Pollutant Control

6.2 Hydrocarbon Management

Figure 1. Service stations are a common source of hydrocarbon pollutants. (Photograph: Department of Water 2007.)

Background

The Unauthorised Discharge Regulations 2004 of the *Environmental Protection Act 1986* make it illegal to discharge substances, such as hydrocarbons, to groundwater or the stormwater system.

The primary aim of hydrocarbon pollution management is to provide at–source containment through the implementation of appropriate structural measures. Non-structural techniques, such as raising the awareness of operators or imposing heavy fines for illegal discharges, are also useful preventive measures. Compliance with control requirements incorporated into building approvals and industry operating licences, as well as pollution discharge inspection and monitoring, help to better regulate the principal sources of contamination.

On any site there may be one or more levels of containment. Primary containment deals with the tank or vessel in which the material is stored. It is therefore the first line of defence and must be fit for purpose. Secondary containment uses devices or structures that capture spills for treatment. These can either be 'local' containment, such as oil-water separators, or 'remote' containment such as floating booms installed on the inlets to ponds or wetlands. Remote containment can be an effective temporary measure for emergency spill response, but should not be considered in preference to local containment measures.

A risk assessment is useful in deciding the appropriate level of containment. The operator should consider the hazardous materials on-site, the risks posed by accidents, the likely failure mode of the primary containment, the sensitivity of receiving environments and the potential pathways for any resultant discharge to enter the stormwater system or be transported to receiving environments.

Commonly applied non-structural practices for hydrocarbon management include:

- Preventing the mixing of stormwater and wastewater (for example from industrial processes or wash-down of vehicles or floors) and treating these water streams separately.
- Servicing, repairs and other activities that may result in contaminants such as oils, grease, solvents, acids, fuels, coolants and surfactants accumulating on hardstand areas should be undertaken in weatherproof and contained areas to prevent these contaminants entering the stormwater system.
- Activities should be undertaken on sealed concrete floors that prevent contaminants entering groundwater and enable comparatively easy clean-up of any spilt servicing fluids.
- Floors should be designed to drain to an internal collection sump and/or surrounded with an impervious perimeter bund. Any stormwater be diverted away from the workshop floor and chemical or parts storage areas.

- Wastes and wastewater should be disposed of in an approved manner, such as by removal off-site by a waste recycling and disposal contractor, or treatment and disposal to sewer where permitted.
- Chemicals and waste products should be stored in weatherproof and contained areas to prevent weathering of storage containers and to minimise the risk of contaminants from accidental spillage or ruptured containers entering the stormwater system or the environment. Storage tanks, such as underground fuel tanks, should be inspected and tested for leakages. All loading and unloading should also be undertaken in contained areas.

Oil-water separators are used to remove remnant pollutants that cannot be controlled using the practices outlined above.

Oil-water separators are often used in retrofit situations to provide some water quality treatment at a lot scale, particularly for small industrial or commercial lots where larger BMPs are not feasible due to site constraints. There is a variety of both proprietary and non-proprietary oil-water separators available, ranging from chambered designs to man-hole types. Many of these systems are 'drop in' systems and incorporate some combination of filtration media, hydrodynamic sediment removal, oil and grease removal, or screening to remove pollutants from stormwater. The standardised designs allow for relatively easy installation.

These separators are best used in commercial, industrial and transportation type land uses (i.e. impervious areas that are expected to receive high sediment and hydrocarbon loadings, such as carparks and service stations). However, oil-water separators cannot be used for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols and alcohols.

For non-structural control information, refer to Sections 2.2.6. 'Maintenance of premises typically operated by local government', 2.2.8. 'Maintenance of vehicles, plant and equipment (including washing)', 2.2.10. 'Stormwater management on industrial and commercial sites', 2.3.4. 'Education and participation campaigns for commercial and industrial premises', 2.4.2 'Point source regulation of stormwater discharge and enforcement activities' and 2.5.1 'Risk assessments and environmental management systems' of Chapter 7: Non-structural controls. For further information on managing stormwater and preventing pollution from industrial sites, see the following Water Quality Protection Notes: *Industrial Sites near Sensitive Environments – establishment and operation* (Department of Environment 2004a), *Mechanical Servicing and Workshops* (Department of Environment 2005a), *Stormwater Management at Industrial Sites* (Department of Water 2006a), *Mechanical Equipment Washdown* (Department of Water 2006b), *Radiator Repair and Reconditioning* (Department of Water 2006c), *Service Stations* (Department of Water 2006d), and *Toxic and Hazardous Substances- storage and use* (Department of Water 2006e), available on the Department of Water website: <http://drinkingwater.water.wa.gov.au>.

Further information about spills and emergency response is available at <http://emergency.environment.wa.gov.au>.

Performance efficiency

Selection of an appropriate oil-water separator is largely governed by the level of hydrocarbon interception that is required and the likely oil droplet size. Performance efficiencies for various types of oil-water separators are described below, based on information detailed in Engineers Australia (2006).

- **Flow density-based separators**: use a series of simple flow baffles to trap sediment and floating oil (Figure 2). The collected oil is removed by an oil skimmer to a separate storage tank or periodically removed by a suction tanker. The application of these separators is limited to medium (100-140 µm) size oil droplets (i.e. runoff conditions close to the source, with limited emulsification of the oil). The maximum treatable catchment area is typically less than 0.2 ha.

- **Coalescence plate-based separators**: use closely packed plates coated with a material that repels water and attracts oil, causing oil droplets to coalesce (i.e. join together). The accumulated oil on the plate then floats to the surface of the separation chamber. The close spacing of the plates reduces the distance that an oil droplet must travel before it reaches a collection surface. Therefore, to achieve the same degree of treatment as a flow density-based separator, a smaller device can be used. These separators are capable of high interception rates (>90%) for small (50–60 µm) oil droplets that are typical of oil that has been highly emulsified by stormwater. The maximum treatable catchment area is typically less than 0.5 ha.

- **Vortex-based separators**: use the energy of the vortex to promote the density separation of oil and water. Vortex-based separators are capable of intercepting very fine (20–30 µm) oil droplets.

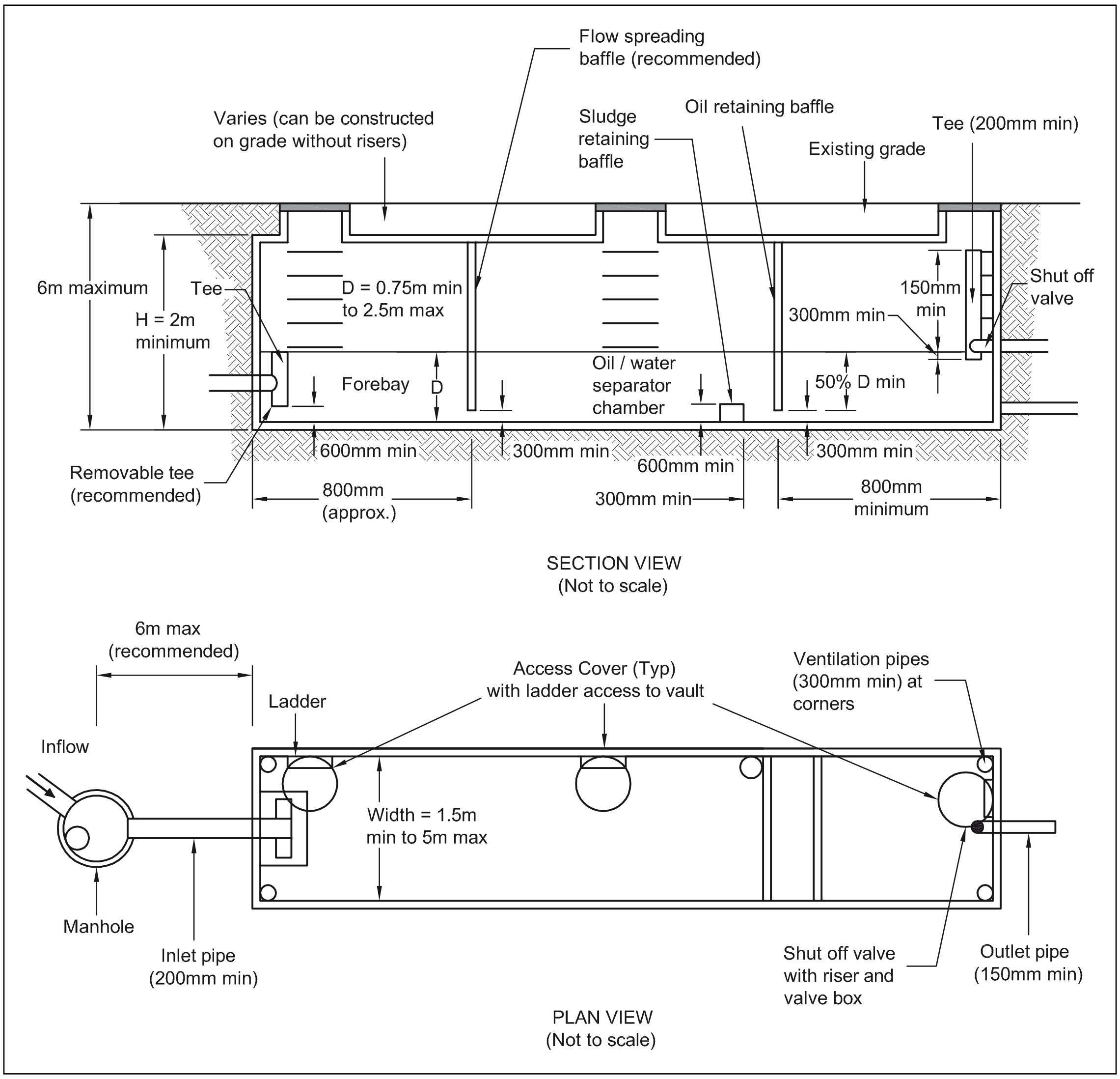

Figure 2. Typical Flow Density-Based Separator Layout. (Source: Auckland Regional Council 2003.)

Cost

The construction costs for oil-water separators will vary greatly, depending on their size and depth.

A life cycle cost method is recommended in assessing the true costs of oil-water separator systems. This approach takes into consideration the capital costs as well as maintenance, servicing and disposal costs over the life of the system.

Due to the high variability and lack of standardisation of available cost data, it is recommended that capital costs for individual systems be assessed on a case by case basis.

Maintenance costs will also vary significantly depending on the size of the drainage area, the amount of residual collected and the clean-out and disposal methods available (Schueler & Shepp 1993). The cost of residual removal, analysis and disposal can be a major maintenance expense, particularly if the residuals are toxic and are not suitable for disposal in a conventional landfill.

Design considerations

Only rainfall runoff that may contain hydrocarbons (e.g. runoff from carparks or areas adjacent to fuel pumps) should enter the oil-water separator that is part of the stormwater treatment system. Runoff that is relatively clean (e.g. roof runoff) should be managed separately to minimise the volume of stormwater that requires a high level of treatment. Oil-water separators installed to treat stormwater runoff at industrial or commercial sites should not be used to collect and treat wastewater or fluids from chemical or petroleum spills.

Careful evaluation of the maintenance and disposal issues is highly recommended. Higher residual hydrocarbon concentrations in trapped sediments cause maintenance and residual disposal costs associated with oil-water separators to be higher than other BMPs. Proper disposal of trapped sediment, oil and grease is required as trapped material is likely to have high concentrations of pollutants and might be toxic.

Ease of access for maintenance and inspection is required. In particular, lids should be kept as lightweight as practical.

Oil-water separators should be designed and constructed as offline systems only. In addition, it is recommended that the contributing area to any individual inlet be limited to approximately half a hectare or less of impervious surface.

Design guidelines

The following design guidelines for an oil-water separator are based on Auckland Regional Council (2003). Auckland Regional Council (2003) is provided as a design reference for oil-water separators in Engineers Australia (2006).

Rise velocity

The rise velocity for an oil droplet within a separator can be calculated, given the water temperature (which affects the viscosity of the water) and the density of the oil. This rise velocity is then used in the sizing calculation for the device.

$$V_r = \frac{g.D^2(1-s)}{18v}$$

Where:

V_r = rise velocity of an oil droplet (m/s)
s = specific gravity (e.g. oil 0.9, diesel 0.85, kerosene 0.79 and gasoline 0.75)
D = droplet diameter (m)
v = kinematic viscosity of water (m^2/s)
g = gravitational acceleration (m/s^2)

Design flow

The required design (treatment) flow rate can be calculated using the Rational Method equation:

$$Q_d = \frac{C.i.A}{1000}$$

Where:

Q_d = required design (treatment) flow rate (m^3/hr)
C = coefficient of runoff
i = rainfall intensity for selected design rainfall event (mm/hr)
A = catchment area (m^2)

In WA, a design rainfall recurrence period of 1 in 6 months can be expected to achieve water quality treatment of at least 95% of the expected annual runoff volume. For small catchments, a critical storm of minimum 10 minute duration should be used.

Tank sizing for flow density-based separator

The base area of the tank (A_b) is a function of the rise velocity (V_r), expressed in m/hr, and design flow rate (Q_d), expressed in m^3/hr:

$$A_b = \frac{F.Q_d}{V_r}$$

The factor F is dimensionless and accounts for short circuiting and turbulence effects, which can degrade the performance of the tank. The factor depends on the ratio of horizontal velocity (U) to the rise velocity (V_r), as shown in Table 1 based on Auckland Regional Council (2003).

Table 1. Factor F for calculation of tank sizing

U/V_r	Factor (F)
3	1.28
6	1.37
10	1.52
15	1.64

The volume and area calculated by this method refer to the main compartment of the tank. Additional volume should be allowed for inlet and outlet sections of the tank.

Other key sizing requirements detailed in Auckland Regional Council (2003) for sizing the main compartment of the tank are:

- Length to be at least twice the width
- Depth to be at least 0.75 m
- $U \leq 15V_r$

Additionally, it is recommended that the width is typically between 1.5 m to 5 m, and depth is less than 2.5 m (and between 0.3 to 0.5 times the width). Some of these additional recommendations will not be appropriate for smaller catchments.

To avoid re-entrainment of oil and degradation of performance, it is recommended that the maximum horizontal flow velocity in the main part of the tank be less than 25 m/hr.

Tank sizing for coalescence plate-based separator

Plate separator suppliers can provide an approximate size to achieve the required oil droplet diameter separation at the chosen design flow rate. The plan area (A_{plan} in m^2) of each plate can be approximated from the following equation:

$$A_{plan} = \frac{Q_d}{V_r.N}$$

Where N = the number of coalescing plates and the rise velocity (V_r) and design flow rate (Q_d) are expressed in m/hr and m^3/hr respectively.

Other considerations

A high flow bypass may be required in certain situations so that flows above the design flow do not enter the oil-water separator and cause re-suspension of debris or entrainment of oils.

A bypass system may not be required where the catchment draining to the oil-water separator is small and therefore the volumetric increase in runoff can be accommodated by the tank size. An adequately sized tank is generally preferable to a bypass system, which will result in contaminants potentially reaching the main drainage system and receiving water bodies.

Where a bypass system is installed, an inlet baffle should be included. The inlet baffle prevents the collected oil from recirculating back into the bypass system and subsequently into the drainage system.

To achieve an even flow distribution across the tank at the inlet, a baffled inlet port or other device is used. The sizing of the inlet port or baffle should be such that some head loss is provided to spread the flow. It is recommended that velocities of the maximum separator flow should be less than 0.5 m/s to avoid oil emulsification.

Maintenance

The effectiveness of oil-water separators is highly dependent on regular maintenance. Regular inspection and maintenance is required to reduce the risk of re-suspension of debris or entrainment of oils. Failure of hydrocarbon management systems is usually caused by a lack of maintenance.

Recommended maintenance practices are outlined below:

- The device should have a site specific maintenance plan, providing guidance on a suitable inspection regime, maintenance practices (including guidelines on the equipment to be used, health and safety procedures, waste disposal arrangements, etc.) and responsibilities. These plans should be prepared in consultation with relevant maintenance personnel.
- In the case of proprietary systems, use the manufacturers' recommended maintenance specification as a basis. However, stormwater managers are required to critically assess the adequacy of manufacturers' recommended maintenance schedules on a case by case basis. Where necessary, the maintenance requirements or cleaning frequency may need to be increased, particularly for high risk catchments (see Engineers Australia (2006) for further information on catchment risk assessment for hydrocarbon management). Frequent inspection is initially necessary following installation of the device to develop an appropriate inspection and cleaning regime. Maintenance schedules should not be fixed, but reviewed regularly to reflect the performance outcome from ongoing monitoring and optimise the maintenance regime.
- Periodic removal of sediment is required to maintain the capacity of oil compartments, prevent blockages of inlets and maintain the functioning of coalescence plates. As a general guide, in areas of high sediment loading, inlets should be inspected and cleaned after every major storm event, and inspected at least monthly. Typically, oil separators need to be maintained every 1 to 6 months.
- Suitable equipment to extract the waste from the drainage system needs to be used (e.g. machinery that operates via suction rather than flushing).

- Nuisance problems such as odours and mosquito breeding can occur with the use of wet chambers. Therefore, regular visual inspection of chambers is required during the mosquito risk breeding months and pollutants removed and mosquito control undertaken when necessary.
- The amount of material removed from each chamber should be documented so that the frequency of maintenance can be adjusted if required.
- A representative sample of the sediment should be analysed before disposal. If the sediment requires disposal in a landfill, refer to the *Landfill Waste Classification and Waste Definitions 1996* (As amended) (Department of Environment 2005b) to determine the appropriate landfill type and the waste acceptance criteria. The Department of Environment and Conservation regulates the transportation of wastes that may cause environmental or health risks. It does this through the application of the Environmental Protection (Controlled Waste) Regulations 2004. Controlled waste is generally defined as any waste that does not meet the acceptance criteria for a Class I, II or III landfill site. The *Guideline for Controlled Waste Generators* (Department of Environment 2004b) specifies that a generator is a person whose activities produce or apparatus results in the production of controlled waste. Generators are required to use a Department of Environment and Conservation controlled waste licensed carrier to transport the material off-site and be in possession of a controlled waste tracking form.

Worked example

The following worked example has been adopted from Auckland Regional Council (2003) and amended to represent local hydrologic conditions.

A service station in Perth is to be fitted with an oil-water flow density-based separator to treat runoff that is potentially contaminated with hydrocarbons. Runoff from the roof should be separated from runoff that is likely to be contaminated with hydrocarbons (e.g. pavement runoff). The wastewater from the car wash area is to be directed to a water reuse system, which is connected to the sewer. The flow density-based oil-water separator installed to treat pavement runoff will have a catchment area of 300 m^2 draining to the device.

The rainfall intensity for a 10 minute critical storm duration with a return period of 0.5 years (i.e. ${}^{0.5}i_{10m}$) in Perth is 34 mm/hr. The separator design flow, using the Rational Method equation is:

$$Q_d = \frac{C.i.A}{1000}$$

$$= \frac{1.0 \times 34 \times 300}{1000}$$

$$= 10.2 \text{ m}^3/\text{hr}$$

The separator is to be designed for this example to capture a 60 μm droplet of oil (s = 0.9) rising through water at 15°C (which has a kinematic viscosity $\nu = 1.139 \times 10^{-6}$ m^2/s)

To calculate the rise velocity:

$$V_r = \frac{g.D^2(1-s)}{18\nu}$$

$$= \frac{9.81.(60 \times 10^{-6})^2(1-0.9)}{18.(1.139 \times 10^{-6})}$$

$$= 1.72 \times 10^{-4} \text{ m/s}$$

The rise velocity is 1.72×10^{-4} m/s (or 0.62 m/hr).

The maximum design flow horizontal velocity (U) at the separator is 15 V_r = 15 (0.62 m/hr) = 9.3 m/hr. Therefore the flow cross section (depth times the width) is Q_d/U = (10.2 m^3/hr) / (9.3 m/hr) = 1.1 m^2. The minimum required depth is 0.75 m, which gives a width of 1.5 m. These dimensions are within the recommended guidelines of the depth being typically half the width.

For U = 15 V_r, an F of 1.64 is then used (from Table 1) to calculate the base area A_b:

$$A_b = \frac{F.Q_d}{V_r}$$

$$= \frac{1.64 \times 10.2}{0.62}$$

$$= 27 \text{ m}^2$$

With this plan area and a width of 1.5 m, the length is 18.0 m. The volume of the main chamber of the tank will be 20.2 m^3 (excluding inlets and outlets). The tank will actually be longer to allow for an inlet chamber and an outlet section, which, as an approximate guide, could add an additional 20% to the total tank volume.

References and further reading

Auckland Regional Council 2003, *Design Guideline Manual: stormwater treatment devices*, Technical Publication No. 10 (July 2003), Auckland Regional Council, Auckland, New Zealand.

Department of Environment 2004a, Water Quality Protection Note: *Industrial Sites near Sensitive Environments – establishment and operation*, Department of Environment, Perth, Western Australia.

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