Monitoring and Control of CSO's – Guideline Document

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ABSTRACT

The National Measurement System Policy Unit (NMSPU) has identified concern at Government level regarding the environmental impact of Combined Sewer Overflows (CSOs). To address these concerns, the NMSPU launched a project for Flow Metrology: Project KT10 – Measurement and Control of Combined Sewer Overflows as part of its Knowledge Transfer section of the Flow Programme.

BHR*Solutions* has worked in partnership with the University of Sheffield on this project and have undertaken a survey of the views of Water Companies, Flow survey contractors, the Environment Agency, Equipment suppliers and other researchers and consultants working in the area of CSOs and have reviewed investigations to assess the operation of CSOs in the field to produce a Guideline Document on the monitoring of CSOs. This paper presents a brief summary of the survey findings and the interested reader is referred to the full paper, available from BHR Group.

1. INTRODUCTION

Combined sewer systems incorporate Combined Sewer Overflows (CSOs) to divert excess stormwater into nearby receiving waters, thereby relieving other hydraulic structures within the system and avoiding flooding in urban areas. These discharges that are spilled to the receiving waters contain both foul sewage and stormwater and hence they contain large amounts of pollutants in the form of gross and finely suspended solids and pollutants in solution. These pollutants can have significant aesthetic, oxygen demand or toxic impact on the quality of the receiving water.

The Urban Wastewater Treatment Directive (UWWTD) requires member states to take action to limit pollution from CSOs and to improve unsatisfactory intermittent discharges (UIDs). An intermittent discharge may be derived form any of the following asset types:

- A Combined Sewer Overflow structure (CSO)
- An emergency overflow at pumping stations/detention tanks
- The overflow from the storm tanks at a wastewater treatment works (WwTW)
- The overflow from the emergency spill weir at a WwTW

A full review of the sewerage network within each water utility company has shown that, to date, a total of approximately 1700 uCSOs have been improved and hence some 5500 UIDs have yet to be upgraded. Morris (2000) reported that the largest numbers of uCSOs occur in previously heavily industrialised areas and to meet the performance targets approximately 3 overflows have to be upgraded per week in these areas during the AMP3 period. Hence significant capital expenditure is planned within this period. In order to ensure a BATNEEC approach to upgrading, significant attention has focused on the cost and benefit of ‘as constructed’ schemes. Hence there is a need for guidance on the best methods of monitoring CSOs to assess their hydraulic and pollution retention performance.

2. WHY MONITOR CSOS?

Monitoring of CSOs can provide valuable information on their hydraulic and qualitative performance. This may be to establish problem CSOs, to enable retrofitting to improve individual CSO performance, or to assess the performance of a new CSO as part of a post project appraisal (PPA).

The monitored performance of a CSO can be used to check the compliance of individual CSOs against the consents set by the Environment Agency (EA). In addition, when a screen is fitted to a CSO chamber, monitoring equipment can provide information on whether the screen is operational or whether it has overtopped, for example. This information can also be used to determine the frequency and duration of storm events. Similarly, monitors can trigger alarms to report screen malfunction, i.e. blinding and subsequent overtopping.

2.1 CSO performance

CSO performance can either be hydraulic or quality related. Monitoring can provide feedback on such performance in terms of the frequency, duration, magnitude and quality of spill events. This information can be used to identify which CSOs in a catchment contribute to poor river quality. Armed with this knowledge, future improvements can be targeted and the success of these improvements may be established by comparing the results of the pre- and post-project completion appraisal.

From a hydraulic viewpoint, regulatory requirements for CSOs, specified by the EA, are expressed in terms of a frequency and duration of discharge to receiving waters. Inland, this value varies from site to site and is a function of the sensitivity of the receiving waters and their recreational usage. For coastal areas, overflows may discharge a maximum of 3 times within any one bathing season.

Receiving water quality must meet with the following directives: the Urban Wastewater Treatment Directive (UWWT), the Bathing Water Quality Directive and the Shellfish Directive.

2.1.1 Frequency compliance

To test for frequency compliance it is preferable to monitor a continuous record of water level within the chamber over at least an annual series of storm events. The number of times the water level in the chamber exceeds the height of the spill crest weir may then be used to establish the frequency of spill events against compliance.

Alternatively, a short-term monitoring exercise can be performed using a depth monitor in the chamber and a depth and velocity monitor in the inlet pipe to the chamber. These monitors remain in place until a pre-specified number of individual measured rainfall events have occurred. The data from the monitors is used to extract information that may be used to verify or calibrate a mathematical model to describe the hydraulic performance of the CSO structure. This requires the relationship between the inflow, continuation flow and spill flow to be established and hence it is necessary to establish the head discharge relationship for the continuation flow outlet and the spill flow weir. The mathematical model is then used with an annual series of storm events to predict the annual spill frequency and hence to check compliance.

2.1.2 Pollution compliance

Any individual overflow is specifically designated as unsatisfactory by the Environment Agency (EA) against one or more of the following criteria:

- Aesthetic pollution into receiving waters
- Inland water quality and its effect on rivers
- Coastal water quality and its effect on bathing waters
- Coastal water quality and its effect on shell fishery

Once a discharge has been classified as unsatisfactory, the extent of this classification is required to differentiate between a discharge that causes a minor unsatisfactory situation and a discharge that causes a major problem. For example, Lewis and Myerscough (2000), highlighted that of two overflows, both judged as unsatisfactory against the Bathing Water criteria, one had an average spill frequency of 5 events per bathing season whilst the other spilled 30 times per bathing season, against a target value of 3. Although both CSOs failed to meet the consent criteria there was a large difference in the performance of the two CSOs.

Effort therefore must be directed to better understand the current status of CSOs and their impact prior to the formulation of an acceptable upgrading solution. This understanding can only be achieved by the effective monitoring of overflows during storm events. Such monitoring has to be completed to assess the frequency and duration of operation and where required, the qualitative performance in terms of both pollution concentration and load. This will allow the identification of where the problems lie and of their extent. Once the extent of the unsatisfactory operation of individual overflows is better understood an improved solution can be developed to meet the relevant standards.

3. MONITORING EQUIPMENT

The survey highlighted a wide range in the use of monitoring equipment and its application. Few CSO studies appear to have been completed.

Overflow monitoring techniques available can consist of one or more of the following:

- Frequency and duration measurement (Event monitors)
- Flow measurement
- Quality measurement (Auto-samplers)
- On-line quality monitors
- Integrated systems

From this list, event monitors are the most commonly encountered monitoring devices. Flow measurement is not always required and it is a difficult quantity to obtain accurately (to within ± 10%). Quality measurement may be required in some cases, but is also extremely difficult to quantify and to accurately measure. In respect of water quality, the polluting load of the spill can be estimated by assigning a BOD or Ammonia value to the wastewater, usually based on the average concentration data reported by WRc (FWR 1998). Alternatively, quality sampling can provide information on the pollution concentration and load.

On-line quality monitors and integrated systems are not currently widely used within the wastewater industry but these would offer real benefit and allow the opportunity for real time control (RTC).

The principal requirement for monitoring equipment was identified by Balmforth et al. (1995) as being safe, easy to install, reliable in operation and easily transportable between sites. In general, this precludes the use of equipment requiring a mains power source due to the often remote location of CSOs, however if power is on site, it can extend the range of monitoring options available. The following sections describe the functions of the most commonly encountered monitoring devices.

3.1 Frequency, duration and quality measurements

Event monitors consist of a depth monitor located in the CSO and an event recorder. These are mechanical devices that can operate continuously or intermittently. The closing of a contact is usually employed as a trigger for an intermittent system. Such a device could also be used in a continuous system to increase the rate of data collection during a storm event. Blanksby (1999) has performed an evaluation of several event loggers and the interested reader is referred to his report.

The following equipment can be used to measure the frequency and duration of a spill event:

- Float switch
- Gate meter/Flowstick/Swing meter
- Pressure transducer depth measurement
- Ultra-sonic depth measurement

To accurately monitor the hydraulic performance of a CSO chamber, measurement of the inflow, continuation flow and spill flow components are required at a time when the overflow is in operation. However, experience has shown that it is extremely difficult to get an accurate flow balance. In the inflow sewer, the WRc (1987) and the WaPUG (2001) Code of Practice are frequently used.

Where water quality is required, automatic samplers are commonly used in the absence of any suitable on-line technology. The most difficult aspect in the use of this equipment is associated with the trigger mechanism and with a blinding of the intake due to ragging.

During the first flush, there is a high risk that the sampling hose will block due to an accumulation of rags or sediment load. If a blockage occurs at this stage of the event, then the probability of the collection of useful subsequent data is very low.

Once the event has occurred it is important that the monitoring teams visit the site as quickly as possible to collect the quality samples (where taken) and check that everything worked correctly with initial data interrogation and analysis. This is to establish if the event was of a sufficient magnitude and duration to meet the criteria laid out for what is considered an acceptable storm to verify the performance of the CSO chamber. In terms of quality monitoring, development of performance criteria to readily identify acceptable storms is required.

From the above discussion it is clear that the reliable, accurate and cost effective measurement of the quality parameters in a sewer flow and at the site of a CSO is extremely difficult and time consuming. Effectively dedicated staff are required for each monitoring site and it is essential that good lines of communication are maintained between all interested parties. Care should also be taken to properly commission the equipment. However, at the present time quality sampling is not yet specified in the consent requirement by the EA.

4. TYPICAL RESULTS

The dry weather flow in the inflow to a CSO chamber follows a typical diurnal pattern as detailed in Figure 1. Changes are observed in the pattern dependent on the day of the week but in general there is an increase in flow and pollution concentration in the periods 6.00 – 10.00am and 4.00 – 7.00pm. Late evening and in the early hours of the morning the flow and pollution are low. These peaks and low flows correspond with the pattern of human activity. Clearly therefore the time that a storm occurs will have a significant influence on the initial concentration of the combined dry weather flow and the stormflow that initially enters a CSO chamber.

The monitored performance of an on-line chamber is shown in Figure 2 and an off-line chamber is shown in Figure 3. The inflow characteristics to the on-line chamber highlight that the time to first spill is a critical feature as this determines the initial concentration of the spill flow component. The results of the case studies found that the time taken to fill the conventional on-line designs of CSO chamber was relatively short but in the example shown this was sufficient to retain the significantly high concentrations of pollutants in the first flush load. However there was little separation of the pollutants in fine suspension and solution.

In contrast the spill from an off-line chamber occurs later in the storm event, as can be seen from Figure 3 and this is again beneficial to the overall retention of pollution when a first flush of pollutants enter the chamber. However Stovin *et al.* (1999) reported that in large chambers the pollution retention performance of the finely suspended solids and pollutants in solution was little better, if at all, than the flow split i.e. the ratio of the continuation flow to treatment and the inflow to the chamber.

Significant work by the UKWIR Research Group (Long 1998; Saul 2000) has focussed on the performance of conventional CSO chambers to retain aesthetic solids in chambers with and without screens. It was observed that all conventional chambers were inefficient at retaining the near neutrally buoyant solids and that these solids were divided in the same ratio as the flow. Hence some of these solids were spilled to the receiving waters and, as many of these types of solids may be easily recognised as being sewerage derived, may lead to public complaint and hence consent failure. In contrast CSO screens, particularly those with mesh apertures, were reported to retain these solids. As a consequence the industry is including screens within CSO chambers to meet the aesthetic regulatory requirements of AMP3. Guidance on the design of a screened CSO chamber is provided by WaPUG (2001).

5. CONCLUSIONS

Due to space restrictions, only the major conclusions have been included here. The full list of conclusions and recommendations are given in the Guideline Document.

- A wide range of practices and equipment were encountered, depending on the individual flow survey and Utility companies, based on their experience and preferences.
- To date, only a small number of CSO monitoring exercises have been completed and in these studies the instrumentation and data collection programmes have generally been site specific. The results do however provide valuable information.
- The Water Research Centre's "Guide to Short-Term Flow Surveys of Sewer Systems" (WRc 1987) is still very much in use. Certain aspects have been updated by the Wastewater Planning Users Group "Code of Practice for the Hydraulic Modelling of Sewer Systems" (WaPUG 2001).
- For effective monitoring to take place, it is essential that good lines of communication and co-ordination are maintained between the different groups of people involved. For example, the client, the Civils and E & M contractors, the operator, and the maintenance and data analysis teams so that everyone is working towards the same goals.
- Commissioning of the installed monitoring and data logging equipment prior to data collection should not be overlooked. This should include the testing of telecommunication connections, both initial and sustained battery-life and charge.
- Effective and regular maintenance and calibration of instrumentation is essential to achieve good quality results.
- Details of an effective sampling and measurement system to monitor the performance of CSOs are provided in the Guideline Document.

Copies of the Guideline Document can be obtained by contacting:

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6. REFERENCES

Balmforth, D. J. Lonsdale, K. Nussey, B. B. and Walsh, M. (1995) "A Methodology for Monitoring the Performance of Combined Sewer Overflows" *J.CIWEM, Vol. 9, October*

Blanksby, J. “Event Logger Evaluation” *UKWIR report number 99/WW/08/7*

FWR (1998) Urban Pollution Management Manual Update Foundation for Water Research

Lewis, B. and Myerscough, P. (2000) “AMP3 – Mission Impossible?” *Paper presented at the WaPUG Autumn Meeting, November*

Morris, G. (2000) “Regulatory Requirements for Storm Sewerage Management” *Paper presented at the North Western and North Wales Branch of the CIWEM afternoon meeting, 18th April*

Saul, A. J. (2000) “CFD Evaluations of the performance of High-Side Weir Chambers” Report to WaPUG committee

Long R. J. (1998) “Report PT82 – Post Project Appraisal” *Environment Agency Sewer Modelling Procedures Project*

Stovin, V. R., Saul, A. J., Drinkwater, A. and Clifforde, I. T. (1999) “Field Testing CFD-based Predictions of Storage Chamber Gross Solids Separation Efficiency” *Wat. Sci. Tech., Vol. 39, No. 9, pp161-168*
Wastewater Planning Users Group (WaPUG) (2001) “Code of Practice for the Hydraulic Modelling of Sewer Systems” www.wapug.org.uk

Water Research Centre (1987) “Guide to Short-Term Flow Surveys of Sewer Systems”

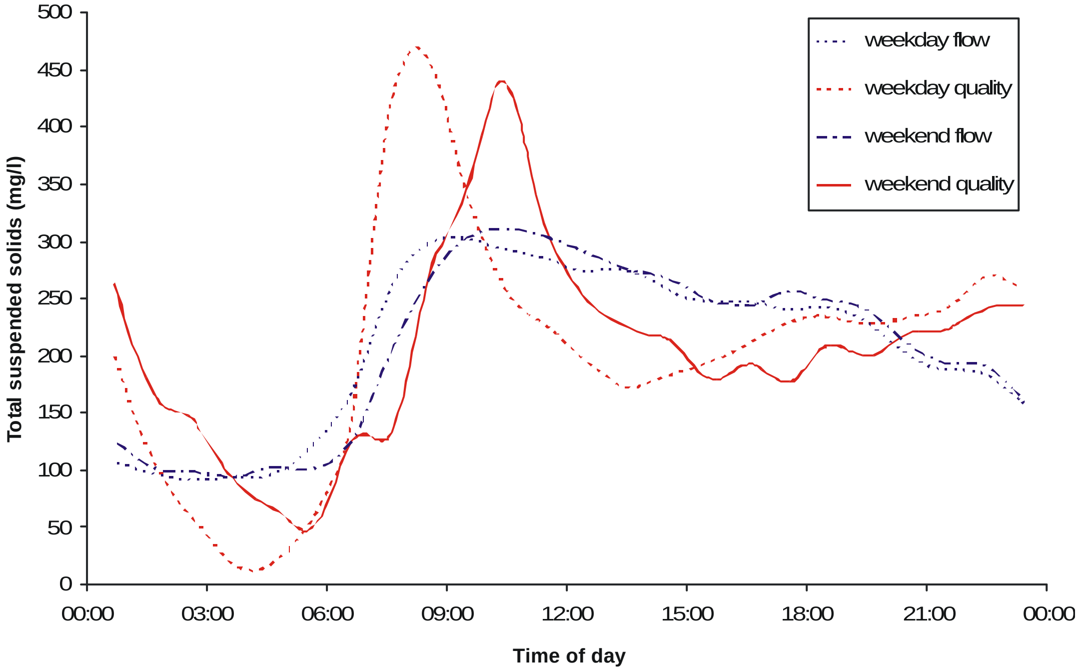


Figure 1: Typical diurnal patterns of the quality of dry weather flow

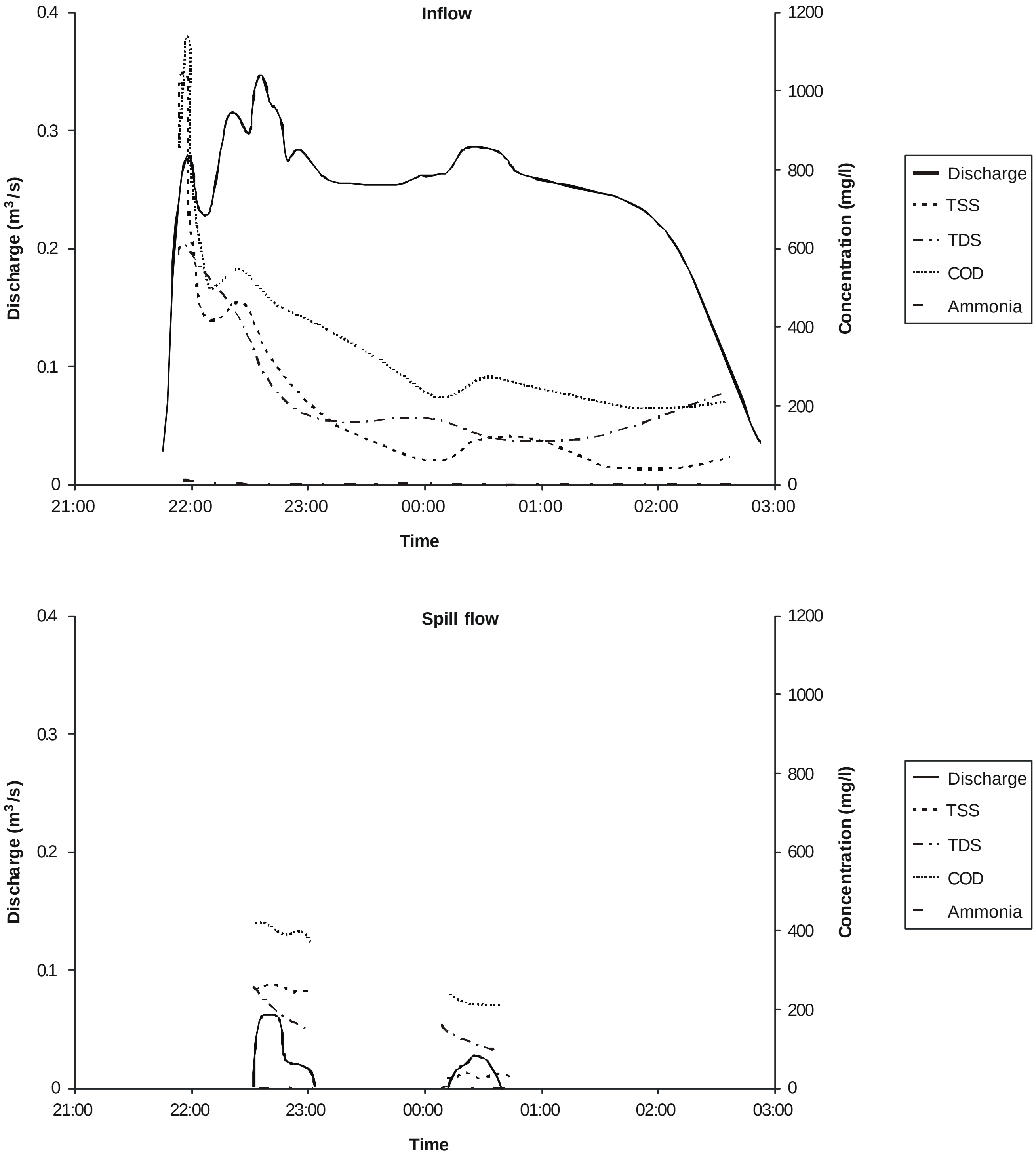
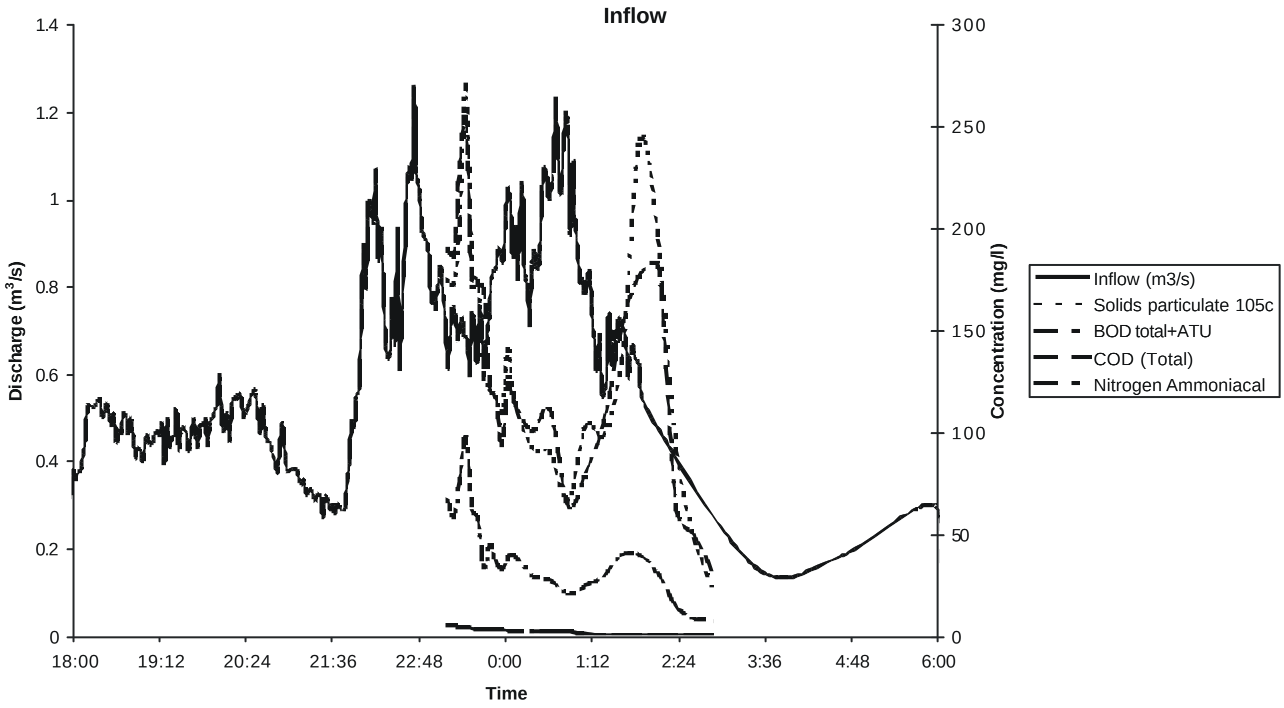


Figure 2: Hydraulic and quality performance of on-line chamber



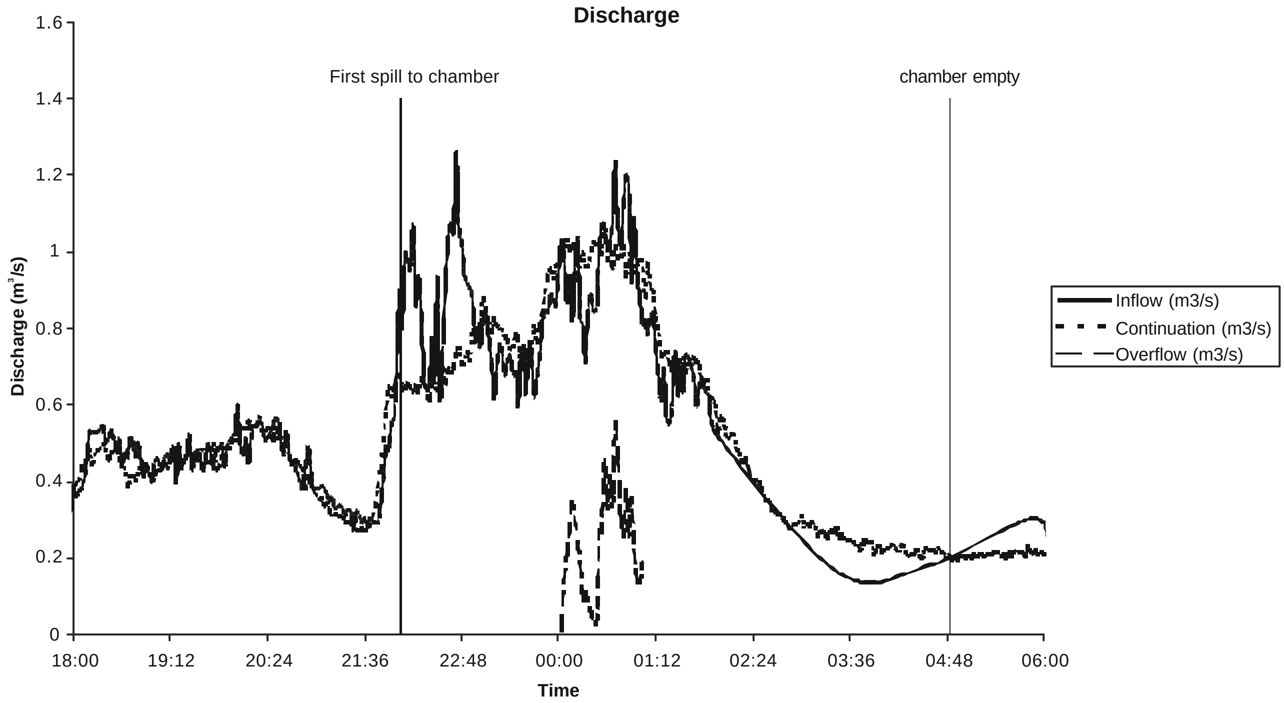


Figure 3: Flow and quality data in off-line chamber