PAPER 8

Dry weather flow - not just a number

by

Judy Payne of CIRIA

Dry weather flow - not just a number

Judy Payne, CIRIA
Roger Saxon, Environment Agency
Bob Armstrong, Montgomery Watson

Introduction

Dry weather flow is used in the design, operation and modelling of sewage treatment works and sewer systems, and for consent-setting in water quality planning. Dry weather flow is a convenient concept, but attempts to define it more precisely lead to problems in its measurement and application. This paper explains why these problems arise and how to avoid them.

What is dry weather flow?

Dry weather flow is all flow in a sewer that is not directly caused by rainfall. It is made up of domestic wastewater, infiltration and industrial effluent:

$$DWF = PG + I + E$$

where P = population served
G = average domestic water consumption
I = infiltration
E = industrial effluent discharged

Dry weather flow has traditionally been defined in terms of quantity, but its quality is also important. This paper is concerned with both quantity and quality.

Why do we need information on dry weather flow?

Wastewater treatment works
Treatment works are designed to treat peak dry weather flows. In the UK, this has traditionally meant three times the domestic and industrial components of average daily dry weather flow, plus an allowance for infiltration. The UK implementation of the UWWTD suggests that works are designed with a *normal treatment capacity to treat the diurnal variations in dry weather flow.* As the peak flow can vary seasonally and from day to day, this has lead to the concept of Maximum Daily Peak Flow (MDPF), which is the maximum flow arriving on any dry day.

For the design of primary and secondary treatment processes, information is needed on dry weather flow quality. This includes settleability and loads of suspended solids plus BOD, COD, and ammonia; usually expressed in kg/day. If nutrients are to be removed, information on nitrogen and phosphorus loads are also needed. Information on other parameters (pH, temperature, sulphates, etc.) that affect treatment processes is desirable.

If the works is to be modelled, then more detailed data is needed; including information on how flows and quality vary during the day.

Sewer systems
Sewer systems are also designed to carry peak flows. For foul systems, these peak flows are usually defined as multiples of dry weather flow. If a system is being modelled, diurnal flow profiles are usually needed.

Information on dry weather flow quality is sometimes needed - particularly information on sediment characteristics so the sewers can be designed not to silt up. For modelling purposes, additional information on quality is often needed.

Water quality planning
For planning and modelling, and in order to set consent conditions, details of sewage flows are required. These include estimates of summer and winter infiltration rates, the domestic and industrial components of sewage, and information on pumping regimes. Information on the daily variation in flow might also be required for modelling.

Discharge consents are set for combined sewer overflows and for treatment works discharges. Consents are usually based on dry weather flows and quality parameters including suspended solids, BOD and ammonia. Nitrogen and phosphorus limits are imposed if nutrient removal is required.

What is the problem?

The definition of dry weather flow given above is correct. The needs of sewage treatment works designers, sewerage engineers and water quality planners are known. So what is the problem?

The problem occurs when we try to use the definition to obtain data, or when we try to improve the definition so that it is clear how to obtain the data. The Institute of Water Pollution Control produced a simplified definition of dry weather flow in 1975, to provide a common basis for measurement:

> *Dry weather flow is the average daily flow to the treatment works during seven consecutive days without rain, following seven days during which the rainfall did not exceed 0.25mm on any one day.*

This definition has a major strength - it highlights the fact that rainfall effects are evident in flows long after the rain has stopped. It also has a major weakness - it does not take account of seasonal differences in infiltration. A treatment works designed to treat peak summer flows would not perform as intended during winter when infiltration was higher.

Seasonal differences in infiltration are the main problem for users of dry weather flow information. As well as the direct effect on dry weather flow quantities, infiltration affects quality parameters. As infiltration flows are usually relatively clean, the most common effect is dilution of water quality parameters. For this reason pollutants should always be expressed as loads rather than concentrations, as loads are not influenced by infiltration rates.

A second difficulty is attenuation of flows within the system. As flow passes through the system, the ratio of peak to average flow therefore reduces and in large systems the ratio of minimum to average flow can increase. The point of measurement therefore affects the flow itself. This effect is marked only on large systems, particularly those where the treatment works is some distance from the catchment served.

A third difficulty is in measuring pollution loads that are influenced by deposition and erosion within the sewer system. Some systems deposit solids (and associated pollutants such as metals and BOD) during dry weather, then re-suspend the solids when flows rise in wet weather. Measured pollution loads on such systems will exclude pollutants deposited upstream, and this effect will become more marked further down the catchment. The effect will also vary with the slope of the catchment.

A short term survey of dry weather flow at a treatment works can therefore be misleading in terms of quantity (seasonal variation in infiltration can not be observed) and in terms of quality (which will depend on the deposition and erosion characteristics of the system).

Dry weather flow - data analysis

Because of the difficulties in obtaining dry weather flow data, CIRIA is running a project to produce guidance on typical flow and quality parameters needed for the design and operation of treatment works and sewer systems, and for water quality planning.

Dry weather flow data is notoriously difficult to transfer between catchments. Given the difficulties described above and the unique industrial effluent discharge patterns for each catchment, this is not surprising. It is reasonable to assume, however, that domestic sewage flows and quality are similar for all catchments. If infiltration, industrial effluent and effects due to attenuation, sedimentation and erosion can be calculated; quantity and quality patterns should emerge in the remaining domestic flows. These patterns could be used to predict dry weather flow characteristics.

To test this theory, information was collated from 95 sites. All had some flow and quality measurements at hourly (or shorter) intervals over at least one 24 hour period. The quality data usually included suspended solids, ammonia and BOD or COD.

Using a method developed by an earlier CIRIA study, the total measured flow was split into population-generated flow and infiltration. The measured pollutant concentrations were then adjusted to remove the diluting effects of the calculated infiltration. The adjusted data were examined for patterns in flow, ammonia, TSS and BOD.

The analysis has highlighted the importance of obtaining accurate flow rate measurements to complement dry weather flow quality measurements. Inaccurate flow measurement can lead to incorrect estimation of infiltration and incorrect estimation of per capita output, not only in terms of flow but also in terms of daily pollutant loadings.

The analysis has also revealed that infiltration flows are often higher than generally expected. Instances where infiltration represents 50% or more of the dry weather flow are not uncommon.

Removal of infiltration from measured dry weather flows reveals consistent diurnal patterns for flow and ammonia. Patterns are less consistent for TSS and BOD - probably because of the difficulties in sampling, especially where sedimentation and erosion occur in the sewer system.

The diurnal pattern of variation for ammonia is different to that for TSS and BOD. Finally, patterns in quality as well as patterns in quantity change as flows move through the sewer system.

Conclusions and recommendations

- The concept of dry weather flow is useful, but we should remember it is not just a number. Remember the difficulties of infiltration, flow attenuation, sedimentation and erosion when deciding what figures to use.
- Major investment decisions are based on these measurements. It is recommended that DWF data is checked against population, average per capita sewage inputs, and sludge make before investment decisions are taken.

- For long term monitoring and control of sewage discharges, dry weather flow as defined by IWPC has serious deficiencies. An alternative parameter for monitoring and forward planning of sewage discharges is required.
- Given the difficulties in sampling TSS from foul sewage, some thought needs to be given to more robust methods for determining whether a treatment works is achieving 50% removal of TSS at primary sedimentation (in line with UWWTD requirements).
- With the available data it is not possible to draw firm conclusions on the characteristics of dry weather flow. The following figures are suggested as a starting point in the absence of any catchment specific data:

flow	140 to 160 litres per head per day
ammonia	7 to 8 grams per head per day (as N)
BOD	55 to 60 grams per head per day (as O_2)
TSS	55 to 60 grams per head per day

- Because of infiltration, attenuation, and other effects; it has not been possible to derive universal profiles for the diurnal variation in flow, ammonia, TSS or BOD. It has been possible, however, to derive dimensionless profiles suitable for small areas (typical of the contributing areas in a detailed computer model) for population-generated dry weather flows.
- For modelling of sewerage systems, it is recommended that population-generated and infiltration components of dry weather flow are input separately.

Acknowledgements

The work described above was carried out under CIRIA RP533 *Characterisation of dry weather flow in sewers*. The results and views presented in this paper have not yet been endorsed by the Project Steering Group. CIRIA gratefully acknowledges the support of the Project Steering Group and the project funders: Southern Water Services Ltd, North West Water Ltd, the Water Service Northern Ireland, and SADWSS.