Assessing Directly Connected Impervious Areas in Residential Subdivisions in Western Sydney, NSW

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Key Points

- Industry Guidelines such as ARR 2016 recommend the use of Effective Impervious Area or Directly Connected Impervious Area (DCIA)
- Research to date has been based on catchments that have a lower lot density than subdivision currently under development in Western Sydney. There is need for DCIA values that are suited to the increasing lot densities.
- Cardno has undertaken an assessment of DCIA for subdivisions presently under construction in Western Sydney.
- It was found that the estimated DCIA was significantly lower than the TIA specified from Local Government design guidelines. This suggests that stormwater infrastructure designed using TIA is oversized.

Abstract

Research shows that use of Total Impervious aAea leads to the over-estimation of runoff volumes. However, newer residential catchments have a much higher lot density than the research catchments. Therefore there is a need for data for Directly Connected Impervious Areas (DCIA) on current subdivisions.

As a step towards addressing the lack of impervious area data for current subdivisions a detailed evaluation was undertaken of DCIA for five residential subdivisions in four different Local Government Areas in Western Sydney. The results were compared with the guidance given in the respective Council guidelines. It is was found that the DCIA estimates are significantly lower than TIA in the Council guidelines.

Keywords

Directly Connected Impervious Area. DCIA, ICIA

Introduction

A few decades ago stormwater design was only about conveying the peak flows from larger storms. Detention only considered those flows the 100 year ARI flows. Times have changed and the momentum is building towards a more holistic approach to stormwater management. The design of these new methods of stormwater management depends on the calculation of runoff volume, not just peak flows.

Building momentum requires us not only to adopt new ways of managing stormwater, but also to ensure the parameters we use are based on the latest available research. Impervious Area is a key parameter for the estimation of runoff volume. However, it is a parameter that has not been kept up with the changing momentum. Unfortunately the impervious area values currently being used in design and master planning are not consistent with current research nor are they appropriate for the contemporary approaches to stormwater management.

Definitions

Total Impervious Area (TIA) consists of two main components as follows:

> **Directly Connected Impervious Area (DCIA)** is impervious area that drains directly to the stormwater drainage network via pipes and/or gutters. The main components are DCIA are roofs and roads;
>
> **Indirectly Connected Impervious Area (ICIA)** is impervious area that runs off onto pervious surfaces. Thus some or all of the runoff is lost before it is collected by the Stormwater system. ICIA includes footpaths, paving, garden sheds etc.

Effective Impervious Area (EIA) is the area that generates a rapid response in rainfall events. Research shows that this is usually less than the DCIA.

Sources of Guidance

Research

Abundant research has been published demonstrating that runoff volumes depend on DCIA or EIA rather than TIA. A brief description of the two most relevant to design in Australia is given here.

Phillips et.al. (2014) was one of the research projects undertaken for AR&R 2016. DCIA and ICIA were measured for 8 catchments, one catchment in each State and Territory of Australia. EIA was then calculated by a regression analysis of rainfall versus runoff volume. DCIA was found to be 81% to 95% of the TIA. EIA was found to be 59% to 66% of the TIA for most catchments with one catchment in the ACT having an EIA/TIA up to 80%. The catchments used in this analysis have a lower lot density than the subdivisions being constructed in Western Sydney.

Dayaratne (2000) derived relationships for DCIA and ICIA by calibrating ILSAX models on several catchments in Victoria. These relationships are presented in the *DRAINS User Manual* (O'Loughlin & Stack 2014). However when these relationships are extrapolated beyond 15 lots/ha the impervious fraction decreases. Thus the relationships are not suitable for the design of the higher density subdivisions currently under construction in Western Sydney

Industry Guidelines

An extensive overview of this EIA is found in Section 3.4.1 in Book 5 of *ARR 2016.* It recommends that the Effective Impervious Area (EIA) be used for runoff estimation rather than Total Impervious Area (TIA). According to *ARR 2016* the use of TIA "can result in the overestimation of urban runoff volumes and peak flows". This conclusion is based on a number of research publications dating back to the 1970s.

The (Draft) MUSIC Modelling Guidelines for NSW (2010) also state that effective impervious area be used for MUSIC modeling. An EIA/TIA factor 0f 0.55 is recommended which is at the lower end of the range estimated by Phillips et.al. (2014).

Local Government Guidelines

Most subdivisions in Western Sydney are designed using impervious area from the Design Guidelines published by the local government authority. These guidelines specify a "Fraction Impervious for Runoff Co-efficient". These impervious fractions are tied to the rational method. It is questionable whether parameters intended for deriving runoff coefficients is suitable for estimating runoff volumes. No guidance is provided in local government guidelines for estimating DCIA or EIA.

Assessment of DCIA in Western Sydney Subdivision

As the subdivisions under construction in Western Sydney have a higher density than the catchments used in the above research. The effect of increasing lot density on DCIA needs to be assessed.

Methodology

The following procedure was used to estimate the DCIA for selected subdivisions.

1. Four subdivisions, each in a seperate Local Government Area, were selected for assessment to derive DCIA for low density residential development. In addition medium density developments within two of these subdivisions plus a third medium density section in a fifth subdivision were also selected.
2. Impervious areas were classified as DCIA or ICIA following the procedure adopted by Phillips et.al.. This classification is summarized in Table 1

Table 1. Classification of DCIA and ICIA

Area	DCIA	ICIA
Residential Lots	Roof, driveway	Hardstand areas, paving, garden sheds
Road Reserve	Road carriageway, driveway, kerb ramps	Footpath, shared path

3. For each of the 4 subdivisions data was collected from house and land package advertisements. Initially data was gathered for about 90 lots across the 4 subdivisions. After checking the data, the sample was reduced to 70. To estimate the roof area was estimated as the ground floor area plus the area of the garage, patios etc. plus an allowance for eaves which was assumed to be the perimeter multiplied by 0.45m. Driveway areas were estimated from the DCP requirements and the size of the garage. This process gave a realistic estimate of lot roof area and driveway area and thus total DCIA for each lot.
4. For the integrated development, architectural and landscape plans need to be submitted as part of the development process. Thus for these medium density lots roof areas, driveway areas and hardstand areas could be measured directly from the DA drawings.
5. A regression analysis using the data from steps 3 and 4 was undertaken to derive a relationship between lot size and DCIA.
6. A sample low-residential area was selected from each of the 4 subdivisions. One of the criteria was that each sample area contained at least four of the sample lots. This was in addition to the 3 medium density areas selected above, giving a total of seven (7) sample areas.
7. DCIA and ICIA in the sample area road reserve were measured from design drawings using CAD. Thus the measurements are more accurate than would be obtained from aerial photographs.
8. The Lot DCIA relationships derived in Step 5 was combined with the road reserve measurements in Step 7 to estimate the total DCIA for each sample area.

Results and Discussion

Figures 1 and 2 show roof areas and DCIA respectively plotted against lot size. It was found that there is a statistically valid linear relationship between lot size and DCIA. However the very wide scatter suggests other factors also influence the dwelling size and thus the DCIA.

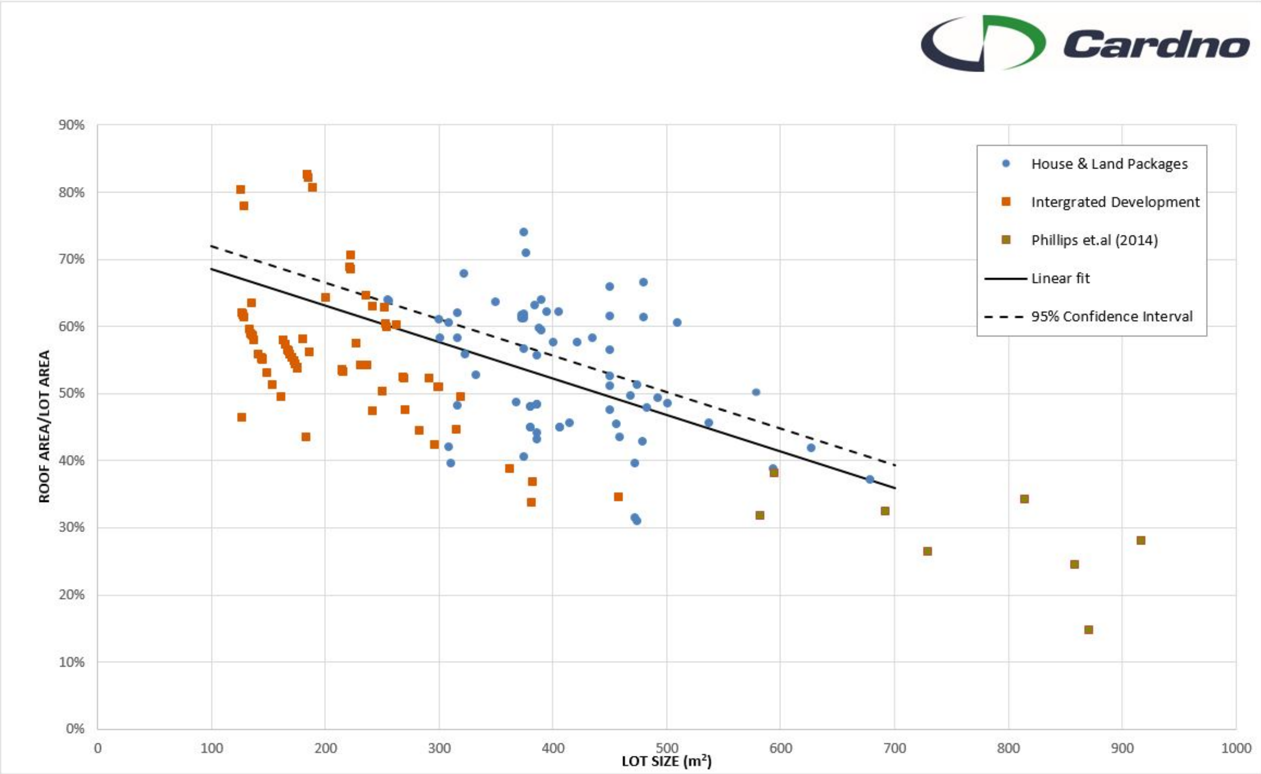

Figure 1. Percentage Roof Area versus Lot Size

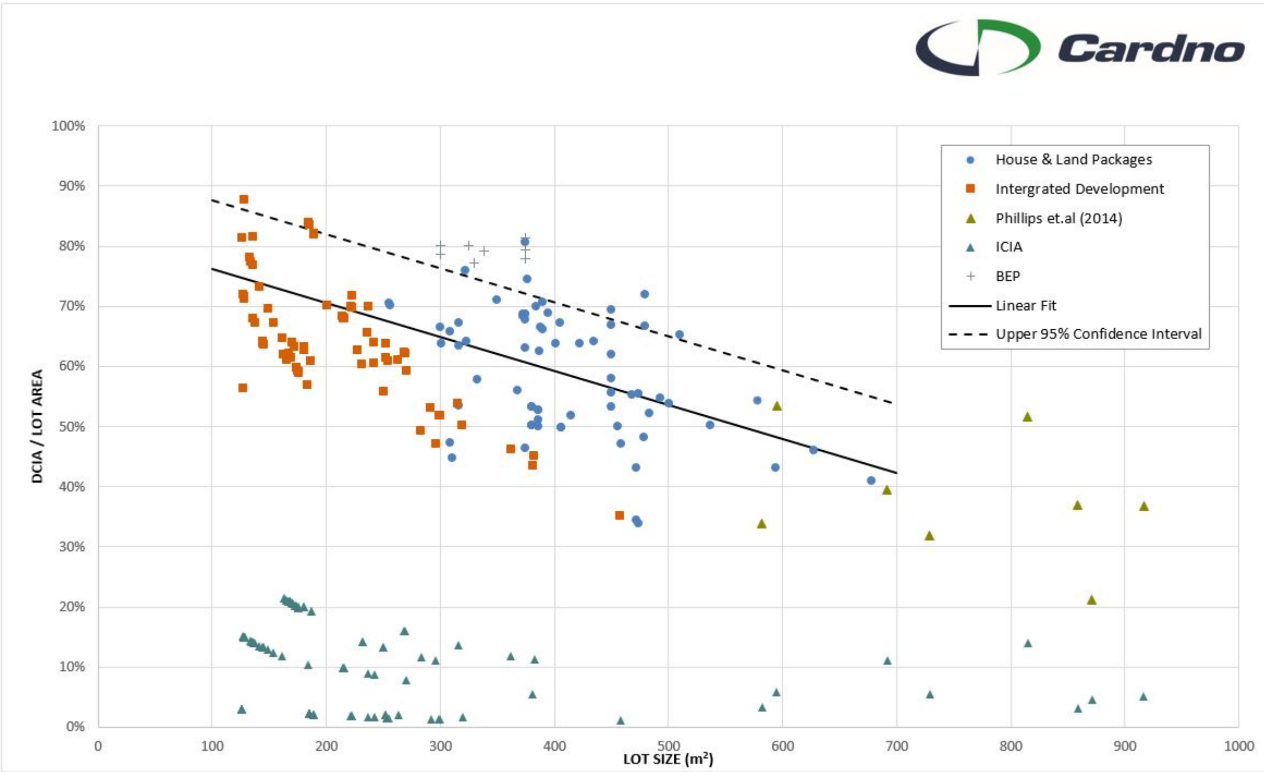

Figure 2. Percentage Lot DCIA versus Lot Size

The equations of best fit and their 95% confidence intervals are as follows:

% Roof area = 74% - 5.4×10^{-4} x Lot Size

95% confidence interval: +/-3.5%

% Lot DCIA = 82% - 5.7×10^{-4} x Lot Size

95% confidence interval: +/-11%

It can be observed that there is significant variation in roof sizes so this needs to be considered in the values we adopt for design and master planning. Different Stormwater management objectives may require different estimates of DCIA.

There was no discernable relationship for ICIIA. Different medium density developments had differing percentages of Lot ICIA.

It was found that DCIA and ICIA for the road reserves were very similar in 5 of the 7 sample areas. DCIA was found to range from 65% to 69% with an average value of 67%. ICIA ranged from 10% to 17% with an average of 13%.

For each low density residential sample area DCIA was calculated using both the mean and the upper 95% confident interval relationships. These estimated DCIA are shown on Figure 3 along with the results from Dayarante (2000) and Phillips et.al. (2014).

Total impervious area for each sample area was also calculated using impervious fractions from the Council Guidelines. Table 3 compares the estimated DCIA with the results from the Council TIA estimates. It was found that even if the upper 95% confident interval values were adopted for Lot impervious area, the resulting DCIA was significantly lower than TIA estimated using the Council guidelines. This suggests that most stormwater infrastructure designed using the fraction impervious from Council guidelines is oversized. This increases the cost of new housing developments and unnecessarily increases the maintenance burden for Local Government Authorities.

Subdivision	Dwellings/Ha	DCIA (mean)	DCIA (+95% CI)	TIA from Council Guidelines
EL	16.6	59%	66%	85%
GH	16.6	59%	67%	75%
CP	17.3	56%	64%	82%
WD	18.2	63%	70%	89%
WD_MD	37.1	64%	n.a.	90%
R_MD	37.6	66%	n.a.	87%
EL_MD	44.0	75%	n.a.	85%

Conclusions

DCIA or EIA is recommended for the design of stormwater infrastructure by both industry guidelines and research publications. In order to comply with the industry guidelines, Cardno has undertaken an assessment of DCIA for subdivisions in Western Sydney. The estimated DCIA values were significantly less than the TIA specified in Council guidelines. This suggests that stormwater infrastructure in new subdivisions is oversized.

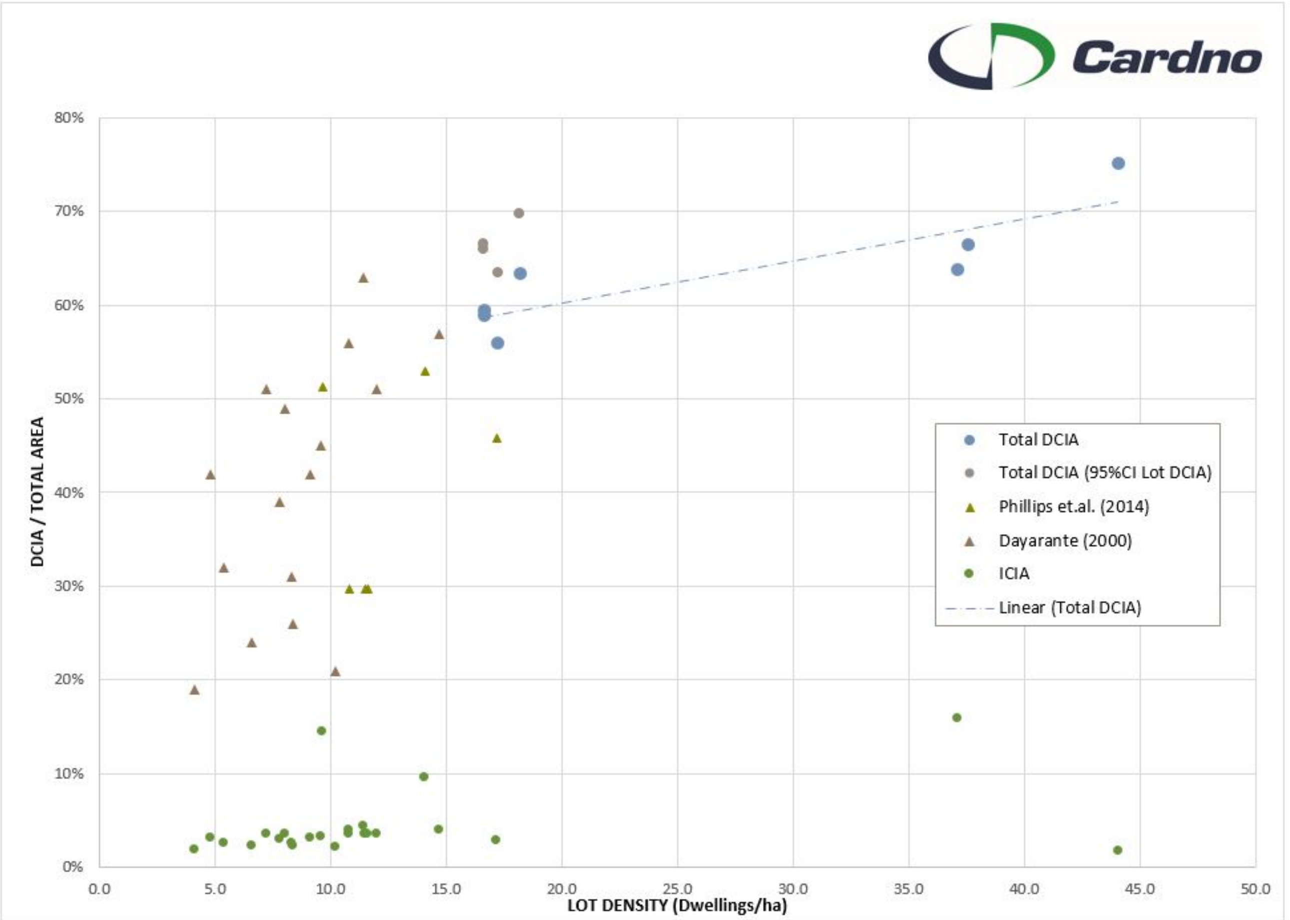

Figure 3. Percentage Subdivision DCIA

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