Investigation on parameters influence first flush occurrence in urban residential catchment

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Abstract:

The knowledge of first flush is important particularly when dealing with stormwater treatment plant. Therefore, the parameters influence the first flush occurrence is essential. The objective of this study was to identify the influence of rainfall characteristics, catchment characteristics and type of pollutants on first flush occurrence. The study was conducted in an urban residential. 23 storm events were sampled and analysed for three water quality parameters; total suspended solids, total phosphorus and total nitrogen. Results show that the existence of first flush is depends on the rainfall characteristics, catchment characteristics and type of pollutant.

Introduction

First flush phenomenon is an important issue in urban stormwater management. The existence of first flush is debated by researchers as several studies have observed the phenomenon while other studies have not found discernable evidence (Han et al. 2006; Tiefenthaler et al. 2008). The existence of first flush will benefit stormwater management as a treatment system could be designed to treat the most polluted discharge volume and to release the remainder of the runoff. This has implications in relation to the size of the treatment facility as it could be reduced, thus reducing the cost. Therefore, it is essential to have an in-depth understanding of the first flush phenomenon in order to design an effective stormwater treatment system.

There are several aspects that need to be clarified due to the inconsistent results found in research literature. This includes first flush definition and it's existence and influential parameters in relation to first flush occurrence. Therefore, this paper is to investigate the occurrence of of first flush phenomenon and to determine the first flush influential parameters which only applicable in urban residential catchment in Gold Coast, Australia.

Research Methodology

Study Area

Three small catchments in Coomera Waters were chosen as the study areas. Coomera Waters is an urban residential area located in Gold Coast, Australia. The residential areas were developed around a 17 ha lake and natural wetlands and provided with Water Sensitive Urban Design (WSUD) in order to protect the natural waterways from being polluted by the stormwater runoff. Figure 1.0 shows the three small catchments with the monitoring stations. Each of the stations contained an ISCO automatic water sampler, a Campbell Scientific data logger, a solar regulator and a RF radio.

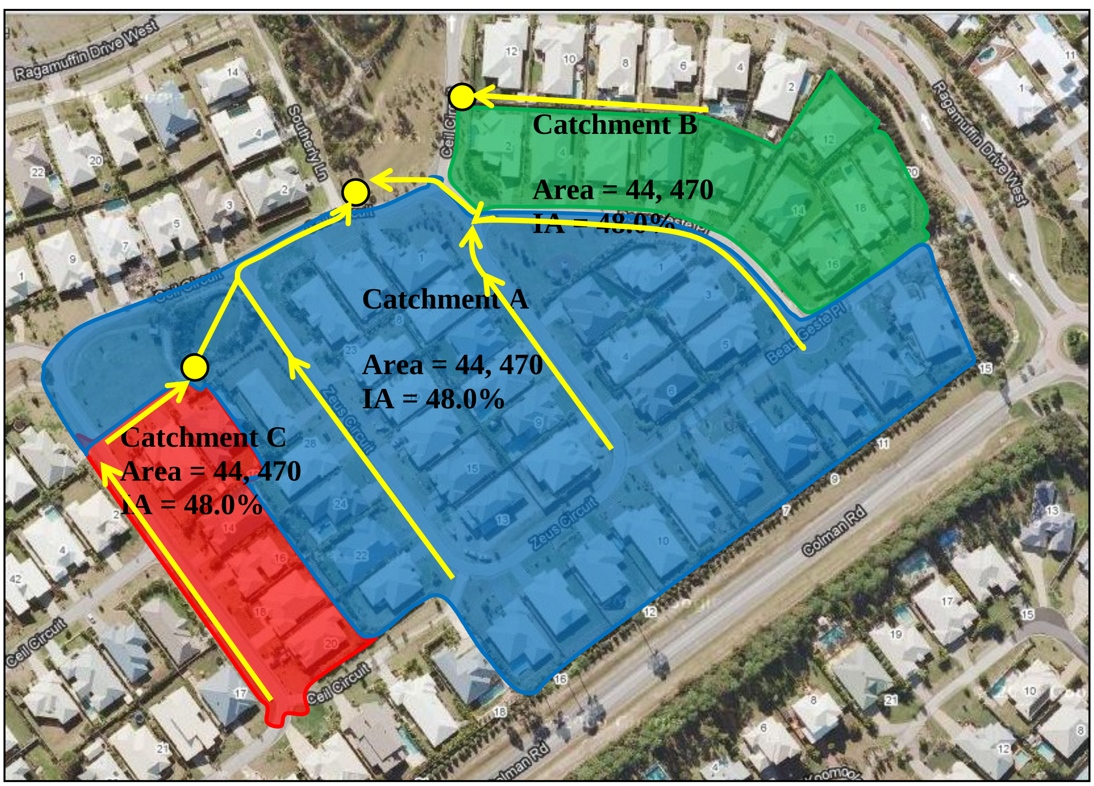

Figure 1.0 The three small catchments of Coomera Waters and it's characteristics

Sample Collection and Data Testing

23 storm events were sampled and analysed in order to determine occurrence of the first flush phenomenon. The ISCO automatic water sampler was programmed to collect the water in 1L plastic bottles and up to 24 bottles can be collected. A V-notch weir was used to measure the runoff volume either at the catchment outlet stormwater culvert or at the inlet of the WSUD devices such as bioretention systems. 2 rain gauges were installed in two catchments; Catchment A and Catchment C to record the rainfall. Three common water quality parameters were selected namely Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN). These water quality parameters were chosen as these are most common water quality pollutants found in urban stormwater, particularly in residential areas and these are the primary pollutants treated by stormwater treatment devices (Alias, 2013). In order to analyse the occurrence of first flush phenomenon, Mass Based First Flush (MBFF) was selected as the method to determine first flush occurrence.

Results and Discussions

Figures 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0 and 10.0 show the MV curves for all the sampling episodes for TSS, TP and TN in Catchment A, Catchment B and Catchment C, respectively. Table 1.0 tabulates the first flush coefficient, a values and identifies the possible occurrence of first flush for TSS, TP and TN for all selected storm events. The experimental fitting between LV and M was satisfactory with the average correlation coefficient (r^2) was 0.95 in determining the a value. Therefore, it can be concluded that results were reliable.

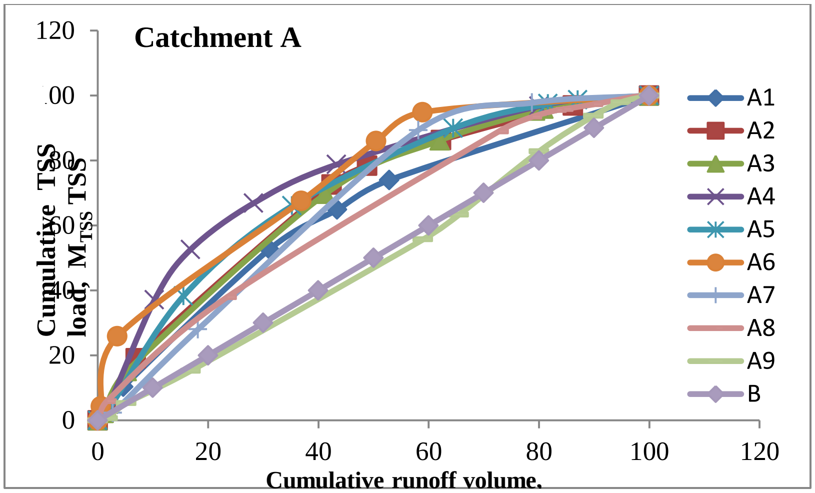

Figure 2.0: Variations of LV curves for TSS in Catchment A

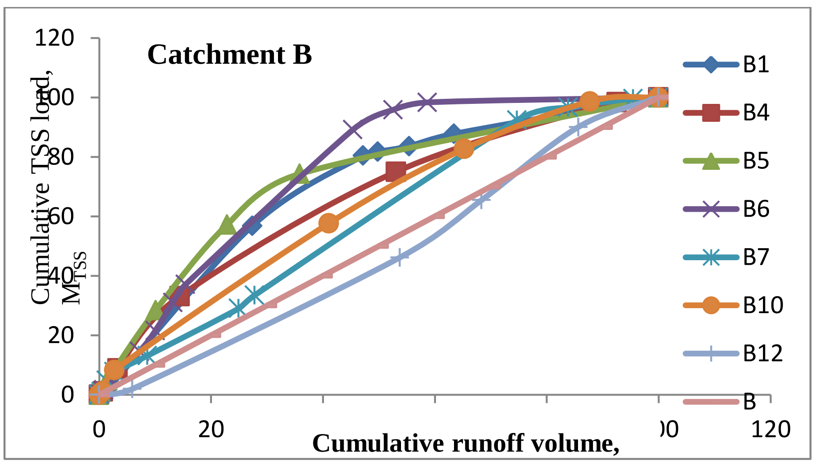

Figure 3.0: Variations of LV curves for TSS in Catchment B

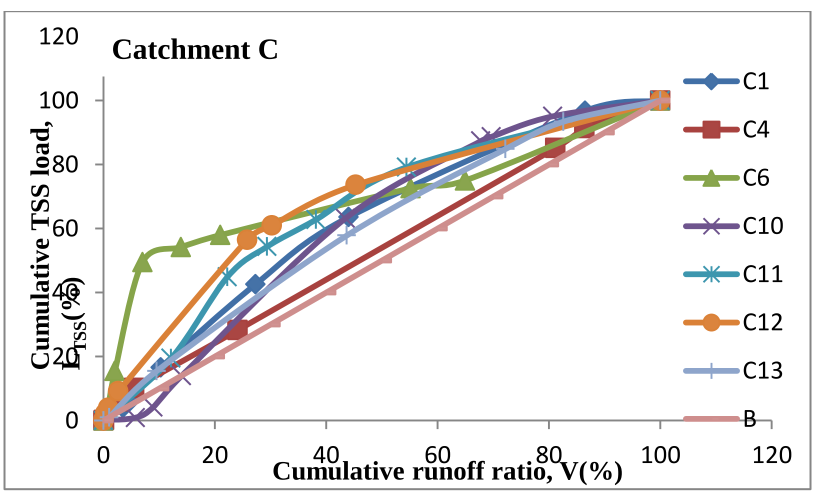

Figure 4.0: Variations of LV curves for TSS in Catchment C

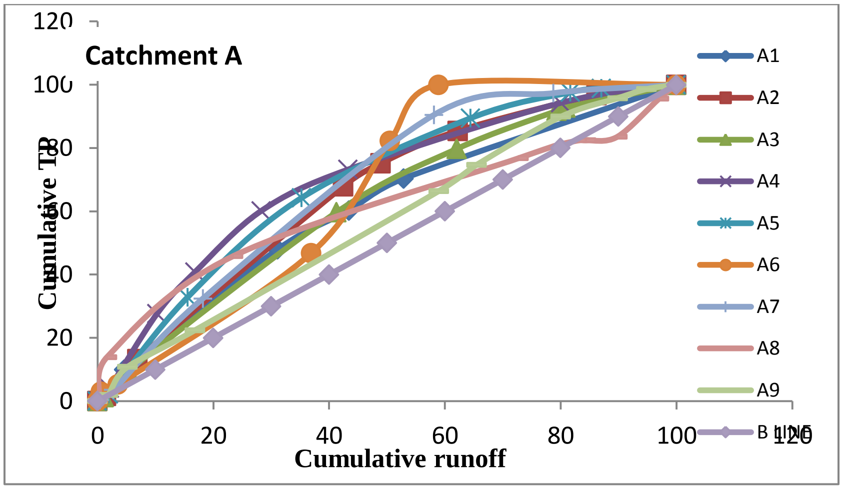

Figure 5.0: Variations of LV curves for TP in Catchment A

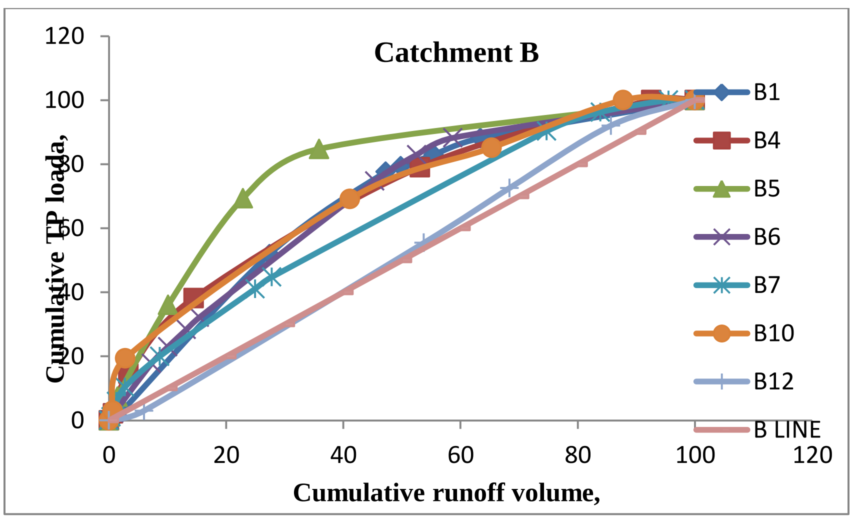

Figure 6.0: Variations of LV curves for TP in Catchment B

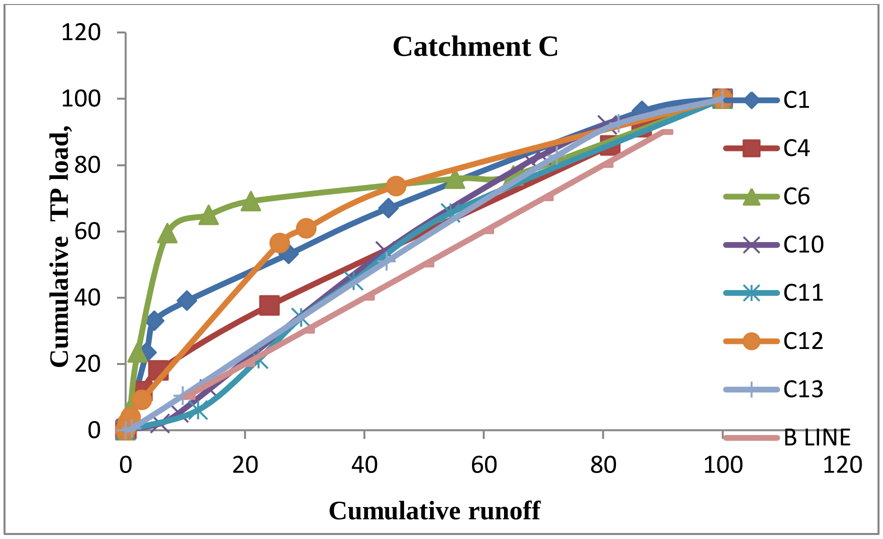

Figure 7.0: Variations of LV curves for TP in Catchment C

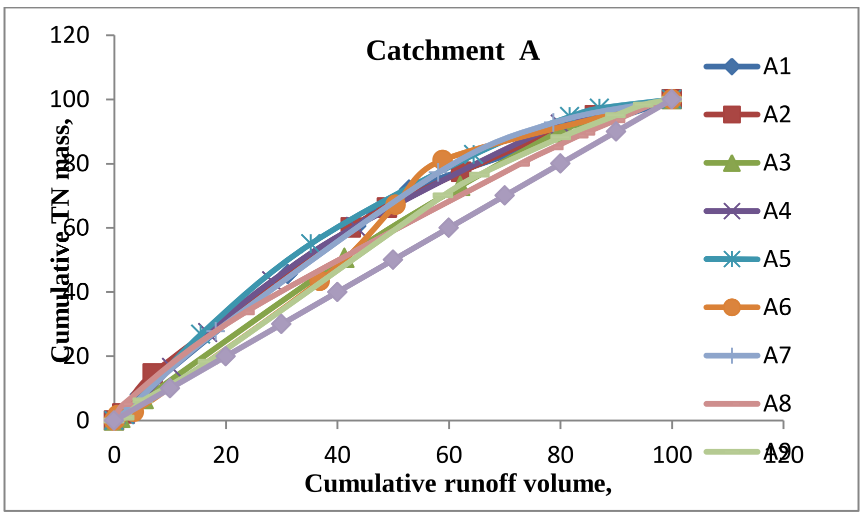

Figure 8.0: Variations of LV curves for TN in Catchment A

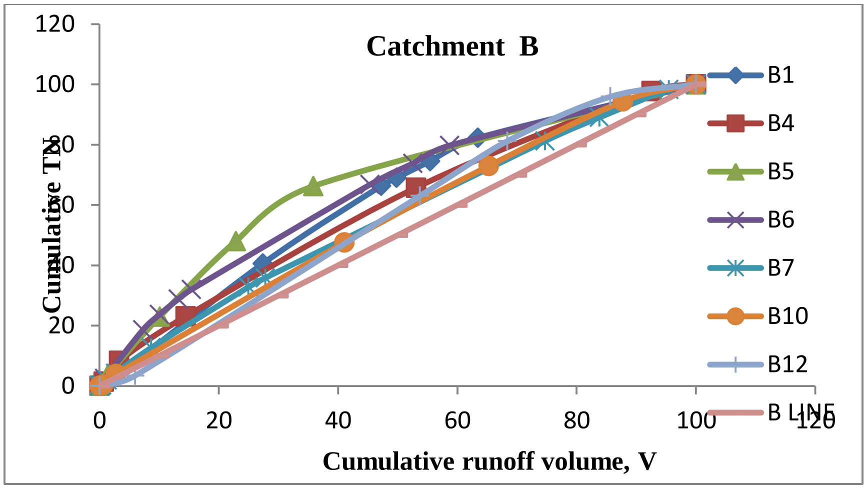

Figure 9.0: Variations of LV curves for TN in Catchment B

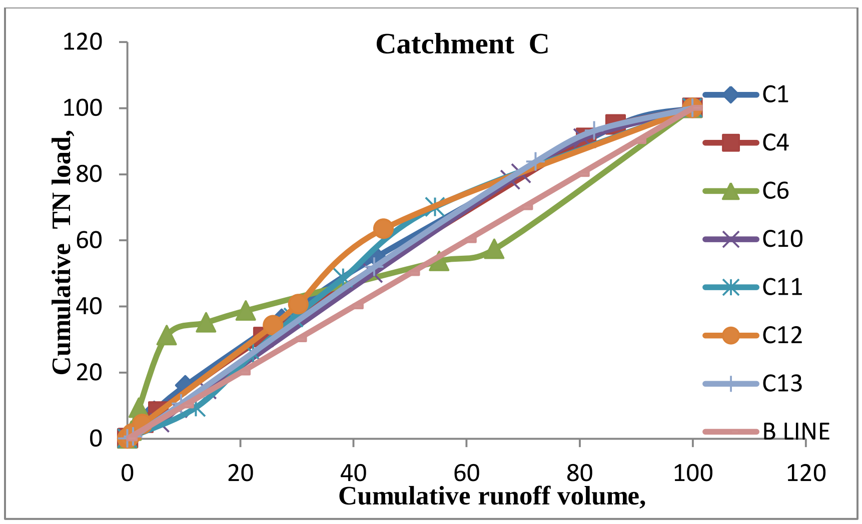

Figure 10.0: Variations of LV curves for TN in Catchment C

Table 1.0: Identification of first flush occurrence for TSS, TP and TN for the selected events

Pollutant	**TSS**		**TP**		**TN**	
Event No.	**a_{TSS}**	**FF**	**a_{TP}**	**FF**	**a_{TN}**	**FF**
A1	0.8194	**YES**	0.8291	**YES**	0.8901	**YES**
A2	0.7513	**YES**	0.9600	**YES**	0.8341	**YES**
A3	0.7668	**YES**	0.9004	**YES**	1.0129	**NO**
A4	0.6155	**YES**	0.6910	**YES**	0.9048	**YES**
A5	0.7782	**YES**	0.8594	**YES**	0.9324	**YES**
A6	0.7075	**YES**	0.8213	**YES**	0.9094	**YES**
A7	1.1242	**NO**	1.0528	**NO**	1.0158	**NO**
A8	0.7719	**YES**	0.5988	**YES**	0.8072	**YES**
A9	1.1451	**NO**	0.8900	**YES**	1.0704	**NO**
B1	0.8555	**YES**	0.9157	**YES**	0.9941	**YES**
B4	0.8197	**YES**	0.6793	**YES**	0.8125	**YES**
B5	0.8082	**YES**	0.7456	**YES**	0.8655	**YES**
B6	0.8714	**YES**	0.8313	**YES**	0.8252	**YES**
B7	0.7717	**YES**	0.7131	**YES**	0.9353	**YES**
B10	0.8169	**YES**	0.6106	**YES**	1.0161	**NO**
B12	1.3793	**NO**	1.2224	**NO**	1.1623	**NO**
C1	0.8890	**YES**	0.4114	**YES**	0.8317	**YES**
C4	0.9189	**YES**	0.7671	**YES**	0.9469	**YES**
C6	0.5174	**YES**	0.4158	**YES**	0.6584	**YES**
C10	1.3493	**NO**	1.2207	**NO**	1.0065	**NO**
C11	0.6308	**YES**	1.1107	**NO**	0.9633	**NO**
C12	0.6975	**YES**	0.6975	**YES**	0.9293	**YES**
C13	0.9531	**YES**	1.0814	**NO**	1.0746	**NO**

According to Figures 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0 and Figure 10.0, there are variations in the LV curves. Most of the events exhibited first flush as the LV curve is above the bisector, as observed for example, for A1, B1 and C1 in Figures 2.0, 3.0 and 4.0 respectively. However, there were several events where first flush had not occurred, for example, A9.

As observed in Figures 2.0 and Table 1.0, the first flush existence is influenced by three primary factors; rainfall characteristics, pollutant type considered and catchment characteristics. This influence can be explained by three cases presented in Table 2.0. There are events where first flush is produced and events where first flush is not produced (for example A1 and A7). This indicated that rainfall characteristics influence the occurrence of first flush. For Events 1, 4, and 6, first flush occurred for all three catchments, whereas, for events 7 and 12, first flush occurred for all pollutants in one catchment but not in another. This suggests the possible influence of catchment characteristics on first flush occurrence. According to Events 7 and 12, first flush was observed in the smaller catchment. This is in agreement with the past studies as researchers have noted that first flush frequently occurred in small catchments rather than in big catchments (Adams and Papa 2000; Lee et al. 2002).

The existence of first flush is also influenced by the pollutant species. According to Table 3.0, the first flush effect which was observed for certain pollutants, may not exist for other pollutants for the same rainfall as observed for Events A3, A9, B10, C11 and C13. Based on the observations for these events, TSS consistently exhibited the first flush phenomenon except for Event A9 while TN did not indicate first flush occurrence. The possible reason for such behaviour requires further investigations.

Conclusions

Based on the finding of this results, it can be concluded that first flush occurrence varies within rainfall, type of pollutant and catchment characteristics. TSS was found had the highest frequency of first flush occurrence compared to Total Phosphorus and Total Nitrogen. The occurrence of first flush existence is influenced by three primary factors; rainfall characteristics, type of pollutant and catchment characteristics.

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