# STORMWATER BED LOAD AND GROSS POLLUTANT EXPORT RATES AND THEIR IMPLICATIONS FOR TREATMENT DEVICES

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**ABSTRACT**

Many factors influence the mobilisation and transportation of stormwater contaminates from surfaces. Size, mass and density of the contaminants will greatly affect their ability to be transported to the receiving water body. Contaminates are transported by four main mechanisms:

- Dissolved
- In suspension (suspended solids)
- Saltation or bed load (bouncing along the bottom).
- Floating.

There has been much research into suspended solids loading rates in urban stormwater. Unfortunately sampling techniques which obtain data on suspended solid loads tend not to measure bed or gross pollutants. This has resulted in bed and gross pollutant loads often being over looked in the design of treatment systems. Bed load and gross pollutants are also term gross solids or coarse sediment.

Bed & gross pollutant loads can be double the suspended solid load by mass and significantly more by volume because of their larger particle size. While they have lower toxicity than suspended solids they have significant management implications for the long term performance of treatment devices. For example bed & gross pollutant loads can cause premature failure as the device does not have the storage capacity for them. This also creates higher than budgeted maintenance costs.

This paper examines the composition of retained material in Enviropod Filters from numerous sites in Australasia and compares these with Laboratory testing on the Enviropod Filter. The paper suggests loading rates for bed and gross pollutants for different land uses and discusses the implications for design and management of treatment devices.

## 1. INTRODUCTION

It is hypothesised that a considerable amount of the material in stormwater, is being transported into the reticulation system as bed load or gross pollutants. This in turn contributes a significant proportion of overall contaminants in stormwater.

To date there has been limited research carried out on quantifying the loads and effects of bed load or gross pollutants. Work by Allison at the Cooperative Research Centre for catchment Hydrology, Melbourne, Australia (CRC 1998) examined gross pollutant loads and identified a relationship between gross pollutants, organic matter and nutrients. While the concentrations of nutrients are generally lower in gross pollutants they contribute a significant proportion to the overall transported sediment load.
Most work has been examining the retained material from end of line GPT's which are often undersized for the catchments they treat. This work examines the particle size distribution from

320 Enviropod filters installed in 4 locations. The Enviropod Filter is a catchpit (catch basin) insert.

The Enviropod Filter is located at the interface of the road surface and the reticulation system. All particles trapped in the filter have been transported from the road surface to the reticulation system, and are assumed would continue to travel down the reticulation system to the receiving environment unless they are trapped.

This study is focused on the larger material being transported in urban runoff; therefore the following definitions have been adopted for suspended solids, bed load and gross pollutants. These were obtained through correspondence with the CRC for catchment hydrology.

- Suspended Solids (TSS) <1mm (T. Wong, CRC Catchment Hydrology, pers.com)
- Gross Pollutants (GP) >5mm (Allison, CRC 1998)
- Bed Load (BL) 1mm<x<5mm

## 2. THE ENVIROPOD

The Enviropod filter is a gully pit insert which comprises a supporting framework, overflow system and a removable filter bag. Fitted with a 200 micron filter bag, fine sediment, bed load and gross pollutants are trapped.

The Enviropod requires servicing every 2 to 6 months. This is easily performed with inductor or by hand. The frequency of servicing is dependant on many natural and physical factors.

Enviropods have been used for over 8 years in Australasia and there are now over 4000 filters installed in cities such as Sydney, Melbourne, Auckland and Brisbane and in major tourist destinations such as the Gold Coast, Tasmania and Noosa.

The performance of the Enviropod Filter (200 micron bag) has been independently evaluated by Auckland City Council in the laboratory (ACC & Tonkin & Taylor). This was conducted using a range of synthetic sediment samples and sediment collected from a road in Auckland. The Enviropod filter essentially removed all the sediments greater than 100 micron in size. Removal of sediments less than 100 micron was approximately 20%. Figure 1 shows the relative efficiencies for an Enviropod Filter fitted with a 200 micron filter bag, at varying particle size ranges.

*Figure 1: Sediment removal by the Gullypit Containing an Enviropod Filter with a 200 micron mesh (Tonkin & Taylor)*

## 2.1 A STORMWATER SAMPLER

An Enviropod filter can be used as an environmental sampler or indicator. The small catchment areas, enables easy identification of contaminant sources within the catchment.

The Enviropod retains gross pollutants and coarse to fine sediments. A conventional sampler does not sample gross pollutants. Gross pollutants are often a transportation mechanism for more toxic contaminants, however if they are retained in a dry environment they can aid in removal of other contaminants such as dissolved metals.

By strategically placing a number of Enviropods through a catchment a large amount of localised information about stormwater contamination can be obtained.

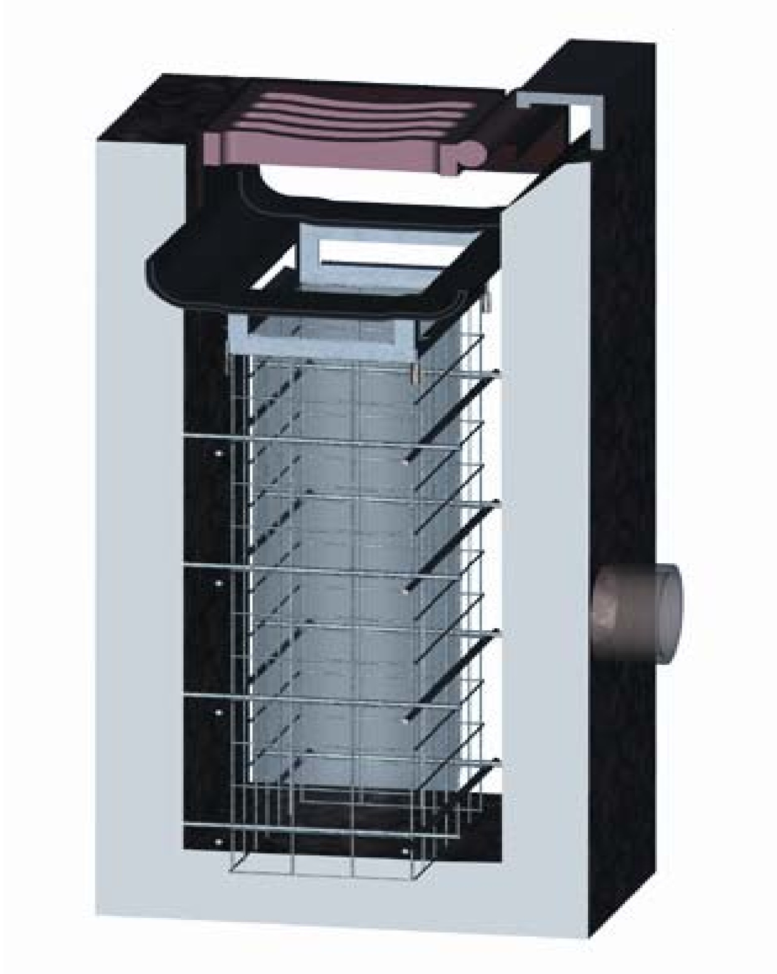

*Figure 2 The Enviropod Filter*

*Figure 3 the Enviropod Filter installed*

*Figure 4: Removable 200 micron Filter Bag.*

*Figure 5 Supporting Frame Work.*

## 3. METHODOLOGY AND STUDY CATCHMENTS.

This paper pulls together information from numerous studies. Samples were collected from retained material trapped in the Enviropods installed in various catchments throughout

Australasia, over approximately a 4year period. 76 samples were collected from 4 catchments. This analysis is representative of approximately 200 Enviropods.

Samples were collected at routine servicing of the Enviropods; this was typically between 1 to3 months depending on loading rates. Some catchments were broken into sub catchments to analyse different land use. Some samples were composites from larger sample sets

Estimates on the percentage bed load and gross pollutant loads have been obtained by comparing laboratory testing with retained material. It was assumed that the Enviropod had 100% efficiency on particles over 100 microns and 20% efficiency for under 100 micron particles. The following sections briefly describe the four catchments.

### 3.1 BLACKBUTT CREEK CATCHMENT (KU RING-GAI CITY, SYDNEY, AUSTRALIA).

80 Enviropods are installed in the 17.4 hectare, Blackbutt Creek catchment. The catchment was subdivided into three sub catchments these were; commercial (Comm.), urban (Urban) and urban base (Base).

Urban and urban base sub catchments have essentially residential land use, however the urban catchment is located on grade, with a moderate to steep slope. The catchment has extensive vegetation with many large evergreen indigenous trees (Gums trees), and the surrounding geology is predominantly sand stones.

The commercial sub catchment is situated at the top of the catchment and collects stormwater runoff from retail outlets along the Pacific Hwy (an arterial road) and from light industrial/commercial properties in the north-west corner of the study area. This sub catchment has high levels of pedestrians associated with the use of the retail areas and the nearby train station.

### 3.2 LINCOLN ROAD (WIATAKERE CITY, AUCKLAND, NEW ZEALAND).

This trial site in Wiatakere City is a highly trafficked arterial road. It is an access route to a nearby motor way. Adjacent to Lincoln Road (South side) is a light commercial area consisting of “strip malls”, entertainment facilities and car parking. To the north of Lincoln Road is a residential area that falls away from the catchment. The surrounding geology is predominantly clays. The catchment has very minimal slope <0.5% and the surrounding vegetation consists manly of urban lawns.

### 3.3 SYDNEY CBD (NSW, AUSTRALIA).

A collection of samples were taken from Enviropods installed in double sumped pits from the Sydney CBD. The surrounding catchments were 100% impervious with the exception of a few suffering inner city trees in planter boxes. The Enviropods were located on streets with a high number of low speed traffic movements. These Enviropods encounter a high level of illegal discharge from nearby shop owners as well as a high litter loading, including numerous “sharps”.

### 3.4 NORTH SHORE CITY (NORTH HARBOUR, NEW ZEALAND).

North Shore City has over 300 Enviropods installed over 5 catchments. 3 composite samples were obtained from 3 catchments. The three catchments are typical sub-urban catchments with a mixture of residential and small commercial areas.

## 4. MOBILISED PARTICLE PARTITIONING

Analysing all 76 samples obtained from the 4 catchments, the percentage of particles over 1mm in the retained material, has a normal distribution. On average of 34% of the particles retained in the Enviropod were over 1mm in size with 95% confidence intervals of 30.6% to 37.8%.

Considering the efficiency of the Enviropod on under 100 micron sized particles it is estimated that 21% of the total solid load being transported is over 1mm in size with 95% confidence intervals of 30.6% to 37.8%.

Figure 6 shows the mean composition of the retained material from each site.. Approximately ¼ to ½ of the loads were particles over 1mm. The bulk of the particles over 1mm are being transported as bed load. Flat areas tended to have lower percentage of larger material being transported into the Enviropods. This is understandable as flow velocities from these areas are typically lower.

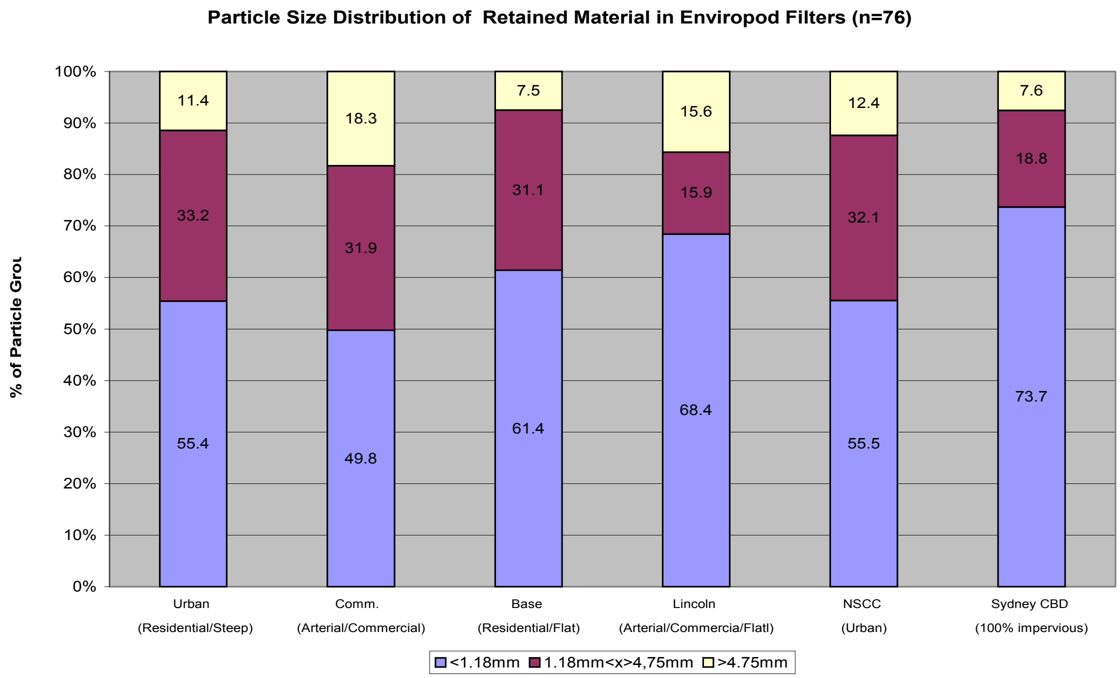


*Figure 6: Particle Size Distribution of material in Enviropod Filters*

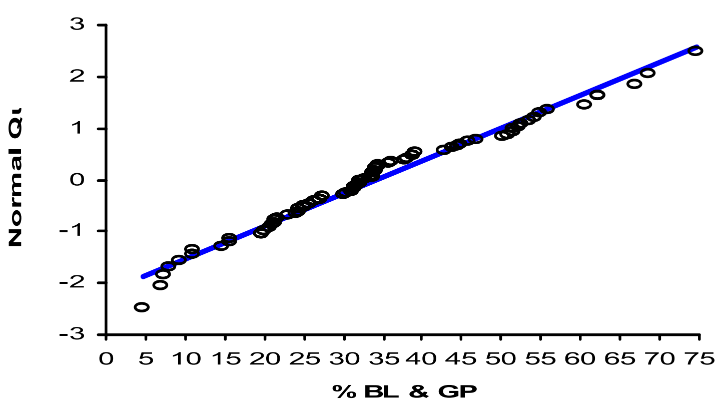


*Figure 7. Normal Distribution for % of Particles > 1mm in Retained Material.*

The Blackbutt Creek catchment had a high percentage of larger particles than the other study catchments. This is attributed to the steep slope of the catchment, which is a factor to the bed load rates. The figure below shows the particle size distribution of retained material in different land use in the Blackbutt Creek study. Approximately 30% of the retained material was bed load.

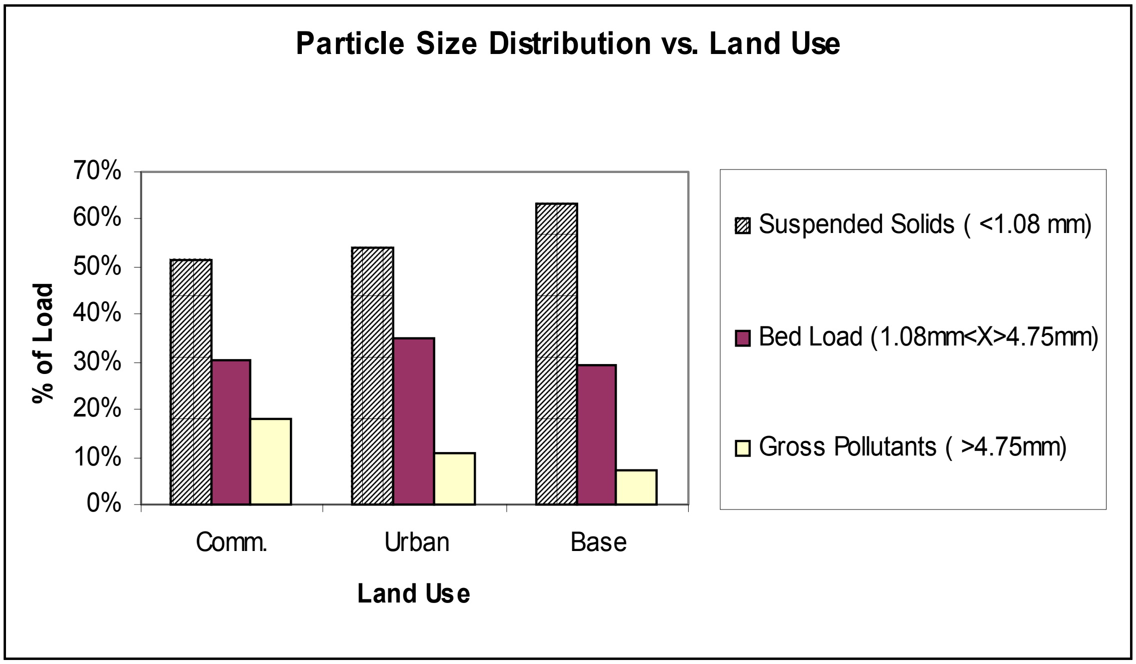


*Figure 8. Particle Composition by land use, Blackbutt Creek.*

# 5. BED LOAD AND GROSS POLLUTANT LOADING RATES.

## 5.1 ENVIROPOD REMOVAL RATES.

The average removal rate from the Enviropod filter over the 4 sub catchments was 932 kg/ha/an with 95% confidence intervals of 674 to 1191 kg/ha/an. The removal rates again showed a normal distribution. The mean removal rates for the different locations are shown in table 3.

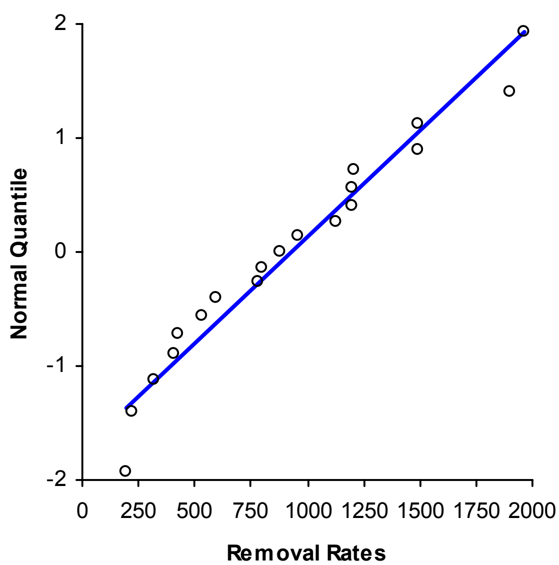


*Figure 9 Normal Distribution for Enviropod Removal Rates.*

| Catchment | n | Mean (kg/ha/an) | 95% CI of Mean (kg/ha/an) | |
|---|---|---|---|---|
| Urban (Residential/Steep) | 5 | 392 | 220 | 564 |
| Comm. (Arterial/Commercial) | 5 | 1243 | 710 | 1776 |
| Base (Residential/Flat) | 5 | 704 | 244 | 1163 |
| Lincoln (Arterial/Commercial) | 5 | 1203 | 301 | 2105 |

*Table 1 Enviropod Removal Rates by land use..*

## 5.2 BED LOAD AND GROSS POLLUTANT RATES.

Figure 10 show that there was a variation in loading rate with the different land use. Commercial / Arterial areas had the highest rates of particles over 1mm despite the less intense vegetation in the areas. This is attributed to the high rates of bed load in these sub catchments. These would be being generated through vehicle and pavement wear from higher traffic movements.

Bed loads tend to contribute more to the mass of, over 1mm particles than gross pollutants. This can be expected as these particles are gravels and have a higher density. Bed load was also a contributing factor to the higher loading rate encountered in the base sub catchment of Blackbutt Creek.

The data also shows that monthly loading rates across all land uses were proportional and generally related to rainfall. This suggests that rainfall is important in determining maintenance frequency.

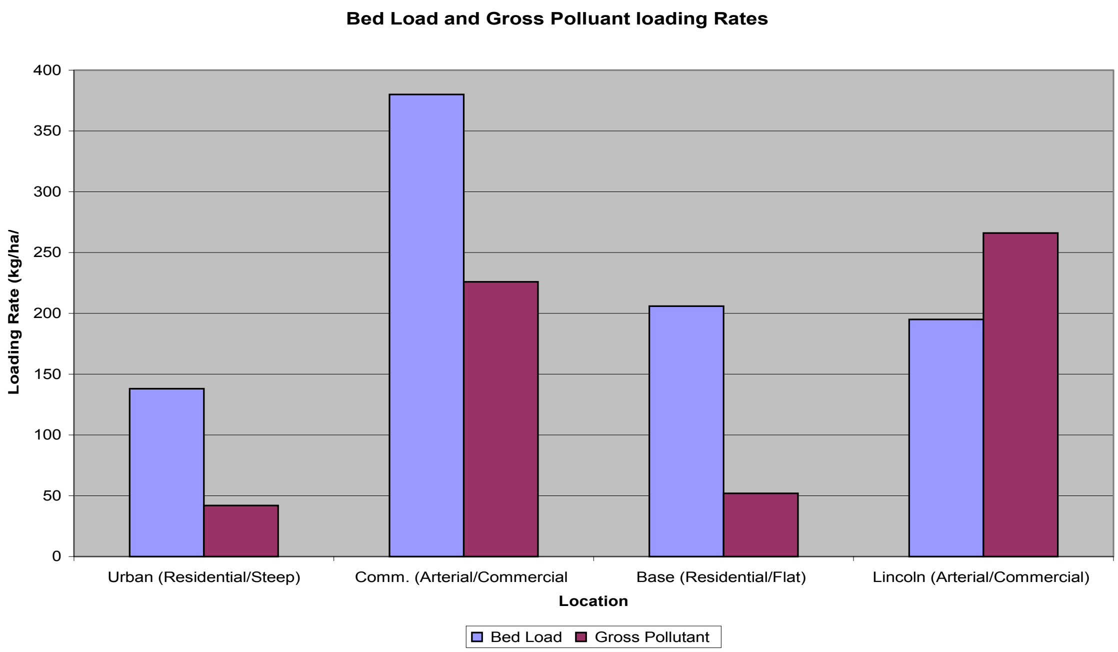


*Figure 10 Loading Rates for Bed Load and Gross Pollutants.*

| Particles >1.18mm | n | Mean | 95% CI of Mean | |
|---|---|---|---|---|
| Residential | 10 | 218 | 146 | to 291 |
| Arterial | 9 | 541 | 404 | to 679 |
| General | 19 | 371 | 268 | to 476 |

*Table 2 Loading Rates for Bed Load and Gross Pollutants.*

# 6. VOLUME RATES.

Bed load and gross pollutants are larger particles. They tend to have lower density than suspended solids. The total volume of solids occupy in a treatment device is largely dominated by the gross pollutant and bed load volumes as finer particles tend to occupy the voids between larger particles.

Total solids transported in stormwater are a mixture of organic and non organic material. When retained it is a mixture of all size particles, as particles in stormwater naturally flocculate. It is therefore very difficult to measure solely the density of bed load and gross pollutants.
Loads were measured in all studies it terms of mass retained. An analysis of retained in-situ density was performed to estimate volumes and determine loading rates by volume. In-situ density is the volume of the material retained in the Enviropod divided by the weight removed. This would be the volume this material would occupy in the receiving environment or downstream treatment device.

The in-situ density of retained material is highly variable and is greatly dependent on moisture content. It is dependent on anticcedenant rainfall and weather the pits are sumped. The Enviropod can be installed to hold retained material dry if desired. The majority of the pits in the study areas were dry Enviropods.

21 pits were analyzed for in-situ density. Allison at the CRC suggests gross pollutants have a mass density (wet) of 250 kg/m3. The mean density of retained material in the study areas was 237 kg/m3, this is much lower than the in-situ density of suspended solids (approx. 1000kg/m3) and therefore a much greater volume

| | n | Mean | 95% CI of Mean | |
|---|---|---|---|---|
| In-situ Density of Enviropod Retained Material | 21 | 237 | 183 | to 292 |

*Table 3 In-situ density of Retained Material.*

In the Blackbutt Creek study there was a lower in situ density (estimated 176 kg/m3) because of the high vegetation loading. As a result 60m3 (3.5 m3/ha/an) of material was removed from the Blackbutt creek catchment in 12 month study period.

The volume of material entrained in urban runoff is an important factor in determining the appropriate sizing of a stormwater treatment device. Volume of removed material is related to rainfall. In the Blackbutt creek study a volume removal curve vs. rainfall (Figure 11) was determined to estimate maintenance frequency.

In Blackbutt Creek there are 80 Enviropods with a total storage volume of 8.6 m3, installed over a total catchment area of 17.2 hectare. This equates to approximately 0.5m3 of storage for each hectare. Assuming an Enviropod should be cleaned when it is 2/3 full, the Enviropods should be cleaned after approximately 100mm of rainfall.

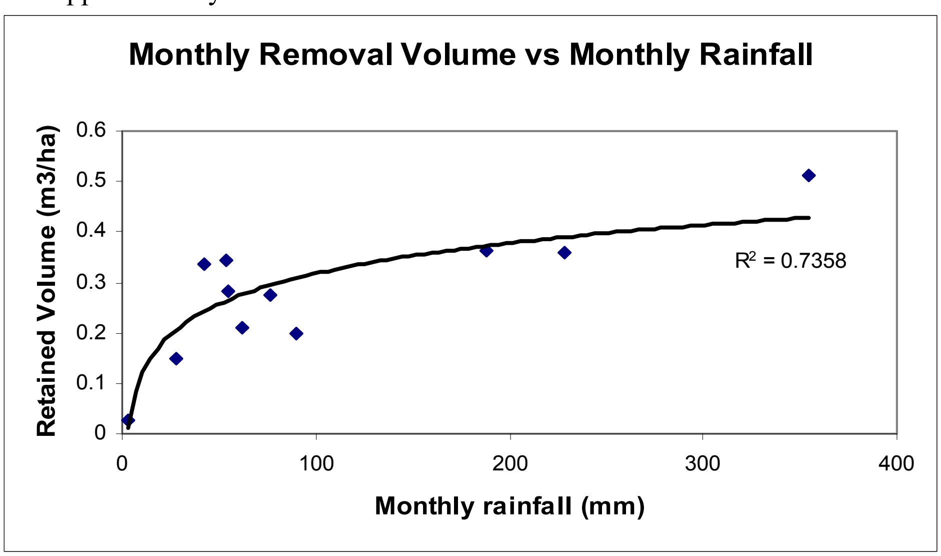


*Figure 11: Volume Removal Curve Blackbutt Creek.*

# 7. NUTRIENTS PARTITIONING.

Part of the Blackbutt Creek study included an examination into the contribution > 1mm particles were having on total exported rates of phosphorus and Nitrogen. Large organic particles such as leaves and clumps of topsoil are a source of nutrients in stormwater. These large particles erode and breakdown as they travel through the stormwater system. These particles also can degrade in receiving environments or in wet treatment devices.

The results showed that over 1mm particles contributed significantly to the total load of nitrogen and phosphorus being captured (Table 4 & %). Comparing the results to 3rd party modelling (Table 6) this is a significant contribution to the over all load.

| NITROGEN | < 1mm kg/ha/an | >1mm kg/ha/an | All Particles kg/ha/an |
|---|---|---|---|
| Commercial | 1.28 | 1.63 | 2.91 |
| Urban | 0.26 | 0.45 | 0.72 |
| Base | 0.68 | 1.66 | 2.34 |
| Average | 0.74 | 1.25 | 1.99 |

*Table 4: Nitrogen loading Rates for Blackbutt Creek*

| PHOSPHOROUS | <1mm kg/ha/an | >1mm kg/ha/an | All Particles kg/ha/an |
|---|---|---|---|
| Commercial | 0.36 | 0.38 | 0.74 |
| Urban | 0.07 | 0.08 | 0.15 |
| Base | 0.30 | 0.43 | 0.73 |
| Average | 0.24 | 0.30 | 0.54 |

*Table 5: Phosphorous loading Rates for Blackbutt Creek*

| Year | TP kg/ha/an | TN kg/ha/an |
|---|---|---|
| Dry (10%ile) | 0.4 | 3.4 |
| Average | 1.2 | 9.5 |
| Wet (90%ile) | 2 | 16.2 |

*Table 6: 3rd Party Modeled Export Rates for Blackbutt Creek (Hughes Truman)*

# 8. IMPLICATIONS FOR STORMWATER TREATMENT

This study has shown that particles over 1mm can be a significant contribution to the contaminant loads from a catchment. Consideration of Bed and Gross Pollutant Load is helpful in many aspects of stormwater management. Some examples are listed below:

Sizing Treatment Devices- Consideration needs to be made of the volume of gross pollutants being transported and the storage volume of the device. For example in Blackbutt Creek a treatment practice with storage capacity of 20m3 will require cleaning 3 times a year.

Efficiency of Devices and Maintenance- frequency – The efficiency of a treatment device is dependent on frequent maintenance. Retained material is easily re-suspended if a devices become over full. Accurate estimates of bed and gross pollutant volume will aid in efficient maintenance programmes and sizing of devices.

Maintenance Programmes. Gross pollutant demonstrated seasonal variations and higher bed load rates were associated with arterial roads. Management practices such a street sweeping can be programmed around these observations.

Use of Pre-treatment - If large volumes are being encountered or estimated in a catchment it is beneficial to use pre treatment before the principle treatment device. The principle treatment device is generally targeted at the fine or dissolved component of contaminates. The pre treatment method chosen must have adequate capacity and be easily maintained because of the possible high volumes shown in this report.

At Source treatment - The study revealed many ideas to the application of at treatment to a catchment. At source treatment (e.g. Catchpit Inserts) can be target in high loading areas. Loading rates were approximately 4 times for TSS, TN in commercial areas than in residential areas and 5 times for TP. High loading rates were also encountered at the base of steep catchments.

Consideration of Bed and Gross Pollutant loads in design and operation will lead to more efficient stormwater management.