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A novel integrated system for stormwater management

Un nouveau système intégré pour la gestion des eaux pluviales

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RÉSUMÉ

Un nouveau système integré pour la gérance des eaux pluviales est decris. Le système est composé de trois éléments clés; une étape de traitement des eaux pluviales, une étape de stockage, et une étape de contrôle/atténuation du débis. L'implementation effective de la gérance des eaux pluviales et l'utilisation du système dans une structure préventive plutôt que curative apporte de la flexibilité ainsi que d'importantes économies, en particulier dans les zones urbaines. Les éléments du système sont décris en détails, soulignant leurs avantages comparés aux alternatives conventionelles.

ABSTRACT

A novel integrated system for stormwater management is described. The system is made up of three key elements; a stormwater treatment stage, a stormwater storage stage, and a flow control/attenuation stage. The use of the system within a 'preventative' rather than 'curative' framework provides flexibility and significant cost savings in the implementation of effective stormwater management, especially in the urban environment. The system components are described in detail highlighting their benefits compared with conventional alternatives.

KEYWORDS

Source control, distributed storage, stormwater treatment, flow control, attenuation, gross pollutants trap, vortex separators, sediments

1.0 INTRODUCTION

Conventional stormwater and urban drainage systems have evolved over the last century to resolve problems of flooding and pollution resulting from wet-weather impacted events. The underlying philosophy governing their evolution, centered on "getting rid of rainfall-runoff as quickly as possible", has resulted in 'end-of-pipe solutions' that have often involved the provision of large interceptor/relief sewers, massive storage tanks in downstream locations and centralised wastewater treatment facilities.

The conventional approach has been contrasted with an alternative approach based on managing and controlling flows closer to their sources resulting in Source Control and Distributed Storage systems. These alternative systems have been found to offer major cost savings (Andoh and Declerck, 1999).

The current norm of providing two sewerage systems, one draining sewage to the sewage works and the other draining surface water directly to the river, emerged during the first quarter of the twentieth century. The combined sewer system in which foul sewage and urban runoff are collected together predated the separate sewer system. While water-related environmental efforts in the second half of the twentieth century focussed on the control of point-source effluent discharges, it is now becoming increasingly recognised that stormwater run-off itself is also a major source of pollution (CIWEM/IWA, 2000; Ellis, 1991).

Runoff from parking areas, highways and other impervious surfaces in urban areas, drained by separate surface water sewers, have been found to contain high concentrations of pollutants. These include oil and other hydrocarbons, microbial organisms, heavy metals and other toxic micro-pollutants, many of which have been found attached to suspended solids and sediments. Apart from their detrimental effect on the quality of receiving water bodies, where excessive sediment build up occurs, this can also lead to flooding, and in cases where surface water is drained into a combined sewer system, premature spilling of overflows.

In particular, sediments tend to settle to form deposits on streambeds (the benthos). The organic solids in the benthos cause a delayed oxygen demand and the solids associated pollutants can have a chronic impact on the ecosystem of the watercourse thereby inhibiting ecological development. The level of toxicity in the benthos may also build up progressively resulting in long-term problems.

For many years, a number of academics and industrialists have been advocating the application of distributed storage and source control approaches to rectifying the problems associated with stormwater management in both a sustainable and cost effective manner (Smisson, 1980; Urbonas and Stahre, 1993). While there is some way to go before such approaches themselves become regarded as standard practice, there has certainly been a shift and degree of acceptance to such approaches in recent years.

With increasing awareness of the polluting impact of uncontrolled discharges of stormwater runoff especially from highly urbanised catchments, legislative and regulatory instruments have been enacted in a number of developed countries (such as Australia and the USA) to control and mitigate the adverse environmental impacts of stormwater. This trend, coupled with increasing acceptance of Source Control, Distributed Storage and other Best Management Practices in the drive for more sustainable urban drainage systems (SUDS) has heightened the move towards alternative innovative urban drainage systems.

Particularly in the case of 'new' developments, planning consents increasingly require that the increase in the rate of urban run-off is compensated by the provision of a sufficient volume of storage capacity to act as a buffer to adjacent watercourses. Certainly, in many modern housing developments where space is not an issue, open ponds are created, both resolving the stormwater problems as well as providing an attractive 'natural' feature to be enjoyed by local residents. In highly urbanised catchments however, such approaches are not always practical due to space constraints.

The development and use of innovative 'hard structures' in the upstream parts of highly urbanised catchments has provided alternative cost-effective stormwater management systems for the control of both water quantity (alleviating flooding) and water quality (preventing pollution). These innovative 'hard structures' have been found to be more efficient, more compact and more effective "controls" than conventional systems thereby providing significant cost savings in addition to improved efficacy.

The paper describes a novel integrated system for stormwater management - 'The Hydro Stormwater Management System'. This system and its components have been applied successfully in the UK and other countries for a number of years.

2.0 INTEGRATED SYSTEM FOR STORMWATER MANAGEMENT

2.1 The Hydro Stormwater Management System

The Hydro Stormwater Management System, depending on the specific application, comprises of three key elements:

- a stormwater treatment stage – The Downstream Defender®;
- a stormwater storage stage – The Stormcell® Storage System; and
- a flow control / attenuation stage – The Hydro-Brake® Flow Control.

The component parts in themselves are standalone devices. These are novel technologies configured as highly optimised 'hard structures' offering significant benefits, including significantly improved performance characteristics compared with their conventional counterparts.

The individual components can be used with other conventional systems, providing scope for retrofitting, however the real benefits are gained when they are used together in an integrated fashion. The system provides a flexible integrated way of treating, containing and controlling stormwater in the urban environment especially where space is a major constraint. In particular, significant cost savings are realised when the system is used within a preventative framework (i.e. within the upstream rather than downstream parts of urban catchments).

A schematic of a system incorporating each of these three components is shown in Figure 1. The component parts of the Hydro Stormwater Management System are described in more detail highlighting their benefits compared with conventional alternatives.

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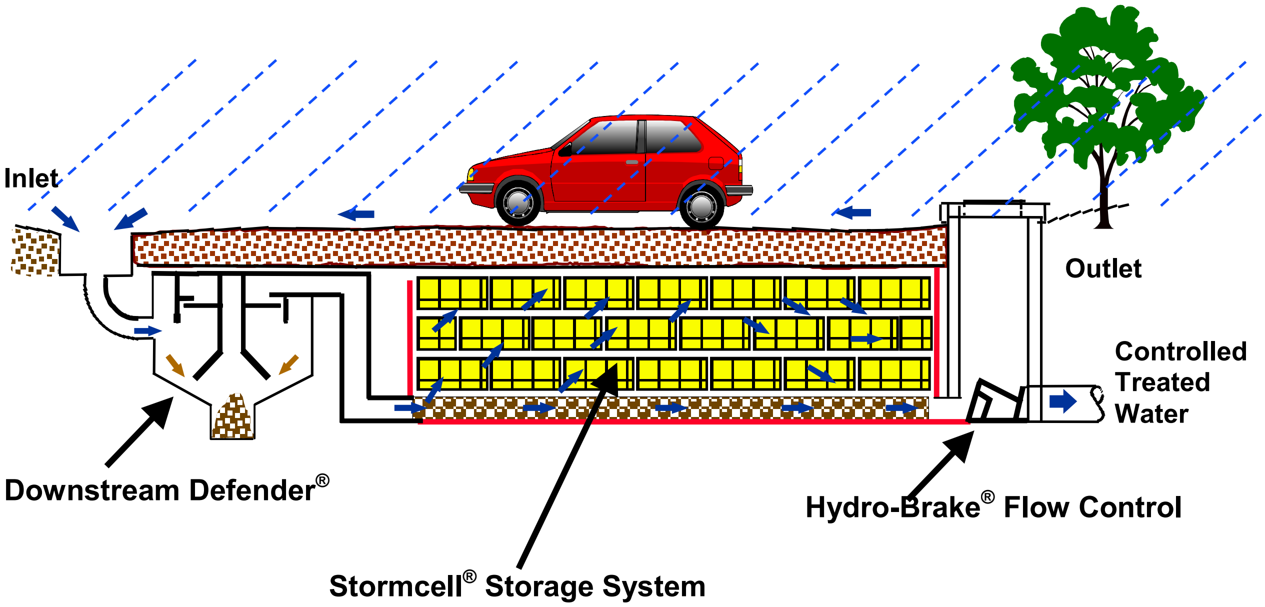

Figure 1: Hydro's Stormwater Management System Showing Treatment, Storage and Flow Control Elements

2.2 Stormwater Treatment Stage - The Downstream Defender®

The Downstream Defender® is derived from a family of high-rate rotary flow sedimentation devices generally classified as 'Hydrodynamic Vortex Separators'. The history, development and application of hydrodynamic vortex separators for improvements in environmental quality are described elsewhere (Andoh, 1998; Brombach, 1992). When compared to conventional sedimentation/storage chambers, hydrodynamic vortex separators have been found to provide equivalent sedimentation performance in a significantly smaller footprint (typically a quarter to a fifth) representing a significantly more compact process (Andoh and Smisson, 1994). The principles of hydrodynamic separation have been demonstrated to be appropriate for the removal of sediments and oils, as well as other debris, from urban run-off (Faram et. al., 2000).

While conventional storage chambers are likely to enable some degree of treatment to be effected on contained water, this would tend to manifest as a maintenance commitment. One advantage of using a high rate rotary sedimentation type system is that pollutants are concentrated to a small area for periodic removal by a truck mounted gully sucker.

To date there are over 400 Downstream Defender® installations providing environmental protection, removing settleable solids, sediments (including grits, silts and their associated pollutants), and oil from stormwater runoff. A recent development of the Downstream Defender® providing improved oil capture and retention is described elsewhere (Faram et. al., 2000). This configuration, shown in Figure 2, provides separate shielded zones for the collection of sediments and oil/floatables thus making the device uniquely resistant to re-entrainment of captured material.

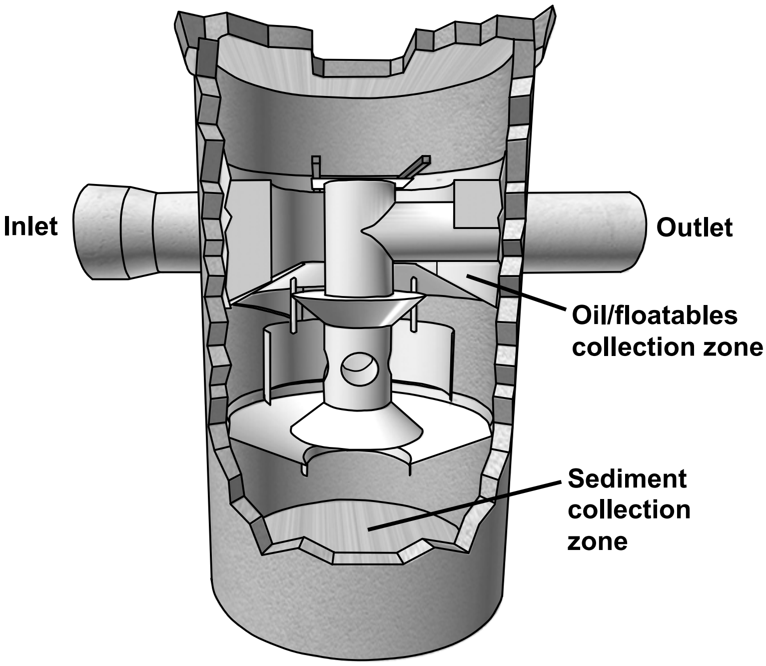

Figure 2: Sectional View Through the Downstream Defender®

2.3 Stormwater Storage Stage - Stormcell® Storage System

Hydro's Stormcell® Storage System is essentially a geoplastic 'honeycomb' media produced in block form and is used as an alternative method of achieving underground storage or infiltration at low cost. Made up of hexagonal cells of extruded polypropylene, Stormcell® blocks have a very high voidage ratio (95%), and excellent structural integrity (capable of withstanding loads of up to 400 kN/m^2). This compares with conventional crushed stone or aggregate systems with voidage ratios of typically less than 40%.

One of the most appealing attributes of the system compared with traditional box culverts, oversized pipes and concrete tanks, is its flexibility, where factors such as the shape and depth of the storage volume are not critical, expanding its range of applicability. When used as a hydraulic storage media, Stormcell® is simply installed directly under other civil engineering constructions such as car parks, low passage roads, and other similar structures where a cost-effective, practical solution is being sought (Andoh et. al., 2000).

The application of Stormcell® is relatively straightforward. Figure 3 shows the basic components that produce a typical 'on-line' storage facility. Dry weather flows pass through the perforated distribution pipe-work maintaining the usual self-cleansing regime. As the surface water flows increase during a storm event, the water level rises or 'backs up', with the restriction generally provided by a flow control such as a vortex flow control. Flows are contained within the Stormcell® whilst displaced air escapes through the venting arrangement. Water levels are allowed to subside after the storm.

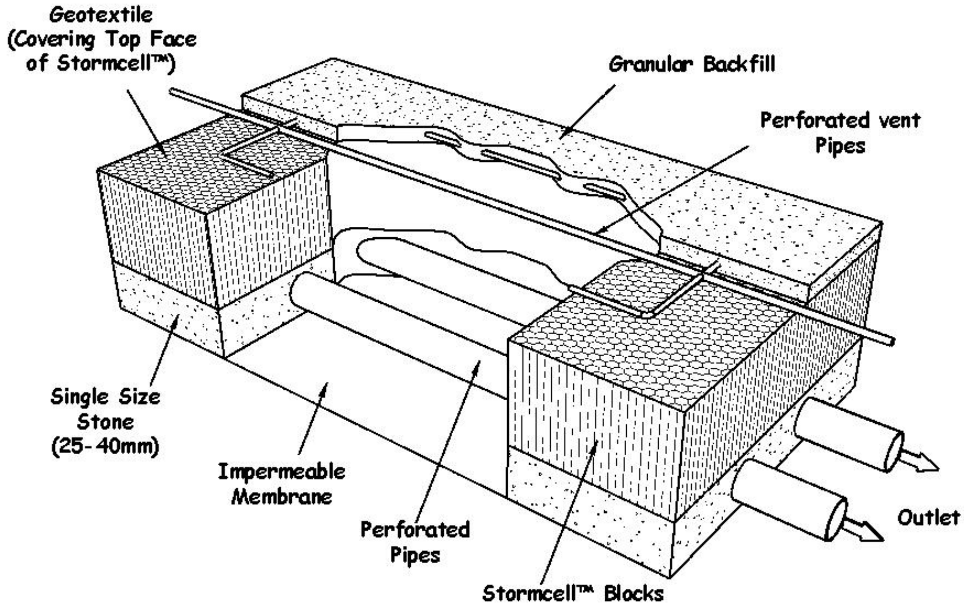

Figure 3: Sectional View Through Stormcell® Storage System

While the majority of installations have been in commercial and industrial developments such as supermarkets, warehouses and factories, a growing area of interest for its use is with the housing developers, where the Water Service Companies are beginning to accept such installations for adoption.

'Hydro Stormcell®' is marketed and manufactured in France as 'Nidaplast H20PP' by Induplast. The product was first used for surface water storage in France in 1986, and has subsequently been used in over 500 installations around mainland Europe, constituting a total storage volume exceeding 80,000 cubic metres. Since the first UK installation in 1995, over 200 further installations have been made, with a total storage volume of over 32,000 cubic metres. In most UK installations, Stormcell® media has been used in conjunction with a Hydro-Brake® Flow Control (vortex flow control).

2.4 Flow Control / Attenuation Stage - The Hydro-Brake® Flow Control

Vortex Flow Controls (e.g. The Hydro-Brake® Flow Control) are self-activating passive flow control devices with no moving parts and no external power source requirements. Vortex flow controls are well known for their advantages over orifice plates, throttle pipes, and other conventional flow control devices (Brombach, 1989). These devices utilise the head loss across a fluid vortex and are less prone to blockage due to the fact that they have an open area, which is typically 400% to 600% larger than that of the equivalent conventional devices (such as orifice plates, partly closed penstocks, etc.).

Vortex flow controls typically have two distinct modes of operation. In the first mode, termed pre-initiation, the device behaves like an unrestricted orifice, allowing relatively high flows to be discharged at low operating heads (see Figure 4). As the operating head increases, the upstream water energy is converted into rotary motion within the device. This has the effect of generating high peripheral velocities and the creation of an air-core occupying most of the outlet of the device and producing a back pressure opposing the through flow. The throttling effect results in the device behaving like an orifice with a significantly smaller opening. This mode of operation is known as the post-initiation mode. Figure 4 shows an example of a 200mm-diameter (outlet aperture) vortex flow control in its post-initiation mode, operating like a 107mm-diameter orifice plate.

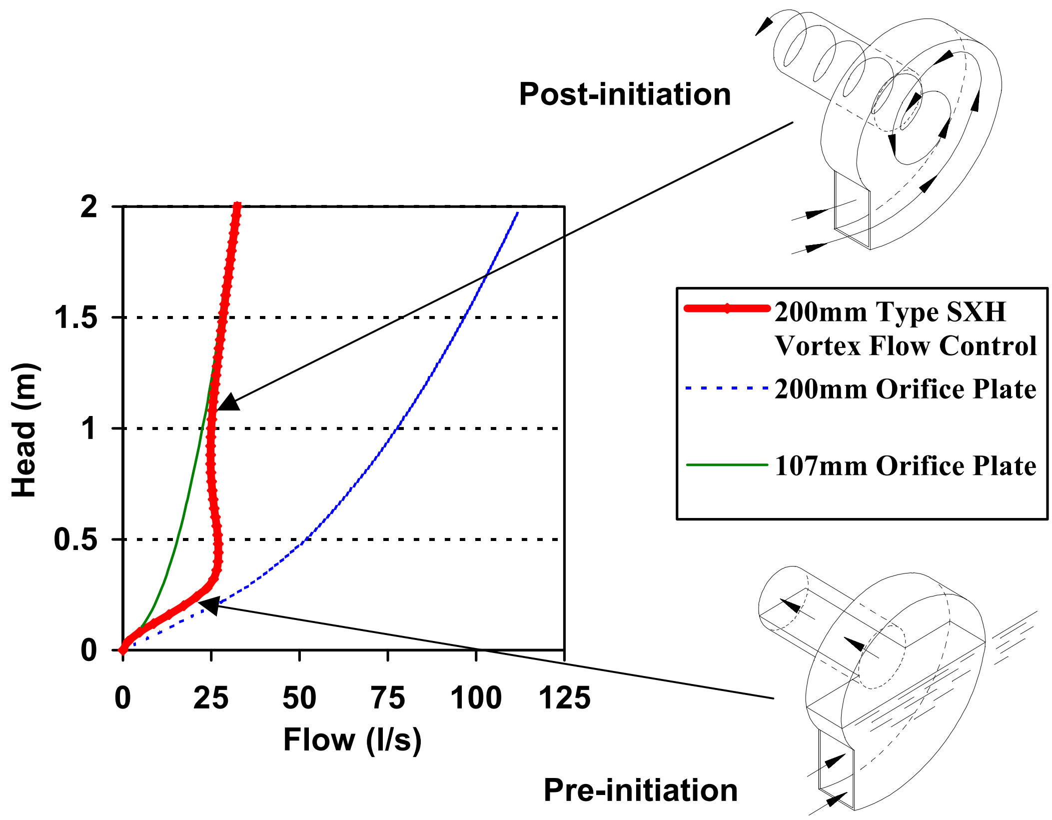

Figure 4: Comparative Head Flow Characteristic for Flow Controls

Due to the rotary motion of the flow within the volute of the vortex flow control, the discharge from its outlet is in the form of a spiraling flow with a central core of entrained air. This pattern of flow is different from the jet emitted from an orifice or partly closed penstock (or slide gate valve) in that it does not contain the same high energy per unit of cross-sectional area. Vortex flow controls are therefore less likely to cause scour and structural damage to downstream structures or cavitation within the control device. The entrained air results in the aeration of the flow and helps prevent the onset of septicity. To date, over 15,000 units have been installed within sewerage networks.

3.0 CONCLUSIONS

With increasing urbanisation and its attendant requirements for improvements in urban drainage and stormwater management infrastructure, 'end-of-pipe solutions' have been found to be costly and fraught with difficulties due to lack of space, and additional factors such as disruption to local communities. A novel integrated system for stormwater management comprising of treatment, storage and flow control /

attenuation components, provides a flexible cost-effective system with major benefits compared with conventional systems. This is particularly the case when these systems are applied in an upstream rather than downstream location in urban catchments.

The control of oil/floatables and sediments together with their associated pollutants is achieved in a compact high rate rotary flow sedimentation device – the Downstream Defender®. A novel modular geoplastic media with 95% voidage and high structural integrity (Stormcell®) provides a flexible system for storing stormwater and a passive vortex flow control (Hydro-Brake® Flow Control) enables the controlled release of the stored stormwater with minimal risks of blockage. The components making up the integrated system have no moving parts and no power requirements and as such have very little maintenance requirements.

Increasing use and adoption of these systems is providing an Eco-friendly alternative to conventional systems for stormwater management in the urban environment.

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