Effectiveness of Sand filters in improving water quality in Henderson Creek

A. Fernando*, A. Manirambona*, and B. Coulibaly**

* The School of Built Environment, Unitec New Zealand, Private Bag 92025, Carrington Road, Mt. Albert, Auckland, New Zealand
(E-mail: afernando@unitec.ac.nz; antoinem@xtra.co.nz)
** Boubacar Coulibaly & Associate Limited, Auckland, New Zealand.
(E-mail: coulibaly@xtra.co.nz)

Abstract
Stormwater runoff is identified to be the dominant urban source that conveys pollution into Auckland's waterways. As one of the many ongoing efforts to rectify this contamination, the City Councils in the region have installed various stormwater management devices to control the inflow of contaminants. The Waitakere City Council, in particular, has initiated a movement to improve the quality and condition of the two major waterways of Waitakere, the Henderson and the Huruhuru Creeks. Many storm-filters and sand-filters have been installed to treat stormwater runoff from car parks and roads that are perceived to be the major source of contaminants. However, there is very little monitored data to verify if these devices are achieving their targeted removal efficiencies. This paper presents the results from a preliminary qualitative assessment from an ongoing study of three sand-filters and a downstream-defender installed in the Opanuku and Oratia catchments that feed into the Henderson Creek. The efficiency of the devices was evaluated based on the most commonly found urban stormwater contaminants in Auckland, namely, suspended solids, lead, zinc and copper. Pollutant concentrations of inflow and outflow from these devices were assessed for wet-weather events. Data and results gathered revealed that the efficiency is heavily dependent on the proper operation of the devices. Comparisons were made between these preliminary results and those for a well maintained sand-filter installed within Unitec, Mt. Albert premises as well as data from overseas. For the sand-filters in this study, the sediment removal, in general, meets the expected removal efficiency of 75%; however, the poor operational conditions have a detrimental effect on the removal of heavy metals. Operational issues are high-lighted and recommendations are made with regard to the continuation of data- gathering and the maintenance needs if sand-filters are to perform at their intended efficiency and bring noticeable change to the pollution levels in the Henderson Creek.

Keywords
Henderson Creek, downstream-defenders, Sand filters, sediment removal, Stormwater runoff.

INTRODUCTION

With "Project Twin Streams", Waitakere, a suburb of Auckland in New Zealand is endeavouring to approach future stormwater management holistically using the most effective balance possible between soft and hard engineering. Waitakere City considers itself as an Ecocity, therefore stormwater quality is treated to be of very high priority.

The soft engineering approaches include encouraging local residents to minimise the litter, organic waste (glass clippings, etc) vehicle pollution, herbicides, detergents and garden fertilisers entering the City's waterways; to reduce the amount of concrete and asphalt (which increases rain run-off) on their property whilst also installing rain-gardens or rainwater tanks to catch run-off from hard surfaces; to clean cars at carwash outlets or on a grassy area to reduce contamination of stormwater thus preventing paint and oil getting into stormwater drains; to clear weeds, and plant trees and shrubs along the extensive stream banks. (WCC, 2003).

The hard engineering solutions include installation of various types of stormwater filtering and attenuation devices. The stormwater treatment devices design guideline manual (Technical Publication 10 [TP10]) prepared by the Auckland Regional Council aims to provide guidance for designing, constructing and maintaining such stormwater treatment devices with the objectives of improving water quality by removing contaminants from stormwater, and/or managing flooding and erosion by limiting the volume and peak flow of stormwater discharged. (ARC, 2003).

Traditional urban runoff control devices such as ponds and wetlands are not suited for built up areas where high runoff volumes and pollutant loads have to be dealt with within small open spaces. Filtration devices, which are much smaller in size, have been identified as a suitable retrofit option. The local authorities in the Auckland region, including Waitakere City Council, have installed several sand filters and storm filters to treat runoff from car parks and roads. However, there is little monitored data collected in the Auckland region to verify if the devices are achieving the targeted design standards. There is also virtually no cost-benefit analysis available to judge if the ratepayers in the region are reaping the dividends from the installation of these stormwater treatment devices. An attempt is made in this on-going study to assess the performance of the devices and to determine the cost-benefit ratio.

A number of studies carried out overseas and in New Zealand have shown that street runoff can be toxic to some algae, fish and insects. Tests on such life forms living in urban streams have been found to contain concentrations of lead, zinc and copper higher than those established for the protection of marine biota (City Design, 1997).

Sand filters are one of the most effective Best Management Practices (BMP) but are sensitive to solids loading and bio-fouling. They typically involve large volumes of sand and crushed rock in open or underground facilities. Recommendations for the maintenance frequency range from annual light maintenance to periodic media replacement every five years.

Sand filters tend to develop a layer of sediment on the surface. This layer governs flow through the filter and eventually occludes the filter altogether. Light maintenance includes removal of trash and debris and removing the top 20mm sand/sediment layer. Major maintenance procedures include the complete removal and replacement of the sand layer and under drain system. (Hynds Environmental, 2004; Lenhart & Harbaugh, 2000).

Location of treatment devices

The Project Twin Streams run by Waitakere City Council covers the Huruhuru stream draining the Swanson catchment and Henderson creek draining the Oratia and Opanuku catchments (Figure 1).

Figure 1: The extent of Project Twin streams (Courtesy of Waitakere City Council)

Henderson Creek forms at the confluence of the Oratia and Opanuku streams in the suburb of Henderson. It flows north for 3 km from the confluence before flowing under the northwestern motorway (Figure 2). Beyond the motorway, the creek joins the Huruhuru creek and flows into an estuary that enters the upper Waitemata Harbour.

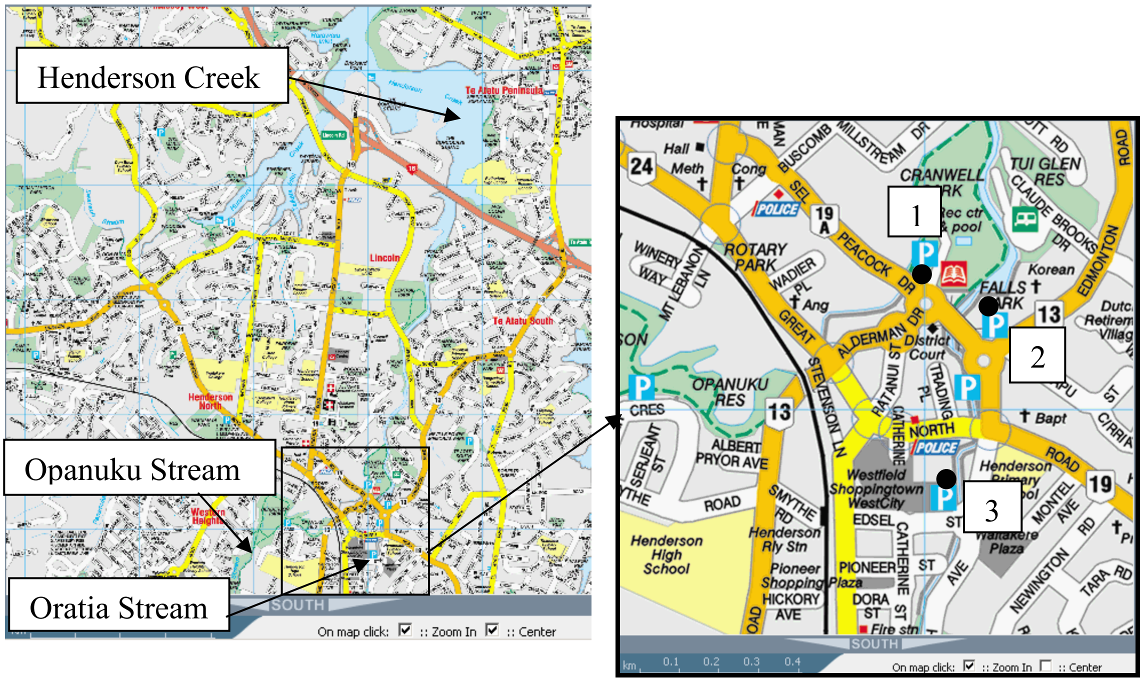

Figure 2: Location of the sand filters (Wises, 2005)

The three sand filter devices installed by the Waitakere City council that were tested in this exercise are at three car parks, namely, Sel Peacock Drive (denoted by 1 in above figure), Korean Church (2) and Pack N' Save super market (3). The three filters were designed by CouliBaly & Associates Limited for impervious areas of 10,000m², 7,600m² and 2,200m² respectively.

Sel Peacock Drive: Stormwater runoff enters this sand filter via a downstream-defender which enables sedimentation before entering the filtration media compartments in the sand-filter. At the upstream end of the downstream-defender there is a manhole from which a by-pass pipe conveys the stormwater to the outlet chamber when the downstream-defender is unable to cope with large runoff rates. It was noted in wet weather that a significant amount of by-pass occurs. The filter media consists of sand of 400mm depth separated by filter cloth. The filtration bed is designed to drain the volume of the tank in 24 hours. The inlet to the tank is a 450mm pipe while the outlet consists of two 300mm pipes discharging through a 1.2m diameter manhole that discharges into the Henderson Creek.

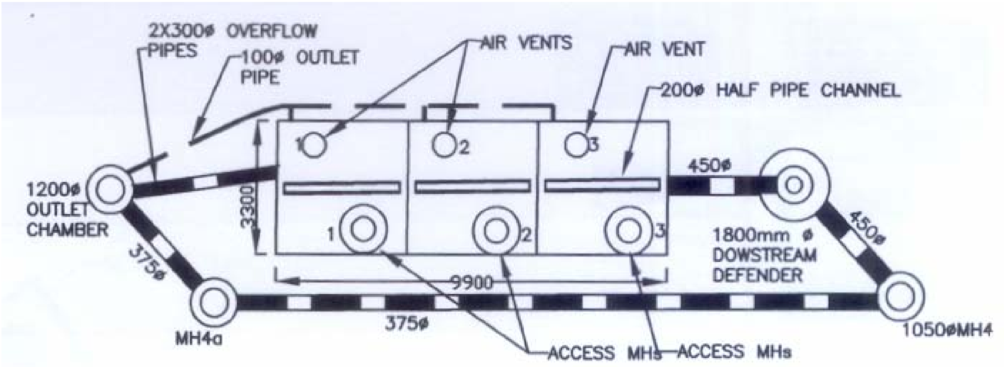

Figure 3: Schematic plan view of the Sel-Peacock Drive sand-filter arrangement (CouliBaly & Associates Ltd., not to scale)

Korean Church: Stormwater runoff directly enters the inlet chamber through a 225mm pipe which then distributes the flow into the sand filter by three 150mm diameter pipes. The filter media is again sand of 400mm depth separated by filter cloth. The three outlet pipes each 150mm diameter, discharge to the Henderson Creek via a 1.2m diameter manhole.

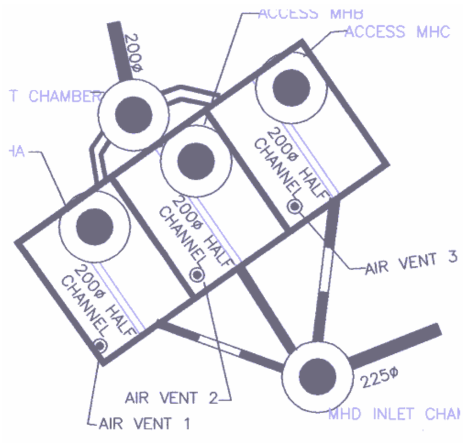

Figure 4: Schematic plan view of the Korean Church sand-filter arrangement (CouliBaly & Associates Ltd, not to scale)

Pack 'N Save: Stormwater runoff directly enters the inlet chamber through a 375mm pipe which then distributes the flow via three 200mm diameter pipes into the compartments of the filter. The filter media is identical to the filters above with filter cloth providing separation. Two outlet pipes each 100mm diameter discharges to the Henderson creek.

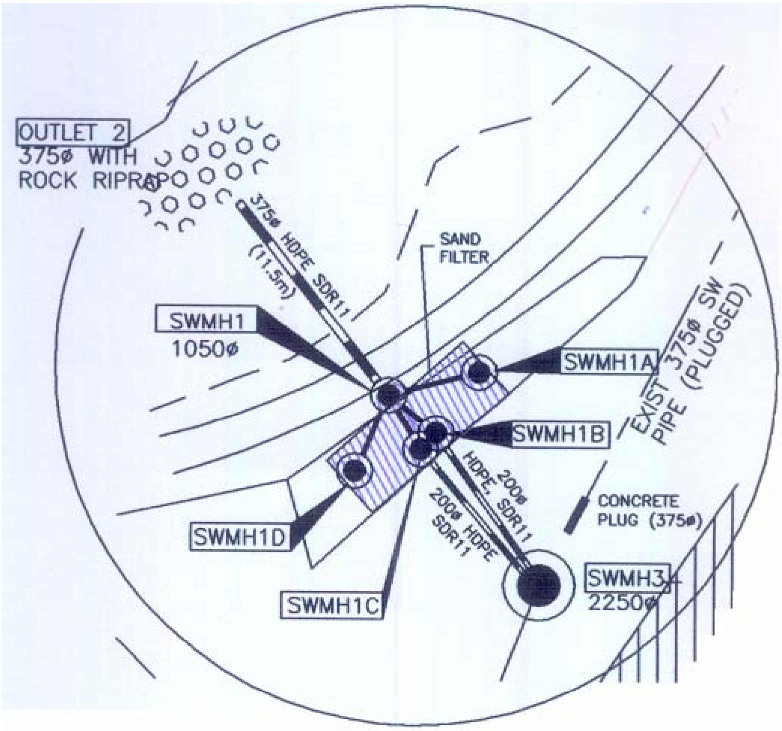

Figure 5: Schematic plan view of the Pack 'N Save sand-filter arrangement)
(CouliBaly & Associates Ltd., not to scale)

Expected Performance of filters

TP10 of the ARC requires that the filtration devices satisfy the following removal efficiencies for the contaminants:

Table 1. Contaminant removal expectations (ARC, 2003)

Contaminant	Removal expectation
Sediment	>75%
Total lead	>75%
Total zinc	>75%
Total copper	>75%
Hydrocarbons	>75%

The only known measurements in Auckland for functioning filters are those from a device installed in the premises of the Unitec Mt Albert campus for which the efficiencies for all the substances other than Hydrocarbons (which was not measured) was greater than 90% (ARC, 1994 & 2003).

METHODS

Water sampling was undertaken at inlet and outlet of all the sand filters following storm events. A 2L sample and a 250mL sample constitute one set of samples. The collected samples were tested for suspended solids (SS), total lead, total zinc and total copper. The method of sample analysis was according to the codes of APHA (American Public Health Association) 1998 and USEPA 6010.

Attempts were made to reach the filters within the first 15 minutes from the onset of the storm event to enable sampling indicative of mobilisation of sediment and organic particulates in response to runoff. Sampling logistics in the absence of automated samplers, as well as differences in rainfall intensity and duration may have contributed to some variations in measured water quality.

The results presented in this paper are from a limited set of three storm events that occurred between October 2004 and January 2005. The collected samples were tested at the WaterCare Laboratory Services on the same day.

RESULTS AND DISCUSSION

The measured pollutant concentration values at the inlet and the outlet of each filter are summarised in the tables below.

Table 2. Concentrations of pollutants at Sel Peacock Drive sand filter combined with downstream-defender

Parameter	No of storms	Inlet concentration (mg/L)		Outlet concentration (mg/L)	
		Mean	Range	Mean	Range
Suspended solids	3	125.20	17-143	4.9	2.9-6.3
Lead total	3	<0.03	<0.02-0.03	<0.02	<0.02
Zinc total	3	0.134	0.095-0.163	0.112	0.097-0.139
Copper total	3	0.012	0.006-0.016	<0.006	<0.006

Table 3. Concentrations of pollutants at Korean Church sand filter

Parameter	No of storms	Inlet concentration (mg/L)		Outlet concentration (mg/L)	
		Mean	Range	Mean	Range
Suspended solids	2	78.5	32-125	19.5	17-22
Lead total	2	<0.02	<0.02	<0.02	<0.02
Zinc total	2	0.08	0.065-0.094	0.034	0.031-0.037
Copper total	2	<0.007	<0.006-0.008	<0.006	<0.008

Table 4. Concentrations of pollutants at Pack 'N Save sand filter

Parameter	No of storms	Inlet concentration (mg/L)		Outlet concentration (mg/L)	
		Mean	Range	Mean	Range
Suspended solids	2	25	22-28	7.40	3.8-11
Lead total	2	<0.02	<0.02	<0.02	<0.02
Zinc total	2	0.091	0.05-0.131	0.0365	0.036-0.037
Copper total	2	<0.01	<0.006-0.013	<0.006	<0.006

The thresholds for detectable Lead and Copper concentrations are 0.02mg/L and 0.006mg/L respectively.

Contaminant Removal efficiency : The efficiency defined as 1-[outlet concentration/inlet concentration] was calculated as a percentage for each filter. The average values for each filter compared with those from Unitec filter and from an overseas observation (a filter installed in Alaska, according to Horner & Horner, 1995) are shown in the following table:

Table 5. Removal efficiency of sand filters

Parameter	Location				
	Sel-Peacock Drive	Korean Church	Pack 'N Save	Unitec	Alaska(USA)*
Suspended solids	82%	65%	68%	96%	81%
Lead total	>33%	-	-	98%	80%
Zinc total	15%	56%	50%	93%	82%
Copper total	>54%	-	>54%	90%	60%

* Horner & Horner, 1995. - No detectable levels.

The removal efficiencies for suspended solids are below the expected 75% level for two out of the three sand filters. Even if it is argued that the outlet sampling did not exactly correspond and match in timing with the inlet sampling, the fact that high outlet concentrations occur at the outlet following a rainfall event suggest either an under-performing sand-filter or bypass of flow directly into the outlet. The only filter that passes the expected efficiency (Sel-Peacock Drive) is the one preceded by a downstream-defender that enables some pre-treatment before reaching the sand filter unit.

Because Lead and Copper occur at levels below the detectable levels, the removal efficiency can at best be approximated. However, it is reassuring to observe that the Lead and Copper concentration levels of the stormwater discharge into the creek are low.

Removal efficiency for Zinc, for the limited sampling above, shows that levels are well below those measured at Unitec and in Alaska. During sampling it was observed that, at Sel Peacock Drive, the inlet manhole surcharges possibly leading to complete by-pass of sand-filter when high runoff was recorded. This may explain the detection of high outlet concentrations i.e., low removal efficiencies.

LIMITATIONS

The preliminary sampling carried out in this study requires to be extended before full conclusions can be made. However, the fact that these results show low removal efficiencies for SS, compared to the well maintained Unitec filter, suggest that the sand filters need more frequent attention and maintenance.

Other limitations of this study include number of samples collected being low, duration of testing being short, corresponding rainfall data not being collected and maintenance regime of the filters being poor prior to the testing. The results must be viewed under these limitations. Further testing is needed to make more conclusive comments on the performance of the filters.

CONCLUSIONS

This limited sample testing study reveals that the suspended solid removal efficiencies of two of the three sand filters that divert stormwater flow to the Henderson Creek are below the expected 75%. The Lead, Copper and Zinc concentrations in the water treated by the sand-filters appear to be below the lab detectable threshold limits and firm conclusions cannot therefore be drawn. Observations made during sampling that took place within the duration of rainfall events indicated that there can be instances when stormwater bypasses the sand filter all together and thereby providing no treatment at all.

It can be concluded that the three sand filters in this study which were installed to mitigate the stormwater pollutant loading into Henderson Creek need maintenance and possibly be supplemented by additional filter capacity to prevent overloading. The two filters that have lower than acceptable SS removal will benefit from the installation of a down-stream defender to treat the stormwater prior to entering the filters.

Further testing must be conducted to monitor the performance degradation over time and relative to the occurrence of clean-outs. The acquisition of such statistically reliable data will take time but will be valuable for all stake-holders.

ACKNOWLEDGEMENTS

Assistance of Professor Graham Smith of the School of Built Environment in securing funding for sample testing is gratefully acknowledged. Support from Grant Hudson to initiate this project is thankfully acknowledged.

REFREENCE

ARC (Auckland Regional Council) (1994). *Efficiency of an urban stormwater filter, Unitec, Auckland, New Zealand*, Technical Publication 45, September.

ARC (Auckland Regional Council) (2003), Techinical Publication 10, stormwater treatment devices design guideline manual. http://www.arc.govt.nz/index.cfm?34C9C2A8-1BCF-4AA1-91AF-CC49CFE4A80C&level1_circuit_uuid=13345213-1B02-4155-AF5D-DACE90AE6FE1&circuit_homepage_uuid=1

City Design (1997). Water quality assessment, Issue B, Mt. Wellington/Southdown (WELS006) Report, Prepared for Metowater Ltd; Released by John Herald.

Horner, R.R. and Horner, C.R., 1995, *Design, Construction, and evaluation of sand filter stormwater treatment system, Part II, Performance monitoring*, Report to Alaska Marine Lines, Seattle, Washington; 30 W 55 Street, Seattle WA 98107.

Hynds Environmental Systems Limited, Auckland, New Zealand http://www.hynds.co.nz/environmental.

Lenhart, J. H, and Harbaugh, R., 2000, *Maintenance of Stormwater Quality Treatment Facilities*, Engineering and Research, Stormwater Management Inc, Stormwater Management Facilities Management Group, USA.

WCC (Waitakere City Council) (2003). *Waitakere stormwater project gets financial boost*, Press Release of Waitakere City, Thursday, 19th June 2003, 3:50PM, http://www.scoop.co.nz/stories/AK0306/S00087.htm

Wises (2005), http://www.wises.co.nz/map/