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Use it or lose it - it makes cents
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Kiama CBD's stormwater treatment and reuse project

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Abstract:

This project demonstrates the value of stormwater as a resource by treating contaminated runoff from Kiama's CBD and then storing and reusing the treated stormwater. Council's Stormwater Management Plan requires the reuse of stormwater for non-potable purposes to be maximised and by undertaking this type of project they demonstrated leadership on this issue to the community.

The project was developed as a "treatment train" in three stages, *viz:* 1. gross pollutant trapping strategy; 2. a sand filter to provide high level treatment; and 3. water storage and reuse.

As part of a life cycle cost analysis for gross pollutant trapping strategies, three options were assessed, *viz*: 1. a proprietary 'end of pipe' GPT; 2. 'at source' controls (i.e. dry pit inserts); and 3. a system using a combination of the two. The life cycle costing indicated that using 'at source' controls was the least cost alternative, however, the life cycle cost associated with this option was highly sensitive to frequency of maintenance. Other factors were considered including up front costs and the ability of Council to maintain devices using internal resources. A treatment train comprising 106 *Enviropods* and one sand filter in Hindmarsh Park has been constructed in the Black Beach catchment.

Following the implementation of the gross pollutant source controls, the second stage of the treatment train was installed. This involved the use of a highly innovative sand filter incorporating *Hydrocon* pipes, direct infiltration and surface storage. Life cycle costing and maintainability were integral to the sand filter design giving support to the use of an innovative product such as the permeable *Hydrocon* pipes. The sand filter has reduced pollutants significantly - Faecal coliforms have been reduced from 6,000 cfu/100ml down to 4 cfu/100ml and TP has been reduced from 0.13 mg/l to 0.042 mg/l for the storm events monitored.

The reuse stage of the project is currently being designed with estimates of substantial savings in water. A final stage in the treatment train will be an ultra-violet disinfection system to mitigate public health and safety risks. Treated stormwater will then be stored and distributed for irrigation on landscaped areas.

1. Introduction

Kiama Municipal Council received a Stage 4 Stormwater Trust grant to help fund the implementation of best practice stormwater management in Kiama's CBD. The project titled *Kiama Catchment Caretakers* comprised an integrated suite of non-structural and structural controls to protect Black Beach and Kiama Harbour from the impacts of stormwater pollution.

Council partnered with STORM_CONSULTING to develop an optimal stormwater treatment train providing sufficient treatment for irrigation reuse of stormwater on landscaped areas on the foreshores of Hindmarsh Park, adjacent to Black Beach.

The project comprises three major components, viz.:

- gross pollutant trapping strategy
- sand filter incorporating a range of innovative design attributes
- water storage and irrigation reuse system.

Consistent with the conference theme, Council had the vision to use stormwater, rather than losing it. Similarly, life cycle costing facilitated decisions on effective use of maintenance resources. These issues are explored in this paper.

1.1 Catchment characteristics

Figure 1 shows the location of the project in relation to its catchment. The catchment consists of four subcatchments with two main subcatchments - the 35 hectare Subcatchment 1 and the 6.5 hectare Subcatchment 2. Both lie in the southern part of the catchment. Landuse in the catchment is a mixture of residential, commercial and open space. The CBD of Kiama is situated in the lower central part of the catchment along two main streets and it is thought to generate most of the pollution load of the catchment. Subcatchments are drained by a network of pipes. Subcatchment 1 discharges to a trunk stormwater pipe that flows beneath Hindmarsh Park. Subcatchment 2 joins this trunk stormwater pipe at Shoalhaven Street, beneath the South Coast railway line.

Hindmarsh Park, Black Beach and Kiama Harbour are key community assets, providing high quality recreational opportunities to locals and a busy tourist trade. Swimming and boating is popular in the Harbour. It is important to protect the recreational and environmental values of the Harbour from the effects of stormwater pollution - particularly litter, sediments, hydrocarbons and pathogens.

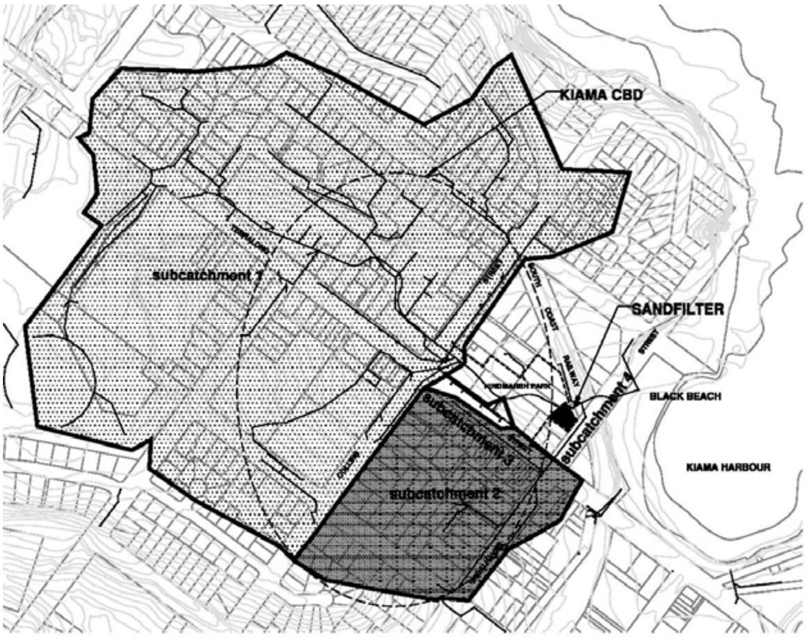

Figure 1: Project location in relation to catchment

2. Gross pollutant trapping strategy

Two proprietary products were considered for the gross pollutant trapping strategy: *Enviropods* and *CDS* units. *Enviropods* are classified as 'at source' controls while *CDS* units are 'end of pipe' control. With a budget of $100,000 to install any gross pollutant traps, STORM investigated three options that are essentially combinations of these two products, as summarised below:

- **Option 1** investigated using *CDS* unit(s) for Subcatchments 1 and 2 with Enviropods in Subcatchments 3 and 4;
- **Option 2** investigated a combination of installing a *CDS* unit on the trunk line in Hindmarsh Park (at about 6.6 m depth) together with the remaining catchments in the CBD area covered by *Enviropods* (*Enviropods* filters are a gully pit insert, designed to provide at source stormwater treatment). With this configuration, the *CDS* unit would treat the 35 Ha upper catchment (Figure 1) with *Enviropods* treating the 7 hectare lower catchment; and
- **Option 3** investigated the installation of only *Enviropods* on most pits in the 42 Ha catchment. Some pits in areas believed to be subject to very little gross pollutant loading would not be fitted with gross pollutant traps.

2.1 Key issues driving the GPT strategy

(a) Constructability

Installation of *Enviropods* into stormwater pits is generally simple, but not all pits within the catchment are suited to the *Enviropod* inserts. Some of the older pits are kerb inlet only with no grate. These older pits are in strategic locations for pollutant trapping and thus would need to be rebuilt/replaced to incorporate the litter basket inserts. Other pits have extremely low depths to the pipe inverts and are therefore unsuitable without reconstruction. The capital cost of reconstruction would be offset by the reduced capital cost of the *Enviropods* over the *CDS* units.

Constructability of the *CDS* unit in Hindmarsh Park proved to be difficult given that it would need to be constructed on a stormwater line buried at about 6.6m depth. The base of the *CDS* unit would be about 8.6 m below the ground surface. To excavate to such a depth, at least one working platform at about 4m below the surface would need to be constructed. The proximity of trees and buildings would likely pose a constraint to the construction of a ramp down to this working platform possibly necessitating lowering of an excavator down to the working platform by crane. The platform would need to accommodate the full swing of the excavator with an area of approximately 25 m^2. The whole excavation would need to be sheet piled to prevent a collapse.

(b) Maintenance requirements

The maintenance frequency required for the *Enviropods* could only be inferred for the purposes of life cycle cost assessment (estimated between $20-25 per maintenance episode). Life cycle costs of the *Enviropods* were particularly sensitive to the frequency of maintenance. If the maintenance frequency was increased from two to three events per annum, then *Enviropods* may not be the cheapest option.

Additionally, the ability of Council to maintain devices was a major consideration of the GPT strategy. Council did not wish to be locked into outsourcing device maintenance, especially where specialist and expensive equipment would be involved. For this reason, Council was more comfortable with *Enviropods* as they can be readily maintained with in-house resources.

(c) Ongoing monitoring

While the trapped contents of both devices can be analysed to infer catchment pollutant loads, the litter baskets will allow Council to effectively identify gross pollutant hotspots. This allows Council to then target the residents/proprietors in that area with education to reduce the pollution.

(d) Life cycle costing

The optimal gross pollutant strategy was determined by applying a 50-year life cycle cost comparison which integrated maintenance of the devices. The *CDS* unit is guaranteed to last 50 years with the *Enviropods* lasting about 10 years between bag replacements. It was assumed that the galvanised steel frames of the *Enviropods* would not deteriorate within the 50 year period.

Maintenance and capital costs were obtained from each supplier and have formed the basis of the life cycle cost assessment. A present value approach was adopted to discount the future maintenance costs into present value dollars. The capital cost and present value of the maintenance costs were then added to provide a total life cycle cost. We assumed that the relative environmental benefit of each unit was similar. Both manufacturers predict they will capture gross pollutants down to 200 µm in size.

Table 1 shows that Option 3, using only *Enviropods*, is the cheapest. However a sensitivity analysis indicated that if the *Enviropod* maintenance frequency increased to 3 times per year then Option 2, utilising a combination of *CDS* units and *Enviropods*, would be the cheapest option.

Enviropods significantly reduce the cleaning and maintenance requirements of stormwater pits and pipes. It is worth considering that the cleaning/maintenance costs of the stormwater pits and pipe network in the catchments would be reduced to virtually zero if Option 3 was selected. This cost reduction was not quantified in the life cycle assessment. Council would only have to save $1,000 per year on this maintenance cost to result in Option 3 becoming cheaper than Option 2 by about $30,000.

(e) Final strategy

Taking into account all the key issues discussed above, Council decided to proceed with Option 3 and install 106 *Enviropods* wherever possible in Subcatchments 1, 2 and 3. Further, Council opted for a sand filter in Hindmarsh Park to treat the 6.5 Ha Subcatchment 2 such that reuse of treated stormwater would be feasible. The sand filter details are discussed in the next section.

2.2 GPT performance

Monitoring of volume of pollutants caught in 26 *Enviropods* installed in Subcatchment 1 (December 2002 to February 2003) indicated a generation rate of 757 kg/ha/year and containing 60% organics, 32% sediment and 8% litter. The recommended cleaning rates are 16 pods to be cleaned out quarterly and 10 pods to be cleaned out every second month.

Table 1: Life Cycle Costing for gross pollutant trapping options in Kiama CBD

	Devices	No.	Unit supply & installation cost ($)	Capital Cost ($)	Maintenance events / device / annum	Cost per maintenance event ($)	Annual maintenance cost ($)	10 year replacement cost	Maintenance PV (5% discount rate)	**Total Life cost**
OPTION 1										
Subcatchment 1	CDS large	1	80000	80000	4	875	3500			
Subcatchment 2	CDS small	1	60000	60000	3	600	1800			
Subcatchment 3 - Terralong St	Enviropod	4	680	2720	3	20	240			
Subcatchment 4	Enviropod	2	680	1360	3	20	120			
Total				**$144,080**			5660	**0**	**$103,329**	**$247,409**
OPTION 2										
Subcatchment 1	CDS large	1	80000	80000	4	875	3500			
Subcatchment 2	Enviropod	26	640	16640	3	25	1950			
Subcatchment 3 - Terralong St	Enviropod	4	640	2560	3	25	300	240		
Subcatchment 4	Enviropod	2	640	1280	3	25	150	120		
Total				**$100,480**			5900	**360**	**$108,987**	**$209,467**
OPTION 3										
Subcatchment 1	Enviropod	79	550	43450	2	25	3950	4740		
Subcatchment 2	Enviropod	26	550	14300	3	25	1950	1560		
Subcatchment 3 - Terralong St	Enviropod	4	550	2200	3	25	300	240		
Subcatchment 4	Enviropod	2	550	1100	3	25	150	120		
Total				**$61,050**			6350	**6660**	**$139,541**	**$200,591**

3. Sand filter Design

The sand filter is to accept and treat the flows from the 6.5 hectares of Subcatchment 2. The design objectives of the sand filter included:

- treat at least the first flush of polluted runoff from the catchment, attempting to as close as possible achieve compliance with ANZECC Guidelines for the Protection of Aquatic Waterways;
- a safe device that does not cause any public harm or threat;
- a device that is easily and cost effectively maintained;
- a system that would allow for the potential to reuse the treated stormwater. If reuse were to be achieved then Council would also be able to demonstrate the value of stormwater as a resource. This was considered to be highly desirable given the recent approval of a Council-proposed subdivision that requires compulsory roof water use.

The design of the sand filter is shown in Figure 2. It is designed such that stormwater runoff flows firstly enter special *Hydrocon* pipes. *Hydrocon* pipes are permeable pipes and allow for water to be treated through a number of complex mechanisms. Essentially, chemically assisted settlement leads to the accumulation of fines in the base of the pipe and also in the walls of the pipe through adsorption. As these pipes fill and water flows out through semi-permeable walls, pollutants are filtered or adsorbed by the pipe matrix. The water then surcharges through a sand matrix in which the *Hydrocon* pipes are bedded. When the sand matrix is full, flow enters a piped outlet with an orifice sized to allow surcharge into an above ground, grassed surcharge basin where it is stored temporarily. Treated water is collected in a subsoil drainage manifold at a level below the *Hydrocon* pipes and is discharged into the existing drainage network.

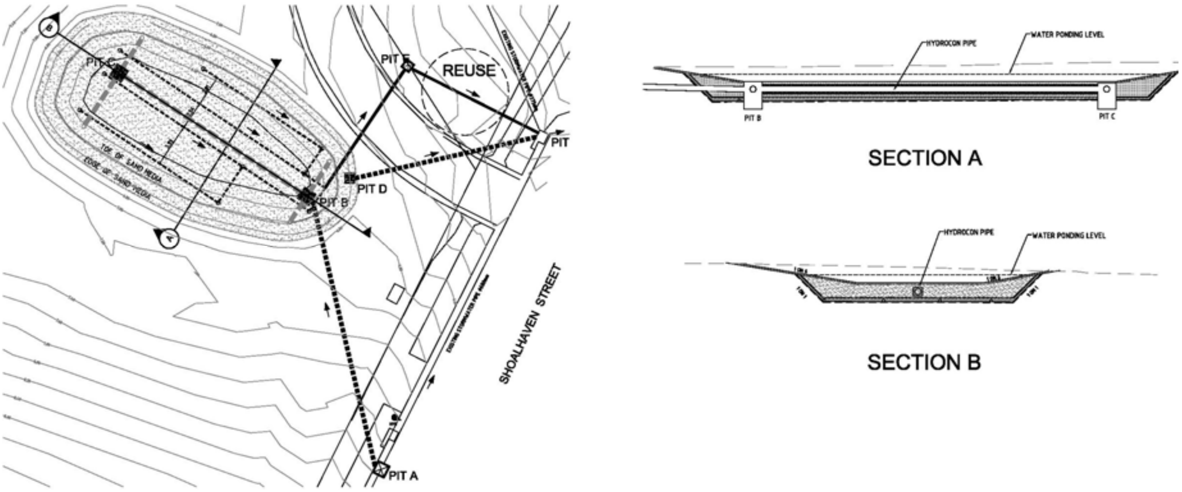

Figure 2: Sand filter design

Overflows from the surcharge basin are directed to a pit located on the outer edge of the sand filter, which defines the top water level of the sand filter. The overflow pit is connected by pipe to an existing pit in Shoalhaven Street and allows overflow to be piped away rather than flow overland.

Figures 3 and 4 show the sand filter during construction, and post-construction when the water is surcharged in to the depression above the device during heavy rainfall.

Figures 3 and 4: Sand filter during construction and post-construction showing surcharge above the device

3.1 Key sand filter design issues

(a) Pre-treatment of flows

Pre-treatment is essential to prevent sand filter clogging and thereby increasing its life. Pre-treatment of inflows is required to prevent the sand filter -from becoming clogged. This was achieved by installing *Enviropods* with specially fitted fine sediment filter bags. These bags are intended to remove down to at least 200 µm size sediment particles from the flow.

(b) Maintainability

Design of the sand filter needed to facilitate each of the following maintenance activities:

- regular maintenance of the pre-treatment devices (*Enviropods* and *Ecosols*);
- flushing the *Hydrocon* pipes approximately once per annum, based on the quantity of sediment accumulation within the pipes. It is envisaged that an eductor truck will need to be educting from the pit as the pipes are flushed;
- once every 10 years, the top 10 cm of sand and top soil of the sand matrix may need to be replaced to prevent the build up of toxicants in the surface soil layers;
- flushing the subsoil drainage pipes from the flushing points once every year to remove any accumulated sediment;
- allow the grass on the surface of the sand filter to grow deep roots to facilitate infiltration of stormwater. Every 2 months, liberally spike the grass surface so that the infiltration pathways are kept open.

(c) Predicted performance of the sand filter

A water quality model of the sand filter was developed by STORM_CONSULTING based on 6 minute pluviograph data. Sand filter performance was modelling for an "average" year. The model utilised the MUSIC software (Model for Urban Stormwater and Improvement Conceptualisation) developed by the CRC for Catchment Hydrology.

Suspended Solids and Total Nitrogen were predicted to comply with ANZECC guidelines for the Protection of Aquatic Environments (6 and 1.6 mg/L respectively). The predicted Total Phosphorus performance does not comply with the ANZECC guidelines for the protection of aquatic ecosystems (0.037 mg/L). However, the model did not include the water quality benefits of the *Hydrocon* pipe system which is capable of removing up to 50% of the phosphorus from the stormwater. Thus it is considered that the predicted result here is conservative and that compliance with ANZECC may well be achieved by the sand filter.

Based on the performance of *Hydrocon* pipes in Germany and the performance of sand filters in Australia, it was predicted that close to 100% of metals would be trapped and removed from the flow by the system.

A flux analysis of the sand filter was also undertaken. It was determined that the sand filter will overflow on three occasions during an "average" year of rainfall. Importantly, the flux analysis showed the system went into bypass after a significant volume of runoff entered the sand filter. Therefore, the first flush of stormwater runoff will be treated by the sand filter. Analysis also indicated that the sand filter does not appear to overflow so frequently that it would cause a nuisance to the amenity value of Hindmarsh Park. It is likely that flows up to 1 in 1 year storm will be piped. The excess flow from larger storm events (that exceeds the storage capacity of the basin and the overflow pit) will flow over the grass and onto the existing laneway where it will be picked up by the existing drainage system.

(d) Actual performance of the sand filter

In order to determine if the water reuse component of the project could feasibly proceed, Council collected and analysed water quality data for the sand filter during some storm events. Samples were collected prior to entering the sand filter and immediately after sand filtration. The results are shown in Table 2 below.

Table 2: Sand filter performance during storm events

Pollutant	**Upstream of sand filter**	**Downstream of sand filter**
Total suspended solids (mg/L)	28	17
Total nitrogen (mg/L)	1.1	1.2
Total phosphorus (mg/L)	0.13	0.042
Thermotolerant (Faecal) coliforms MF (mg/L)	4,000	6
Iron (mg/L)	0.71	0.26

These results confirm the predicted performance of the device for TN and TP, however, TSS performance was not as predicted (17 mg/L actual *vs*. 6 mg/L predicted). The excellent results for Thermotolerant coliforms indicate that reuse may feasibly proceed with a low health risk to the public and operators.

4. Stormwater reuse

With Council assured that the sand filter performance allows for reuse of the treated stormwater, they proceeded with design of the reuse system. Essentially the requirements include storage of treated stormwater (from the sand filter) and distribution of treated water as irrigation. The area chosen for reuse is the Black Beach foreshore and eventually Hindmarsh Park (this will enable Hindmarsh park to be disconnected from the town water supply). Figure 2 shows the location of the proposed storage tank.

The tank will be wholly buried below ground to reduce visual impact. The storage will be a 45kL concrete tank. A deep well constructed next to sand filter outlet will allow transfer of treated flows to the surface *via* submersible pumps to the holding tank.

In order to fully alleviate concerns for public and operator health, the irrigation water will be treated with a small ultra-violet disinfection unit to remove all pathogens.

5. Conclusions and recommendations

This project has highlighted the feasibility of stormwater treatment and reuse in urban areas using a treatment train approach. While the project was undertaken in a coastal area, it has applicability to almost any location. The fact that the project was conducted in stages moving down the treatment train was highly appropriate. Monitoring of treatment train performance at each stage enabled correct design decisions to be made and ensured that each stage was feasible.

Some of the lessons learnt from the project are summarised below:

- The selection of *Enviropod* filtration at 200µm was too fine ensuring excellent performance, however, the filter bags became too heavy to remove and they fell apart under this weight. They were replaced with Council's own bag design.
- While at first *Enviropods* were chosen as the pit GPTs, they caused blockages in some pits and were seen to be inferior in quality to modified *Ecosol* devices which Council now prefers.
- While this paper focuses on technical aspects of the project, it should be noted that it was undertaken with extensive education of the local community. This non-structural aspect of the project also contributed to its overall acceptance and success.