LETTERKENNY GENERAL HOSPITAL

FLOOD MANAGEMENT STRATEGY

DRAFT G (Final), 02-04-14

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Contents

1. Background

1.1 Events of 26th July 2013

On Friday 26th July 2013, commencing at approximately 5.30pm, flooding of Letterkenny General Hospital occurred following intense rainfall in the area. The source of the flood water was a local stream, known as the Sprackburn Tributary (a tributary of the River Swilly), which runs in a south-east direction towards the hospital and enters a 1350mm diameter circular culvert running through the hospital grounds.

1.2 Frequency of Flooding

The event of 26th July 2013 should not be viewed in isolation, as the site has experienced several recent flooding incidents, or 'near misses', most recent as follows:

- 12th November 2009 – breach during Mc Namara Construction
- 14th December 2011 – breach at culvert entrance during construction of A&E block
- 18th May 2013 – significant rainfall event (without a breach at the culvert entrance)
- 26th July 2013 – major breach and consequent flooding of the hospital
- 18th December 2013 - significant rainfall event (without a breach at the culvert entrance)

Based on rainfall radar images for 26th July 2013 it can be deduced that at 1700hrs (BST/local time), rainfall intensity exceeded 57mm/hr in an area local to the catchment of the Sprackburn Tributary. Based on verbal accounts of the event and on CCTV footage at the hospital it appears that the intense rainfall event lasted between 15 and 25 minutes. Following preliminary discussions with Met Eireann, and interpolating from the best available information, this rainfall intensity and duration can be considered to have a return period somewhere between a 1 in 20 year and a 1 in 25 year event.

We would however caution against drawing any absolute conclusions from this assessment of return period based solely on rainfall radar data, as the reliability of the return period assessment is low, given that the rainfall intensity data is taken from a radar based over 200km away and there are a number of topographical and other interferences that limit the accuracy of the data.

Given the more frequent flooding events nationally and the ongoing evidence of climate change, it is clear that a Flood Management Strategy for Letterkenny General Hospital is an essential element to protect the hospital.

1.3 Purpose of this Document

Following the significant damage to buildings on the hospital site, a Flood Management Strategy (this document) has been prepared to minimize the risk of future flood related damage to the building and other assets at Letterkenny General Hospital.

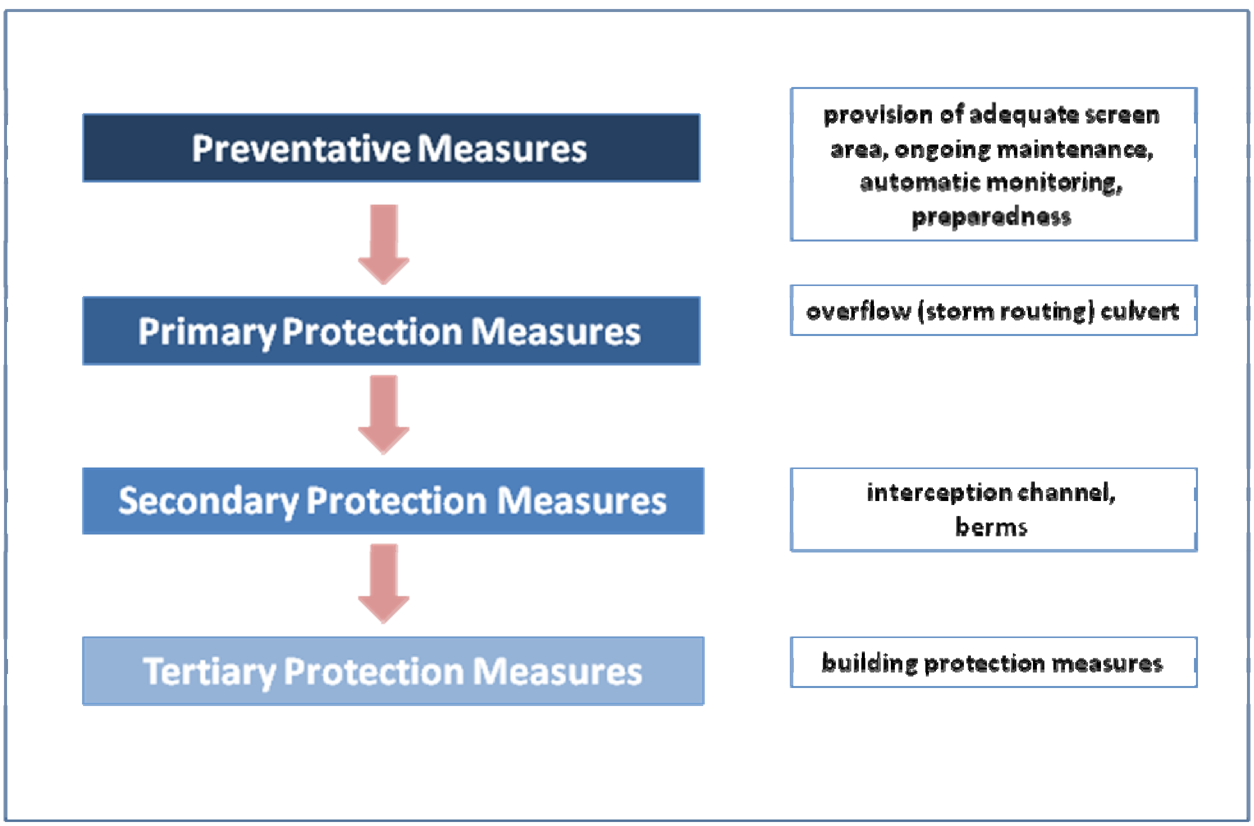
1.4 Terminology

The following terms are used throughout this report.

- *Headworks* – the entire installation upstream of the existing culvert entrance, on the hospital property, mainly incorporating screens and ancillary items such as CCTV, water level monitoring etc.
- *Breach* – an event where water overtops the banks of the channel at the headworks and becomes overland flow
- *Preventative measures* – preparedness measures which are designed on an ongoing basis to prevent a breach from occurring at the headworks in the event of a storm. They include ongoing maintenance, automatic monitoring, provision of adequate screen area, preparedness etc.
- *Primary protection measures* – works that are proposed as part of the construction contract to prevent a breach/overtopping at the headworks in the event of a storm. These include the proposed overflow culvert.
- *Secondary protection measures* – measures that will intercept overland flow at the headworks in the event of a breach and subsequent overland flow at that location.
- *Tertiary protection measures* – measures deployed at the entrances to the various buildings on the hospital site that are designed to prevent water entering the buildings, in the event that primary and secondary measures are not effective.
- *Significant event* - an event, including status orange or red rainfall warnings, or an alarm generated at the headworks, that requires mobilisation of resources to prevent a breach at the headworks (or in response to a breach)

- *Trash screen* – as described by the document titled *Security and Trash Screen Guide (UK Environment Agency, 2009,* a copy of this document is included in **Annex B),** a culvert screen whose primary function is to prevent debris from entering the culvert
- *Security screen* - as described by the document titled Security and Trash Screen Guide (UK Environment Agency, 2009), a culvert screen whose primary function is to prevent people from entering the culvert
- *Sprackburn Tributary* - the main stream in the catchment with a catchment area of 0.92km^2. This stream enters the 1350mm culvert at its headwall
- *Northern Tributary* - the secondary stream which joins with the Sprackburn Tributary on the hospital site before entering the 1350mm culvert at its headwall. This has a catchment area of 0.47km^2.
- *Incident Manager – the most senior person from Hospital Maintenance involved in the response to an incident, and consequently the person that has the authority to make key decisions*

The various levels of protection measures are shown in diagram form below.



2. Main Hospital Assets

2.1 Description of Hospital Campus

The original Letterkenny Hospital was constructed around 1960 and this original section of the building is still in use and located on the centre of the campus. The building is a single storey reinforced concrete structure and houses Outpatients, Radiology, Catering and some ward facilities, this section of the building has be augmented over the years by means of permanent, semi-permanent and prefabricated extensions. To the extreme west of the 1960's building is the Laboratory which was constructed in the early 1970's and extended in 2004 using pre fabricated construction.

A significant multi-storey Ward block was added to the end of the 1970's and commissioned in 1980 to the south of the 1960's building and is connected by means of two glazed link corridors. This building consists of five levels with the ground floor constructed one level below the original 1960's building. Extensions have been added to this multi storey building, firstly in 1996 consisting of four floors to the West with a subsequent four floor extension added to this around 2000. A further single storey prefabricated modular interim ward was added at ground floor level to the east of the original multi storey in 2006.

A new Acute Mental Health Unit was added to the west of the Original 1960's building in 2011, connected by means of a link corridor to the existing 1960's part of the building.

A new four storey Medical Block was added to the north of the original building and was commissioned in 2012. This building is also connected to the original 1960's building by means of a link corridor. The commissioning of the Medical Block has resulted in a significant area of the original 1960's Hospital being vacated. The Medical Block Building houses a new Emergency Department and Medical Assessment Unit on the Ground floor and three 24 Bed Medical Wards on the Floors above. There is a roof top plant room housing the air handling units and a separate ground floor plant room.

There is also a three storey (former Nurses Home) building located to the northeast of the original 1960's building which is not connected but it's ground floor is located a level above the 1960's building. There are also various out houses, Plant Rooms, Boiler Houses etc strategically located around the campus

The existing Sprackburn stream was culverted in the 1970's to facilitate the construction of the Laboratory and the original Psychiatric Unit (which was demolished and the new Mental Health Unit constructed in 2011). As part of the Medical Block construction in 2009 – 2012 an additional section of the Stream was culverted but this did not significantly impact on the stream or add any additional load to the culvert headwall

The overall layout of the hospital campus is shown below.

2.2 Potential Sources of Flooding

2.2.1 Sprackburn Catchment (main risk item)

The main source of risk in relation to flooding at the hospital is the location of the hospital campus in the catchment of the Sprackburn Tributary. The Sprackburn catchment is characterised by a steep channel slope, with woodland/urban landuses and represents an ongoing risk which requires careful management to prevent future flooding incidents. There are two sub-catchments in the overall Sprackburn catchment:

- The main stream (Sprackburn Tributary), which has a catchment area of $0.92km^2$.
- The Northern Tributary, a secondary stream, with a catchment area of $0.47km^2$, which joins with the Sprackburn Tributary on the hospital site. This sub-catchment includes lands that drain to the stream via the open channel, and additional lands that drain via a culvert

Together the combined stream enters a culvert at its headwall to the north of the hospital buildings. The culvert consists of three sections:

- 324m of single bore 1350mm diameter concrete culvert
- 26m of twin 1000mm diameter concrete culverts underneath Circular Road
- 96m of twin 900mm diameter concrete culverts running parallel to Oakfield Terrace, and discharging to an open channel

Together these two sub-catchments cover an area of 1.39km^2.

2.2.2 Surface Water Drainage on the Hospital Site (secondary risk item)

While the most significant risk of flooding at the hospital relates to the Sprackburn Catchment, there is a secondary risk of flooding arising from the surface water drainage around the site itself, and from contributing road drainage which is conveyed to this system. (see Section 4.3.4 outlining planned preventative measures for existing stormwater network, attenuation tank, valves, gully and pipe inspection and cleaning etc).

The total area of this catchment is 0.098km^2, or 6.6% of the overall catchment area of 1.48km^2.

The layout of this drainage system is shown on Drawing 7284-6017 in **Annex C**.

2.3 Peak Flows

'*The Planning System and Flood Risk Management'* (PSRFM) guidance document, published in 2009 by The Department of Environment, Heritage and Local Government (DoEHLG) and the Office of Public Works (OPW), discusses flood risk in terms of three flood zones. Due to the nature of the Hospital is classified as a 'Highly Vulnerable Development' requiring consideration to be made for flood events up to a frequency of 1 in 1000 years (Flood Zone B).

There are no hydrometric gauges located in the vicinity of the site, so quick response runoff was estimated using the Institute of Hydrology Report No 124 (IH124) Flood estimation for small catchments. Peak flows were calculated using catchment descriptors for a number of rainfall events, shown in Table 1.

Table 1 Peak Design Flows for Various Return Periods

Return Period (years)	Flow (m^3/s)	Flow with Climate Change (m^3/s)
5	1.63	1.96
100	3.30	3.96
1000	5.48	**6.58**

The above table outlines the flows that typically can be expected to reoccur once every 5, 100, or 1000 years, with an allowance for the effect of climate change as referred to earlier in this document. For example, over the next 100 years, the estimated peak flow is estimate7d at 3.3 m3/s, increasing to 3.96m3/s taking account of climate change. It should be noted that a 1 in 100 year event does not mean that if such a flood happened this year, it would not happen for another 100 years. It is more accurate to describe the 100 year return period flood as a flood that in any year has a 1 in 100 change of occurring (i.e. 1% chance). Similarly a 1 in 1000 year flood has a probability of 0.1% of occurring in any year.

The existing culvert has sufficient capacity to cater for a 1in 1000 year event.

3. Description and Performance of Culvert Headworks at July 2013

3.1 General Layout

The screens in place in July 2013 at the entrance to the culvert were installed in 2011/2012 after the culvert was extended in 2009 to facilitate the construction of the new A&E Department, and consisted of a coarse screen, approximately 15m upstream of the culvert entrance, followed by a second screen at the culvert entrance itself, as shown in the photos below.

Figure 1: Upstream Trash Screen

Figure 2: Downstream Security Screen

Comparing the screens in place in July 2013 to the guidelines in respect of key physical parameters, the following table summarises what is known about these screens:

Table 2: Description of Screens in Place in July 2013

Parameter	***Upstream***	***Downstream***
Designation (assumed)	Trash	Security
Angle of bars	60	60
Angle to the flow	90	90
Screen area (m^2)	3.2	10.5
Degree of blinding (design)	*Not known*	*Not known*
Bar spacing (centre to centre)	200mm	100mm
Bar shape	Round	Round

3.2 Automatic Monitoring Facilities

No automatic monitoring facilities were recommended or installed at the culvert headworks prior to the events of 26th July 2013.

3.3 Performance of Existing Culvert Headworks on 26th July 2013

The downstream screen blocked on 26th July 2013, as the upstream screen was overwhelmed by the amount of debris arriving at it, part of which transferred to the downstream screen. The photograph below shows the substantial quantity of debris captured by the upstream screen. The screen was completely overwhelmed and in all likelihood a substantial quantity of debris bypassed this screen and made its way to the downstream screen.

Figure 3: Upstream Trash Screen after the Flood

4. Preventative Measures

4.1 Outline of Prevention Strategy

The basic principle of the Flood Management Strategy envisages various levels of protection, that when taken cumulatively, mitigate the risk of flooding at Letterkenny General Hospital. The proposed preventative measures at the hospital are as follows:

A. The provision of adequate screen area upstream of the culvert entrance to prevent excessive debris build up on the culvert entrance screen
B. Ongoing preparedness (including screen maintenance programme) to keep the screens debris free
C. Measures to reduce the debris load in the catchment
D. Suitable automatic monitoring (alarmed water level monitoring and CCTV) that will provide notice of a 'significant event'

Works to deliver items A & D are planned to be completed in August, 2014 as part of the main construction contract, the focus of which are the Primary Protection Measures as discussed later in this report. In the interim, a number of preventative measures have also been put in place pending the completion of this construction contract, and these are discussed in Section 4.6.

4.2 Provision of Adequate Screen Area (Item A)

4.2.1 Proposed Screen Modifications

In the document titled *Flooding at Letterkenny General Hospital: Review of Screen Design, Nov 2013 prepared by Tobin Consulting Engineers,* the following proposals were put forward in relation to screen modifications at the headworks

- The total trash screen area required is $43m^2$
- The total area provided at the existing security screen (to be called '**Screen 4**') is $10.5m^2$. This will perform the dual role of trash screen and security screen and hence its area can be taken into consideration in the calculation of new screen area required, which is $32.5m^2$
- It is proposed to replace Screen 4 with a screen consisting of a bar spacing of 140mm as discussed above.

- A new 'coarse' trash screen is to be constructed approx 15m inside the property boundary, upstream of the confluence of the Sprackburn Tributary and the 'Northern Tributary'. This screen will be called '**Screen 1**' and will be designed to prevent large objects such as oil drums, toys, gas cylinders etc. (as previously experienced in the catchment) from passing and causing blockage to downstream screens. The total screen area provided at this location will be 2.5m^2. The screen angle will be set at 60º to the horizontal.
- The remaining area requirement of 30m^2 will be split between two new structures.
- **Screen 2** will be constructed approx. 30m downstream of Screen 1, and will consist of two stepped screens as shown on Drawing 7284-2014. This will have a bar spacing of 200mm in accordance with Section 8.4 of the *Security and Trash Screen Guide* and will screen debris on the Sprackburn Tributary. A total of 13.5m^2 screen area will be provided here. The screen angle will be set at 60º to the horizontal.
- The existing upstream screen will be demolished and replaced by **Screen 3** which will be constructed approx. 15m upstream of the culvert entrance, and will also consist of two stepped screens as shown on Drawing 7284-2014. This screen will have a bar spacing of 200mm in accordance with Section 8.4 of the *Security and Trash Screen Guide* and will screen debris on the both the Sprackburn Tributary and Northern Tributary. The screen angle will be set at 60º to the horizontal. A total of 16.5m^2 screen area will be provided here.

The area provided by each trash screen is shown in Table 3.

Table 3 Trash Screen Area

Screen	Area (m^2)	Designation
1	2.5	Coarse Trash
2	13.5	Fine Trash
3	16.5	Fine Trash
4	10.5	Security/Trash (main culvert)
5	N/A	Security (overflow culvert)
Total Trash Screen area	**43.0**	

4.2.2 Sequence of Screen Performance in the Event of a Storm (as designed)

In the document titled *Flooding at Letterkenny General Hospital: Review of Screen Design, Nov 2013*, the annual debris load arriving at the screens is estimated to be $75m^3$/yr.

While the screens will be kept largely debris free, in accordance with the Environment Agency's *Security and Trash Screen Guide* the proposed screen design takes account of this worst case scenario where a significant portion of the $75m^3$/yr is mobilized in up to three significant events annually, rather than continuously over a longer duration. During such an event the screens will perform in the following way:

- The coarse trash screen (Screen 1), with a bar spacing of 300mm will quickly be blinded by coarse debris such as plastic drums, toys, traffic cones etc., with finer debris arriving behind and adding to the blinding. This screen is designed as a 'sacrificial' screen to quickly filter out coarse debris, allowing the downstream screens to filter out finer debris. The coarse screen will be overtopped (with water retained in the channel above the screen) and water will continue to Screen 2. The first fine trash screen (Screen 2), with a bar spacing of 200mm will then filter out finer debris such as twigs, leaf litter and anything else not retained at Screen 1. It too is designed to be overtopped and water will continue to Screen 3. An alarmed water level monitor mounted at this location will indicate that the screen has been overtopped.
- The second fine trash screen (Screen 3), with a bar spacing of 200mm will then filter out fine debris from the Northern Tributary and anything else not retained at Screen 2. It too is designed to be overtopped and water will continue to Screen 4 at the culvert entrance. Again an alarmed water level monitor mounted at this location will indicate that the screen has been overtopped.
- The combined security/trash screen at the culvert entrance (Screen 4) is designed to filter out any debris not removed by the three screens upstream. It is not considered likely that the debris load arriving at this location will be significant. Nevertheless a water level monitor mounted downstream of this screen will provide information on the relative water levels either side of the screen.
- If the debris load is such that all of the above four screens become blocked and water cannot enter the 1350mm culvert, the water level will rise to 63.69mOD and will overflow into the proposed storm routing culvert.

- It addition a ‘breach alarm’ will be provided at the culvert entrance to indicate that a breach is about to occur. The bank behind the culvert entrance is to be raised by 1m as part of the proposed works, so that the ‘breach level’ is increased from 64.20mOD (current breach level) to 65.20mOD (proposed breach level).

4.2.3 Sequence of Culvert/Overflow Culvert Performance in the Event of a Storm (as designed)

The design rationale for the proposed overflow culvert is that it will only come into operation when the water level reaches the soffit level of the existing culvert, which is 63.69m. This will happen when Screen 4 becomes blinded to such an extent that water cannot enter the main culvert.

4.3 Ongoing Preparedness (Item B)

4.3.1 Ongoing Screen Maintenance Programme

The following protocols have been put in place for the ongoing maintenance of the proposed screens at the headworks:

Normal Inspection Routine:

- The responsibility for the overall management and monitoring of the Sprackburn stream will rest with the Facilities Manager through the Maintenance Department at Letterkenny General Hospital.
- The Maintenance Foreman will monitor the 5 day weather forecast and relevant rainfall alerts in order to inform his future actions.
- The relevant Heath & Safety precautions as per The Safety, Health and Welfare at Work Act 2005 must be adhered to at all times.
- A member of the Maintenance Staff (weekdays) or Security Staff (weekends and Public Holidays) will be allocated to inspect the screens daily, between 3.30pm and 4.30pm. All actions should be recorded in the log-book and photographs should be taken. Any significant volume of debris removed should also be photographed.
- All Inspections / Actions taken are logged on the following sheet

Daily Inspection Log

Record/Log of Sprackburn Stream Management and Monitoring

Date	Time	Water Level	Action Taken	Signed

Date	Time	Detailed Actions if relevant

4.3.2 Monitoring of Weather Forecasts and Warnings

Met Eireann have recently implemented a new system for weather warnings. It is proposed that Status Orange and Status Red Rainfall Warnings be used to anticipate significant events at Letterkenny General Hospital, but recognizing that the possibility remains of localized rainfall events that would not be covered by such warnings (**eg. the rainfall of 26th July 2013 would not have been subject to such a Weather Warning, given that it was quite localized, hence the importance of local monitoring at the culvert entrance**).

The following text is taken from the Met Eireann website.

STATUS ORANGE - Weather Warning - Be Prepared
This category of ORANGE level weather warnings is for weather conditions which have the capacity to impact significantly on people in the affected areas. The issue of an Orange level weather warning implies that all recipients in the affected areas should prepare themselves in an appropriate way for the anticipated conditions.

STATUS RED - Severe Weather Warning - Take Action
The issue of RED level severe weather warnings should be a comparatively rare event and implies that recipients take action to protect themselves and/or their properties; this could be by moving their families out of the danger zone temporarily; by staying indoors; or by other specific actions aimed at mitigating the effects of the weather conditions.

When will Weather Alerts/Warnings be issued?

Weather Alerts and Warnings will be issued whenever weather conditions meeting the detailed thresholds defined below are anticipated within a 48-hr period. There will be judgement required on the part of the forecaster who must weigh up the possible severity of the weather conditions and the likelihood of their occurrence. However on some occasions (weekends, holiday periods) it may be necessary to issue Weather Warnings beyond this 48-hr horizon, if sufficient certainty derives from examination of the weather charts. Normally, however, a Weather Advisory (see below) will be used to flag severe weather beyond 48hrs and Advisories will normally anticipate only "Orange" or "Red" criteria weather hazards.

Given that the thrust of the Weather Warnings service is on potential "Impacts" of weather rather than on the numerical values attained by the weather elements themselves, it may on occasion be appropriate to issue warnings at a level higher than that strictly justified by the anticipated weather elements. An example would be when heavy rain was expected which might not quite meet the "Orange Warning" criteria but which might give rise to significant flooding because of already saturated ground, or because of a combination of rain, wind and tide in a coastal location.

Weather Warning Criteria (rainfall only)

The criteria for an Orange Weather Warning is as follows:

- *50mm – 70mm in 24 hrs*
- *40mm – 50mm in 12 hrs*
- *30mm – 40mm in 6 hrs*

The criteria for a Red Weather Warning is as follows:

- *70mm or greater in 24 hrs*
- *50mm or greater in 12 hrs*
- *40mm or greater in 6 hrs*

4.3.3 Increasing Preparedness in Response to Weather Warnings

The proposed responses to weather warnings (rainfall) are as follows:

- **Orange** Rainfall Warning:
    - Check that Normal Inspection Regime is in place
    - Check Catchment Area (Zones 1 and 2)
    - Confirm Availability of Personnel

- **Red** Rainfall Warning:

In addition to actions undertaken in response to an Orange Rainfall Warning, the following actions are to be undertaken in response to a Red Rainfall Warning.

- All catchment zones and screens will be monitored and maintained constantly by at least two Maintenance Staff. All other Maintenance Staff should be put on stand-by notice.
- A mechanical digger and driver will be mobilised.
- The General Manager and Hospital Facilities Manager will be informed of the situation and the Hospital Duty Manager (Bleep 403) updated hourly.
- A check will be undertaken that Tertiary Protection Measures are ready for immediate deployment

4.3.4 Maintenance of the Existing Storm Water Network within the Hospital Site

Maintenance of the storm water network around the hospital site shall be undertaken in compliance with ISEN 752:2008 Drain and Sewer Systems Outside Buildings (or later edition). An extract from this document is included in **Annex A**.

4.4 Measures to Reduce the Debris Load in the Catchment (Item C)

4.4.1 Catchment Inspections

It is recognized that debris load was a major contributing factor in the event of 26th July 2013. Based on accounts from the personnel who removed the material and from our inspection of material taken from the screens, the debris consisted of a wide range of material, including tree branches (large and small), domestic rubbish, tyres and other items including barbeques, gas cylinders and large items of plastic. **The presence of such loose material in or adjacent to the stream or capable of being washed into the stream by heavy overland flows was a major contributory factor to the flood event.**

The catchment can be divided into three distinct zones as shown in Figure 4 below.

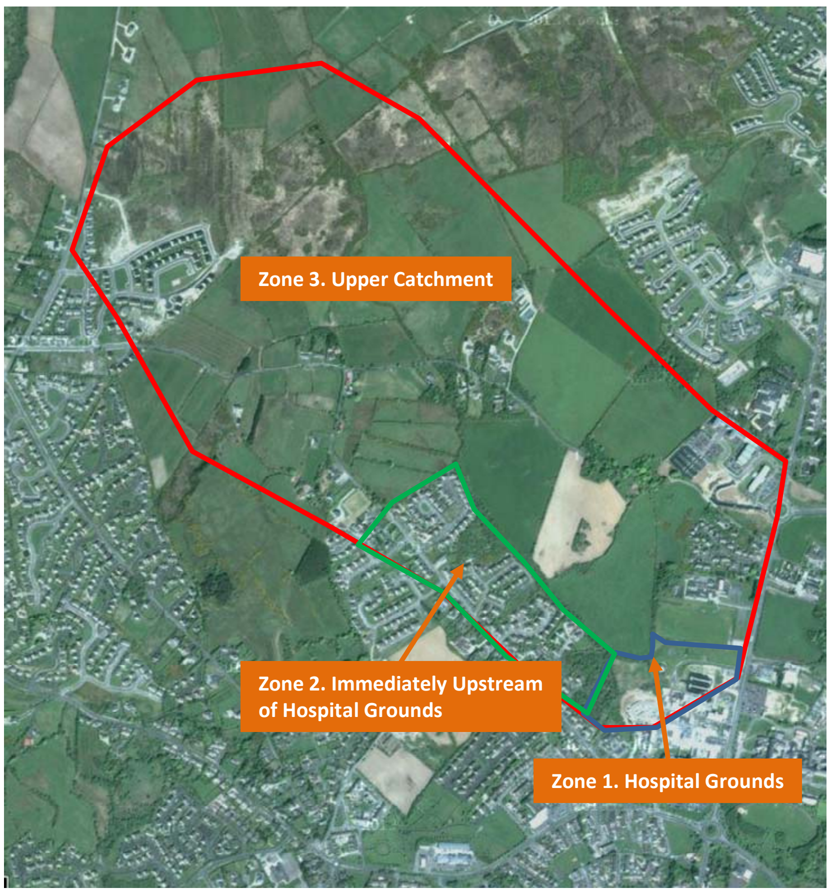


Figure 4: Catchment of the Sprackburn Tributary

The catchment has been examined in detail and the inspection regime can now be broken down into three distinct zones:

- **Zone 1**: that portion which lies on HSE owned lands and where inspections are easy to conduct and hence should be carried out daily. This only covers a small portion of the overall catchment area however.
- **Zone 2:** that portion which lies immediately upstream of HSE owned lands but can be accessed via public roads running north off Long Lane (eg. Ballyboe & Hazelbrook Crescent): It is recommended that a visual inspection of the stream is carried out from those locations on a weekly basis, with a focus on household generated debris.
- **Zone 3:** the upper catchment, beyond the limit of housing on Long Lane: This is more difficult to access and requires landowner agreement to do so. It is recommended that for this upper catchment, agreement is secured with the relevant landowners to allow access for inspection & commitment on the part of the landowners to remove any risk materials/debris identified, it is further recommended a visual inspection of the stream is carried out on a monthly basis, and/or during a significant dry spell in the summer where the ground would be hard and rainfall runoff rates would be high following heavy rainfall. There should be a focus on non-household debris such as branches in these inspections.

Catchment inspections should include:

- Time and date stamp photographic record of the stream (Zones 2 and 3 only), noting any buildup of domestic or other significant debris
- Inspections should be recorded in a log book and signed by the person undertaking the inspection
- Inspections should note in particular the presence of potentially floatable debris from areas where properties back on to the stream

4.4.2 Local Awareness & Community Liaison

Debris arriving in hospital property from outside the catchment has been identified in the analysis of the storm event of 26th July 2013, as being a contributing factor to the breach which occurred.

Section 6.3.4 of the *Security and Trash Screen Guide* (UK Environment Agency, 2009), states that:

> *Reducing large household refuse (such as furniture, mattresses and carpets) is likely to have a significant impact on debris load. Enforcement action by the local authority and/or waste regulation staff may be necessary to reduce the volume of this kind of debris. It may be possible to reduce the debris load from large household refuse by a public awareness campaign at the fly-tipping hotspot.*

The following proposals are put forward for a Public Information Campaign, organised by Hospital Management in conjunction with the Local Authority and public representatives to increase local awareness in relation to fly tipping of debris in the catchment:

- Meeting with local residents and landowners within the stream catchment
- Press releases/updates, as appropriate

4.5 Automatic Monitoring (Item D)

4.5.1 The Need for Automatic Monitoring

The need to install automatic monitoring at the headworks, and the extent of that monitoring , is based on an analysis of the risk of a blockage of the screens (including an analysis of debris load, flood frequency etc.) , and the consequences of such a blockage. In Section 4.7 of the *Security and Trash Screen Guide*, the following considerations are discussed in terms of reducing the overall risk profile associated with a screen blockage:

- An assessment of the need for CCTV monitoring
- An assessment of the need for automatic water level monitoring

The decision to install CCTV and water level monitoring is based on a Design Risk Assessment, in accordance with Table 4.4 of the document which is reproduced below as Table 4. This risk assessment combines probability (of a blockage occurring) and consequence (if it does occur).

Table 4 Design Risk Assessment

Blockage of culvert	Score				
	5	4	3	2	1
Probability	**More frequently than one in two years**	**One in two to one in five years**	**One in five to one in 10 years**	**One in 10 to one in 25 years**	**Less frequently than one in 25 years**
	Regular recorded blockage (e.g. once or twice in the last two years).	Some record of blockage (e.g. once or twice in the last five years) or Culvert size under one m^2, catchment urban or woodland.	Culvert size under one m^2 and at least 50 per cent urban or woodland or Culvert size over one m^2 and under three m^2 with potential blockage points.	Culvert size over one m^2 and under three m^2 or Culvert size over three m^2 with no upstream public access.	Culvert size over three m^2
Consequence	**Over £1 million**	**£100,000 to £1 million**	**£10,000 to £100,000**	**£1,000 to £10,000**	**Under £1,000**
	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).
Damage caused by debris to infrastructure of culvert	**Score**				
	5	4	3	2	1
Probability	**More frequently than one in two years**	**One in two to one in five years**	**One in five to one in 10 years**	**One in 10 to one in 25 years**	**Less frequently than one in 25 years**
	Impact damage to structure from debris in flow (e.g. once or twice in the last two years).	Impact damage at frequency of once or twice in the last five years.	Some impact damage possible due to size of debris.	Low but some possibility of impact damage.	Rare likelihood of damage or no impact damage possible.
Consequence	**Over £1 million**	**£100,000 to £1 million**	**£10,000 to £100,000**	**£1,000 to £10,000**	**Under £1,000**
	Repairs involving diversion of watercourse and works to full length of culvert.	Repairs involving significant temporary works and works to more than half of culvert length.	Repairs involving some temporary works and repairs to less than half of culvert length.	Repairs requiring no temporary works.	Minor repairs required, not in urgent need of attention. May be encompassed in general maintenance.

The guidelines state that:

> *Any proposed screen site with a consequence score of five, for either blockage or damage (see Table 4.4), must have remote water-level monitoring installed, linked by telemetry to an operational centre and should have CCTV as an integral part of the scheme. Any proposed screen site with a consequence score of four, for either blockage or damage (see Table 4.4), must have remote water-level monitoring installed, linked by telemetry to an operational centre as an integral part of the scheme. In this scenario the installation of CCTV should be considered. At all other sites, remote water-level monitoring must be considered as part of the Design Risk Assessment. It can only be omitted where the risk can be acceptably mitigated or the consequence is negligible.*

In relation to Letterkenny General Hospital, looking at the *Probability* of a culvert blockage, and the *Consequence* of such an event in terms of the impact on the hospital, this would suggest that both water level monitoring and CCTV are required at the trash screens.

4.5.2 Proposals for Water Level Monitoring

It is proposed to retain and/or install the following facilities for automatic water level monitoring at the headworks:

- The existing water level monitor immediately upstream of the culvert entrance (Screen 4) is to be retained (designated as **WL4**)
- A new water level monitor is to located inside (Screen 4) at the culvert entrance (to provide data on differential level u/s and d/s of that screen) (designated as **WL4A**)
- A new water level monitor is to located at the new Screen 5 (overflow culvert) to provide data on levels in excess of the soffit level of the existing culvert (designated as **WL5**)
- A new water level monitor is to located at the coarse trash screen (Screen 1) to provide data on the likelihood of overland flow occurring at that location (designated as **WL1**)

The location of these monitors is shown in Figure 5 below.

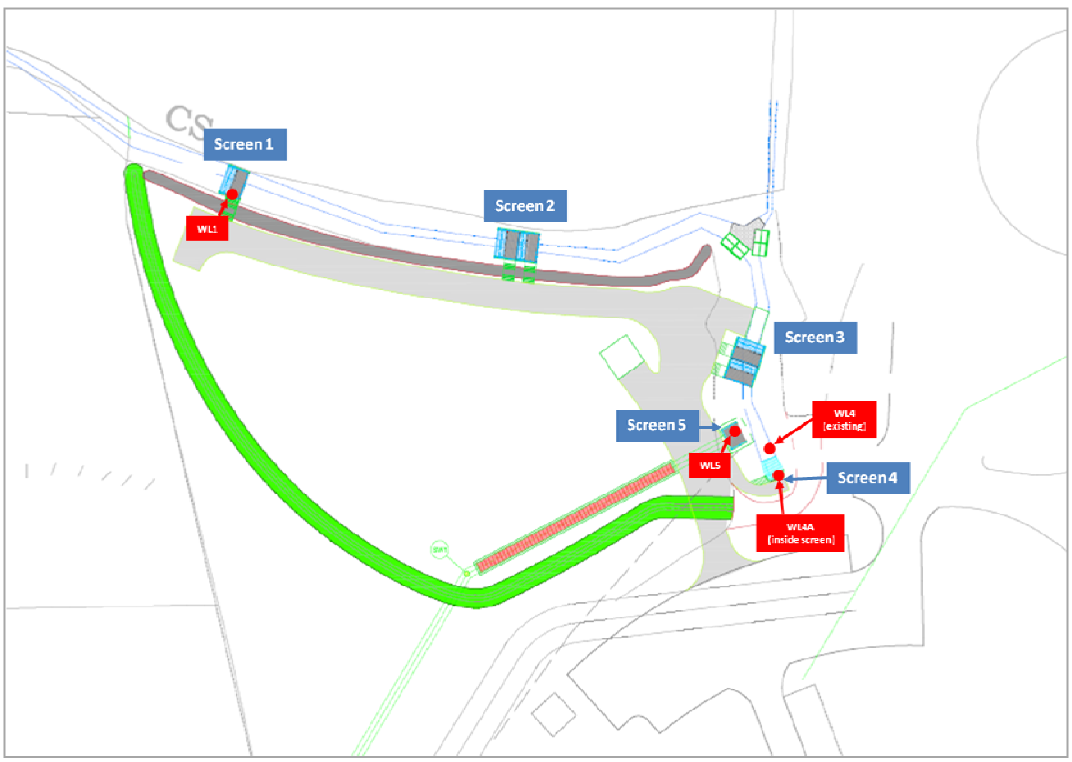


Figure 5: Location of Water Level Monitors and Screen Designation

4.5.3 Proposals for Setting Alarms

A significant body of water level data will now be available at the headworks, and setting appropriate alarm levels is a central part of this Strategy. There is a balance between on one hand providing useful data that informs maintenance staff and allows an effective response, but on the other hand avoiding 'alarm fatigue' where numerous unnecessary alarms are raised, resulting in the alarms being ignored. Water level data from the existing monitors has been examined and the following alarms are now proposed. It is proposed that water level data is reviewed over a period of 6 months and the alarm set levels altered accordingly.

Table 5 Proposed Alarm Settings

Data Received from monitor	Alarm #	Message Conveyed	Reason for Alarm	Setpoint (mOD)	Setpoint (other)
WL4	Alarm 1	*300mm depth u/s of culvert*	Early indication of significant rise in water level at culvert entry	**63.00**	
WL4	Alarm 2	*Spill into overflow culvert*	Indicates that water is about to spill into the overflow culvert	**63.69**	
WL4	Alarm 3	*Breach level*	Indicates that water has reached the breach level at the culvert entrance (i.e. top of the raised bank) and is about to overtop the bank	**65.20**	
WL1	Alarm 4	*Screen 1 blocked and overtopped*	Indicates that water has reached platform level at Screen 1	**67.77**	
WL4	Alarm 5	*Rate of Rise*	Indicates that either the culvert entry screen is heavily blinded, or water level is rising rapidly despite a clear screen		**>30mm/min**
WL4 & / WL4A	Alarm 6	*Level Differential (u/s & d/s of Screen 4)*	Indicates that the culvert entry screen (Screen 4) is heavily blinded		**> 1.0m between u/s and d/s water level at culvert entry screen (Screen 4)**

These alarm levels are shown graphically in Figure 6 below.

Figure 6: Proposed Alarm Levels

(note: photo does not reflect the current setup at Screen 4)

4.5.4 Proposals for CCTV

While the focus of this Flood Management Strategy is to provide engineering solutions in the first instance to protect the hospital, supported by automation in relation to water level monitoring, the inclusion of CCTV monitoring is seen as beneficial in providing an additional layer of protection in the following ways:

- As a 'sense check' to allow operators to check that alarms that are generated from water level monitoring are reflective of the actual situation at the headworks
- To provide a remote view on water levels at the headworks

It is proposed to install CCTV at the following locations at the headworks:

- The existing fixed position CCTV camera is to be retained at the culvert entrance (designated **CCTV4**)
- A new variable position CCTV camera is to be installed at Screen 2 (designated **CCTV2**). Under normal circumstances this point at the screen to show the degree of blinding there, but can be rotated remotely to pan over 270 degrees upstream to show if overland flow is taking place. The camera will be installed such that it will return to the 'normal' position if idle for 30 seconds.
- A new variable position CCTV camera is to be installed at the junction of the Sprackburn Tributary and the Northern Tributary (designated **CCTV3**). Under normal circumstances this point at the Screen 3 to show the degree of blinding there, but can be rotated remotely to pan over the junction of the two streams at the overflow culvert entrance. The camera will be installed such that it will return to the 'normal' position if idle for 30 seconds.

The location of these CCTV cameras is shown in Figure 7.

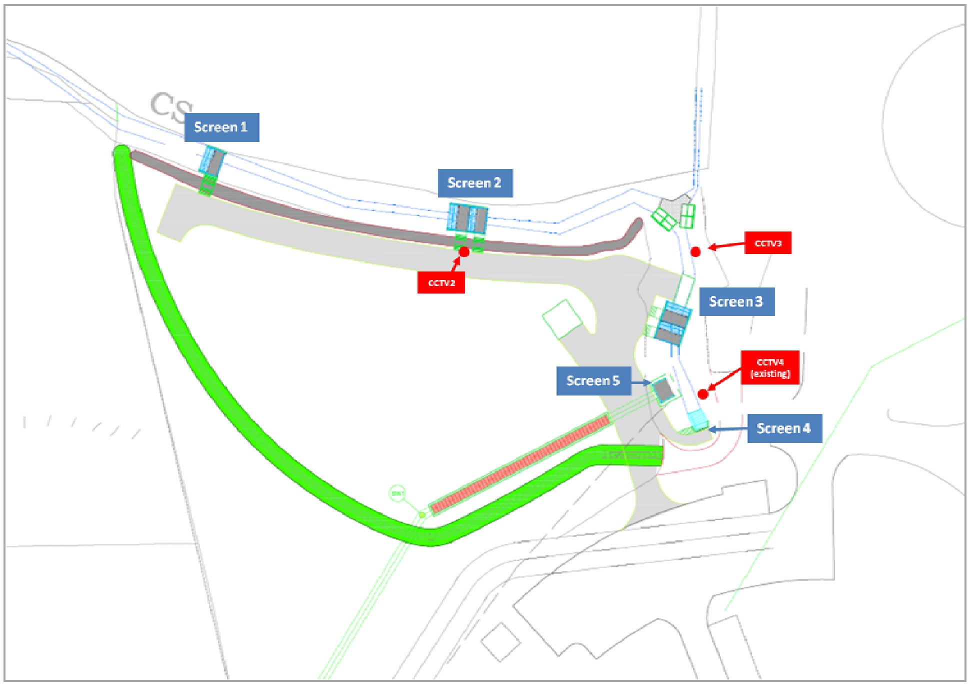


Figure 7: Location of CCTV Cameras

It is proposed to hard-wire each of these cameras to the Maintenance Building as there have been issues with WiFi signal in the past.

The data from the three CCTV cameras will be permanently displayed on a dedicated screen in the Maintenance Building and recorded separately on a dedicated disc to give longer storage and prevent accidental erasing. Data from all significant events are to be retained for a minimum period of 12 months. It is further proposed that designated personnel will be able to access this display screen on their smartphones.

4.6 Interim Preventative Measures

As discussed above a number of preventative measures have been put in place pending the completion of the construction contract. There are as follows:

- A CCTV camera has been erected at the main culvert entrance screen
- Water level monitoring has been installed at the main culvert entrance screen and also at the upstream screen. This facility generates alarms which are conveyed to operations personnel
- There has been an increase in visual inspections at the headworks, coupled with an increase in routine debris removal from the screens
- A Maintenance Protocol has been put in place and accepted as warranty by Allianz, see Annex D

5. Primary Protection Measures

It is proposed (at the time of writing, i.e. Feb 2014) to construct a new ‘storm routing’ culvert at Letterkenny General Hospital, to mitigate the risk of a repeat of the flood event of 26th July 2013 that caused extensive damage to hospital buildings.

The basic principle of this new culvert is that it would come into operation in the event of a blockage to the existing 1350mm culvert, to prevent overland flow. For this reason it will be designed to pass the entire flow during a design storm, and will not operate in parallel with the existing culvert.

The catchment contributing to the new culvert is limited to that upstream of the entrance to the existing culvert. The drainage area contributing to intermediate connection points to the existing culvert, for example road drainage from the Kilmacrennan Road, will continue to discharge to the old culvert in the event of a blockage at the culvert entrance.

The new culvert is to be constructed from immediately upstream of the existing screens, to the connection point downstream of the hospital, as shown in Figure 8.

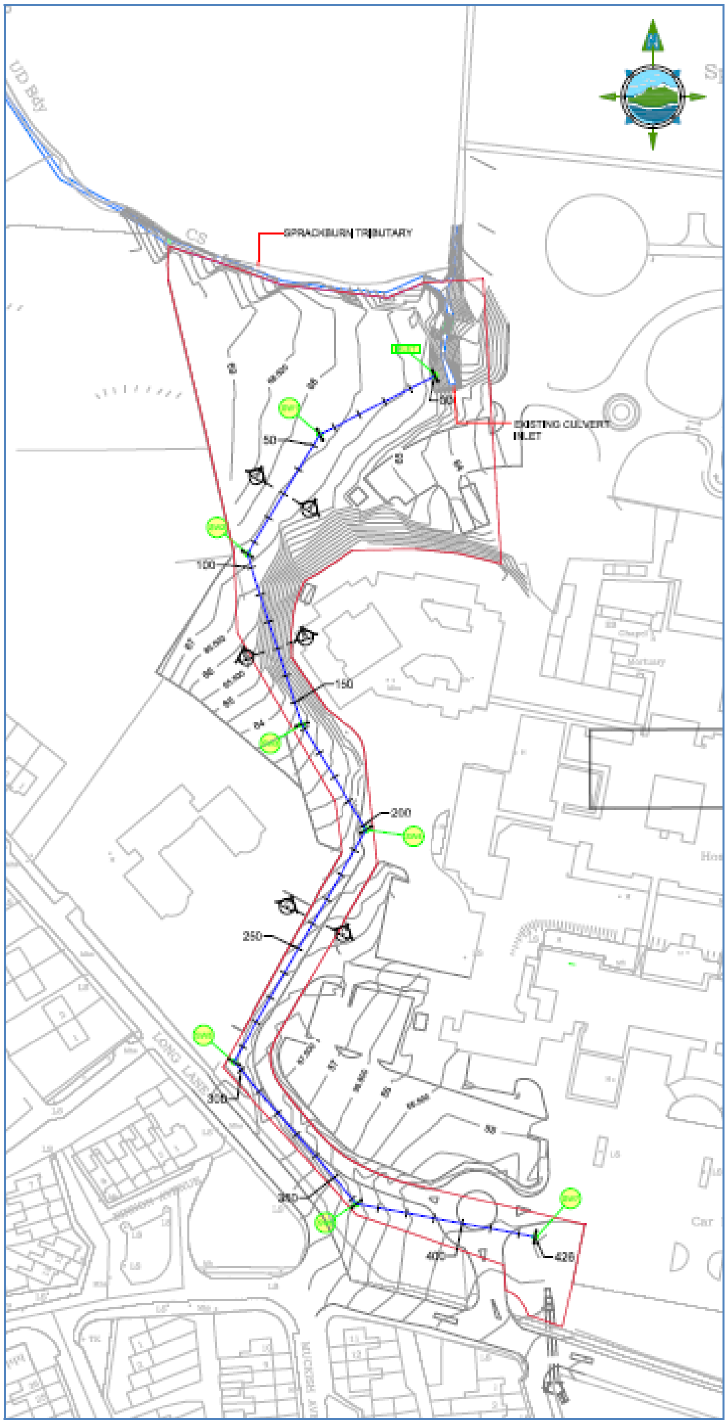


Figure 8: Route of Proposed Overflow Culvert

6. Secondary Protection Measures

Assuming that preventative and primary protection measures fail, and water leaves the stream channel and becomes overland flow, it is proposed (at the time of writing, i.e. Feb 2014) to construct an Interception Channel to return flow to the proposed overflow culvert. In this way overland flow will not spill towards the hospital buildings, but will instead be conveyed around the buildings via the overflow culvert.

Berms will be constructed at the headworks to divert overland flow into the Interception Channel, as shown in Figure 9.

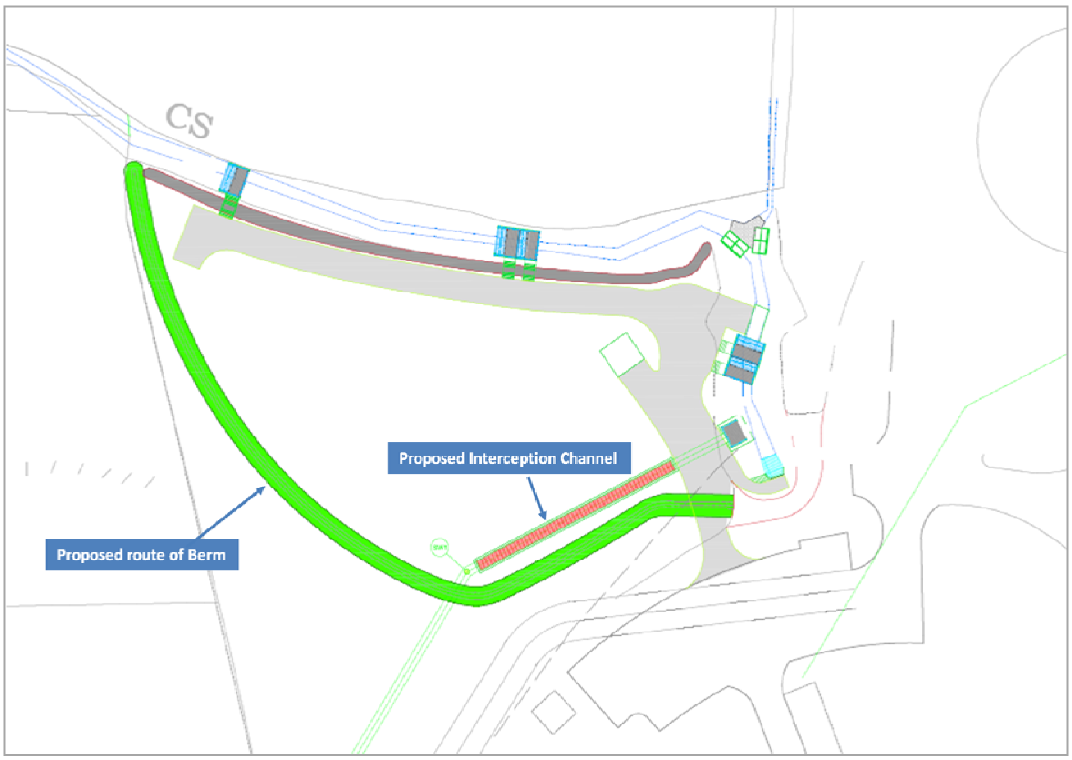


Figure 9: Interception Channel and Berm

7. Tertiary Protection Measures

7.1 Proposed Building Protection Measures

The focus to date has been on Primary and Secondary Protection measures as described earlier in this document. In the unlikely event that the above measures fail, and a breach occurs, it is proposed to install appropriate Tertiary Protection measures closer to the existing buildings.

As this is a specialized area, it is proposed to invite Specialist Flood Protection companies to visit and survey the site, and, taking on board the Primary and Secondary measures proposed, make submissions with respect to further Tertiary Protection measures. It is expected that such measures will involve making provision for the quick installation of flood gates at entrances to the buildings, making provision for the rapid installation of flood barriers, etc.

These proposals will be assessed and recommended solution(s) will be implemented. It is proposed to go to the market in March 2014 and have Tertiary Protection measures in place by end August, 2014.

7.2 Deployment of Building Protection Measures

To be completed following the approval/installation of the recommendations referred to above.

8. Alarm Response Protocols

8.1 Alarm Response Protocols

8.1.1 Communication of Alarms

(note that the actions below include elements of the current alarm response protocols, February, 2014)

Actions in Response to Alarms 1 and 4 (i.e. early warning alarms)

- Automatic text message to nominated mobile phone numbers as per Appendix 1.
- Maintenance Staff will check the screens between normal working hours* and Security will check the grills at all other times.
- All debris to be removed immediately.
- All removed debris to be logged and photographed.

Actions in Response to Alarms 5 and 6 (i.e. alarms generated prior to a likely deployment of personnel that indicate a serious problem at the headworks)

- Automatic text message is sent to nominated mobile phone numbers
- Automatic telephone call from control centre to the Security mobile phone and in the event of not being able to contact Security, the control centre will contact hospital reception, to inform them of the rise in water levels. Hospital Reception will contact Hospital Security and Maintenance.
- Nominated *Sprackburn Maintenance on-call person* to attend promptly on site as per agreed roster.
- All debris to be removed immediately and in the event of significant debris additional maintenance staff should be called.
- All removed debris to be logged and photographed.
- Maintenance Foreman on duty should attend promptly on site and assume the role of Incident Manager.
- In the absence of the Maintenance Foreman, the Nominated Maintenance Sprackburn on call person will assume the role of Incident Manager.
- Incident Manager to update Hospital Duty Manager (Bleep 403) and provide an update every 20mins.
- In the event of significant concerns the Maintenance Manager, the Facilities Manager, General Manager, the Deputy General Manager, and the Director of Nursing & Midwifery should be called.

Actions in Response to Alarms 2 and 3 (i.e. additional alarms likely to be generated when personnel have already been deployed to the headworks, but which provide additional data such as an imminent spill into the overflow culvert or an imminent breach)

All measures as per Alarms 5 and 6, plus the following:

- All Tertiary Protection Measures to be put in place.
- Hospital Major Incident Plan will be initiated.
- All relevant external contractors & emergency services to be mobilised, such as:
    - Fire Brigade
    - E.S.B.
    - D.S. Environmental

(Note that maintenance normal working hours: 8am to 4.30pm Mon to Thurs and 8am to 3.30pm on Fri)

8.1.2 Incident Manager

It is proposed that for every response to a *Significant Event*, an Incident Manager will be nominated. This nomination is required for every *Significant Event* so that it is clear to all response personnel which person on-site has the authority to exercise 'Command and Control' and to direct personnel as is necessary. The position of Incident Manager carries the following responsibilities:

- The Incident Manager must be part of the response team for the incident (i.e. they will not necessarily be the most senior person in the organization)
- They will have sufficient authority to direct resources as required
- They will make it clear to all response personnel that they are acting as Incident Manager
- They will record in a Log Book that they acted as Incident Manager for that incident
- They will have responsibility for keeping a log of the incident (times, personnel deployed etc.) and for notifying key stakeholders
- Only the Incident Manager will have the authority to decide if the culvert entry screen is to be collapsed to prevent flooding

8.1.3 Sequence of Debris Clearance from Screens

It is important to note that Screens 1, 2 and 3 are designed to become fully blocked and overtopped during a storm event. Consequently all efforts in relation to clearance of screen debris during a storm (as opposed to routine maintenance) need in the first instance to be concentrated at the main culvert entry screen (Screen 4), and then at the upstream screens only when water levels recede and the danger of overland flow has passed.

8.1.4 Collapsing the Main Culvert Entrance Screen (Screen 4)

The proposed upgrade works at the headworks will include the facility to collapse the culvert entry screen. It should be noted that this is a measure that is only to be utilized as a last resort if the Incident Manager decides that all other measures to protect the buildings on the hospital campus from flooding have failed. Collapsing this screen will transfer the debris load into the culvert and may cause downstream problems and/or blockages, and will require a post-event cleanup operation. The installation of a penstock on the main culvert entry screen however will facilitate this cleanup by allowing flow to be diverted into the overflow culvert.

8.2 Availability and Deployment of Suitably Trained Personnel

The alarm response protocol as detailed in Section 8.1 of this Strategy details the deployment of Maintenance Staff.

In the unlikely event of an imminent breach at the headworks (i.e. Alarm 3), the Hospitals Major Incident Plan will be activated.

8.3 Media Communications

The Hospital General Manager or designated deputy will liaise with all external media through the Hospital Group Communications Department.

9. Safety and Health of Personnel

9.1 Facilitating Screen Maintenance

Screen cleaning is covered under Section 11.1 of the Security and Trash Screen Guide and has been used in the development of maintenance facilities at the screens. It is important to provide the necessary facilities to allow screen maintenance to be undertaken safely, both routinely, and during the often difficult conditions that exists during a storm event.

The following safety provisions are proposed to facilitate screen maintenance.

- Access platforms with a working depth of 2m to allow manual raking
- The maximum reach for manual raking will be set as 2m, and this will allow temporary storage of material on the platform.
- Edge protection will be provided at all screens
- It will be possible to access the immediate vicinity of all four screens with a hiab lorry and/or tracked excavator to remove larger items and to transport away debris.
- A concrete plinth and skip will be provided for the temporary storage of debris removed from the screens.
- All screens will be floodlit
- Access steps will be provided to all platforms
- A welfare hut will be provided immediately adjacent to the headworks

9.2 Access to Existing and Proposed Culverts

It will also be necessary to access the existing and proposed culverts to provide ongoing maintenance and jetting. In the first instance, maintenance staff will follow hospital Standard Operating Procedures for such work, but to facilitate such access the following proposals are made:

- A penstock will be installed on the inlet to the existing culvert. This will allow flow to be shut off to this 324m long culvert and diverted to the overflow culvert. It should be noted that there are a number of intermediate connections to the existing culvert, in particular the 600mm connection approximately half way along the culvert.
- Intermediate access points are being provided on the overflow culvert at manholes. Working platforms are being provided at each of these locations.

9.3 Particular Safety Measures During a Storm

As mentioned above difficult conditions often exist during a storm event, at the very time which required targeted screen cleaning and debris removal. It is recognized that this is a particularly hazardous time for operatives, and consequently the following measures are proposed to mitigate the risk to the safety of personnel.

9.3.1 Lone Working

While routine debris clearance from the screens can be carried out by one operative, it will be standard operating procedure that a minimum of two persons are deployed to respond to a storm event.

9.3.2 Harness Connection Points

Harness Connection Points will be provided on a secure surface at each of the screens. When operatives need to step onto any of the screen platforms during a storm event, it will be mandatory for them to wear a harness that can be secured to a Harness Access Point.

10. Administration of the Strategy

10.1 Training

The effectiveness of this Strategy is heavily dependent on the personnel that have a role in its implementation. Consequently it is proposed to provide training and rehearsal for personnel, to include the following;

- Relevant Health and Safety Training for the various tasks
- Catchment Inspections (frequency and recording)
- Appropriate Screen Maintenance Procedures including periodic review
- CCTV and Water Level Alarms
- Deployment of Penstock and collapsing of Culvert Entrance Security Screen
- Deployment of Tertiary Protection Measures

10.2 Awareness of the Strategy

The Strategy will be communicated to all relevant hospital staff through the Hospital Governance Structure, i.e. HEB; HMB; Heads of Department briefings; Facilities Management Team meetings.

The Strategy will also be shared via the LGH/PCCC Management Meeting.

Broader awareness of the strategy will be achieved through the Public launch of the Strategy and the annual stakeholder review.

10.2.1 Rehearsal of Response Measures

Appropriate simulations for the various relevant responses will be conducted and reviewed on an annual basis.

10.3 Integration with Hospital Major Incident Plan

Letterkenny General Hospital has a Major Incident Plan in place for extreme events, and it is important to define the boundaries between this Strategy and the Major Incident Plan to ensure that the response to a flooding event, or a potential flooding event is clearly set out and that there is a clear understanding of responsibilities in an emergency.

It is proposed that this Flood Management Strategy be used as the primary tool to prevent and respond to flooding events. However, it is recommended that the overlap between this Strategy and the hospital's Major Incident Plan be reviewed in light of the development of this Strategy.

10.4 Review of the Strategy

It is proposed that this document be retained as a 'live' document that is reviewed either periodically, or as necessary following a Significant Event. It is not intended that the document be prepared as a once-off to satisfy a short-term need, but instead it should be a useful tool in the overall flooding risk mitigation at the hospital site.

10.4.1 Responsibility for Review

The Hospital Facilities Manager will instigate a review of this strategy on an annual basis or after a significant event. The review will include all stakeholders, Hospital Maintenance personnel, Hospital Management and HSE Estates

10.4.2 Review and Reporting on effectiveness of Strategy

The Hospital Facilities Manager will convene a Steering Group Meeting (annually) to review the strategy, incidents and significant events for the period and will commission an annual report.

The Annual Report will be written by the Hospital's Facilities Dept and should include the following information:

- Number of significant events with details of each event.
- Record and details of debris collected.
- Relevant data from water level alarms etc.
- Any recommendations to steering group.

The Steering Group will meet at least yearly and should be made up of representatives from Donegal County Council, OPW, local relevant housing association reps, Hospital rep and Estates Rep. The agenda should include the discussion of the Annual Report as detailed above and all actions arising from this report

Annex A ISEN 752:2008 Drain and Sewer Systems Outside Buildings

National Standards Authority of Ireland
Údarás um Chaighdeáin Náisiúnta na hÉireann

IRISH STANDARD

I.S. EN 752:2008

ICS 93.030

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DRAIN AND SEWER SYSTEMS OUTSIDE BUILDINGS

This Irish Standard was published under the authority of the National Standards Authority of Ireland and comes into effect on:
4 April 2008

Price Code AB

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I.S. EN 752:2008

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 752

January 2008

ICS 93.030

Supersedes EN 752-1:1995, EN 752-2:1996, EN 752-3:1996, EN 752-4:1997, EN 752-5:1997, EN 752-6:1998, EN 752-7:1998

English Version

Drain and sewer systems outside buildings

Réseaux d'évacuation et d'assainissement à l'extérieur des bâtiments

Entwässerungssysteme außerhalb von Gebäuden

This European Standard was approved by CEN on 24 November 2007.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 752:2008: E

Contents

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Foreword

This document (EN 752:2008) has been prepared by Technical Committee CEN/TC 165 "Wastewater Engineering", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2008, and conflicting national standards shall be withdrawn at the latest by July 2008.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 752-1:1995, EN 752-2:1996, EN 752-3:1996, EN 752-4:1997, EN 752-5:1997, EN 752-6:1998, EN 752-7:1998.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

Drain and sewer systems are part of the overall wastewater system that provides a service to the community. This can be briefly described as:

— removal of wastewater from premises for public health and hygienic reasons;

— prevention of flooding in urbanised areas;

— protection of the environment.

The overall wastewater system has four successive functions:

— **Collection**;

— **Transport;**

— **Treatment;**

— **Discharge.**

Drain and sewer systems provide for the collection and transport of wastewater.

Historically, drain and sewer systems were installed because there was a need to remove the polluted water to prevent diseases.

Traditionally, drain and sewer systems were constructed to collect and transport all types of wastewater together irrespective of the initial source. This led to difficulties in handling the peak flows in times of heavy rainfall and to the introduction of combined sewer overflows, which discharged polluted water to surface receiving waters.

It was later recognised that separate systems, where foul wastewater was kept separate from runoff derived from surface water, would be an improvement over such combined systems.

Although many drain and sewer systems started out as combined systems there are strong arguments for considering the separation of foul wastewater and surface water. The pollutant effects are not the same and the separation of effluents allows for the different treatment for each element of wastewater, providing more environmentally friendly solutions.

This concept is included in the approach of integrated sewer management.

EN 752 provides a framework for the design, construction, rehabilitation, maintenance and operation of drain and sewer systems outside buildings. This is illustrated in the upper part of the diagram below. EN 752 is supported by more detailed standards for the investigation, design, construction, organisation and control of drain and sewer systems such as those listed in the lower part of the diagram. To support these detailed standards information will come from specifications produced by individual organisations for their own use. Product standards should also take into account the functional requirements in EN 752 through EN 476, EN 773, EN 1293, EN 13380 and EN 14457.

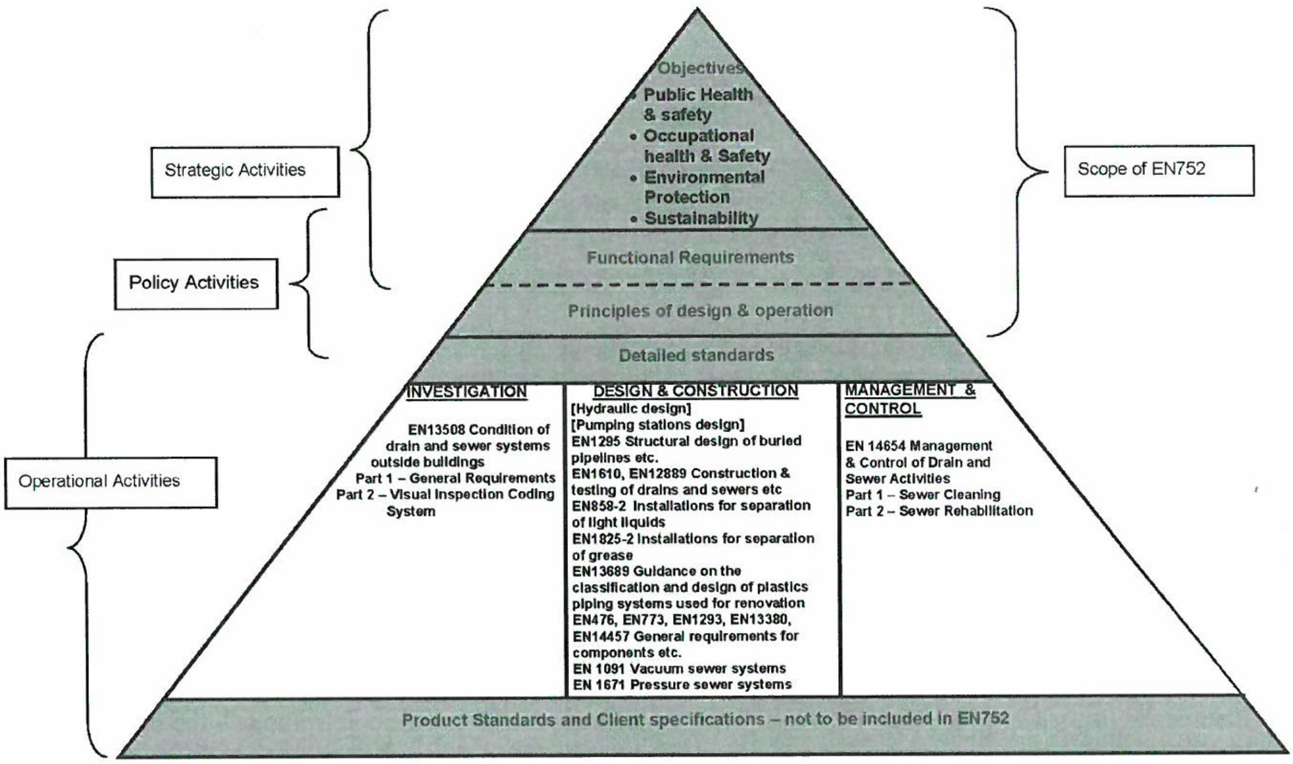

Figure 1 — Pyramid Diagram

— flow performance;

— water tightness;

— proper structural embedment.

For ancillaries the performance requirements specified in relevant European product standards should be taken into account. Grease separators shall be installed in accordance with EN 1825-2. Separator systems for light liquids shall be installed in accordance with EN 858-2.

11 Operations and Maintenance

11.1 Introduction

The purpose of operations and maintenance is to ensure that the drain and sewer system perform in accordance with the functional requirements defined in clause 5 and in accordance with any operations and maintenance plan (see 6.4).

Operations include:

— starting or stopping pumps;

— inserting dam boards;

— regulating valves and weirs;

— using detention tanks;

— acting in accordance with contingency and emergency plans;

— measuring wastewater quality;

— inspecting periodically;

— pest control (see C.10);

— making connections to existing drains and sewers (see C.11);

— control of disused drains and sewers (see C.12);

— control of building activities over or adjacent to sewers (see C.13).

Urgent interventions that are generally intended to be temporary are included in operations.

Maintenance includes:

— local repair or local replacement of damaged pipes or other structures in order to maintain the functioning;

— cleaning and removal of sediments, obstructions etc. to restore hydraulic capacity;

— maintenance of mechanical plant (e.g. pumps).

Effective operation and maintenance of the drain and sewer system will depend on, for example:

— planning;

— rights of access;

— sufficient number of competent personnel;

— clear assignment of responsibilities;

— suitable equipment;

— knowledge of the system, its operational components and the users connected;

— adequate records and analysis.

There can also be requirements relating to the resolution of performance deficiencies, for example to remedy failures and problems within acceptable timescales.

11.2 Objectives

Operations and maintenance has the following objectives to:

— ensure that the entire system is operationally ready at all times and functions within the performance requirements;

— ensure that the operation of the system is safe, environmentally acceptable, and economically efficient;

— ensure that as far as possible the failure of one section of a sewer system will not adversely affect the performance of the other parts.

11.3 Data requirements

Data shall be collected:

— for management purposes;

— for regulatory reporting purposes (e.g. properties at risk of flooding);

— meet statutory requirements (e.g. maintaining plans showing the location of the public sewers).

It is possible to store a wide range of data on drain and sewer systems. However, collection, validation, storage and updating the data can be expensive. The amount of data collected depends on the reasons listed above.

The information can include:

— inventory of the system including records of drains, sewers, manholes, pumping installations, combined sewer overflows, detention tanks etc.;

— details of permits for influents into the system (trade effluents, hazardous materials etc.);

— details of permits to discharge from the system into receiving waters (combined sewer overflows, pumping installations etc.);

— records of inspections of the system (e.g. closed circuit television (CCTV) survey reports);

— records of incidents such as blockages, collapses, pumping station failures, rising main failures and flooding incidents;

— information on rainfall;

- records of planned maintenance work carried out;
- actual response times for dealing with emergencies;
- information on the cost of incidents and maintenance activities to allow budgetary control and performance review;
- information about the hydraulic capacity; and
- records of system performance (see 6.2.3).

Computer based geographical information systems (GIS) are a powerful tool for storage retrieval and analysis of information on sewer systems.

11.4 Investigation and analysis of operational problems

To deal with operational problems in the most cost effective way, it is necessary to investigate and understand their causes and effects. Investigations can be required to determine:

- route of a pipeline;
- cause and location of the sediment, blockage or collapse;
- cause and location of a surface depression;
- location, source, quality of making of a connection;
- quality of a repair;
- condition of a pipe;
- extent of scale or grease build up;
- effectiveness of sewer cleaning work;
- origin, quality and composition of influent;
- quantity and composition of the wastewater;
- presence of hazardous gasses;
- watertightness.

Operational investigation techniques available include:

- dye tracing;
- electronic location (using radio transmitters and a directional receiver);
- closed circuit television (CCTV);
- walking through sewers;
- mirrors;
- flow measurement;

— sampling and analysis;

— insitu measurement of the composition of influent;

— watertightness tests (see EN 1610).

Operational problems concern the various components of the drain and sewer system. The techniques available to resolve them are described in Annex C.

12 Performance testing

It is necessary to test and assess the performance of the drain and sewer systems during construction, at the completion of the construction stage and also during the operational life of the system.

Examples of tests and assessments are:

a) watertightness test with water;

b) watertightness test with air;

c) infiltration test;

d) visual inspection;

e) dry weather flow assessment;

f) monitoring of inputs to the system;

g) monitoring effluent quality, quantity and frequency at point of discharge to receiving water;

h) monitoring within the system for toxic and/or explosive gas mixtures;

i) monitoring of discharge from system to treatment works.

The tests to be undertaken to determine the performance being achieved by the drain or sewer system will depend on whether it is a new system, a rehabilitated system, or an existing system being tested.

The effectiveness of maintenance should be assessed by comparing the performance of the drain or sewer system with the requirements (see 5.1). In addition, for reactive maintenance, target response times can be used as an assessment.

13 Qualifications and Training

Personnel at all levels shall have appropriate training to allow them to carry out their work safely and competently. This on-going training shall introduce and explain relevant legislation and techniques. Training shall be repeated periodically when required and should cover safety, technical and legal topics where appropriate.

The owners of construction works (procuring entity for public work or private agent for a private contract, or their designer) shall request a proof that the enterprise carrying out the work is sufficiently qualified for the specific work.

Annex C
(normative)

Operations and maintenance

C.1 Introduction

The purpose of operations and maintenance is to ensure that the drain and sewer system performs in accordance with the functional requirements defined in clause 5.

C.2 Operations planning

C.2.1 Inspection routines

Inspection routines, including frequencies, shall be established for the system, taking into consideration the requirements and importance of each component. Routines shall include the inspection of:

— pipelines including inspection chambers, manholes and outfalls, taking into account the gradient and/or velocity;

— pumping installations, according to potential risk and type of equipment;

— overflows and detention tanks, taking into account storm frequency;

— inverted siphons, depending on risk of blockage and potential consequences;

— separators, according to technical requirements;

— grit chambers, gullies etc., taking into account storm frequency, capacity and land use.

C.2.2 Operations procedures

Procedures for the operation of the components of the system should include plans for:

— operation of pumping stations;

— operation of any special components (e.g. vacuum or pressure installations within the system);

— setting dam boards, valves and weirs;

— operation of detention tanks;

— showing the assignment of responsibilities for carrying out procedures.

C.2.3 Contingency Planning

Contingency planning is the process of setting out procedures to be used in case of breakdown of a part of the system. It should also include procedures for dealing with major failures and other emergencies. Procedures could be required for a range of possible incidents including:

— accidental spillages of toxic, noxious or explosive substances;

— discharge of special substances used in fire fighting;

— failure of pumping stations or pre-treatment facilities;

— flooding due to an exceptional rainfall event;

— major sewer collapse.

Contingency plans shall include:

— details of emergency services;

— estimated times for response (in general terms);

— lists of those to be notified;

— location of available resources;

— procedures to be followed (including protection of receiving waters and wastewater treatment plant).

The resource requirements will need to be determined, including:

— personnel;

— vehicles;

— equipment;

— materials.

These resources will sometimes need to be available at short notice. This can influence resourcing decisions for normal operations and maintenance work.

C.3 Pipelines

C.3.1 General

The common problems associated with drains and sewers (man entry and non man-entry) can be divided into two types, functional problems and structural problems.

C.3.2 Functional problems

Functional problems can include:

— blockage - this usually occurs when sediments/debris are deposited within the sewer system, forming obstructions and a reduced pipe capacity;

— sedimentation - this can also lead to blockages;

— encrustation - build up of mineral deposits on the wall of the pipeline;

— grease - deposited on the wall of the pipeline;

— intrusion of tree roots;

- infiltration or exfiltration caused by structural problems (see C.3.3);
- failure of air valves and other protection systems (for rising mains).

Examples of available methods are:

- jetting;
- winching;
- rodding;
- cleaning balls;
- remote controlled equipment;
- flushing;
- manual methods.

When carrying out cleaning activities consideration shall be given to the potential impact of the work on the receiving wastewater treatment plant. Measures shall also be taken to avoid discharges of heavily polluted matter to receiving waters through combined sewer overflows.

Residues from maintenance activities on drain and sewer systems shall be disposed of in accordance with the requirements of national or local regulations or the relevant authority in such a way as not to cause pollution.

In severe cases, rehabilitation can be necessary.

Cleaning activities in drains and sewers shall be carried out in accordance with EN 14654-1.

C.3.3 Structural problems

Structural problems can include:

- collapse;
- cracking or fracturing of the pipe;
- chemical attack or corrosion;
- ground erosion outside the wall of the pipe - usually caused by infiltration of soil into the pipe;
- defective connections;
- pipe deformation;
- open or displaced joints between pipes.

The following methods can be used to deal with the problems described above:

- repair;
- renovation;
- replacement.

Where problems are widespread or a significant length of sewer is involved a drainage area study (see clause 6) of the whole catchment area or part of it should be considered.

C.4 Manholes and Inspection Chambers

Manholes and inspection chamber are needed for access to sewers and drains for maintenance and operations. The problems include:

— defective covers - these include covers which are broken, cracked, ill-fitting or are not flush with the ground level;

— problems with access - e.g. inadequately sized access shaft, or defective steps or ladders;

— structural problems with the fabric of the chamber including chemical attack and infiltration;

— sediment in the invert;

— odours or gas/oxygen deficiency.

These can be solved by works such as:

— cleaning;

— replacement and resetting of the covers;

— repair, renovation or renewal of the fabric of the chamber;

— reconstruction of access;

— replacement of steps or ladders;

— efficient ventilation.

C.5 Combined sewer overflows

The purpose of combined sewer overflows is to spill excess flows from a system to receiving water (see 8.5 and 9.4.7).

Problems associated with combined sewer overflows include:

— blockages;

— siltation of the chamber;

— fouling of screens;

— structural problems.

Blockages can be caused by:

— restriction in size of the downstream sewer resulting in low flow velocity upstream leading to silting; and,

— general build-up of silt/debris in the chamber.

Siltation can be minimised by:

— high pressure water jets to clean the chamber;

— high volume suction units to remove debris;

— flushing of the chamber.

Planned maintenance can be necessary in order to limit the environmental impact to satisfy the requirements of national or local regulations or the relevant authority. The problem can be solved using planned maintenance procedures, which includes inspection and reporting. From the report, work can be given a priority and inspection frequencies determined.

Screens, where fitted, can require cleaning following heavy storms.

Structural problems arising may be dealt with in a similar fashion to structural problems in manholes.

C.6 Detention tanks

The role of the detention tank is to reduce peak flows by the temporary storage of wastewater within the system. They are often used to reduce flooding and to reduce discharge and pollution load from combined sewer overflows. The problems include:

— blockage of flow control devices;

— removal of sediment.

Methods of optimising the removal of sediments are:

— modifications to the structure of the tank e.g. by use of low friction coatings (these shall not be used on areas required for access as it can be a hazard to operatives);

— modification of inlet design to increase scour;

— modification to the benching or installation of dry weather flow channels;

— use of mechanical plant in the tank to periodically remove sediments.

Where a blockage has occurred and wastewater has been detained for some time, clearing the blockage suddenly can have an unacceptable impact on the wastewater treatment plant. Consideration shall be given to the gradual emptying or removal of effluents from the tanks.

C.7 Separators, settling chambers and gullies

Separators are used to intercept light liquids e.g. oil, petrol, etc., grease or solids. Planned maintenance of separators is required if they are to function efficiently.

Grit separators, settling chambers and gullies are often used to prevent sand and gravel from entering the system.

Separators, settling chambers and gullies shall be emptied periodically to prevent blockage, especially after spillages and, where appropriate, severe storms.

Separator systems for light liquids shall be operated and maintained in accordance with EN 858-2. Grease separators shall be operated and maintained in accordance with EN 1825-2.

C.8 Pumping installations

The main problems associated with pumping installations are as follows:

- blockage of pumps, valves, screens etc. by debris;
- power failure;
- failure of rising main;
- electrical or mechanical failure of a component of the pump, its control equipment, or telemetry unit;
- crust formation inhibiting the operation of control devices;
- noise and/or vibration;
- odour complaints;
- excessive power consumption;
- vandalism.

To minimise maintenance and operations requirements and costs, careful attention needs to be given to the design of the pumping station and its equipment. Where the composition or volume of flows have changed substantially or where equipment is coming to the end of its life a reconsideration of the design is necessary (see Annex F).

Solutions to some of these problems include the following:

- repair or replace the pumping equipment;
- reduce extraneous water;
- installation of warning or telemetry systems;
- installation of septicity prevention plant or ventilation of wet well;
- review of the control system;
- installation of standby power supplies.

In addition the installation of warning or telemetry systems can help reduce the impact of failure by allowing early correction of actual or incipient failures.

C.9 Inverted siphons

The main problem associated with inverted siphons is sedimentation and blockage of the pipe. Planned inspection and maintenance should be carried out to ensure that inverted siphons continue to operate efficiently.

Inspection can include:

- checking that washout valves and pumps can be operated;
- checking for surcharging at the upstream end of each pipe, which can be a sign of partial blockage;
- visual inspection of pipelines.

Cleaning methods can include:

— high pressure water jets;

— high volume suction units to remove debris;

— flushing of the inverted siphon;

— use of cleaning balls.

C.10 Pest control

The principal pest problem in sewers is related to rats, though in some areas especially where there is insufficient ventilation, or deposits of faecal sediments, insects such as cockroaches or mosquitoes can also be a problem.

Since the sewer network can be a refuge for rats, control of rodents is needed to minimise health risks (including Leptospirosis and Salmonella) and to prevent structural damage caused by burrowing.

Treatment programmes should be carried out in accordance with the requirements of national or local regulations or the relevant authority, to control the infestation. To ensure maximum effectiveness treatment programmes for sewers and drains should be carried out on a catchment wide basis and should be co-ordinated with the treatment of surface infestations.

Areas for treatment should be identified, in collaboration with national or local regulations or the relevant authority and by reference to records of sightings of rodents. Areas may also be categorised according to the risks to public health. The treatment programmes should be recorded and the effectiveness measured so that records can be used to plan future programmes.

C.11 Making connections to existing drains and sewers

A large proportion of structural problems on drains and sewers are associated with poorly made lateral connections. Problems are particularly common where manholes, inspection chambers or pre-formed junctions are not used.

The control of new connections shall be undertaken to ensure that:

— fabric of the drain or sewer is not weakened or damaged by the connection;

— no operational problems are caused by the connection;

— sewer is inspected at the point of connection before and after construction;

— system is watertight at the point of connection;

— connections are made to the correct sewer, where there are separate sewer systems.

Connections other than at manholes or inspection chambers should be made using pre-formed junctions.

New connections to brick sewers should be avoided, however if one is necessary, a thorough inspection of the sewer shall be made beforehand.

C.12 Control of disused drains and sewers

Disused drains and sewers shall be removed or, where this is impracticable, they shall be filled with suitable material to prevent, for example, structural deterioration, unauthorised use, ingress of groundwater or infestation by rodents.

C.13 Control of building over or adjacent to sewers

The construction of buildings in close proximity to drains and sewers should be controlled in order that the operation and maintenance of the sewer system is not impaired by:

— excessive loading leading to structural failure of part of the drain or sewer system;

— prevention of access by maintenance personnel or equipment to manholes or inspection chambers, wastewater pumping stations, or other ancillary structures;

— prevention of access by maintenance personnel or equipment for excavation to a repair a defect on a pipeline;

— creating an undue risk of failure of the building in the event of a structural failure of the drain or sewer;

— obstructing an overland flow path leading to an excessive risk of flooding in the building.

Annex D
(normative)

Health and Safety

D.1 Safe systems of work

Employers shall, so far as is reasonably practical, provide and maintain systems of work that are safe and without risks to health. The systems of work shall cover all aspects of the works including above-ground operations (for example manhole location and traffic control), access to the sewer system and all operations in the confined space of the sewer system. There shall be a written plan detailing systems of work for rescue and emergency evacuation procedures. Employers shall also set out procedures for detection and prevention of sudden inflows of toxic, flammable or potentially explosive substances, hot liquids or flood water discharged into the sewer system. Special precautions shall be taken when entering inverted siphons.

The team size shall be sufficient to ensure that suitably trained personnel are:

— on the surface to summon assistance and/or effect a rescue should it become necessary;

— on the surface and in manholes to ensure that there is communication between personnel in the sewer and both the entry and exit manholes.

D.2 Training and supervision

All personnel shall have appropriate training to enable them to carry out their work safely. In particular, all personnel involved in sewer work shall have appropriate training in safety procedures for work in confined spaces. Supervisors shall be competent in the management of work in the confined space of drains and sewers.

D.3 Hazardous atmospheres

D.3.1 Oxygen deficient and toxic atmospheres

A range of oxygen deficient or toxic atmospheric conditions can occur in sewer systems. Appropriate atmospheric monitoring equipment must be used continuously whilst any worker is in the system. Forced ventilation should be used to maintain an atmosphere fit for respiration.

D.3.2 Potentially explosive atmospheres

The so-called "ATEX" Directives 94/9/EC and 99/92/EC apply to equipment and protective systems for use in potentially explosive atmospheres and to work in potentially explosive atmospheres respectively. Directive 94/9/EC sets out requirements for the classification of equipment for use in a range of potentially explosive atmospheres along with requirements for the protective systems to be applied to that equipment. Directive 99/92/EC sets out requirements for the classification of workplaces in which a potentially explosive atmosphere can occur and for worker safety in such atmospheres.

A potentially explosive atmosphere can occur at any time during the operation of a sewer system, and this should be addressed as part of the design of the system. Appropriately protected plant and equipment along with their power and control systems should be specified and installed. The build up of potentially explosive atmospheric contaminants should be avoided by the use of forced ventilation coupled with adequate atmospheric monitoring.

Whilst concentrations of potentially explosive atmospheric contaminants can build up when workers are already in the sewer system, and evacuation should then take place in accordance with the nationally recognized action limits, entry to the system should not take place when hazardous concentrations of potentially explosive contaminants exceed 10 % of their lower explosive limits or the permissible national limits.

Additional national or local requirements can apply.

D.4 Traffic control

Measures shall be taken to warn and control traffic. These shall comply with the requirements of national or local regulations or the relevant authority and can include the provision of warning road signs and flashing beacons.

D.5 Protective equipment and welfare facilities

All necessary ventilation, lighting, communication and lifting equipment and, rescue equipment shall be provided and shall be appropriate to the task undertaken. Personal protective equipment including appropriate protective clothing and warning clothing shall be provided.

All persons employed in work which involves entry into manholes or sewers or contact with raw wastewater shall have access to washing and showering facilities.

Self rescuers and first aid equipment shall also be provided.

D.6 Emergency procedures

Breathing apparatus shall be available on site and the team shall be sufficiently trained in its use to escape or be able to affect rescue in the event of oxygen deficiency or operatives inhaling toxic or asphyxiating gases. In the event of a collapse of a person in a confined space, no-one shall attempt to enter the confined space to attempt a rescue without breathing apparatus.

When the working area could be flooded a warning and evacuation procedure shall be foreseen, and the organization of the working area shall take into account these constraints.

D.7 Temporary works

Temporary works and arrangements for dealing with flow shall be designed with safety in mind. Care shall be taken to ensure that exhaust fumes from pumps or other machinery are kept away from manholes and that any dams or stoppers are sufficiently robust to withstand any hydraulic pressure likely to be applied while in use.

D.8 Excavation work

When carrying out excavation work precautions shall be taken to avoid any danger to persons caused by collapse of the sides of the excavation, and to avoid damage to other utility services in the proximity of the excavations. Due regard shall also be taken to the need for safe operation of machinery and in particular the need for adequate working space.

NOTE EN 1610 provides guidance on trenching work.

D.9 Hazardous materials

The use of materials and chemicals in sewer renovation work, which can be toxic, flammable, or irritate human skin or internal organs, or are otherwise hazardous, should be minimised. When handling, storing, or using hazardous materials, the system of work shall deal specifically with the precautions necessary, including particular reference to their use in confined spaces. Processes can also generate dusts and fumes. Careful checks shall be made on the levels of harmful atmospheric contaminants and appropriate remedial measures taken where necessary.

D.10 Vaccinations

National or local regulations or the relevant authority can require vaccination (e.g. against polio, tetanus) for personnel working in contact with foul wastewater.

Annex B Security and Trash Screen Guide (UK Environment Agency, 2009)

defra
Department for Environment Food and Rural Affairs

Environment Agency

delivering benefits through science

Trash and Security Screen Guide 2009

Flood and Coastal Erosion Risk Management Research and Development Programme

The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned by the Environment Agency's Evidence Directorate and funded by the joint Environment Agency/Defra Flood and Coastal Erosion Risk Management Research and Development Programme.

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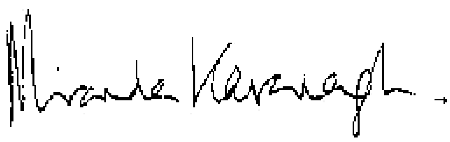

Miranda Kavanagh

Director of Evidence

Foreword

This guide outlines current good practice for the design, assessment, management and operation of trash and security screens upstream of culverts in England and Wales. It updates and supersedes the *Trash Screens: Design and Operation Manual*, published by the Environment Agency (2002). That publication had itself updated and superseded National Rivers Authority (NRA) Publication P-126, *Interim Guidance Notes for the Design and Operation of Trash Screens* (1993).

This guide promotes the use of a risk-based approach to assessing the requirement for and design and management of trash and security screens. It is for use throughout the Environment Agency and we will encourage local authorities and others involved in the design and management of screens to follow this guidance to:

- encourage asset managers, planners and designers to carefully consider the need for a screen, and to fully investigate alternative means of achieving the desired outcome and to ensure new screens are only provided where the benefits are significant and outweigh the risks;
- provide a comprehensive guide to the planning and design of a screen, following confirmation of the decision that a screen is required;
- provide guidance to owners and operators of screens on how they should be monitored, operated and maintained to ensure optimum performance.

The conclusions and recommendations set out in this document are for guidance only and are not mandatory. All decisions regarding screens should be taken in the context of a particular site and after evaluation of the risks and options available. There is no such thing as a standard or universal design for a screen and the drawings and photographs are included to illustrate the principles only.

In general, the Environment Agency wishes to discourage the use of any form of screen except where the benefits are significant and outweigh the risks. This guide should help to ensure that appropriate factors are taken into account in all stages of the decision-making process.

Peter Robinson

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Independent Consultant

Thanks are also extended to our staff both past and present, and too numerous to mention individually, who contributed to the 2009 and earlier editions of this guide.

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PART ONE – INTRODUCTION AND OVERVIEW

1 Introduction

Culverts are conduits that enclose flowing bodies of water, for example to enable a stream to pass under a road. Screens can be installed on the ends of culverts for two main reasons:

- **Trash screens** reduce the amount of trash and debris entering the culvert (where it could cause a blockage).
- **Security screens** prevent unauthorised access to the culvert.

It is possible for a screen to serve both of these functions, although normally there will be one dominant purpose.

A trash or security screen can also affect the hydraulic performance of a watercourse and impact upon flood risk. The Environment Agency Trash Screen Policy is based on a risk-based approach. The expectation is that new screens will be provided only where the need is justified and the benefits outweigh the risks.

The aim of asset managers is to ensure that assets:

- always perform as designed;
- are fit for purpose;
- provide value for money;
- minimise both the flood and general health and safety risks.

This Trash and Security Screen Guide (the guide) supports this aim by:

- encouraging asset managers, planners and designers to consider carefully the need for a screen, and fully investigate alternative means of achieving the desired outcome;
- providing comprehensive guidance on the planning and design of a screen (following confirmation of the decision that a screen is required);
- providing guidance to owners and operators of screens on how they should be operated and maintained to ensure optimum performance.

1.1 Scope of the guide

For clarity and emphasis the guide is split into three main parts relating to:

- introduction and overview;
- assessment of need for a trash or security screen including the assessment of existing screens and the risk of providing or not providing a new or replacement screen;
- screen design, monitoring, and operational considerations.

The guide does not cover 'fine mesh' weed screens and filters, which are commonly provided at pumping stations.

The approach described in this guide is derived from studies into the performance of trash screens across the UK. Much of the guidance is based on empirical research comparing well-performing screens against those where problems have developed.

1.2 Use of this guide

This guide has three potential user groups:

- anyone responsible for assessing the need for a new or existing screen;
- designers of screens;
- asset managers responsible for maintenance and operation of screens.

The guide sets out how each step of the requirement/need for a screen and risk assessments, design and operational management should be addressed. Design tasks address the design of a completely new screen and the refurbishment or improvement of an existing one.

The recommended risk-based approach uses a scoring system based on identifying hazards and assessing the probability of them occurring. A risk score is then used as a decision-support tool to determine whether or not to provide a screen.

A flow chart is included at the end of Section 3 to assist asset managers and designers. It illustrates the step-by-step approach to assess the need for a screen and the processes to be followed during its subsequent design.

1.3 Context

This *Trash and Security Screen Guide* supersedes the *Trash Screens: Design and Operations Manual* (Environment Agency 2002) which itself replaced the National Rivers Authority (NRA) Publication P-126, *Interim Guidance Notes for the Design and Operation of Trash Screens* (NRA 1993).

Other engineering and environmental design guides have been produced by the Environment Agency, CIRIA and HR Wallingford (see References section). These should be consulted at the time of design or assessment to ensure that best practice is being applied. The guide will form a companion guide to the CIRIA *Culvert Design and Operations Guide* which is scheduled to be published in 2009.

1.4 Role of the Environment Agency

The Environment Agency has a number of roles relating to trash screens including:

- regulatory authority, issuing land drainage consents for new works;
- site owner;
- operating authority, exercising permissive powers via a maintenance regime.

Procedures need to be followed within these roles, and we must be able to show that best practice has been used in the design and assessment of screens.

This is most readily demonstrated by an audit trail showing use of this guide. To ensure good practice all decisions made regarding the design and assessment of a screen should be recorded in a decision-support register. Specific decision-support registers have been identified for both new and existing screens. Further details are found in Sections 4.9 and 5.3 respectively.

1.5 Key guidance

Key guidance boxes such as the one below are included throughout the guide to highlight important points. They should not be regarded as complete summary of a particular section.

Key guidance 1: Use of screens
We discourage the use of any form of screen except in circumstances where the benefits are significant and outweigh the risks.

1.6 Definitions

Definitions of technical terms are given in the Glossary.

2 Classification of screen types

Understanding the primary purpose of the screen is fundamental to making the correct decisions on the need, risks and detailed design for the screen. Throughout this guide screens are referred to as being either a trash screen or a security screen and this section provides more detail on this distinction.

However, it is quite common for a screen to perform more than one function and, if so, it is necessary to consider different design criteria and specifications for each type of screen. If this approach introduces different and conflicting requirements, the final design needs to result from an evaluation and consideration of the risks associated with the particular installation.

2.1 Trash screens

Key guidance 2: Objective of a trash screen

The objective of a trash screen should not be to trap as much debris as possible. In fact, the screen should trap as little debris as possible commensurate with the aim of preventing material that could cause a blockage from progressing downstream.

The type of trash screen required will depend upon the nature of the debris in the watercourse. The type of debris can be loosely classified into three types:

- coarse debris (such as boulders and tree trunks);
- general debris (anything from branches/plants to armchairs and oil drums);
- a combination of coarse and general.

Screens for finer material debris are not covered in this guide.

The distinction between debris types and trash screen types is not clearly defined, and relates mainly to the spacing of the bars on the screen. However, coarse screens are often placed some distance upstream of the culvert and are designed to overtop when obscured by debris whereas general debris screens are usually situated at the inlet to the culvert. This guide addresses both types of trash screen, though those relating to general debris are covered in greater detail.

2.2 Coarse debris (including boulders) screens

Coarse debris can be classified as:

- bed load which rolls along the bed and should pass through any screen;
- floating debris.

Coarse debris may include large vegetation (such as tree trunks) and boulders.

Depending on the nature of the watercourse, it may be possible to reduce coarse debris by routine inspections and physical removal. However, it is unlikely that all potential debris can be removed before it arrives at a trash screen site.

Coarse debris is likely to require stronger screen bars and the weight of the debris is likely to be greater than general debris. Screen bars are likely to be more widely spaced.

Debris collecting on a coarse screen will be overtopped by the continuing flow and such screens need to be designed to ensure that overtopping does not cause flooding.

2.3 General debris screens

In many urban locations, general debris may be present accidentally (such as wind-blown debris) but more often arises through a deliberate act (for example, disposal of household waste such as old carpets, furniture, garden cuttings).

Some debris may arise from vandalism (such as shopping trolleys, road signs). This type of debris varies in physical size and weight, and is often the most difficult to remove from a screen.

Screen bar spacings have to be sufficiently small to enable the trapping of materials without being too small so as to be prone to unnecessary blockage.

2.4 Combination of debris screens

There will be sites where a combination of debris is likely. In this situation, a combination of screen types may be appropriate, with a low-level coarse screen sited upstream of the main general debris screen.

2.5 Security screens

Key guidance 3: Objective of a security screen

The purpose of a security screen is to prevent unauthorised access to the pipe or culvert.

Unauthorised access to a pipe or culvert or other enclosed space presents the greatest risk at sites where children may be playing or where a rapid rise in water levels is possible.

If a culvert site cannot be fenced to prevent unauthorised access, there may be justification to install a security screen particularly if the risk of unauthorised entry is greater than the risk of blockage of a screen at the site. Security screens prevent unauthorised access to the pipe or culvert but a screen at the downstream end of the pipe will also prevent escape and this should be always taken into account.

For a security screen to be effective it must by definition be similar to a general debris screen in its general characteristics but screen bar spacing becomes the main design criterion.

This guide covers the justification and risk assessment processes in relation to types of screen in Section 4.

PART TWO – ASSESSING THE NEED FOR A SCREEN

3 Assessing need

3.1 Identify the options

It should **not** be assumed that a screen is the right answer to a particular problem.

There is no doubt that a properly designed screen can reduce or even eliminate the probability of debris blockage or of unauthorised access. It is also true that screens themselves can cause severe problems, most notably local flooding due to blockage of the screen. It is therefore essential that all practical alternatives are investigated and eliminated before reaching the decision to provide a screen.

The need to explore other options is reinforced by the fact that, in all cases, it is necessary under the Water Resources Act 1991 and the Land Drainage Act 1991 to seek approval and where necessary a formal consent from the Environment Agency before installing a screen in a watercourse. This requirement applies to all proposals both from within the Environment Agency and from external parties.

Key guidance 4: Policy

The guidance contained in this document is generally in accordance with the Environment Agency's draft policy regarding screens. Nothing in this guidance supersedes or overrides the stated policy of the Environment Agency.

Approval is unlikely to be given unless the promoter of the screen can demonstrate that all other options have been explored and rejected as impracticable. Any application for approval will therefore need to be supported by evidence that a credible investigation of alternatives has been carried out.

Options fall into three broad categories namely:

- do nothing;
- reduce the debris or access problem at source;
- design, install and maintain a screen.

The identification of options applies equally to trash screens and security screens because, although the primary function of the latter is to prevent unauthorised access, any screen will accumulate debris over time.

Key guidance 5: Options

It should not be assumed that a screen is the right answer to a particular problem.

In any given situation, a screen is only one of the options available to remove or reduce the perceived risk. A decision to provide a screen at any location must be based on a full appreciation of the risks and benefits. It is essential that all practical alternatives are investigated and eliminated before reaching the decision to provide a screen.

3.2 Do nothing

In all cases, the ‘do nothing’ option (no active intervention) means just that – no action is taken to lower or remove the perceived risk. This option is only acceptable if the perceived risk is shown to be small or non-existent, or if the risks associated with taking any form of action outweigh those of taking no action. Nevertheless, the ‘do nothing’ option provides a baseline against which other options are compared.

Figure 3.1 Highway culvert with no requirements for a screen.

Figure 3.1 shows a relatively short and straight large cross-section culvert under a rural highway; the probability of debris causing a blockage is small, the flood risk is small and there is no justification for a trash screen.

The culvert can flow full or close to full as it is in the picture. It is relatively short so the risk of any person becoming trapped within the culvert is small and the site is fenced. There is no justification for a security screen.

Figure 3.2 Culvert in a residential area with no requirements for a screen.

Figure 3.2 shows a culvert with similar characteristics to the highway culvert shown in Figure 3.1. The risk assessment at this site identified no requirements for a screen both for trash and security.

3.3 Reduce problem at source

The next group of options focuses on removing or reducing the risk by actions that address the problem at source rather than its consequences, for example by looking at ways to reduce the debris load in a stream or keeping children away from the entrance to a culvert.

These options can include such measures as discouraging illegal dumping in or near a watercourse and fencing off an unsafe inlet rather than installing a security screen. Although it will only be applicable in certain circumstances, removing the culvert (day lighting) and reinstating the open watercourse should always be considered.

3.4 Install a screen

The remaining options involve the construction of works, including screens, to reduce or remove the risk. The consideration of options should not focus only on the particular structure in question, but should examine the 'hydraulic system' and the process of debris movement. This is particularly important when there are significant flood risks. Assessment of options must be consistent with System Asset Management Plans (SAMPs).

All options should be given due consideration, although it will often be possible to dismiss some without detailed investigation because they are unacceptable. This process should be documented to trace the decision-making process. As far as is reasonably practicable, all interested parties should be involved in this process or at least kept informed.

Decision-making may be aided by benefit-cost analysis though, in the case of a security screen, it is often difficult to put monetary values on the risks avoided. However, this approach does ensure that operation and maintenance costs are properly considered.

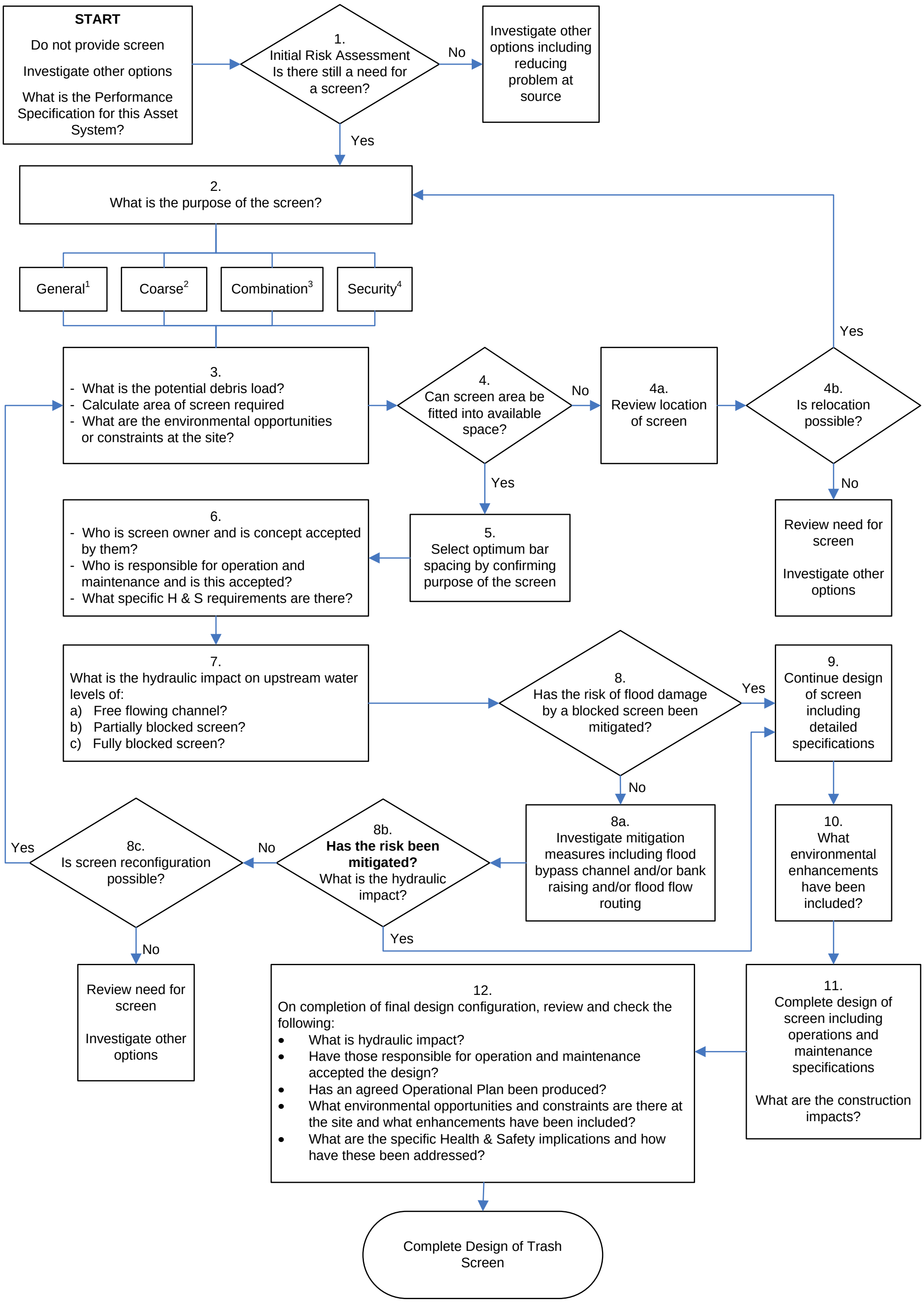
Key guidance 6: Justification

The decision to install a screen must be fully justified.

Justification may take the form of a benefit-cost assessment in which all the costs and benefits are evaluated over the whole life of the screen. In the case of a security screen, the emphasis may shift away from a simple economic analysis but, even so, the justification must be clear and the economics must be investigated so that both the initial investment and the long-term costs are understood and accepted.

An alternative is the multi-criteria approach in which interested parties are able to agree the criteria and then score them. The main advantages of this approach are that it is transparent and all interested parties have an opportunity to contribute. However, it can often be difficult to agree the weighting given to individual criteria.

The flow chart in Figure 3.3 is intended to assist asset managers and designers. It illustrates: the step-by-step approach required to assess the need for a screen; the stages at which various levels of justification are required; and the processes to be completed in the subsequent design.



[1] General – Preventing debris (e.g. food packaging & containers, small branches, leaves, twigs) from passing into a culvert where it could accumulate and obstruct the flow
[2] Coarse – Preventing large items of debris (e.g. oil drums, pallets, sofas) from passing downstream where they could become lodged in a culvert and thereby cause a blockage
[3] Combination – A mixture of two or more of the other screen purposes
[4] Security – Preventing people (principally children) from entering a culvert

Figure 3.3 Flow chart to consider requirement for a new trash or security screen.

4 Risk assessment and management

Key guidance 7: Risk assessment

Assessment of all the risks taking into account probability and consequence is an essential part of the appraisal process. This process must include the risks associated with installing a screen, as well as assessment of the perceived risks that led to the investigation into the need for a screen.

4.1 Introduction to risk

To understand the term 'risk' better, it is necessary to define the term 'hazard'. A hazard is some event, phenomenon or human activity with the potential to cause harm. Risk is best understood when considered in terms of its two component parts:

- probability that the hazard will occur;
- consequence of it occurring.

For example, the consequence of being run over by a bus (the hazard) is severe, but the probability of it happening is very low – especially if normal precautions are taken. Overall, therefore, the risk is low. Similarly, the consequences of being swept into a long culvert flowing full would be severe, resulting in death by drowning. However, if the probability of it happening is very low, then the risk may be acceptable.

In assessing risk it is important to take a broader view rather than looking at a site in isolation. In taking this wider perspective it is essential to assess the nature of the problem as well as examining the potential impacts of providing a screen.

4.2 General hazards associated with screens

Key guidance 8: Flooding risk

All screens, regardless of their primary purpose, will collect debris. This will obstruct flow, causing the upstream water level to rise, and will increase the probability of flooding. This is a key factor where the flooding would lead to significant damage to property and/or infrastructure.

The greatest hazard associated with the provision of a screen is that it becomes blocked, restricting flow and causing water levels upstream to rise and flood the local area. However, this is not the only hazard and Table 4.1 lists the main hazards.

Table 4.1 Hazards associated with trash and security screens.

Hazards associated with not providing a screen	Hazards that may arise as a consequence of installing a screen in a watercourse
Death or injury as a result of someone entering a culvert or being swept in during a flood	Flooding caused by debris accumulating on a screen and blocking it
Flooding resulting from blockage of the culvert by debris	Injury to those responsible for maintaining and cleaning the screen
Damage to the interior of a culvert or services it contains (uncommon)	Environmental degradation – visual impact, restrictions to wildlife movement, lighting nuisance, health impacts of accumulating trash at the site, vandalism
	Structural failure
	Restriction on access in an emergency

Figure 4.1 Culvert inlet on private land.

The culvert in Figure 4.1 is steep (about one in 30) and the outfall would present hazardous conditions for anyone swept into the culvert. The forested area upstream also generates a lot of woody debris. However, the culvert entrance is on private land and it has been determined that it is not necessary to provide a security screen.

There is no history of blockage of the culvert by trash or debris. This is probably due to the steeply sloping 1.3 metre diameter smooth concrete pipe culvert which generates a rapid flow velocity and is capable of conveying the debris load. There are residual risks of blockage or accident, but the provision of a screen carries a greater risk as it would inevitably block quickly in a flood and would lead to flooding of adjacent property.

4.3 Consultation and stakeholder engagement

It is vital that the designers of the screen identify and consult those who will be responsible for maintaining and cleaning it. Consultation with local residents is also essential if the true risks are to be identified and assessed. The consultation process will encourage sensible discussion on, for example, the real risks of not providing a security screen and possible alternatives.

Key guidance 9: Operational risks

It is a fundamental part of the planning and design process that the maintenance requirements are fully assessed and accepted by the owner or operator of the screen. In particular this relates to:

- regular cleaning of the screen and safe disposal of accumulated debris;
- emergency response in the event that the screen becomes blocked with debris during a flood event.

Failure to address these issues has, in the past, led to serious flooding and subsequent legal action.

Even when all possible steps are taken to ensure that the course of action adopted is based on sound reasoning and good data, and with the consent of all interested parties, it is essential that responsibility is defined, accepted and recorded in an operational plan.

4.4 Risk issues – Trash screens

4.4.1 Blockage of a screen

A major hazard with serious consequences is that of flooding to property caused by partial or full blockage of a screen or, in the event that a screen is not provided, blockage of the culvert.

Complete blockage of a culvert will result in the flow finding another route. This might cause minimal nuisance with, for example, water flowing at shallow depth across a road. Alternatively, such a blockage can cause extensive and damaging flooding which can be particularly hazardous in an urban area. An inappropriately designed screen can have the same impact, but the blockage can happen much more quickly and may occur much more frequently.

It is difficult to predict how quickly a screen will become blocked or the degree of blockage that will occur. Experience indicates that in some cases blockage and resulting flooding can happen very quickly.

The factors that affect the degree of build-up of trash are covered in Section 6.

Partial blockage of a screen has an impact equivalent to constructing a weir or otherwise constricting the stream. Water will have to flow over it and the upstream water level will be increased by the obstruction.

It is relatively straightforward to assess the impact of partial obstruction on upstream water levels; it is more difficult to decide on a credible degree of blockage. Varying degrees of blockage should be modelled and the impacts of subsequent flooding identified.

In most cases, the main hazard associated with trash or debris entering a culvert is that it will accumulate and cause a blockage in a place where it is difficult to remove. In addition, there are occasionally situations when large items of debris could damage the culvert interior or the services therein. Such situations are rare and can normally be overcome by alternative measures such as protecting the vulnerable areas or relocating the services.

Trash and debris blocking a culvert is relatively rare, much less common than the same material blocking a screen. By definition, the spacing between the bars of a screen is much smaller than the width of the culvert. This means the accumulation of trash and debris on a screen is much more likely (and much more rapid) than any such accumulation within the culvert.

Figure 4.2 Poorly designed screen.

The image in Figure 4.2 illustrates a screen which is effective at keeping debris out of the culvert and preventing unauthorised access; however, it is not well designed, demonstrating the impact that poor design can have for blockage of a screen. The provision of horizontal bars greatly increases the rate of build up of trash, preventing even very small items from passing harmlessly into the culvert. These bars also make raking the screen to remove debris very difficult and the steep angle to the horizontal compounds this problem.

Design of the inlet structure itself is not ideal. The flared wing walls complicate the screen shape and they are too short to accommodate an effective transition from the earth channel to the culvert. There are no facilities to enable cleaning activities to be undertaken safely.

Key guidance 10: Risk of blockage (trash screens)

Before deciding that a trash screen is necessary, it is essential to assess the probability of blockage of the culvert. This is a two-part process involving:

- consideration of the nature of the debris load and its source;
- likelihood of this material accumulating in the culvert.

4.4.2 Nature of the debris load

Assessment of the debris load is described in detail in Section 6. Part of the design process involves identifying the source of the material in the watercourse. Sometimes there is a readily identifiable localised source of the debris likely to cause a problem. Such debris often consists of large items that are more likely to lodge within a culvert. Example sources include:

- fly-tipping sites (hotspots of illegally dumped rubbish);
- trees and other plants in or adjacent to the banks of the watercourse;
- industrial and/or commercial areas where, for example, scrap timber is dumped on the banks of the watercourse;
- farms (straw bales, fertiliser sacks);
- residential properties whose owners treat the stream at the bottom of their garden as a convenient site for the disposal of garden and other waste.

In each case, there are options for addressing the problem at source, greatly reducing the probability that debris will enter the watercourse (see Section 6.4). In all such cases, we are likely to support any actions taken to reduce the incidence and/or extent of the problem. Solutions include:

- local awareness campaigns;
- fencing industrial sites where materials are stored on the stream bank;
- greater policing of fly-tipping hotspots.

Small items of debris – which includes most natural debris as well as litter – will be conveyed through the culvert in the same way that they are carried in the stream. In contrast, this same material can accumulate rapidly on a screen, restricting the flow and resulting in the blockage that provision of the screen sought to avoid.

4.4.3 Likelihood of material accumulating in the culvert

The second stage of examining the probability of a culvert becoming blocked involves an assessment of the culvert itself.

In the case of a culvert that has not yet been built, it is usually possible to reduce the likelihood of blockage by designing to avoid the risk factors outlined in Table 4.2.

Table 4.2 Risk factors for culvert blockage.

Factor	Issues
Size	The smaller the culvert, the more likely it is to become blocked. The preferred option is to avoid multiple barrel culverts and adopt the largest size practicable.
Bends, steps and changes of cross-section	These should be avoided as they can trap larger items of debris, which start to cause a blockage.
Length	The longer the culvert, the greater the probability that debris will be trapped somewhere, and the more difficult it is to remove a blockage
Hydraulic design	A culvert that flows with a free water surface, even in large floods, is less likely to trap large debris than one which flows full.
Inverted siphon culverts (those where the barrel dips down to pass under an obstruction)	These are more likely to block due to the accumulation of debris during periods of low flows. Such culverts should be avoided except in circumstances where there is no other practicable option.

In the case of an existing culvert, removing the hazardous elements may be difficult. Nevertheless, possible solutions should be examined. These include:

- eliminating the hazard by ‘day lighting’ the culvert (removing it and reinstating an open channel) where it is practical and reasonable to do so;
- providing a manhole/access chamber at a problem point to make access easier (this may introduce other hazards associated with working in confined spaces);
- trapping larger debris upstream of the culvert entrance using a coarse screen that can overtop;
- providing remote water-level monitoring at a site where a trash screen is not justified in order to identify increased water levels in the culvert/inverted siphon, indicating possible blockage.

4.4.4 Assessing the risk of blockage of a culvert or damage to the interior of a culvert

It is often difficult to assess the real risk associated with debris in a culvert, but the following guidance will help to assess the degree of risk based on known parameters.

Use the scoring system shown in Table 4.3 to analyse the risk and requirement for a trash screen at a site. The risk score is the product of the probability and consequence for each of the risk categories. Assessment of the score for each risk area provides the basis of the decision to install a screen or not.

Table 4.3 Scoring system for trash screens.

Score	**5**	**4**	**3**	**2**	**1**
Probability	High	←		→	Low
Consequence	Very Significant	←		→	Insignificant

This scoring system should be used to examine the main risk areas, namely:

- blockage of culvert;
- damage caused by debris to infrastructure of culvert.

Table 4.4 provides guidance on assessing scores based on historical and factual site data.

For each of the two risk factors (blockage and damage), there is a possible maximum score of 25. For example, a probability score of five **multiplied** by a consequence score of five gives a total score of 25, and a probability score of three multiplied by a consequence score of four provides a total score of 12.

The decision rules below should be applied to the higher of the blockage and damage scores.

Key guidance 11: Decision rules (blockage and damage)

For either of the risk factors (blockage or damage) a score of 15 and above indicates that a screen is required.

Those scoring between seven and 14 should be investigated further and, where there is uncertainty in the significance of the consequence score, the Area Flood Risk Manager should be consulted.

For scores of six and below, it is unlikely that a screen is required.

Further clarification on the inclusion of remote water-level monitoring and CCTV monitoring is set out in Section 4.7.

Table 4.4 Guidelines for assessing risk and requirement for a trash screen.

Blockage of culvert	**Score**				
	5	**4**	**3**	**2**	**1**
Probability	**More frequently than one in two years**	**One in two to one in five years**	**One in five to one in 10 years**	**One in 10 to one in 25 years**	**Less frequently than one in 25 years**
	Regular recorded blockage (e.g. once or twice in the last two years).	Some record of blockage (e.g. once or twice in the last five years) **or** Culvert size under one m^2, catchment urban or woodland.	Culvert size under one m^2 and at least 50 per cent urban or woodland **or** Culvert size over one m^2 and under three m^2 with potential blockage points.	Culvert size over one m^2 and under three m^2 **or** Culvert size over three m^2 with no upstream public access.	Culvert size over three m^2
Consequence	**Over £1 million**	**£100,000 to £1 million**	**£10,000 to £100,000**	**£1,000 to £10,000**	**Under £1,000**
	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).	Cost of flooding damages **plus** Cost of removing blockage and culvert repair (per event).
Damage caused by debris to infrastructure of culvert	**Score**				
	5	**4**	**3**	**2**	**1**
Probability	**More frequently than one in two years**	**One in two to one in five years**	**One in five to one in 10 years**	**One in 10 to one in 25 years**	**Less frequently than one in 25 years**
	Impact damage to structure from debris in flow (e.g. once or twice in the last two years).	Impact damage at frequency of once or twice in the last five years.	Some impact damage possible due to size of debris.	Low but some possibility of impact damage.	Rare likelihood of damage or no impact damage possible.
Consequence	**Over £1 million**	**£100,000 to £1 million**	**£10,000 to £100,000**	**£1,000 to £10,000**	**Under £1,000**
	Repairs involving diversion of watercourse and works to full length of culvert.	Repairs involving significant temporary works and works to more than half of culvert length.	Repairs involving some temporary works and repairs to less than half of culvert length.	Repairs requiring no temporary works.	Minor repairs required, not in urgent need of attention. May be encompassed in general maintenance.

4.5 Risk Issues – Security Screens

Key guidance 12: Risk of blockage (security screens)

If a screen is proposed for security reasons it also needs to be assessed for the flood risk associated with its potential blockage following the methods set out in this guide.

The issues associated with blockage of a screen discussed in Section 4.4.1 are equally applicable to security screens and should be considered along with the following additional risks when assessing the risks associated with security screens.

4.5.1 Identifying the risk

The open mouth of a culvert or, in particular, an inverted siphon is often thought to present a significant hazard. Most often this is associated with the perception that adventurous or inquisitive children will enter the culvert and thus be exposed to injury or death by drowning. Sometimes the perception is that someone may fall into the watercourse in a flood and be swept into the culvert and be drowned.

In fact, the probability of death by drowning in the UK is small: the Royal Society for the Prevention of Accidents (RoSPA) estimates the risk to be 0.8 per 100,000 population.

In 2003, there were a total of 381 deaths by drowning of which 144 occurred in rivers and streams (http://www.nationalwatersafety.org.uk/inlandwatersafety/facts.htm).

Many of the latter were associated with alcohol and bravado, and most were in large rivers. While any premature death is tragic, it is clear that the probability of drowning by being swept into a culvert or inverted siphon is relatively small.

There are also health risks associated with playing in streams, most notably *leptospirosis* (Weil's disease). As this is associated with rat urine, and it is possible that the hazard is greater inside a culvert than it is along the banks of a watercourse.

In the face of real concerns expressed by local residents, recourse to statistics and reassurances can be insufficient to convince people that a screen is likely to cause more problems than it solves. It is therefore recommended that local residents are consulted and involved in the process of exploring other options.

4.5.2 Quantifying and reducing risk

The first part of the process is to attempt to quantify the risk to life and limb, taking into account the probability and the consequence. In order to present a hazard, a culvert clearly has to be large enough to be accessible by a child. In reality, this covers the vast majority of existing culverts.

A number of factors affect the degree to which a particular culvert presents a hazard to anyone entering it (see Table 4.5). If it can be demonstrated that the factors listed in Table 4.5 indicate a low level of risk, it should be possible to argue that there is no need for a security screen.

Table 4.5 Factors affecting the extent to which a culvert presents a hazard.

Factor	Issues
Length	A short culvert in which the outlet can be seen from the inlet is unlikely to be more hazardous than an open channel. A long culvert with bends and changes of cross-section presents a more significant hazard.
Flow velocity/slope	The higher the flow velocity the greater the hazard. A culvert (including the inlet transition) in which the flow velocity is locally high is more hazardous than one with similar velocities to the watercourse upstream. A steep culvert is more hazardous than one with a flat gradient.
Full flow	A culvert flowing partially full (with a free water surface) is unlikely to be significantly more hazardous than an open channel. A culvert that has a tendency to flow full in floods is potentially more hazardous. An inverted siphon, in which the central part is always full of water, is most definitely a hazard.
Location and accessibility	A culvert entrance that is near a residential area, yet which cannot readily be seen by passersby, is likely to attract children. Although adventurous children are not put off by difficult access, the probability that a child will be exposed to the hazard is likely to be greater if access to the culvert entrance is easy.
Rate of rise of flood	A flashy stream, in which the water level can rise rapidly, will present a greater hazard than one that takes time to rise.

If there is evidence of a significant hazard, it is appropriate to explore a range of measures to reduce the risk by reducing the probability that harm will occur and/or by making the situation less hazardous. The ideal solution is to remove the hazard completely, but this is often not practical.

Figure 4.3 Screen on a small culvert not securely fixed in place.

In Figure 4.3 a screen was provided at the entrance to a small but very long culvert which passes under a developed site. The intention of the screen was to prevent blockage of the culvert by debris such as oil drums and planks. This objective was not initially achieved because the screen was not securely fixed to the culvert headwall. The risk of vandalism should be assessed at all screen sites.

In the case of a proposed culvert (one which is in the process of being planned and designed), the aim should be to design it so that the hazards are eliminated as far as possible. For existing culverts, there are a number of options to reduce risk (Table 4.6).

Table 4.6 Examples of options to reduce safety risks associated with culverts.

Option	Comments
Fencing the culvert entrance	Complete exclusion is difficult to achieve because the fencing cannot extend across the watercourse. Nevertheless it is possible to strongly discourage access. Consider deepening the bed immediately upstream of the culvert mouth and/or constructing a low weir at the culvert entrance to create an area of deeper water (even at low flows) which deters access. However, the deeper water may present a hazard, so this option needs careful consideration.
Community engagement	Involving the local community, especially through schools, can be very effective in discouraging children from playing in a dangerous area. However, action needs to be comprehensive and ongoing to remain effective.
CCTV	Cameras can be used as part of a programme of policing hazardous areas. Regular monitoring and rapid response are necessary for this option to be effective.
Warning signs	These have limited impact in isolation but may work better when combined with any of the options above.
Telemetry	Used to remotely detect rapidly rising water levels and relay intruder alarms or other security systems.

Where there is a real and significant risk that cannot be reduced to an acceptable level by any of the means outlined in Table 4.6, a security screen may be the only answer.

4.5.3 Assessing the safety hazard

In situations where there is considered to be a safety hazard, there is no shortcut to carrying out a full risk assessment. However, Table 4.7 and 4.8 can be used as an initial guide, helping the designers to determine the likely degree of risk by first assessing the significance of the hazard.

The scoring system for safety screens differs from that for trash screens in that the total score is derived by **addition** rather than multiplication of the individual scores.

Table 4.7 Scoring system for security screens.

Score	5	4	3	2	1
Hazard	High	←	───	→	Low

Using Table 4.8, a score of one (low) to five (high) should be assessed for each of the five factors and then a total score achieved by **adding** together each of the five scores. This will give a maximum score of 25 (significant hazard) and a minimum of five (not significantly hazardous).

Table 4.8 Assessment of the safety hazard presented by a culvert.

Factor/Score	5	4	3	2	1
Length of culvert	Over 100 m	51-100 m	21-50 m	11-20 m	Under 10 m
Slope of culvert	Over 1 in 50	1 in 50 to 1 in 100	1 in 100 to 1 in 250	1 in 250 to 1 in 1,000	Under 1 in 1,000
Full flow?	Always full (inverted siphon)	Often flows full	Sometimes flows full	Rarely flows full	Never flows full
Location and accessibility	In an area where children congregate	Close to an area where children play	Close to a residential area	Not close to residences or relatively inaccessible	Remote or inaccessible
Rate of rise of flood	Less than one hour	Several hours	Within 12 hours	12-24 hours	Number of days
TOTAL	25	20	15	10	5

In the further assessment of these sites, other factors that have not been scored should also be considered. These factors include:

- hazards within the culvert;
- nature of the culvert outfall;
- reduction in culvert size along its length;
- straightness of the culvert.

Key guidance 13: Decision rules (safety)

Any hazard risk score above 20 out of maximum 25 will require the provision of a security screen.

Further detailed consideration should be given to potential need for a security screen at those sites that score 15 or more.

Figure 4.4 shows a crude security screen at the downstream end of a small culvert. Note that the screen is almost totally blocked with small debris from the inside. This debris must have entered the culvert by passing through the inlet, which may also have a screen.

Figure 4.4   Crude security screen at the downstream end of a small culvert.

Figure 4.5   A security screen on the outlet of a culvert.

Figure 4.5 shows another security screen on the outlet of a culvert with a lockable gate to allow access for maintenance. A trash screen is fitted to the inlet to the culvert. Debris passing through the inlet screen can accumulate on the inside of the outlet screen, which is difficult to clean. Regular inspection and cleaning may be necessary to ensure that there is no build-up of trash at the outlet.

Both of the above examples highlight issues associated with providing a screen at the outlet to a culvert which must be balanced with the security risks associated with not including the screen.

Key guidance 14: Screens on the culvert outlet

No screen should be provided at the outlet of a culvert unless there is a security screen at the inlet, as this could lead to the accidental death of anyone entering the culvert.

A screen only at the outlet would also collect debris that would be difficult to remove.

Where this situation can not be avoided, a hinged screen must be considered and secured by 'fail-safe' fixings to enable emergency opening of the screen.

4.6 Environmental risks

Although the environmental impacts of installing a screen are likely to be relatively small, there should always be an assessment of the potential impacts.

It has been suggested that screens can obstruct the passage of some wildlife, but this is considered unlikely with the bar spacing recommended in this guide.

If there is any uncertainty in the suitability of the screen design, specialist environmental staff should be consulted. In the case of a security screen, however, the safety of children must take precedence.

Environmental risks and opportunities are addressed in more detail in Section 9.

4.7 Use of water level monitoring and CCTV to reduce risk

Where there is a risk of flooding to houses or other property as a result of screen blockage, the use of remote water-level monitoring using telemetry and closed circuit television (CCTV) to give early indication of a developing problem must be considered.

The recommended method for detecting screen blockages is to position water level monitors upstream and downstream of a screen with the data transmitted – normally by telemetry – to an operational centre. Under normal conditions (when a screen is relatively free flowing with little debris build-up), the difference in the two water levels will be small. When the screen is blocked, there will be a greater difference in level between the upstream and downstream sensors; if the blockage remains, this difference will increase as the flow increases. Alarms can be triggered by the increasing difference between the two water levels. Alarms can also be triggered by high upstream water levels alone. Design issues related to remote monitoring are discussed further in Section 11.13.

The option of CCTV allows monitoring staff to observe conditions at the screen, enabling them to see actual site conditions and to detect early build-up of debris. They are thus able to organise a suitable response.

CCTV is also useful if there are problems with vandalism at the site – both as a deterrent and as a means of early warning. Design issues related to CCTV are discussed further in Section 11.14.

If the Design Risk Assessment deems water-level monitoring and CCTV essential to the screen design, then they are **not** optional parts of the design which could be removed in the event of budgetary constraints.

Key guidance 15: Need for monitoring

Owners and operators of existing screens and designers of new screens must consider the use of remote water-level monitoring and CCTV as an aid to:

- understanding the way in which the screen performs;
- determining the operational response at times of high flows when the risk of blockage is at its greatest.

Key guidance 16: Decision rules (monitoring)

Any proposed screen site with a consequence score of five, for either blockage or damage (see Table 4.4), must have remote water-level monitoring installed, linked by telemetry to an operational centre **and** should have CCTV as an integral part of the scheme.

Any proposed screen site with a consequence score of four, for either blockage or damage (see Table 4.4), must have remote water-level monitoring installed, linked by telemetry to an operational centre as an integral part of the scheme. In this scenario the installation of CCTV should be considered.

At all other sites, remote water-level monitoring must be considered as part of the Design Risk Assessment. It can only be omitted where the risk can be acceptably mitigated or the consequence is negligible.

Figure 4.6 shows a security screen at the entrance to a large relief culvert. Note that this photograph is for illustrative purposes only and may not represent best practice for all situations.

The security screen shown includes the following features:

- removable chains to allow access for cleaning the screen (however, these are particularly susceptible to theft and vandalism);
- steps giving access to the screen for maintenance operations;
- a lockable access door in the lower screen (bottom right of the photograph) to enable access inside the culvert for maintenance operatives;
- two-stage screen to facilitate safe cleaning and to reduce the likelihood of complete blockage;
- warning sign to raise awareness of hazard;
- site fencing to deter access.

Figure 4.6 Security screen at the entrance to a large flood relief culvert.

4.8 Other operational risks

The proper management of screens is an essential element in the management of risks associated with their design and installation**.**

Risks associated with the maintenance and operation of screens are considered in Section 13 of this guide.

4.9 Decision support – new screens

It is important to show that best practice has been applied in the design and assessment of trash screens.

Application of these principles is most readily demonstrated by an audit trail showing use of this guide. To ensure good practice, all decisions made regarding the design and assessment of a screen should be recorded. This demonstrates to the operators of a screen that the designer has identified the risks associated with a site and where appropriate, mitigated against them.

A decision-support register for new screens is included (see Figure 4.7) and it is recommended that all decisions and justifications are set out within this, or a similar, register to ensure a suitable audit trail.

Stage	Description	Reference Section in Guide	Justification for Decision
START	**Do Not Provide Screen. Investigate other Options.** What is the Performance Specification of the Asset System?	Section 3 Section 4	
1	**Initial Risk Assessment** ▪ Is there still a need for a screen? ▪ What is the consequence of not screening the location?	Section 3 Section 4	
2	What is the purpose of the Screen? ▪ General – accumulation of small/medium debris ▪ Coarse – accumulation of large debris e.g. oil drums, pallets, sofas ▪ Combination ▪ Security – risk of people entering the pipe/culvert section	Section 2	
3	▪ What is the potential trash and debris load? ▪ Calculate area of screen required ▪ What are the environmental opportunities or constraints at the site?	Section 6 Section 7 Section 9	
4	▪ Can the screen area be fitted into available space? ▪ Review location of screen ▪ Is relocation possible?	Section 7 Section 11	
5	Select optimum bar spacing by confirming purpose of the screen	Section 8	
6	▪ Who is screen owner and is concept accepted by them? ▪ Who is responsible for operation and maintenance and is this accepted? ▪ What specific H & S requirements are there?	Section 13	
7	What is hydraulic impact on upstream water levels of: i. Free flowing channel? ii. Partially blocked screen? iii. Fully blocked screen?	Section 10	
8	▪ Has the risk of flood damage by a blocked screen been mitigated? ▪ What is the timescale for screen blockage and flood damage? ▪ Investigate mitigation measures including flood bypass channel and/or bank raising and/or flood flow routing ▪ Has the risk been mitigated? ▪ What is the hydraulic impact? ▪ Is screen reconfiguration possible or required?	Section 10 Section 11 Section 12	
9	Continue design of screen including: ▪ bar spacing, size, shape ▪ angle to horizontal, alignment to flow, number of stages ▪ location of cleaning platforms ▪ fabrication of materials, fixings & fastenings	Section 11	
10	What environmental enhancements have been included?	Section 9	
11	Complete design of screen including site specific requirements: ▪ provision for safe cleaning ▪ temporary storage of debris ▪ access by vehicles and operatives ▪ security fencing ▪ lighting, telemetry and CCTV Has Regional Telemetry team agreed the proposals? Has MEICA team agreed the proposals? What are the construction impacts?	Section 11 Section 13	
12	On completion of final design configuration, review and check the following: ▪ What is hydraulic impact? ▪ Have those responsible for operation and maintenance accepted the design? ▪ Has an agreed Operational Plan been produced? ▪ What environmental opportunities and constraints are there at the site and what environmental enhancements have been included? ▪ What are the specific Health & Safety implications and how have these been addressed?	Section 10 Section 13	

Figure 4.7 Decision-support register for new screens.

5 Assessment of existing screens

5.1 Reason for an assessment

Formal assessment of assets is a fundamental part of good asset management. Routine assessment of assets happens informally during every event when the structure performs its function up to the original design standard.

Formal assessments are required to determine whether:

- performance of the asset will meet the current policy or operational requirements or performance specification;
- the original design standards are still relevant;
- the asset is operating at an optimum performance level.

As assets, all trash screens should be subject to formal assessment by their operating authority. The assessment may be prompted by:

- changes to the characteristics of the watercourse and associated debris;
- changes to the flood discharge under which the asset must perform satisfactorily;
- changes to the asset management regime applied by the operating authority;
- recognition that the trash screen has reached the end of its design life;
- ‘failure’ of the trash screen.

5.2 Criteria to be assessed

For many trash screen sites, there is little historical data on the original design, operation and maintenance. Furthermore, there is rarely any record of inspection and cleaning of the screen – information which is of great value to its future requirements.

An asset manager should aim to generate and collate this type of data for future assessment and to provide the basis for justifying change. The data can be used to:

- refine the whole life cost of the asset;
- assess the environmental impact of the structure and its operational regime.

Before the assessment of any assets, the availability of data should be considered to identify where gaps exist.

Assessment of the original design should include:

- identification of the current site owner;
- review of all criteria shown in this guide for the design of new screens.

Assessment of the maintenance regime should include:

- review of the number of routine and non-routine maintenance visits;
- frequency of these visits;
- amount of debris removed on each occasion.

Assessment of the operational plan should include a review of the performance specification to ensure:

- it is relevant for the current situation at the site;
- all legislative requirements, including health and safety, are met.

All operating authorities should ensure that legislative requirements are fully met.

Assessment of an existing screen may reveal that the characteristics of the screen and watercourse are unchanged from the original design criteria. However it may be that, for example, the land use has changed or that the benefits of preventing flooding no longer exist. In such situations, the maintenance regime may need to be reconsidered and a new operational plan produced.

If an assessment finds that any elements of a screen are not performing to the required standards, modifications should be made according to the guidance in Section 11.

Key guidance 17: Assessment of existing screens

Existing screen sites should be subject to the same level of review as for the justification of the requirement for a new screen at a site.

Existing screens should also be reviewed with the same vigour as new screens when considering the requirement for asset maintenance and ongoing operational requirements.

5.3 Decision support – existing screens

It is important to show that best practice has been applied in the assessment of all existing assets where a screen is present.

Application of these principles is most readily demonstrated by an audit trail showing use of this guide. To ensure good practice, all decisions made during the assessment of an existing screen should be recorded. This shows that the ongoing requirement for the screen has been assessed and the performance of the screen is adequate.

A decision-support register for existing screens is included in Figure 5.1 and it is recommended that all assessment decisions and justifications are set out within this, or a similar, register to ensure a suitable audit trail.

Stage	Description	Reference Section in Guide	Justification for Decision
START	**COLLECT BACKGROUND DATA ON THE EXISTING SCREEN** ▪ **Original Designer Assessment or Notes** ▪ **Operational Manual** ▪ **Logbook (and/or records of any incidents)** ▪ **Maintenance Records (Has the screen been maintained and by who?)** ▪ **What is the Performance Specification of the Asset System?**	Section 5 Section 13	
1	**Initial Baseline Data Assessment** ▪ Why was the screen installed originally? ▪ How was it designed, i.e. were any guidance notes used or followed? ▪ Who was it designed by? ▪ What were the hydraulic and hydrological conditions at the time? ▪ Who is the current owner? ▪ What are the current operational & maintenance costs?	Section 5 Section 13	
2	**Changes to the Baseline Conditions** What, if any, are the changes over time and why: ▪ Screen ▪ Hydrology ▪ Debris ▪ Operations Delivery ▪ Land Use ▪ Health & Safety Requirements ▪ WFD Opportunities	Section 2 Section 4 Section 6 Section 10	
3	▪ Does existing screen meet current guidance? ▪ Does existing screen perform? ▪ Investigate Alternative Options as a result of the outcomes of stage 2 ▪ What are the consequences of not screening the location? ▪ **Is there still a need for a screen at the site?**	Section 4 Section 10 Section 13	
4	▪ Assess the current screen for continued suitability ▪ Carry out a review of the screen requirements and assessment of purpose based on debris load, screen area, detailed specification, hydraulic conditions, H & S etc ▪ **Does current screen arrangement still meet design requirements?**	Section 10 Section 11	
5	**Retain Current Screen** ▪ Ensure ongoing maintenance of the screen ▪ Assess the suitability of the operational procedures and update where required ▪ Monitor & review the ongoing suitability of the screen at regular intervals Is appropriate documentation in place, including H & S file and Operational Plan?	Section 13	
6	**Design New Screen** ▪ Proceed to the design of a new screen using the flow chart to assist consideration of the requirement for a new trash or security screen (Section 3.3) ▪ Complete full process and review of the design Is appropriate documentation in place, including H&S file and Operational Plan?	Section 2 Section 3	
	Report outcome to Asset Systems Management Team Leader		

Figure 5.1 Decision-support register for existing screens.

PART THREE – DESIGN, MONITORING AND OPERATIONAL REQUIREMENTS

6 Evaluation of potential debris load

As with all engineering design, the quality and suitability of the final product relies on the quality and usefulness of input data.

Many factors influence the design of the trash screen. Although the structural elements of design will generally be straightforward, it is the layout and size of the screen and associated inlet between the watercourse channel and the culvert or other structure that will require substantial design effort.

Key guidance 18: Effective design

To produce an effective design, it is essential to appreciate:

- the factors that influence the type and amount of debris;
- the hydraulic performance of the channel;
- accessibility and maintainability of the screen.

6.1 Types of debris

The upstream catchment should be examined and the type of debris likely to enter the watercourse identified. Table 6.1 indicates the types of debris that may be experienced.

Table 6.1 Categories of debris.

Category	Description
Small vegetation (Sv)	Leaves, twigs, garden waste, small branches and plants
Large vegetation (Lv)	Trees, large branches, shrubs, mats of weeds
Domestic refuse (Dr)	Packaging, small containers (cans, bottles, cartons), plastic bags
Large household refuse (Lhr)	Furniture, mattresses, carpets
Large non-domestic refuse (Lndr)	Cars, shopping trolleys, ladders, pallets, straw bales

The make-up of the debris should be analysed roughly – in the order of the nearest ten per cent for each category.

It is technically straightforward to take a sample of debris and determine the volume and weight of the different categories in Table 6.1. This analysis should be undertaken over a period of time to verify both the type and rate of accumulation of debris. Such sampling should be linked to existing routine and non-routine maintenance visits.

6.2 Evaluation of the catchment

6.2.1 Catchment characteristics

The collection of data on catchment characteristics is necessary to determine the type of debris likely to find its way into the watercourse and the predicted amount.

6.2.2 Contributing upstream length

The length of watercourse (and its tributaries) upstream of the culvert that are likely to be contributing debris should be measured.

The total length should be taken to a point where no additional debris can enter. This will be the upstream limit of a catchment to a position that prevents debris from passing downstream (such as another trash screen or lake).

6.2.3 Gradient of watercourse

The average gradient of the watercourse in design should be determined over the contributing upstream length. This is the measurement of the largest stream length in the catchment upstream of the culvert – from the culvert to the furthest point upstream as defined above. Points at 10 and 85 per cent along this main length are identified and the elevation noted. The slope between these two points is then the average gradient, which is referred to as ‘S1085’.

6.3 Reduction of debris load and illegal dumping

Possible ways of reducing debris load to reduce the probability of a screen blocking or to obviate the need for a screen should be considered at the earliest stage of the design process.

For example, public consultation and community outreach initiatives can significantly reduce the occurrence of trash and debris in watercourses.

The need to provide full flood flow capacity of the channel must be considered in conjunction with other legislation that seeks to retain ‘natural’ river beds and banks.

It is particularly important to consider what debris might be transported into the watercourse channel from the channel margins in flood events that are more extreme than recent historic floods.

6.3.1 Reduction of small vegetation

A reduction in small vegetation is likely to have a minimal impact on debris load. If small vegetation has been identified as a particular hazard at a site, it is probable that the contributing upstream length is significant.

Although it may not be possible to reduce the load at the structure to be protected (culvert entrance), it may be possible to construct upstream screens to reduce the load at the critical location. Each additional screen would require a maintenance regime.

6.3.2 Reduction of large vegetation

A reduction in large vegetation is likely to have a significant impact on debris load.

It may be possible to reduce the load by routine ‘scavenging’ of the watercourse to remove debris and/or the management of upstream vegetation to remove it before it becomes debris. Negotiation with riparian owners is necessary for this type of regime.

Consideration should be given to the environmental benefits of allowing large vegetation to accumulate in the floodplain of a watercourse.

6.3.3 Reduction of domestic refuse

Reducing domestic refuse (such as small containers and food packaging) is likely to have a significant impact on debris load in urban areas.

This type of debris is usually placed in a watercourse by riparian owners ‘over the garden fence’ or by casual ‘dumpers’ using a known fly-tipping hotspot.

In urban areas, riparian owners are sometimes unaware of the potential risk caused by this type of debris. The risk is made greater if the dry weather flow is insufficient to transport the debris, which only becomes mobile under high flow conditions. In this situation, a large volume of debris can quickly accumulate at a screen following heavy rainfall in the catchment.

It may be possible to reduce the debris load from domestic refuse by a public awareness campaign targeted at riparian owners.

6.3.4 Reduction of large household refuse

Reducing large household refuse (such as furniture, mattresses and carpets) is likely to have a significant impact on debris load.

This type of debris is usually placed in a watercourse by casual ‘dumpers’ making use of a known fly-tipping hotspot.

Enforcement action by the local authority and/or waste regulation staff may be necessary to reduce the volume of this kind of debris.

As with domestic refuse, the risk is made greater if the dry weather flow is insufficient to transport the debris, which only becomes mobile under high flow conditions. In this situation, a large volume of debris can quickly accumulate at a screen following heavy rainfall in the catchment.

It may be possible to reduce the debris load from large household refuse by a public awareness campaign at the fly-tipping hotspot.

It may be necessary to undertake routine ‘scavenging’ of the watercourse to remove debris before it is transported downstream to the screen site. Negotiation with riparian owners may be required to implement this type of regime.

6.3.5 Reduction of large non-domestic refuse

Reducing large non-domestic refuse is likely to have a major impact on debris load. This type of debris is often associated with industrial land adjacent to the watercourse.

If the source of the debris is directly related to the commercial or industrial activity of an adjacent site, enforcement action against the site owner should be explored to prevent the debris entering the watercourse.

If the debris is associated with an adjacent site but is not directly related to its activities, it may be possible to liaise with the site owner to secure the material and reduce the possibility of it becoming debris load.

If this does not reduce the debris load, it may be possible to create a physical barrier between the site and the watercourse to limit the possibility of the debris load entering the channel. However, such an option must not compromise the flood flow capacity of the watercourse or prevent access for maintenance.

Key guidance 19: Public engagement

The first step in addressing a problem caused by the actions of the local community is to engage with locals to explore how the problem can be reduced or eliminated.

No trash screen should be promoted until the alternative of addressing the problem at source has been fully explored.

6.4 Sediment load

In general, sediment is not a major problem for the design of screens. However, sediment load is intrinsically linked to the geomorphology of the catchment and the designer should as far as possible ensure that the design of the screen and culvert accommodates this. If it is likely to be a problem for the design of a screen, it can be assumed to also be a problem for the structure which the screen protects.

Any solutions to reduce sediment load are generally site-specific.

As sediment load is primarily dependent upon source material and flow velocity, the opportunity to reduce the volume of sediment falling out of suspension, and hence transport, relates primarily to avoiding any change of velocity through the screen site. Designers should therefore avoid significant reduction in flow velocity at a screen site. If this is not possible, the opportunity to reduce flow velocity upstream of the site should be investigated to ensure any sediment accumulates away from the screen.

The construction of a ‘silt/gravel trap’ is one option in which the velocity is slowed by deepening of the channel over a short length. However, this is not an easy solution to a sediment problem because it introduces an additional maintenance regime, a requirement to dispose of the material removed from the trap and the need to consider the overall impact of sediment removal from the watercourse.

There are further environmental issues related to the construction of a ‘silt/gravel trap’, which is likely to have an impact on the geomorphology of the watercourse.

Such issues include restriction of coarse sediment movement down the channel, and artificial widening and slowing of the watercourse in the area of the ‘silt/gravel trap’.

Cross-channel structures can reduce velocity sufficiently to reduce transport, but can act as physical barriers that prevent further downstream transmission of coarse sediments (enhanced coarse sedimentation upstream and reduced supply downstream). Large reductions in sediment supply can cause a number of morphological changes further downstream, primarily increased bed and bank erosion.

7 Determination of screen area

7.1 Components of a screen

The main components of a trash screen are set out in the section drawing shown in Figure 7.1 and the plan drawing in Figure 7.2. Table 7.1 gives details of the main components of a screen.

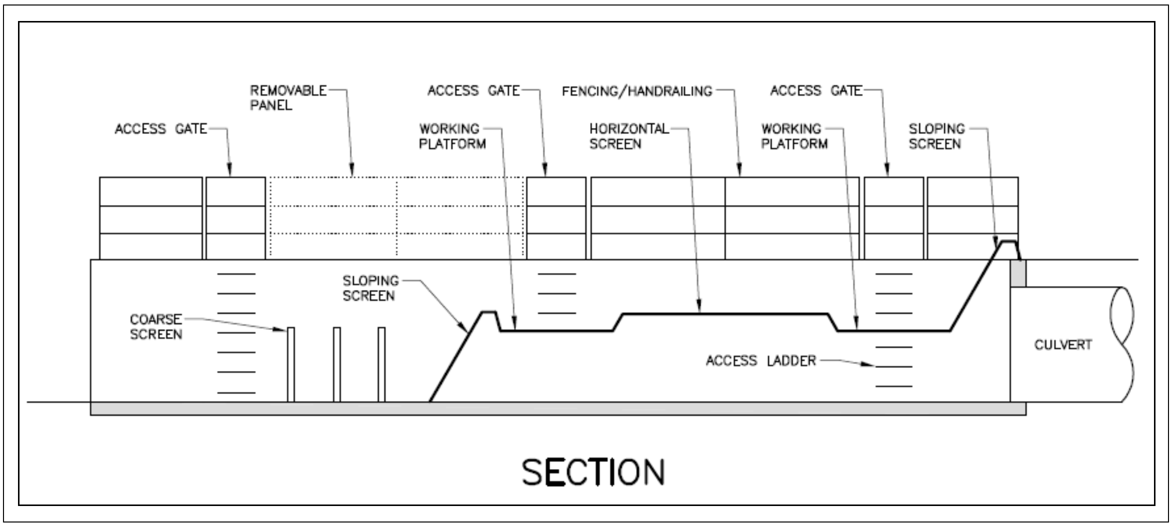


Figure 7.1 Section drawing of the components of a trash screen.

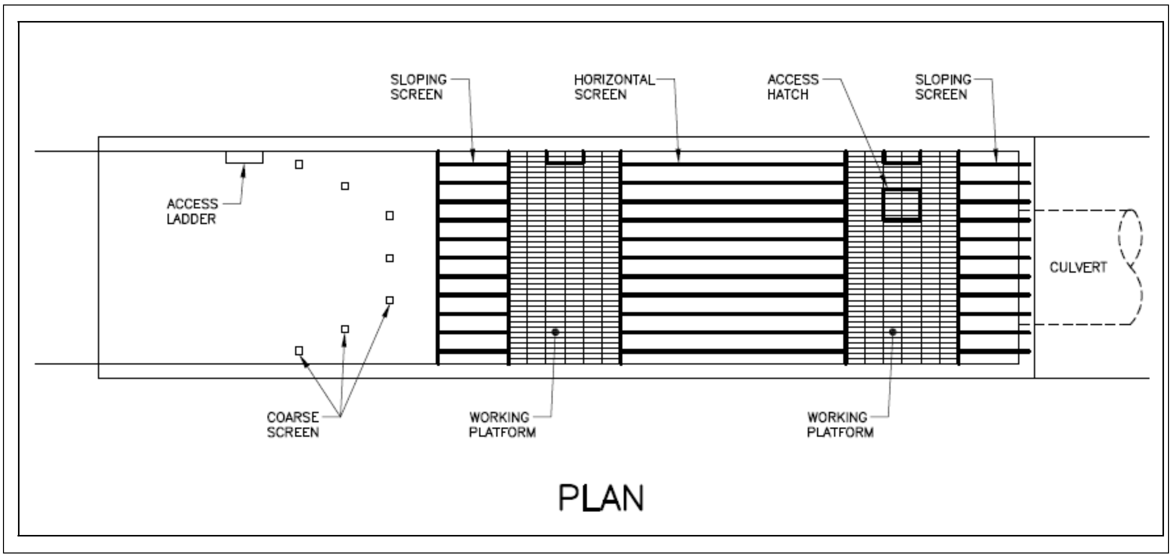


Figure 7.2 Plan drawing of the components of a trash screen.

Table 7.1 Main components of a screen.

Component	Description
Sloping screen	This provides the main screen area.
Horizontal screen	This provides the main screen area.
Coarse screen	This can collect initial larger debris to reduce the impact on, and potential damage to, the main trash screen. The coarse screen is often located some distance upstream of the main screen, and there may be two or more coarse screens at intervals.
Working platform	This provides access to the screen for clearance of the trash. Even if it is constructed from open tread panels, the area of the working platform should not be included as part of the effective screen area (see Figure 7.3).
Access gates and removable panels	These provide access to the required sections of the screen to aid trash removal.
Access hatch	This is provided in the working platform to enable access to the culvert for periodic inspection.
Fencing/handrailing	This increases security and reduces the hazard associated with a potential fall into the channel.
Access ladder	This is provided to enable access to the main trash screen and the culvert in order to: • clear trash from the screen in routine/non-routine events; • inspect the culvert; • respond to emergency or safety-related issues.

7.2 Screen area

Before determining the screen area required for a site based on the assessment of the likely type and amount of debris, it is important for the designer to understand which areas of the screen are suitable for inclusion in the calculation of screen area.

The screen area is the total area of the installation that can collect debris and be cleared effectively. Figure 7.3 highlights those areas that can be taken as effective screen area, that is those which can convey flow without requiring an unacceptable high water level upstream.

Sections of the trash screen that can contribute to the screen area are limited to the inclined/sloping sections of screen along with suitable horizontal sections of screen. The screen area on an inclined section is calculated as the actual screen width multiplied by the inclined length. Horizontal sections of screen can be included in the calculation of screen area only if they are not designed to function as working platforms. Working platforms must not be included in the effective screen area as they tend to have small bar spacings, or none at all, so are prone to rapid blinding.

Although the indicative water surface profile is shown horizontal in Figure 7.3, this may not necessarily be the case. In particular, the last element of the screen (the upper inclined section immediately upstream of the culvert) may not therefore be fully effective. The extent to which this occurs will depend on the degree of blockage and its distribution on the screen, together with the flow rate at the time.

Detailed hydraulic analysis would be required to determine the water surface profile. Designers are therefore urged to avoid being over-optimistic about the effective area of a screen when it is both multi-stage and incorporates horizontal sections.

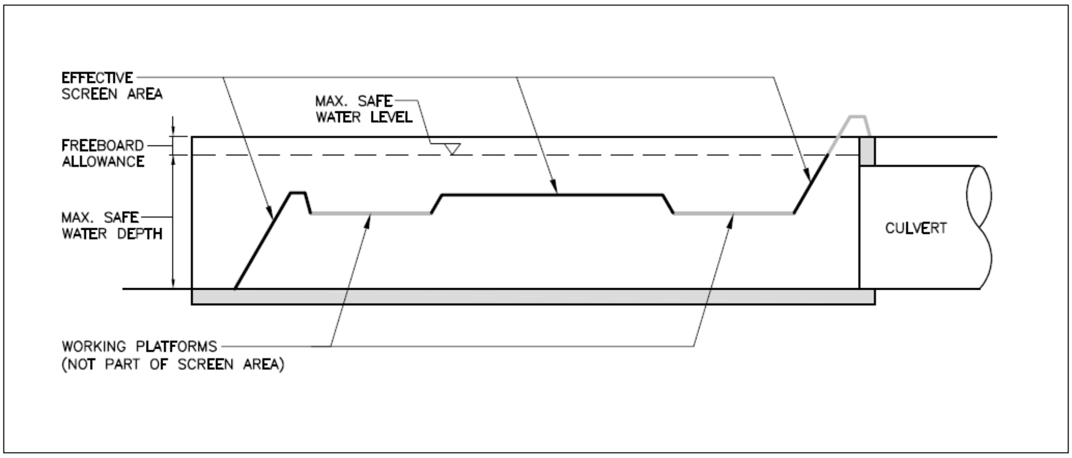


Figure 7.3 Section of a trash screen showing effective screen areas.

Key guidance 20: Screen area

To be eligible for inclusion in the effective screen area, an element of the screen:

i. must be below the maximum allowable water level;

ii. must not be a working platform designed for use by operatives;

iii. must not include those parts of the screen obstructed by the supporting structure for the screen.

7.3 Estimation of required screen area

The derivation of screen area is fundamentally important if the trash screen is going to perform its function (security or prevention of blockage and/or damage to the culvert) successfully without increasing the occurrence of flooding.

The majority of failures that have occurred following the introduction of a new screen in a watercourse have been due to underestimation of the screen area required.

The approach described in this guide is derived from over 15 years of study into the performance of trash screens across the UK. Much of the information used to calculate screen area is based on empirical research comparing well-performing screens against those where problems have been experienced. Factual data on debris amounts against upstream catchment characteristics provide the best basis for screen area derivation.

Caution should be applied in any variation from the evidence-based approach set out in Section 7.4. Any such deviation must be supported by data (such as debris amounts recorded over a two-year period at the site) and the justification for it recorded.

The evidence-based method looks at the contributing upstream areas and, using key characteristics, estimates the likely amounts of debris arriving at the screen location.

The method, which is derived from empirical data, has been found to reasonably reflect the actual debris amounts arriving at screen sites during bank full events. Asset owners and designers with limited knowledge of trash screens are often surprised at the large design screen areas which result from the evidence-based method.

7.3.1 Lower and upper limits to screen size

Analysis of satisfactorily performing trash screens over the past 15 years has found there are lower and upper limits to screen size relative to the size of culvert protected. The evidence from the number of screens examined suggests that the design screen area should be between three and 30 times the minimum culvert area.

When applying the evidence-based method:

- If the calculated screen area is less than three times the minimum culvert area, the design area should be increased to three times the culvert area.
- If the calculated screen area exceeds 30 times the minimum culvert area then, provided there are no unusual aspects to the upstream catchment which could generate exceptional amounts of debris, the design screen area can be capped at 30 times the minimum culvert area.

Key guidance 21: Screen size

The design screen area should be determined by using the evidence-based method detailed in the guide, checking that the resulting area is between three and 30 times the minimum cross-sectional area of the culvert being protected.

If the calculated area is greater than 30 times the minimum culvert area, a design screen area of 30 times the minimum culvert area may be used provided there are no unusual aspects to the upstream catchment which would generate exceptional amounts of debris entering the watercourse.

7.4 Evidence-based method for determining screen area

7.4.1 Debris amount

The maximum debris amount (Da) is the anticipated maximum amount of annual debris arriving at the screen in non-routine events.

If there are site-specific data on debris amounts collected over a reasonable period of time (say two years or more), these should be used in subsequent calculations.

If no such data are available, a value for Da can be estimated from Figure 7.4 for the following catchment types:

- woodland;
- urban;
- suburban;
- open public areas (including golf courses);
- open non-public areas (including farmland).

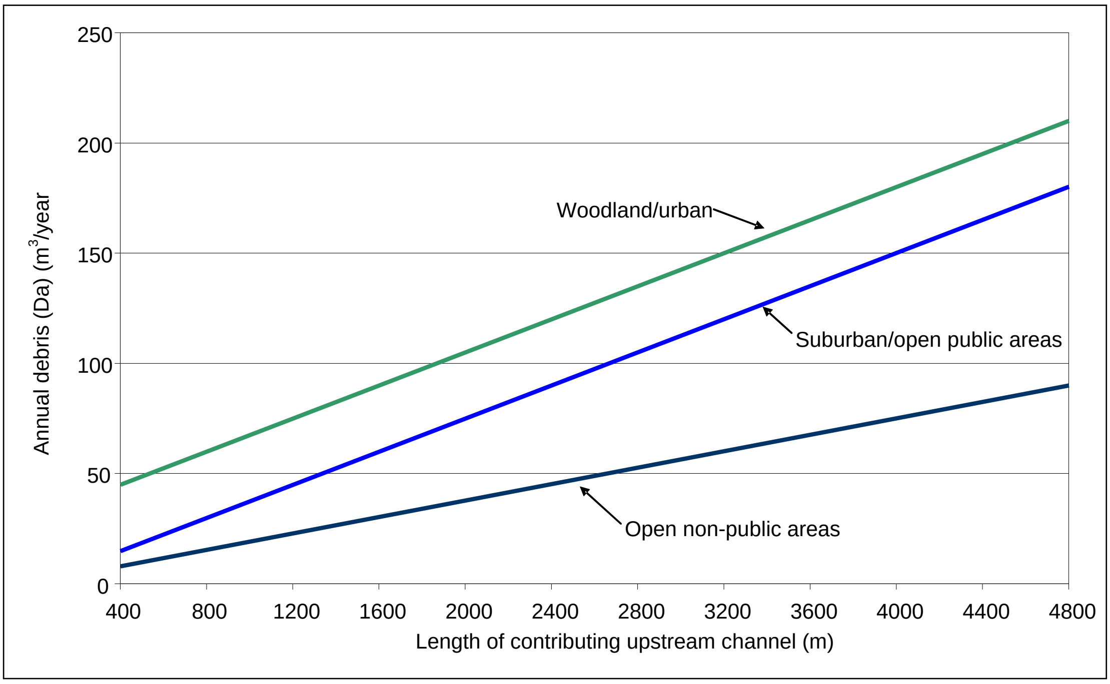


Figure 7.4 Amount of debris expected from different catchment types.

7.4.2 Design debris amount

The design debris amount (Dda) is determined by measuring the contributing length in each of the five catchment types and adding the values of Da (from Figure 7.4) to provide a total Da.

Using the average gradient (S1085) of the main contributing upstream length, the total value for Da obtained from Figure 7.4 is adjusted according to the rules set out in Table 7.2. This adjusted value is the total design debris amount (Dda), which is used to determine the size of screen as follows.

Table 7.2 Determining design debris amount.

Average gradient (S1085)	Design debris amount (Dda)
Less than 1 in 250	1 Da
One in 250 to 1 in 500	0.75 Da
One in 500 to 1 in 1000	0.5 Da
Greater than 1 in 1000	0.25 Da

7.4.3 Blinded depth factor

The next step is to determine the blinded depth factor (Bdf). This is based on the predominant catchment type and is intended to reflect the degree of blockage formed by the likely debris type on the screen. Table 7.3 is used to determine Bdf.

If there is a mix of catchment types, then Bdf is an averaged value taking into consideration contributing lengths.

Table 7.3 Blinded depth factor.

Predominant catchment type	Blinded depth factor (Bdf)
Woodland	0.63
Urban	0.23
Suburban	0.20
Open public areas	0.37
Open non-public areas (including farmland)	0.32

Figure 7.5 Multi-stage screen at the outlet from a flood storage facility.

Figure 7.5 illustrates a screen which is prone to blinding by vegetation. The degree of blockage of the screen may change the hydraulic performance of the outlet of the flood storage facility, which is fundamental to its optimum use. Removal of trash from the screen is complicated by the fact that there is no disposal area located near to the screen. It demonstrates the importance of accurately assessing the type of debris and the debris amount during the design of a screen.

7.4.4 Calculation of size of screen

The size of screen required is obtained by entering the Dda and Bdf for the screen site in the equation below, together with the likely number of significant events in the year.

$$\text{Screen area (m2)} = \frac{\text{Design debris amount (Dda)}}{\text{No. of significant events} \times \text{Blinded depth factor (Bdf)}}$$

For the purpose of this guide, a significant event is an event that has sufficient flow to lift debris off the bed and banks of the watercourse which otherwise would have stayed *in situ* during normal flows.

The number of significant events should be taken as three. Any variation on this value is only allowed if there is evidence from records (such as hydrological data over a period of five years) that such a change is justified.

Key guidance 22: Significant events

A significant event is an event that has sufficient flow to lift debris off the bed and banks of the watercourse.

Unless there is justification based on hydrological data/records, the number of significant events should be taken as three.

7.5 Screen layout

Having determined the area and components of the screen, it is possible to identify the potential screen layout. This can then be used for the hydraulic analysis (Section 10).

The potential layout is likely to develop through a number of iterations. There is no standard answer but there will be a layout which, under all design conditions, will provide the most efficient solution.

Information regarding single stage and multiple stage trash screen typical details is covered further in Section 11.

8 Selection of optimum bar spacing

8.1 Importance of bar spacing

It is essential to select the most appropriate bar spacing to maximise the effectiveness of the screen in fulfilling its design objective.

There is little point in placing a screen across a watercourse that allows material to pass of a size that could block the culvert it is protecting. Likewise if the screen is intended to exclude children, the screen bars must be spaced so as to prevent a child squeezing between them into the culvert. Experience has shown that children are more likely to take on the challenge of finding a way through the screen in dry conditions rather than being caught by, or washed through, a screen in high flows. The risk to a child dramatically increases if he or she has managed to squeeze through a screen into a culvert and is then trapped if sudden heavy rainfall occurs upstream.

There is always a need to determine the minimum spacing between bars necessary to exclude material that could potentially block (or in some cases, damage) the culvert or, where necessary, to exclude children. However, the spacing should not be reduced further to avoid trapping material that would otherwise pass harmlessly downstream.

Key guidance 23: Bar spacing (general)

The spacing between the bars of a screen should be the widest commensurate with achieving the objective(s). It is counterproductive to have a screen that traps debris which would otherwise pass harmlessly through the culvert. The chosen spacing must be checked to ensure that it does not conflict with any requirements for the passage of fish or wildlife.

Regardless of the spacing of the bars, material will build up on a screen. The rate of material collection will be a function of the debris arriving at the screen and the spacing of the bars.

Figure 8.1 shows a coarse screen at the inlet to a flood relief culvert. Despite the large spacing between the bars, the screen remains susceptible to collecting large volumes of material – much of it of a size that could flow through the culvert without causing blockage problems.

Figure 8.1 Coarse screen at a flood relief culvert inlet showing degree of debris build-up (the 'Beaverscreen' effect).

8.2 Bar spacing for security screens

If the screen is required as a security screen (to prevent adults and children entering), the clear space between its bars should be **140 mm**. This may seem a precise measurement, but experience has shown that screens with bars at this spacing normally ensure that children are prevented from getting through.

Key guidance 24: Bar spacing (security screens)

Security screens should be designed to have a clear space of 140 mm between bars. The hydraulic impact of bar spacing must be reviewed and investigated fully.

Caution should be taken in the detailed design of the screen. Design tolerances for producing a screen often lead to a spacing greater than the 140 mm recommended. This has been a problem where screens abut concrete side walls to the channel. Figure 8.2 shows an example where children were able to gain access.

In addition, there is often a desire to widen the spacing to the edge of the channel to assist the movement of animals. This guide recommends that safety should remain paramount and the spacing recommended above (140 mm) adhered to.

Figure 8.2 Design tolerances allowed children to squeeze between the concrete sidewall and the end bar on the screen.

8.3 Bar spacing for trash screens

Trash screens not required to act as security screens generally fall into two categories:

- those placed upstream of culverts including inverted siphons;
- those placed at the intake to land drainage pumping stations.

Trash screens are placed upstream of culverts and inverted siphons to prevent material entering that might otherwise cause blockage and subsequent flooding. This would, in turn, threaten the safety of people and property, and could cause more costly damage in the culvert or inverted siphon.

A thorough evaluation should be made of the type and size of material which would, if allowed to enter the culvert or inverted siphon, tend to accumulate and form a blockage. The following guidance is based on the characteristics of the watercourse and the culvert:

- A small diameter culvert (under one metre, for example) would be at risk from twigs and branches in addition to the commonly discarded supermarket trolley. In this case, a clear space of 150 mm between bars is recommended as the minimum spacing for this type of screen.
- For an urban location where there is a need to exclude oil drums or sofas, but allow smaller debris to pass, a clear space of 300 mm between bars may be appropriate.

Key guidance 25: Bar spacing (trash screens)

Trash screens placed upstream of culverts and inverted siphons should have a minimum clear spacing of 150 mm between bars. The spacing should prevent the passage of material of the type and size likely to pose a significant risk at the site.

In urban locations where larger debris needs to be excluded but smaller debris should be allowed to pass, spacing of 300 mm between bars may be appropriate.

8.4 Bar spacing for weed screens

Trash screens placed at the intakes to land drainage pumping stations are often referred to as weed screens. Their function is primarily to collect floating material that could otherwise be drawn into the pumps and affect performance or cause damage.

It is unusual for large heavy material to accumulate at these pumping stations as the velocity of the channels leading to the sites is low. The need to prevent weed and similar material entering the pumps results in a screen with more closely spaced bars.

As with all trash screens, reducing the bar spacing means the screen becomes blocked more quickly. Therefore, a regular cleaning regime must be established for this type of trash screen. Land drainage authorities, particularly land drainage boards, are well aware of this requirement and will establish a system of manual maintenance or automatic raking for the screen. It is not appropriate to rely on automatic raking where large or heavy material can accumulate at the screen.

Key guidance 26: Bar spacing (weed screens)

Trash screens (or weed screens) placed at the intake to land drainage pumping stations can be designed with a clear spacing of around 75 mm between bars, provided regular cleaning is carried out manually or by an automatic raking system.

8.5 Bar spacing on existing screens

For existing screens, the optimal bar spacing should be in line with the guidance provided above, depending on the type of screen required (trash and/or security).

However, to limit the need to unnecessarily amend efficiently performing trash screens, there is no justification to change an existing screen because of its bar spacing.

9 Environmental consequences and opportunities

All responsible authorities should consider both the primary flood risk management function of a screen and its environmental context. This covers the ecological status and targets for the watercourse and site-specific opportunities for environmental improvements. The early involvement of environmental specialists is most likely to identify any opportunities. The environmental opportunities will vary between sites and will be linked to the degree of environmental risk.

The potential for screens to have a negative impact on wildlife migration routes was highlighted in Section 4.6. Environmental specialists will be required to assess the likely impact and advise on mitigation and enhancement measures where a wildlife route or the ecological continuity of a watercourse could be interrupted by the installation of a screen. In our case, specialists from the National Environmental Assessment Service (NEAS) or the Area Fisheries, Recreation and Biodiversity teams should be consulted.

Key guidance 27: Environment

Designers must have regard to the environment and seek to reduce the impact of the screen while also seeking opportunities for environmental gain. However, the primary purpose of the screen must not be compromised.

9.1 Fish migration

Only mature salmon species could be discouraged by a screen and the installation of a screen on a salmon migration route would be very unusual. Other fish species are unlikely to be affected by bars with a minimum clear spacing of 140 mm.

In reality, fish migration is much more likely to be adversely affected by the presence of a culvert – with long, small diameter culverts having the greatest impact. If the negative impact on fish migration is a serious environmental concern, removal of the culvert should be considered. This would remove the need for a screen and resolve the fish migration issue. However, if a security screen is needed for health and safety reasons, this must take precedence over opportunities for environmental enhancement.

9.2 Aesthetic appearance

Screens often have a stark visual appearance and may offend the eye, not fitting in with the character of the local environment in certain settings. However, a culvert entrance is less likely to be found in such a sensitive environment.

The accumulation of trash on the screen tends to make it even less attractive, but this can be reduced by regular cleaning. This process will also improve the environment of the watercourse downstream by removing unwanted and unsightly debris.

9.3 Waste disposal

The temporary storage of trash and debris removed from a screen will become offensive and must be regularly removed from the site and disposed of safely. Trash and debris must not be burned at the screen site.

9.4 Ecological status

The Water Framework Directive (WFD) requires that the ecological status of rivers and streams is maintained and, where possible, improved. While culverting of a watercourse would lower its ecological status, the addition of a screen is unlikely to have a measurable impact other than a small increase in the length of channel bed that is artificial. Small reductions in ecological status can probably be more than offset by local improvements to the channel and such opportunities should be investigated.

10 Hydraulic analysis

10.1 The importance of hydraulic analysis

A major concern in the design of a screen is the risk of flooding if the screen becomes blocked (partially or completely) with debris. An essential part of the design process is to assess what could happen if a trash screen blocks with debris and what can be done to mitigate the flood risk. The screen design can then be refined to minimise flood risk.

Assessment of how a trash screen could cause flooding is a hydraulic problem, therefore a hydraulic analysis is required.

The purposes of the hydraulic analysis are to:

- check that the screen design is efficient from a hydraulic point of view;
- assess the impacts of blockages on hydraulic performance of the system;
- understand the flow velocities associated with the screen in terms of safety;
- refine the design of the screen so that:
    - it performs efficiently under a range of flow and blockage conditions;
    - the flood risk arising from blockage of the screen is minimised;
    - safety hazards are understood and managed or mitigated.

To achieve these objectives, the hydraulic analysis should include the screen and the structure it 'protects' (the system as a whole). The screen and structure cannot be considered in isolation. If the screen blocks, the way in which water flows through or round the structure must be considered.

To ensure a trash screen is efficient from a hydraulic point of view, the following issues should be considered:

- the layout of the trash screen will affect the way in which the flow will change as the screen blocks;
- the hydraulic impact of a screen is generally small when the screen is clean, but can increase rapidly once debris starts to accumulate;
- the full design flow should generally pass through the screen (except where the design allows flow to bypass the screen when it is blocked by debris);
- where a screen consists of several screen sections, the screen should be designed so that all sections contribute to trapping debris without increasing the upstream water levels to a level that would cause flooding.

10.2 Design criteria

Hydraulic structures, including culverts, are normally designed so that the upstream water level for a particular 'design flow' does not exceed a specified upstream level (usually a threshold above which property flooding would occur), plus a freeboard allowance.

This design condition should also take account of:

- additional allowance in capacity for an increase in flow by climate change;
- additional allowance for greater run-off from development in the catchment;
- deterioration of the culvert with time (expressed as increasing roughness of the culvert barrel);
- possible blockage of the culvert.

10.3 Hydraulic performance

10.3.1 Head loss

The head loss is the pressure needed to drive the flow through (or over) a constriction in a channel – in this case a culvert and screen. Head loss represents the difference between water levels upstream and downstream of the culvert and screen. The total head loss is referred to as the afflux caused by the constriction in a channel.

The screen contributes to the total head loss through the structure (Figure 10.1). Table 10.1 lists the components of the head loss from downstream to upstream.

Table 10.1 Components of head loss.

Component	Description
Outlet head loss	The loss of flow energy that occurs as the flow expands from the culvert into the watercourse downstream of the culvert
Friction head loss	The loss of flow energy caused by the friction of the culvert barrel surfaces (and bends, transitions and so on within the culvert)
Inlet head loss	The loss of flow energy that occurs when the flow contracts from the upstream watercourse into the culvert
Screen head loss	The loss of energy that occurs when the flow passes through the screen

The proportion of the total head loss through the culvert caused by the screen is small for a clean screen (Figure 10.1).

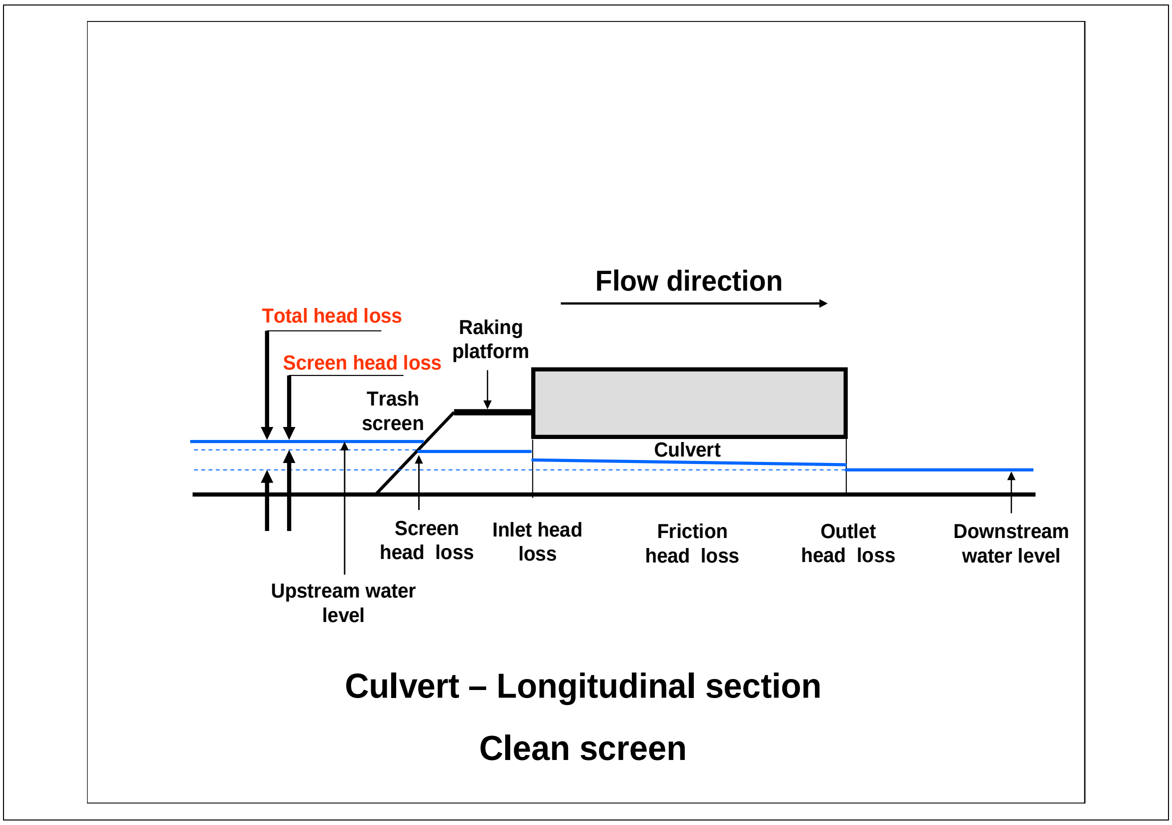


Figure 10.1 Contribution of a clean screen to the total head loss at a culvert.

The contribution of the screen to the total head loss depends on:

- the obstruction caused by the bars;
- the degree of blockage of the screen by debris.

Once a screen starts to become obscured by debris, the head loss across it increases significantly. This is because:

- the area available for flow through the screen reduces;
- the constriction to flow caused by the screen and the associated flow velocity increases.

In such circumstances, the head loss across the screen can become significant. The impact of blockage by debris is illustrated in Figure 10.2, which shows that the screen loss represents the largest component of the overall head loss through the screen.

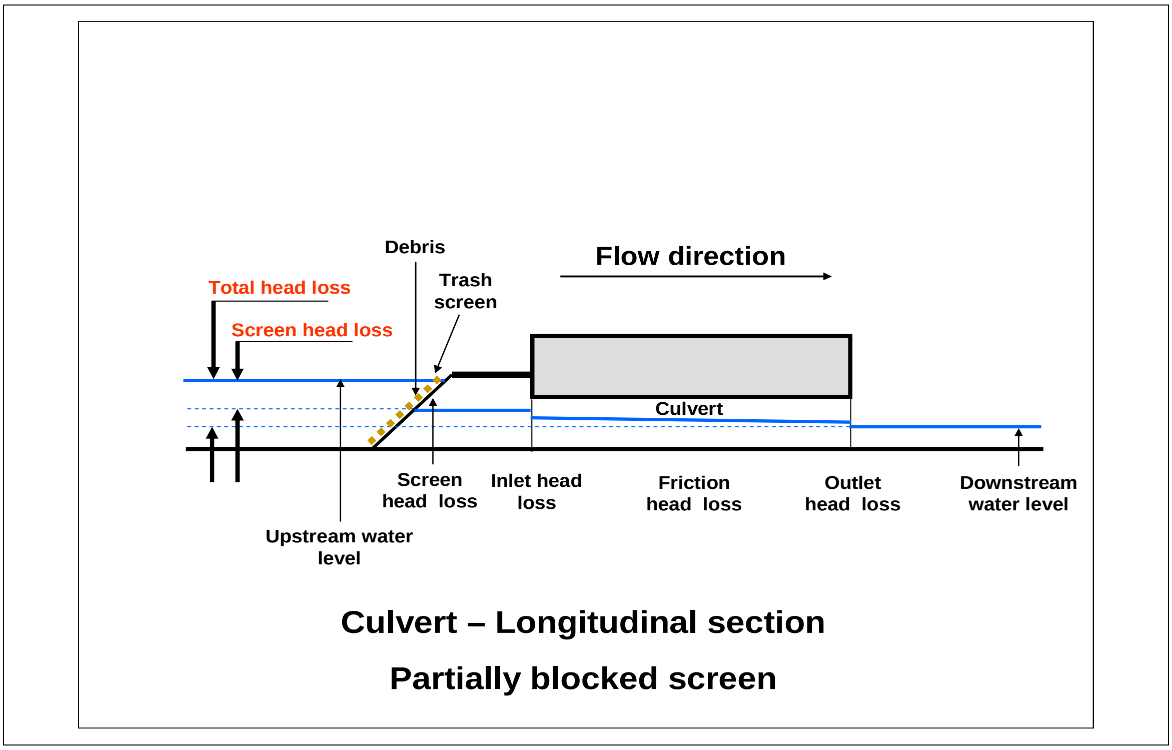


Figure 10.2 Impact of debris on partially blocked screen on total head loss.

Once debris starts to accumulate on a screen, it promotes further trapping of debris and a screen can quickly become completely blocked. The impact of this is shown in Figure 10.3, where the flow in the watercourse causes flooding and very little flow passes through the culvert. If there is no flow path across the obstruction, the flooding can be severe as there is no 'escape route' for the water. The use of bypass channels to avoid this eventuality is discussed in Section 12.

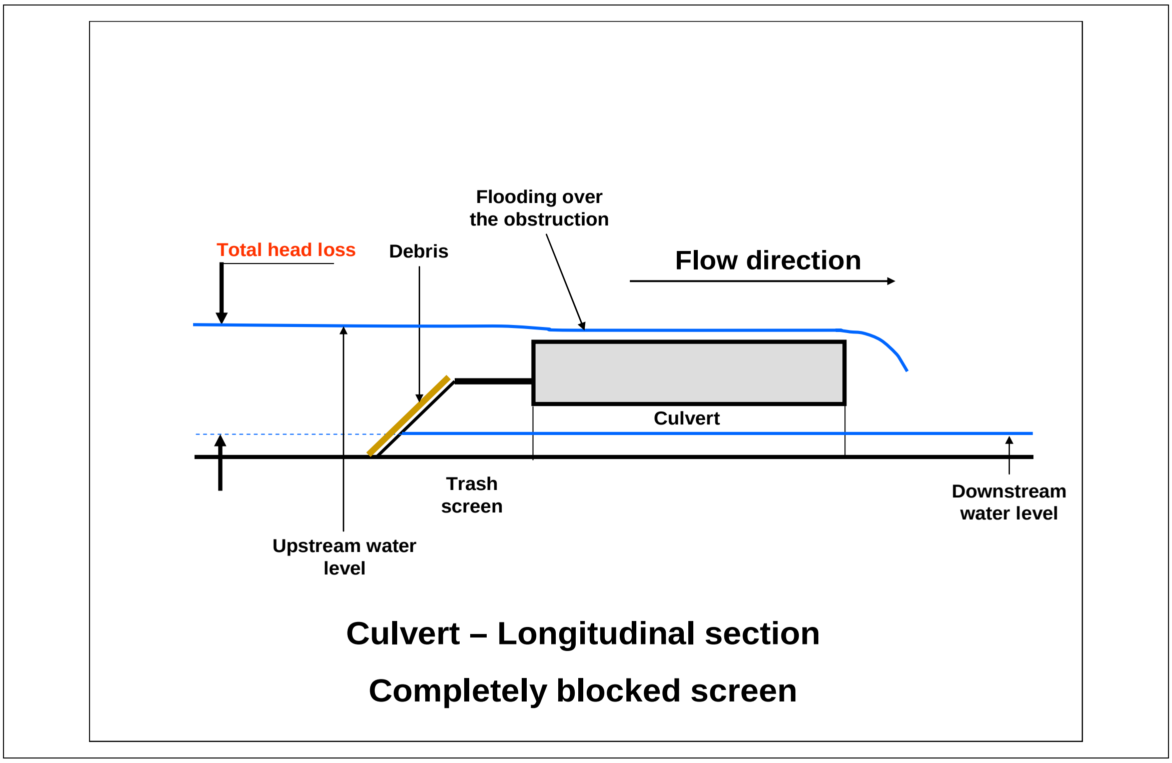


Figure 10.3 Flooding caused by total blockage of a screen.

10.3.2 Afflux

The afflux is an increase in water level that can occur upstream of a structure at high flows. Afflux can be defined as the maximum difference in water level, at a location upstream of a structure, between the structure being in place and it if were to be removed. In other words it is the additional top water level relative to the level that would exist if the structure was not present. This is not the same as the head loss (the upstream to downstream top water level difference).

10.4 Approach to hydraulic analysis

A screen normally forms an integral part of the overall culvert structure. The hydraulic analysis should be carried out for the whole structure plus the associated watercourse upstream and downstream, and not just the trash screen. It should cover:

- design conditions;
- design process;
- screen layout;
- hydraulic calculation;
- hydraulic modelling;
- refinement of the screen design.

These elements are detailed below.

10.5 Design conditions

The design conditions to be considered are:

- combinations of size of the flow in the watercourse;
- degree of blockage of the screen.

The critical design condition for a culvert with a screen is likely to be the coincidence of high flow with a significant degree of blockage on the screen.

10.5.1 Flow

The design flows to be used in the design of a screen are as follows.

- For a new culvert, the screen should be designed for the ‘design flow’ of the new culvert. In urban areas, the current design flow is nominally the flow with an estimated one per cent chance of being exceeded in any one year (‘100-year’ flow) – though the design flow frequency may change as a result of project appraisal. An additional allowance is recommended to take account of the possible impacts of climate change. This will depend on the expected life of the structure, but a design flow 20 per cent higher than the current design flow is normally recommended (Defra 2006).

- For an existing culvert, the design flow is the present capacity of the culvert. In practice, the addition of a screen will increase the head loss through the culvert and therefore reduce the capacity.

- In both cases (new or existing culvert), a flow that exceeds the design capacity should also be used to assess performance in extreme flood conditions. The result of this test can be used to modify the design of the system to minimise flood risk. Flow with an estimated 0.1 per cent chance of being exceeded in any one year ('1,000-year' flow) should be used for this test.

- In addition, performance should be assessed for a more frequently occurring event. This will provide operational information on the screen's performance, enabling operational staff to prioritise the screen for cleaning during a flood. Flow with an estimated 20 per cent chance of being exceeded in any one year ('five-year' flow) should be used for this test.

These recommendations are summarised in Table 10.2.

Standard methods for predicting flood flows are available and methods for estimating flood flows are therefore not provided in this document. The main method used in the UK is given in the Flood Estimation Handbook (Institute of Hydrology 1999). This provides 'no data' methods for estimating flood flows.

It is normally recommended that the results are reviewed using local data (where available) to ensure the flow estimates take account of local conditions. These data include flow data from local gauging stations (where available). Flood flow data for gauging stations in England and Wales are available from the HiFlows-UK website (http://www.environment-agency.gov.uk/hiflowsuk/). However, screens are often on small watercourses for which no gauged flow data are available.

10.5.2 Blockage

The area of screen calculated using the evidence-based method described in Section 7.4 includes an allowance for partial blockage based on observations of screens over a number of years. In order to carry out a hydraulic analysis, it is necessary to make assumptions about the degree of blockage in any particular flood condition. Recommendations about this are included in Table 10.2.

Table 10.2 Recommended design conditions for the hydraulic analysis of the culvert structure.

Element	Design condition
Culvert design flow	Nominally the 100-year flow for new culverts in urban areas plus 20 per cent to allow for climate change
Culvert design flow with partial blockage of the screen	Blockages of 30 and 67 per cent of the screen area
Extreme flow	1,000-year flow plus 20 per cent to allow for climate change
Frequent flood	Five-year flow
Culvert design flow	With 100 per cent blockage of the screen

10.6 Design process

By this stage, an initial design of the screen will have been developed based on the screen area calculated in Section 7 and the constraints of the particular site. This initial design will show the location and layout of the screen including plans and sections.

The next step is to undertake hydraulic calculations to:

- determine the upstream water levels;
- assess whether the screen achieves the design criteria set in Section 10.2.

The hydraulic design essentially involves calculating the likely water profile through the culvert, screen and the upstream approach channel. The design may be carried out using manual calculation methods (see Section 10.8) or modelling (see Section 10.9).

Feedback from the hydraulic design is used to refine the design of the screen (see Section 10.10).

10.7 Screen layout

While the screen layout will depend on the required screen area and local site conditions, it is essential that the layout is satisfactory from a hydraulic point of view. The hydraulic design is likely to lead to changes to the initial design so that it performs efficiently under the range of design conditions and minimises the risk of flooding when blocked by debris.

Ideally flooding should not occur before a screen blocks. Flooding could be mitigated by the introduction of a bypass route as discussed in Section 12. The normal alternative flow path is over the screen, but the banks of the channel upstream of the screen must be high enough to accommodate the flow (including upstream backwater effects).

Particular problems arise at urban screens, where debris loads are high and space is limited. Two possible approaches to achieving a large screen area in a confined location are to have:

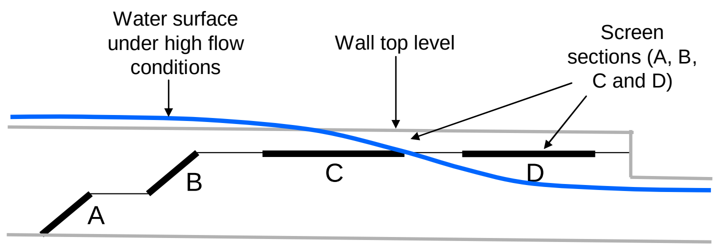
- a long screen located diagonally across the watercourse (where space is limited this might be almost parallel to the watercourse);
- a long screen running parallel to the watercourse where the flow is effectively transferred sideways into a parallel channel.

Even in these cases, where there is a large screen area, there should be a flow route over the screens in case of blockage.

One problem with long screens located diagonally in narrow channels is that they reduce the cross-section of the channel. Large debris could block the narrowing channel, rendering much of the trash screen ineffective. Ideally, the channel cross-section upstream of any part of the screens should not be reduced. In addition, any screen that requires the flow to change direction introduces another head loss and increases the propensity of the screen to trap small debris. Such arrangements cannot be used as an easy way to keep water levels within banks or to achieve the design screen area.

Another approach to preventing screen blockages where large amounts of debris occur is to introduce one or more coarse screens some distance upstream of the culvert, in order to remove large items of debris. This is the equivalent of the ‘boulder trap’ often found in mountainous areas. Such screens will require a hydraulic design to check that the watercourse walls and banks are high enough to prevent flooding if the screen blocks. In such cases, flow would normally pass over the screen which would behave as a weir.

The screen layout should be designed so that flooding cannot occur if only part of the screen is blocked. Figure 10.4 shows a design which attempts to provide a large screen area in a narrow channel. However, only part of the screen is used before flooding occurs. In such cases, a detailed hydraulic analysis is necessary to determine the hydraulic performance under a range of flows and blockage conditions.



Example of a trash screen on a narrow channel:

Longitudinal section

The way in which this arrangement would perform is as follows:

1. Screens A and B (which form a small part of the total screen area) are likely to block first.
2. Flow then passes through screen C but the constricted flow area between screens B and C leads to flooding. The screen is now behaving as a weir.
3. Flooding occurs before screen D becomes effective.
4. A mitigation measure is to raise the walls. This will be needed for some distance upstream.
5. A hydraulic analysis is needed to calculate water levels under a full range of flows and blockage conditions to determine wall levels, etc.

Figure 10.4 Flooding caused by partial blockage of a trash screen in a narrow channel.

10.8 Hydraulic calculation

The most comprehensive study of culvert performance was by the US Federal Highways Administration (FHWA). The results of this study are given in a design guide FHWA (1985), which forms the basis of the method provided in the *Culvert Design Guide* developed by CIRIA (1997). This method is used for calculating the head loss caused by a culvert including the trash screen. This guide is currently being updated to *the Culvert Design and Operations Guide* which will be published in 2009.

The Afflux Estimation System (AES) has been developed by UK operating authorities (see Section 10.9.1) to provide a computer-based tool to estimate afflux at bridges and culverts. For culverts, AES includes methods shared with the FHWA and CIRIA guides. It is intended that AES will be updated alongside the new CIRIA guide to include a method for calculating afflux that takes account of trash screen blockage. This will then allow rapid calculation of head loss through screens as well as culverts.

10.9 Hydraulic modelling

Hydraulic modelling can be used to estimate water levels at the screen and methods are available for any screen configuration. However, before carrying out any modelling it is necessary to confirm that modelling is required. In many cases, it will be possible to undertake the required hydraulic analysis manually using the guidance in this document and its associated references.

The decision whether to use modelling will depend on:

- the complexity of the analysis;
- the availability of data;
- the ease with which the modelling can be carried out.

An important benefit of modelling is the ability to model a range of different conditions quickly once the model is set up.

Whichever approach is adopted, an initial hydraulic design of the screen is advised to ensure:

- the model (or other hydraulic calculation) covers all the design cases;
- each design case is correctly represented within the model.

It is particularly important to consider how the screen (including blockages) should be represented in the model. This involves identifying the locations where upstream water levels are 'controlled' for different design cases.

Key guidance 28: Hydraulic analysis

Depending on the complexity of the site and availability of data, various levels of hydraulic analysis can be carried out.

In many cases manual hydraulic analysis may be sufficient. If the analysis is complex, data is available and modelling can be carried out relatively easily, hydraulic modelling may be the preferred approach.

In the example in Figure 10.4, the upstream water level is initially controlled by the culvert but, as screens A and B begin to block, these become the control on upstream water levels. When screens A and B are fully blocked, the control becomes the weir between screens B and C. If screen C becomes fully blocked, the control becomes the weir between screens B and D. Each control should be represented in the model so that it is able to predict upstream water levels for the full range of flows and blockage conditions.

It is strongly recommended that a screen is modelled as a separate discrete unit so that conditions upstream and downstream of the screen can be clearly identified from the model results. The discrete representation may include the following elements:

- energy loss representing flow through the screen – where there are several screen sections (as in the example in Figure 10.4) a separate loss may be required for each screen section or group of sections;
- weir representing flow over the screen (where appropriate);
- orifice representing flow over the screen (where appropriate);
- bypass routes (where appropriate).

When applying a computational hydraulic model, the designer must be able to represent the relevant elements in the model. The model should include the culvert and screen as separate discrete units. In the example in Figure 10.4, it is important to include the screen losses and a weir to represent flow over the top of the screens.

The leading hydraulic modelling software packages include methods for modelling culverts. These methods are summarised in Table 10.3 for the three most commonly used hydraulic modelling software packages in the UK. All three models use one-dimensional hydraulics and the designer needs to assess values for coefficients for non-standard cases (such as screens that are not perpendicular to the flow).

The designer must also be able to check that the model predictions are reasonable. Separate calculations should be carried out to provide a check on the model results.

Table 10.3 Culvert and trash screen modelling capability of hydraulic modelling software.

Software	Culvert and trash screen modelling capability
ISIS	Method described in the *Culvert Design Guide* (CIRIA 1997). Screens can be modelled as separate units with overflow weirs and other elements as required. ISIS was updated to include Afflux Estimation System (AES) in 2007
HEC-RAS	US Federal Highways Administration method (FHWA 1985)
MIKE11	Components of culverts represented by orifice units and energy losses
Other	Bespoke software developed for channel conveyance may be appropriate, but needs to be carefully considered

Key guidance 29: Hydraulic modelling

When using computational hydraulic models, it is essential that the designer understands the calculation process in the model and ensures the design is represented correctly.

It is the responsibility of the designer to ensure the hydraulic model is capable of modelling the proposed design for all flow and blockage scenarios.

It is difficult to model complex arrangements of culverts and screens accurately using computational models. This is often because there are interactions between the flow through different screen elements or the flows are three-dimensional. Examples include:

- a culvert on a bend, where there may be a very uneven distribution of flow across the screen which affects the way in which silt and debris accumulate (this also applies to screens that are not placed at right angles to the flow direction);
- the one shown in Figure 10.4, where flow over the screen drops vertically through screen sections C and D and then combines with flow through screen sections A and B.

In such cases, it may be better to use a physical model of the culvert and screen, with a scale large enough to avoid scale effects in the modelling.

Figure 10.5 shows the results obtained with a two-dimensional model used in the design of a screen on the River Sheaf in Sheffield.

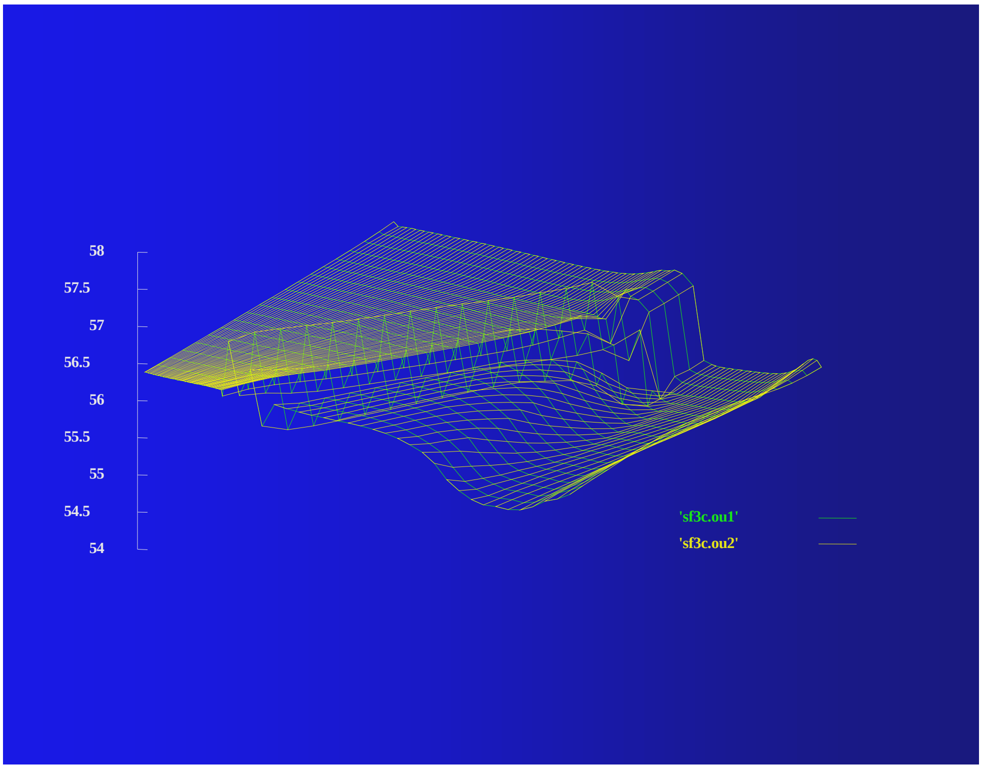


Figure 10.5 Two-dimensional hydraulic model used to aid the design of a screen on the River Sheaf (diagonal alignment to flow).

10.9.1 Conveyance and Afflux Estimation Systems (CES/AES)

The UK operating authorities involved in flood risk management have developed methods and software to estimate water levels in channels and at bridges and culverts. These packages are the Conveyance Estimation System (CES) and Afflux Estimation System (AES).

They have been combined in a single, stand-alone water level estimation software application available to Environment Agency staff and for download at http://www.river-conveyance.net, where supporting documentation can also be found. The CES is also generally available within ISIS and InfoWorks (AES may be included subsequently).

- **Conveyance Estimation System (CES)** This comprehensive software package allows the user to estimate the flow capacity (conveyance) of any reach of channel given data on the dimensions, form and vegetation.
- **Afflux Estimation System (AES)** This package is designed to allow the estimation of the hydraulic impact of a bridge or a culvert on a watercourse. The software will estimate the increase in water level upstream as a result of the constriction caused by the bridge or culvert for a given flow condition.

AES does not currently include a trash screen module or methods for complex culverts (such as those with multiple changes in barrel section or junctions). However the AES does model a full range of flow modes ranging from free flow to surcharged flow, and blockage could be simulated approximately by assuming reduced inlet dimensions.

In common with all software packages, the analysis incorporates certain assumptions, some of which can be user-defined. Before such a package is used for hydraulic analysis, it is vital to ensure it is fit for purpose, and that the assumptions made are appropriate to the problem being analysed.

10.10 Refinement of screen design

The results of the hydraulic analysis should be used to refine the design of the screen and the associated engineering works. This may include:

- improved design and operational criteria for the screen (where the degree of blockage can be related to upstream levels and flood risk);
- adjusting upstream walls and bank levels so that design flows can be accommodated even if blockage occurs;
- designing bypass routes and other mitigation measures to reduce the likelihood of flooding if the screen blocks.

The hydraulic analysis should also cover design details that could improve the hydraulic performance of the screen and culvert and the management of safety hazards such as:

- avoiding areas where sediment could accumulate and affect the hydraulic performance;
- maintenance requirements for the overall structure;
- understanding flow velocities in normal and extreme conditions in and around the screen and culvert.

Key guidance 30: Refinement of screen design

The results of the hydraulic analysis should be used to refine the design of the screen and the associated engineering works.

It should also help to improve the hydraulic performance of the screen and culvert and inform the management of safety hazards.

11 Detailed design of a screen

The design of a trash screen will be unique for each site and depend on a wide variety of factors. It is essential to:

- identify the critical factors in the design of the complete installation;
- record the decisions as to how these factors have been addressed.

The design of a screen should not just focus on reducing flood risk. Although this is the main factor, the following must also be taken into account:

- health and safety of operatives and the general public;
- involvement of the CDM coordinator[1] for the project;
- amenity;
- ecological and environmental impacts, including possibilities for enhancement.

The main aspects to be considered in the detailed design of a screen are discussed below. We have produced typical detail design drawings for a single stage, two stage and coarse screen which can be used as an aid to the design of the screens. Although these are not definitive they provide guidance on the typical layout and design requirements which can be incorporated. The typical detail drawings are available internally at:

http://eams.ea.gov/EAMS/How_We_Work/main/agencydocument19532.htm and http://eams.ea.gov/EAMS/How_We_Work/main/agencydocument19541.htm

Figure 11.1 A recently installed screen in an urban setting.

[1] A CDM coordinator is a role under the Construction (Design and Management) Regulations 2007 (see http://www.hse.gov.uk/construction/cdm.htm)

Figure 11.1 shows a recently installed screen comprising two stages and a small horizontal screen section to the rear of the lower working platform. The screen has been fitted to the sloping sides of the channel and access steps have been provided to both platforms. The support structure for the screen and platforms has intruded into the channel bed - this will introduce an additional head loss.

An access hatch has been built into the culvert through the upper working platform (top right of photo). The site is fenced and has lighting to facilitate working during the hours of darkness. Water levels are monitored and telemetered to an operations centre. This trash screen has incorporated a number of 'good practice' design features.

11.1 Screen cleaning

It is essential that the arrangements for cleaning the screen are appropriate to the nature and quantity of the debris anticipated at the site.

11.1.1 Screen position

The screen position depends on:

- required design size;
- location of the structure to be protected from debris.

Whatever the size of screen, it should be possible for operatives to safely rake it under routine and most non-routine conditions. It may not be possible to rake the screen if it is drowned, but the design should afford operatives early and safe access to the screen once water levels subside. If there is risk of flood damage to adjacent areas, there should be contingency arrangements for screen clearance (vehicle-mounted grabs).

11.1.2 Method of screen cleaning

There are three systems for cleaning screens:

- manually using suitably hooked rakes;
- mechanically by specific grab systems or mobile plant (e.g. hiab lorries);
- mechanically by automated screen-clearing mechanisms.

Each of these systems should be evaluated separately. However, a mechanical system is generally justifiable only in special circumstances – especially given the poor record of this system on screens protecting culverts on rivers in urban environments.

The raking of screens against a significant head of water (during a non-routine event) is usually difficult and can be dangerous for operatives. Screen design should endeavour to minimise manual clearing and provide safety arrangements at the installation. Manual handling risk assessments should be completed for both routine and non-routine clearance.

An automated mechanical screen-clearing mechanism is suitable for sites where the debris load is fairly consistent and builds up more quickly than can be cleared manually.

Issues associated with the use of an automated mechanism include:

- health and safety hazards associated with unauthorised access;
- inability of the mechanism to cope with unusual debris;
- reliability of the mechanical and electrical equipment in adverse weather conditions.

If an automated mechanism is used, its performance should be remotely monitored.

The use of hiab lorries in the mechanical cleaning of a screen can fulfil two requirements. They can be used to clear the screen by removing debris from the channel, and can then transport debris away from the site for proper disposal.

11.1.3 Removal of large items

In some locations, it may be necessary to remove large objects (usually a result of fly-tipping) from the watercourse. The designer should consider the likelihood of this occurring and the best method for dealing with it.

If access is straightforward, bringing suitable mobile plant to site should suffice.

If access is difficult, it may be necessary to have specialist equipment on-site (such as winches and grabs). If this is the case, these should not obstruct the normal clearing arrangements and access ways.

Key guidance 31: Screen-cleaning arrangements

Arrangements for cleaning the screen must be appropriate to the nature and quantity of the debris anticipated at the site.

It should be possible for operatives to safely rake a screen under routine and most non-routine conditions. If a screen is drowned it may not be safe to clear, however the design should afford operatives early and safe access to the screen once water levels subside.

Each method for screen cleaning should be evaluated separately and the design should minimise manual clearing and provide suitable safety arrangements.

11.1.4 Rake details and reach

Manual clearance is traditionally undertaken using hooked rakes with three or four prongs. The efficiency of raking depends on the ability of the operator. The main factor is the stretching required to rake the screen. The operator should be comfortable with the reach required. A two-metre rake length has been found to be the maximum, with 1.5 metres being the preferred length.

The design of the rake should be matched to the screen in question, although it is impractical and inefficient to have a different rake for each screen. The prong length should be enough to allow a firm grip on the debris being raked, but not so long that the prongs snag on the screen cross members (especially at the top of the screen where the bars turn over onto the working platform). A maximum prong length of 150 mm is suggested.

The width of the rake head should not be so wide as to require excessive raking effort. Rake heads wider than about 450 mm are usually impractical.

The prong spacing should be such that the prongs fall naturally between the screen bars. A prong spacing of 150 mm would meet most circumstances but, for smaller debris, 75 mm may be preferable.

Large items (such as armchairs, timber pallets and tree trunks) cannot be readily removed with a rake.

Key guidance 32: Rake reach and prong length

Maximum rake length is two metres, with 1.5 metres being the preferred length.

A maximum prong length of 150 mm is suggested. Rake heads wider than about 450 mm are usually impractical.

11.2 Height of screen and need for stages

To enable clearance to be carried out safely and comfortably a single screen length (dimension parallel to the bars) should be limited to two metres (preferably shorter).

To accommodate a greater area, further stages should be added to the design with working platforms between each stage.

To enable manual handling of debris from one working platform up to the next, the vertical distance between platforms should not exceed 1.2 m.

11.3 Screen bars

Although screen bars must be robust to resist vandalism, narrow bars are preferable because of the reduced impact on stream hydraulic performance. Bar design is therefore a compromise between strength and hydraulic impact.

Flat bars are preferred to round bars because they offer strength with minimal hydraulic impact.

Bar dimensions should generally not be less than 8 × 75 mm for flat bars. Thicker (10 or 12 mm) bars may be advisable where extra strength is required. Attempting to save money by making the bars as slender as possible is a false economy.

Rounding the upstream edges of the bars will slightly improve the hydraulic performance and may reduce the propensity for the screen to trap small debris. However, the additional expense of rounding the edges of mild steel flats may be difficult to justify. The use of round bars to achieve the same effect is self-defeating because the bar diameter will be much greater than the width of a mild steel flat of the same bending resistance.

The maximum unsupported length of a bar should not exceed 1.5 m. Bracing should be provided if the bar length exceeds 1.5 m. Bracing members should be recessed behind the screen to avoid interference with the passage of a cleaning rake.

Figure 11.2 A debris screen on a small culvert.

In Figure 11.2 the screen arrangement could be improved by making full use of the inlet structure by making the slope of the screen less steep. It is also important to note that the bracing member mid-way up the bars is recessed so that it does not interfere with raking of the screen.

The bottom of the bar should be fixed to a horizontal member. The horizontal member may either be embedded in the channel bed or be raised above the bed. The height of the bottom horizontal member above the bed should be similar to the bar spacing dimension for a trash screen, and no more than 140 mm for a security screen.

The top of the bar should have a return length which is fixed to the top horizontal member. The return length should be sufficient to enable the tines of the rake to remain clear of the horizontal member.

Galvanized mild steel is generally considered to be the most efficient construction material for screen bars.

Key guidance 33: Screen bars

Bar dimensions should not be less than 8 x 75 mm for flat bars.

Maximum unsupported length of a bar should not exceed 1.5 m. Recessed bracing should be provided if bar length exceeds 1.5 m.

Figure 11.3 Trash screen in a public park.

Figure 11.3 shows a trash screen where the bar spacing on the screen has been designed to collect large debris. The top of the bars also include a return to enable debris to be raked onto the working platform. The bar return is too shallow and does not allow the tines of the long handled drag rake to clear the front edge of the working platform.

11.4 Screen alignment

The plan alignment of the screen would normally be at right angles to the flow as this provides for debris collection across the full width of the screen. If this arrangement together with multiple stages cannot provide the required screen area, it may be feasible to place the screen diagonally across the channel. In this instance, the impact on both the hydraulics and debris load should be considered in detail.

For the full area of a diagonally oriented screen to be effective, flow direction has to change twice in its passage through the screen – the greater the skew of the screen, the more difficult the flow path. This increases the head loss through the screen and increases the propensity for the screen to block with small debris – both of which must be allowed for in the design.

A diagonal screen in a narrow channel also carries the risk that debris will block the channel part way along the screen, making the arrangement ineffective. The adoption of a diagonal screen is not an easy way to increase screen area – it requires detailed hydraulic appraisal before being accepted as a solution for a site.

Figure 11.4 shows a screen on the River Sheaf in Yorkshire with a diagonal alignment to flow. Two-dimensional hydraulic modelling (see Figure 10.5) was required before and during the design of this screen to ensure this was a suitable option.

Figure 11.4 Screen on the River Sheaf with diagonal alignment to flow.

11.5 Angle of screen

The screen should be placed at a preferred angle of 45° and a maximum of 60° to the horizontal.

Angles to the horizontal of less than 45° tend to result in a working platform that becomes drowned out very quickly during high flows and is unsafe.

Angles steeper than 60° present operatives with a high manual handling risk.

Mechanical installations fall outside these guidance limits. The designer will therefore need to ensure there is suitable reason to depart from this guidance.

11.6 Fabrication and materials, fixings and fastenings

Wherever possible and in line with our waste minimisation programme, the design of the screen should include the reuse of materials if a screen is to be rehabilitated or repaired.

Selection of material for the installation should take into consideration the local area, for example, the need to consider durability and likelihood of theft if the trash screen is to be located in an urban area.

Key guidance 34: Fabrication and materials

The materials from which a screen and its associated platforms and support structure are made should be robust and durable. This is important because the screen often has to perform in a challenging environment (such as corrosion, vandalism, debris loads, cleaning process).

Galvanized steel has been shown over a long time to meet these requirements. Designers wishing to adopt alternative materials must be confident of their ability to remain serviceable for a significant period (for example, 30 years).

11.7 Working platforms

11.7.1 Platform depth

In the context of this guide, platform depth is defined as the distance between the upstream and downstream edges of the working space.

Platform depth should allow operatives to rake the screen by moving from the front to the rear of the platform in comfort and allow for some temporary storage. The depth of platform should therefore be of similar dimensions to the rake reach required (see Section 11.1.4). It is unlikely that the depth of a platform would be less than 1.5 m or greater than 2.5 m.

11.8 Health and safety provisions

The main health and safety issue associated with a screen site is the requirement to maintain, through a number of provisions, the safety of the public and operatives working on the site – both day and night, in high and low flow conditions.

A health and safety file should be completed for all new structures as part of the design requirements of the Construction (Design and Management) Regulations (CDM) 2007 http://www.opsi.gov.uk/si/si2007/20070320.htm (Health & Safety Executive 2007).

Particular attention must be given to hand rails, fencing, ladders and step irons to ensure they are operationally acceptable while meeting current regulatory standards.

Key guidance 35: Health and safety

It can help operatives if the screens for which they are responsible have common features (such as the design of anchorages for safety harnesses). However, health and safety issues cannot be addressed with ‘standard’ designs.

Health and safety provisions must be bespoke, that is, they should be designed for the screen in question and its particular operational requirements, making use of standard equipment where appropriate.

11.8.1 Safety harnesses

Safety harnesses should accommodate the range of operative movement expected on the raking platform in both routine and non-routine circumstances. Suitable anchoring points for operatives’ safety harnesses should be mounted at the rear of the raking platform.

In some cases, the installation of hand rails at the front of the working platform prohibits the raking of the screen. Use of a hook-on system where the operatives secure harnesses to an anchoring point is the preferred option.

Anchoring points can include eyebolts and/or anchor posts. Depending on the layout of the site, there may need to be a series of these.

11.8.2 Warning notices

Depending on the designed level of the working platform(s), clearly visible water-level warning boards should be displayed indicating when it would be unsafe to access the platform. This is a particularly important feature on lower levels of staged screens and has important implications when a maintenance team is unfamiliar with the site (see also Section 11.8.4).

Both the public and operatives should be made aware of the principal hazards, including high velocities caused by partial blockage. It is possible for these to trap an individual against the screen.

11.8.3 Lighting

Lighting must be provided at any site where it is necessary to carry out maintenance activities in the dark.

Under no circumstances should operatives be permitted to work on the screen in darkness.

Suitable lighting provisions are identified as follows:

- if a suitable mains power supply is not locally available, consider a mobile generator;
- mobile lighting may be appropriate in locations subject to vandalism;
- permanent brackets can be installed at the site from which portable lighting can be fixed temporarily;
- if the above lighting arrangements are not possible, hand-held or cap lamps/head torches must be provided;
- there may be an environmental impact as a result of lighting provision.

Key guidance 36: Lighting provision

Under no circumstances should operatives be permitted to work on the screen in darkness.

11.8.4 Water depth indicator

Operatives may be called out to a site with which they are not familiar. They may arrive to find the trash screen submerged by high water levels, making it unclear as to the depth of water in the channel. It is therefore essential to provide a water depth indicator to help operatives decide whether it is safe to clear the screen or not. This can be in the form of stage boards or similar, located upstream of, or in line with, the screen.

11.8.5 Health and safety design review

In the final design check, it is important to ensure:

- generic and site-specific health and safety issues have been adequately addressed;
- there has been sufficient consultation to alleviate all concerns.

11.9 Access to the screen

There are two fundamental design requirements for access to the screen:

- access to the screen must allow cleaning and maintenance operations to take place in both routine and non-routine situations;
- the screen should be safe for maintenance and operational staff to work on both day and night.

11.9.1 Site location

Site location is likely to be related to the culvert entrance, which is normally already set. While some screens can be placed upstream of the culvert and have separate access provisions (such as an overtoppable coarse debris screen), most cases will require access to the screen in the vicinity of the culvert entrance.

11.9.2 Site access

In the majority of cases, vehicle and pedestrian access will be needed. Access should accommodate the removal of collected debris.

If direct access from the public highway does not already exist, the preferred solution is to construct a new access.

A permanent, hard and even surface should be provided in all cases.

Designers must avoid compromising the functioning of the screen by not making proper provision for access for routine maintenance and emergency cleaning operations.

11.9.3 Screen access

A suitable, safe hard-standing area for vehicles and/or operatives should be provided at the end of the site access road. There should be a clearly designated route from this area to screen raking platform(s), and areas that will require regular maintenance.

In addition, the route must be free from:

- tripping hazards;
- unexpected rises or falls;
- obstructions to passage;

- obstacles that would require unnecessary stretching or bending by operatives.

11.10 Storage of debris

11.10.1 Transfer of debris to storage area

The screen should be designed such that debris can be transferred easily to the working platform. Once on the platform, the debris should not impede continuing operations to clear the screen. There should be a clear transfer route from the platform to a temporary storage area off the working area.

11.10.2 Temporary storage of debris

Cleared screen debris needs to be stored temporarily in a holding area before transfer off-site (see also Section 13.4).

The storage area should be:

- remote from the screen itself so there is no possibility of debris migrating back to the screen or watercourse;
- located to make transfer from screen to storage straightforward for operatives.

Provided the debris is stored temporarily (up to 72 hours) within the boundaries of the site, the activity will not be subject to waste regulations.

The capacity of the storage area should reflect the likely volume of debris in a non-routine event. This volume will have been calculated for the evaluation of potential debris load in Section 6. It may be prudent to provide a safety margin, especially if events are frequent and transportation of debris away from the site is difficult.

11.11 Visual amenity issues

Where any new or remedial works can be justified, the opportunity for visual and other environmental enhancements should be identified and implemented (including fencing and planting). This is likely to involve liaison with specialist environmental staff.

11.12 Security arrangements

Security arrangements are also discussed in Section 11.14 on CCTV.

The site must be provided with a level of security appropriate to the characteristics of the local area, and type of screen to be installed.

The primary considerations are whether there are potential issues with children accessing the site and the type of equipment to be kept on the site.

11.12.1 Fencing

Careful consideration should be given to fencing the screen from public access. Certain hazards will require the area to be fenced such as:

- deep water;
- moving mechanical parts;
- significant fall heights.

If fencing is not possible (due to the potential for vandalism, channel geometry and so on), these safety hazards must be mitigated in some other way.

To discourage entry to the channel and the culvert, experience has shown that artificially increasing the depth of the water upstream of the culvert entrance is beneficial. This can be achieved by lowering the channel bed or by providing a crump weir which will hold the water back and create greater depth.

When designing fencing for security around a site, reference should be made to the appropriate part of BS 1722:2006 for guidance on the specification (BSI 2006). The BSI 1722 series specifies requirements for different types of fencing as appropriate.

11.12.2 Culvert entrance enclosure

If a screen is required for security reasons, the culvert entrance should be totally enclosed by the screen (where possible). Total closure means the gaps at the side walls must not be larger than the bar spacing for the screen in question.

11.12.3 Access to the culvert

Access should be provided within the screen arrangement to allow authorised personnel to gain access to the culvert and to the rear of the screen.

The access cover should be integral to the screen construction, but not impede the function of the screen.

There should be fixing arrangements to secure the access cover in the open position to remove the risk of injury to people using it.

There should also be safe access arrangements to enter the culvert (such as a ladder, handholds, locks, keys, stepping-off area).

Cast-in step-irons are not considered appropriate. If a permanent ladder fixing is not feasible, ladder stops should be cast or bolted into the culvert invert and a fixing provided for the head of the ladder.

11.13 Water-level monitoring

Requirements for water-level monitoring to reduce risk are also covered in Section 4.7.

Water-level monitoring can act as a means of alerting the organisation responsible for maintaining the screen to a potential blockage to the screen in a non-routine event – whether this is due to a natural build-up of debris or is the result of vandalism.

Any proposed screen site with a consequence score of four or above (see Section 4.7 and key guidance 15) must have remote water-level monitoring installed, linked by telemetry to an operational centre as an integral part of the scheme. In addition, the installation of CCTV at the site should be considered.

At all other sites, remote water-level monitoring must be considered as part of the design risk assessment. Remote monitoring can be omitted only where risk can be fully mitigated or the consequence is negligible.

When the difference in level is linked to telemetry, it can raise an alarm as the difference increases beyond pre-determined values. Water-level differential is a very good indicator of debris build-up and hence a requirement to clear.

Water-level monitors may be subject to vandalism and need to be protected.

The designer should consider installation of water-level monitors just upstream and downstream of a screen, with the data from this water-level monitoring providing information on the top water level drop or difference across the screen. The Field Monitoring and Data team should be consulted fully.

Reliable water-level monitoring with automated alarms will enable maintenance teams to respond quickly to rising water levels and potential blockage of a screen.

If water-level monitoring was previously available at the site, the data obtained may provide useful information on screen performance to the designer.

Any proposal to include or use water-level monitoring at an installation will require consultation with and approval from the appropriate body. In the case of our screens, this will be the regional telemetry team.

11.14 CCTV

The use of CCTV must be considered as an integral part of the scheme at any proposed screen site with a consequence score of five (see Section 4.7 and key guidance 15) together with remote water-level monitoring.

Incorporating a CCTV system into the design of a screen site (particularly for high risk areas) enables operatives to monitor the situation at the site for changes in river levels and for specific issues related to unexpected blinding of the screen.

If there are health and safety hazards associated with a site (including vandalism) CCTV can be used as a deterrent and/or to monitor the site.

To monitor screen blockages, CCTV can be linked to water-level monitoring so that it becomes activated only when water levels become high.

Any Environment Agency site where the introduction of CCTV is planned will require consultation with both the Mechanical and Electrical team (MEICA) and the Field Monitoring and Data team to ensure proposals are practical, and that any potential expansion in power requirements for a site can be achieved.

The installation of CCTV equipment may require planning permission.

It is also vital that resources are available for remote monitoring of the site and taking any action. To be of value, CCTV should be linked via telemetry to an operating centre capable of responding to vandalism or screen blockage.

12 Screen bypass

12.1 Justification for the provision of a screen bypass

There are two main options for a screen bypass:

- a screen bypass that takes flow round the screen only;
- a full bypass that conveys flow round the screen and culvert, returning it to the channel downstream of the culvert.

In both cases, the aim is to ensure that the flow in the watercourse is passed safely downstream in the event of the screen becoming blocked. The bypass ensures that flow remains in bank in the watercourse, reducing the risk of flooding.

The justification for providing a bypass is to avoid flooding if the screen becomes blocked. A simple assessment of the likely damage that would be caused by flooding (if no bypass were provided) compared with the cost of a screen bypass will indicate whether a bypass is worthwhile.

Key guidance 37: Screen bypass

The need for a screen bypass can often be avoided by adopting a sound design for the screen and ensuring a proactive maintenance regime so that the likelihood of blockage is reduced to an acceptable level.

12.2 Alternative bypass arrangements

A full bypass is only likely to be justifiable if the consequences of flow coming out of bank upstream of the culvert are severe (for example, causing extensive flooding of residential properties).

Creating a full bypass is not usually easy as the flow has to pass under the obstruction that was the reason for the original culvert.

The simplest approach to creating a full bypass is to allow flow to overtop the road or other obstruction that the culvert passes under. This means the water level has to rise, which means the banks of the channel need to be raised for some distance upstream of the culvert to ensure the water remains in bank. In some circumstances, overtopping is not acceptable (such as with a railway or motorway culvert).

A screen bypass is often the preferred arrangement. The most common arrangement is to have separate side channels into which water can flow when the screen blocks. These channels return the flow to the channel between the screen and the entrance to the culvert.

Figure 12.1 shows the example of a screen and bypass facility at Kydbrook. This is a simple but effective 'belt and braces' arrangement that minimises the probability of flood damage occurring while keeping trash and children out of the culvert.

The facility has the following key features:

- there are bypass channels on both sides (under the concrete slabs);
- the bypass entrances are also screened (otherwise the screen function would be compromised, whether a security screen or a trash screen);
- the weir allowing flow into the bypass has a low level and a high level component;
- there is a water-level recorder linked to telemetry to warn of high water level;
- the water level coming out of bank would not cause flooding because there are low flood walls set back from the channel (not visible in the photograph). This allows the horizontal area of the main screen to convey flow when the inclined section is blocked;
- the whole arrangement is fenced to discourage unauthorised access;
- the horizontal portion of the screen is not safe for use as a working platform for cleaning the screen.

Figure 12.1 Kydbrook screen and bypass facility, Ravensbourne, South London.

12.3 Hazards associated with bypasses

The main hazard associated with a bypass facility is that the bypass itself will become blocked by trash.

If the main screen is provided for security reasons, it is not acceptable to have a wider bar spacing on the bypass. If security is not an issue, adopting a wider bar spacing on the bypass screen may be acceptable.

The designer needs to take account of the type of trash and debris in the stream, and assess the probability of larger items bypassing the main stream and causing a problem in the culvert itself.

Key guidance 38: Bypass hazards

The main hazard associated with a bypass facility is that the bypass itself will become blocked by trash.

12.4 Bank raising

Section 12.2 stated the simple solution of raising the level of channel banks upstream of the culvert such that, even if the screen (or the culvert itself) was totally blocked, water could flow over the road (or other obstruction) without coming out of bank.

The disadvantages of this option are:

- nuisance of water flowing over the road;
- elevation of flood water level for some distance upstream of the culvert.

If the culvert passes under a minor road and the watercourse is quite steep, the option of bank raising is likely to be acceptable. It is not acceptable if the culvert passes under infrastructure that itself would be damaged by water flowing over it (such as an industrial area) unless a suitable overtopping flow route can be found.

12.5 Overtopping flood flow route

Consider the following example. A legal claim for compensation was made when a leisure complex was flooded. The complex had been built over a small stream (as an extension to an existing building on the side of a shallow valley). The culvert that conveyed the stream under the extension was provided with a poorly designed security screen which was prone to blockage. No bypass was incorporated in the design.

The result was water flowing through the leisure complex on two occasions, causing extensive damage. Had this problem been recognised at the time of the design of the extension, it would have been relatively easy to provide an open-channel flood bypass route to one side of the building.

Key guidance 39: Overtopping

If overtopping might occur when a screen becomes blocked and it is impracticable to put in place measures to avoid blockage of the screen, the provision of a safe overtopping flow route must be considered if the overtopping would otherwise result in damage to property and/or infrastructure.

13 Other operation and maintenance issues

It is a fundamental part of the planning and design process for a screen that the maintenance requirements are fully assessed and the design is based on realistic assumptions on the frequency and effectiveness of screen cleaning.

It is also vital that the maintenance commitment is accepted by the owner or operator of the screen. In particular this relates to:

- regular cleaning of the screen and the safe disposal of accumulated debris;
- non-routine response in the event that the screen becomes blocked with trash in times of flood flow;
- maintaining the screen in a safe working condition.

The legal implications of not clearing a screen can be significant.

The Environment Agency operates under permissive powers. However, where a trash screen has been cleaned regularly there is the possibility of introducing the ‘custom and practice’ of clearance, which may create liability. This potential liability needs to be considered if the maintenance regime is changed, reduced or the trash screen is removed altogether.

13.1 Flood and coastal risk management systems

We break all main river catchments down into flood and coastal risk management (FCRM) systems.

A FCRM system consists of those assets that contribute, as a whole, to reducing the flood risk to a discrete location or maintaining the status quo (where appropriate). A FCRM system should focus on what it is protecting (properties and other assets) or reduction of the flood risk. This leads, for example, to separate FCRM systems being required for urban and rural areas.

Target condition grades and inspection frequencies are given to the flood defence assets within an FCRM system. These are recorded and communicated between the Asset System Management (ASM) (owner/manager) and Operations Delivery (operators) teams through the performance specification (see Section 13.2).

13.2 Performance specification

A performance specification is a document used by us and produced by the ASM team in consultation with Operations Delivery. It sets out the standards to be achieved rather than detailed methods to be followed. It is used by Operations Delivery as the basis on which to plan, programme and implement its operation and maintenance works.

A performance specification includes information such as:

- details of the flood risk management assets within an FCRM system;
- overall consequence of failure of the system;
- current condition of the assets;
- recommended frequency of visual inspections;
- target condition of the assets.

All trash screens maintained by us are regarded as flood defence assets and target condition grades are therefore set for them. These condition grades are based on the *Condition Assessment Manual* (Environment Agency 2006) and refer to the structural condition of the asset.

We use standard forms of a consistent format and quality to produce performance specifications.

13.2.1 Asset condition inspection cycles

Visual inspection frequencies are determined by the risk (probability × consequence) of flooding on each reach and are identified within the performance specification.

Inspection frequencies range from six to 60 months, although it is possible to specify a more frequent inspection for particularly high risk assets within a reach provided there is sufficient justification.

Conversely, for flood defence assets within a low risk reach (such as a farmer's field) the first step should be to determine:

- whether the asset is actually required;
- whether it could be removed, thus saving time on inspections and maintenance costs.

Based on their inspection frequencies, screens are also subject to:

- operational inspections;
- mechanical inspections;
- Public Safety Risk Assessment (PSRA) inspections;
- health and safety site hazard inspections.

13.3 Operational plans

We produce operational plans for all assets to ensure:

- they are managed consistently;
- they meet required safety and efficiency targets.

Other operators of sites with screens are advised to adopt a similar plan.

The operational plan sets out:

- site-specific issues;
- practices that should and should not be adopted or carried out at the site.

The operational plan should include the health and safety file for the site, explaining how the required maintenance is to be carried out safely. It also identifies all hazards associated with completing any of the tasks at the site.

Contractors employed to operate and maintain screens must be provided with the relevant manuals and other data pertaining to their safe operation. The screen owner will need to ensure, as far as is reasonably practical, that the contractor is competent to undertake the works.

A manual handling risk assessment should be undertaken at the design stage to minimise, as far as is reasonably practical, the risk of injury to operatives from the physical operation of the screen during the clearing operation.

For existing screens where there is no operational plan, it is recommended that one is developed by the Asset Manager to provide guidance to operatives on safe and efficient methods of screen clearance. Procedures should allow for updates and amendments as necessary where practices change.

Key guidance 40: Operational plans

Every Environment Agency-maintained screen should have an operational plan that:

- sets out the inspection and cleaning frequency;
- describes emergency response procedures.

This is recommended as good practice and should be adopted by other operating authorities.

Key guidance 41: Maintenance

All screens have to be cleaned at intervals and may require a rapid response in a high flow event. Establishing the extent and cost of this maintenance liability, and securing a commitment to it from the responsible party, are essential components of the planning and design process.

13.3.1 Non-event (routine) clearance

Installation of a screen will result in the build-up of debris over time. The rate of removal of this debris will be dictated by the rate at which debris accumulates on the screen.

A safe and acceptable system of clearance should be developed to deal with the expected debris. This system should be developed and/or refined over time to ensure the screen does not impede flow during normal operating conditions or become a hazard in itself.

We justify and record the details of the clearance frequency in the operational plan.

13.3.2 Event (non-routine) clearance

There will be instances (during flood flow events) when routine clearance will be unable to cope with the amount of debris collected on the screen. These events are unplanned and need to be dealt with on a reactive basis.

Maintenance and operations procedures need to be clear on the steps to be taken to clear the screen in such an event, to ensure operatives are not placed at risk.

13.3.3 Mobilisation systems

To clear debris during a non-routine event, it is necessary to set up a system that enables operatives to be instructed to attend and clear the screen within the time needed to prevent flood defences being overwhelmed.

Key guidance 42: Emergency response

Screens can block in a matter of hours or less in times of high flow. This is particularly true when high flows follow a prolonged dry spell, when accumulations of debris in the channel can be picked up by the rising water levels ('first flush' effect).

The practicality of mobilising a maintenance team in a short time period to deal with the consequential screen blockage is a major factor during the design process.

13.4 Temporary storage of debris

During non-event (routine) and event (non-routine) maintenance, it will be necessary to store the debris on-site before it can be disposed of.

Procedures must ensure there is no risk to operatives when moving debris and the location of the temporary storage should allow easy transfer from screen to storage.

The capacity of the storage area may be limited by space availability.

Removal of debris at regular intervals is essential and the operational plan will state how long debris should be stored at the screen site.

13.5 Removal/disposal of debris

All debris must be disposed of at a licensed waste disposal site. The designer should check the availability of sites locally and specify the nearest suitable site. We (as owner/manager) will include this information in the operational plan.

13.6 Watercourse maintenance

Upstream maintenance of a watercourse can impact on the screen downstream. The screen design must therefore take into account the watercourse maintenance regime.

In particular, it should consider whether vegetation clearance could result in material flowing downstream to the screen – either at the time of clearance or subsequently (if cut material is left on the channel banks).

13.7 Record of operation and maintenance

Operatives attending the site must make regular and detailed records of:

- inspections carried out;
- requirement for cleaning;
- types and amounts of debris removed.

They should use a site visit log to record this information. This can be used as evidence to justify future work and in the assessment of existing screens.

Key guidance 43: Monitoring and recording

Owners and operators of screens are urged to collect and record data on the operation of their screens. In particular:

- frequency of cleaning;
- quantities and types of debris removed;
- details of problems experienced.

This will facilitate future improvements to the screen and/or its future maintenance.

14 Summary of trash and security screens – Key guidance

The following are the items of key guidance highlighted throughout the guide:

	Title	Guidance
1	Use of screens	We discourage the use of any form of screen except in circumstances where the benefits are significant and outweigh the risks.
2	Objective of a trash screen	The aim of a trash screen should not be to trap as much debris as possible. In fact, the screen should trap as little debris as possible commensurate with achieving the aim of preventing material that could cause a blockage from progressing downstream.
3	Objective of a security screen	The aim of a security screen is to prevent unauthorised access to the pipe or culvert.
4	Policy	The guidance contained in this document is generally in accordance with the Environment Agency's draft policy regarding screens. Nothing in this guidance supersedes or overrides the stated policy of the Environment Agency.
5	Options	It should not be assumed that a screen is the right answer to a particular problem. In any given situation, a screen is only one of the options available to remove or reduce the perceived risk. A decision to provide a screen at any location must be based on a full appreciation of the risks and benefits. It is essential that all practical alternatives are investigated and eliminated before reaching the decision to provide a screen.
6	Justification	The decision to install a screen must be fully justified.
7	Risk assessment	Assessment of all the risks, taking into account probability and consequence, is an essential part of the appraisal process. This process must include the risks associated with installing a screen, as well the perceived risks that have led to the investigation into the need for a screen.
8	Flooding risk	All screens, regardless of their primary purpose, will collect debris. This will obstruct flow, causing the upstream water level to rise, and will increase the probability of flooding. This is a key factor where the flooding would lead to significant damage to property and/or infrastructure.
9	Operational risks	It is a fundamental part of the planning and design process for a screen that the maintenance requirements are fully assessed and accepted by the owner or operator of the screen. In particular this relates to: • regular cleaning of the screen and safe disposal of accumulated debris; • emergency response in the event that the screen becomes blocked with debris during a flood event. Failure to address these key issues has, in the past, led to serious flooding and subsequent legal action. Even when all possible steps are taken to ensure that the course of action adopted is based on sound reasoning and good data, and with the consent of all interested parties, it is essential that responsibility is defined, accepted and recorded in an operational plan.
10	Risk of blockage (trash screens)	Before deciding that a trash screen is necessary, it is essential to assess the probability of blockage of the culvert. This is a two-part process involving: • consideration of the nature of the debris load and its source;

	Title	Guidance
		• the likelihood of this material accumulating in the culvert.
11	Decision rules (blockage and damage)	For either of the risk factors (blockage or damage) a score of 15 and above indicates that a screen is required. Those scoring between seven and 14 should be investigated further and, where there is uncertainty in the significance of the consequence score, the Area Flood Risk Manager should be consulted. For scores of six and below, it is unlikely that a screen is required. Further clarification on the inclusion of remote water-level monitoring and CCTV monitoring are set out in Section 4.7.
12	Risk of blockage (security screens)	If a screen is proposed for security reasons it also needs to be assessed for the flood risk associated with its potential blockage following the methods set out in this guide.
13	Decision rules (safety)	Any hazard risk score above 20 out of maximum 25 will require the provision of a security screen. Further detailed consideration should be given to the provision of a security screen at those sites that score 15 or more.
14	Screens on the culvert outlet	No screen should be provided at the outlet of a culvert unless there is a security screen at the inlet as this could lead to the accidental death of anyone entering the culvert. A screen only at the outlet would also collect debris that would be difficult to remove. Where this situation can not be avoided, a hinged screen must be considered and secured by 'fail safe' fixings to enable emergency opening of the screen.
15	Need for monitoring	Owners and operators of existing screens and designers of new screens must consider the use of remote water level monitoring and CCTV as an aid to: • understanding the way in which the screen performs; • determining the operational response at times of high flows when the risk of blockage is at its greatest.
16	Decision rules (monitoring)	Any proposed screen site with a consequence score of five, for blockage or damage (see Table 4.4), must have remote water-level monitoring linked by telemetry to an operational centre, and should have CCTV as an integral part of the scheme. Any proposed screen site with a consequence score of four, for blockage or damage (see Table 4.4), must have remote water-level monitoring installed, linked by telemetry to an operational centre as an integral part of the scheme. In this scenario the installation of CCTV should be considered. At all other sites, remote water-level monitoring must be considered as part of the design risk assessment. It can only be omitted where the risk can be acceptably mitigated or the consequence is negligible.
17	Assessment of existing screens	Existing screen sites should be subject to the same level of review as for the justification of the requirement for a new screen at a site. Existing screens should also be reviewed with the same vigour as new screens when considering the need for asset maintenance and ongoing operational requirements.
18	Effective design	To produce an effective design, it is essential to appreciate: • factors that influence the type and amount of debris; • hydraulic performance of the channel; • accessibility and maintainability of the screen.
19	Stakeholder	The first step in addressing a problem caused by the actions of the local community is

	Title	Guidance
	engagement	to engage with locals to explore how the problem can be reduced or eliminated. No trash screen should be promoted until the alternative of addressing the problem at source has been fully explored.
20	Screen area	To be eligible for inclusion in the effective screen area, an element of the screen: i. must be below the maximum allowable water level; ii. must not be a working platform designed for use by operatives; iii. must not include those parts of the screen obstructed by the supporting structure for the screen.
21	Screen size	The design screen area should be determined by using the evidence-based method detailed in the guide, checking that the resulting area is between three and 30 times the minimum cross-sectional area of the culvert being protected. If the calculated area is greater than 30 times the minimum culvert area, a design screen area of 30 times the minimum culvert area may be used provided there are no unusual aspects to the upstream catchment which would generate exceptional amounts of debris entering the watercourse.
22	Significant events	A significant event is an event that has sufficient flow to lift debris off the bed and banks of the watercourse. Unless there is justification based on hydrological data/records, the number of significant events should be taken as three.
23	Bar spacing (general)	The spacing between the bars of a screen should be the widest commensurate with achieving the objective(s). It is counterproductive to have a screen that traps debris which would otherwise pass harmlessly through the culvert. The chosen spacing must be checked to ensure that it does not conflict with any requirements for the passage of fish or wildlife.
24	Bar spacing (security screens)	Security screens should be designed to have a clear space of 140 mm between bars. The hydraulic impact of the bar spacing must be reviewed and investigated fully.
25	Bar spacing (trash screens)	Trash screens placed upstream of culverts and inverted siphons should have a minimum clear spacing of 150 mm between bars. The spacing should prevent the passage of material of the type and size likely to pose a significant risk at the site. In urban locations where larger debris needs to be excluded but smaller debris should be allowed to pass, a clear spacing of 300 mm between bars may be appropriate.
26	Bar spacing (weed screens)	Trash screens (or weed screens) placed at the intake to land drainage pumping stations can be designed with a clear spacing of around 75 mm between bars, provided regular cleaning is carried out manually or by an automatic raking system.
27	Environment	Designers must have regard to the environment and seek to reduce the impact of the screen while also seeking opportunities for environmental gain. However, the primary purpose of the screen must not be compromised.
28	Hydraulic analysis	Depending on the complexity of the site and availability of data, various levels of hydraulic analysis can be carried out. In many cases manual hydraulic analysis may be sufficient. If the analysis is complex, data is available and modelling can be carried out relatively easily, hydraulic modelling may be the preferred approach.
29	Hydraulic modelling	When using computational hydraulic models, it is essential that the designer understands the calculation process in the model and ensures the design is represented correctly. It is the responsibility of the designer to ensure the hydraulic model is capable of modelling the proposed design for all flow and blockage scenarios.
30	Refinement of screen	The results of the hydraulic analysis should be used to refine the design of the screen and the associated engineering works.

	Title	Guidance
	design	It should also help to improve the hydraulic performance of the screen and culvert and inform the management of safety hazards.
31	Screen cleaning arrangements	Arrangements for cleaning the screen must be appropriate to the nature and quantity of the debris anticipated at the site. It should be possible for operatives to safely rake a screen under routine and most non-routine conditions. If a screen is drowned it may not be safe to clear, however the design should afford operatives early and safe access to the screen once water levels subside. Each method for screen cleaning should be evaluated separately and the design should minimise manual clearing and provide suitable safety arrangements.
32	Rake reach and prong length	Maximum rake length is two metres, with 1.5 m being the preferred length. A maximum prong length of 150 mm is suggested. Rake heads wider than about 450 mm are usually impractical.
33	Screen bars	Bar dimensions should not be less than 8 x 75 mm for flat bars. Maximum unsupported length of a bar should not exceed 1.5 m. Recessed bracing should be provided if bar length exceeds 1.5 m.
34	Fabrication and materials	The materials from which a screen and its associated platforms and support structure are made should be robust and durable. This is important because the screen often has to perform in a challenging environment (e.g. corrosion, vandalism, debris loads, cleaning process). Galvanized steel has been shown over a long time to meet these requirements. Designers wishing to adopt alternative materials must be confident of their ability to remain serviceable for a significant period (e.g. 30 years).
35	Health & safety	It can help operatives if the screens for which they are responsible have common features (e.g. the design of anchorages for safety harnesses). However, health and safety issues cannot be addressed with ‘standard’ designs. Health and safety provisions must be bespoke, that is, they should be designed for the screen in question and its particular operational requirements, making use of standard equipment where appropriate.
36	Lighting provision	Under no circumstances should operatives be permitted to work on the screen in darkness.
37	Screen bypass	The need for a screen bypass can often be avoided by adopting a sound design for the screen and ensuring a proactive maintenance regime so that the likelihood of blockage is reduced to an acceptable level.
38	Bypass hazards	The main hazard associated with a bypass facility is that the bypass itself will become blocked by trash.
39	Overtopping	If overtopping might occur when a screen becomes blocked and it is impracticable to put in place measures to avoid blockage of the screen, the provision of a safe overtopping flow route must be considered if the overtopping would otherwise result in damage to property and/or infrastructure.
40	Operational plans	Every Environment Agency maintained screen should have an operational plan that: • sets out the inspection and cleaning frequency; • describes emergency response procedures. This is recommended as good practice and should be adopted by other operating authorities.
41	Maintenance	All screens have to be cleaned at intervals and may require a rapid response in a high flow event. Establishing the extent and cost of this maintenance liability, and securing a commitment to it from the responsible party, are essential components of the planning and design process.

	Title	Guidance
42	Emergency response	Screens can block in a matter of hours or less in times of high flow. This is particularly true when high flows follow a prolonged dry spell, when accumulations of debris in the channel can be picked up by the rising water levels ('first flush' effect). The practicality of mobilising a maintenance team in a short time period to deal with the consequential screen blockage is a major factor during the design process.
43	Monitoring and recording	Owners and operators of screens are urged to collect and record data on the operation of their screens. In particular: • frequency of cleaning; • quantities and types of debris removed; • details of problems experienced. This will facilitate future improvements to the screen and/or its future maintenance.

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List of abbreviations

AES	Afflux Estimation System
Bdf	Blinded depth factor
CCTV	Closed circuit television
CDM	Construction (Design and Management) Regulations
Da	Debris amount
Defra	Department for Environment, Food and Rural Affairs
Dda	Design debris amount
Dr	Domestic refuse
FRM	Flood Risk Management
Lhr	Large household refuse
Lndr	Large non-domestic refuse
Lv	Large vegetation
MEICA	Mechanical, Electrical, Instrumentation, Control and Automation
NEAS	National Environmental Assessment Service
NFCDD	National Flood and Coastal Defence Database
PAMS	Performance-based Asset Management System
PSRA	Public Safety Risk Assessment
SAMP	System Asset Management Plan
Sv	Small vegetation

Glossary

Bank full	A situation where the water level in the watercourse equates to the top of the river bank, at the level just before overtopping occurs.
Bracing	Additional strengthening provided for long screen bars that might otherwise be bent in use or as a result of vandalism. Bracing should be recessed so that it does not interfere with movement of cleaning rake.
CCTV	Closed circuit television.
Conveyance and Afflux Estimation Systems (CES/AES)	UK operating authorities have supported the development of the Conveyance Estimation System (CES) to estimate channel flow capacity (conveyance) and in particular flood water levels and the Afflux Estimation System (AES) for estimating the local water surface profiles and head loss associated with bridge and culvert structures (see http://www.river-conveyance.net).
Culvert	An enclosed section of a watercourse.
Debris	Solid material transported within a watercourse particularly during flood events. Debris can move intermittently and has potential to cause blockages that impede the free flow of water.
Flashy	A watercourse or catchment with water levels that rise and fall rapidly in response to rainfall.
Freeboard	The safety margin between the design flood level and the top of a flood bank or wall. Freeboard generally includes allowances for inaccuracy in flood level estimation, settlement of a flood defence and construction tolerance.
Gantry	Part of the installation that carries a mechanical grab device over the screen bars.
Hazard	A physical event, phenomenon or human activity with the potential to result in harm. A hazard does not necessarily lead to harm. In the context of this guide, harm is primarily death or injury to operatives or members of the public, or flood damage to property or infrastructure.
Main river	Usually larger streams and rivers, but the term also includes smaller watercourses of strategic drainage importance. A main river is defined as a watercourse shown as such on a main river map, and can include any structure or appliance for controlling or regulating the flow of water in, into or out of the main river. Main rivers are designated by Defra in England and by the Welsh Assembly Government in Wales.
Non-routine event	An event that requires operatives to attend the site to clear a screen on an unplanned basis and not as part of their regular maintenance routine. Such events are often a result of adverse weather conditions and a high flow event.
Operational plan	A document aiming to improve quality and consistency of management of major operating assets. There is a close link between Operational Plans and major asset management plans

	to ensure assets are managed consistently and meet the required safety and efficiency targets.
Performance specification	A series of documents setting out the standards agreed by Area Asset System Management teams for each Flood and Coastal Risk Management (FCRM) system. It enables resources and investment to be targeted according to flood risk.
Platform (also described as raking platform and working platform)	A horizontal part of a screen provided to allow operatives to stand safely when cleaning a screen. Such platforms require either solid or open-tread flooring, and cannot contribute to the screen area in terms of conveying flow.
Probability	The likelihood that an event will happen (expressed variously, for example, one in 100 years, one per cent in any year, 100 to one against in any year).
Risk	A combination of the probability of occurrence of a defined hazard and the magnitude of the consequences of the occurrence (risk = probability x consequence).
Screen bar	That part of the installation superstructure that collects the debris transported down the watercourse. The spacing of the bars is a critical design element. Spacing can be defined as clear spacing or centre to centre.
Screen rake	A custom-made device used by maintenance teams to remove trash and debris from the screen. Rakes are not capable of removing large or heavy items.
Security screen	Any screen of which the primary purpose is to prevent unauthorised or accidental access to an enclosed section of watercourse.
Significant event	An event that has sufficient flow to lift debris off the bed and banks of the watercourse which otherwise would have stayed *in situ* during normal flows.
Siphon (or Syphon)	More correctly referred to as an inverted siphon. It is a particular form of culvert in which the conduit drops down to pass under an obstruction and then rises up at the other side, such that the centre part of the conduit is always full of water.
Telemetry	Use of telephone or radio transmission to convey data from a remote site to an operational centre.
Tines	Fingers of a grab device designed to pick up debris from the screen bars.
Trash	For the purposes of this guide the terms “trash” and “debris” are synonymous.
Trash screen	Any screen of which the primary purpose is to prevent trash and debris from entering an enclosed section of watercourse.
Watercourse	Any river, stream, brook, beck or drain that acts to convey rainfall run-off and/or groundwater flow.

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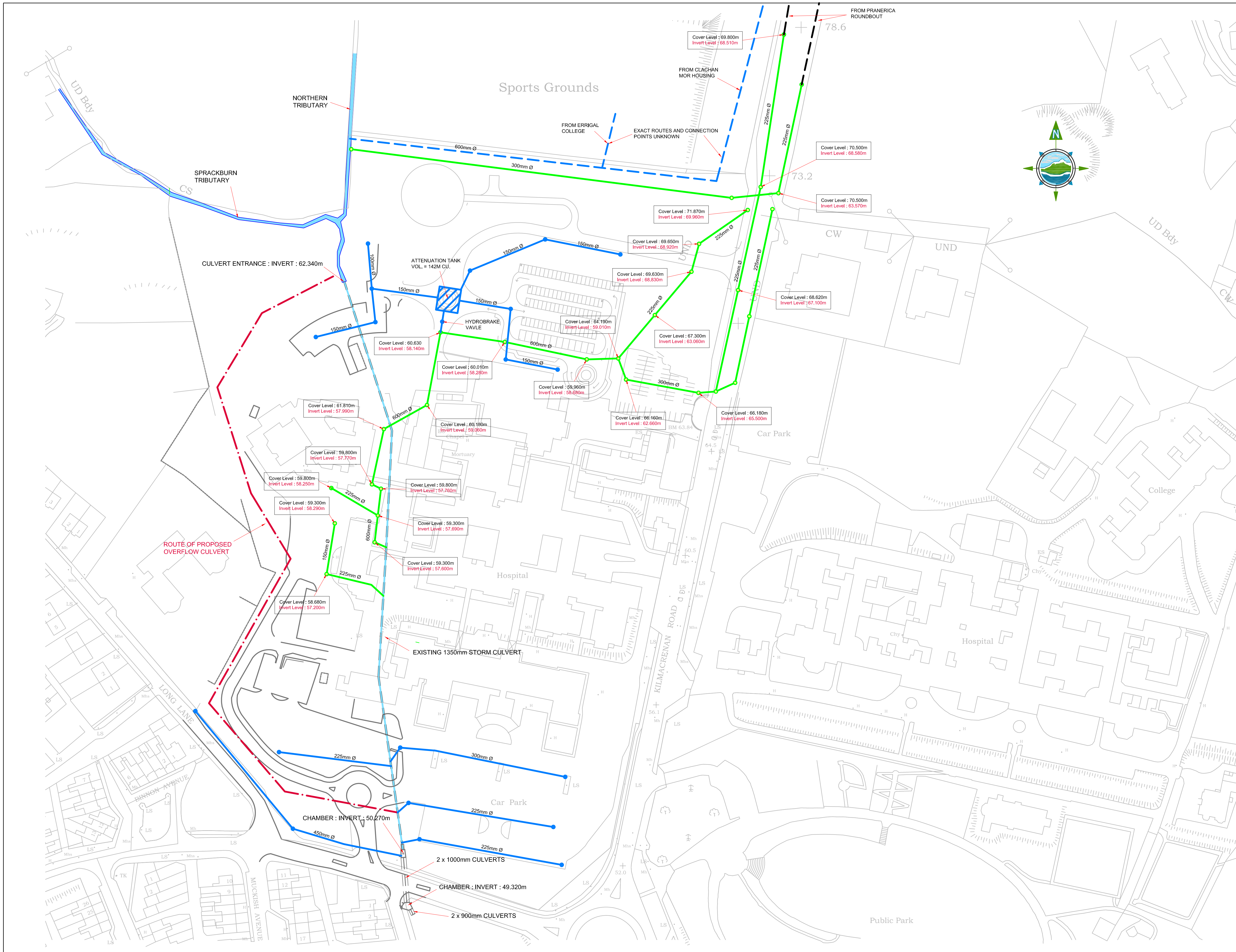
Annex C Drawing 7284-6017 Existing Surface Water Drainage Network



SITE LAYOUT MAP

SCALE 1:1000

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
4. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD, THE GEOGRAPHIC COORDINATE SYSTEM IS TO IRISH TRANSVERSE MERCATOR (ITM)

Rev.	Date	Description	By	Chkd.
A	DEC '13	DRAFT ISSUE TO CLIENT	J.M.	P.R.

Client
HSE ESTATES

Project
FLOOD RISK MITIGATION WORKS AT LETTERKENNY GENERAL HOSPITAL

Title
LAYOUT OF EXISTING STORM DRAINAGE

Scale @ A1: 1:1000

Prepared by:	Checked	Date
J.M.	P.R.	DEC.2013

Project Director: Brian Downes

Drawing Status: TENDER

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Issue A

Annex D Current Maintenance Protocols

Maintenance Protocol for the Management and Monitoring of the Sprackburn Stream at Letterkenny General Hospital

1) General Points:

a) This Protocol supersedes all other maintenance protocols in relation to the management and monitoring of the sprackburn stream.
b) This protocol may be updated following the written report from the external engineers.
c) This protocol will remain in place until the longer term engineering solution is completed.
d) The responsibility for the overall management and monitoring of the sprackburn stream will rest with the Facilities Manager through the Maintenance Department at Letterkenny General Hospital.
e) The Maintenance Foreman will monitor the 5 day weather forecast in order to inform his future actions.
f) The relevant Heath & Safety precaution s as per The Safety, Health and Welfare at Work Act 2005 must be adhered to at all times.

Protocol:

2) During periods where high rainfall is forecast the Maintenance Foreman should action the following:-

a) Ensure that a member of Maintenance Staff is on site and the stream should be monitored constantly.
b) Ensure that the mechanical digger is available for immediate action.
c) Ensure that all sandbags are in place.
d) All actions should be recorded in the log-book.

3) During periods of heavy rainfall the Maintenance Foreman should action the following:-

a) The stream will be monitored and maintained constantly by at least two Maintenance Staff. All other Maintenance staff should be put on stand-by notice.
b) The mechanical digger driver will be on site.
c) The hospital manager on duty will be informed of the situation and updated hourly.

4) Normal Inspection Regime:

a) A member of the Maintenance staff will be allocated to walk and inspect the stream daily. All actions should be recorded in the log-book and photographs should be taken. All removed debris should also be photographed.
b) A member of Maintenance staff will be allocated to inspect the grills at 8.00am, 12 noon and 4pm approx. All actions should be recorded in the log-book and photographs should be taken. All removed debris should also be photographed.
c) A member of Security Staff will be allocated to inspect the grills at 8.00p.m., 12.00 midnight and 4am approx. All actions should be recorded in the log-book and photographs should be taken. All removed debris should also be photographed.

Updated: 29th July 2013, 17th October 2013