hour duration under existing conditions. The peak flow with a SSR of 68 m^3/s was 6.01 m^3/s for the same hydrograph. The reduction in peak flow shows that the OSD has some effect on the 100 year ARI. In order to determine the effectiveness of the OSD (SSR = 68 m^3/s a Peak Flow v ARI chart (Chart 11) was utilised. Chart 11 was plotted by extracting the peak flow data of the representative catchment (Table 4-8).

Table 4-8 Peak Flows

ARI	45min Peak Flow (m^3/s)	1hr Peak Flow (m^3/s)	90min Peak Flow (m^3/s)	2hr Peak Flow (m^3/s)
5	3.7	4.1	4.3	4.0
20	5.0	5.7	6.0	5.5
50	5.7	6.4	6.8	6.2
100	6.5	7.3	7.7	7.0



The equivalent ARI for the peak flow of 6.01 m^3/s was 35 Year ARI for the one hour duration. This identifies that the SSR of 68 m^3/s was not able to reduce the 100 year ARI flow to a 5 year ARI flow for the test subcatchment. Instead, the SSR only achieved a 35 year ARI flow.

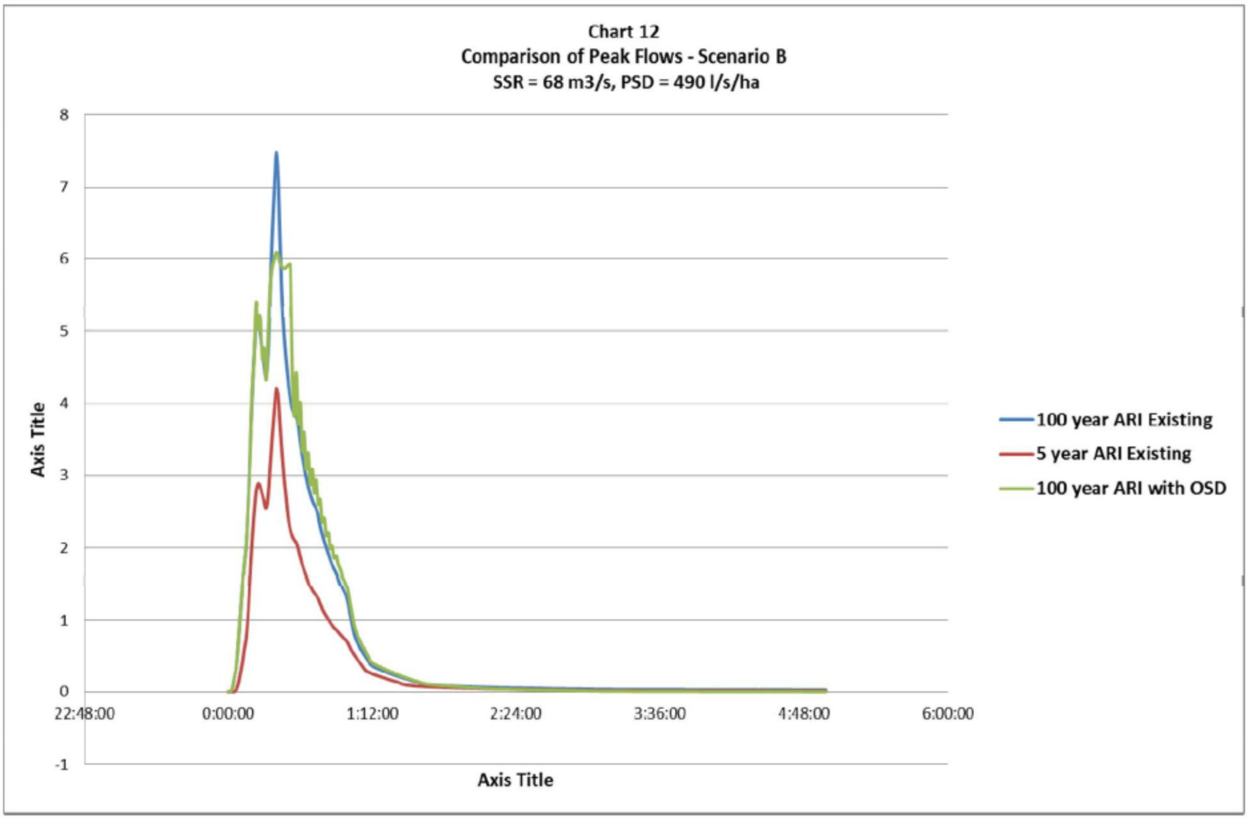
Based on a peak flow of 6.01 m^3/s and the area of the test sub-catchment and the SSR estimated by Council, the following initial SSR and PSD values were identified:

- SSR = 68 m^3/ha
- PSD = 569 l/s/ha

The above values were then refined and verified for the local test sub-catchment using the RAFTS model to achieve the 35 Year ARI flows. The updated SSR and PSD requirements are:

- SSR = 68 m^3/ha
- PSD = 490 l/s/ha

Chart 12 shows the comparison of peak flows (extracted from RAFTS) for the representative catchment area for the 100 Year Ari flows without OSD, the 100 Year ARI flows when an SSR of 68 m^3/ha is applied (i.e. approximately 2,000L per lot) and the 5 Year ARI flows without OSD (Council's Policy Objective).



The OSD parameters were then applied to the Whites Creek Catchment. It was found that OSD was effective for the local catchment but ineffective in the global catchment. **Charts 14 to 18 depict** the existing to OSD comparison for the nodes in **Table 4-5** excluding node 26. The charts depict that the existing OSD policy is inadequate for the local and global catchments.

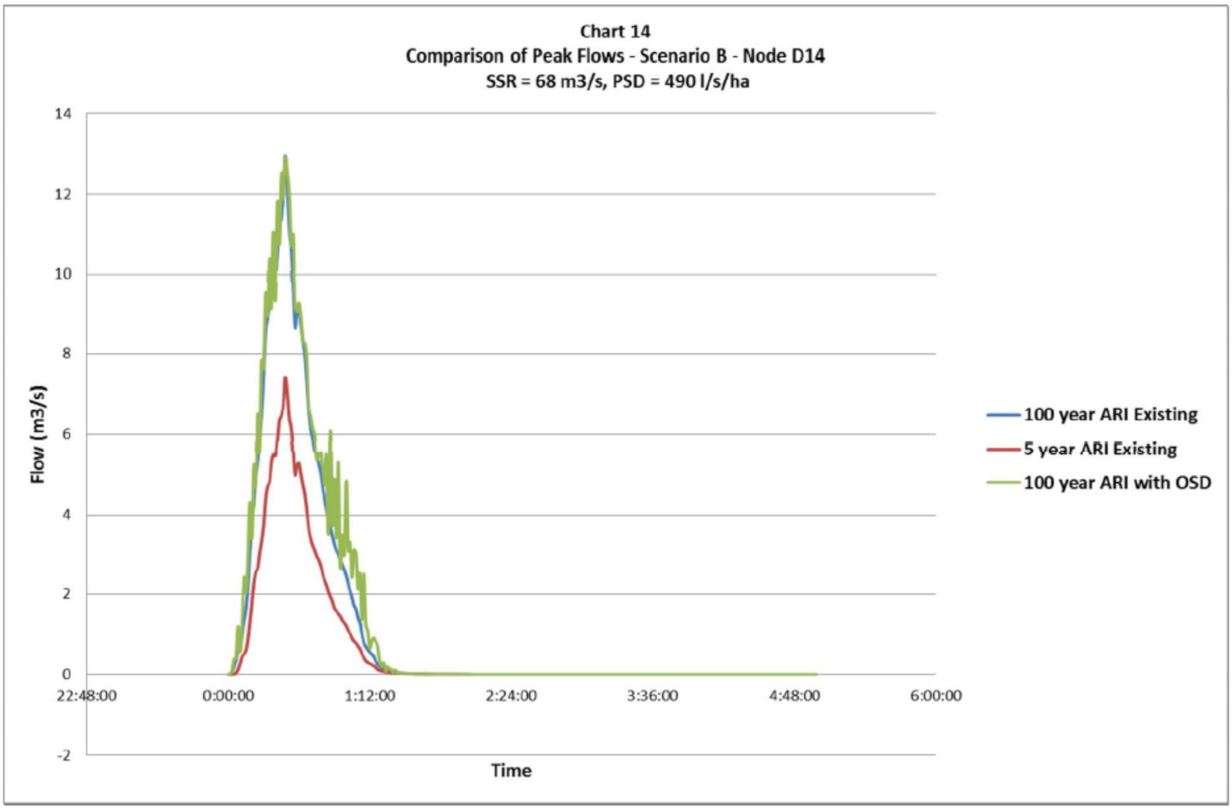


Chart 14
Comparison of Peak Flows - Scenario B - Node D14
SSR = 68 m3/s, PSD = 490 l/s/ha
Flow (m3/s)
14
12
10
8
6
4
2
0
-2
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD

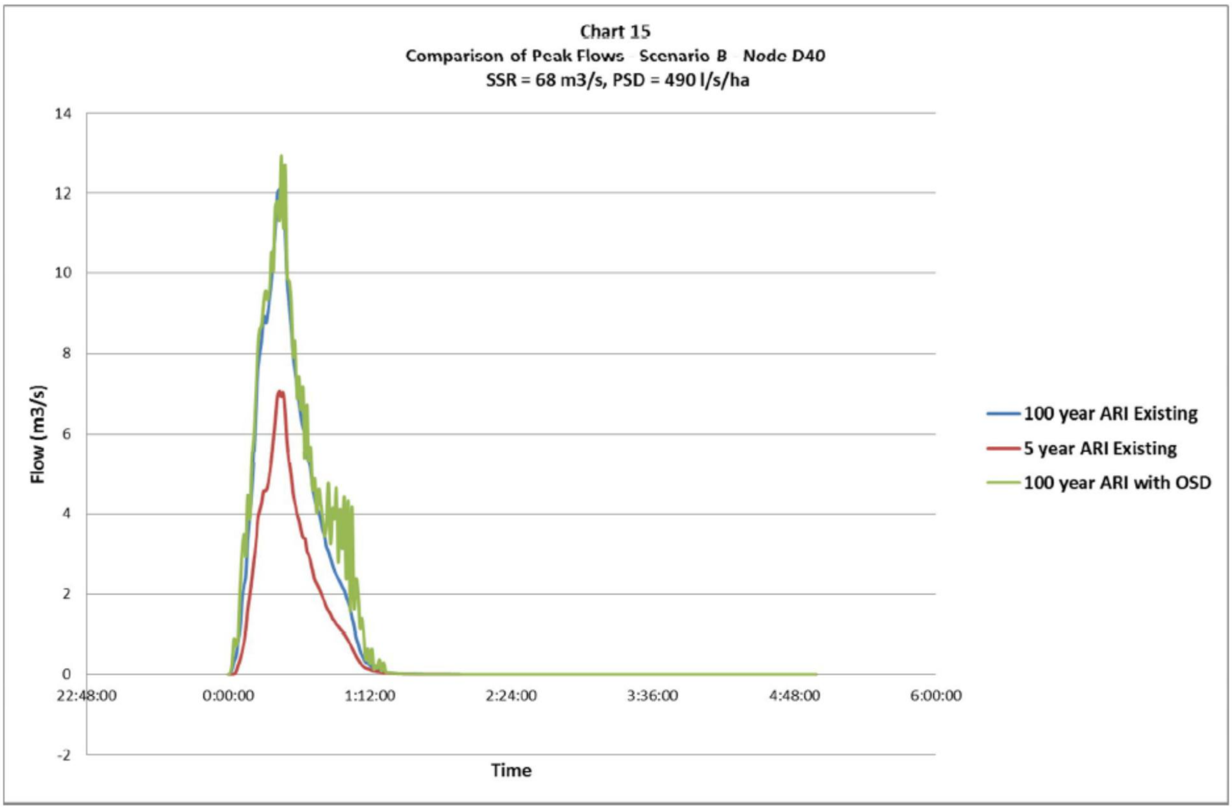


Chart 15
Comparison of Peak Flows - Scenario B - Node D40
SSR = 68 m3/s, PSD = 490 l/s/ha
Flow (m3/s)
14
12
10
8
6
4
2
0
-2
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD

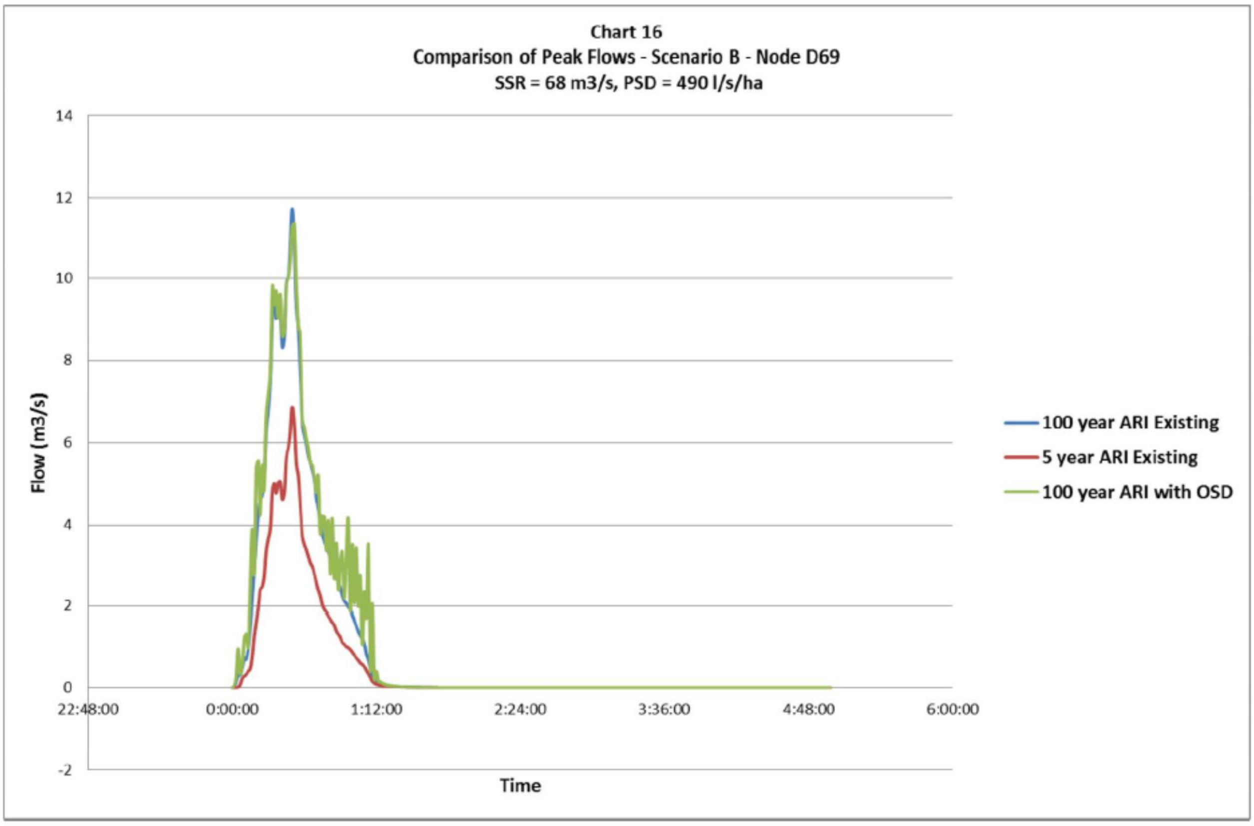


Chart 16
Comparison of Peak Flows - Scenario B - Node D69
SSR = 68 m3/s, PSD = 490 l/s/ha
14
12
10
8
6
4
2
0
-2
Flow (m3/s)
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD

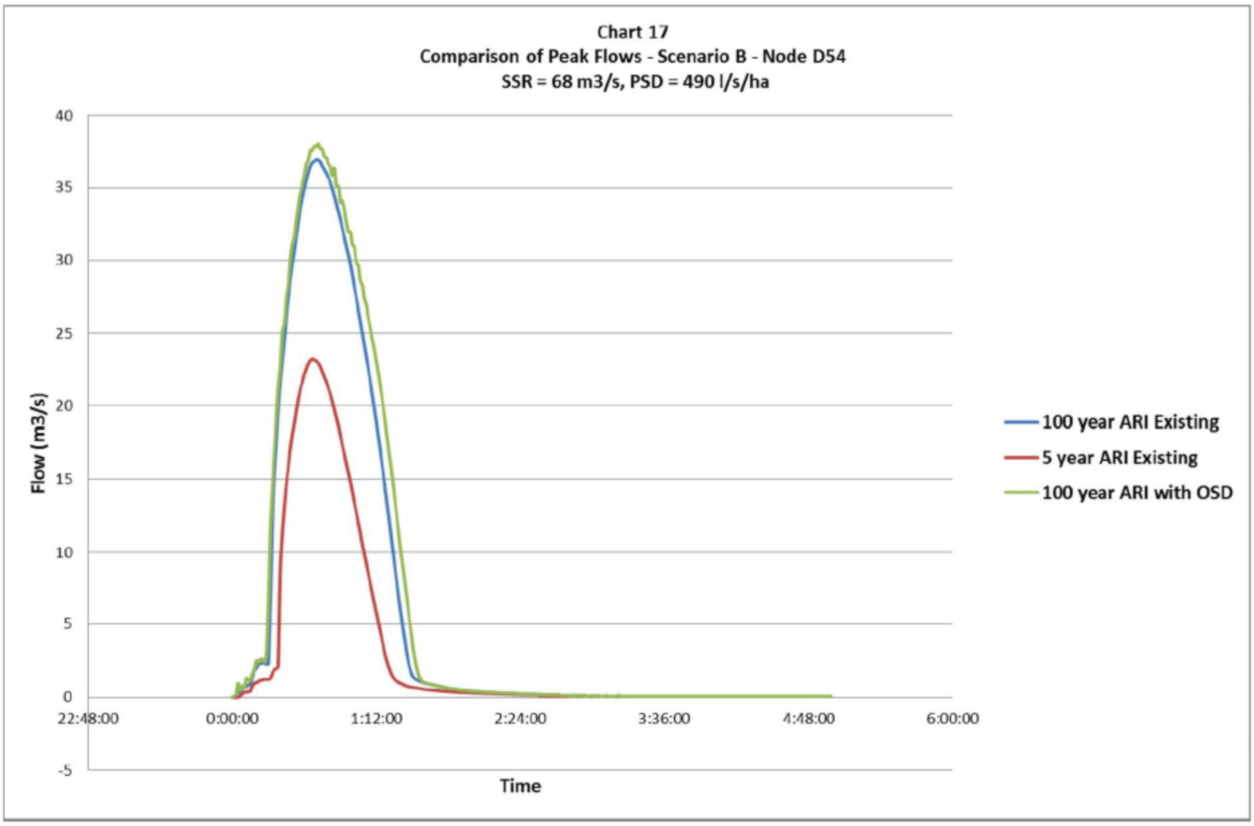


Chart 17
Comparison of Peak Flows - Scenario B - Node D54
SSR = 68 m3/s, PSD = 490 l/s/ha
40
35
30
25
20
15
10
5
0
-5
Flow (m3/s)
22:48:00
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
Time
100 year ARI Existing
5 year ARI Existing
100 year ARI with OSD

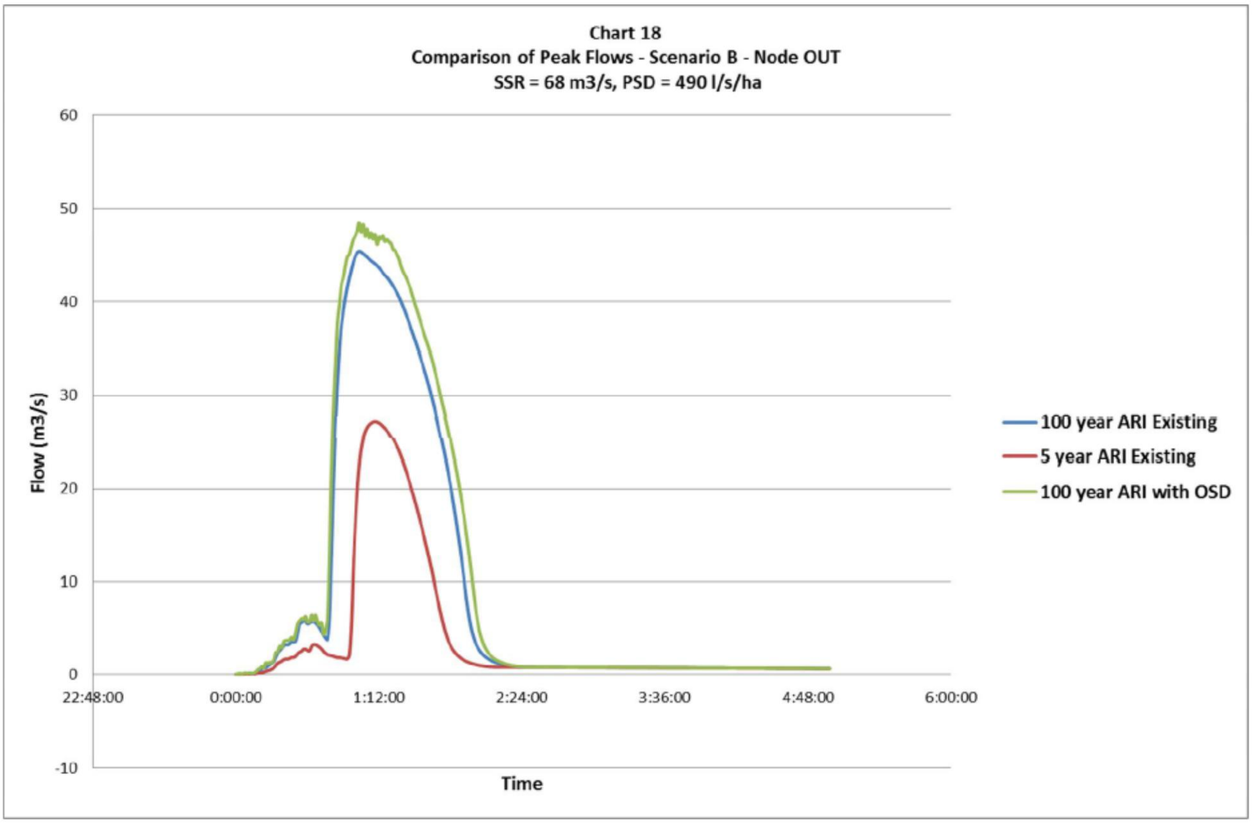


Table 4-9 gives a summary of the peak flows for the different scenarios for the representative catchment.

Table 4-9 – Summary of the Peak flow for the Different scenarios for the representative Catchment (RAFTS)

	Existing – 100year Peak Flow	Existing – 5year Peak	Scenario A Peak Flow	Scenario B Peak Flow
Flow (m3/s)	7.4 7	4.21	6.09	4.20

4.3.3 Downstream OSD Exclusion Zones

The modelling identified that applying OSD had benefits at a small scale but there were limited benefits at the downstream end of the catchment. Exclusion zones for OSD can be applied where the implementation of OSD has negligible benefits or in some cases, actually worsens flooding. For example, it may be beneficial to allow the flows in the downstream portions of the catchment to be discharged prior to the flows from the upstream areas “coming through”. By detaining the local flows in the downstream areas, the flood peaks may actually end up coinciding with other catchment flows, thereby resulting in increased flood levels or durations of flooding.

Hydrological modelling was undertaken to assess the impacts of not applying OSD to the downstream portions of the Whites Creek Catchment. OSD was not applied downstream of Node C73 (see **Figure 4-1)**.

The following OSD parameters were modelled in the upstream areas:

- SSR = 300 m3/ha
- PSD = 300 l/s/ha

The results for both the OSD applied across the whole catchment and OSD removed from the exclusion zones are shown in **Figures 4-5 and 4-6**.

The results indicate that there is very little difference in flood behaviour within the 100 Year ARI flood extent when comparing the application of OSD in the exclusion zones and without OSD in these zones. The small difference that is shown should be interpreted within the context of the limitations of the hydrological modelling. As such, the difference is not considered to be of likely significance.

Although the flood behaviour is not impacted within the 100 Year ARI flood extent, there are local benefits to applying OSD within the exclusion zone. This may include management of property flows to the street, reduced ponding depths on roads and public areas and general reduced likelihood of drainage issues.

4.3.4 No OSD on Low Density Residential Development

While OSD can often more readily be included in commercial, industrial and high density developments, low density (i.e. single lot) residential development can be restricted by lot size and other site constraints such as the ability to excavate for OSD. As such, the impacts of not applying OSD to low density residential development was assessed.

The following OSD parameters were applied:

- Low density (i.e. single lot) residential development: no OSD or OSR
- All other development type: SSR = 300 m^3/ha and PSD = 300 L/s/ha

The results are shown in **Figure 4-7**, this should be compared against **Figure 4-5** to interpret the impact of this scenario on drainage and flood flows. The model results showed that due to the fact that the majority of land use in the catchment is low density residential development, the lack of OSD on these properties resulted in almost no reduction in flood flows across the catchment.

4.3.5 Hydrological Testing of Rainwater Tank Offsets

The research currently available regarding the use of rainwater tanks for OSD suggests that there are considerable opportunities for providing OSD offsets in traditional rainwater tanks.

Council has in the past allowed a rainwater tank offset of 2.5 OSR : 1 OSD. The effectiveness of this approach was tested by reducing the OSD for all lots by 1m^3 and applying a rainwater tank volume of 2,500 L (2.5m^3). The results are shown in **Figure 4-8**. This should be compared against **Figure 4-5** to interpret the impact of this offset scenario has on drainage flows and flood flows. It was found that this significantly reduced the effectiveness of OSD, with the 100 Year ARI Flows in the upstream reaches being reduced to approximately 50 Year ARI flows.

An alternative approach was then assessed as follows:

- OSD was applied to all development except low density (i.e. single lot) residential development at the following rate:
    - SSR = 300m^3/ha and PSD = 300 L/s.
- OSR was applied to all low density (i.e. single lot) residential development, using 5,000 L/lot.

In both of the scenarios above, it has been assumed that the same rainwater tank policy has been applied upstream of the study boundary (i.e. upstream of Parramatta Road).

The results are shown in **Figure 4-9**. This should be compared against **Figure 4-5** to interpret the impact of this offset scenario has on drainage flows and flood flows. The results identified that while the flood management outcomes are not as beneficial as applying OSD to all development types, there is still a flood benefit from this approach (reductions of the 100 Year ARI flows to approximately 20 Year ARI flows in the upstream reaches of the floodplain).

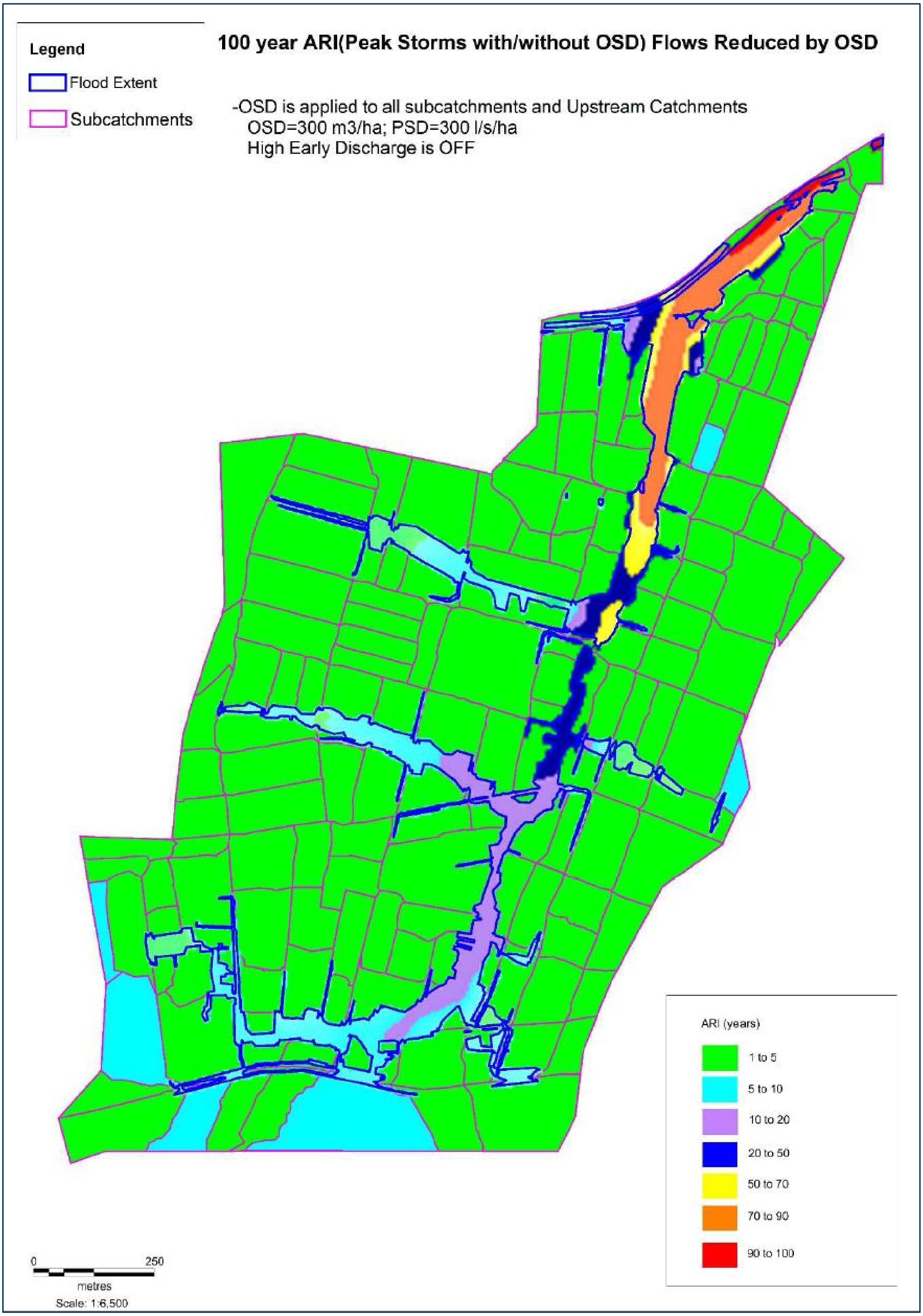


Figure 4-5 OSD Applied to Entire Catchment

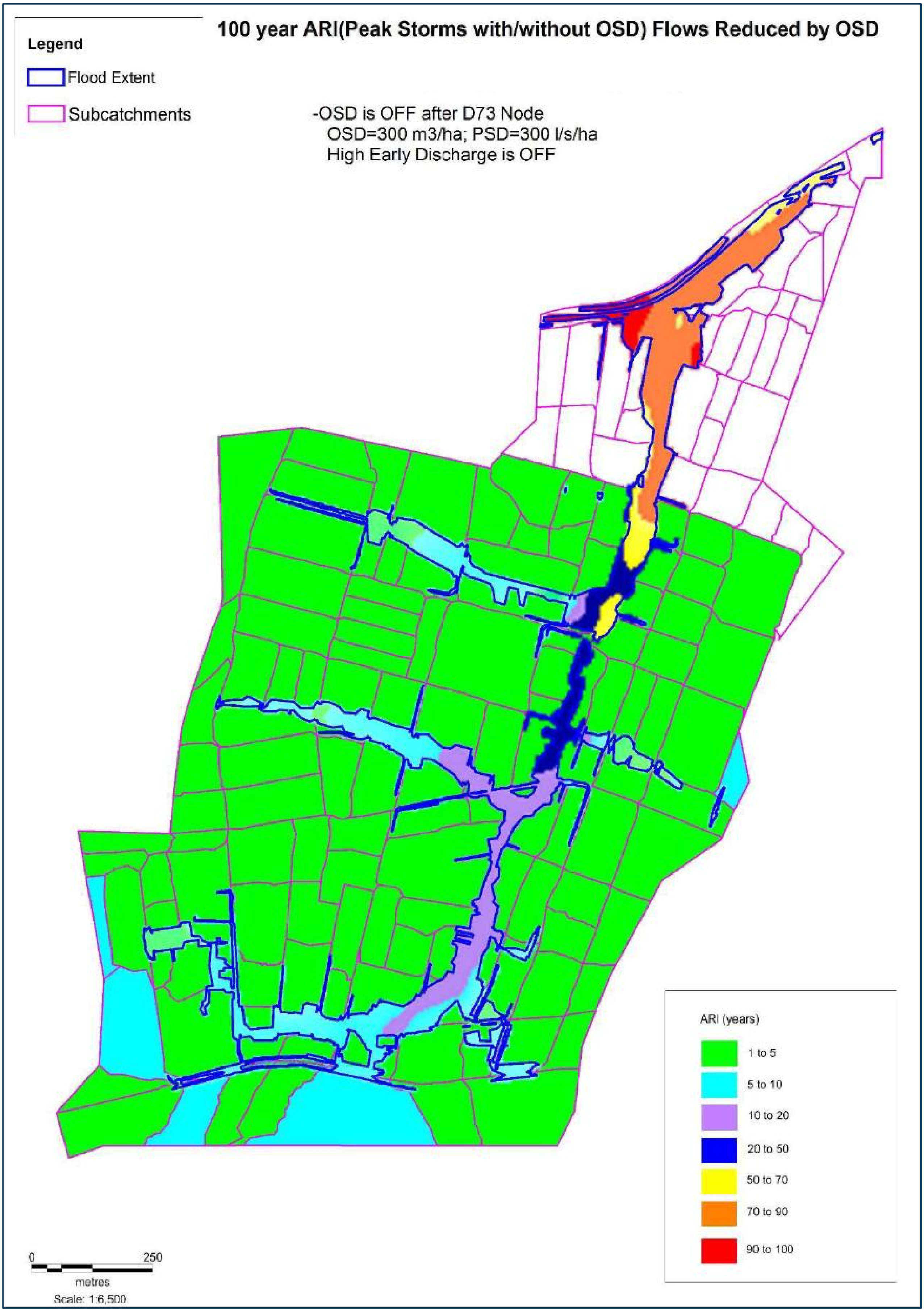


Figure 4-6 OSD not Applied in Exclusion Zones

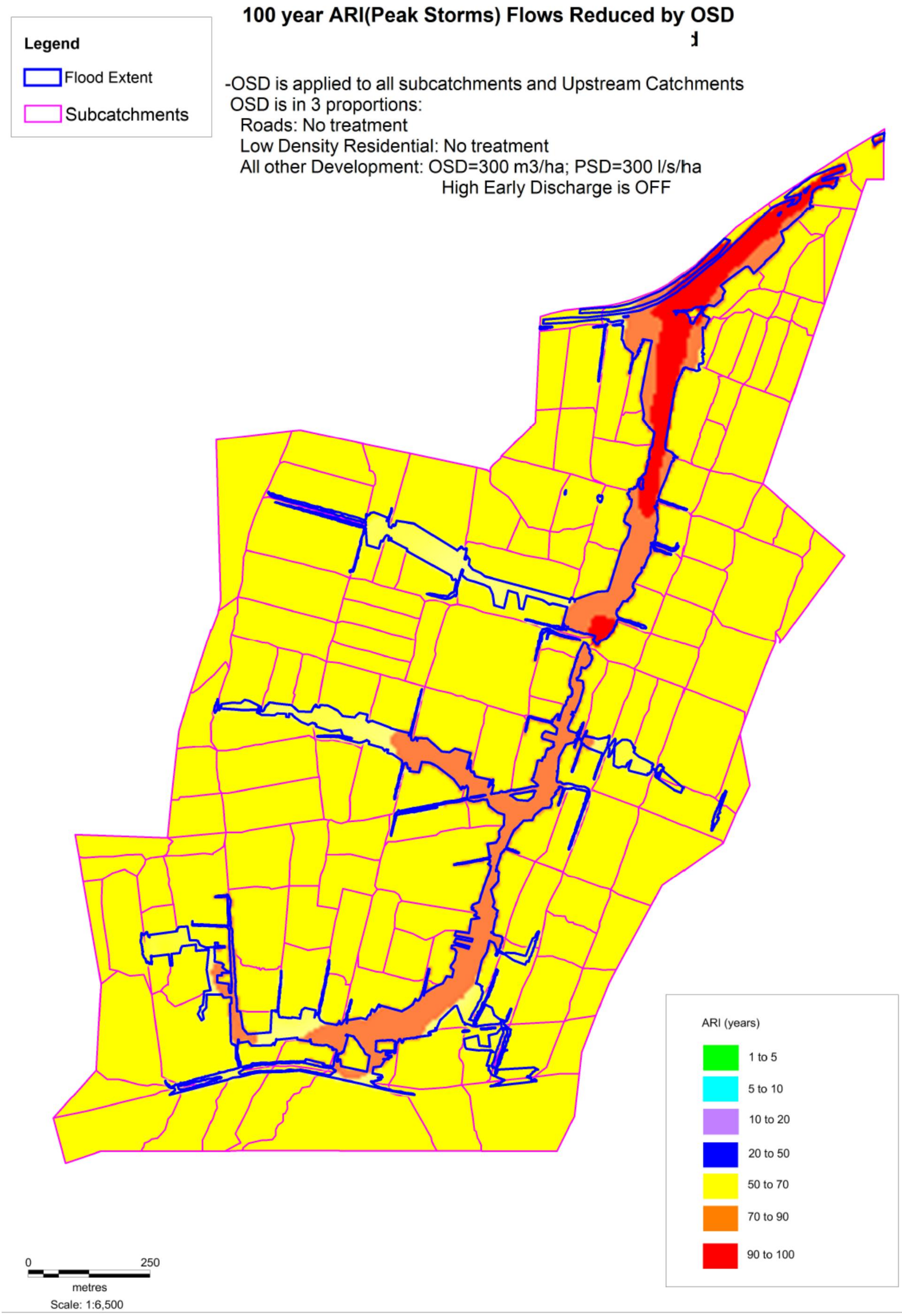


Figure 4-7 No OSD on Low Density Residential Development

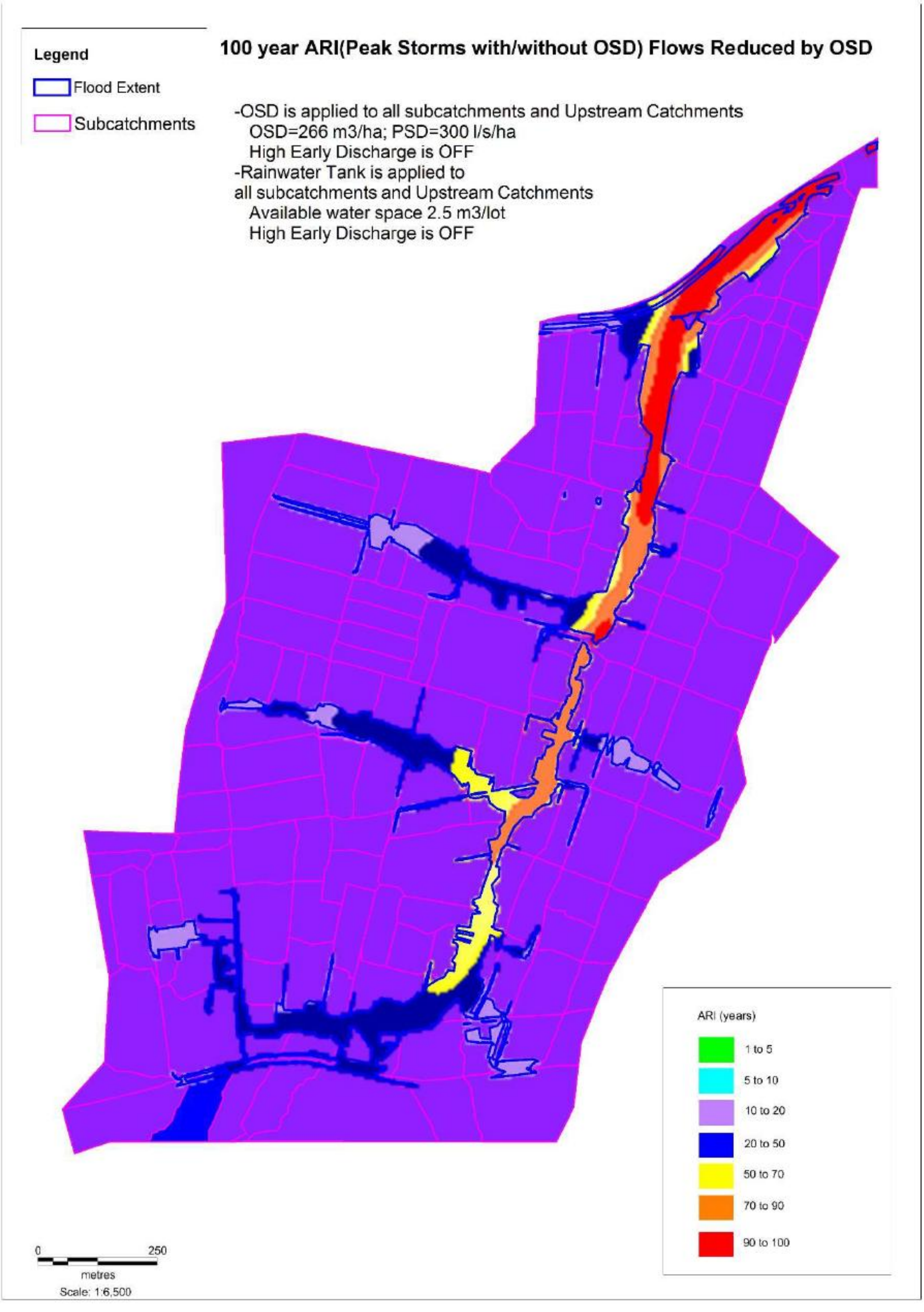


Figure 4-8 Testing 2,500L Rainwater Tank Offset for OSD

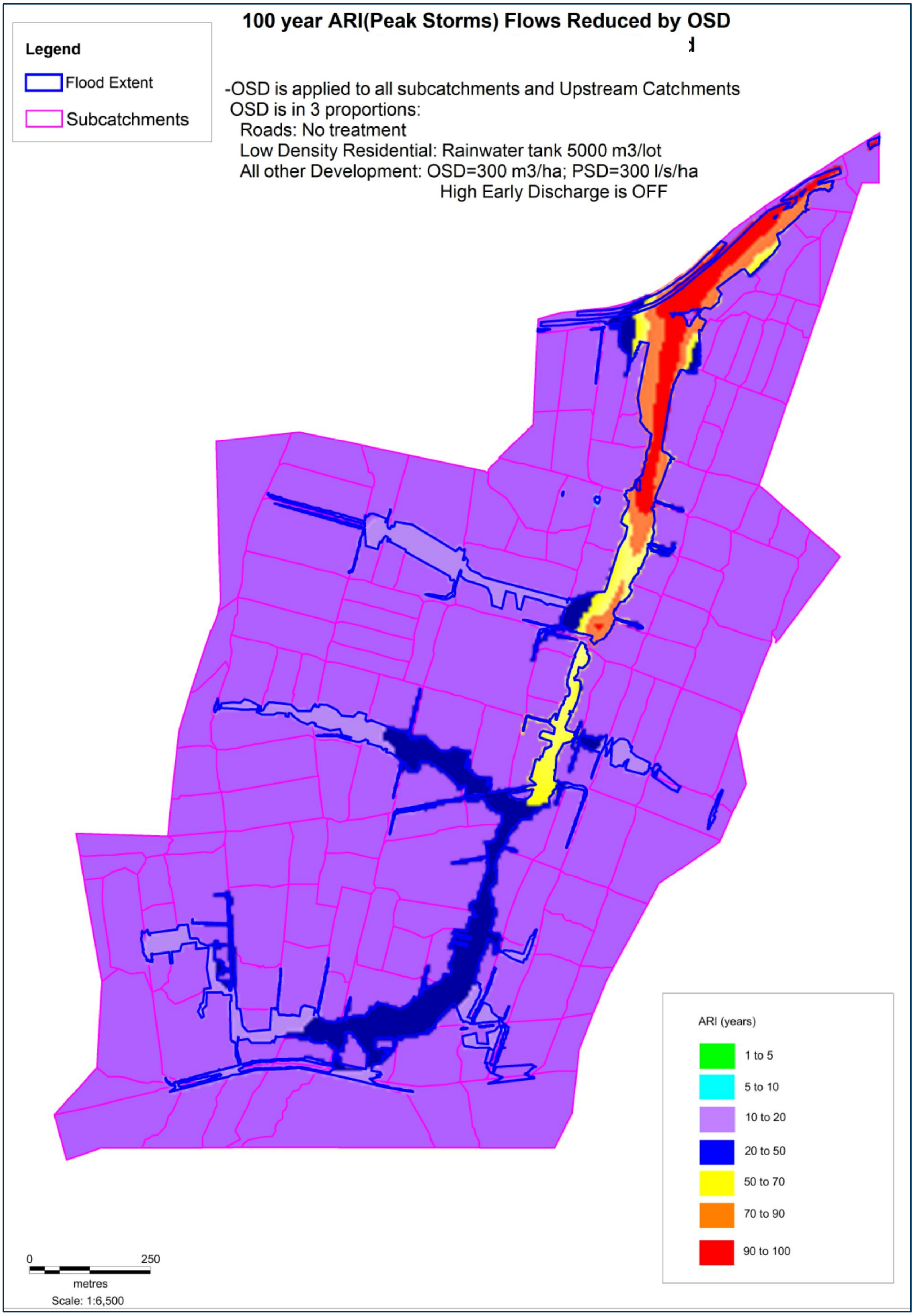


Figure 4-9 Testing 5,000L Rainwater Tank for Low Desnrity Residential

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