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# Technologies for Monitoring, Detecting and Treating Overflows from Urban Wastewater Networks

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Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

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- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

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**EPA RESEARCH PROGRAMME 2014–2020**

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## (2014-W-DS-19)

## EPA Research Report

Prepared for the Environmental Protection Agency

by

Trinity College Dublin

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# Executive Summary

This end of project report has been prepared for the project entitled *Technologies for monitoring, detecting and treating overflows from urban wastewater networks* (2014-W-DS-19). The aim of this report is to present a review of legislation and research literature relevant to the regulation, monitoring and improvement of stormwater overflows (SWOs). A methodology is also presented to enable prioritisation of SWO monitoring in Ireland, the Priority Overflow Selection Tool (POST).

A brief introduction is given in Chapter 1 to the prevalence and challenges faced in SWO improvement in Ireland. In Chapter 2, the primary pollutants of concern are identified, along with their receiving water impacts, and a summary of typical concentrations in overflows is presented. The legislative framework for SWOs is presented in Chapter 3 in two parts: (1) legislation aimed at protecting receiving waters and (2) legislation aimed at licensing SWO discharges. Recent European Union (EU) infringement cases are discussed in relation to the Urban Waste Water Treatment Directive (UWWTD). In Chapter 4, guidance and best practice for SWO appraisal and improvement is reviewed. The review covers Ireland, the UK, other EU countries, the USA and Canada. Some of the limitations of current SWO assessment methodologies used in Ireland are identified, and alternatives are discussed. Chapter 5 describes the development and application of POST. Chapter 6 gives an overview of technologies for SWO monitoring. The review focuses on emerging and low-cost technologies. Chapter 7 presents technologies for SWO improvement, including traditional methods (referred to as grey infrastructure), such as storage tanks and emerging sustainable drainage techniques (referred to as green infrastructure). The appraisal of SWO improvement options is also briefly discussed.

This review has highlighted the advancement of SWO assessment methodologies in the EU and elsewhere, which have yet to be widely adopted in Ireland. Methods such as receiving water impact assessment based on spill frequency and volume are required to demonstrate compliance with the UWWTD and Water Framework Directive (WFD). However, there are currently insufficient data on SWO spills in Ireland to implement such approaches. Nevertheless, the development of low-cost SWO monitoring technologies may facilitate more widespread monitoring and the development of modelling approaches for impact assessment in Ireland. Furthermore, while SWO improvement in the UK has mainly consisted of grey infrastructure components, experience from the USA and elsewhere indicates that green infrastructure may provide more environmentally beneficial and resilient solutions for SWO improvement in Ireland.

# 1 Introduction

In Ireland, the majority of urban areas are drained by combined sewer systems, which convey wastewater and stormwater in a single pipe. During rainfall events the capacity of the combined sewer system may be exceeded. A stormwater overflow (SWO) is a structure designed to divert excess flows from the sewer network, either directly or via a storm sewer system, to the receiving water. SWOs may also be referred to as combined sewer overflows (CSOs). Sewer overflows can occur on gravity sewer networks, or at pumping stations if the pump capacity is exceeded. Overflow structures are also provided for pump stations in the event of mechanical or electrical failure, which are referred to as emergency overflows (EOs). An important distinction between SWOs and EOs is that SWOs discharge because of insufficient flow capacity during storm conditions, whereas EOs operate only where there is a mechanical or electrical failure.

SWO discharges contain a mixture of raw sewage and stormwater and are thus a source of microbial pathogens, oxygen-demanding substances, suspended solids, toxic substances, nutrients and gross solids (US EPA, 2004). SWO discharges have been recognised as a potential cause of receiving water impairments including beach closures, contamination of drinking water supplies and reductions in chemical and ecological status.

The extent of SWO installations in Ireland is significant: based on best available data, approximately 1300 SWOs were under licence or under application as of 2014 (for agglomerations greater than 500 population equivalents). An assessment of the impact of SWOs was carried out under the Water Framework Directive (WFD) Urban Pressures report (CDM, 2009). Based on sewer network models, the report concluded that cumulative annual spill volumes were in the order of 5–10% of the total annual combined flows. An assessment of nutrient loads to Irish rivers estimated that 1% of nitrogen loads and 5% of phosphorus loads were attributable to SWOs (Mockler *et al*., 2016). An assessment of performance against environmental criteria is an ongoing requirement for SWOs under the wastewater discharge authorisation for each agglomeration; however, SWO performance data are not currently available in many cases. This may be due in part to the challenges posed by the monitoring of SWOs, which can be located in remote areas or under trafficked areas, discharge intermittently, and be highly variable in terms of discharge volume and quality.

Intermittent discharges from SWOs are identified as a receiving water pressure in the WFD River Basin Management Plans. Hence, to contribute to attainment of WFD goals and to ensure compliance with the Urban Waste Water Treatment Directive (UWWTD), targeted improvements of SWO structures and associated sewerage may be required. This report aims to review (1) the characteristics of intermittent discharges; (2) the current legislative framework for SWO control in Ireland; (3) guidance and best practice for SWO assessment in the EU, the USA and Canada; (4) current and emerging technologies for SWO monitoring; and (5) technologies for SWO improvement. A methodology to prioritise SWO monitoring has also been developed, which is described in Chapter 5.

# 2 Characteristics of Intermittent Discharges

Pollutants in intermittent discharges are derived from a number of sources, such as the dry-weather sewage stream; re-suspension from sewer deposits during storm events; and stormwater runoff (Gromaire *et al*., 2001). The relative contribution of each source differs according to rainfall characteristics (depth, duration and intensity) and antecedent conditions. The drainage catchment characteristics also influence the pollutant concentrations of dry-weather discharges, of which commercial and industrial inputs may be a substantial component in some agglomerations. The sewer system configuration, including pipe gradients and condition, also determines the importance of in-sewer processes.

The initial phase of a rainfall event may also generate a high concentration of pollutants, known as the *first flush*. A number of factors contribute to this, including the erosion of sediments that accumulate on paved surfaces over the preceding dry-weather period (Morgan *et al*., 2016) and re-suspension of sewer deposits (Arthur and Ashley, 1998). While initially high concentrations of pollutants have been observed for some catchments, the existence of a pollutant mass first flush effect remains controversial (Bertrand-Krajewski *et al*., 1998; Morgan *et al*., 2017).

Seasonal effects can also influence spill occurrence, with higher spill frequencies recorded in summer months in some catchments (Schroeder *et al*., 2011). Finally, the methodology employed in sampling intermittent discharges (grab/composite sampling, for example) may also influence storm event mean spill concentration. It is therefore unsurprising that pollutant concentrations in intermittent discharges can vary over several orders of magnitude, in temporal and spatial terms.

Based on their impacts on the environment and drinking water supplies, the pollutants of concern in discharges from SWOs are microbial pathogens; oxygen-demanding substances; suspended solids; toxic substances; nutrients; and gross solids (US EPA, 2004). Typical ranges of pollutant concentrations in intermittent discharges are shown in Table 2.1. The impacts, sources and concentrations of pollutants in intermittent discharges are discussed in the following sections.

## 2.1 Microbial Pathogens

Microbial pathogens are microorganisms that cause disease in receiving water biota and illness in humans. They originate from the faeces of humans and animals, and primarily comprise bacteria, viruses and parasites. Bacteria in wastewater are classed as indicator or pathogenic bacteria. Indicator bacteria are used as a surrogate for pathogenic (disease-causing) bacteria, which may be difficult to detect. Common indicator bacteria are faecal coliforms, *Escherichia coli* (*E. coli*) and enterococci. Stormwater may be an important source of *E. coli* at the beginning of a spill event, but diminishes over the course of the event (Madoux-Humery *et al*., 2013).

## 2.2 Oxygen-demanding Substances

Dissolved oxygen (DO) is consumed in the decay of organic matter in water by microorganisms. Organic matter in sewage derives from human and kitchen waste, as well as industrial sources. Urban stormwater also transports organic matter from landscaping and pet waste. Common tests of DO consumption are the biochemical oxygen demand, measured in a 5-day test ($BOD_5$), and the chemical oxygen demand (COD). Overflows with high levels of $BOD_5$ lower the DO levels in receiving waters and can result in fish kills. Effects in rivers have been observed in two distinct phases: initial DO reductions due to the soluble BOD fraction in overflows and a delayed effect associated with the particulate fraction (Jubb *et al*., 1999). The effect of particulate-bound BOD can persist for 12–24 hours after the overflow spill (Hvitved-Jacobsen, 1982). SWO impacts on receiving waters will also depend on ambient DO levels, which are influenced by photosynthesis, temperature, pressure and salinity, among other factors.

**Table 2.1. Pollutant concentrations (mean and range) reported in worldwide studies of intermittent discharges**

| | Unit | USA | EU | Vancouver | Montreal | Paris | Paris |
|---|---|---|---|---|---|---|---|
| Faecal coliforms | CFU or MPN/100 ml | $2.15\times10^{5}$ (603)<br>$3–4\times10^{-7}$ | | $3.9\times10^{5}$ | | | |
| *E. coli* | CFU or MPN/100 ml | | | | $1.5\times10^{6}$ (10) | $1.5\times10^{6}$<br>$3.8\times10^{5}$–$6.4\times10^{6}$ | |
| Enterococci | CFU or MPN/100 ml | | | | | $4\times10^{5}$ | |
| BOD | mg/l | 43 (501)<br>3.9–696 | 79 (166)<br>17–409 | 60 | | | 135 (52)<br>54–200[a] |
| COD | mg/l | | 311 (266)<br>81–906 | | | | 336 (52)<br>157–491[a] |
| TSS | mg/l | 127 (995)<br>1–4420 | 250 (249)<br>61–870 | 59 | 136 (10) | 214 | 237 (52)<br>121–394[a] |
| Cadmium | µg/l | 2 (401)<br>0.16–30 | 1.3 (27)<br>0.2–81 | 3.2 | | | |
| Copper | µg/l | 40 (346)<br>10–1827 | 75 (29)<br>25.4–161 | 77 | | | 86–134 (4) |
| Lead | µg/l | 48 (438)<br>5–1013 | 91 (61)<br>3.8–362 | 89 | | | 46–175 (4) |
| Zinc | µg/l | 156 (442)<br>10–3740 | 320 (69)<br>61.4–699 | 81 | | | 658–1137 (4) |
| Total PAHs | µg/l | | | | | | 0.98–2.58 (4) |
| Total phosphorus | mg/l | 0.7 (43)<br>0.1–20.8 | 2.3 (157)<br>1–6.9 | 1.9 | | | 3.5 (52)<br>2.3–5.4[a] |
| Total nitrogen | mg/l | 3.6 (373)<br>0–82.1 | 10.3 (160)<br>3.9–28.2 | | | | 22 (52)<br>15–37[a] |
| Source | | US EPA (2004) | Aarts *et al.* (2013) | Environment Canada (1992) | Madoux-Humery *et al.* (2013) | Passerat *et al.* (2011) | Gasperi *et al.* (2012) |

**Values in parentheses denote number of sampled events for mean value.**

**[a]10th percentile to 90th percentile values.**

**BOD, biological oxygen demand; COD, chemical oxygen demand; *E. coli*, *Escherichia coli*; MPN, most probable number; PAH, polycyclic aromatic hydrocarbons; TSS, total suspended solids.**

## 2.3 Total Suspended Solids

Total suspended solids (TSS) are solids carried in suspension in wastewater and stormwater, derived from decaying organic material and silt, and are classified as the fraction of material captured on a 0.45 µm filter. Suspended solids can be problematic for receiving waters, causing reduced light penetration, clogging of fish gills and filling of interstitial spawning zones (Caux *et al*. 1997; Eriksson and Johansson, 2005). Furthermore, a large proportion of toxic substance, nutrients and other pollutants are transported by suspended solids (Morgan *et al*., 2013). Elevated TSS concentrations have been linked to rainfall depth and intensity in some catchments, suggesting that surface sediment entrained in runoff is the main contributor to TSS. In other catchments, TSS concentrations have been associated with weak or negative dilution factors (storm flow/dry weather flow), indicative of in-sewer sediments as the primary source of TSS. In some cases, sewer sediments can contribute up to 75% of TSS loads (Gasperi *et al.*, 2010; Passerat *et al.*, 2011).

## 2.4 Toxic Substances

Toxic substances include heavy metals, hydrocarbons and organic compounds. In wastewater, the main sources of concern are industrial discharges. Vehicle emissions and vehicle wear (e.g. brake linings, leakage) may also contribute heavy metals and hydrocarbons to urban stormwater. The UK Highways Agency compared ecotoxicity data with typical concentrations of heavy metals and other toxic substances in highway runoff, concluding that dissolved copper (Cu) and zinc (Zn) posed the highest risk to aquatic organisms in terms of short-term toxicity (UK Highways Agency, 2009). Emission limits were derived for these elements, based on 6-hour and 24-hour exposures (Table 2.2). Sediment-bound toxicity emission limits were also defined (Table 2.3), recognising the long-term impacts such as reduced receiving water biodiversity (Fitzpatrick *et al.*, 2004).

## 2.5 Nutrients

Nutrients in wastewater generally comprise nitrogen and phosphorus. High levels of either element can lead to excessive growth of algae in lakes and rivers, resulting in harmful reductions in DO concentrations. Although concentrations of nutrients are significantly higher in wastewater, stormwater may also contribute nutrients derived from lawn fertilisers and the decay of organic matter. Nutrient loadings were estimated for a 59 km$^2$ catchment in south Dublin, Ireland (MCOS, 2001), containing 63% rural area, 19% residential, 15% industrial, 2% developing and 1% major highway. Stream and storm event sampling was conducted during the study. The results indicated that industrial land uses contributed the highest proportion of phosphorus (61%), followed by residential (22%) and rural (12%). The loadings in urban areas were mostly related to rainfall events. A national assessment of nutrient loads to Irish rivers estimated that SWOs contributed 1% of nitrogen loads and 5% of phosphorus loads (Mockler *et al.*, 2016). This was based on reported spill volumes where data were available; otherwise, a spill rate of 3% of annual flow was assumed.

**Table 2.2. Runoff-specific thresholds for copper and zinc**

| Threshold | Cu (µg/l) | Zn (µg/l) | | |
|---|---|---|---|---|
| | | Hardness | | |
| | | Low | Medium | High |
| $RST_{24h}$ | 21 | 60 | 92 | 385 |
| $RST_{6h}$ | 42 | 120 | 184 | 770 |

**RST, runoff-specific threshold.**

**Source: UK Highways Agency (2009). Reproduction of this table is licensed under the Open Government Licence 3.0.**

## 2.6 Gross Solids

Gross solids comprise litter, vegetation and other debris that is discharged from SWO spills (generally >5 mm in size, although definitions vary). This material includes sanitary products flushed from toilets, as well as street litter that is transported by stormwater runoff. The main impacts of gross solids are aesthetic problems and entanglement or ingestion by wildlife. Owing to the heterogeneous composition of gross solids, there is no established protocol for their analysis, which means that this parameter is often omitted in monitoring studies (Roesner *et al.*, 2007). However, gross solid loads have been correlated with rainfall and runoff volumes in stormwater drainage systems (Allison and Chiew, 1995).

**Table 2.3. Threshold effect levels (TELs) and probable effect levels (PELs) for sediment-bound pollutants**

| Substance | Copper | Zinc | Cadmium | Total PAH | Pyrene | Fluoranthene | Anthracene | Phenanthrene |
|---|---|---|---|---|---|---|---|---|
| Unit | mg/kg | mg/kg | mg/kg | µg/kg | µg/kg | µg/kg | µg/kg | µg/kg |
| TEL | 35.7 | 123 | 0.6 | 1684 | 53 | 111 | 46.9 | 41.9 |
| PEL | 197 | 315 | 3.5 | 16770 | 875 | 2355 | 245 | 515 |

**PAH, polycyclic aromatic hydrocarbon; PEL, probable effect level; TEL, threshold effect level.**

**Source: UK Highways Agency (2009). Reproduction of this table is licensed under the Open Government Licence 3.0.**

# 3 Legislative Framework

There is a significant volume of national and EU legislation relevant to intermittent discharges. The following review outlines the legislative framework in two parts: (1) legislation aimed at protecting receiving waters; and (2) legislation specific to the control of SWOs.

## 3.1 Legislation Protecting Receiving Waters

The WFD (EU, 2000) is the key policy driver in the water sector: it enacts new measures and assembles existing legislation with the aim of achieving at least good ecological status in all waters of Member States. Legislation aimed at protecting receiving waters includes the Habitats Directive (EU, 1992) and the Freshwater Pearl Mussel Regulations (SI 296, 2009). Legislation has also been enacted to protect other beneficial uses of receiving waters, such as the Bathing Water Directive (EU, 2006a). Although the Shellfish Regulations (SI 268, 2006) have been repealed and replaced by the WFD, the requirement to protect and preserve shellfish waters is maintained under the WFD. In addition, shellfish production waters are routinely monitored in Ireland by the Sea Fisheries Protection Board and the Marine Institute (Marine Institute, 2016).

In terms of limiting the effects of intermittent discharges, there are no prescriptive emission limits set out in these policy instruments; rather, point and diffuse discharges likely to cause pollution must be controlled to the extent that they do not prevent the attainment of good ecological status or other receiving water goals. The monitoring requirements of the various receiving water policy instruments are set out in Table 3.1. The monitoring requirements refer to measurements in receiving waters only, i.e. they do not specifically require monitoring of overflow discharges.

### *3.1.1 Surface Water Regulations*

The Surface Water Regulations (SI 272, 2009) require public authorities to promote compliance with environmental quality standards (EQSs) and to undertake measures to progressively reduce input of priority and hazardous substances to the water environment. They state that point and diffuse sources liable to cause pollution are prohibited, except where a prior system of authorisation has been established. The manner in which these discharges are

**Table 3.1. Summary of monitoring and control requirements related to receiving water quality**

| Receiving water | Monitoring requirement/ frequency | SWO control requirements (non-exhaustive) | Reference |
|---|---|---|---|
| Bathing waters | Three or four samples per bathing season. Enterococci and *E. coli* | Management measures, including surveillance, early warning systems and monitoring, with a view to preventing bathers' exposure by means of a warning or, where necessary, a bathing prohibition; adequate measures to prevent, reduce or eliminate the causes of pollution | SI 79 (2008), as amended by SI 351 (2011) |
| Surface waters | As per Annex V of WFD: physico-chemical, 1–3 months; biological, 6ds to 3 years; morphology, 6 years | Measures to protect or restore surface water bodies to at least 'good' status; reduction of pollution caused by priority substances; establishment of river basin management plans and programmes of measures to meet WFD objectives | SI 272 (2009) |
| FPM habitats | Every 6 years. Surveys of FPM populations, macroinvertebrates, macroalgae, phytobenthos, macrophytes and siltation | FPM habitat management plans, surveys of municipal, industrial and CSO discharges | SI 296 (2009) |

**FPM, freshwater peral mussel.**

authorised is not strictly prescribed, but may include a combination of the following:

- a system of emission limits that considers the receiving water's assimilative capacity in relation to the EQS values;
- emission controls based on best available techniques; this approach may be suited to SWOs, where emissions are sporadic and highly variable, leading to difficulty in applying absolute limit values;
- basic measures including the Urban Waste Water Treatment Regulations (SI 254, 2001); or
- measures identified in the river basin management plans.

#### 3.1.2 Bathing Water Regulations

The Bathing Water Regulations [SI 79, 2008, as amended (2011)] mandate identification, monitoring and assessment of bathing waters in Ireland. The monitoring must occur during the bathing season, with four samples to be taken, or three for geographically remote areas. Since the bathing water sampling calendar is predetermined, sampling is not targeted at wet-weather events. The assessment is based on a statistical analysis of the current and preceding 3 years of sample data, except in particular circumstances. The bathing waters are classified as poor, sufficient, good or excellent according to their bacteriological quality, as defined in the bathing water classifications.

#### 3.1.3 Freshwater Pearl Mussel Regulations

These regulations (SI 296, 2009) set out environmental quality objectives for habitats of the freshwater pearl mussel (FPM) and require the publication of sub-basin management plans with specified programmes of measures (POMs) to meet the objectives of the regulations. FPM populations must be assessed every 6 years. The conservation status of a FPM population is determined by the numbers and size of FPMs present. The criteria for an acceptable habitat include favourable ecological status of macroinvertebrates and phytobenthos, as well as low levels of macrophytes and siltation. With respect to wastewater discharges, FPM sub-basin management plans have called for surveys of municipal, industrial and SWO discharges to be prioritised for FPM catchments (NS2, 2009). Furthermore, the review of wastewater discharge licences (WWDLs) should ensure that emission limits comply with the objectives of the FPM regulations.

#### 3.1.4 Habitats Directive

The aim of the Habitats Directive (EU, 1992) is to contribute to biodiversity through the conservation of natural habitats and wild flora and fauna of interest to the EU, by maintaining or restoring habitats to a favourable conservation status. It requires the establishment of Natura 2000 sites, a network of nature protection areas comprising special areas of conservation (SACs), designated by Member States under the Habitats Directive, and special protection areas (SPAs), designated by Member States under the Birds Directive (EU, 2009). Member States must take steps to avoid the deterioration of SACs and SPAs. Any plan or project likely to have a significant impact on a Natura 2000 site must be subject to an appropriate assessment of its implications, and mitigation measures must be provided as necessary.

## 3.2 Legislation Controlling Intermittent Discharges

#### 3.2.1 Urban Wastewater Treatment Directive

The UWWTD (EU, 1991) requires collection and secondary treatment for all discharges from agglomerations > 10,000 population equivalents (PE), and for discharges to fresh waters and estuaries for agglomerations > 2000 PE. Wastewater entering collection systems shall be provided with appropriate treatment for discharges to fresh waters and estuaries for agglomerations < 2000 PE and for discharges to coastal waters for agglomerations < 10,000 PE. Tertiary treatment must be provided for discharges to sensitive areas for agglomerations > 10,000 PE. The directive also requires pre-authorisation of all urban wastewater discharges, and monitoring and reporting of the performance of the treatment plant and of the receiving water quality.

#### 3.2.2 Waste Water Discharge (Authorisation) Regulations

The Waste Water Discharge (Authorisation) Regulations (SI 684, 2007) are intended to prevent and reduce pollution of waters by wastewater. They require an application for a discharge licence for all agglomerations > 500 PE, and a certificate of authorisation for agglomerations < 500 PE. Part 6 of the regulations requires the applicant to identify monitoring and sampling points and indicate proposed arrangements for the monitoring of discharges and the likely environmental consequences of such discharges.

*Annual environmental report*

An annual environment report (AER) must be submitted for each licensed agglomeration, and should include performance data relating to the wastewater collection and treatment system, including any SWOs. The data to be submitted in the AER include results of monthly influent monitoring, receiving water quality and the wastewater treatment works' (WWTW) treatment efficiency. The AER may also contain important information relating to the condition, spill frequency and impact of SWOs. Specifically, the AER reporting guidelines require (EPA, 2014):

- an estimation of the percentage of PE load collected in the sewer network but discharged without treatment via SWOs;
- a complaints summary, which may be indicative of discharges from SWOs;
- a reported incidents summary, to include emergency overflow activation. SWO spills that occur because of insufficient flow capacity during rain events are not currently classified as reportable incidents provided the SWO pass forward flow is greater than a specified value, given by *Formula A* (see equations 4.1 and 4.2).

A SWO identification and inspection report is first required in the second AER, to be reviewed every 3 years, with updates in intervening years. In addition to the identification and inspection report, the following two summary tables (Tables 3.2 and 3.3) must be included in the AER. These tables contain information on the frequency and volume of SWO spills on an annual basis. However, it would be useful to collect data on individual spills, such as the date and volume of spill, to identify critical rainfall depths that cause

**Table 3.2. SWO identification and inspection summary report 'Table A'**

| WWDL name/code for SWO | Irish grid reference | Included in Schedule A4 of the WWDL | Significance of the overflow | Compliance with DoEHLG criteria | No. of times activated | Total volume discharged ($m^3$) | Total volume discharged (PE) | Estimated/ measured data |
|---|---|---|---|---|---|---|---|---|
| | | Yes/No | Low/Medium/ High | Yes/No/Not yet assessed | | | | Measured/ Estimated |

**Source: EPA (2014).**
**DoEHLG, Department of the Environment, Heritage and Local Government.**

**Table 3.3. SWO identification and inspection summary report 'Table B'**

| | |
|---|---|
| How much sewage was discharged via SWOs in the agglomeration in the year ($m^3$/year)? | |
| How much sewage was discharged via SWOs in the agglomeration in the year (PE)? | |
| What percentage of the total volume of sewage generated in the agglomeration was discharged via SWOs in the agglomeration? | List the percentage of load generated that does not enter the WWTP |
| Is each SWO identified as non-compliant with DoEHLG guidance included in the programme of improvements? | Yes/No<br>List the relevant section of the programme of improvements |
| The SWO assessment includes the requirements of Schedule A3 & C3 | List the relevant section of the SWO report |
| Have the EPA been advised of any additional SWOs/changes to Schedule C3 and A4 under Condition 1.7? | Yes/No<br>Provide details where relevant |

**Source: EPA (2014).**
**DoEHLG, Department of the Environment, Heritage and Local Government.**

spills. It should be noted that in many cases the data on spill occurrence, duration and volume are unavailable owing to the small proportion of SWOs monitored.

*Integrity of sewers risk assessment*

The *Guidance Document to Assess the Integrity of Sewers and their Accessories* (EPA, 2012), along with the datasheet templates, may be used to establish and maintain the programme of improvements of a sewer network. The tool can be used to demonstrate the extent of the wastewater network; the extent of overflows that occur within the network; and the risk to human health and the environment arising from discharges from the wastewater works. A wastewater network risk assessment is completed using a spreadsheet comprising four sections, each having an associated maximum risk score: hydraulic risk assessment (150); environmental risk assessment (500); structural risk assessment (150); and operations and maintenance risk assessment (200). The tool is indicative and a high risk score should prompt detailed investigations to determine if the result is valid; to close information gaps in the tool that are contributing to the high score; and to identify areas for further investigation. It should be noted that a high risk score may be due to a lack of information for the sewer network in question.

The hydraulic risk assessment seeks to determine the level to which the performance of the wastewater network has been characterised. Confirmation that hydraulic performance assessments, computer models, manhole surveys and flow surveys have been completed is sufficient to reduce the risk score; the survey or model details are not required to be submitted to the Environmental Protection Agency (EPA). The structural risk assessment concerns the integrity of sewers based on CCTV surveys, but does not specifically address SWOs. The operations and maintenance risk assessment requires identification of the frequency of sewer surcharging and flooding in the last 5 years, which may point to activation of SWOs.

In relation to SWOs, the environmental risk assessment checks compliance with the guidance document *Procedures and Criteria in Relation to Storm Water Overflows* (PCSWO; DoEHLG, 1995) by examining:

- the percentage of SWOs in the network assessed for *significance* according to the guidance document;
- whether an impact assessment for each SWO has been completed, including setting of performance criteria according to the guidance document;
- the percentage of SWOs that comply with performance criteria above;
- whether the causes of overflows have been identified.

## 3.3 EU Infringement Cases Relating to SWOs

The EU Commission may initiate legal proceedings against Member States that are deemed to be failing in their obligations under EU law. This process commences with the issue of a letter of formal notice to the Member State. Where the Member State disagrees with the opinion of the Commission, or fails to implement a solution to rectify the suspected violation, the Commission can refer the case to the EU Court of Justice.

### *3.3.1 EC v. United Kingdom of Great Britain and Northern Ireland, 2012*

In pre-litigation, the Commission issued a number of formal notices to the UK regarding excessive overflows from wastewater networks in Whitburn and London, which were in breach of the UWWTD (Case 301/10, 2012). In particular, Annex 1(A) was cited:

> The design, construction and maintenance of a collection system shall be undertaken in accordance with the best technical knowledge not entailing excessive costs, notably regarding:
>
> *volume and characteristics of urban waste water,*
>
> *prevention of leaks,*
>
> *limitation of pollution of receiving waters due to storm water overflows.*

A footnote to Annex 1 states:

> Given that it is not possible in practice to construct collecting systems and treatment plants in a way such that all waste water can be treated during situations such as unusually heavy rainfall, Member States shall decide on measures to limit pollution from storm water overflows. Such measures could be based on dilution rates or capacity in relation to dry weather flow, or could specify a certain acceptable number of overflows per year.

In its second formal notice of 2005, the Commission stated that excessive overflows occurred to the River Thames from wastewater networks in the London area, even in moderate rainfall conditions.

The main points presented to the Court were:

- The Commission argued that the UWWTD must be interpreted as providing an absolute obligation to avoid spills from SWOs save for exceptional circumstances.
- The Commission stated that it did not intend to impose a maximum 20 spills per annum rule, but higher spill frequencies, particularly in moderate rainfall, indicated non-compliance with the UWWTD.
- The Commission accepted the UK method of defining a spill event but held that a spill frequency approach alone cannot demonstrate compliance with the UWWTD, since the definition of a spill event may differ between Member States.
- The UK contended that the Commission erred by basing compliance with the UWWTD on spill volume, suggesting that a detailed assessment of the performance of the collection system or the treatment plant concerned must be carried out with reference to the environmental impact of the discharges on receiving waters.
- Since the concept of unusually heavy rainfall is not defined by the UWWTD, the Commission argued that the concept must be assessed in light of all the criteria and conditions prescribed by the directive, in particular the concept of best technical knowledge not entailing excessive costs (BTKNEEC).
- The Commission stated that, in assessing the concept of BTKNEEC, the consequences that stormwater overflows have for the environment would thus enable examination of whether or not the costs that must be incurred to carry out the works necessary for all urban wastewater to be treated are proportionate to the benefit that this would yield for the environment.
- The number of overflow events from the Whitburn pumping station varied from 56 to 91 between 2002 and 2004, with volumes between 359,640 $m^3$ and 529,290 $m^3$. Between 2006 and 2008, the annual number of spills varied from 25 to 47 (248,130–732,150 $m^3$).
- The Commission, relying on a 2005 Thames Tideway Strategic Study Report (Thames Water, 2005), observed that overflows to the Thames River numbered approximately 60 per annum, even in periods of moderate rainfall.
- In relation to works under way (Thames Tideway interceptor tunnel), the Commission stated that a Member State cannot secure dismissal of the action merely because the activities and works that will, in future, cure the failure to fulfil obligations are under way.

> Consequently, by failing to ensure appropriate collection of the urban waste water of the agglomerations a p.e. of more than 15000 of Sunderland (Whitburn) and London (Beckton and Crossness collecting systems), in accordance with Article 3(1) and (2) of, and Annex I(A) to, Directive 91/271, and appropriate treatment of the urban waste water of the agglomeration with a p.e. of more than 15000 of London (Beckton, Crossness and Mogden treatment plants), in accordance with Article 4(1) and (3) and Article 10 of, and Annex I(B) to, Directive 91/271, the Court ruled that the United Kingdom has failed to fulfil its obligations under the UWWTD.

In March 2015, the UK was referred to the EU Court of Justice relating to poor wastewater collection and treatment in 17 agglomerations (EC, 2015). Of these, two agglomerations were referred in relation to excessive overflows in Llanelli and Gowerton. The Commission commented:

> Innovative and environmentally positive sustainable urban drainage solutions are now being implemented to improve the situation. However the current spill rates are still too high and compliance is not foreseen before 2020. The deadline for having in place compliant collecting systems for these agglomerations was end 2000.
>
> EC, 2015

The case was initiated despite efforts to reduce the frequency of discharges to 10 per annum by reducing stormwater inflows to the combined system (WWT, 2012), which suggests that the timescale for improvements is at issue.

The stance taken by the Commission in these infringement cases provides some clarity on how the UWWTD should be implemented with regard to SWOs. A spill frequency limitation approach, in isolation, cannot be used to demonstrate compliance with the UWWTD, but spill frequencies greater than 20 per annum may indicate non-compliance. The Commission restated the requirement to avoid spills save for exceptional circumstances, i.e. unusually heavy rainfall. Since the term ‘unusually heavy rainfall’ is not defined in the UWWTD, the Commission stated that investments in sewerage upgrades should be weighed against environmental benefits. The requirement to quantify environmental benefits would imply that impacts on the chemical and ecological condition of receiving waters from SWO spills should be assessed quantitatively. Therefore, subject to sufficient monitoring data being available in the future, a quantitative, combined spill frequency limit coupled with intermittent water quality standards for receiving waters (such as those provided in the Urban Pollution Management (UPM) procedure) should be applied in Ireland. Given that monitoring data are not available at present to carry out detailed assessments of SWO spill frequencies and impacts, methods to prioritise SWO monitoring are presented in Chapter 5.

# 4 Guidance and Best Practice for SWO Planning and Impact Assessment

## 4.1 Ireland

### *4.1.1 Procedures and criteria in relation to stormwater overflows*

Compliance with the PCSWO document is a condition of wastewater discharge licences in Ireland. The guidance includes a summary of the relevant legislation (as of 1995 – DoEHLG, 1995), and design principles for new SWOs and SWO retrofit. Unsatisfactory SWOs are identified as meeting any one of the following criteria:

a) causes significant visual or aesthetic impact and public complaints;

b) causes deterioration in water quality in the receiving water;

c) gives rise to failure in meeting the requirements of national regulations on foot of EU Directives;

d) operates in dry weather.

Criteria are also set out to assess the significance of the SWO discharge (Table 4.1), and methodologies to assess the impact of the SWO are recommended, where the complexity of the method is related to the significance of the discharge. This approach was adopted from the *Sewer Rehabilitation Manual* (SRM; WRc, 1986), now in its fourth edition (WRc, 2014).

*Low-significance overflows*

For low-significance overflows, three *minimum data* techniques were considered appropriate to assess the impacts: *Formula A*; the Scottish Development Department (SDD) method; and the Quality Impacts of Storm Overflows: Consent procedure (QUALSOC) method. *Formula A* was the result of an extensive study carried out in the UK in the 1950s and 1960s (Ministry for Housing and Local Government, 1970). *Formula A* (equations 4.1 and 4.2) replaced the traditional approach of estimating peak wastewater

**Table 4.1. Criteria for assessment of SWO significance**

| Overflows to freshwaters | Overflows to coastal waters and estuaries |
|---|---|
| *Low significance* | |
| Dilution > 8:1 (river 95th percentile flow to foul DWF) | Estuaries and coastal waters not designated as |
| No interaction with other discharges | bathing or shellfish waters |
| *Medium significance* | |
| Dilution < 8:1 | PE 2000–10,000 |
| Limited or no interaction with other discharges > 2000 PE | Affects identified bathing waters and shellfish waters |
| Cyprinid fishery | |
| Only if all of the above criteria apply | Only if both criteria apply |
| *High significance* | |
| Dilution < 2:1 | PE > 10,000 |
| Interaction with other discharges > 10,000 PE | Affects identified bathing waters and shellfish waters |
| Cyprinid or salmonid fishery | |
| Only if all of the above criteria apply | Only if both criteria apply |

**Source: DoEHLG (1995).**

discharges of 6 times the dry-weather flow (DWF), by including allowances for stormwater discharges (related to population rather than water consumption) and industrial effluent:

$$\text{SWO setting} = \text{DWF} + 1360P + 2E \text{ (l/day)} \quad (4.1)$$

$$\text{DWF} = PG + I + E \quad (4.2)$$

where P = population, G = water consumption (l/person·day), I = sewer infiltration rate (l/day) and E = average industrial effluent rate.

A development of the *Formula A* approach was published by the SDD in 1977. The procedure considered the dilution available if the SWO discharged to a watercourse. The dilution factor compared the minimum flow in the watercourse (95th percentile, or flow exceeded 95% of the time) with the wastewater DWF. For dilutions greater than 8:1, the SWO was considered satisfactory where the overflow setting was determined using *Formula A*. For lower dilution rates, provision of wastewater storage was required to varying degrees (Table 4.2).

QUALSOC (WWA, 1988) is a mass balance model that considers the overflow volume, estimates of overflow quality and dilution to estimate pollutant concentrations in the receiving water. These are then compared with acceptable limits based on the receiving water classification.

*Medium-significance overflows*

For medium-significance overflows, the use of a sewer hydraulic model is recommended, coupled with the SRM (WRc, 1986, 2014) estimates of overflow quality, and the Comparative Acceptable River Pollution (CARP) procedure (Crabtree *et al.*, 1988) to assess receiving water impacts. The SRM's estimated SWO pollutant concentrations range from 75 mg/l BOD for steep catchments to 125 mg/l for flat catchments. Alternatively, site-specific overflow quality can be estimated from monitoring of DWF using dilution factors, or direct monitoring of SWO activations. The CARP procedure calculates the pollutant load in the receiving water using the hydraulic model outputs and the estimates of overflow quality. The loadings in the proposed river reach are then compared with loadings in a similar river reach where the water quality is known to be acceptable.

**Table 4.2. Recommendations for SWO storage**

| Dilution factor | Overflow setting | Storage (litres) |
|---|---|---|
| > 8 | *Formula A* | None |
| > 6 | *Formula A* + 455 × population | None |
| | or *Formula A* | 40 × population |
| > 4 | *Formula A* | 40 × population |
| > 2 | *Formula A* | 80 × population |
| > 1 | *Formula A* | 120 × population |

**Source: SDD (1977). Reproduction of this table is licensed under the Open Government Licence 3.0.**

*High-significance overflows*

For high-significance overflows the use of complex models is *justifiable*. It is recommended that a sewer quality simulation model is coupled with a dynamic water quality impact model. However, it is recognised that the costs associated with data collection for model calibration and verification can be substantial, and the benefit of using such models must be weighed against the potential reduction in construction costs associated with a more efficient design, and the ability to assess the performance of the improved wastewater network.

### *4.1.2 Limitations of PCSWO*

The PCSWO relates the significance of the discharge to the level of assessment (modelling), and hence the degree of monitoring data required. Therefore, the methods outlined in the PCSWO are relevant to the development of a SWO monitoring strategy. However, some aspects of the PCSWO must be examined in light of revised legislation, and advancements in sewer monitoring and modelling techniques since its publication in 1995.

Estimates of combined sewer DWF are used to investigate dilution of overflows in receiving waters, and also to assess the likelihood of a spill event, by comparing the pass forward flow of the SWO with the likely peak flow (multiple of DWF or *Formula A*). Indeed, a comparison of *Formula A* with SWO spill setting and pump station forward flow has been included in a number of recent AERs (Irish Water, 2015). Since this criterion is used to determine SWO compliance, it is important to consider the uncertainty of *Formula A* estimates. There are very limited data on spill volumes and frequencies for SWOs in Ireland that could be compared with the prediction of peak flow by *Formula A*. However, since *Formula A* is a relatively fixed proportion of DWFs (see Figure 4.2), the uncertainty of *Formula A* predictions can be demonstrated by analysing predictions of DWF.

This is illustrated by examining DWFs for a catchment in Cork City. The analysis utilised data derived from the report *Tramore Valley Sewer Combined Storm Overflows* (CCC, 2011). The report provided average measured DWFs (from flow meters or pump run-times) in seven combined sewers along with estimates of DWF from residential and commercial development geodata. The following assumptions were made in the report for the estimation of DWFs: domestic water consumption, 145.5 l/head·day; occupancy, 2.93 persons/dwelling; and commercial unit water consumption, 1500 l/unit·day.

The present analysis consisted of a regression of measured DWF (dependent variable) against estimated DWF (explanatory variable) using Minitab 17 statistical software. A plot of measured DWF against estimated DWF is shown in Figure 4.1, along with the 95% prediction interval (i.e. the interval over which the measured flow is expected to reside in 95% of cases, for a single value of estimated flow). From Figure 4.1 it is apparent that for an estimated flow of 20 l/s, the upper prediction interval is 56 l/s – 2.8 times higher. Thus, DWFs, and by extension peak combined sewer flows estimated from geodata, may under- or over-estimate actual DWFs, due to variations in water consumption, infiltration and surface water inputs across catchments. This could lead to the false assumption that a SWO is compliant if the spill setting is less than the estimated peak flow. Conversely, SWOs may be deemed non-compliant based on estimated peak flows, when in reality the actual flow is less than the pass forward flow.

Noting that the preceding analysis was based on a small sample size (and thus conclusions based on this data set alone should be made with caution), it is evident that estimates of DWF (and peak flow) from geodata must consider the uncertainty of the prediction. That does not preclude the use of this type of assessment, but, allowing for uncertainty, its *usefulness* must be questioned. For example, to account for the uncertainty of predictions in the preceding analysis, suppose a factor of safety of 2 was applied to the DWF and peak flow estimate. Pass forward flows would then be compared with 12 times DWF. On the basis that the majority of SWOs were originally designed to cater for 6 times DWF, it is apparent that the majority of SWOs would be deemed non-compliant. Estimates of DWF, obtained from geodata and water consumption figures, should be compared with measurements of DWF for a range of Irish catchments.

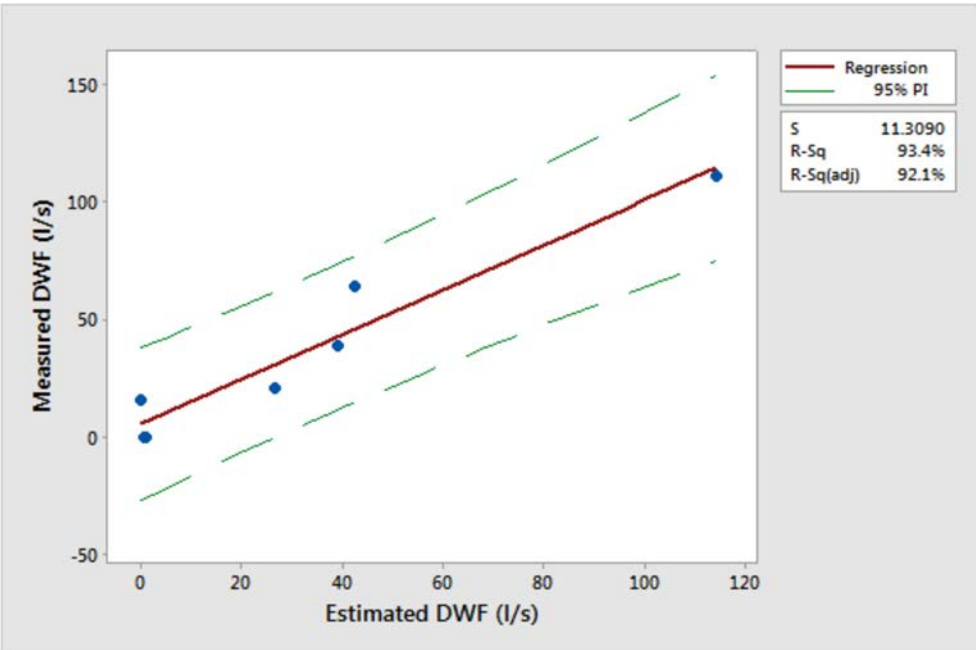


**Figure 4.1. Measured vs estimated DWF for Tramore Valley combined sewers. S, residual standard deviation; R-Sq, coefficient of determination; R-Sq(adj), adjusted coefficient of determination.**

*Formula A* was developed from observations of satisfactory SWOs in UK catchments. Since water consumption, infiltration and surface water inflows can vary considerably between catchments, this rule-of-thumb approach does not guarantee any particular spill frequency or volume. Nevertheless, it has been applied widely in Ireland to design and assess SWOs.

In developing the spill criteria reproduced in the PCSWO, *The Technical Committee on Storm Overflows and the Disposal of Storm Sewage* (Ministry of Housing and Local Government, 1970) included a method for estimating the proportion of annual spill volume (as a percentage of total annual combined volume), in response to changes in the overflow setting. These spill rates were calculated for a theoretical catchment with the following attributes: annual rainfall, 760 mm; impermeable area, 42 m$^2$ per person; and water consumption, 136 l per person·day. The percentage volume discharged is shown in Table 4.3, derived from the guidance document *Storm Sewage Separation and Disposal* (SDD, 1977).

To demonstrate the implications of using *Formula A* for SWO spill control, data were analysed from the *Cork City Storm Water Overflow Assessment* (CCC, 2014). This study provided estimates of DWFs in 58 SWOs in Cork City, and an assessment of *Formula A* and pass forward flows. The ratio of the peak flow, estimated using *Formula A*, to the DWF is shown in Figure 4.2. The average peak flow calculated from *Formula A* was 6.6 times the DWF. It is interesting to note the relatively small spread of *Formula A* to DWF ratios in Figure 4.2, with the majority of ratios in the range of 6 to 7. Therefore, while it does allow somewhat for stormwater inflows (related to population) and industrial discharges, *Formula A* is still a relatively fixed multiple of DWF.

Interpolating this average overflow setting (6.6 × DWF) from Table 4.3 would result in an annual spill volume of 35% of rain falling on impervious areas, or 17.5% of total rain, assuming 50% impervious ratio for urban areas [imperviousness can vary from 35% to 100% (Butler and Davies, 2010)]. This overflow spill rate is unlikely to meet the UWWTD requirement to avoid spills, *save for exceptional circumstances.* It should be noted that differing water consumption and catchment characteristics between the Cork City agglomeration and those used in the UK study (Ministry for Housing and Local Government, 1970), and differences in estimated versus actual combined flow rates may affect the exact percentage spill volume. However, the

**Table 4.3. Percentage overflow volume vs DWF multiplier**

| Overflow setting (× DWF) | Volume discharged (% of rainfall on impermeable area) |
|---|---|
| 6 | 39 |
| 8 | 31 |
| 12 | 20 |
| 20 | 9 |

**Source: SDD (1977). Reproduction of this table is licensed under the Open Government Licence 3.0.**

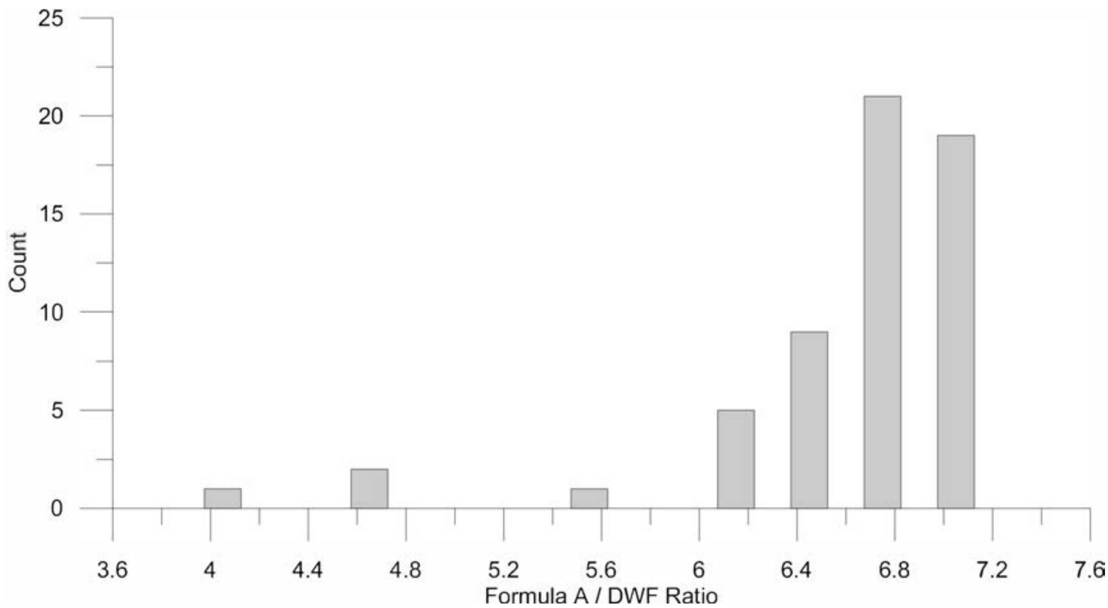


**Figure 4.2. Histogram of the *Formula A* to DWF ratio.**

spill volumes were of the same order of magnitude reported by Anta *et al*. (2007), who reported annual spill volumes of approximately 25–35% of the annual combined flow for overflow settings of 5–7 times the DWF. The analysis of the Cork City agglomeration data highlights the need for further research in Irish catchments to relate the overflow settings to measured spill volumes and frequencies, particularly given the widespread use of *Formula A* in the AERs.

In the PCSWO, UK Environment Agency Guidelines (Environment Agency, 2012b) and Scottish EPA Guidelines (SEPA, 2014), the significance of the discharge is related in part to the degree of dilution provided by the receiving water, along with the type of receiving water. An 8:1 dilution ratio is set out in the PCSWO as the limit below which an overflow setting of *Formula A* (without storage) constitutes an acceptable level of protection for the receiving water. This 8:1 dilution factor was derived from the *1915 Royal Commission* 20/30 [BOD/SS (suspended solids)] standard for treated effluents discharging to rivers (Harrison, 2014) and was based on a number of assumptions (RCSD, 1915):

- Odour problems occurred where the BOD concentrations exceeded 4 mg/l in rivers.
- Rivers that were neither exceptionally polluted nor exceptionally pure had a BOD of 2 mg/l, on average. This concentration was assumed for the diluting component in order to calculate receiving water concentrations of BOD.
- The concentration of SS in treated wastewater was assumed to be 30 mg/l and the BOD was assumed to be 20 mg/l.
- To achieve a minimum standard of 4 mg/l BOD, a dilution rate of river to sewer flow of 8:1 was required.

Under the Surface Water Regulations (SI 272, 2009), the BOD limit that supports good ecological status is ≤ 2.6 mg/l (95th percentile) or ≤ 1.5 mg/l (average flow). Since attainment of at least good status is required under the WFD, a limit of 2.6 mg/l (95th percentile) must be applied. This compares with the receiving water quality limit of 4 mg/l inherent in the PCSWO in the calculation of the 8:1 dilution ratio. Thus, the receiving water target BOD concentration implicit in the PCSWO is 1.5 times higher than what is required to achieve WFD good status. Furthermore, the concentration of BOD in combined overflow discharges is in the order of 80 mg/l (Table 2.1), four times the concentration assumed (20 mg/l in the RCSD) for the treated effluent.

Applying these revised figures (spill BOD concentration, 80 mg/l; river maximum concentration, 2.6 mg/l), and assuming a background BOD concentration of 1 mg/l in the receiving water, would result in a minimum dilution ratio of 50:1 for adequate river protection. However, this dilution test is somewhat misleading, since it compares the DWF in the sewer with the receiving water flow, when in fact it is only the SWO spill volume that mixes with the receiving water flow. Exceedance thresholds for receiving waters are now assessed in the UK against predicted spill frequencies and volumes (FWR, 2012).

Another drawback of adopting a minimum dilution approach is that it does not account for other pressures impacting on the receiving water. The approach defines controls for SWOs that are designed to achieve a minimum receiving water quality standard for the discharge in question. However, where multiple SWOs designed in this manner discharge to the same receiving water, the result is, at best, the maintenance of the existing river status, or, considering increased urbanisation and rainfall intensities due to climate change, likely long-term deteriorations in chemical and ecological status. Furthermore, this approach does not account for chronic pollution from pollutants attached to the sediments in SWO discharges. These sediments can transport priority pollutants, such as heavy metals from stormwater (Morgan *et al*., 2013, 2016), which can accumulate over time, leading to reduced biodiversity in receiving waters (Fitzpatrick *et al*., 2004).

The 8:1 dilution ratio threshold of SWO flows in the receiving river has been used to determine storage volumes for SWOs in the PCSWO. Since this dilution is not protective of the Surface Water Regulations' standard for BOD, the 8:1 threshold should not be considered a threshold for compliance with the Surface Water Regulations. The ratio of DWF to receiving water 95th percentile flow is a useful indicator of the relative volumes (which could be linked to potential pollution risk), but its use should be restricted to assisting the priority ranking of SWOs. In future, this approach should be replaced by an estimation of spill frequency and volume, and calculation of dilution ratios for the spilled volumes that are protective of receiving water standards (such as those presented in the section *Standards for protection of river aquatic life*).

Another example of the limitations of the *Formula A*/ pass forward flow assessment is provided by the *Cork City Storm Water Overflow Assessment* (CCC, 2014). This report assessed 58 SWOs in the Cork City agglomeration, including compliance with visual/ aesthetic criteria. This was achieved by reviewing complaints between 2010 and 2013, and through discussion with drainage maintenance staff, who conducted routine inspections and maintenance of the SWOs on a fortnightly basis. Among the 58 SWOs, debris in the receiving water was observed for 13 (22%), and public complaints were received in relation to six of the SWOs. The report also included an assessment of *Formula A* to pass forward flows ratios, in which it was expected that ratios less than 1.0 would be associated with compliant SWOs (implying no debris at the outfall) and ratios greater than 1.0 would be associated with problematic SWOs.

To check the influence of screening, the distributions of screen types for the debris and no-debris groups were investigated. As shown in Table 4.4, the two groups had similar distributions of screen types, i.e. the screening type did not appear to influence the presence of debris at the overflow.

**Table 4.4. Percentage of screen types for debris and no debris groups**

| Group | Screen type | | | |
|---|---|---|---|---|
| | Dip plate | Two dip plate | Single Wilkes | Two Wilkes |
| Debris | 64 | 7 | 11 | 18 |
| No debris | 62 | 8 | 8 | 23 |

Dot plots and 95% confidence intervals of the *Formula A* to pass forward flow ratios were prepared from the CCC data, as shown in Figure 4.3 for the debris ($n = 13$) and no debris ($n = 45$) groups. Since the confidence intervals overlapped, it is clear that under repeated sampling there would be no significant difference between the mean *Formula A* to pass forward flow ratios for the two groups, i.e. this ratio was unsuitable for predicting SWO compliance in terms of visual/aesthetic impacts. Since this analysis was limited to a single catchment, future research should examine the *Formula A* to pass forward flow ratio for other catchments in Ireland (when data are available), in particular its ability to predict receiving water problems.

### *4.1.3 Greater Dublin Strategic Drainage Study*

The Greater Dublin Strategic Drainage Study (GDSDS) was commissioned in 2001 in response to increased demands on drainage infrastructure due to economic and population growth. The objective of the study was to *identify policies, strategies and projects* for the development of a sustainable drainage system in the Greater Dublin Region. A summary of the GDSDS guidance and recommendations relevant to SWOs is provided in the following sections.

Volume 3, Chapter 7, of the GDSDS Policy Document (Dublin Drainage Consultancy, 2005) deals with intermittent discharges and was prefaced with a review of guidance for SWO planning in Ireland that consisted of:

- *Procedures and Criteria in relation to Storm Water Overflows* (DoEHLG, 1995), it was noted that there had been many changes in legislation

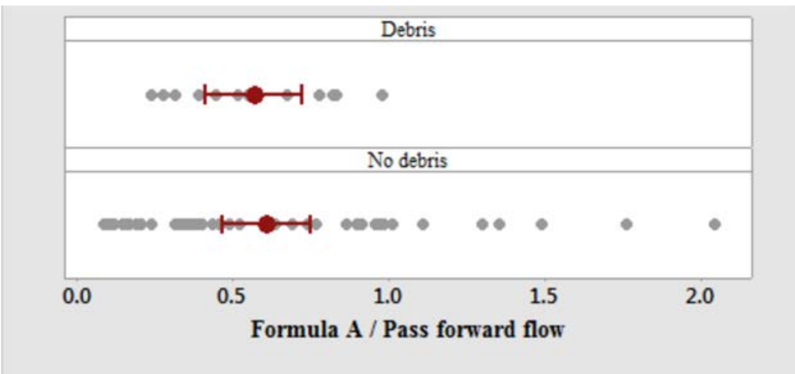


**Figure 4.3. Dot plots and 95% confidence intervals for SWOs with debris and no debris.**

and advances in modelling techniques since the publication of this guidance;
- guidance produced for specific schemes [a maximum spill frequency of 4 times per year was cited from the *River Tolka Water Quality Management Plan* (MCOS, 1995)].

The GDSDS guidance recommended that intermittent discharges were not assessed in isolation, but a total catchment approach should be taken, and the urban pollution management (UPM) procedure (section 4.2) may provide a structured method for deriving solutions. Long-term SWO planning was encouraged within the framework of a Drainage Area Planning approach, which considers other sewer network deficiencies (e.g. flooding, structural and operational) before SWO solutions are implemented. Two criteria were introduced for SWO assessment: *trigger levels*, criteria that identify *unsatisfactory* SWOs that need to be upgraded; and *target levels,* or performance criteria, typically in the form of receiving water limits, which determine if the SWO discharge impacts beneficial uses such as aquatic life and bathing.

*Trigger levels*

The guidance recommended that the PCSWO criteria (a) and (d) for the identification of unsatisfactory SWOs (section 4.1.1) could be determined from visual inspections using established criteria (FWR, 1994a), and the level of public complaint depends on the *location, who is affected, and how long the problem has been occurring*. However, it was recognised that many SWOs may be classed as unsatisfactory based on these criteria alone.

Criteria (b) and (c) require comparison of ecological and water quality in receiving waters with prescribed standards. However, it was recognised that the extent to which SWO discharges lead to impairments of receiving waters may be difficult to quantify. Therefore, it was suggested that an assessment of SWO spill frequency is initially undertaken to gain an insight into the relative importance of the discharge.

*Target levels*

Target levels were discussed, particularly the application of the UPM procedure (second edition at time of publication of the GDSDS) and UK Regulations in an Irish context, with respect to the protection of river aquatic life, bathing waters and shellfish waters. The GDSDS report considered that the application of *Formula A* alone was no longer appropriate, since *Formula A* was not a strong indicator of SWO performance. As wet-weather receiving water standards have not yet been developed in Ireland, and the UK River Ecosystem Classification system (RE1 to RE5) was roughly equivalent to Ireland's River Quality Value system (Q5 to Q1, now replaced by WFD water status), it was advised in the GDSDS that the procedures set out in the UPM were appropriate. In addition to complying with the UPM fundamental intermittent and 99th percentile standards, two further criteria were recommended for SWO assessment: compliance with the Phosphorus Regulations [now repealed and replaced by the Surface Water Regulations (SI 272, 2009)] and the aim of achieving 'good' ecological status as required by the WFD.

The guidance recommends general adoption of the UPM methods for demonstrating compliance with bathing water uses (spill frequency or EQS methods; see section 4.2.1). However, owing to the shorter duration of the Irish bathing season (109 vs 153 days), the guidance recommended that, if using the spill frequency method, the maximum number of spills should be limited to two, rather than three (as in the UK). In the development of a long-term SWO plan, the guidance recommended that costs are initially based on the spill frequency method, with EQSs to be investigated if cost savings are possible based on this approach.

No shellfish waters were designated in the Greater Dublin Region at the time of publication of the GDSDS guidelines; however, it was considered prudent to specify a maximum number of spills of 10 per annum (as per the UPM approach), which would probably be achieved if the number of spills in the bathing season was limited to two.

The UPM approach of relating maximum spill frequency to the level of screening required was recommended in the GDSDS, with a notable exception. It was considered that the low or non-amenity classifications, subject to reduced solids retention requirements, were not suitable for use within the Greater Dublin Region as:

- The solids retention performance of chambers designed in accordance with good engineering design (FWR, 1994b) has been shown to be relatively poor (various studies reported in WaPUG, 2001). Chambers designed to this standard may not therefore comply with the requirement under the Dangerous Substances Directive to limit the release of persistent synthetic substances (PSS).

- In using any amenity use standards, all areas that could reasonably be affected by a discharge must be considered and the highest amenity category applied. On this basis, and taking account of the characteristics of the GDSDS area, it is apparent that, for the majority of discharge locations, a moderate or high category would be appropriate.

*Compliance testing*

Compliance testing involves the simulation of alternative SWO and wastewater network improvements until a solution is found that meets environmental and other criteria. The GDSDS guidance advocates an iterative approach, where simple models are used as a first approximation of the problem. The guidance makes a number of observations through experience of implementing the UPM procedure, which are summarised below:

- Sewer models must represent the full range of flow conditions, including infiltration, and flow must be verified upstream and downstream of SWOs.
- Continuous simulation of SWOs should be performed, using long-term rainfall records, to assess spill frequency, volume and duration.
- Building an integrated model of the sewer system and receiving water is more economical than building separate models. Biological surveys may serve as an initial assessment of SWO impacts. Compliance testing with receiving water standards should be based on 99th percentile standards, but intermittent standard compliance may lead to more economical solutions in some cases.
- In the UK, SWO impacts are usually assessed in terms of emission standards (spill frequency and volume), rather than with an EQS approach. The definition of a spill should be clearly set out, and multiple SWO structures discharging to a receiving water should be assessed in tandem.
- Provision of screening is the common approach to mitigating amenity impacts, and screens are typically designed to cater for events up to the 1 in 5 year storm.

### 4.1.4 Programme of measures, discharges from urban wastewater treatment plants

In accordance with WFD requirements, river basin management plans (cycle 1) were produced for each river basin district These presented the status of each significant water body, set out the objectives for future ecological status and proposed POMs to achieve these objectives. To support the preparation of POMs, the report *Programme of Measures, Discharges from Urban Wastewater Treatment Plants* (Mott McDonald, 2010) was prepared. This report presented a methodology to prioritise wastewater infrastructure upgrades in order to achieve compliance with regulations (UWWTD, Shellfish and Discharge Authorisation). The priority classification (1–3) was assigned to each WWTW discharge (total of 912 in database), with priority 1 discharges requiring the most urgent attention.

The classification was based on a two-step process. In step 1, priority 1 discharges were identified. These discharges were either listed as a pressure in the Pollution Reduction Programme (PRP) of a Designated Shellfish Water or not in compliance with the UWWTD due to a lack of treatment provision or failures in effluent standards. In step 2, the capacity of the WWTW, the assimilative capacity of the receiving water (BOD and nutrients) and upstream/downstream Q ratings were checked and classified according to the receiving water designation (including nutrient-sensitive waters, shellfish waters and freshwater pearl mussel catchments). At the end of stage 2, the discharges were classified as priority 1, 2 or 3. The impact of SWOs was also addressed: where deteriorations in receiving water quality occurred that were not linked to the treated effluent discharge, it was recommended that the overflow be investigated. This occurred in 140 of the 912 WWTW discharges (15%) assessed in the report.

## 4.2 The UK

The UK experience of retrofitting a large number of SWOs provides valuable insights and guidance, given the similarity of climate and sewerage infrastructure in the UK and Ireland. At the beginning of the 1990s, there were estimated to be 25,000 SWOs in England and Wales, 8000 of which were causing pollution problems (Clifforde *et al.*, 2006). In response to the need for major sewerage infrastructure improvements, a methodology was developed through an industry-wide collaboration, resulting in the UPM procedure.

### *4.2.1 UPM procedure*

UPM is defined as "the management of wastewater discharges from sewer and sewage treatment systems under wet weather conditions such that the requirements of the receiving waters are met in a cost effective way" (FWR, 2012).

It is noteworthy that UPM is concerned with wet-weather conditions only, i.e. the wastewater network is assumed to operate satisfactorily under dry-weather conditions, and it does not consider emergency overflows. The solutions developed by using the UPM procedure are also those that meet environmental objectives at a minimal cost. The UPM procedure considers the entire sewer system, i.e. the sewer network, the treatment works and SWOs. The first UPM manual was released in 1994 (UPM1), the second edition in 1998 (UPM2) and the third edition in 2012 (UPM3). The latest edition included a review of the UPM procedure against WFD requirements (Environment Agency, 2012a), and the use of the UPM procedure is now a requirement for intermittent discharge permit applications (Environment Agency, 2012b). The major components of the UPM procedure are initial planning (including the question – is a UPM study required?), data collection and compliance testing. In the following sections, the UPM regulatory approach, UPM study planning, modelling and data collection methods are discussed (sections 1–4 of the UPM manual) with respect to relevant UK legislation. Sections 5, 6 and 7 of the manual set out the application of UPM modelling tools that will be specific to individual projects, so are not included in this review.

The setting of environmental criteria is a prerequisite for an effective UPM project. These criteria relate to the beneficial uses of the receiving water. The beneficial uses that were identified as being most at risk from SWO discharges were identified as river aquatic life; bathing; shellfish harvesting; and general amenity. The majority of standards adopted for the UPM procedure are EQSs, which must be achieved in the receiving water. The standards applied to each beneficial use classification are discussed in the following sections.

*Standards for protection of river aquatic life*

Discharges from SWOs must be evaluated against the EQSs set out in the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (EU, 2013). However, recognising that these standards are more applicable to continuous discharges, fundamental intermittent standards (FISs) were developed as part of the UPM2 procedure. These standards were derived from eco-toxicological research in freshwater ecosystems (Milne *et al*., 1992). The standards were developed for three ecosystem types:

5. ecosystems suitable for sustainable salmonid fishery;
6. ecosystems suitable for sustainable cyprinid fishery;
7. marginal cyprinid fishery ecosystems.

The FISs are defined for three return periods (RPs) up to 1 year, and three durations of SWO discharge: 1 hour, 6 hours and 24 hours. An example of the intermittent DO standards is shown in Table 4.5. Standards also apply for ammonia ($NH_3$), BOD and each ecosystem type. However, meeting these EQSs does not guarantee protection of the ecosystem, and a number of other factors must be considered, including:

- combined effects of low DO and high unionised $NH_3$;
- effects of low DO and high unionised $NH_3$ in the inter-gravel water;
- effects of SWO spills from storm of > 1 year RP;
- effects of other potentially harmful substances in the overflow;
- random clustering of SWO spills;
- seasonal effects;
- diurnal fluctuations in DO.

**Table 4.5. Intermittent DO limits suitable for sustainable salmonid fishery**

| Return period | DO concentration (mg/l) | | |
|---|---|---|---|
| | 1 hour | 6 hours | 24 hours |
| 1 month | 5 | 5.5 | 6 |
| 3 months | 4.5 | 5 | 5.5 |
| 1 year | 4 | 4.5 | 5 |

**Source: FWR (2012), Chapter 3, Section 2.3.2. http://www.fwr.org/UPM3/index.htm**

The standards developed for freshwater ecosystems may also be suitable for brackish/tidal waters, although local considerations should be taken into account. The UPM procedure references the largest tidal study conducted in the UK, the Thames Tideway Strategic Study, and the standards set therein (Table 4.6).

An alternative approach to intermittent water quality standards are high percentile criteria (99th percentile), which have been extrapolated from the 90th or 95th percentile continuous discharge limits. For example, in the UK a WFD good status limit of 5 mg/l BOD (90th percentile) equates to a 99th percentile limit of 11 mg/l. This approach is more straightforward to apply, but the UPM guidance states that compliance with both criteria may be required by the regulator.

### *Standards for protection of bathing waters*

The two methodologies for protection of bathing waters are spill frequency emission standards and risk-based EQSs for bacteriological contamination (FWR, 2012). The spill frequency emission standard does not require the use of receiving water models and ensures a high rate of compliance with the Bathing Water Directive (EU, 2006a) (less than 5% chance of non-compliance). The UK standard states 'the maximum number of independent storm event discharges via the CSOs to identified bathing waters, or in close proximity to such waters, must not, on average, exceed the spill frequency standard of 3 spills per bathing season' (FWR, 2012). However, it is stated that the frequency of three spills per season would have to be reduced to two spills per season to gain the excellent classification under the Bathing Water Directive. Alternatively, compliance can be demonstrated by meeting the Bathing Water EQSs 98.2% of the time (in the case of 95th percentile Bathing Water Limits).

**Table 4.6. Intermittent standards for the Thames Estuary**

| DO (mg/l) | Return period (years) | Duration (no. of 6-hour tides) |
|---|---|---|
| 4 | 1 | 29 |
| 3 | 3 | 3 |
| 2 | 5 | 1 |
| 1.5 | 10 | 1 |

**Source: FWR (2012), Chapter 3, Section 2.3.2. http://www.fwr.org/UPM3/index.htm**

The increased threshold ensures that the risk of non-compliance with the Bathing Water Limits is less than 5%, based on the sampling regime (DOENI, 1999).

The spill frequency standards and bathing water EQSs are average values over a number of bathing seasons. For SWO planning and analysis purposes, rainfall records should be examined from at least 10 bathing seasons up to a limit of 25 bathing seasons. SWO spills are classified as follows:

- a discharge < 12 hours: one spill;
- a discharge of 12–36 hours: two spills;
- for each additional 24 hours: one additional spill.

### *Standards for protection of shellfish waters*

As with the standards for protecting bathing waters, the requirements of the Bathing Water Directive (EU, 2006a) can be met through spill frequency standards or risk-based EQSs. Using the spill frequency approach, the maximum number of spills permitted to *identified* shellfish waters is 10 per annum, but this figure may be reduced where the duration of the discharge exceeds 24 hours. With the risk-based EQS approach, a limit of 1500 faecal coliforms per 100 ml applies (for continuous and intermittent discharges combined), which must be complied with 97% of the time (Environment Agency, 2012b).

### *Standards for protecting amenity use*

The protection of amenity use involves the removal of gross solids from intermittent discharges, which is normally achieved through screening of overflows. Guidelines have been developed (Environment Agency, 2012b) to demonstrate compliance with the UWWTD, which relate the level of screening to the amenity value of the receiving water. For example, high-amenity areas [such as contact (immersion) sports and shellfish areas] require 6-mm screening, whereas low-amenity areas (such as a footpath adjacent to a stream) require only good engineering design of the overflow. The guidelines recognise that it may not be possible to screen all flows: 6-mm solid separation targets are met by screening either the flow rate that treats 80% of annual discharge volumes (as determined by rainfall time-series analysis) or the flow rate that treats 50% of the volume of the annual return period storm. Overflows up to the 1 in 5 year storm event should be subject to 10-mm screening.

*Location of outfall to coastal waters*

A further provision of the UPM procedure is that, for coastal discharges, the outfall should be below the mean low-water springs level (MLWS). Where this is not possible, SWO spills should be limited, and where outfalls are located above the mean high-water springs level (MHWS), spill frequency should be limited to once in 5 years.

*Planning a UPM study*

Section 3 of the UPM manual describes the scoping procedure for a UPM study. It addresses two key issues that should be considered at the outset: (1) the need for a UPM study; and (2) the environmental framework by which current and future performance of the wastewater network will be assessed.

The need for a UPM study is determined by a review of the available information for the catchment in question and a preliminary source apportionment assessment. The review of current information for the catchment should identify if there is a current or potential receiving water problem related to wastewater discharges. Relevant existing data may include the receiving water quality and river flow data, SWO and WWTW performance data, and catchment management plans. The source apportionment assessment should consider, at a minimum, intermittent discharges; wet-weather discharges from WWTWs; surface water outfalls; and industrial discharges.

If a UPM study is required, the modelling effort will be determined by the complexity of the problem and the cost of possible solutions. At this stage, a review of available data and study constraints is recommended, which will identify data collection requirements.

*Complexity of modelling*

The *Additional Guidance for Water Discharge and Groundwater Activity Permits* (Environment Agency, 2012b) provides guidance on the level of complexity of modelling required to provide *environmentally protective solutions* for SWOs. This is important in the context of SWO monitoring, since the data requirements are linked to the model complexity. The Environment Agency (EA) guidance relates required model complexity to the significance of the discharge. The definitions for the significance of discharge are equivalent to those presented in the SRM, which were subsequently adopted in the PCSWO. However, the modelling requirements of the EA are somewhat different from those of the PCSWO, principally due to advances in modelling techniques for sewer networks and receiving waters.

The EA guidance considers the use of *Formula A* coupled with simple mass balance calculations sufficient in the case of low-significance discharges, provided compliance is demonstrated with 99th percentile receiving water and FISs, and no environmental problems have been previously identified. This is an important distinction from the PCSWO, which considers only the dilution and interaction criteria to allow use of *Formula A* to demonstrate compliance.

In respect of medium-significance overflows, a validated sewer hydraulic model coupled with simple stochastic river impact modelling is considered adequate for the majority of cases. For high-significance overflows, detailed flow and water quality modelling in the sewer system and in the receiving water is required to demonstrate compliance with FISs.

### 4.2.2 Extent of monitoring

The *Additional Guidance for Water Discharge and Groundwater Activity Permits* (Environment Agency, 2012b) outlines requirements for monitoring of SWOs in the UK. The monitoring requirements include:

- spill event occurrence and duration where SWOs are known to be problematic, the SWO has been improved but significant uncertainties were associated with the modelled performance, or the SWO was costly or high profile;
- flow monitoring on pump stations where performance is uncertain;
- event and duration monitoring for improved SWOs that discharge to designated shellfish waters or bathing waters (telemetry required).

The Scottish Environmental Protection Agency (SEPA) has adopted the UPM procedure for SWO assessment and improvement. The regulatory method for sewer overflows (SEPA, 2014) provides guidance on monitoring requirements for new and modified SWOs as follows:

- event recording for discharges to designated bathing and shellfish waters;
- for agglomerations >2000 PE discharging to rivers, event recording (dilution of river at 95th percentile flow to sewer DWF >8:1) and flow recording (dilution of river at 95th percentile flow to sewer DWF <8:1).

Water companies in the UK are now monitoring a significant proportion of sewer infrastructure, to demonstrate compliance with receiving water quality targets in response to pressure from the Department for Environment, Food and Rural Affairs, which is seeking monitoring of the *vast majority* of SWOs by 2020 (DEFRA, 2013). The following is a summary of overflow monitoring from selected UK water companies:

- Northumbrian Water – over 85% of SWOs are now monitored; ‘almost all’ will be monitored by 2017 (NWL, 2015).
- Welsh Water – sewer infrastructure includes 3200 SWOs and 828 WWTWs. Investment in monitoring in 2015–2020 will include the installation of event and duration monitors in 2300 network assets and flow monitors at 60 SWOs (Welsh Water, 2015).

## 4.3 Austria

The design of SWO retention tanks in Austria follows the national standard (ÖWAV-RB 19, 2007). The catchment SWO efficiency, η, is defined as the proportion of runoff treated at the WWTW. Calculation of η requires the use of a catchment hydraulic model, but the methodology is innovative in allowing improvements to η through the use of surface water infiltration and real-time control (RTC) of the sewer network (Kleidorfer and Rauch, 2011). Importantly, all the SWOs and WWTWs within a sewer network are assessed as a single entity. The following equations from ÖWAV-RB 19 have been derived from De Toffol (2009).

η (%) is estimated from:

$$\eta = \frac{(VQ_C - VQ_d)\cdot C_D - VQ_O \cdot C_O}{(VQ_C - VQ_d)\cdot C_C}\cdot 100 = \frac{VQ_R \cdot C_C - VQ_O \cdot C_O}{VQ_R \cdot C_C}\cdot 100 \qquad (4.3)$$

where $VQ_C$ = total annual volume of combined sewage (m$^3$/year), $VQ_d$ = total annual volume of DWF (m$^3$/year), $VQ_0$ = total annual volume of overflow discharge (m$^3$/year), $VQ_R$ = total annual volume of surface runoff (m$^3$/year), $C_C$ = pollutant concentration of DWF (mg/l) and $C_O$ = pollutant concentration in overflow discharge (mg/l).

The SWO efficiency is subdivided into $\eta_d$, the SWO dissolved pollutant efficiency, and $\eta_p$, the SWO particulate pollutant efficiency. The standard requires minimum $\eta_d$ and $\eta_p$ values, depending on the design basis of the WWTW (Table 4.7).

Assuming equal concentrations of dissolved pollutants in the DWF and stormwater, $\eta_d$ can be expressed as:

$$\eta_d = \frac{VQ_R - VQ_O}{VQ_R}\cdot 100 \qquad (4.4)$$

For the calculation of $\eta_p$, the mean sedimentation efficiency ($\eta_{sed}$) is required:

$$\eta_{sed} = \frac{C_{SWO} - C_O}{C_{SWO}}\cdot 100 \qquad (4.5)$$

where $C_{SWO}$ = pollutant concentration in SWO structure (mg/l).

**Table 4.7. Required SWO efficiency for dissolved and particulate pollutants**

| Rainfall intensity | WWTW design load (PE) | | | |
|---|---|---|---|---|
| | <5000 | | >5000 | |
| | $\eta_d$ (%) | $\eta_p$ (%) | $\eta_d$ (%) | $\eta_p$ (%) |
| $I_{1,12} \leq$ 30 mm/12 h[a] | 50 | 65 | 60 | 75 |
| $I_{1,12} \leq$ 50 mm/12 h | 40 | 55 | 50 | 65 |

**[a]$I_{1,12}$ = rainfall intensity of 1-year, 12-hour event.**
**Source: De Toffol (2009).**

The particulate pollutant efficiency for each SWO, j, is then calculated from:

$$\eta_p = \eta_d + \frac{\Sigma_j (VQ_{O,j} \cdot \eta_{sed,j})}{VQ_R} \quad (4.6)$$

In the absence of detailed information on the sedimentation rate in the SWO structure, estimation efficiency rates are provided in the standard (Table 4.8).

Further to the emission-based controls, six receiving water quality standards are applied, which are assessed for each SWO separately.

1. *Hydraulic impact*: to limit erosion in receiving watercourses, the overflow discharge from the 1-year storm should be 10–50% of the receiving water annual flow. The lower limit applies to small watercourses or where bed sediments are unstable. The upper limit applies to rivers with stable bed sediments and higher biota recolonisation potential.
2. *Acute ammonia toxicity*: for salmonid waters, the $NH_3$ concentration over a 1 hour duration should not exceed 2.5 mg/l at 20°C and not exceed 5 mg/l for cyprinid waters.
3. *Oxygen depletion*: the DO concentration downstream of the SWO discharge should be greater than 5 mg/l. Recognising the difficulty in modelling DO changes arising from intermittent SWO discharges (in addition to diffuse sources), detailed assessment of DO is required only if anaerobic conditions occur during DWFs or the river slope is less than 3–5 m/km.

**Table 4.8. Sedimentation efficiency of SWO structures**

| Specific volume (m³/ha impervious) | | | η (%) |
|---|---|---|---|
| Hydrodynamic separator | Tank | In-pipe storage with D/S overflow | |
| 3 | 5 | 10 | 20 |
| 7 | 10 | 20 | 35 |
| > 10 | > 15 | > 30 | 50 |

**Source: De Toffol (2009).**

4. *Solids*: TSS should not exceed 50 mg/l in receiving waters.
5. *Bacteria*: discharges to bathing waters should be limited where possible.
6. *Aesthetics*: at sensitive locations, screening of overflows should be provided.

## 4.4 Germany

Detailed guidance on the sizing and design of SWO detention tanks is provided in ATV-A 128 (1992). The guidance is based on limiting the annual pollutant load of COD to the receiving water (COD is assumed to be representative of other pollutant parameters). Since COD levels are influenced by complex in-sewer processes, reference values are presented for German conditions: 107 mg/l, stormwater runoff; 600 mg/l, wastewater DWF; and 70 mg/l, treated wastewater. Compliance of SWOs and WWTWs in sewer networks must be assessed separately and in combination.

The required information for assessment includes:

- WWTW annual discharge volume;
- impervious area connected to sewer network;
- population connected to sewer network;
- commercial and industrial flow estimates;
- flow time in the sewer network;
- catchment slope;
- annual rainfall.

Depending on catchment variables, this results in overflow settings of 3–6 times DWF and typical detention volumes of 20–30 m³/ha impervious area (Zabel *et al*., 2001). Although compliance with this guideline is still mandatory in some German states, it has a number of shortcomings (Scholes *et al*., 2008):

- The only criterion considered is the annual mean COD load into the river. Acute effects from SWOs (oxygen depletion, $NH_3$ toxicity, hydraulic stress) that pose a major threat to the river are not considered.
- The allowed COD load is calculated using a very rough procedure, sometimes leading to inappropriate results.
- It focuses on storage tank solutions.

An EQS-based approach is adopted for the guideline document *BWK-M3* (2001). SWO discharges are deemed acceptable if the annual maximum river flow at the overflow point does not exceed the stream annual mean flood flow by more than 10% and maximum concentrations in the river are achieved for $O_2$, $NH_3$ and TSS (Kabelkova *et al*., 2010). *BWK-M7* (2007) provides detailed river quality limits that are based on the frequency and duration of discharge (Scholes *et al*., 2008).

## 4.5 Spain

Although national standards have yet to be adopted in Spain (Anta *et al*., 2013), regional guidelines are in place for SWO management. For example, the *Technical Regulations for Galician Hydraulic Works* (ITOHG, 2009) presents *simplified* and *complete* design criteria for the estimation of SWO storage volumes. Three criteria must be satisfied in applying the simplified approach:

- Impervious area of catchment is < 10 ha.
- Population is < 3000 PE.
- There is no risk of flooding.

Should these be satisfied, the catchment impervious area, land use and receiving water classification determine the specific SWO storage volume (Table 4.9).

The *simplified* sizing criteria were based on modelling/monitoring studies of six urban catchments in north-west Spain, with the aim of limiting the annual spill frequency to 15–20 spills (Hernaez *et al*., 2011). This spill frequency would be excessive in many circumstances, such as discharges to bathing waters; however, the methodology (developed using local data) may be useful.

Should the *simplified* criteria not be met, the *complete* design procedure applies, where SWO spills should be modelled using the US EPA Storm Water Management Model [SWMM, US EPA (2015)], or similar urban water quality model. In terms of emission standards, SWO discharges must be limited to 15–20 occurrences or 10–15% of the annual runoff volume. Where compliance with EQSs is required, the UPM procedure is recommended, although specific guidance is not provided (Hernaez *et al*., 2011).

## 4.6 USA

The SWO control policy (FR, 1994) established a national framework for the control of SWO discharges. The policy recognised the site-specific nature of SWOs and their impacts, and so provided flexibility in tailoring solutions to local situations. A two-stage approach was proposed: immediate implementation of nine minimum technology-based controls and development of long-term SWO control plans.

The nine minimum controls are:

1. proper operation and regular maintenance programmes for the sewer systems and the SWOs;
2. maximum use of the collection system for storage;
3. review and modification of pretreatment requirements to ensure that SWO impacts are minimised;
4. maximisation of flow to the WWTW;
5. prohibition of SWOs during dry weather;

**Table 4.9. Minimum SWO storage volume using simplified method**

| Receiving water classification[a] | Flow to WWTW | SWO storage volume ($m^3$/ha impervious) | | |
|---|---|---|---|---|
| | | Rural | Urban | Dense urban |
| Sensitive | 3 × DWF | 80 | 100 | 110 |
| Non-sensitive | 3 × DWF | 60 | 80 | 90 |
| Sensitive | 5 × DWF | 56 | 70 | 77 |
| Non-sensitive | 5 × DWF | 42 | 56 | 63 |
| Sensitive | 7 × DWF | 32 | 40 | 44 |
| Non-sensitive | 7 × DWF | 24 | 32 | 36 |

**[a]According to Urban Wastewater Treatment Directive (91/271/EEC).**
**Source: Anta et al. (2013).**

6. control of solid and floatable materials in SWOs;
7. pollution prevention;
8. public notification to ensure that the public receives adequate notification of SWO occurrences and SWO impacts;
9. monitoring to effectively characterise SWO impacts and the efficacy of SWO controls.

Characterisation of SWO impacts and controls are intended to be conducted in tandem with the development of the SWO long-term control plans (LTCPs). The purpose of the plans is to ensure that discharges are compliant with the requirements of the Clean Water Act (CWA, 1977), through the national pollutant discharge elimination system (NPDES) permitting programme. The plans are primarily targeted at reducing or eliminating discharges to sensitive waters (including bathing waters, drinking water abstraction points and shellfish areas). In addition, non-sensitive discharges are required to demonstrate compliance with receiving water quality through one of two mechanisms: a *presumption* approach or a *demonstration* approach.

The *presumption* approach specifies performance criteria that would be likely to meet Clean Water Act goals, recognising that data and modelling of wet-weather events often do not give a clear picture of SWO controls necessary to protect water quality standards. The criteria are:

- no more than four spills per year; or
- spillage of no more than 15% of annual combined sewer flows (or equivalent mass of pollutants).

In addition, SWO spills are required to be treated for removal of floatable and settleable solids.

The *demonstration* approach is acceptable where the SWO control plan demonstrates that water quality and designated uses of the receiving water are protected; the maximum pollution prevention that is reasonably attainable is provided; and cost-effective expansion and retrofit options are included in the plan should additional controls be necessary.

The SWO control policy outlines detailed monitoring requirements: frequency, duration, flow rate, volume and pollutant concentrations in the overflow, as well as receiving water impact assessment. However, it is recognised in the policy that monitoring and modelling efforts are interlinked and that the complexity of modelling should reflect the information needs associated with evaluation of SWO control options.

When considering alternative control options, the policy recommends the development of cost/performance curves, including an analysis of the costs associated with incremental improvements in receiving water quality. The LTCP should also evaluate control alternatives that are designed to pass forward 100%, 90%, 85%, 80% and 75% of flows to full treatment (or 0, 1–3, 4–7 and 8–12 spills per year).

Individual states have taken different approaches to meet the NPDES and SWO control policy; examples of these are described in the following sections.

#### *4.6.1 Indiana*

The Indiana Department of Environmental Management provides guidance for SWO treatment facilities for consideration as a LTCP strategy. The treatment of overflows in storage structures is provided by retention of the first flush for later transport to the WWTW; removal of solids and floatables; and chlorination. Specific treatment criteria consist of (IDEM, 2008):

- retention of storms equal to the 1-year, 1-hour event (approximately 10 mm for Dublin City) for subsequent treatment in the WWTW;
- treatment of flows in the SWO storage facility for events up to the 10-year, 1-hour event (approximately 20 mm for the Dublin region).
- flows in excess of the 10-year, 1-hour event should be provided with whatever treatment feasible taking into account the capacity limitations of the SWO treatment facility and the WWTW.

SWO treatment consists of:

- detention of the 10 year, 1-hour event peak flow for at least 30 minutes to provide adequate solids settling time and disinfection;
- skimming of detained flows to remove solids and floatables;
- disposal of solids and floatables in accordance with applicable laws and regulations;
- disinfection of all detained flows to achieve a maximum daily *E. coli* concentration of 235 CFU/100 ml;

- dechlorination, where necessary, to meet the maximum residual chlorine concentration of 0.06 mg/l.

### 4.6.2 Pennsylvania

The Pennsylvania Department of Environmental Protection (PDEP) requires SWO licensees to comply fully with the nationwide SWO control policy, including the development of LTCPs for agglomerations greater than 75,000 PE. For smaller agglomerations, a LTCP is not required, but licence-specific conditions will apply. The PDEP assigns the highest priority to SWOs that have been documented as posing a public health hazard, or have caused reductions in receiving water quality leading to loss of beneficial uses.

The PDEP encourages catchment-based solutions to reduced SWO impacts and will not approve the repair or replacement of a SWO without a detailed analysis that compares two scenarios: upgrade of the SWO and separation of stormwater from the combined sewer network. Post-construction monitoring is required for SWO upgrades or implementation of LTCPs (or part-of) to confirm the effectiveness of the control measures.

In addition to licence-specific measures, the following control applies all SWOs:

> All discharges of floating materials, oil, grease, scum, sheen and substances which produce colour, tastes, odour, turbidity, or settle to form deposits shall be controlled to levels which will not be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life.

For each permitted SWO, an annual report must be submitted to the PDEP that includes (PDEP, 2013):

- location of SWOs, and frequency, duration and magnitude of any overflows;
- rain gauge data that identify the rainfall depth causing each overflow;
- identification of any in-stream water quality impacts, and effects on downstream water users;
- total number of regular SWO maintenance inspections;
- list of blockages and other non-scheduled maintenance, suspected discharges that occurred as a result of blockage, and corrective actions.

### 4.6.3 Washington State

The Washington Administrative Code 173–245 (Washington State, 2000) establishes a system and criteria for the *greatest reasonable reduction of combined sewer overflows at the earliest possible date*. Similar to other US state requirements, the code requires the attainment of the greatest reasonable reduction of overflows, without causing violations of receiving water standards or restrictions of the characteristic uses of the receiving water. In addition, the code makes specific reference to sediments in overflows, requiring that this material (1) does not exceed sediment criteria or standards; or (2) does not have an adverse biological effect. These important criteria recognise that impacts from SWOs may arise from chronic pollution associated with contaminated sediments, even where receiving water quality limits for dissolved pollutants are met.

The code requires SWO reduction plans to be prepared, which must be integrated into general sewer plans, and plans for new and upgraded WWTWs. The SWO reduction plan consists of the following.

1. **Baseline assessment** – evidence of current SWO operation using a combination of field sampling and mathematical modelling to establish the annual discharge frequency and volume of discharges, and their effects on receiving waters. Where groups of SWOs can be shown to be similar (catchment hydraulics and pollutant loads), sampling of only one SWO is required. Sampling of SWOs serving residential catchments only may not be required. Sampling of sediments upstream and downstream of SWOs may indicate historic impacts. If the SWOs collect discharges from sources other than domestic sources, then a screening analysis of heavy metals and organics in the receiving water sediments is required.

2. **Consideration of treatment alternative** – including stormwater best management practices (BMPs), sewer maintenance programmes, reducing infiltration, storage, disinfection and sewer separation.

3. **Analysis of treatment options** – estimates of water quality and sediment quality improvements arising from treatment options. This may include analysis of stormwater discharges where these drain industrial and/or commercial facilities. The

impacts of SWO improvements should also be analysed relative to discharges from WWTWs affected. The analysis should also include cost of construction, operation and maintenance.

4. **Priority ranking** – each municipality must propose a ranking of SWO improvement projects, considering the following: highest priority is afforded to SWOs discharging near water supply intakes, public primary contact recreation areas, and shellfish harvesting areas; cost-effectiveness evaluation of each project, which may be expressed as a cost per annual volume reduction or similar measure; and assessment of environmental impacts arising from existing SWOs.

5. **Schedule** – for achieving the *greatest reasonable reduction of combined sewer overflows at the earliest possible date*. This should consider total cost of compliance; economic capability of the municipality; other expenditure aimed at improving water quality; and the severity of existing and potential impacts of SWOs on receiving water quality and beneficial uses.

#### *4.6.4 Maine*

The state requires that SWO facility plans are developed to deal with problems associated with SWO discharges, primarily bacteria, solids, turbidity and odour (Maine DEP, 1994). It is recommended to structure the plan in four parts: (1) problem identification; (2) identification of short-term measures to be taken immediately, such as good maintenance, and projects to minimise inflow and infiltration; (3) analysis of alternatives for SWO and stormwater abatement; and (4) development of a long-term master plan to prioritise SWO improvements.

Monitoring of SWO discharges should be conducted in both summer and winter, and sample a range of storm event durations and intensities to characterise SWOs in *all foreseeable conditions*. Monitoring requirements are dependent on whether or not a sewer model is used: where no modelling of the sewer network is performed, all overflows should be monitored for a minimum of six storms between March and September, with at least one 1.5 inch storm (38 mm). If modelling of the sewer system is planned, only 25% of the SWOs (with coverage of >50% of the drained area) should be monitored for six storm events for model calibration, with a further two events monitored for model verification.

For estimation of pollutant loads, four storm events should be sampled, using flow-weighted samplers capable of capturing the first flush. For SWO discharges into environmentally sensitive receiving waters, the following parameters should be tested: SS, BOD, pH, lead, zinc, chromium, copper, cadmium, mercury, iron, arsenic, silver, total Kjeldahl nitrogen, total ammonia, nitrate/nitrite nitrogen, total phosphorus, petroleum hydrocarbons, polycyclic aromatic hydrocarbons, polychlorinated biphenyls (PCBs) and herbicides (2,4-dichlorophenoxyacetic acid and dicamba). Alternatively, acute toxicity tests can be used as screening measures to identify highly polluted samples requiring further analysis. A reduced pollutant characterisation programme may apply to less sensitive waters.

## 4.7 Canada

The Wastewater Systems Effluent Regulations (WSER; Government of Canada, 2010) came into effect in January 2015. WWTW effluent quality standards for carbonaceous BOD, TSS, residual chlorine, ammonia and acute lethality must be met on a phased basis for agglomerations collecting or designed for volumes in excess of 100 $m^3$/day. Monitoring of WWTWs and SWOs commenced in 2013. For SWOs, reporting of spill date and spill volume is required. A points-based system identifies the priority wastewater networks and requires compliance by 2015 (>70 points), 2020 (<70 points), 2030 (50–70 points) and 2040 (<50 points). More points (and thus higher priority) are assigned to SWOs that carry a high proportion of the total agglomeration flow, spill frequently and discharge to sensitive areas.

The WSER regulations with respect to SWO management are more prescriptive than the requirements contained in the *Canada-wide Strategy for the Management of Municipal Wastewater Effluent* (CCME, 2009) These general requirements include:

- There should be no increase in overflow frequency due to development or redevelopment, unless it occurs as part of an approved overflow management plan.

- There should be no overflow discharge during dry weather, except during spring thaw and emergencies.
- Floatable materials should be removed, where feasible.
- Standards should be achieved within 7 years.
- SWO action plans should be completed within 7 years.
- Implementation should be by province/territory.

While the wording and scoring system contained in the WSERs have been seen as overly complex for wastewater utilities (CWWA, 2010), the regulations represent a step towards harmonisation of wastewater treatment across Canada. The scoring system may require some refinement, but does allow improvements in SWOs to be compared with WWTW upgrades in a systematic way.

# 5 Priority Overflow Selection Tool

Two important tasks should precede the improvement of SWOs in Ireland: (1) the identification of *priority* SWOs that need to be upgraded; and (2) the setting of environmental criteria by which alternative retrofit solutions can be judged.

The second task requires environmental criteria to be set, but these will be dependent on the characteristics of the catchment, the sewer network and the receiving water. As noted in the GDSDS (Dublin Drainage Consultancy, 2005), the UK UPM manual (FWR, 2012) provides a structured method that is suitable for addressing *unsatisfactory* discharges.

The following chapter describes the development of a tool to address the first task: the identification of priority overflows that require further investigation and possible improvement. This tool is referred to as the Priority Overflow Selection Tool (POST).

In addressing the problem, POST should ideally satisfy the following criteria:

- can be applied on a national basis;
- is transparent and can be easily implemented by the relevant stakeholders;
- makes use of available data sets;
- can be adapted as new data become available;
- is compliant with relevant directives and regulations;
- considers the uncertainty of data and models used;
- takes a conservative approach;
- recognises economic constraints (i.e. it is not possible to monitor all SWOs);
- targets resources where environmental problems are known to exist;
- monitoring resources match the scale of problem and receiving water amenity (environmental and economic).

The output of POST will be the priority monitoring level for each SWO in question. Three priority levels are proposed:

- **priority 1** – requires prompt installation of monitoring equipment;
- **priority 2** – requires further investigation (such as field surveys) to establish the requirement for monitoring;
- **priority 3** – not currently prioritised for monitoring.

## 5.1 Data Availability

At the time of development of POST, the following SWO data were available: AER summary spreadsheets (as provided by the EPA) and AER returns for each agglomeration.

The information contained in the AER summary spreadsheet for each SWO comprised:

- location of SWO;
- receiving water name and type;
- compliance with the PCSWO (yes/no);
- significance of discharge (low/medium/high);
- spill frequency/volume (measured in only 4% of SWOs, so not included in POST).

In a very limited number of cases, further information was available in the individual AERs for the agglomeration; however, this was available only in PDF format, and sufficient records were not available to populate a national model. Therefore, POST was developed solely on the information provided in the AER summary spreadsheet.

## 5.2 Step 1 – Identification of Non-compliant SWOs

Assessment of SWOs against the PCSWO criteria for unsatisfactory overflows is currently reported in 48% of cases. It is envisaged that this figure will increase as the process for SWO assessment is standardised. Given the limitations of the methods currently employed to assess criteria (b) and (c) for problematic SWOs, it should be noted that compliance with the PCSWO does not guarantee compliance of a SWO with current legislation, including the UWWTD. Rather, the criteria are used to identify the SWOs most in need of investigation, particularly where non-compliance results from criterion (a) or (d).

## 5.3 Step 2 – Classification of SWO Significance

Assessment of SWOs against the PCSWO criteria for significance is currently reported for approximately 38% of SWOs. The assessment is based on the population served; the designated use of the receiving water; and the dilution in the receiving water (for discharges to rivers). Recognising that the dilution ratio of the sewer DWF to the receiving water flow does not imply compliance with WFD receiving water targets, the significance assessment should be viewed as useful in identifying discharges from large agglomerations; SWO structures that carry higher flows relative to the flow in the receiving river; and sensitive receiving waters.

In POST, the compliance and significance of the SWOs are combined to determine the priority of the SWO, as shown in Figure 5.1. Given the uncertainty of the assessment criteria for compliance and significance, the assignment of SWO priority should not be viewed as fixed; the assignment of priority should also take into account local factors (such as sewer infiltration, etc.) to assign a higher or lower priority as necessary.

## 5.4 Step 3 – Identification of Discharges to Protected Receiving Waters

Once the priorities of SWOs are assigned, it is proposed to rank each group (priority 1, 2 or 3) according to their proximity to downstream protected areas. Currently, the presence of protected areas downstream of the SWO discharge point is not included in the AER spreadsheet. The details of such protected areas would be useful for POST implementation. As an interim measure, the proximity of a SWO to a protected area was assessed: it should be recognised that this method may identify protected areas within a proximity buffer of a SWO, even where the SWO discharge is not hydraulically connected to the protected area. Downstream protected areas may include:

- drinking water abstraction points, as identified under the Drinking Water Directive (EU, 1998);
- SACs as designated under the Habitats Directive (EU, 1992);
- SPAs as designated under the Birds Directive (EU, 2009);
- nutrient-sensitive areas as designated under the Urban Wastewater Treatment Directive (EU, 1991);
- salmonid waters as designated under the Quality of Salmonid Waters Regulations (SI 293, 1988);
- bathing waters as identified under the Bathing Water Directive (EU, 2006a);
- shellfish waters as identified under the Shellfish Water Directive (EU, 2006b);
- freshwater pearl mussel habitats as identified under the Freshwater Pearl Mussel Regulations (SI 296, 2009).

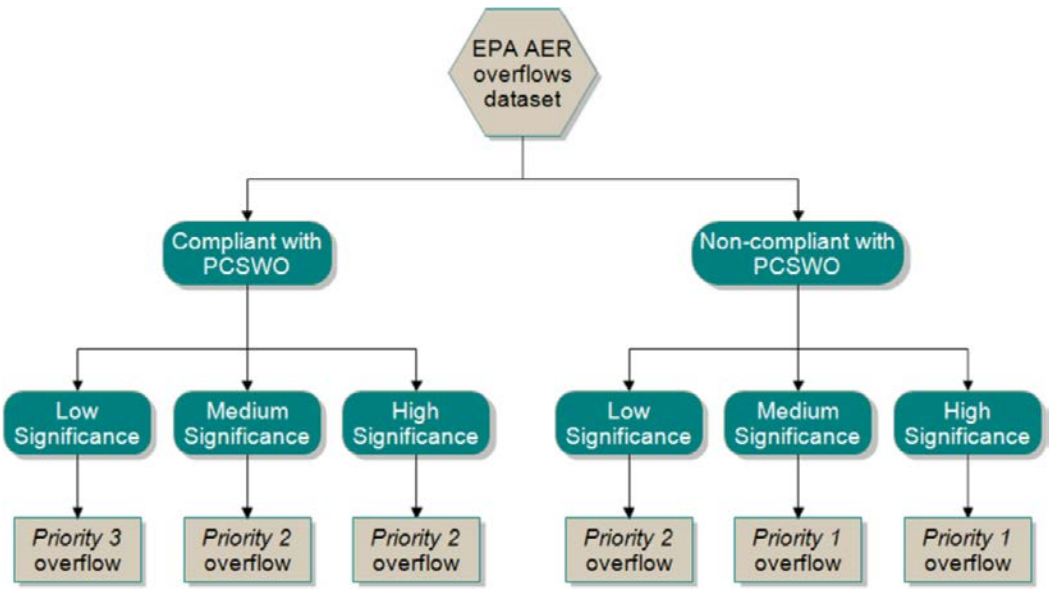


**Figure 5.1. POST priority assignment.**

The extents of protected areas can be identified from the EPA *WFD Register of Protected Areas* (https://gis.epa.ie/LatestReleases/Release/17), which is available in a geodatabase format. Extents of freshwater pearl mussel habitats may also be available, pending agreement with the National Parks and Wildlife Service. In future, protected areas downstream of SWOs could be identified in the AERs, along with the EPA *WFD Register of Protected Areas* identifier code. The receiving river identifier code could also be included, where applicable. This information should be available in a geodatabase format and would greatly enhance the robustness of the POST model.

## 5.5 POST Implementation

The following analysis is intended as a demonstration of POST, using the data currently available in the AER spreadsheet. It should not be interpreted as a complete analysis of all SWOs in Ireland.

### *5.5.1 SWO data interrogation*

Data on SWOs were supplied by the EPA in Excel format based on the 2014 AER returns. The record of all discharges from agglomerations (licensed discharges only) comprised 1574 entries. Discharges identified as *primary discharge*, i.e. discharges from WWTWs, were removed. However, discharges identified as *primary discharge/stormwater overflow* or *primary discharge/emergency overflow* were retained. This resulted in a data set of 1291 entries. Of these, compliance was assessed for 621 SWOs and significance was assessed for 486 SWOs. Both compliance and significance were assessed for 370 entries. This data set ($n = 370$) formed the basis of the analysis.

### *5.5.2 Identification of non-compliant SWOs*

Of the 370 SWOs, 183 were reported to be compliant with the PCSWO (49%), with the remainder reported to be non-compliant. At first glance, the proportion of non-compliant SWOs may appear to be high. However, it is unclear if this data set is representative of the national situation. For example, a SWO is more likely to be inspected if it is subject to public complaint (and thus classified as non-compliant). Furthermore, the AER spreadsheet does not indicate the cause of non-compliance.

### *5.5.3 Classification of SWO priority*

The compliant and non-compliant groups were next classified according to their significance, as shown in Figure 5.2. This resulted in the following priority assignment:

- priority 1 – 24%;
- priority 2 – 32%;
- priority 3 – 44%.

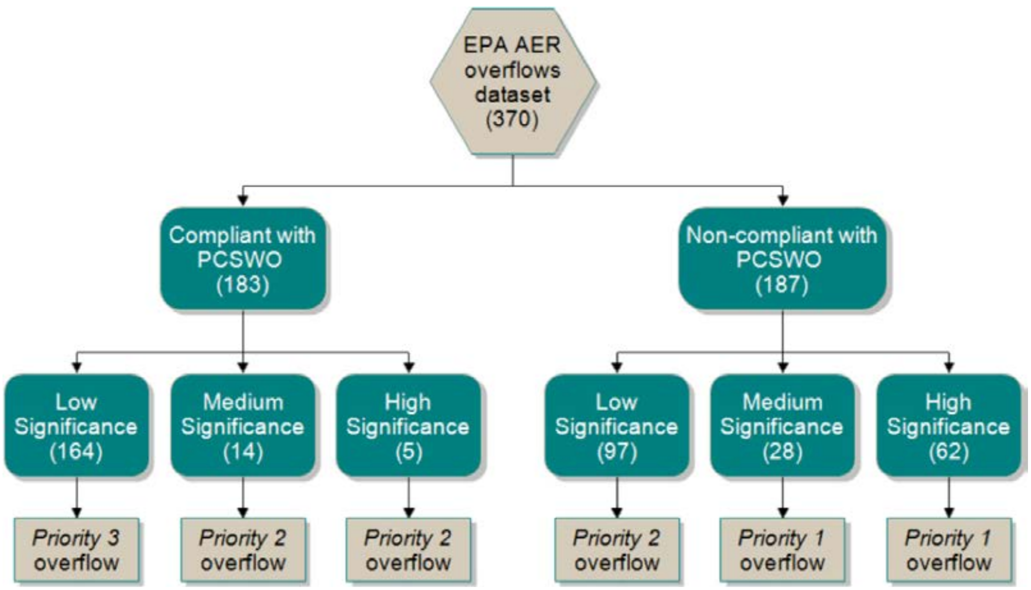


**Figure 5.2. Summary of POST implementation.**

As discussed in the previous section, these percentages do not necessarily represent the situation nationally.

#### 5.5.4 *Identification of discharges to protected receiving waters*

Nearby protected waters were identified from the SWO location and the EPA *WFD Register of Protected Areas* shapefiles (Figure 5.3), using a geographical information system (GIS) proximity buffer. The applicable protected areas varied by the receiving water type (Table 5.1); thus, proximity analysis was separated into coastal (39 SWOs), estuarine (97 SWOs) and river (234 SWOs) groups.

The proximity analysis was conducted separately for the three priority classes. Four proximity buffers were used to rank SWOs in each priority class: 0.5 km, 1 km, 2 km and 5 km. The percentages of SWOs situated within a given protected area proximity zone are listed in Table 5.2. For example, 78% of priority 1 SWOs discharging to estuaries were located within 0.5 km of a protected area, and 92% of SWOs in this group were located within 2 km of a protected area. On average, between 59% and 80% of SWOs (across all priority groups and receiving water types) were located within 1 km of a protected area. This indicated that, among the sample of 370 SWOs, the majority were within close enough proximity to protected areas to potentially cause an impact, should the SWO be problematic.

### 5.6 Future Development of POST

As the information contained in completed AERs becomes standardised nationwide under Irish Water management, it should be possible to collect more detailed agglomeration data relevant to SWOs, such as the drainage catchment area and percentage of impervious area. This process may be facilitated through the increased use of GIS databases to store drainage network data. Drainage area plans and modelling studies are being progressed, but these will be limited to the larger agglomerations. For smaller agglomerations, it may still be necessary to estimate SWO spill frequencies and volumes to test compliance with EQSs. A methodology to estimate the impact of SWO spills on EQS values, based on agglomeration geodata, is presented in the following section. This has been adapted from the UK Highways Agency

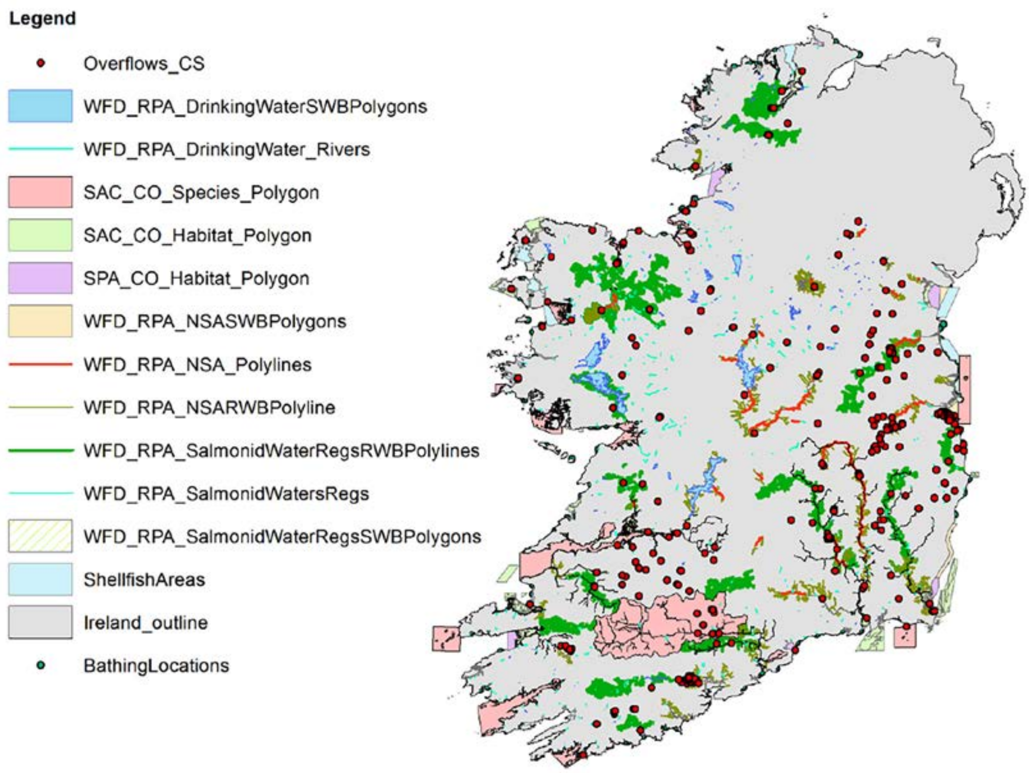


**Figure 5.3. WFD protected areas and SWO locations.**

**Table 5.1. EPA shapefiles used for proximity analysis**

| EPA shapefile | Coastal waters | Estuaries | Rivers |
|---|---|---|---|
| WFD_RPA_DrinkingWaterSWBPolygons | | | x |
| WFD_RPA_DrinkingWater_Rivers | | | x |
| SAC_CO_Species_Polygon | x | x | x |
| SAC_CO_Habitat_Polygon | x | x | x |
| SPA_CO_Habitat_Polygon | x | x | x |
| WFD_RPA_NSASWBPolygons | x | x | x |
| WFD_RPA_NSA_Polylines | | | x |
| WFD_RPA_NSARWBPolylines | | | x |
| WFD_RPA_SalmonidWaterRegsRWBPolylines | | | x |
| WFD_RPA_SalmonidWaterRegs | | | x |
| WFD_RPA_SalmonidWaterRegsSWBPolygons | x | x | x |
| Shellfish_Areas | x | x | x |
| Bathing_Locations | x | x | x |

**Table 5.2. Percentage of SWOs within protected areas**

| Priority | Buffer (km) | Coastal | Estuary | River | Mean |
|---|---|---|---|---|---|
| 1 | *n*[a] | 5 | 37 | 48 | – |
| | 0.5 | 60 | 78 | 75 | 71 |
| | 1 | 80 | 86 | 75 | 80 |
| | 2 | 100 | 92 | 83 | 92 |
| | 5 | 100 | 100 | 94 | 98 |
| 2 | *n*[a] | 22 | 34 | 60 | – |
| | 0.5 | 45 | 62 | 52 | 53 |
| | 1 | 55 | 68 | 55 | 59 |
| | 2 | 55 | 74 | 65 | 64 |
| | 5 | 100 | 100 | 85 | 95 |
| 3 | *n*[a] | 12 | 26 | 126 | – |
| | 0.5 | 67 | 58 | 41 | 55 |
| | 1 | 75 | 81 | 50 | 69 |
| | 2 | 83 | 96 | 57 | 79 |
| | 5 | 92 | 96 | 83 | 90 |

**[a]*n* = numbers of CSOs in each group.**

risk assessment methodology for stormwater outfalls (Crabtree *et al*., 2008).

The proposed procedure is as follows.

1. Collect the following minimum information for each SWO catchment: DWF (measured or estimated from geodata); catchment area; average catchment slope; catchment shape; percentage impervious and interception storage (estimated).
2. Obtain time-series rainfall data (at the appropriate resolution) from the nearest Met Éireann recording station (minimum 10-year record). Alternatively, generate synthetic rainfall time series.
3. Select inter-event time to separate rain events and rank by total rainfall (highest to lowest).
4. For each event, calculate the average flow from total rainfall; the impervious area; percentage impervious and interception storage. Permeable areas could also be included.
5. Using peak flow ratio (see following section), calculate peak flow and compare with pass forward flow of SWO.

6. Estimate average annual spill frequency and volume for each SWO, and calculate frequency of exceedances of EQS values.

Validation of the procedure would be required as follows, when sufficient data are available from Irish Water.

1. Select a number of SWOs where hourly sewer flow data are available (ideally 10+ years). At present, this is likely to be at WWTWs only.
2. For each SWO, calculate peak flow factors (event peak flow/average flow) for all events.
3. Examine peak flow factors for each catchment, in terms of (non-exhaustive):
   (a) rainfall duration;
   (b) peak rainfall intensity;
   (c) catchment impervious;
   (d) catchment slope;
   (e) catchment shape.
4. Using a multiple regression approach or similar, calculate peak flow factors for given catchment variables. Validate regression model using a separate data set.

# 6 Technologies for SWO Monitoring

## 6.1 Traditional Methods for SWO Event Monitoring

There are a range of existing methods to measure SWO spill frequency, from simple to complex. In general, more complex methods provide more comprehensive data and require less post-processing. Traditional monitoring methods are listed below, in order of increasing complexity:

### *6.1.1 Visual observation*

This method requires crews to be present at the SWO during spill events, so rapid deployment in response to rainfall events is required in addition to careful safety planning. However, there are many advantages to visual observation of SWO spills: photographic and video evidence of the spill can be collected; water levels and flows can be measured manually; and effectiveness of screens and other pollution control devices can be assessed.

### *6.1.2 Manual methods*

SWO activation can be passively recorded using a wooden block (or other floatable) placed on the SWO weir wall or other flow control structure. Dislodgement of the block indicates that a spill has occurred. Alternatively, a chalk board can be placed at an appropriate location in the SWO (or chalk can be sprayed on dry interior walls). The wash-off of chalk indicates that a spill has occurred. Bottle boards can also indicate the maximum height of flow. Although these methods are simple and robust, a crew is still required to inspect the SWO after the rain event.

### *6.1.3 Flow monitoring*

Flow measurements are generally made using a combination of depth/pressure sensors, weirs, flumes and ultrasonic/electromagnetic velocity sensors. Flow conversions, which convert signals and cross-sectional geometry to flow data, can be made on board the devices and either stored for later retrieval via laptop or transmitted via telemetry. Calibration/validation of flow data is an important stage of site setup, since the correct positioning of sensors is critical. Incorrect positioning can lead to erroneous flow measurements due to unstable flows, surcharging and backwater effects. Validation of flow records may be performed by using a number of flow measurement methods simultaneously. Flow monitoring of SWO events can provide a wealth of information on SWO activation/duration/volume, but can be expensive to install and maintain compared with visual and manual methods. A summary of flow measurement techniques is provided in Table 6.1 (US EPA, 1999).

## 6.2 Emerging and Low-cost Methods for SWO Event Monitoring

### *6.2.1 Rainfall analysis*

Analysis of historical rainfall in association with other SWO monitoring data offers the possibility of predicting spill occurrences and volumes at a reasonable cost, given that rainfall records are widely available. Advances in methods to analyse rainfall records in relation to SWO spills have occurred in recent years in tandem with the emergence of long-term SWO monitoring data for calibration and verification.

Mailhot *et al*. (2015) developed a statistical model corresponding to a Bernoulli trial, which was based on daily observations of SWO occurrence/non-occurrence (using blocks and other simple recording devices) and daily rainfall statistics. Using a large data set (3437 SWOs), it was possible to correctly predict the occurrence of a spill in over 53% of locations to a statistically significant level. However, the model could not reliably predict overflows in structures where spills occurred fewer than 10 times per annum. Since the occurrence of SWO spills was recorded at each location, the model was not useful in identifying critical SWOs. Rather, it was intended as a high-level planning tool allowing the number of spills in a given year to be compared with the prediction based on a long-term rainfall record. This would indicate, controlling for the influence of rainfall, if the number of SWO spills was changing in response to housing development controls, sewer network improvements, changes in maintenance practice or other factors.

**Table 6.1. Summary of SWO event-monitoring devices**

| Monitoring method | Description | Advantages | Disadvantages |
|---|---|---|---|
| *Manual methods* | | | |
| Timed flow | Timing how long it takes to fill a container of a known size | • Simple to implement<br>• Little equipment needed | • Labour intensive<br>• Suitable only for low flows |
| Dilution method | Injection of dye or saline solution in the system and measuring the dilution | • Accurate for instantaneous flows | • Not appropriate for continuous flow<br>• Outside contaminants could affect results |
| Direct measurement | Use of a flow meter and surveying rod to measure flow and depth manually | • Easy to collect data | • Labour-intensive<br>• Multiple measurements may be needed at a single location |
| Chalking and chalking boards | Blowing chalk into a CSO structure or installation of a board with a chalk line. The chalk is erased to the level of the highest flow | • Easy to implement | • Provides only a rough estimate of depth |
| Bottle boards | Installation of multiple bottles at different heights where the highest filled bottle indicates the depth of flow | • Easy to implement | • Provides only a rough estimate of depth |
| *Primary flow* | | | |
| Weir | Device placed across the flow such that overflow occurs through a notch. Flow is determined by the depth behind the weir | • Many CSOs have an existing weir<br>• More accurate than other manual measurements | • Cannot be used in full or nearly full pipes<br>• Somewhat prone to clogging and silting |
| Flume | Chute-like structure that allows for controlled flow | • Accurate estimate of flow<br>• Less prone to clogging than weirs | • Not appropriate for backflow conditions<br>• More expensive than weirs |
| Orifice plate | A plate with a circular or oval opening designed to control flow | • Can measure flow in full pipes<br>• Portable and inexpensive to operate | • Prone to accumulation of solids |
| *Depth sensing* | | | |
| Ultrasonic sensor | Sensor mounted above the flow, which measures depth with an ultrasonic signal | • Generally provides accurate measurements | • May be impacted by solids or foam on flow surface |
| Pressure sensor | Sensor mounted below the flow, which measures the pressure exerted by the flow | • Generally provides accurate measurements | • Requires frequent cleaning and calibration |
| Bubble sensor | Sensor that emits a stream of bubbles and measures the resistance to bubble formation | • Generally provides accurate measurements | • Requires frequent cleaning to prevent clogging |
| Float sensor | Sensors using a mechanical float to measure depth | • Generally provides accurate measurements | • Must be accurately calibrated prior to use and regularly checked for fouling |
| *Velocity meters* | | | |
| Ultrasonic | Meter design to measure velocity through a continuous pulse | • Instrument does not interfere with flow<br>• Can be used in full pipes | • More expensive than other equipment |
| Electromagnetic | Meter design to measure velocity through an electromagnetic process | • Instrument does not interfere with flow<br>• Can be used in full pipes | • More expensive than other equipment |

**Source: US EPA (1999).**

Schroeder *et al*. (2011) proposed a methodology for analysing long-term rainfall and level data to identify rain events that were likely to lead to a SWO spill. This was achieved in three steps:

1. Using a subset of data that included rainfall- and SWO-level data, the critical rainfall depth that caused a spill was identified, with a given probability.
2. The critical rainfall depth was validated from an independent rainfall and level data set.
3. The full rainfall record was used to identify SWO spills.

This methodology was applied to four combined sewer catchments, each having a record of 8 years of rainfall data and 2 years of rainfall/water-level data. Three catchments had no SWO improvements completed, and one had sewer improvements comprising raising of weir crests and increasing of pumped sewer outflow rate from two to three times DWF.

The rainfall time series was disaggregated into individual rainfall events by defining a minimum inter-event threshold of 6 hours (the time required for the storm tanks to empty). Of the rainfall characteristics investigated (rainfall duration, rainfall depth and peak 1-hour rainfall intensity), the rainfall depth was the most useful criterion for identifying SWO spill occurrences. The critical rainfall depth was determined to be 9.7 mm for the improved sewer catchment (95% of SWO events had a rainfall depth of greater than 9.7 mm) and 4.7 mm for the remaining catchments. Analysis of the long-term rainfall data revealed that the unimproved catchments had a high variability of SWO events year on year, with standard deviations of 5.5, 6.7 and 9.1 events/annum. A strong seasonal influence was also noted: the number of SWO events was 50–100% higher in summer than in winter, presumably due to the higher intensity of summer rainfall events.

Guo and Saul (2011) used artificial neural networks (ANNs) and rainfall data to predict water levels in 20 SWOs in the UK. The advantage of data-driven models is that a detailed understanding of the physical and chemical processes occurring on and in the sewer network is not required to relate inputs (rainfall) to outputs (water levels and flow rates). An adaptive linear ANN (ADALINE) was used to predict water levels three time-steps ahead (15 minutes total). The average correlation coefficient between measured and predicted values was 0.95, demonstrating the potential of this method. However, ANN models cannot be transposed from one site to another, and so a long-term rainfall record and a period of SWO monitoring is required for individual catchments. Another drawback of this method is its limitation to short-term predictions.

The use of rainfall radar data may reduce the data collection requirements, particularly in large catchments where several rain gauges may be needed. Mounce *et al*. (2014) calibrated an ANN using radar rainfall over a 20 $km^2$ catchment in the UK. In total, 3 months of SWO water level and rainfall data were used to train the model, and 3 months of data were used to test the model predictive power. Water levels in the SWO were predicted with just 2% root mean square error (RMSE) for 15-minute ahead predictions with unseen data, and 5% RMSE for 75-minute ahead predictions.

### *6.2.2 Temperature measurement*

Monserrat *et al*. (2013) monitored 13 SWOs using a low-cost temperature sensor network. Over the 1-year monitoring period, encompassing 57 rain events, the occurrence and duration of spills were correctly determined 80% of the time. The temperature sensor was installed on top of the SWO weir wall or, in the case of side weirs, on the invert of the outlet pipe. During normal operating conditions, the sensor measured the temperature of the sewer gases. A shift to lower temperatures indicated a SWO spill, with the recovery of temperature signifying the end of the spill. Thus, event occurrence and duration could be recorded. The temperature sensor used was a Hobo Pendant UA-002-64 (Onset Computer Corporation), capable of storing readings at 3-minute intervals for 120 days, at a unit cost of €45. A separate mobile sensor reader (Hobo Shuttle U-DTW-1) was also required, costing €240. The total equipment cost to monitor 13 SWOs, including software, was €924. It was noted by the authors that this equipment was not rated as explosion-proof.

The main limitation of this monitoring technique was related to the construction of the SWO structure: for side weirs, the sensor (placed on the invert of the pipe) was partially submerged during dry weather in some cases; in drop weirs, splashing of water led to erroneous temperature readings. However, with careful placement of the sensor, these problems should be avoidable. Another limitation was situations where fluctuations in ambient temperatures led to high signal-to-noise ratios. In these SWOs, it was less evident when an event occurred, and automatic detection of SWO spills based on temperature data (using a moving window algorithm) was less successful. The need to visit the site to download data is a further limitation of this technique; however, communication of the data to a central server would eliminate the need for site visits.

Hofer *et al*. (2014) developed this method by installing two temperature sensors within a SWO: one mounted on the invert of the main channel (permanently submerged); the other on the invert of the overflow channel (submerged during overflow). The temperature of the wastewater ranged from 16 to 22°C, and in the overflow channel from 4 to 19°C. Temperatures in the wastewater channel were always higher than those in the overflow channel. SWO spills were detected from the deviation between the temperature readings. The accuracy of the method was verified with an area–velocity flow meter placed in the overflow channel, which also allowed the temperature deviation threshold to be optimised. Using the optimum deviation threshold of 0.2°C, all of the 20 SWO spills that occurred were correctly identified, and the spill duration was recorded to within 6 minutes of duration measured with the flow meter. The authors recommended laboratory inter-calibration of the temperature sensors and calibration/validation of each installation using a flow meter, over a wide range of flows. Furthermore, they recommended investigation of non-contact infrared temperature sensors, to reduce installation and maintenance costs.

Fibre-optic cables may also be used to measure temperature in sewer systems. Schilperoort and Clemens (2009) described the laying of a fibre-optic cable on the invert of an 1850-m-long combined sewer. Temperatures could be recorded, over 2-m segments, with precision of 0.15°C. The researchers demonstrated that relative flow contributions at junctions could be determined by looping of the cable into branched connections to the main sewer and by applying conservation of flow and energy equations upstream and downstream of the junction. Hoes *et al*. (2009) outlined a method for locating illicit connections to storm sewer networks using fibre-optic distributed temperature sensor networks, which was applied successfully to two storm sewers (1264 and 1160 m long).

The advantage to using fibre-optic cables in SWOs (as opposed to single-temperature sensors) is the potential to measure at several points in the SWO structure (dry weather channel, overflow, outfall pipe, submerged, floating). The disadvantage at present is cost: the cable costs in the region of €5/m (Hoes *et al*., 2009), and a suitable signal reader/computer (Oryx, Sensornet UK) costs in the region of €30,000. However, the Oryx unit can read up to four signals simultaneously, so a fibre-optic system may be cost-effective if several SWOs are located within a reasonable distance. Furthermore, distributed sewerage temperature data could be collected for detection of illicit connections or modelling of in-sewer processes.

### 6.2.3 Water-level sensors in the sewer network

If water levels are monitored nearby in the sewer network, corresponding water levels and spill volumes from the SWO can be estimated. Sonnenberg *et al*. (2011) used downstream pump station level data and a standard weir discharge equation to estimate SWO spill volume. The volume calculated from this method was within 3% of the baseline measurement (from an area–velocity probe mounted in the SWO outlet pipe). This approach may be cost-effective in utilising sensors already installed in the sewer network. However, it may not be suitable for sewer systems with steep gradients or unsteady flow, and validation of the method is recommended for each site.

### 6.2.4 Image analysis

Nguyen *et al*. (2009) presented a vision-based system for measuring water level in SWOs. A series of level markers were mounted on the side wall of a SWO main channel. A video camera and infra-red LED source were mounted at the top of the SWO (to avoid water contact), pointing at the level markers. The captured images were then rectified (the camera could not be mounted perpendicular to the side wall), and the water surface level was calculated. The automatic detection of water level was accurate to within 13 mm of the reference measurement. It was also possible to estimate flow velocity in the main channel by tracking of solids on the water surface, although these measurements were subject to higher errors (Jeanbourquin *et al*., 2011). The vision-based system requires specialist expertise in setup/calibration of the image processing software, and the cost is somewhat high [approximately €10,000 per installation as of 2009; Nguyen *et al*. (2011)].

#### *6.2.5 UV/VIS spectrometry*

Multi-parameter ultraviolet–visible (UV/VIS) spectrometry has been used to capture detailed on-line pollutant measurements in wastewater. Gruber *et al*. (2005) described the application of UV/VIS spectrometry in two SWOs (Graz and Vienna, Austria). Since water quality can vary widely within the wastewater cross-section, the placement of the sensor in the flow stream is critical (a similar problem occurs in obtaining representative samples from the flow stream using automatic samplers). In the Graz SWO, the sensor was installed under a floating pontoon that was secured in the main wastewater channel. Thus, the sensor was always located in the top water layer, and measurements were representative of the wastewater spilling from the (side) weir. For the Vienna SWO, an offline (bypass) monitoring station was established where samples were pumped from the main channel, using submersible grinder and peristaltic pumps, into flumes where the sensors were located.

The sensor (s::can) was factory calibrated for the measurement of TSS, COD, ammonium, pH and temperature. However, when compared with laboratory analysis of wastewater samples, it was found that the probe underestimated concentrations during daylight hours and overestimated concentrations at night in both SWOs. Similarly, underestimations of concentrations occurred during dry weather conditions and low flow. Thus, field calibration of the sensor was necessary. Maintenance of the floating sensor was carried out every 1–2 weeks, which involved cleaning of the sensor and bottom of sewer. The use of a video camera linked to a website helped to identify when maintenance was required. The bypass monitoring station required more intensive maintenance to prevent blockage of the measurement flumes. The researchers noted that, in both installations, the presence of an integrated pressurised-air cleaning device was essential to avoid fouling and subsequent drift of readings between routine maintenance. The cost of the UV/VIS probe was approximately €23,000.

#### *6.2.6 Low-power sensors for event duration monitoring*

One of the challenges of SWO monitoring is the remote location of many sites, which inhibits the installation of permanent power supplies. Low-power sensors, suitable for autonomous, long-term deployment, have recently been developed for these applications. The sensors include accelerometers and dielectric transducers and consume just 0.002% of the power required for a typical ultrasonic sensor (Back, 2014). They are more suited to event detection than level/flow measurement, which would be sufficient for the majority of SWOs. These low-power sensors can also be used in conjunction with traditional sensors (which operate in storm conditions only) to provide level measurement and compensation for sensor drift (Stoianov *et al*., 2007). Anglian Water trialled 800 flow detection accelerometers (supplied by Radio Data Networks) between 2010 and 2013, coupled with 120 data transmitters. The installation contributed to the reduction of incidents in pollution hotspots by up to 60%, with data transmission costs of £3900 per annum for all sites, despite the large volume of traffic of approximately 80 million messages (Back, 2014).

## 6.3 Technologies for SWO Telemetry

Telemetry involves the sensing and measurement of data from a remote location and transmitting the data to a central or host location. Data typically required for a SWO include water level, flow rate and overflow activation. Owing to the remote locations of many SWOs, wireless transmittal of data is standard for most telemetry networks. The sensor may be placed in the flow stream, for measurement of sewer flows, or at the top of the manhole, to measure level or SWO activation. Sensor readings are transmitted via an antenna mounted on the underside of the manhole, within the road pavement, or wired to a nearby pole. These data may be transmitted locally to a gateway or concentrator, capable of receiving multiple signals. The advantage of using a local network with a gateway is that only one component requires linkage to the mobile GSM (or other service) to transmit information to the base station, thus reducing data transmission charges. Another advantage of using a local network is the possibility of building in capacity for expansion of the network, for example by adding additional SWOs or monitoring information. At the base station, sewer monitoring data can be stored and accessed. It is also possible for the base station to communicate with the remote location, such as to operate valves or flushing gates via supervisory control and data acquisition (SCADA) systems (Back, 2014).

# 7 Technologies for SWO Improvement

Given that SWO problems are strongly site specific, solutions to reduce the frequency of spills or to improve the quality of discharges must consider a wide range of control options, singly or in combination. Technologies for SWO improvement comprise five general approaches (US EPA, 2004):

1. operations and maintenance;
2. collection system controls;
3. storage facilities;
4. treatment technologies;
5. sustainable drainage systems.

## 7.1 Operations and Maintenance

Operations and maintenance practices are aimed at maximising the available capacity in the sewer network to minimise the frequency and volume of spills. Sewer inspection, via manual or CCTV methods, can identify inflow and infiltration problems so that remedial action may be taken. Infiltration into sewer systems is a significant problem, causing reduced capacity in WWTWs and increased SWO spill occurrences. In Dublin, infiltration into the sewer network (through leaking joints etc.) represents approximately 18% of the flow to full treatment (Dublin Drainage Consultancy, 2005). In addition to traditional methods of sewer inspection, recent developments have included the use of acoustic inspection tools. These devices, such as the SL-RAT and the Sewer Batt, can be operated from ground level. Thus, they provide a rapid screening-level assessment of sewer condition, without the need for confined-space entry.

Pollution prevention also forms an important part of sewer management, which is implemented through education, regulation and enforcement, with the aim of reducing the quantities of harmful and nuisance substances from entering the sewer system. Of particular concern are fats, oils and greases (FOGs), which are frequently discharged from household and restaurant kitchens. When hot, these substances are easily transported through domestic drainage systems. However, upon reaching the sewer network they cool and solidify. When deposits aggregate sufficiently, blockage occurs in the sewer network, which may lead to activations of SWOs. In the USA, FOGs are the leading cause of sewer blockages (US EPA, 2004), accounting for 62% of sewer blockages in New York City (Gregory, 2014). In response to FOG problems, trade effluent licences granted in Ireland now include requirements for appropriately sized grease traps in premises where FOGs are likely to arise. Recently, the Dublin City Council FOG management programme has been successful in reducing FOGs entering the sewer system: since its inception in 2008, blockages have been reduced from approximately 1000 to 50 annually (Curran, 2015).

## 7.2 Collection Systems Controls

Collection system controls are works carried out to the sewer network to maximise flow capacity to the WWTW, which include of rehabilitation of sewers and the use of RTC.

Rehabilitation of sewers is necessary not only to reduce infiltration to the sewer network, but also to minimise the risk of sewer collapse, since washout of bedding materials often accompanies sewer infiltration. Considering the cost and disruption caused by sewer rehabilitation, works are usually prioritised using a risk-based approach. The Sewer Risk Management system (WRc, 2014) employs such a procedure and benefits from (Butler and Davies, 2010):

- being risk based and using sophisticated decision-support tools;
- taking advantage of the latest technologies for in-sewer inspection and renovation;
- recognising the high economic cost of sewer replacement, thus placing a high value on assets already in-ground.

RTC maximises the storage capacity available within the sewer network by activating flow controls, such as weirs and valves, in response to rain and sewer flow conditions. The operation of an RTC system requires the permanent installation of monitoring and telemetry equipment, but the benefits can be significant: the use of RTC reduced the required storage volume costs for the Quebec sewer improvement programme by 50% (Fradet *et al*., 2011). While RTC systems do require an in-depth understanding of the sewer network (via a hydraulic and/or quality model), several other benefits can also be realised:

- The network is continuously monitored, so incidents liable to cause pollution can be responded to in a timely manner.
- Future upgrades to the system can be modelled.
- Future scenarios such as climate change and population growth can be simulated.

## 7.3 Storage Facilities

Storage facilities enable combined sewer networks to cope with larger flow rates by providing temporary storage volume during rain events. Storage may be provided on-line or off-line, and such facilities (and associated pumps, pipework, etc.) are often referred to as grey infrastructure (as opposed to vegetated controls that are known as green infrastructure).

On-line storage may be achieved by regulating flows from large-diameter low-gradient sewers by means of a vortex flow control or orifice. If feasible, this is an economical approach, since the only infrastructure required is the flow regulator, but the effects of these controls need to be modelled to ensure that no upstream flooding results. The traditional approach to resolving sewer network flooding and SWO discharges has been to progressively increase the size of the sewers from upstream to downstream in the network, and to provide on-line or off-line storage at the WWTW or SWO. However, distributed storage, located in the upstream network using multiple flow regulators, can achieve the same control of combined flows at 50% of the cost of the traditional approach (Andoh and Declerck, 1999). A drawback in providing on-line storage, particularly in flat catchments, is the potential for settling of solids in sewers as flow velocities are reduced; increased levels of inspection and maintenance should be planned for these locations.

Unlike on-line controls, off-line facilities are empty during dry weather; when rain events occur, off-line storage is activated via weirs or pumps. The storage facility may be constructed at a similar depth to the sewer, or in confined urban areas (with many underground services) in deep underground shafts and tunnels. One such scheme is the planned London Thames Tideway Tunnel. The scheme will provide a storage capacity of 1.25 million $m^3$ when completed in 2023, using 31 km of 7.2-m-diameter tunnels at depths up to 75 m. The total cost of the project is estimated to be £4.2 billion (Stovin *et al*., 2013). While the project has been designed to minimise spills from 36 SWOs into the River Thames, the approach has been criticised for failing to incorporate green infrastructure components.

## 7.4 Treatment Technologies

In scenarios where the provision of additional network storage or source control measures are not sufficient, treatment of sewer overflows may be required. Treatment of overflows can involve a combination of physical (removal of solids and floatables), chemical and biological treatment, either at the WWTW or at SWOs upstream in the sewer network.

### *7.4.1 Plant modification*

Treatment of overflows at the WWTW can be achieved through modification of processes during wet-weather operation. For example, Ahnert *et al*. (2008) demonstrated the potential of reducing COD loads to overflow by 30–50% by routing overflows to the secondary clarifier. Nielsen *et al*. (1996) reported increased hydraulic loading capacity in the WWTW (25–75%) through aeration of the primary settling tank in conjunction with 1-hour predictions of flow using rain gauges in the sewer catchment. Other modifications may include the reuse of discontinued process tanks for temporary storage of overflow volumes. Certain solutions to increase the flow to treatment (and thus reduce spill volumes) may come at the expense of lower effluent quality. Although these approaches can be more beneficial in terms of receiving water impacts, they are often discounted because of the current emission-based regulatory system (Benedetti *et al*., 2010).

### *7.4.2 Disinfection*

Disinfection is the destruction, inactivation or removal of microorganisms that have the potential to cause infection. Disinfection of wastewater is typically achieved through chemical dosing (e.g. chlorine) or

UV radiation. Disinfection of wet-weather discharges poses particular challenges (WEF, 2013):

- Overflows are highly intermittent. This requires complex dosing strategies and is not optimal for the operation of UV lamps, which require warm-up time.
- SWOs can contain high concentrations of suspended solids that interfere with UV disinfection.
- Chemical disinfectants can react with organic matter in overflows, resulting in by-products that are harmful to humans and aquatic life.

These limitations mean that the majority of SWO disinfection occurs at the WWTW. However, significant savings may be realised by adopting disinfection processes to address bathing water concerns. Welsh Water examined options for the upgrade of a 240,000 PE plant at Cog Moore. Compared with the conventional option of increased stormwater storage and full flow to treatment (25,000 $m^3$ and +15%, respectively), a UV treatment system delivered equivalent bathing water quality at approximately one-third of the capital and operational cost of the conventional system, and a 90% saving in carbon emissions (Barcock and Scannell, 2010).

### *7.4.3 Physical treatment*

Physical treatment of overflows involves the removal of suspended solids, gross solids and floatables. Traditionally, this has been achieved through screening of overflows, based on aesthetic considerations. In fact, the retrofitting of screens in the UK Asset Management Plan 3 (AMP3) (2000–2005) represented approximately half of the SWO upgrade works (2500–3000 in total costing approximately £1 billion). The PCSWO guidance document does not promote or discourage the use of screens, but notes that UK guidance (WRc, 1988) recommends screening only in exceptional circumstances, when the receiving water has a high amenity value. This approach has changed in the UK, where the Environment Agency now requires screening for medium- and high-amenity waters (Environment Agency, 2012b).

The PCSWO recommends that, where screens are installed, attention should be paid to their location, velocity through the screen, raking and maintenance arrangements. Maintenance of screens is a concern for network operators, as a build-up of material (blinding) of the screen can lead to screen failure, spills of untreated wastewater, surcharging and flooding of the sewer network. Therefore, the method of screen cleaning, either manual or powered, must be carefully considered and allowance made for inspection and maintenance. The choice of cleaning method has been related to the likely spill frequency; spill frequencies above 3–10/annum have justified the installation of powered screens in the UK (Dublin Drainage Consultancy, 2005).

A review of SWO upgrade construction, including screen installation, was undertaken for 201 SWOs upgraded during AMP3. The issues highlighted were as follows (FWR, 2005):

- **Positioning of SWOs**. Some SWOs (25%) were located under highways/carriageways. Accessing these SWOs for maintenance would be disruptive and more costly due to traffic management requirements. A further 46% were located in other public spaces or within private grounds. Access to these SWOs may have caused nuisance/hazard to the public, and access to private property cannot be guaranteed. In another 19% of SWOs, there was no vehicular access within 10 m of the chamber.
- **Construction of SWOs**. In 54% of SWOs, there was no full plan area access above the screen and 58% of SWOs did not provide access for personnel to both sides of the SWO (spill and pass-forward). In addition, 48% of SWOs were not fully and correctly installed. One of the common faults was in side-weir SWOs, where the weir wall was not straight: this prevented the screen from being flush with the weir, and thus gaps were present for solids to escape.

The recommendations included:

- A greater level of inspection should be carried out during and after construction.
- Good construction practice, including working to specified tolerances, must be reinforced.
- Post-project appraisals (PPAs) should be adopted more widely. PPAs should ideally occur no earlier than 6 months after handover, and assess if the design and construction of the SWO is fit for purpose.

- The cost of PPAs should be built in to the project cost.

Hydrodynamic vortex separators (HDVSs) have also been developed to remove solids from wastewater overflows. These devices set up rotational flow regimes within a cylindrical vessel to provide enhanced particle separation. For SWO applications, they are typically installed with an underdrain to pass low flows onwards to the sewer network and a screen to capture gross solids. An advantage of the HDVS compared with a coarse screen is its ability to capture TSS and other pollutants. A 5-year US study of SWO treatment with a HDVS (Hydro International Storm King), encompassing 40 rain events, reported the following removal efficiencies (WEF, 2003): oil and grease, 90%; grits and solids, > 90%; lighter fraction of TSS, 40%; heavy metals, 50%; and phosphorus, 60%. The retrofit of an existing overflow with a HDVS may require reconstruction of the overflow chamber and/or additional excavations. However, the cost of this may be acceptable where the quality of the overflow is of concern (i.e. removal of TSS etc. is required). Another benefit of HDVSs (and other packaged proprietary systems) is that assembly work on-site is minimised.

## 7.5 Sustainable Drainage Systems

Sustainable drainage systems (SuDS) are a suite of measures designed to alter the timing and volume of stormwater entering the combined sewer system, as well as reducing the volume of wastewater generated. These techniques, known as low-impact development (LID) or green infrastructure (GI) in the USA, are also referred to as water-sensitive urban design (WSUD) in Australia. The reduction of stormwater volumes to the combined sewer can be achieved through a variety of measures that include infiltration (e.g. soakaways) and vegetated ponds (which balance and infiltrate flows). SuDS are most effective when implemented close to the source of runoff. For example, it is cheaper to dispose of roof runoff within the curtilage of private properties than to combine the disposal of roof and road runoff (CIRIA, 2012). While the use of SuDS is now mandatory for new developments in Ireland, retrofitting of SuDS will be required if this is strategy is to be effective in addressing existing problematic SWOs.

Retrofitting of SuDS at source is more cost-effective and less disruptive than modifying sewer infrastructure that may be located below busy streets, and adjacent to other underground services (gas, electricity, etc.). A simple, low-cost approach to dealing with stormwater at source is to encourage homeowners to disconnect roof drainage outlets from the public sewer, and direct them to vegetated areas or infiltration areas located within private property. A “downspout disconnection programme”, initiated in Portland, Oregon, in 1995, has incentivised homeowners to disconnect downspouts in over 56,000 properties, reducing stormwater volumes into the sewer network by 250,000 $m^3$/annum (CIRIA, 2012). Although green infrastructure is not incorporated into the current Thames SWO improvement scheme, potential volume reductions of 54% are thought to be achievable (Stovin *et al*., 2013). Furthermore, a GI approach provides benefits in terms of biodiversity, and is more resilient to climate change and population growth (Ashley *et al*., 2013).

Reducing wastewater flows can be achieved through a combination of water saving and reuse strategies. The provision of low-flow toilets and shower heads can reduce flow rates to the combined sewer. Rainwater harvesting, which involves the storage of rainwater for use in toilet flushing and supply to washing machines/dishwashers, can reduce water consumption (and wastewater volumes) by 30–60%, using a 4- to 6-$m^3$ tank, depending on consumption habits and the available roof area (Herrmann and Schmida, 1999).

## 7.6 Appraisal of SWO Improvement Options

The UPM procedure (FWR, 2012) provides a comprehensive methodology to test compliance of improvement options with receiving water quality goals. However, given the significant cost of SWO improvement schemes [approximately €1.4 million per scheme in AMP2 (Clifforde *et al*., 2006)], an economic appraisal of improvement options should be undertaken. The cost–benefit analysis should include tangible items (cost of materials and labour) and intangible items (reduced traffic disruption and environmental benefits). The inclusion of intangible costs and benefits is of particular importance when comparing traditional SWO solutions (such as concrete storage tanks) with GI approaches, and tools that monetise GI environmental costs and benefits are now freely available (e.g. Green Infrastructure North West, 2011). When intangible costs and benefits are included in option appraisal, GI solutions can provide significant cost savings over the project lifespan (Stratus Consulting, 2009). A cost–benefit analysis framework for SWO improvement should be developed for Ireland, to enable improvements to be prioritised on a national basis.

# 8 Conclusions and Recommendations

## 8.1 Conclusions

### *8.1.1 SWO monitoring*

The small proportion of SWOs monitored at present in Ireland limits the ability to prioritise national investment, on a national scale, in SWO improvements that will provide the highest environmental benefit. Monitoring of SWOs must be prioritised using the best available information, which is based on theoretical calculations and subjective assessments in many cases. A monitoring priority selection tool (POST) has been developed to rank SWO priority based on compliance with subjective criteria and the significance of the discharge.

Three priority levels were proposed as the output of POST: priority 1 requires prompt installation of monitoring equipment; priority 2 requires further investigation (such as field surveys) to establish the requirement for monitoring; and priority 3 is not currently prioritised for monitoring. Using POST, the 370 SWOs in the data set were assigned a priority level; they were found to be 24%, 32% and 44% for priority 1, priority 2 and priority 3 discharges, respectively. It should be noted that these results reflect the data set used and may not be representative of SWOs nationally. Of the priority 1 discharges, 80% on average were located within 1 km of a protected area (as designated by EU or national legislation). This demonstrates the importance of SWOs as a potential pollution source and highlights the need for greater monitoring of SWO performance. In the UK, there is a shift towards more widespread monitoring of SWOs, as opposed to a risk-based approach. Northumbrian Water is currently monitoring 85% of SWOs, and the UK government is seeking monitoring of the *vast majority* of SWOs by 2020.

There are a number of emerging SWO monitoring technologies that should facilitate more widespread monitoring in Ireland. Some technologies, such as temperature sensors or accelerometers, have the advantage of lower cost at the expense of SWO spill information (e.g. event duration only). However, these techniques can be augmented to provide spill volume using a combination of rainfall data and short-term flow surveys. The provision of telemetry for SWO monitoring greatly increases its utility, for example for notification of blockages, or use in RTC of sewer networks.

### *8.1.2 SWO regulation*

The quality of intermittent discharges varies significantly because of the influences of land use, topography, sewer network configuration and rainfall patterns, among other factors. Therefore, SWO impact assessments that rely on published estimates of spill quality must also consider the effect of uncertainty in those estimates.

The AER is the primary mechanism for assessing the compliance of SWOs with the UWWTD, WFD and associated directives and regulations in Ireland. The AER includes data on the frequency and volumes of SWO spills. However, since only a small proportion of SWOs are monitored (approximately 4%), SWO compliance must be assessed based on minimum data techniques, such as theoretical calculations and visual inspections.

SWO compliance is currently assessed against four criteria for unsatisfactory SWOs, set out in the PCSWO guidance document. Two of these criteria (operates in dry weather and causes aesthetic impacts or public complaints) can be readily assessed with the information available. However, the remaining criteria (causes deterioration in water quality and causes water quality standard violation), as currently assessed, may not be sufficient to demonstrate compliance with the WFD and UWWTD. In the UK, reliance on minimum data techniques is acceptable only if it can be proven that their use is protective of receiving water quality standards. Similarly, approaches to SWO assessment in other EU Member States have combined simplified techniques with assessments of receiving water quality impacts, which require data on spill frequency and volume.

### *8.1.3 SWO improvement*

Blockages and infiltration into the sewer network are a significant cause of SWO spills. Therefore, knowledge of sewerage condition is important. Recent technology innovations, such as acoustic inspection tools, which can be operated from ground level, present the opportunity to perform sewerage inspections at a lower cost than CCTV inspection methods. RTC of the sewer network, such as the operation of weirs and valves in response to sewer-level data, is another important development in SWO management, where significant cost savings can be realised in comparison with the provision of storage volume alone.

Treatment of SWO spills has been less widely adopted in Ireland than the UK, possibly due to concerns over maintenance. In the UK, the installation of SWO screens is mandatory for discharges to medium- and high-amenity sites. Screening may be suitable for SWOs to address aesthetic problems; however, the reduction in gross solid discharges should be weighed against the potential for increased spill frequency and volume should the screen become blocked, and monitoring should be considered where screens are installed.

The increased use of SuDS in new developments should reduce, in the long term, the volume of stormwater entering combined sewer systems. However, the retrofit of SuDS in lieu of providing network storage has not been adequately investigated for some improvement schemes, including the UK Thames Tideway Tunnel (Stovin *et al*., 2013). A comprehensive comparison of SuDS retrofit with SWO storage can only be made where intangible benefits, such as reduced traffic disruption and environmental benefits, are factored into cost–benefit analyses.

## 8.2 Recommendations

### *8.2.1 SWO monitoring*

POST, presented in Chapter 5, outlines a method to prioritise SWO monitoring using subjective criteria and theoretical calculations. This has allowed a preliminary assessment of monitoring needs on a national basis. However, this analysis was based on a sample of 370 SWOs and should be repeated on the full data set, once a complete record of SWO significance and compliance (with the PCSWO) is available. Furthermore, given the costs associated with the installation of monitoring equipment, it is recommended that a more robust prioritisation tool, outlined in section 5.6, is developed based on research on the relationship between spill events and rainfall/catchment data.

A number of low-cost monitoring technologies have been developed in the last decade. They have been tested to a varying degree in sewerage networks and should be trialled in a number of pilot studies to confirm their suitability. To minimise study costs, it should be possible to test a number of sensor platforms while investigating combined sewer flow relationships, such as:

- correlation between DWFs derived from geodata and water consumption, and measured DWFs;
- correlation between SWO spill setting (*Formula A* or DWF multiplier) and percentage annual spill volume;
- ability of *Formula A* to pass forward flow ratio to predict SWO problems.

### *8.2.2 SWO regulation*

The AER forms the basis of SWO assessment in Ireland. For future AERs, the following additional information, for each SWO in the agglomeration, would be useful for priority ranking:

- details of SWO spills, including spill date and preceding rainfall;
- protected areas downstream of SWOs and the EPA identifier codes;
- upstream and downstream EPA q-station codes;
- catchment and network data including catchment area, percentage impervious and SWO pass forward flow.

SWO compliance with the WFD, UWWTD and other regulations is currently assessed with reference to subjective criteria, receiving water quality (upstream and downstream of the discharge point) and comparison of *Formula A* with the pass forward flow, among others. When sufficient data on spill quality and volume are available, assessments of intermittent impacts on freshwaters should be made using the UPM fundamental intermittent standards (pending development of standards specific to Ireland), or high percentile standards. For discharges to bathing and to shellfish waters, assessments of spill frequency and/or impacts on EQSs should be adopted. This approach will require more data on SWO spill frequency, volume and quality. These data may not be available for some time, so an interim method for estimation of spill frequency and volume is presented in section 5.6, based on previous research by the UK Highways Agency. This methodology needs to be validated using data from Irish catchments and could be developed in tandem with SWO sensor testing.

### 8.2.3 SWO improvement

There is a wide array of SWO improvement options, which may be applied singly or in combination, depending on the characteristics of the catchment, sewer network and receiving water. A number of telemetry and RTC systems are now available; where SWO monitoring equipment is to be installed, telemetry should be considered to facilitate rapid response to blockages or to enable integration with RTC.

Provision of additional sewerage storage volume, such as concrete tanks, has been traditionally used to address SWO problems, but retrofit of SuDS are now more common in the USA and to an extent in the EU. If traditional and green solutions for SWO management are to be compared reliably, a framework needs to be developed for SWO improvement cost–benefit analyses in Ireland.

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# Abbreviations

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|---|---|
| **AER** | Annual environmental report |
| **AMP3** | Asset Management Plan 3 |
| **ANN** | Artificial neural network |
| **BOD** | Biological oxygen demand |
| **BTKNEEC** | Best technical knowledge not entailing excessive costs |
| **CARP** | Comparative acceptable river pollution |
| **COD** | Chemical oxygen demand |
| **CSO** | Combined sewer overflow |
| **DO** | Dissolved oxygen |
| **DWF** | Dry weather flow |
| **EA** | Environment Agency |
| ***E. coli*** | *Escherichia coli* |
| **EO** | Emergency overflow |
| **EPA** | Environmental Protection Agency |
| **EQS** | Environmental quality standard |
| **EU** | European Union |
| **FIS** | Fundamental intermittent standard |
| **FOG** | Fat, oil and grease |
| **FPM** | Freshwater pearl mussel |
| **GDSDS** | Greater Dublin Strategic Drainage Study |
| **GI** | Green infrastructure |
| **GIS** | Geographical information system |
| **HDVS** | Hydrodynamic vortex separator |
| **LID** | Low-impact development |
| **LTCP** | Long-term control plan |
| **NPDES** | National pollutant discharge elimination system |
| **PCSWO** | Procedures and Criteria in Relation to Stormwater Overflows |
| **PDEP** | Pennsylvania Department of Environmental Protection |
| **PE** | Population equivalent |
| **POMs** | Programmes of measures |
| **POST** | Priority Overflow Selection Tool |
| **PPA** | Post-project appraisal |
| **QUALSOC** | Quality Impacts of Storm Overflows: Consent procedure |
| **RMSE** | Root mean square error |
| **RP** | Return period |
| **RTC** | Real-time control |
| **SAC** | Special area of conservation |
| **SCADA** | Supervisory control and data acquisition |
| **SDD** | Scottish Development Department |
| **SEPA** | Scottish Environmental Protection Agency |
| **SPA** | Special protection area |
| **SRM** | Sewer rehabilitation manual |
| **SS** | Suspended solid |
| **SuDS** | Sustainable drainage system |
| **SWO** | Storm water overflow |
| **TSS** | Total suspended solids |
| **UPM** | Urban pollution management |
| **UV/VIS** | Ultraviolet-visible |
| **UWWTD** | Urban Waste Water Treatment Directive |
| **WFD** | Water Framework Directive |
| **WWDL** | Wastewater discharge licence |
| **WSER** | Wastewater Systems Effluent Regulations |
| **WSUD** | Water-sensitive urban design |
| **WWTW** | Wastewater treatment works |

**AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL**
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

## Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

**Rialú:** *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

**Eolas:** *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

**Tacaíocht:** *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

## Ár bhFreagrachtaí

### Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

### Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

### Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

### Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

### Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

### Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

### Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

### Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

### Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

### Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

### Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

# EPA Research Report 240

## Technologies for Monitoring, Detecting and Treating Overflows from Urban Wastewater Networks

epaResearch
Climate - Water - Sustainability
*Identifying pressures • Informing policy • Developing solutions*

Authors: David Morgan, Liwen Xiao and Aonghus McNabola

In Ireland, most urban areas are drained by combined sewer systems, which convey wastewater and stormwater in a single pipe. During rainfall the capacity of combined sewers may be exceeded, leading to untreated discharges to receiving waters via storm water overflows (SWOs). SWO discharges are a source of microbial pathogens, toxic substances and other pollutants, which may contribute to beach closures or reductions in chemical and ecological status. There are approximately 1300 SWOs under license in Ireland, however performance data is available for only a fraction of sites, due to the costs and technical challenges associated with SWO monitoring. This report presents a literature review of regulation, monitoring technologies and improvement strategies for SWOs based on international best practice. A risk-based methodology to prioritise SWO monitoring is also developed and applied to an Irish dataset.

## Identifying pressures

The project identified that compliance of SWOs in Ireland with EU and national legislation is evaluated primarily with reference to public complaints, visual inspections, and empirically-based estimations of SWO capacity. These methods are open to interpretation and difficult to implement, particularly where SWO outfall pipes are submerged or obscured. The capacity of SWOs is calculated based on population data and water consumption as a surrogate for measured sewer flows, however the project highlighted that the uncertainty inherent in this approach has not been investigated. Most EU countries have prescribed a SWO spill frequency limit in isolation or coupled with a receiving water impact assessment to demonstrate compliance.

## Informing policy

In advance of more widespread spill monitoring of SWOs in Ireland, the project recommended that further data on SWO activations be collected under the current Annual Environmental Report, submitted by each local authority. The data should include the date of spills, preceding rainfall and catchment data such as percentage impervious and SWO pass forward flow. This will enable preliminary models to be developed to rank SWO performance on a national scale. SWO and sewer flow data should be used from several study sites to investigate the uncertainty of the current empirical SWO capacity assessment method.

## Developing solutions

The project developed a methodology to prioritise SWO monitoring using currently-available SWO assessments and mapping of sensitive receiving waters. This geographical information system (GIS) tool was tested using a dataset of 370 SWOs in Ireland, assigning approximately 24% of the sample as Priority 1, i.e. requiring immediate installation of monitoring equipment. Of the Priority 1 SWOs, 80% were located within 1 km of a protected area, as designated by EU or national legislation. The report identifies low-cost technologies for SWO spill monitoring such as temperature measurement which can be used in conjunction with traditional flow measurement methods. The review of SWO improvement options found a move towards green infrastructure to reduce stormwater flows to combined sewers, as an alternative to the provision of sewer network storage, due to its multiple environmental benefits and increased resilience to climate change.

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