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STORMWATER HARVESTING TRIALS FOR "IRRIGATION" OF STREET TREES AND WATER QUALITY AND QUANTITY IMPROVEMENT

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ABSTRACT

Street trees in urban environments suffer from a severe limit of space available for plots. This combined with conventional drainage systems that take water away from the site lead to limitations on the health, growth and potential development of the trees. The impermeable environment exacerbates the already disturbed, deoxygenated and contaminated soil conditions by requiring surface compaction of these small spaces.

Trees in urban environments can also adversely affect adjacent infrastructure. As the tree grows, the roots seek out sources of water and grow along this path. These sources can be located under roads, inside pipes or adjacent to housing. These roots cause cracking of the road pavement, pipes and footings and can cause heaving of the footpath and gutter. This is a major concern to councils as the funds required to remove the roots and reinstate the damaged area are significant.

A field research project has commenced that will trial systems that harvest road runoff (for "irrigation" of street trees) and provide water quality and quantity benefits, reducing the impacts of stormwater on receiving environments. A controlled "irrigation" system will encourage the tree roots to grow towards the distribution source and away from the adjacent infrastructure. This will direct the roots to grow parallel to the roadways and houses, with the ultimate goal of keeping the roots within the strip of land between the roadway and the footpath.

INTRODUCTION

Stormwater quality entering creeks and rivers is an increasing problem due to increased urbanisation and use of transport infrastructure. The increase in impervious surfaces prevents water entering the soil and in the case of roads, starves street trees of much needed moisture. As a result street tree roots tend to migrate to the road pavement, leading to adverse structural performance impacts. An opportunity exists to address the problems of stormwater from roads and lack of moisture to street trees through harvesting road runoff, cleansing it and then distributing it to the street trees.

Transport SA, City of Mitcham, Treenet and The Urban Water Resource Centre (UniSA) have combined resources to undertake this project. Foremost to the project is Transport SA's corporate policy to produce "A transport system in harmony with the environment". To achieve this water quality issues need to be addressed to ensure the impacts on receiving environments are minimised.

The harvesting and distribution structures used in this trial have been the subject of many prior individual investigations. It is their combined use to harvest and treat road runoff and use this to water local street trees that has not been trialed in the field. This next step will be the main focus of the project.

BACKGROUND

Source Control Theory

The management of urban stormwater quality is a critical issue affecting the environmental conditions of natural watercourses and our coasts. With ever-increasing pressure placed on existing urban drainage infrastructure, solutions such as "source control" is, in most cases, the only feasible measure available to local government authorities. This concept avoids the historical 'end of pipe' solutions prevalent with drainage design in previous years where the water is directed out of the catchment and treated as a whole at the end of the system.

Source control of stormwater involves both the water and pollution contents of runoff being retained on-site by employing methods that hold rainwater where it falls and which preserve the intrinsic water balance of the local area. This practice may reproduce hydrological behaviours bearing close resemblance to those of the original forested catchments they replaced.

First Flush Theory

The "first flush" is the first surge of flow during a rainfall event that conveys "built-up" pollution on roadways to the drainage system. The latter part of a long rainfall event will produce a pollution load of much lower concentration than that experienced during the "first flush", this phenomenon is most obvious in arid climates like Adelaide. A paper titled "Water Pollution in Urban Environments" (1995) indicates the first flush may contain 30–50% of the total runoff, but carry 60-90% of the pollutant load. Therefore the harvesting devices were designed to capture only the 'first flush' component of the runoff allowing it to capture a high concentration of pollution with a minimal volume of runoff.

Environmental Effects of Road Runoff

Typical road runoff may consist of gross pollution or litter (>4mm diameter), suspended solids (<4mm diameter), heavy metals, hydrocarbons (fossil fuel based), nutrients, biochemical oxygen demand (BOD), herbicides and asbestos. The bulk of these pollutants are as a result of vehicle and road interactions, including braking, accelerating, turning, idling and the actual physical break-up of the pavement itself (Argue *et. al.* 1999).

Contaminated road runoff can have a profound effect on receiving environments, whether they are a watercourse or on-site infiltration. Likewise the constituents of road runoff affect both marine and freshwater ecosystems.

Perhaps the biggest effect on the environment is from the high load of sediment and suspended solids entering the receiving waterways. This increases the turbidity and therefore reduces the amount of light penetrating the surface. This affects the feeding and photosynthesis of many aquatic species (Water pollution in Urban Environments 1995). In addition to this, nutrients and other organic matter deoxygenate the water, causing death to much aquatic life and allowing nuisance plants to thrive. In the long term the water bodies become silted up, restricting flow and continue to release toxicants or nutrients into the environment.

Hydrocarbons also have a profound effect on receiving environments, particularly the long chain polycyclic aromatic hydrocarbons (PAHs) (Argue *et. al.* 1999). Short chained PAH's break down in a number of days, but it is the long chained PAH's which cause long term damage to the environment as they often require years to break down.

This project is not concerned with the collection of gross pollutants as there are gross pollutant traps (GPT) implemented downstream of the project area to protect the waterways. Though it is acknowledged that these contaminates are recognised as a problem if deposited in the natural environment.

METHODOLOGY

Design Philosophy

The final designs for this project incorporated a wide range of concepts and ideas. These ensured the suitability of the designs in conjunction with our project aim and objectives. These include

- harvesting and treatment of “First Flush” road runoff
- ensuring designs have no adverse affects on adjacent infrastructure
- irrigation of street trees
- ease of installation and minimise maintenance

In consultation with stakeholders it was decided that three of the original designs would be used in the trial. These designs included Permeable Paving, Terrabond and a modified Side Entry Pit (SEP) with a channel insert. Each of these designs is composed of three sections; Harvesting Component, Treatment Section and a distribution trench common to each design.

Figure 1. indicates the site outlay for all three designs. The specific harvesting and treatment section vary for each and therefore individual diagrams for the Permeable Paving, Modified Side Entry Pit and Terrabond are contained in Figures 2, 3 and 4 respectively.

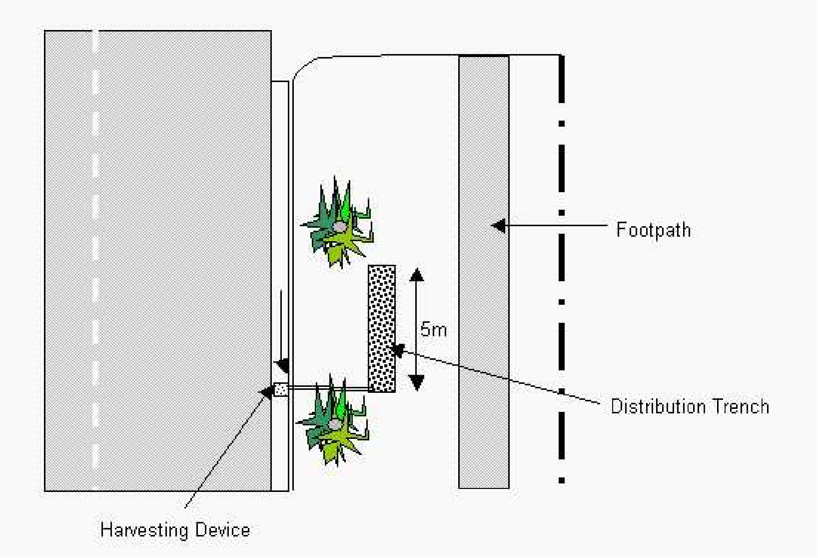

Figure 1: Site Overview

Permeable Paving

The specification for the Permeable Paving provided by Boral (2003) was adopted in this project. This required the paving blocks (80mm deep) to be bedded on 5mm screenings, 50mm thick, underlain by geotextile fabric. This ‘upper layer’ must be structurally supported by a 350mm thick, free-draining clean crushed stone section containing 20mm size gravel with 30% voids, although these dimensions and sizes can vary depending on the site requirements.

The key to the infiltration performance of this system is, undoubtedly, the restriction to flow, which takes place at the geotextile layer. (Rommel *et al.* 2001) The 350mm deep gravel section may be used for initial storage of the infiltrated runoff before discharging to the trench. This gravel section is viewed as a secondary filter offering relatively small resistance to the passage of flow through it and retaining little if any sediment. (Suarman, M. *et al.* 1996)

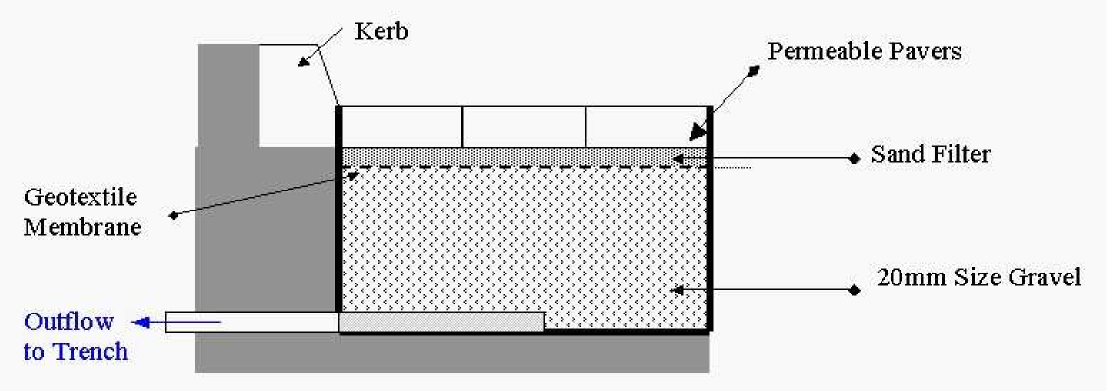

Figure 2: Cross Section of Permeable Paving Sub-Structure

One of the concerns with the permeable pavers design is the rate of clogging and its expected lifespan. Previous studies undertaken have involved impervious/pervious areas of 1:1. In this design the area of permeable pavers is quite small relative to the area of runoff and it is anticipated that the rate of clogging will be higher as the pavers are subjected to a greater volume of runoff and subsequent pollution load.

Modified Side Entry Pit (SEP)

This design involves the adaptation of existing drainage infrastructure in the implementation of source control theory. This will involve inserting a channel at the upstream section of the SEP refer Figure 3. The initial stormwater is captured in the channel and directed to a receiving pit located at the rear of the SEP. The pit will be layered with geotextile allowing filtration of the captured runoff. The entire system will be designed to fully hold the first flush volume incident from the catchment only. Once at capacity the remaining runoff will overflow the channel and be directed to the municipal drainage system.

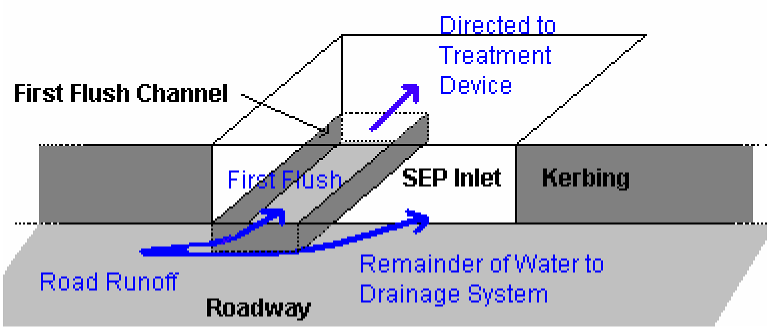

Figure 3: Modified Side Entry Pit (SEP)

Terrabond

A recent product introduced to the market is Terrabond, which is similar in performance to a porous paver or surface. The device is formed by binding particular sized gravel with an extremely strong resin, such that it contains almost 50% voids (Terrabond 2003). The manufacturer of Terrabond Systems Ortis Holdings Pty. Ltd., states the product has extreme bearing capacity, but due to a lack of technical data it is assumed this is only the case when underlain by a strong material. The product is therefore suitable for some vehicular loading. It is normally installed around trees in paved urban environments, thus enabling the trees to receive water that they normally cannot because of an impermeable surface. However, the device can be installed anywhere that requires a porous surface to remove water, including a roadside gutter as in this project refer Figure 4. The product can be specified in varying thicknesses, shapes and gravel sizes.

Infiltration Capacity

There has been very few trials performed on the Terrabond product and before it could be used in the project some testing was deemed necessary. Recent testing of the Terrabond in the gutter of a road test rig by Pezzaniti (2003) at the University of South Australia revealed the following infiltration rates using both a fine and coarse

gravel product. The road rig was firstly set to a 4% slope and various flows were released down the gutter to see how effective the device was at removing water from a steady gutter flow. The same procedure was then repeated with the test road rig set at only 0.25% slope.

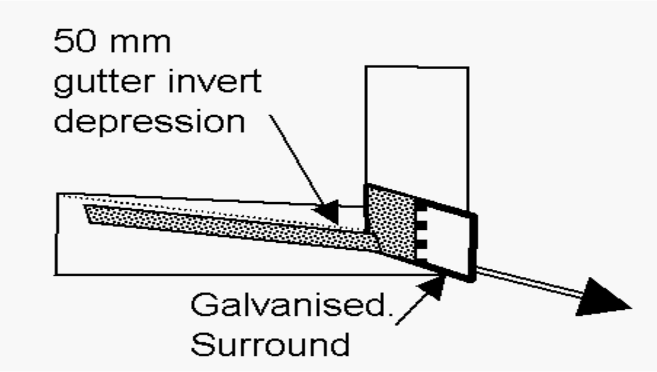

Figure 4: Cross-Section of Terrabond Kerb Installation

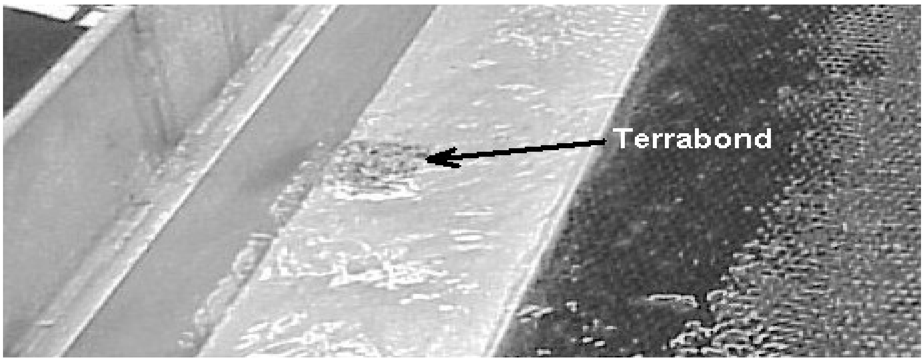

Figure 5 Test Road Rig showing Terrabond installation in gutter

The testing yielded a minimum infiltration rate of 13.2 L/min for the fine gravel Terrabond on the 0.25% grade rig with a roadway flow of 2 L/s. At the other extreme the maximum infiltration rate of 30 L/min was recorded for the coarse gravel Terrabond on the 4% grade test rig with a roadway flow of 240 L/s. As expected the larger gravel devices had a higher infiltration rate than the finer gravel mix.

The testing was performed using clean water and there is no recorded testing using a simulated pollutant load. If the product blocks up internally, the infiltration rate of the device will reduce accordingly and less water will subsequently be harvested. As such during modelling of the device a 50% blockage and therefore 50% reduction in infiltration rate was used. A benefit of the design is that the Terrabond instillations will be removable and can therefore be cleaned periodically.

In this design the Terrabond unit acts as the harvesting device and also the cleansing device. Again there has been no testing performed on the product in this respect, but it is assumed that the device due to its matrix structure will provide at least coarse filtration. This is one aspect of the design that will need to be closely monitored.

Distribution Trench

The trench will be filled with free-draining clean crushed stone of 14mm size with 30% voids, a porous pipe from the harvesting device will be passed through the gravel bed to evenly distribute the water over the entire length of the trench. The dimensions of the standard trench are 5000:600:300mm (LWD) which yields a storage capacity of 270L. Each trench is sized to fully contain only the ‘first flush’ volume of water harvested. The stormwater will be stored in the cavities between the stones whilst it slowly percolates into the surrounding soil through the geotextile.

There will be five trench trials undertaken as part of this project. One type will be entirely encased within a geotextile membrane and the second will also have a geotextile surround but will incorporate an impermeable base and lip at the edges allowing captured water to be stored for uptake by the trees during extended dry periods.

The third trial will involve a trench 150mm deep as opposed to the standard depth of 300mm. The smaller trench will allow evaluation of designs capturing only 135L of first flush. In relation to the average annual stormwater runoff retained, the cost -benefit is significantly better for the larger trench system as most of the expense is involved in the collection component. However this smaller volume will enable the distribution from one collection device to be spread over more sites by interconnecting the smaller trenches and thus perhaps benefiting more trees.

Monitoring

In this project there will be 4 monitoring components. When combined they will provide an overall assessment as to how successful the devices are at achieving their aim and what effects the systems are having on the surrounding environment.

The major component will be a network of moisture probes. These probes can be inserted into the tubes and moisture is measured at vertical spacings of 100mm. This will provide details of the horizontal and to a lesser degree the vertical movement of water through the soil, giving an indication of the wetting bulb surrounding the trench. Adjacent to the road pavement and footpath there will be a moisture monitoring tube, this will be particularly important in indicating whether water is migrating into the road pavement. A key requirement of this project is to avoid adverse moisture interference with adjacent infrastructure.

The water level in the trenches will be monitored. This will produce data on how frequently the trench fills up, how long it takes to drain and also allow water samples to be extracted for monitoring the quality of water entering the soil.

Moisture monitoring at a control zone will be carried out to assess ‘normal’ site conditions. The control zone will be located sufficiently far away to ensure they are not influenced in any way by the distribution trenches. By comparing the data recorded by the control tubes and the other moisture monitoring tubes, conclusions will be drawn as to how effective the distribution trenches have been at evenly distributing the water to the soil.

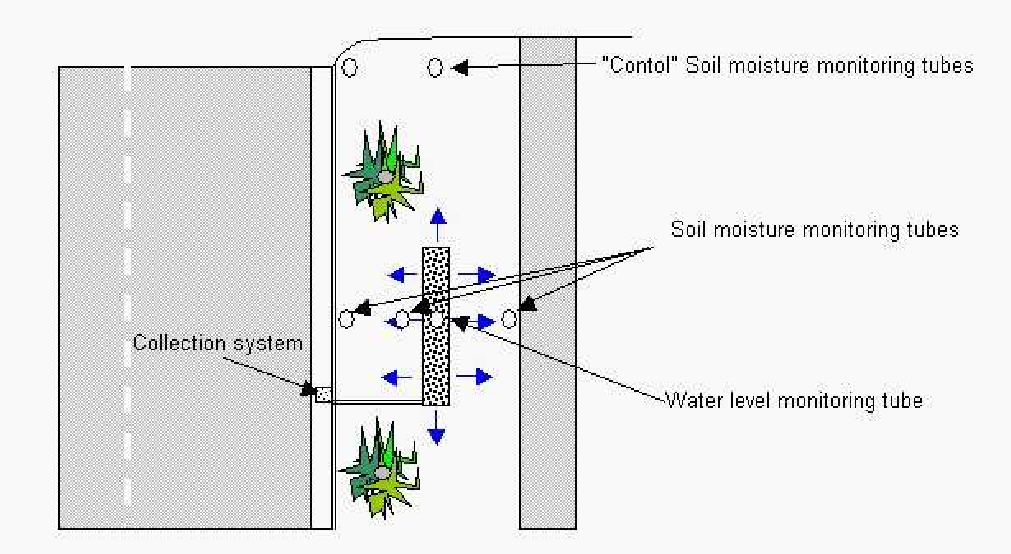

Figure 6 Location of Monitoring Tubes

An important aspect to the three components detailed above is that the data will be continuously logged. This will provide the highest level of accuracy and consistency. Without accurate data a comparison between the systems is somewhat meaningless and the outcomes may be misleading, as the full picture is not realised.

Lastly the street trees will be visually inspected by Treenet staff and compared to those trees outside the trial site. This will indicate the trees general health and its growth rate relative to a traditionally maintained street tree.

At both the start and the end of the project a sample of the soil will be taken from the site. This will allow the determination of any soil contamination that has occurred due to infiltration of the treated runoff.

CONCLUSION

To summarise the designs, there are essentially 3 harvesting devices. The permeable pavers, Modified SEP and the Terrabond. In all but the modified SEP design, the harvesting device is also responsible for the cleansing of the road runoff. The modified SEP will however, have a separate collection and filter pit that the water is required to pass. In all designs the water is then gravity fed through a pipe to a distribution trench.

These systems have been designed to minimise impact on the surrounding infrastructure and are easy to install and require minimal maintenance.

To date the devices have been installed and the project is about to enter the monitoring stage. The monitoring will enable the determination of the suitability of the designs for implementation in future construction works.

Long term monitoring is required to determine seasonal performance characteristics and ideally the project would run for a couple of years.

Depending on the outcomes of the project, there is a potential for such systems, as those trialed to become common practice of authorities such as Transport SA and Local Councils for widespread incorporation into the transportation network.

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