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URBAN WASTE WATER TREATMENT DIRECTIVE (91/271/EEC)

Procedures and Criteria
in relation to
Storm Water Overflows

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Storm Water Overflows

1. Introduction

The Urban Waste Water Treatment Directive 91/271/EEC(UWWTD) which came into effect on 30 June, 1993 provides a framework for action to deal with the pollution threat from urban and industrial waste water. In relation to urban waste water, specific requirements apply to the provision of collecting systems and treatment plants and Member States must also decide on measures to limit the pollution from storm water overflows. This paper is intended to assist local authorities and their consulting engineers in the evaluation of requirements for implementation of the latter aspect of the UWWTD. In particular, the paper indicates the general approach and the design criteria to be followed and discusses the way these criteria might be implemented.

The overall approach is to ensure that the efficiency of the collecting system is considered in addition to the efficiency of the ultimate treatment process. In this way, the overall performance of the sewerage system is defined rather than that of the treatment plant only.

The European Commission has commissioned a consultant to carry out a review study of stormwater pollution control systems used in EU Member States. The purpose of the study is to do a comparative analysis of current practices in terms of environmental benefit and economic consequences, to develop general and technical guidelines and recommendations for good practice which can be adopted by waste water operators, and to propose suitable variants to the general guidelines to meet local needs where appropriate. The criteria and guidelines set out in this paper will be reviewed in due course in the light of any recommendations of the study report which is due to be completed shortly.

2. Directive's Requirements

Article 3 of the Directive requires Member States to "ensure that all agglomerations are provided with collecting systems for urban waste water,

- at the latest by 31 December, 1998 for those with a population equivalent of more than 10,000 discharging into a sensitive area
- at the latest by 31 December, 2000 for those with a population equivalent (p.e.) of more than 15,000, and
- at the latest by 31 December, 2005 for those with a population equivalent of between 2,000 and 15,000.

It further requires that collecting systems satisfy the requirements of Annex 1(A) of the Directive which stipulates that

"The design, construction and maintenance of collecting systems 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,
- the limitation of pollution of receiving waters due to storm water overflows."

In a footnote to the above requirements, the Directive recognises 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. As a result, it requires Member States to decide on measures to limit pollution from storm water overflows and suggests that such measures:-

(1) could be based on

- dilution rates, or
- capacity in relation to dry weather flow, or

(2) could specify a certain acceptable number of overflows per year.

3. Quality Standards

3.1 General

Apart from the specific requirements of the UWWTD, certain quality standards or objectives for the aquatic environment must be considered in relation to the provision of upgraded or new storm water overflows. These comprise standards in the following European Union Directives:-

- Council Directive of 8 December 1975 concerning the quality of bathing water (76/160/EEC)
- Council Directive of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life (78/659/EEC)
- Council Directive of 30 October 1979 on the quality required of shellfish waters (79/923/EEC)
- Council Directive of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in Member States (75/440/EEC)

These standards have been given legal effect in Ireland in each case by means of the following national Regulations:-

- S.I. No. 155 of 1992 Quality of Bathing Water Regulations, 1992 and S.I. No. 145 of 1994 Quality of Bathing Waters (Amendment) Regulations, 1994;

- S.I. No. 293 of 1988 European Communities (Quality of Salmonid Waters) Regulations, 1988;
- S.I. No. 200 of 1994 Quality of Shellfish Water Regulations, 1994;
- S.I. No. 294 of 1989 European Communities (Quality of surface water intended for the abstraction of drinking waters) Regulations, 1989.

These Regulations generally require compliance with the imperative (I) standards prescribed but, in the case of bathing waters, it should be noted that the guide values therein must be the aim, since it is adherence to the guide values (and not the mandatory I values) which enables areas to qualify for Blue Flag status.

Apart from the need to ensure that the standards set in Regulations are complied with, sanitary authorities must also consider standards (or objectives) set down in Water Quality Management Plans as well as the standards/objectives recommended by the Technical Committee on Effluent and Water Quality Standards in its "Memorandum No 1 : Water Quality Guidelines (1979 Report)". Information Note: In regard to the latter Memorandum, the Department is at present considering the making of regulations under Section 26 of the Water Pollution Act 1977 setting quality standards in regard to waters generally for a range of List II Dangerous Substances pertinent to the Irish situation.

3.2 Bathing Waters

As regards the protection of bathing waters, restricted spill frequency and volume of storm water discharged is required during the bathing season from mid-May to August.

The use of Time Series Rainfall for storm events confined to these months allows the determination of frequency and volume of spill using the calibrated hydraulic model of the network. Iterative use of the model with a variety of storage volumes will determine the solution to satisfy the limits adopted.

The National Rivers Authority (NRA) in the UK has set out standards for consenting storm water overflows into or in close proximity to bathing areas and water contact/recreational use waters and these standards can be summarised as follows:

- The maximum number of independent storm events discharged via the SWO must not, on average, exceed 3 per bathing season for identified bathing waters unless it can be shown that the design will achieve the water quality standards of the Bathing Water Directive for at least 98.2% of the time.
- The maximum number of independent storm events discharging via storm water overflows affecting water contact/recreational use waters must not, on average, exceed 7 times per bathing season.
- The soffit level of the overflow outfall must be located below the level of the low water mark of mean spring tides (MLWS); otherwise a spill frequency criterion of 1 spill in 5 bathing seasons will apply.
- Normally the incoming flow must exceed that calculated from "Formula A" before the storm water overflow spills unless there are high dilutions available.
- Discharge flows are required to be screened to at least 10mm and where the frequency of spill is greater than once per year, 80% of the volume should be screened to at least 6mm.

Network models using the WALLRUS software package can be used to establish the storage volume requirements to meet the criteria for potential SWO spills to the identified bathing waters.

The type of screen used to achieve the requirements should be of the screenings retention type and not of the removal type. That is, the screenings intercepted by the screen should be retained in the sewer system and not removed for separate disposal. This will reduce running and maintenance costs of screening at storm water overflows.

3.3 Sensitive Areas

The requirements for effluent treatment prior to discharge to sensitive areas is for a minimum percentage reduction of 80% of total phosphorus and 70-80% of total nitrogen. It would appear reasonable that a volume reduction in storm sewage spill of this magnitude would be a consistent standard in this area. That is, the volume overflows as a percentage of rainfall run-off volume to the foul sewer would be a maximum of 20%.

This will require that a combination of storage and other sewerage improvements be considered to contain 80% of storm water run-off using Time Series Rainfall analysis in the Wallrus models for the contributing catchments. This level of containment (80%) would be a minimum value and should correspond to a proportionately higher percentage containment of nutrients since part of the nutrient load is carried in suspended solids, retention of which would be maximised in the design of the overflow structures.

4. Assessment Criteria for Existing SWO's

In assessing the operation of an existing SWO, one must determine if it:

- (1) causes significant visual or aesthetic impact and public complaints,

- (2) causes deterioration in water quality in the receiving water,
- (3) gives rise to failure in meeting the requirements of national Regulations on foot of EU Directives (Bathing Waters, etc.)
- (4) operates in dry weather.

5. Options following Assessment

Following assessment of an SWO on the basis of the criteria set out above, there are a number of options which can be considered in the context of remedying any capacity constraints. The first and most widely used option is an upgrading of the existing system. As the design considerations associated with upgrading also apply to new SWO's, these are dealt with together in section 6 below. Other options are "use of storage" and "active control". The use of storm water storage tanks is increasingly recommended as an alternative to the up-sizing of downstream capacity and this is dealt with in section 7 below. Active control, which involves effective use of spare storage capacity of sewer networks, is a relatively new approach and is dealt with in section 8 below.

6. Upgrading SWO's/New SWO's

6.1 Design Criteria

The general criterion for the future design of storm water overflows is defined as an absence of visible signs of sewage-derived debris (e.g. oil slicks, foaming etc.) and of deposits or algal growths caused by sewage discharge. This requires that the effects of organic/nutrient loads deposited in bed sediments must also be considered.

Design criteria for storm water overflows must take into consideration the following:

- beneficial uses of receiving waters and corresponding standards and water quality objectives,
- the nature and strength of sewage including the effects of re-suspension and "first foul flush" effects which may increase rather than diminish sewage strength in the sewer with increasing flow, and policy in relation to industrial discharges to the sewer,
- the siting of overflow discharges and their potential for aesthetic nuisance, and
- the type of overflow and its efficiency in containing as far as possible floating debris and solids generally, i.e. maximum solids separation.

6.2 Design Principles

The main difficulty in relation to setting standards for storm water overflows is the lack of information available on the effects of transient shock loadings on the receiving water and the difficulty of predicting their effects. Random physico-chemical sampling may not identify pollution associated with overflows. Biological sampling and assessment of receiving waters and bed sediments provides a more accurate assessment of on-going environmental conditions. Such sampling will be expected to indicate the biological impact of transient pollution.

The minimum setting for storm water overflows has traditionally been six times dry weather flow (6 DWF). In the UK this approach was replaced by "Formula A" following the report of the Technical

Committee on Storm Overflows and the Disposal of Storm Sewage (HMSO 1970)¹.

This is defined as follows:

$$\text{Formula A} = \text{DWF} + 1.36P + 2E \text{ m}^3/\text{day}$$

where 'P' is the population served and 'E' is the industrial effluent flow.

This provides broadly for 6 DWF from the domestic contribution but uses only a factor of 2 on the industrial effluent flow. This appears very low particularly where industrial effluent comprises a significant proportion of the total flow and constitutes high strength wastes with potentially toxic impacts. This was recognised in the report with a recommendation to increase the term '2E' in such situations.

Formula A should be considered as the minimum overflow setting in all situations whilst, at the same time, recognising its limitations in that

- no account is taken of the impermeable area draining to the overflow,
- no account is taken of the flow regime or use of the receiving water,
- there is no set method for making allowances for industrial discharges,
- no account is taken of the impact of intermittent pollution on the quality of the receiving water.

In addition, the following steps should also be applied:

- (i) subjective criteria should be applied to exclude spills to minor watercourses and small, relatively clean, streams and such receiving waters should be deemed unsuitable for such discharges,
- (ii) storm overflow structures should be designed in accordance with the WRC publication ER304E² with acceptable types of overflow structure limited to high side weir, stilling basin and vortex chamber overflows designed to achieve efficient solids separation and retention,
- (iii) outlet control should maximise the retained flow at a near constant rate within the system capacity,
- (iv) such an overflow should be designed for effective containment of detritus and floating debris,
- (v) overflow structures should be capable of being properly maintained with provision for adequate ventilation, safe access and lighting,
- (vi) overflow discharge points should be discreetly located and for, coastal outfalls, should be taken, where practical, to low water level,
- (vii) traditional structures of the low side weir type and ad-hoc overflows of the hole-in-the-wall type should in time be replaced by properly designed overflows, rationalised where possible to a minimum number of overflow structures for each system.

The preliminary assessment of each overflow should also have regard to possible "first foul flush" effects. These will depend on the nature of the sewage and the nature of the sewers upstream and their gradients. Such flows have the potential for severe pollution due to extremely high BOD₅ levels, potentially toxic levels of ammonia and hydrogen sulphide, and long term degradation associated with a high level of organic solids deposited on the bed of the receiving water which continue to depress dissolved oxygen levels and release nutrients.

In general, research has shown that sewage strength frequently increases significantly during this "first foul flush" period, which tends to approximate to the time of concentration 'T_c', following which the strength decreases and the effects of dilution become evident.

6.3 Detailed Design Requirements

A well designed and effective SWO must be capable of meeting the following general requirements:

- (1) good hydraulic control,
- (2) good separation of gross pollutants,
- (3) reliability,
- (4) minimal maintenance requirements, and
- (5) reasonable cost.

Generally, SWOs designed to WRC Report ER304E will meet these requirements though the hydraulic control (in particular for smaller SWOs) and the separation of gross solids needs careful consideration.

Hydraulic control at SWOs may be achieved by orifice plate, throttle pipe, vortex regulators or by adjustable penstocks. The WRC Report recommends that orifice throttles should have a diameter of opening of at least 200mm to reduce the risk of blockage. Likewise the diameter of a throttle pipe should not be less than 200mm and its length should ideally be between 3m and 30m long. Where penstocks are used, a clear ope capable of passing a 200 mm sphere should be provided. A vortex regulator may be used where the minimum required dimension of opening of 200mm cannot be met . These are usually of stainless steel construction and are fitted into the entrance of the continuation pipe. This device restricts the flow passing forward while allowing solid objects to pass through unrestricted. Generally each device is designed for the specific application and will require some maintenance from time to time.

Recommended chamber dimensions are given in the WRC Report for high side weir and stilling pond overflows to ensure good separation of gross polluting solids. The Report notes that, as performance is sensitive to minor changes in configuration, care should be taken not to deviate from the recommended chamber dimensions. Vortex overflows do not rely on a stilling effect to separate gross solids but require a significant drop in invert (1.5 times inlet diameter) and are therefore best suited to sewers with steeper gradients.

Hydro-dynamic separators are now available in prefabricated form which facilitates installation. These operate in a similar manner to vortex overflows with peripheral spill. Care should be taken in the selection of such devices to ensure that effective solids separation and hydraulic control is achieved.

The WRC Report recommends that screens should only be used in exceptional circumstances, for example, where the receiving water has a high amenity value. Where they are used, proper attention should be given to their location, the velocity of flow through the screens, raking and maintenance arrangements.

6.4 Planning Methodologies

Various methods are available or are currently being developed for establishing discharge settings and acceptable spill regimes. The use of a particular method is dependent on the level of significance placed on the particular overflow and the receiving water at the discharge point. This should be based on a combined assessment of the size of the contributing catchment, the available dilution, and the classification of the receiving water at the location of the overflow.

The Urban Pollution Management Steering Group(UK) have developed criteria for the initial assessment. Table 1 in Appendix 1 sets out the criteria for freshwaters and Table 2 those for coastal waters and estuaries. Recommended approaches depending on the level of significance of the overflow are set out in Appendix 2. These appendices are included for general guidance only; it will be necessary to examine each situation on its merits.

7. Use of Storage

The use of storm water storage tanks is increasingly recommended as an alternative to the up-sizing of downstream capacity for reducing or eliminating storm water overflows. These tanks can be on-line or off-line and operate on the principle that flows in excess of the downstream capacity can be contained until the storm has sufficiently abated to allow the stored storm water to be returned to the sewer. The downstream capacity of the system is therefore maximised and overflows are minimised. The tanks are generally sized to contain the overflow that would arise from a storm with a specific return period, the 'design event'. Typically, a storm of one hour duration with a return period of five years is used for a built-up area.

Calibrated hydraulic models of sewer networks are being developed which will be used in conjunction with Time Series Rainfall³ to calculate overflow frequency and volumes. Use of sampling data of recognised parameters will allow estimates to be made of the pollution loads associated with such overflows.

Experience has shown that relatively modest storage volumes can appreciably reduce the frequency of overflows. While the reduction in the volume of overflow may not be as significant, overflows from major storm events will be relatively dilute discharges coinciding with relatively high flows in receiving waters. These conclusions are evident from consideration of the pattern of rainfall - occasional extreme events of high intensity and critical duration as compared with the majority of rainfall which tends to be of relatively low intensity.

The design of storm water storage tanks to effectively retain floatables and for ease of cleaning out and maintenance is very important. Traditionally, small storm tanks have been circular tanks designed exactly as for settling tanks. Larger storm tanks have tended to be rectangular in shape containing chain driven scraper equipment for cleaning out of settleable solids. A number of methods have now been developed including the "tipping bucket" method to wash out flood deposits at the end of tank use. This system comprises a container fabricated from stainless steel mounted on bearings on the end wall of the tank. The shape of the container is designed so that it automatically tips and empties when full thus flushing the settled deposits on the floor of the tank to the return sump. The number and capacity of tipping buckets required to effectively clean the tank is a function of the dimensions of the tank.

8. Active Control

Sewer systems, particularly large trunk sewer networks in cities and large towns, have significant storage volumes which could be more effectively utilised to reduce pollution from SWOs. Active (or real time) control of a combined sewer system will result in optimised performance from existing control structures and more cost effective upgrading of the system. Sewer system controls using telemetry to collect information and remotely operated control structures have been introduced in some major cities in Europe and the U.S. to take advantage of these benefits thus reducing the amount of capital investment required. The tools necessary to be capable of implementing active control in a sewer system are:

- spare capacity in the sewers,
- spatial variability in rainfall,
- knowledge of rainfall pattern and the response of the sewer network,
- data collection sensors,
- decision making system,
- operating hardware including telemetry control system.

Such systems will bring the operation of sewerage networks into a new era of management control which to date has been employed only on the distribution of potable water. The key to such control is data collection and an understanding of the way the sewerage network responds to rainfall events. Such an understanding will allow the operator derive maximum benefit from

the existing infrastructure and make informed decisions on cost effective improvements. From an Irish perspective, the potential for using active control would be limited to the larger urban centres where justification may be found for the costs involved.

9. Catchment Management

Future developments will undoubtedly include a more integrated approach to catchment management. This will result in river models together with sewage treatment works models and sewer network models being used to predict impacts of discharges on receiving waters for parameters such as dissolved oxygen, BOD₅, SS etc. This will lead to a better understanding of impacts on river water quality and will require that a much broader approach be adopted by engineers involved in the design and management of urban wastewater systems.

Table 1 - UPM Indicative Impact Assessment Criteria for Storm Overflows to Freshwaters

Low Significance

Dilution > 8 : 1 (foul DWF @ 95% ile flow)
 No interaction with other discharges

Medium Significance

Dilution < 8 : 1
 Limited or no interaction with other discharges
 > 2,000 population equivalent
 Cyprinid fishery

only if all these criteria apply.

High Significance

Dilution < 2 : 1
 Interaction with other discharges
 > 10,000 population equivalent
 Cyprinid or salmonid fishery

only if all of these criteria apply

Table 2 UPM Indicative Impact Assessment Criteria for Storm Overflows to Coastal Waters and Estuaries

Low Significance

Estuarial and coastal waters not containing EC
 identified bathing waters and shellfish waters

Medium Significance

Population equivalent 2,000 - 10,000
 Affects identified bathing waters and shellfish waters

only if both criteria apply.

High Significance

Population equivalent > 10,000
 Affects identified bathing waters and shellfish waters

only if both criteria apply.

Appendix 2

A. Low Significance SWOs

For overflows of low significance minimum data techniques such as "Formula A", SDD Method⁴, and QUALSOC⁵ would be used. The SDD Method developed by the Scottish Development Department is an improvement on "Formula A" in that an account, albeit arbitrary, is made of the available dilution in the receiving water to recommend the size of storage tanks to be provided at an overflow. These recommendations are reproduced in Table 3 attached. It should be noted that the dilution factor used is that normally used for treatment works discharges and is therefore not a measure of the dilution of the overflow discharge but simply a measure of the relative size of the sewerage system and the river. Apart from this improvement, the limitations listed above with regard to "Formula A" apply equally to the SDD Method.

QUALSOC was the next improvement to the use of "Formula A" and was developed by the Welsh Water Authority. In principle the method is a dilution model which estimates the flow and pollutant concentration being discharged from the overflow, dilutes this with the estimated flow in the river and compares the resulting pollutant concentration with desirable limits. However, it does this by estimating discharges without having a model of the sewerage network or of the river to calculate the impact of discharges from particular events. The results therefore require careful interpretation to determine what they actually mean. The main limitations of this approach are that considerable skill is required to answer the following questions:

- what flow is likely in the river when the overflow is occurring?

- how frequently will the overflow occur?
- what effect will a "first foul flush" have?
- is there interaction with other discharges?

Table 4 attached shows the National Rivers Authority (U.K.) guidance standards for the use of QWALSOC.

Relatively little data about the sewer network or receiving water is required for any of these methods. Shortcomings include the limited consideration given to the environmental impact of the discharge and the inability to size any in-sewer flow attenuation facilities to counter restricted downstream capacity. Solutions identified by these methods may not be the most cost effective as a result.

B. Medium Significance SWOs

For overflows of medium significance the use of a hydraulic model such as WALLRUS for the sewer network and what are known as the Interim Procedure and CARP⁶, (Comparative Acceptable River Pollution), would be appropriate.

The Interim Procedure estimates concentrations of various pollutants in overflow discharges and was first introduced in the second edition of the Sewerage Rehabilitation Manual⁷. It was designed to be used with a sewer hydraulic model which would predict the volume of overflow spill. The Procedure is based on a simplifying assumption that the pollutant concentration can be represented by an average concentration that was constant throughout the spill and that was the same for each rainfall event. The pollutant concentrations can be obtained in three

ways, given here in order of increasing cost:

1. Use the figures published with the Procedure which were derived from taking samples of overflow spill from about eight catchments and are reproduced in Table 5 attached.
2. Measure concentrations in the dry weather flow and use the dilution factors published with the Procedure which were derived from the same catchments and are reproduced in Table 6 attached.
3. Install sampling equipment at overflows and measure concentrations during a number of spill events to produce site specific average concentrations.

The CARP technique was developed by the WRC to give a method of comparing the impact of discharges to a receiving water. This involved looking not just at the total load of pollutant in a year, but at the pattern of discharge of pollutants throughout the year. It also developed a measure of the impact of the discharge which should be independent of the river size. There are limitations to the use of this procedure:

- The average concentrations for pollutant discharge are intentionally chosen to represent the highest likely concentration, and so will overestimate the spill.

- The average concentrations do not take into account change in concentration during an event in particular "first foul flush" effects or the beneficial effects of storage tanks in capturing the "first foul flush" and only spilling the later, cleaner flow.

- Only one standard river has been defined for this procedure which is for a Class 2, fast flowing stream. There is a doubt as to whether the standard applies to rivers of different character, for example, lowland rivers or very large rivers.

- The results can be influenced by the choice of river reach length used in the calculations.

For coastal discharges the hydraulic network model can be used directly to assess compliance with a spill frequency criterion. While there is a need for a considerably larger amount of data for these methods, their use in addition to taking the impact on the receiving waters into consideration, also allows storm water detention facilities to be sized with some confidence.

C. High Significance Overflows

For overflows of high significance, the use of complex models is justifiable. For the inland waters a sewer quality simulation model such as MOSQUITO⁸ and a dynamic impact model such as MIKE 11⁹ would be employed, in addition to the WALLRUS model, together with a method to generate suitable Time Series Rainfall data where adequate historical records do not exist.

MOSQUITO has been developed to simulate the changing quality of sewage throughout a storm event and models BOD, COD Suspended Solids and Ammonia. Standard pollutant mixture characteristics are given for use where local data are not available. Characteristics are also given for pipe sediments in combined systems and for pollutants initially in gully pots. Verification of the model is essential and is structured so that the standard values used to construct the model are replaced by measured values in stages, and only if necessary. This ensures that only essential data need be collected and a catchment which is accurately represented using the standard values can be modelled with the minimum of data collection.

MIKE 11 is a software package for simulating river water quality for selected parameters which can be used to assess the impact of storm water overflow discharges and check compliance with water quality objectives.

For marine situations, a marine advection/dispersion model would be required to assess the bacteriological impact relative to the criteria set down in the Bathing Water Directive.

As the costs associated with data collection, setting up, calibration and verification of these models are substantial their use should be restricted to the major urban schemes with high significance overflows. Where they are used, the benefits of having a detailed model of the existing system and the ability to test the effects of various options allows much greater confidence in the proposed solution. This should lead to more cost effective

solutions being proposed.

The level of investment that should be put into the preparation of these models should, of course, be assessed by taking into consideration, not alone the likely savings to be made in the short term by the construction of the more cost effective solutions that will be developed by their use, but also by the ongoing benefits such models will provide in assessing the performance of the augmented sewer network.

Dilution Factor	Overflow Setting	Storage Tank
> 8	Formula A	None
> 6	Formula A + 455P or Formula A	None
> 4	Formula A	40 l/hd
> 2	Formula A	80 l/hd
> 1	Formula A	120 l/hd

Dilution factor = Average DWF / 95% ile flow.

River Class	BOD Limit		
	95%ile mg/l	99%ile mg/l	MAC mg/l
1B	5	9	12
2	9	16	20

Determinand	Flat Catchments	Steep Catchments
	mg/l	mg/l
BOD	125	75
COD	390	330
NH3	8	4
SS	420	340

Determinand	Flat Catchments	Steep Catchments
	mg/l	mg/l
BOD	0.5	0.3
COD	0.7	0.9
NH3	0.3	0.3
SS	1.5	1.5

References

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9. MIKE 11 User Guide. Danish Hydraulic Institute 1990.

