WaPUG Guide
The Design of CSO Chambers to Incorporate Screens

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Version	Revision	Revision Details	Date
2			11/06/01
2	1	Minor clarification to text and figures.	20/06/01
3	0	Major revision	03/1106

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Preface
The first draft of this Guide was produced in October 2000 to provide engineers with better support for design in AMP3. Response to the Guide was encouraged and, as a result of feedback from many individuals and organizations, there were a number of strategic issues that led to significant changes in the guide and these are summarised as follows:

- *Chambers designed to achieve solids retention by stilling or dynamic separation can be very effective, and a combination of stilling and screening that requires larger chambers but smaller screens may prove more cost effective in certain circumstances.*
- *Where the screen alone is providing the solids control the primary driver for chamber dimensioning is the proper accommodation of the screen.*
- *The performance of the chamber and screen combined should be at least as good as the separation values given in UPM2.*
- *The chamber sizing is based on a 1-year return period design flow whereas the screen is designed using a 5-year return period flow. This can be confusing and the Guide should preferably be consistent in the return period used for design.*
- *The sizing and geometry of the chamber should result in an appropriate distribution of flow over the full surface of the screen. In particular, care should be taken in design to ensure that the jet from the upstream sewer is dissipated in the chamber and excessive turbulence does not occur.*
- *Further guidance is needed in the application of the rules to avoid the formation of supercritical flow in the chamber.*
- *The configuration of the invert and bed benching of the chamber in relation to the geometry of screens that are located within the body of the chamber should be reviewed.*
- *There is evidence to show that the spacing between the scumboard and the weir may be reduced to 200mm (previously 300mm).*

To take account of these comments the guide was updated in June 2001.

In addition, some feedback on the initial guide related to the important aspect of sediment control within sewerage systems and the role CSOs have to play in this. Others referred to the control of pollutants in fine suspension or solution. The authors recognised that these were very important considerations in sewerage design, but felt that the Guide should be limited to the design of CSO chambers in which screens were to be used to control aesthetic pollutants. Construction methods, materials and prefabrication were also considered to be beyond the scope of the Guide with the guide aiming to detail the geometry of the chamber leaving choice of materials, construction method and screen type to the designer.
Some contributors felt that the rectangular geometry chosen was somewhat limiting in practice and pointed to the successful use of other shapes, such as tapered chambers and circular section chambers. The authors regarded such designs to be equally successful with the proviso that appropriate testing substantiated the design and performance of the chamber. However, most of the alternatives appeared to be specific commercial designs where data on performance characteristics was not available in the public domain. The authors felt that it was inappropriate to include them specifically within a generic guide such as this, but would encourage designers to seriously consider such alternatives.
Since the production of the updated guide experience with chamber design and screen operation has developed and the authors feel that it is now appropriate to update the design guide. Specifically the following points are addressed:

- *New guidance on inlet flow conditions*
- *Advice on CSO chamber construction issues, generic screen selection and access.*

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1. Introduction

The purpose of this Guide is to set out current best practice in the design of new CSO chambers to meet aesthetic regulatory requirements using screens. It is aimed primarily at design engineers but it should also prove valuable to environmental regulators, operations personnel, sewer network modellers and drainage area planners.

Recent practice in CSO chamber design uses the ER304E (Balmforth et al 1988) and FR0488 (Balmforth et al 1994) reports as guides. These reports were written at a time when the preferred option for retaining aesthetics was by stilling or dynamic separation. Screen technology was still in its infancy and generally not favoured because of concerns over effectiveness and operational reliability. When properly designed the FR0488 chambers have been shown to provide significant retention of aesthetic solids and other finer settleable or floating material. However, a significant proportion of aesthetic solids are neutrally buoyant and do not therefore lend themselves to separation and retention in this way. This deficiency has been addressed by the introduction of screens into CSO chambers, and this guide provides guidance on the design of CSO chambers that incorporate screens.

The Guide has been written following a thorough review of best practice, and incorporates information recorded from field trials at the Wigan CSO test facility (Thompson and Saul, 2001), the United Utilities' Warrington Test Facility, Hetherington and Dempsey (2002), Balmforth (2003), and significant experience gained from the operation of screened CSO's in the field, Gordon (2004), Hanson and Cutting (2004).

The Guide seeks to provide a general approach to the design of new CSO chambers for use with screens. The Guide now includes aspects of screen selection but explicitly excludes recommendations relating to retrofitting screens to existing CSO chambers, as this was beyond the scope of its objectives. However the general principles set out will form a useful background for engineers seeking to provide a retrofit solution.

The Guide does not seek to replicate information readily available elsewhere. For example, there is no guidance on the hydraulic design of throttles and continuation flow devices. This is because such aspects are adequately covered in previous guides ER 304E and FR 0488. Readers should refer to these guides for further information.

2. Historical Review

Developments in the design of CSO chambers have built on a series of laboratory studies and fieldwork evaluations of their hydraulic and solids retention properties. This work was appraised by Balmforth and Henderson (1988) who presented the first UK design guide for CSO chambers, the WRc ER304E report (Balmforth et al 1988). This guide gave detailed recommendations for the hydraulic design of chambers and appropriate dimensions of four common types of CSO chamber: the end weir stilling pond, the high side weir chamber, the vortex chamber with peripheral spill weir and the Hydrodynamic Separator™. Subsequently the ER304E design guide was upgraded to the FR0488 design guide (Balmforth et al 1994).

Thompson and Saul (2001) reported on the hydraulic and total solids separation performance of different proprietary screens positioned within different geometry CSO chambers. The screens tested included static screens, non-powered dynamic screens and self-cleaning non-powered screens and screens with powered cleaning mechanisms. This work has highlighted that most screens are effective at retaining ‘solids greater than 6mm in any 2 dimensions’ and hence are able to meet the regulatory requirements to retain a significant quantity of these types of solids. Similar tests have been completed at the United Utilities full-scale test facility at Warrington, Hetherington and Dempsey (2004), and as a consequence it has been considered feasible to enhance the design and performance of the screened CSO. The latter facility has enabled the hydraulic performance of the chamber design to be evaluated at flows up to and including the five-year return period peak.

In addition, to optimize the design of screened CSO chambers, use has been made of recent advances in Computational Fluid Dynamics (CFD). This technique allows the prediction of the flow pattern and the solids separation performance of different geometry CSO chambers for a range of flow conditions. Hence the application of CFD, in association with laboratory and fieldwork evaluation, has shown that it is feasible to predict the comparative performance of different geometry chambers and hence to derive a design of chamber that is more cost effective for use with screens.

This guide has been based on the above findings together with subsequent experience in the operation of ‘as built’ CSO chambers with screens.

3. Regulatory Requirements for Aesthetics

This section summarises the aesthetic control requirements for all new and existing unsatisfactory discharges to inland and tidal waters in England and Wales and these are based on the combined criteria of the amenity use of the receiving water and the spill frequency, as set out in Table 1. It should be appreciated that CSOs may also have to meet other water quality objectives with respect to dissolved and finely suspended pollutants, and bacteria. Recommendations for the control of these pollutants are beyond the scope of this Guide.

Table 1 Regulatory requirements for aesthetics

Amenity Classification	Spill Frequency	Aesthetic Control Requirement
<u>High Amenity</u> i) Receiving water passes through formal public park ii) Formal picnic site iii) Influences area where bathing and water contact sport (immersion) is regularly practised (wind surfing sports canoeing) iv) Shellfish waters	> 1 spill per annum ≤1 spill per annum	6 mm solids separation[1] 10 mm solids separation[2]
<u>Moderate Amenity</u> i) Boating on receiving water ii) Popular footpath adjacent to watercourse iii) Watercourse passes through housing or frequented town centre area (bridge, pedestrian/shopping area) iv) Recreation and contact sport (non-immersion) area	> 30 spills per annum	6 mm solids separation[1]
	≤30 spills per annum	10 mm solids separation
<u>Low Amenity</u> i) Basic amenity use only ii) Casual riverside access on a limited/infrequent basis (bridge in rural area, footpath adjacent to watercourse) <u>Non-Amenity</u> i) Seldom or never used for amenity purposes ii) Remote or inaccessible area	Not applicable	Solids separation achieved through "best engineering design" of CSO chamber (high side weir, stilling pond, vortex)

Notes

1. For spill flow rates up to and including the design flow[3], separation from the effluent, of a significant quantity of persistent material and faecal/organic solids greater than 6 mm in any two dimensions. Spill flow rates in excess of the design flow[3] shall be subject to 10 mm solids separation[2].

2. For spill flow rates up to and including the flow resulting from a 1 in 5 year return period storm, separation, from the effluent of a significant quantity of persistent material and faecal/organic solids giving a performance equivalent to that of a 10 mm bar screen.

3. Where Time-Series data is available, the design flow for 6 mm separation[1] shall be the flow equivalent to 80% of the flow volume that would be discharged in an annual time series. Where Time-Series data is not available, the design flow for 6 mm solids separation[1] shall be the flow equivalent to 50% of the volume that would be discharged in a 1 in 1 year return period design storm.

4. UPM 2 (1994) defines "good engineering design" in the context of the above as a chamber designed in accordance with FR0488 (Balmforth et al, 1994)

5. For definitions please refer to NRA 1994.

4. Fundamentals of CSO Design

The operational requirements of an effective CSO structure are directly compatible with the overall objectives of a sewerage system. An effective CSO should:

1. *provide adequate hydraulic relief of the sewerage system so as to meet the target for flood control.*
2. *control the pass forward (continuation) flow so as to protect the downstream sewerage system and wastewater treatment works from overloading.*
3. *control/treat the spill flow so as to meet the regulatory requirements for intermittent discharge to the receiving water.*
4. *minimise any operational requirements for maintenance and not expose operatives to unnecessary risk.*
5. *minimise whole life cost*

Achieving the desired spill capacity whilst correctly regulating the continuation flow (objectives 1 and 2) will be met through correct hydraulic design of the chamber. In particular the flow in the chamber should be sub critical and care should be taken to check flow conditions at entry to the chamber and in the incoming sewer to ensure that this is achieved. The continuation flow to the downstream sewer should be regulated to ensure that consent setting is met.

This Guide focuses primarily on the design of a chamber that will incorporate an appropriately designed screen (objective 3 as it relates to aesthetic pollutants) and ensures flow patterns that are commensurate with effective screen operation. The recommended chamber is also designed to be compact and to minimise the risk of sedimentation or blockage (objective 4 and 5).

The Guide also seeks to give advice, based on operational experience, of appropriate criteria and features associated with location and construction issues, access, screen selection, ancillary equipment, commissioning, maintenance and post project appraisal. These are important considerations in the overall design of chambers but it is also recommended that guidance should be sought from screen suppliers and from operations staff with experience of recent installations. Clearly, the chamber dimensions must be sufficient to accommodate the screen and to allow for access for maintenance.

5. Design of the WaPUG Chamber

The AMP2 Guidelines (NRA 1994) identify separate design flows for the 6mm and 10mm standard. Where only 10mm solids separation is required, the design flow is the 1 in 5 year peak flow. Where 6mm solids separation is required, a lower flow, less than a 1 year return period, is specified, with the excess flow up to the 5 year peak receiving 10mm solids separation. In practice, it is usual not to provide a dual screening facility in this way but to incorporate only one screen with 6mm apertures in two dimensions for the full range of flows up to the 5-year return period flow.

The chamber should be designed to provide good flow conditions to ensure the effective performance of the screen in terms of its retention of solids, cleaning mechanism, and return of the screenings to the continuation flow. As the screen is providing the aesthetics control, it is not necessary for the chamber to provide any degree of solids separation, i.e. there is no requirement for stilling, settling or dynamic separation.

5.1 *Chamber Type*

High side weir structures may be the preferred option for most applications as the slender structure has the advantage that it may more easily accommodate the majority of screen types, is easily adapted to existing sewer alignments and is less likely to require service diversions when constructed in or close to the highway. However, when static screens are the preferred option, an extended stilling pond may provide a viable alternative, since the wider chamber may more easily accommodate the required screen area. In such cases the screen should be fitted horizontally between the scumboard and weir. The scumboard may be moved upstream to accommodate the screen.

In all chambers, a scumboard protected relief weir should normally be provided, with the scumboard of adequate height to protect the free discharge of solids over the relief weir.

5.2 *High Side Weir Configuration*

Single or double side weir chambers may be used. The single side weir is easier to construct but there may be cost savings in the use of a double sided weir as this would result in a smaller chamber. Note: it is the size of the screen that dictates the total length of the weir and hence the weir length in a double side weir could be half that of the single side weir.

The basic configuration of a single high side weir chamber is set out in plan in Figure 1.

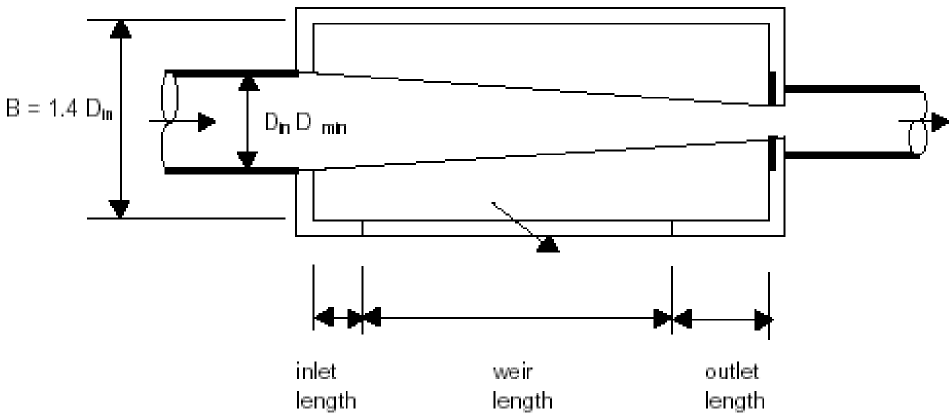

Figure 1. WaPUG Side Weir CSO Chamber

5.3 *Hydraulic conditions at inlet*

As stated earlier, it is desirable that the flow in the chamber is suitable for the effective operation of a screen. This requires that flow throughout the CSO chamber is subcritical, i.e. the depths should be reasonably large and velocities low. The formal definition of subcritical flow is that where the Froude Number is less than 1. The Froude Number is defined in equation 1 as

$$Fr = \frac{V}{\sqrt{g\frac{A}{W}}} \quad \text{.......................................} \quad (1)$$

where	V	=	velocity of flow, m/s
	g	=	gravitational acceleration = 9.81 m/s²
	A	=	cross sectional area of flow, m²
	W	=	width of water surface in metres

Figure 2a illustrates subcritical flow in a side weir CSO chamber.

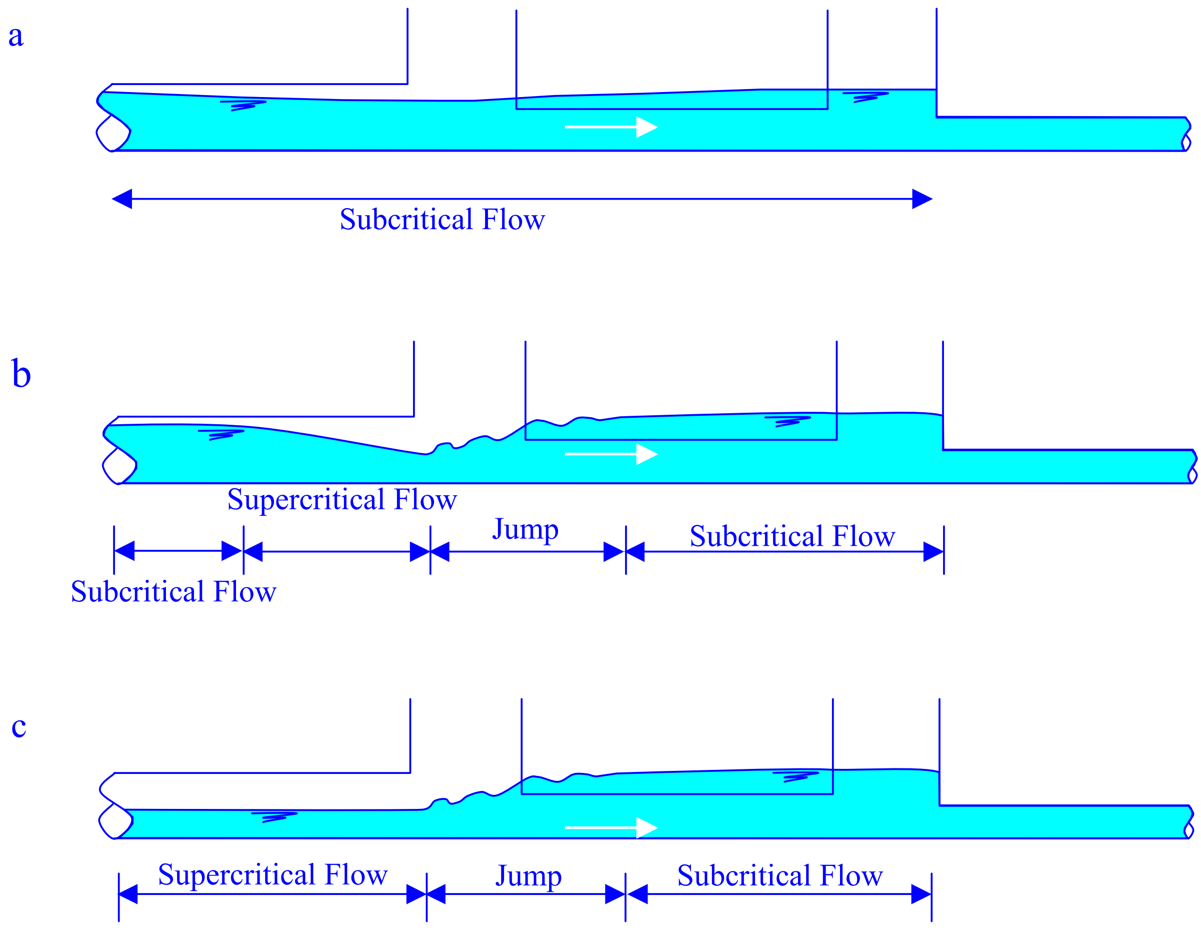

Figure 2. Possible Flow Conditions at Inlet to a CSO Chamber

If the inlet pipe has a mild slope it is usual that the flow in the pipe will be subcritical but it is realised that the inlet flow may be drawn down to form supercritical flow at entry to the chamber. This effect is caused by the presence of the weir. The presence of the outlet control results in a subcritical flow at the downstream end of the chamber and, when the high velocity supercritical flow meets the subcritical flow along the weir, a hydraulic jump is formed, as illustrated in Figure 2b. The turbulence due to the formation of a hydraulic jump in the chamber may adversely affect the performance of a screen. The WaPUG CSO Design Guide provides guidance on how to avoid supercritical flow and, for such flow conditions, provides guidance on the required length of the overflow weir and the diameter of the inlet pipe.

However, a hydraulic jump may also occur where a steep sewer exists at the inlet to the chamber. A steep sewer is one where supercritical flow naturally occurs due to the gradient of the sewer, as illustrated in figure 2c. Ackers et. al. (1968) developed a simple check for a steep sewer by calculating the Froude number at half pipe full flow, given by equation 2. If the value exceeds 1 then the sewer is steep and supercritical flow will form.

$$\mathrm{Fr} = 4.06\frac{Q_{0.5}}{\sqrt{gD^5}} \quad \text{.........................(2)}$$

where $Q_{0.5}$ = discharge in m^3/s at half pipe full (= 0.5 x pipe full discharge)
g = Gravitational acceleration = $9.81 m/s^2$
D = Inlet diameter in metres

A steep inlet sewer is not a problem *per se*. It only becomes an issue if the hydraulic jump occurs in the chamber. Hence, when the inlet sewer is steep, (steep being defined when the Froude number in the inlet pipe is greater than unity at the design flowrate), the designer should determine where the jump is likely to occur. This is done by considering the balance between the change in momentum flux and hydrostatic force, between the supercritical flow in the inlet sewer and the subcritical flow in the chamber. Further guidance on this is given in most classical hydraulics textbooks, for example, Chow (1959), Douglas, Gasiorek and Swaffield, (2001) and Chadwick and Morfett (2002). Alternatively, with steeply sloping incoming sewers consideration should be given to dissipating the energy in the incoming flow by constructing a control structure to move the position of the hydraulic jump upstream into the inlet pipe or to introduce a drop manhole structure, thereby reducing the slope of the incoming sewer. However, if such a control structure is used, care should be taken to ensure that supercritical flow does not occur, on entry to the chamber, at inflow rates that are lower than that of the 5 year design flowrate.

5.4 Chamber Dimensions

The Guide recommends minimum chamber dimensions based on the selected inlet pipe diameter such that the flow in the chamber is suitable for the effective operation of a screen.

5.5 Inlet Diameter

To avoid problems with supercritical flow, it is recommended that a minimum inlet diameter be used. The minimum inlet diameter will depend on the design flow rate, the weir height, the weir length, and the chamber width. In line with previous design guides, the minimum inlet diameter may be estimated using equation 3:

$$\textbf{Dmin = K Q}^{0.4} \ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots.(3)$$

where Q is the 5-year return period peak inflow in m^3/s,
Dmin is the minimum diameter of the inlet pipe in m,
and K is a constant.

Values of K are given in Figure 3 for a chamber width of 1.4D and weir height to inlet pipe diameter ratios on the range 0.6 to 1.0. K values may be interpolated for weir lengths between 4.75D and 6D. For weirs shorter than 4.75D, the 4.75D line should be used. The figure should not be used for weir lengths beyond 6D.

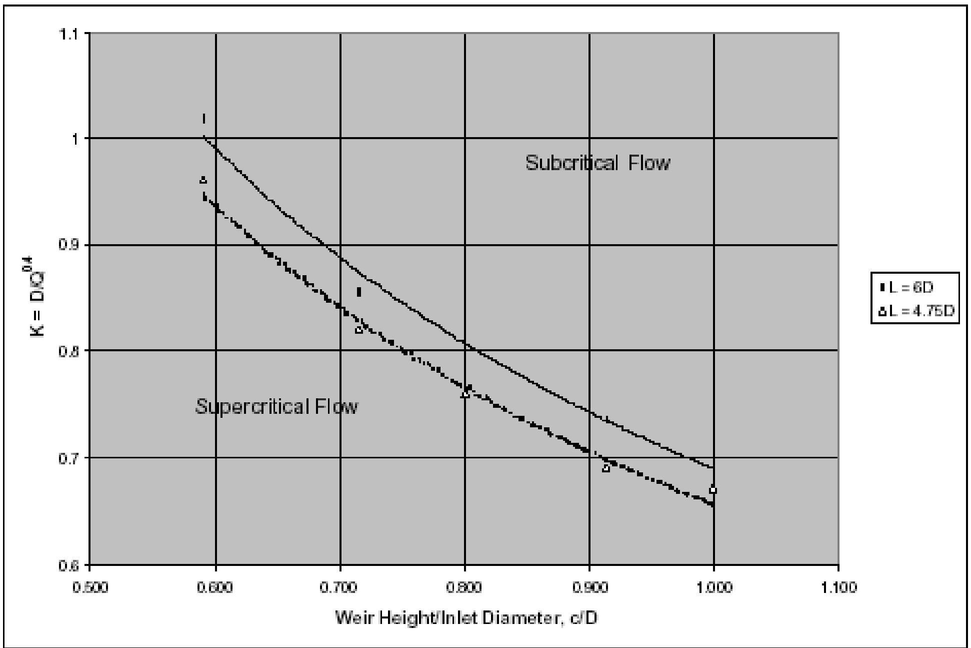

Figure 3. Values of K for use with Equation 1

5.6 Width

The width of the chamber should not be less than 1.4Din. Note also that the width must be sufficient to incorporate any scumboards, or a screen where fitted within the chamber itself. Sufficient room should be provided for access for maintenance where required. If the chamber is widened beyond 1.4D, a wider chamber is unlikely to adversely affect flow conditions but the designer should be satisfied that any increase does not cause operational problems due to the potential for increased siltation.

5.7 Weir Height

If the weir is set too high then the hydraulic gradient in the upstream sewer will rise under storm conditions thus increasing the risk of flooding from manholes or through basement connections. If the weir is set too low then the depth in the chamber at inlet may be insufficient to adequately dissipate the incoming jet from the upstream sewer. Equation 1 and Figure 3 shows that larger diameter inlet sewers are needed with lower weir heights. The weir height should not fall outside of the range given in figure 3. A further check is required to ensure supercritical flow does not form in the inlet to the chamber. Further guidance on how this may be calculated is given in Section 5.3 above

.

5.8 Weir Length

Designers should try to match the chamber weir length to the selected size and length of screen, selected in accordance with the hydraulic performance recommendations of the screen manufacturer. The Guide sets a limit of 6D on the weir length. Checks should then be made using Figure 3 to ensure that flow conditions are sub-critical. Hence the weir length should be sufficiently long to accommodate the screen and be capable of discharging the required spill flows at the specified head. The length of the weir will also affect water levels in the sewerage system upstream, and modelling the chamber in a suitable hydraulic model of the sewerage system should check the effect of this.

5.9 Inlet Length

The weir should not start immediately at the upstream end of the chamber. A short inlet length should be provided to allow the incoming flow to turn onto the screen. The minimum inlet length should be 0.4 D_{in} with a minimum value of 500mm.

5.10 Outlet Length

With a screen that returns the screenings directly into the chamber it is important that the surface flow carries the screenings away from the weir and into the continuation flow. If this is not done, screenings will be continually re-presented to the screen. CFD analysis has shown that the flow pattern and path of individual particles within the CSO chamber are a function of the screen type and the geometry of the chamber, and that, in many side weir chambers, the flow on the surface at the downstream end of the weir is directed towards the weir. Such flow patterns have been substantiated by field observation and, in some cases, this had led to operational problems due to an imbalance of the solids loads issued to the screen with the tendency for more solids to be discharged to the downstream end of the screen with the increased potential for the screen to blind. To overcome this problem an outlet length should be included in the chamber or an alternative method used for screenings return (as described in section 8.2). The required outlet length will again be a function of the chamber and screen type, but, as a general rule in side weir chambers, it is recommended that the outlet length should not be less than 1.5D_{in} with a minimum value of 1.5m, measured from the downstream end of the weir. In addition, for screen types that are positioned to the wet side of the weir, it is recommended that the screen should extend beyond the downstream end of the weir such that distance between the downstream end of the screen and downstream wall of the chamber is not less that D_{in}, with a minimum value of 1m.

5.11 Chamber Height

Within the chamber, chamber depth shall be sufficient to allow easy access for the operator and such that the operator may stand-up within the chamber, wherever possible.

6. Hydraulic Design of the Chamber

The hydraulic design of the chamber involves the correct sizing of the continuation flow control and checking the discharge capacity of the weir and outfall pipe at the target design flow to meet regulatory consents.

6.1 Through flow outlet control

For existing chambers, wherever possible, use should be made of the existing weir and flow control arrangements. In new chambers, the option of utilizing the downstream sewer system as a flow control should be considered but where it is necessary to insert a control device it is possible to use a number of different types of flow control. This Guide has been written on the basis that such a flow control device will either be an orifice plate or penstock. Experience has shown that these types combine effective control with the ability to readily adjust the CSO setting in the field should this be necessary. It is stressed however that the impact of such a 'local' change on the overall hydraulic performance of the system should be checked to ensure that problems do not occur in other parts of the system.

When properly designed the orifice plate and penstock behave as a freely discharging orifice where the discharge is proportional to the square root of the head of water above the centre line of the flow control opening, as given by equation 4.

$$Q_o = C_d A_o \sqrt{(2gH)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where Q_o is the discharge through the flow control
H is the head of water above the flow control centreline
A_o is the area of opening of the flow control
and C_d is the discharge coefficient

The flow control is designed so that it will pass the desired setting when the water in the chamber is just level with the weir. Thus Q_o and H are defined in equation 4. The value of the coefficient of discharge C_d will depend on the geometry. Values of C_d can be obtained from FR0488 (Balmforth et al, 1994). This allows equation 4 to be used to size the opening of the flow control to achieve the desired setting. As an alternative to an orifice plate or penstock, a proprietary flow control may be used. In certain cases these may offer an operational or cost advantage. The flow control opening should be sufficiently large to pass a 200mm diameter sphere.

It is important to note that in designing the flow control a free outlet is assumed, that is, the water level in the downstream sewer does not back up to drown the flow control. This assumption should be formally checked after designing the flow control, using the methodology set out in section 5.2 of FR0488. The discharge capacity of the weir should now be checked. This will depend on the allowable head on the weir under design storm conditions. There are two parts to this check. The first is to check the level of the hydraulic gradient in the main sewer at the screen design flow. This is normally calculated by adding the head on the weir (calculated as described below for the weir without a screen fitted) to the head loss generated by the screen at the design flow (obtained from the screen supplier). The hydraulic gradient should be below the maximum allowable level (for flood control). The second part is to check the level of the hydraulic gradient in the sewers both upstream and downstream of the CSO for the “worst case”. For the purposes of this calculation the design flow will be the target return period flow for flood protection (e.g. 1 in 30 year return period).

The allowable water level in the CSO chamber is based on the allowable hydraulic gradient in the upstream sewer. The maximum allowable level of the hydraulic gradient will be governed by the requirement to control flooding in the upstream drainage area at the design flow. Ideally this will be determined using a verified hydraulic model of the sewerage system.

The maximum allowable water level in the CSO chamber is subsequently used to determine the required level of the relief overflow weir. Ideally, this level is calculated by assuming the 1 in 30 year spill design flow is discharged over the relief weir as it is assumed that the relief weir should discharge all spill flow when the screen is fully blinded. The head of water over the relief weir is given by equation 6 below and hence the relief weir crest level in the given by the maximum water level minus the head of water over the weir.

Note
In practice, in some chambers, and particularly those that have large spill flows, it may not be feasible to design the relief weir to accommodate the 1 in 30 year spill flow. In such cases engineering judgement should be used to assess the balance between the cost and benefit of the relief weir design.

6.2 Weir flow

The basis for calculating the discharge capacity of a weir is the transverse weir equation, expressed as equation 5, where;
:

$$Q_w = C_D \tfrac{2}{3} \sqrt{(2g)}\, L\, H_w^{3/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

with

C_D = discharge coefficient for weir
L = weir length
H_w = head on the weir

A value of C_D of 0.6 should be used for plate weirs, 0.7 for square crested weirs and 0.8 for round crested weirs. The coefficient should be reduced by 10% if the flow over the weir is affected by a scumboard. This should be carefully documented in the design calculations.

6.3 Outfall capacity

The capacity of the outfall should also be checked. The hydraulic effects of any fittings on the outfall pipe, such as a flap valve, should be properly accounted for. There are numerous examples of poor CSO performance that can be attributed to inadequate capacity of the outfall. It may be necessary to reconstruct the outfall or to relocate the CSO. The outlet capacity should be checked for the “short pipe” condition by calculating its discharge capacity assuming the entry behaves as an orifice (equation 5). A coefficient of discharge of 0.6 should be used where entry to the pipe is in the longitudinal direction of the chamber and 0.4 where the outlet is at right angles.

7. Screen selection

7.1 Screen Options

Powered, self-cleansing or static screens may be used.

7.2 Generic factors

Generic criteria that influence screen selection include:

- Screen choice must be integral with the design of chamber.
- The required size of a screen is based on the peak of the 5-year spill flow and the design flow-loading rate for the screen.
- The design flow-loading rate for each type of screen is provided by the system manufacturer or by specific water company policy.
- Screen performance should be effective and be compliant with the EA regulatory guidelines.
- Where appropriate, screens should meet the requirements of individual Water Company Mechanical & Electrical Specifications.
- Screens should be appropriately maintained.

7.3 Site specific considerations

Many site-specific factors influence screen selection and include:

- The amenity value of the receiving water
- The maximum design flow to be screened – this is based on the spill flow corresponding to the critical 1 in 5-year storm event.
- The predicted maximum number of storm spill events per annum.
- The availability of (or the possibility of providing) a suitable power supply
- The nature and characteristics of the upstream catchment as this will influence the temporal distribution of the flow and the aesthetics loadings that enter the screened CSO chamber.

- The location of the overflow in relation to the location of other overflows in the catchment. If upstream overflows are screened the quantities of aesthetic solids may increase towards the downstream end of the system.

- High levels of fats, oils or greases.

- High levels of grit

- A reverse in the flow direction to the screen

7.4 Location of the screen in chamber

The position of the screen can have an important effect on the performance of the chamber and also on the hydraulic performance of the sewerage system. There are three basic screen locations and these are discussed below.

7.4.1 Horizontally Mounted Screen on the Wet Side of the Weir

Examples of horizontally mounted screens, shown in Figure 4, are travelling mesh screens and static screens. To ensure that all the flow passes up through the screen, a transverse baffle plate is normally required along the upstream face of the screen. Screenings are normally returned to the chamber.

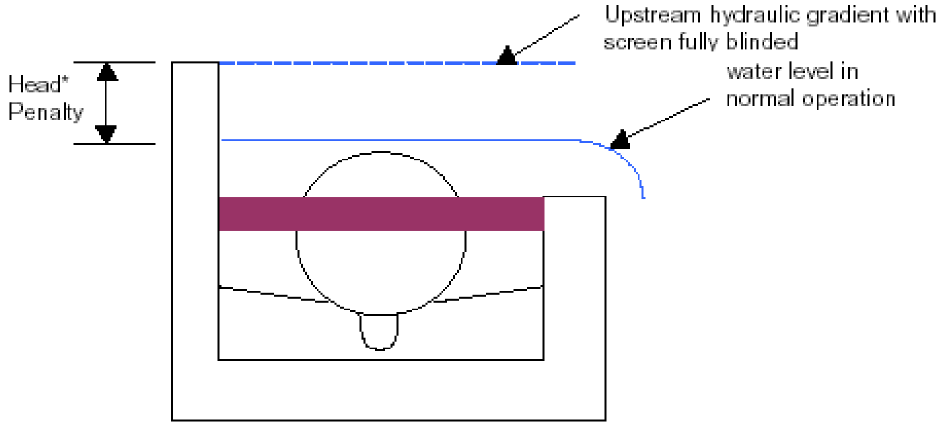

Figure 4 Horizontally mounted screen on Wet Side of Weir

Sometimes referred to as an Upward Flow Screen

*** The head generated by the screen is influenced by the size of the screen and the degree of blinding***

An alternative arrangement is to only fit the screen for part of the width between the weirs, incorporating a vertical back plate to direct the flow under and up through the screen (fig. 5). This arrangement normally attracts far less head penalty should the screen become blinded. Travelling mesh screens are also available in this configuration.

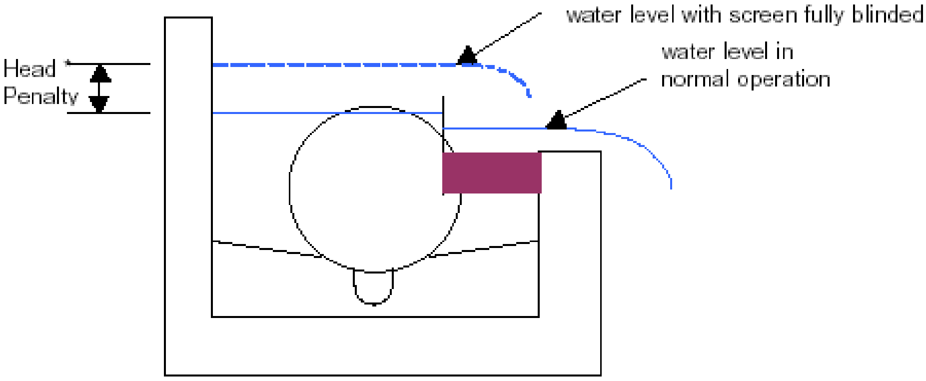

Figure 5 Horizontal Screen Incorporating a Relief Weir
Sometimes referred to as an Upward Flow Screen
**** The head generated by the screen is influenced by the size of the screen and the degree of blinding***

7.4.2 Screens Mounted on the Dry Side of the Weir

Examples include the rotary-brushed screens, run down screens, and flushed mesh screens. These screens usually have some form of back plate over which the flow will spill if the screen becomes blinded, as shown in Figure 6. The crest level of this plate will determine the 'head penalty' and the hydraulic effects on the upstream sewer should again be checked. The design engineer should also ensure that there is sufficient space between the back plate and the wall of the chamber for this plate to act as a relief weir. It is important that a check should also be made to ensure that the level in the spill chamber would not back up to adversely affect the screen.

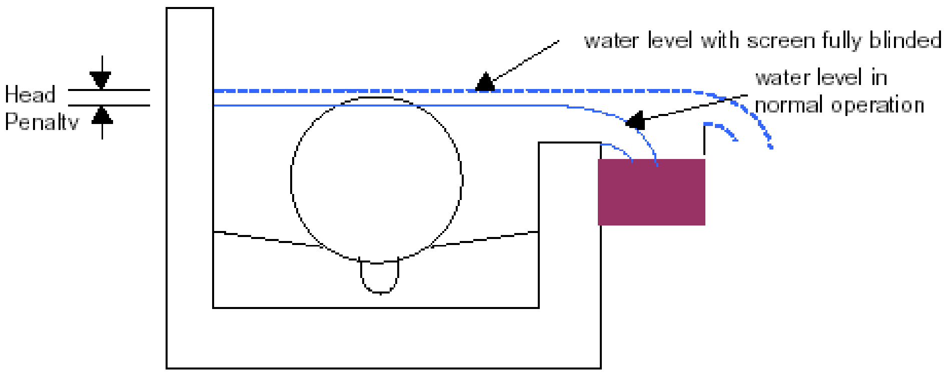

Figure 6 Screen Mounted on Dry Side of the Weir
Sometimes referred to as a Downward Flow Screen

Screens fitted in this position may be susceptible to damage from large objects washed over the weir. Consideration should be given to installing a scumboard to protect the screen in this case (see section 9.6)

7.4.3 Screen Mounted Vertically on the Weir

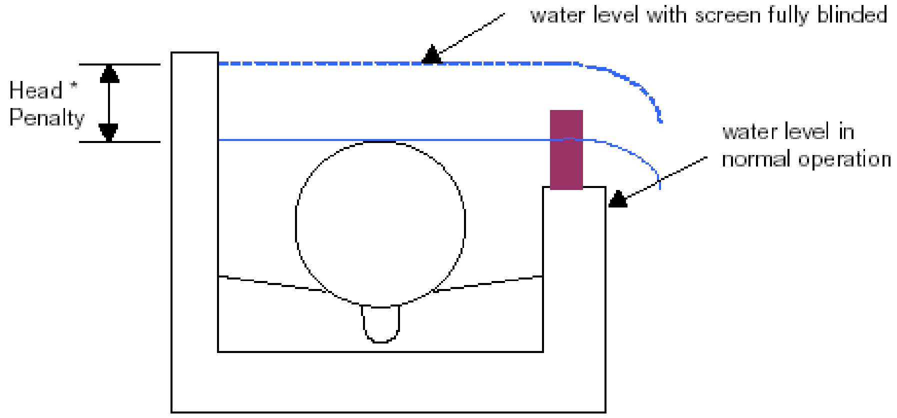

Figure 7 Vertical Weir Mounted Screen
Sometimes referred to as a Side Flow Screen
**** The head generated by the screen is influenced by the size of the screen and the degree of blinding***

Examples of this type of screen, shown in Figure 7, are the mechanically raked bar, travelling band and rotary disc screens. Screenings are normally returned to the water surface in the chamber. The area of screening depends on the head and, as the screen begins to blind during its operational cycle, the head will increase. The design engineer should always check the effect of a completely blinded screen on the maximum water level in the chamber as the resultant 'head penalty' may significantly influence the hydraulic gradient of the flow in the upstream sewer with the potential to affect the risk of flooding upstream. The chamber should be widened to accommodate a scumboard, if necessary.

8. Chamber detailing

8.1 Bed Benching

The invert of the chamber should be formed with a part-circle invert that tapers along the length of the weir to provide a smooth transition from the incoming sewer to a half round invert at exit, as shown below. The minimum width of this channel is company specific. Benching with a cross fall of 1 in 8 should be provided to the dry weather flow channel (fig. 8). The invert of the dry weather flow channel should slope sufficiently to maintain a velocity of at least 0.75m/s at 2 DWF. Other invert geometries may be used provided that they can be demonstrated to be self-cleansing. All benching should be "stepped" locally below access points, to form a safe level surface.

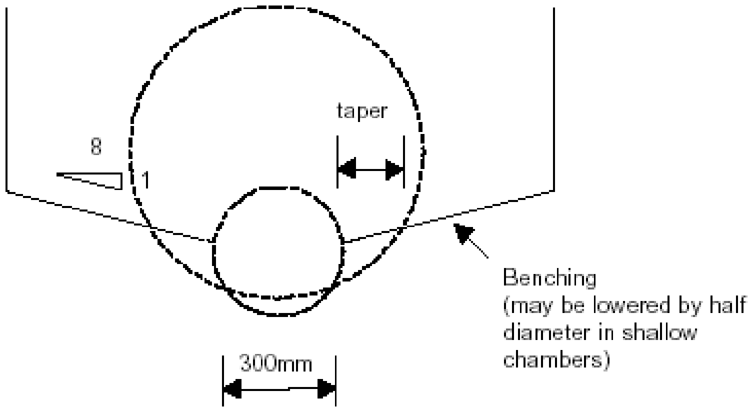

Figure 8. Detail of Chamber Invert

8.2 Relief Weir

A relief weir should be provided to allow the discharge of flows in excess of the screen design flow. This weir may be part of the back plate (baffle plate) of the screen or a separate structure. The weir should be set high enough so that it does not discharge when the 5-year design spill flow is passing through the screen. A suitable allowance for screen blinding (e.g. 50%) should be made when undertaking this check. Further guidance on the hydraulic design and performance weirs is given in Section 6.2. It is preferable that any high-level relief weir should be located upstream of the overflow screen weir.

8.3 Alternative Screening Return

An alternative solution is to return the screenings directly to the continuation flow. An outlet length is not then required, though it will be necessary to have a screenings return chamber downstream of the flow control to return the screenings to, as shown in Figure 9. With this configuration the flow control may be fitted on the "dry" side of the chamber cross wall, facilitating maintenance.

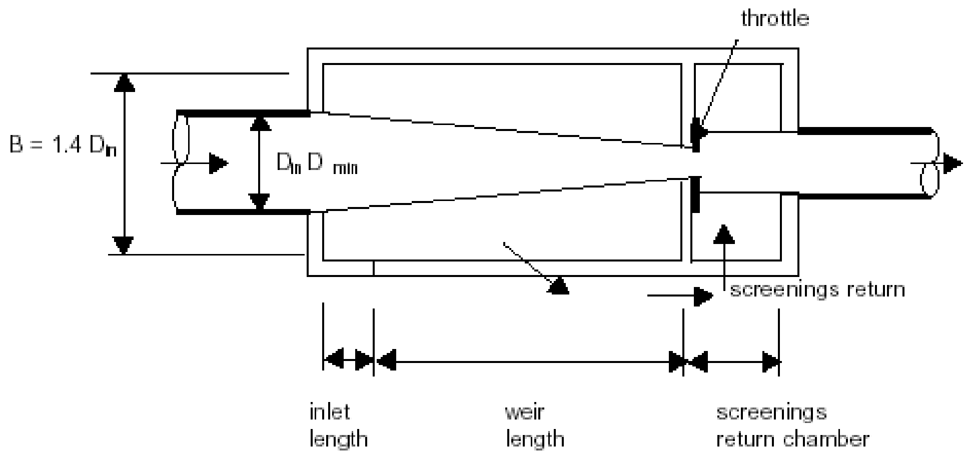

Figure 9. Alternative Screenings Return

9. Ancillary Devices

Design engineers should also refer to appropriate guides, standards and codes of practice related to CSO ancillaries.

9.1 Flow Control Devices

The hydraulics associated with the design of flow control devices was outlined in Section 6.1.

9.2 Kiosks

These are company specific and their installation, where appropriate, may be subject to local planning consents. The security and location of kiosks is a key design consideration.

9.3 Triggers for the operation of powered screens

Instruments to trigger the operation of the different types of powered screen arrangement are usually based on some form of depth or flow measurement.

9.4 Telemetry

The use of telemetry systems to transfer signals from CSO performance measurement instruments to company databases is increasing. However, the details are considered beyond the scope of this Guide.

9.5 Internal Access Equipment

The purpose of good chamber detailing is to provide for safe access to the chamber and screens, and to minimise operational problems and maintenance requirements.

9.6 Scumboards

Scumboards have the advantage that they prevent the floating solids, including fats and greases, and large pieces of debris from being discharged over the weir. These solids may either clog or damage any screen positioned on the dry side of the weir.

Should scumboards be used they should be positioned such that the velocity of flow past the scumboard is less than the velocity of flow over the weir but no less than 200mm from the face of the weir with the lower edge 100mm below the weir crest. The chamber should be widened to accommodate the scumboard if necessary. The scumboard should be fitted for the full length of the chamber and care should be taken to maintain a minimum 200mm opening between the lower edge of the scumboard and the benching. Scumboards should only be used where there is no risk of screenings traps and the scumboard should be positioned so that it does not interfere with the screenings return mechanism. Scumboards are not required for screens that are installed within the flow on the wet side of the spill weir.

9.7 Static Screen Washing Systems

Static screens may be cleaned manually or by using remotely operated screen washing systems. Guidance on the use of these systems is again considered beyond the scope of this report

10. Access – Vehicular / Personnel / Maintenance / Equipment Removal

Access points should be provided, wherever practical, to allow access to the chamber (wet and dry sides of the weir) and to all major maintenance points. These include the continuation flow outlet, the motor / gearbox of powered screens and to any instruments used to monitor the performance of the chamber.

Screen Maintenance Access - as a minimum, these openings should be sized to give necessary access and full screen visibility. For static screens without a mechanical flush cleaning mechanism, it is preferable that the access should permit full screen visibility and the opportunity for full area manual cleaning from above. Access openings should also be sized to enable the screen to be removed / re-installed in manageable sized sections. It is stressed however that large access ports create other risks such as those associated with the security of operators and access to unauthorised personnel and children. They are also difficult to install in highways.

For personnel maintenance access openings should preferably have minimum dimensions of 900 mm x 900 mm. At least two access points are usually required for venting prior to the entry of personnel.

The ground that surrounds the access openings should be hard-standing and sufficiently level to permit the safe use of a tripod / winch that may be used for personnel access.

Lockable covers may be preferable in public access areas, excluding highways.

Consideration may also be given to the use of covers with integral barriers as these provide additional security and protection against surface flooding and odour emissions.

11. Post Project Appraisal

The UK Water Industry has recognised a need for a standardised method for reporting the environmental impact of CSO discharges on receiving waters. UKWIR (2000), proposed a methodology to assist in the identification of CSOs that perform unsatisfactorily. The procedure involved the collection of field data, to include visual observations of dry weather operation, sewage related debris, sewage fungus, public access and water amenity value, together with historical record data, such as the number of public complaints, the number of pollution incidents, and the status of the receiving water course. The procedure aimed to provide a means to assist in the priortisation of improvement schemes, and to act as a "certification" that previously unsatisfactory CSOs subsequently performed to an acceptable standard.

In respect of CSO performance and monitoring, UKWIR (2001) and Christodoulides and Saul (2001) proposed methodologies for post project appraisal. However, following the introduction of many screened CSOs, several UK Water Companies have adopted a structured protocol covering the on-site assessment of CSO / Screen performance, consisting of a series of one-off site inspections reported individually, then summarised with conclusions, recommendations, etc, in a project end-report. Issues under review typically include the following:

CSO Chambers	Type / Design Guide Compliance / Location / Responsibility
Chamber Access	General, Vehicle, Personnel, Screen Removal / Maintenance
Screens	Screen Type / Installation Issues / Condition
CSO / Screen Performance	Operation of Relief / Premature Operation / Self Cleansing
Operation / Maintenance	Operator Awareness / Maintenance Routines
Receiving Watercourse	Location of Outfall / Condition of Receiving Watercourse

The outputs from such multi-location Post Project Appraisal should lead to a series of generic conclusions, that highlight where investment has been correctly targeted and expended, but also indicate areas where the overall investment may not have fully achieved the original objectives. It is stressed however that Post Project Appraisal should not be carried out earlier than six months following the hand over of the equipment / asset to the end user. This delay period avoids genuine 'snags' being included as project failures or shortcomings.

It is also recognised by the industry that there is a need for longer term Post Project Appraisal, with both medium and long-term monitoring exercises that record the hydraulic conditions within a number of different types of screened CSO chamber by means of instrumentation. This information may be further used to refine the design process and assist with product development and the optimisation of system operation, maintenance and control.

However, PPA is often considered to be expensive, but a review by Thompson (2005) completed in the AMP3 periodic review, has highlighted that the benefits, both physical and financial, far outweigh the relatively low cost of the work itself. It is therefore recommended that the industry should routinely fund PPA, conceived at the planning and design stage, such that understanding of system design, operation and performance may be enhanced. The outputs from such PPA and other studies will be used to further update this Guide from time to time.

12. Conclusions

By carefully following the above guidance, cost effective CSO chambers can be designed that meet both flood control and aesthetic environmental quality standards.

The recommended chamber configurations have been developed using the outputs from a number of full-scale field evaluations of performance, supplemented by computational fluid dynamics, which is a proven method of assessing three dimensional flow patterns and solids pathways.

With chambers designed in accordance with this Guide it should be appreciated that the control of aesthetics is solely dependent on the performance of the screen. No information has been given in this Guide regarding screen performance and the users of this Guide should consult appropriate publications and performance data from manufacturers when procuring screening plant.

Users should resist the temptation to modify designs to suit particular site conditions in the absence of supporting performance data, since this may lead to unreliable performance. If modifications are essential, hydraulic model testing, CFD studies or a full-scale field evaluation should be used to confirm the revised design.

It is also recommended that the users of this Guide keep up to date with journal publications and articles on the subject. The Guide will be updated from time to time as further information becomes available.

13. Acknowledgements

The authors would like to thank their respective employers for their permission to work on and draft this guide, and the various individuals and organisations that have contributed to its development.

The authors also wish to recognise the significant contribution from United Utilities, in allowing the use of the results from the UKWIR studies and the Warrington Test Facility in the development of the Guide.

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