THE “MK2” DOWNSTREAM DEFENDER™ FOR THE REMOVAL OF SEDIMENTS AND OILS FROM URBAN RUN-OFF

Michael G. Faram, Paul LeCornu, Robert Y. G. Andoh, Hydro International plc
Thomas Beecroft, Hydro Australasia Pty Ltd

EXECUTIVE SUMMARY

With increasing urbanisation, the problems of stormwater run-off from impermeable surfaces are becoming more apparent. Run-off from roads and parking areas often carries a high sediment load, and this, along with other associated pollutants, for example, polycyclic aromatic hydrocarbons (PAH’s) and oils, can have a detrimental impact on receiving watercourses. Around the world, notably in the USA and Australia, the problem of stormwater related pollution has become very topical, and currently sits high on the agenda of required environmental improvements. A similar situation exists in Europe. The paper describes the development of a high performance system appropriate for the alleviation of these problems.

Worldwide, hydrodynamic vortex separators (HDVS’s) have been applied for both municipal and industrial effluent treatment, including the treatment of stormwater flows prior to either discharge to a watercourse, or temporary storage. These are characteristically low energy, high rate sedimentation systems that have no moving parts or power requirements, and have a small overall footprint compared to more conventional systems. There are two principle mechanisms that dictate this high level of performance. When fluid is introduced into a cylindrical vessel in a tangential orientation, it generates flow rotation. If the vessel has a single central discharge on its upper face, then it can be seen that each fluid element must pass through a long spiral path before it can be released. Effectively, when applied to a flow system that contains either settlable or buoyant material, particles are given sufficient time in which to either rise or fall. A secondary effect that arises due to this kind of flow is a centrally directed sweeping action on the base that causes material to concentrate to a central location, a phenomenon that can be readily demonstrated by simply stirring a container that contains water and sand particles. The internal components of hydrodynamic vortex separators have been specially developed to both control and enhance the effects of these flows, in order to gain maximum performance advantage.

The Downstream Defender™ is a hydrodynamic vortex separator system that has been tailored for stormwater treatment applications. It is a compact system, and is thus cost effective in terms of actual unit costs, as well as excavation costs. It has been successfully marketed in the USA, UK and Australia for a number of years. Although primarily a grit and floatables removal system, on-going developments have given rise to a number of significant enhancements, including purpose designed oil removal facilities, an integral high flows by-pass and an in-line feed-discharge configuration.

The paper provides an overview of the system, including a description of its form and the mechanisms involved in its operation. The results of preliminary laboratory evaluation studies, in which the unit was subjected to inflows containing grits, buoyant plastic beads, and oil, are presented, indicating that high levels of performance can be achieved. A brief account of typical applications is also given.

KEY WORDS

stormwater treatment, gross pollutant trap, hydrodynamic separation

INTRODUCTION

With increasing urbanisation, the problems of stormwater run-off from impermeable surfaces are becoming more apparent. Run-off from roads and parking areas often carries a high sediment load, and this, along with other associated pollutants can have a detrimental impact on receiving watercourses. Run-off from industrial developments is of particular concern. Sediments can smother stream beds, thus blocking out light and destroying vegetation, leading to a degradation in biodiversity. The heavy metals associated with sediments, along with other pollutants such as polycyclic aromatic hydrocarbons (PAH's), can give rise to biological defects in marine animals. The adverse effects of oils are also of concern. In coastal areas, these contaminants can additionally pose a risk to those who pursue water contact based activities such as swimming.

Hydrodynamic vortex separators are well known for their use as grit/sediment and floatables separators in both industrial and municipal applications (Andoh and Smisson, 1993). They are characteristically low energy, high loading rate devices and as such, have a small footprint compared to conventional sedimentation systems (typically one fifth of the area required for a rectangular settlement chamber). Such systems have been applied to the problem of on-line stormwater treatment, giving rise to products such as the Downstream Defender™ and the Storm King® Overflow (a combined sewer overflow system) (Smith and Andoh, 1997). Further developments have concentrated on their oil and floatables removal capabilities, and laboratory evaluation of a modified system has indicated encouraging performance in this respect.

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A description of the key features of the 'Mk2' Downstream Defender™ system is given in the paper, along with an account of the principles involved in its operation. Test data obtained during the development process is presented, and an overview of key applications is given.

THE DOWNSTREAM DEFENDER™ (MK2)

The principle of dynamic separation was first observed by Bernard Smisson, an Engineer from Bristol (UK), who later spent a lifetime researching the principle, and applying it to the practical problem of CSO treatment (Smisson, 1967). Following initial research work in the UK during the 1950's and 1960's, he continued his work in the USA as a consultant on an American Public Works Association (APWA) research programme, which culminated in the development of the US EPA "Swirl Concentrator" (Field, 1972), a predecessor to the enhanced systems of today.

Essentially, there are two dominating principles involved in the operation of a hydrodynamic separator. Hydrodynamic separators have been shown to have a stable near-plug flow flow regime (Alkhaddar *et al*., 1999). This means that fluid elements pass through a very long, spiral flow path prior to exiting via the overflow (this generally takes the form of a downward spiral at outer radial locations, and a smaller upward spiral at the centre). Since the path is long in terms of distance, compared to the physical dimensions of the system itself, it means that suspended particles have plenty of time in which to either rise or settle to the capture regions. A secondary effect, caused by this type of flow structure, gives rise to a sweeping action on the base of such a unit, directing particles to a central location. A similar effect can be replicated by stirring a cylindrical vessel containing water and a small quantity of sand.

The Downstream Defender™ Mk2 effectively utilises these principles to separate both grits/sediments and oils from stormwater. A schematic of the system is shown in Figure 1, illustrating the secondary flow effects described. Rotating flows are inherently unstable, and this can lead to poor separation performance if not adequately controlled. However, the internal components of the Downstream Defender™, which have evolved over decades of development, provide both a controlling and performance enhancing effect. The cone shaped sections above the grit pot and below the floatables/oil trap illustrated in the figure provide stagnant zones which serve to ensure that collected matter cannot be re-entrained once captured.

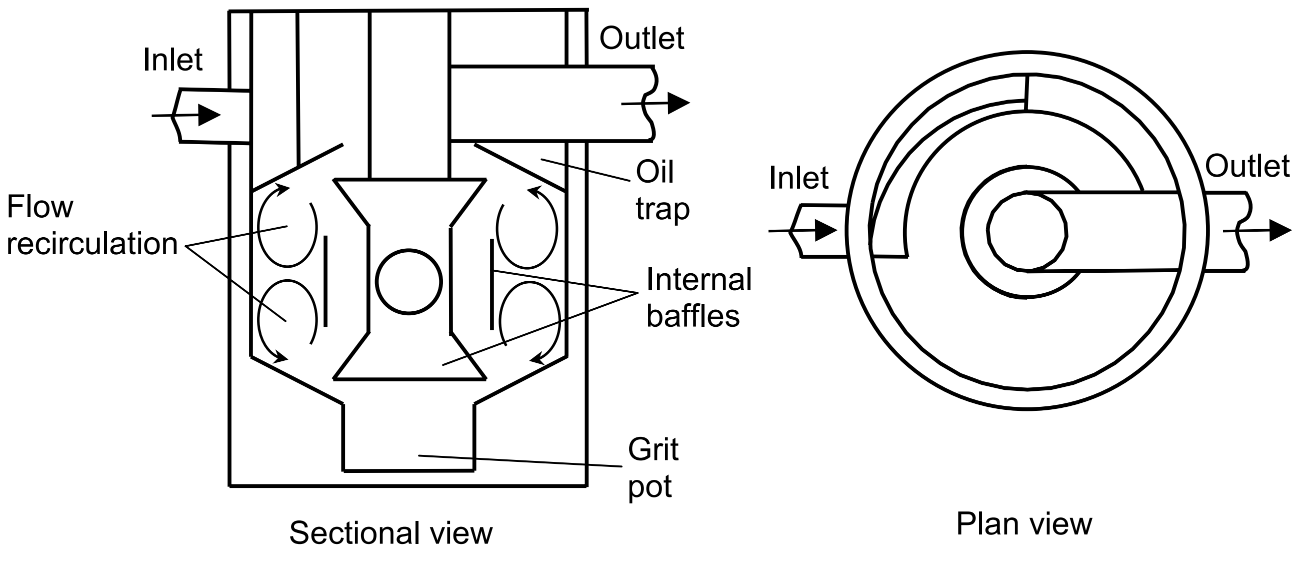

Figure 1 Schematic of the Downstream Defender™ Mk2 illustrating flow effects

The system, by means of a sophisticated flow receiving and diverting chamber, has an in-line inlet-outlet configuration, eliminating the requirement for an upstream manhole, as dictated by some other systems. Additionally, the flow-receiving chamber incorporates an emergency by-pass facility that diverts flows directly to the discharge when the flow exceeds the design flow. This removes the possibility of grit/oil re-entrainment and subsequent loss to the outlet.

The clean-out of particulate matter and oil is achieved by means of a vehicle mounted "gully sucker", with clear paths of access being available to both the grit receptacle and the oil trap.

LABORATORY EVALUATION

Test unit and configuration

For the purposes of preliminary performance evaluation, in which head losses and particle/oil recovery efficiencies were assessed, a 1.2 m diameter polypropylene Downstream Defender™ (Mk2) was set up as part of a continuous flow loop. A schematic of this arrangement is shown in Figure 2.

The unit was fed from a variable speed submersible pump. An inlet box was positioned approximately 1 m upstream of the unit to facilitate both head measurements, and also the introduction of test media.

The overflow/discharge from the unit was allowed to free fall into a receiving tank. After passing over a weir, this then discharged to a lower series of tanks. At this point, a diverter mechanism allowed flows to be directed into a parallel tank for the purposes of timed flowrate measurement. This was sufficiently small in relation to the volume of the test tanks, such that any feedback effects would be negligible.

For each test, the system was given plenty of time to stabilise prior to any measurements being taken.

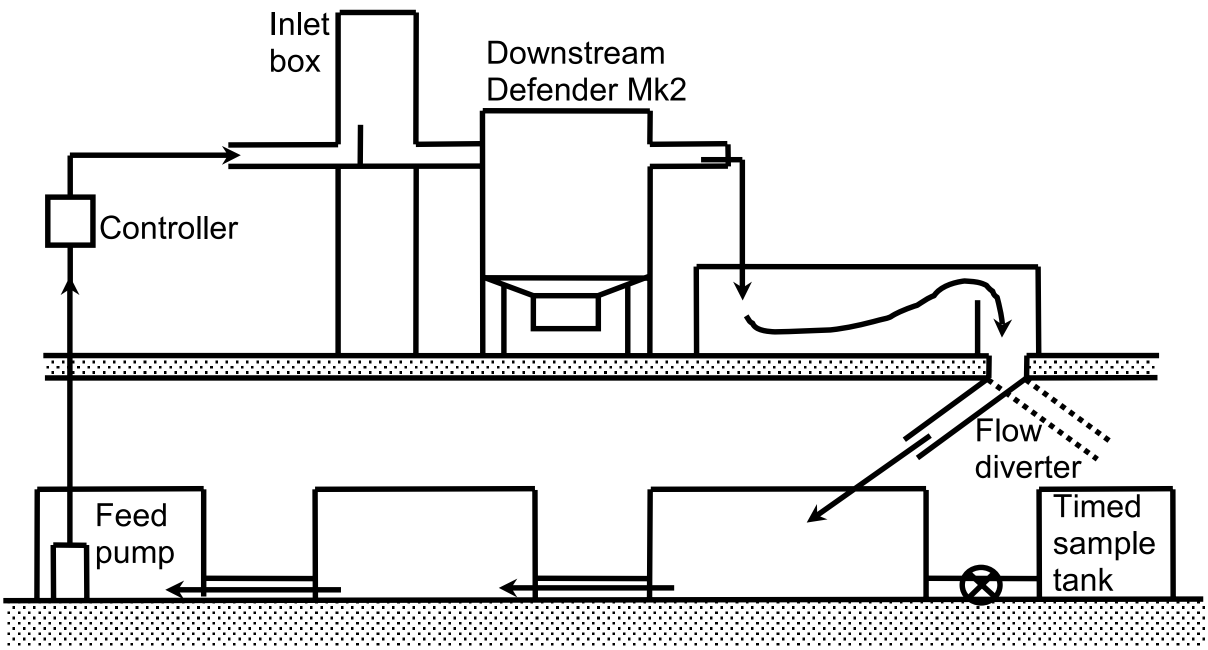

Figure 2 Schematic of the test facility

Grit recovery assessment

In order to assess the ability of the unit to remove grits from the influent stream, material was added at a steady rate, into the upstream inlet box. Tests were performed at flowrates ranging from 7 to 24 l/s, and in each case, a quantity of 1 kg of grit was added, over a suitably long period. Sieve analysis indicated that 62 % of the grit particles were finer than 300 μm, and 31 % fell within the 300-425 μm range.

For each test, the efficiency was assessed by means of drying and weighing the material collected in the lower grit pot. This data is presented in terms of total recovery efficiency in Figure 3. The efficiency is seen to decrease with increasing flowrate, falling from around 100 % at 7 l/s to over 70 % at 24 l/s. This kind of trend would be expected for any sedimentation system.

The unit was designed to by-pass at flowrates exceeding 25 l/s. Hydraulic testing confirmed that, even at flowrates of 40-45 l/s (the pump peak delivery rate), the flow passing into the treatment chamber remained below 30 l/s. Although in the Downstream Defender™ collected matter is sheltered by conical components (previously described), excessive passage of flow into the treatment chamber of any system can potentially lead

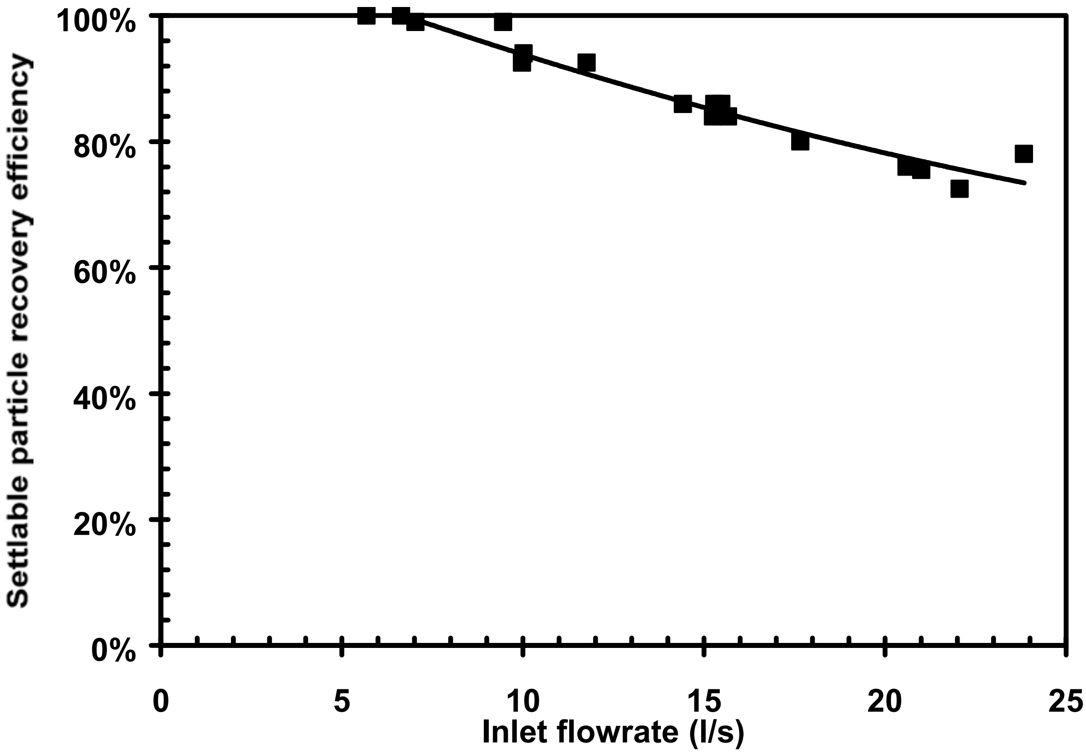

Figure 3 Total recovery efficiency for settlable particles

to the disturbance and subsequent loss of previously separated material.

For all cases below the flowrate at which by-pass commenced, the system head loss did not exceed 300 mm.

Oil/floatables recovery assessment
Test work was undertaken to assess the ability of the unit to intercept floatable material and oil. Initial studies focused on the removal efficiency for buoyant thermo-plastic beads.

The beads used were BP Rigidex HD5502XA, which have a density of around 954 kg/m^3 (compared to 850 kg/m^3 for mineral oils such as petrol, diesel and fuel oil). These take the form of fairly uniform cylindrical particles, with a typical diameter of 3 mm and thickness of 2 mm. Measurements have indicated a rise velocity in water of between 3.7 and 6.9 cm/s (average 4.9 cm/s).

For each test, a known quantity of particles were introduced to the system via the inlet box. As with the testing using grit materials, a range of flowrates were considered. A filter bag was located over the overflow to catch any escaping particles, such that a recovery efficiency could be established.

Figure 4 presents the results of this testing. As with the testing using grit, the expected deterioration in efficiency with increasing flowrate is observed, with efficiency values falling from around 100 % at 7 l/s down to over 70 % at 24 l/s.

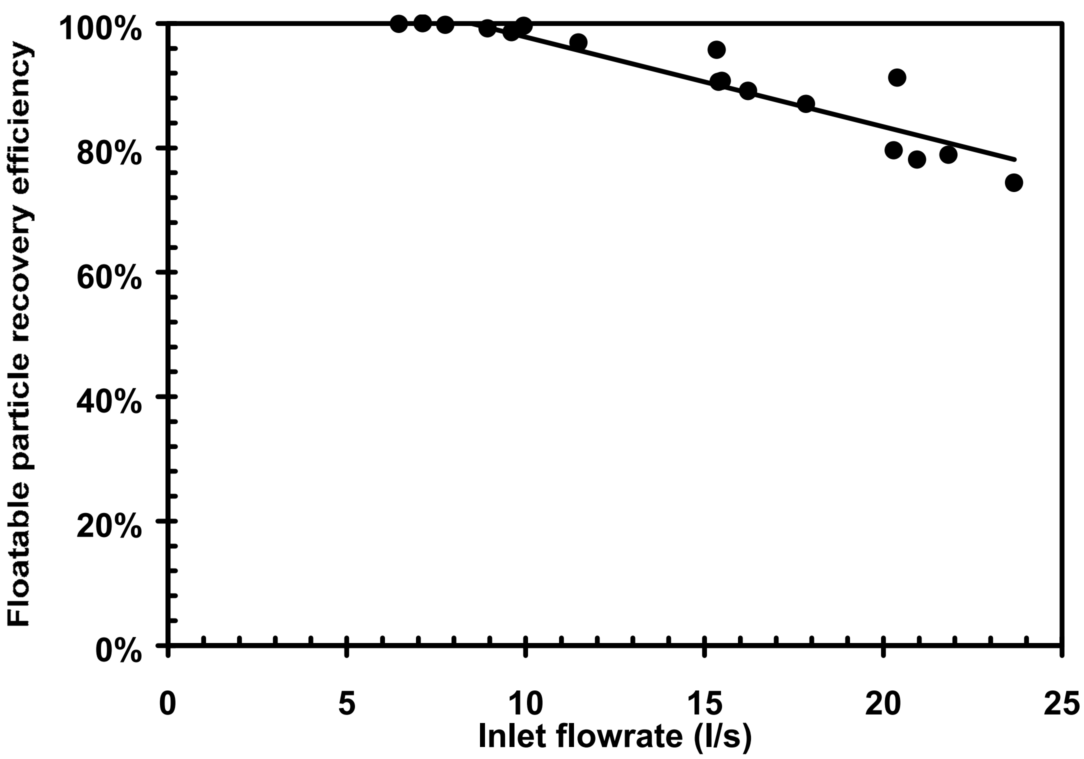

Figure 4 Total recovery efficiency for buoyant particles

A brief series of tests were undertaken to assess the ability of the system to remove oil. The purpose of these was to simply confirm the findings of the tests performed using buoyant plastic beads. For the purposes of obtaining independent verification using defined procedures and sophisticated analysis techniques, the assistance of an academic institution has been employed.

For convenience, in these tests, vegetable oil, with a density of 910 kg/m^3, was selected as a suitable test medium. Using specialised feed pumps, designed for chemical dosing applications, oil was introduced to the system inlet for a range of system inlet flowrates. This was typically regulated to give an influent concentration of around 500 ppm. The recovery efficiency, assessed by means of analysing discharge grab samples using a spectrophotometer, has been shown to be achievable to levels of up to and over 99 %.

SYSTEM APPLICATIONS

The Downstream Defender™ would most commonly be applied as a contaminants interceptor immediately prior to a final discharge point, for example, at a coastal or stream/riverside location. In some instances, depending on the sensitivity of local waters, and the expected nature of contaminants, it might be used to intercept and remove components prior to discharge into a foul sewer.

A common application, particularly in the UK, is that in which the system is used as a debris/floatables trap immediately upstream of stormwater attenuation/storage facilities. When stormwater enters a large chamber such as a storage vessel, settlable material tends to accumulate on the base. This can build up, and can potentially interfere with the operation of discharge flow controls, dictating a maintenance commitment. In this instance, the Downstream Defender™ serves to collect and concentrate debris to a central location. Although this, of course, also requires maintenance, in the form of collection of accumulated material, it can be performed more quickly and effectively.

CONCLUSIONS

The paper describes development work that has lead to the enhancement of the Downstream Defender™, a compact and economical stormwater treatment system. The improvements to the system have included both performance and operational enhancements, and also enhancements to facilitate a simplified installation procedure.

The principle of hydrodynamic separation has been applied extensively around the world for the removal of settlable material in both municipal and industrial wastewater treatment applications. In this respect, it can be regarded as ‘known technology’. In the current work, a system has been adapted in order to provide enhancements in terms of the removal of oils and floatable material. The results of laboratory evaluation, presented in the paper, demonstrate the potential of the system in this respect.

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